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dSPACE MAGAZINE

2/2021

CATARC – Safe automatic parking | Page 20

Hutchinson – Efficient simulation and automation for aviation | Page 10

Shanghai Fuel Cell Vehicle Power System – Pushing forward with validated fuel cells | Page 6

Advancing Detection Technologies

To improve the capability and reliability of advanced driver assistance systems in existing cars, and to overcome the challenges of reaching fully automated driving (L5), automotive radar systems have to provide high resolution in azimuth and elevation in addition to delivering crisp accuracy and discrimination. Uhnder is advancing detection technologies by developing a digital on-chip radar that detects rich, 4-D environments. The development and testing of the radar sensors are supported by the dSPACE Automotive Radar Test Systems (DARTS).

"As a provider of simulation and validation solutions used for the development of connected, self-driving, and electrically powered vehicles, dSPACE is an ideal technology partner for us. In the field of radar technology – a key technology for autonomous driving – it is important to validate newly developed sensor technologies at an early stage. By working with a leading partner like dSPACE, we can bring innovations onto the road faster worldwide."

Dr. Ralf Reuter,
Fellow, and Senior Director of Customer and Application Engineering at Uhnder Inc.

"dSPACE provides solutions for the end-to-end requirements for the research and development process – from product conception to homologation."

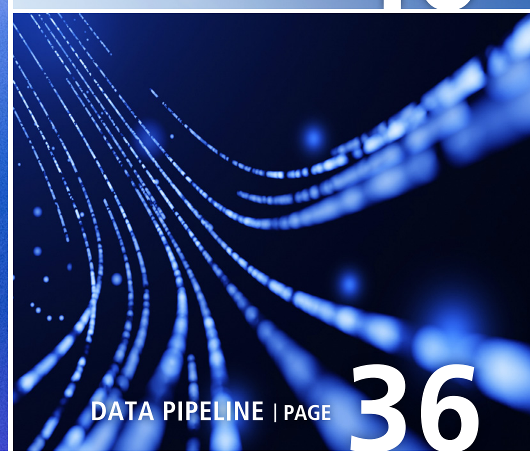
Dear Readers,

Software-defined, digital vehicles are becoming a reality. The automotive industry is experiencing a phase of profound transformation, racing to cover new vehicle requirements and to be able to update the software continuously mid-operation. But it is not just the amount of software in the vehicle that increases. The software components are also reaching new levels of connectivity: in the vehicle, with the environment, and with the back end. This leads to a never-before-seen complexity, which the industry seeks to master. The same applies to safety requirements.
To ensure that complex systems live up to defined quality standards, everybody knows that large parts of validation have to be completed using simulation. But validation does not stop once a vehicle is shipped. The advancement of software requires a process for continuous integration and deployment. Reliable, future-proof methods and tools for simulation and validation are needed to ensure that software releases and tests can be provided during the entire life cycle of a vehicle. Simulation is therefore an important pillar in the quality assurance of software-defined vehicles and allows for quick over-the-air update cycles.
For us, our customers' success is decisive. What have we done and what will we still do to this end?

- The dSPACE team has continuously grown to more than 2,000 employees, of which over 1,450 are engineers and computer scientists. They understand the complexity of your requirements for the research and development process, from product conception to homologation. With our expertise, consulting services, and seamless solutions, we enable you to master the complexity.
- Our end-to-end solutions cover the entire development cycle. This includes prototyping, data replay, as well as software-in-the-loop (SIL) and hardware-in-the-loop (HIL) simulation. Our products can be combined to build an ideal, overall solution, but are also open to the integration of customer or third-party solutions.
- We have upped our skills and capacity in agile software development and have evolved into a company for end-to-end SIL and HIL simulation.
- We continuously build up our technology expertise, both organically and through mergers and acquisitions. We focus particularly on sensors, AI, cloud computing, and data management. We have also joined forces with leading engineering, sensor, and cloud providers.

This is the basis for our entirely new software solutions. Take SIMPHERA, for example, our new, cloud-based platform for simulation and validation. It combines the dSPACE strengths you appreciate in HIL and SIL simulation with scalable cloud computing. Read more about SIMPHERA on page 40. Our newly acquired interests in the highly specialized Deep Tech start-up neurocat reinforce the robustness and quality assurance of AI.
This edition of dSPACE Magazine again shows our determination to be your partner in simulation and validation. This is underlined by the many user stories that have been created together with you, our customers. I hope this issue inspires you. Enjoy reading.

Martin Goetzeler



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Energy from the Cell

Efficient development and validation of controller software for a fuel cell in commercial vehicles

Many challenges related to electrifying vehicles still need to be overcome. One of them is the continuous provision of electrical energy for the long ranges required by commercial vehicles. Shanghai Fuel Cell Vehicle Power System Co., Ltd. relies on fuel cell technology, using a simulator provided by dSPACE to efficiently develop and validate the fuel cell software.

Hydrogen is considered the cleanest energy source of the 21st century. The fuel cell technology, used to obtain electrical energy from hydrogen, is therefore a pillar of future-oriented energy supply for many companies in the automotive industry. Due to the range requirements and efficiency criteria, this holds true for commercial vehicles in particular. The technology company Shanghai Fuel Cell Vehicle Power System Co., Ltd., Shangran Power for short, is working on supplying fuel cell systems to industrial enterprises. Systems for power ranges between 40 kW and 55 kW have been available since 2001.

Zhang Lingxia, a HIL test engineer responsible for fuel cell controllers in HIL tests as well as the development and maintenance of HIL systems, explains the company's overarching objective: *"Especially in the field of commercial vehicles, we receive many requests with regard to electrifying powertrains. With our new high-performance*

Picture credits: © Shanghai Fuel Cell Vehicle Power System Co., Ltd.

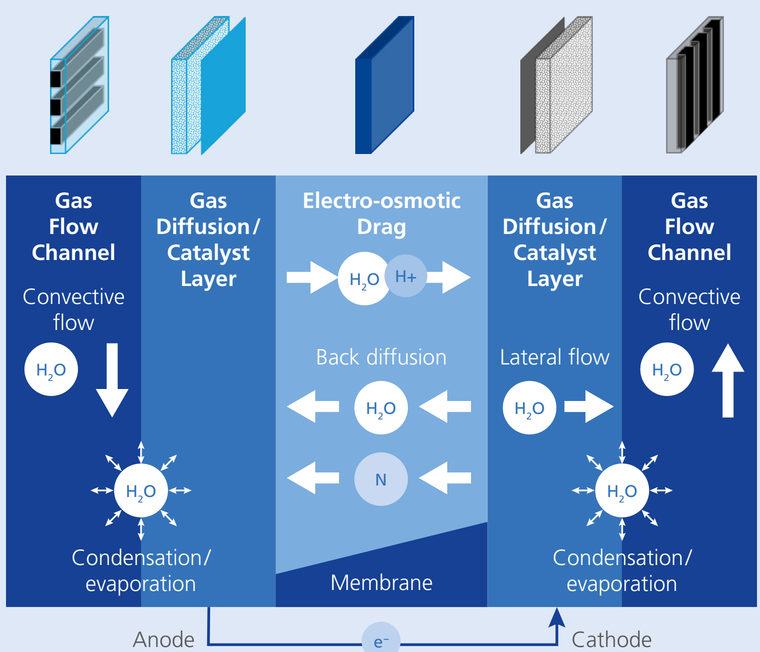
> "We are very happy with the test solution from dSPACE. It satisfies our requirements for the comprehensive functional testing of fuel cells."
>
> *Zhang Lingxia, HIL test engineer, Shanghai Fuel Cell Vehicle Power System Co., Ltd.*

fuel cell system, we aim to offer an energy supply solution tailored precisely to commercial vehicles." The fuel cell system named START-300E is designed to meet the following requirements:

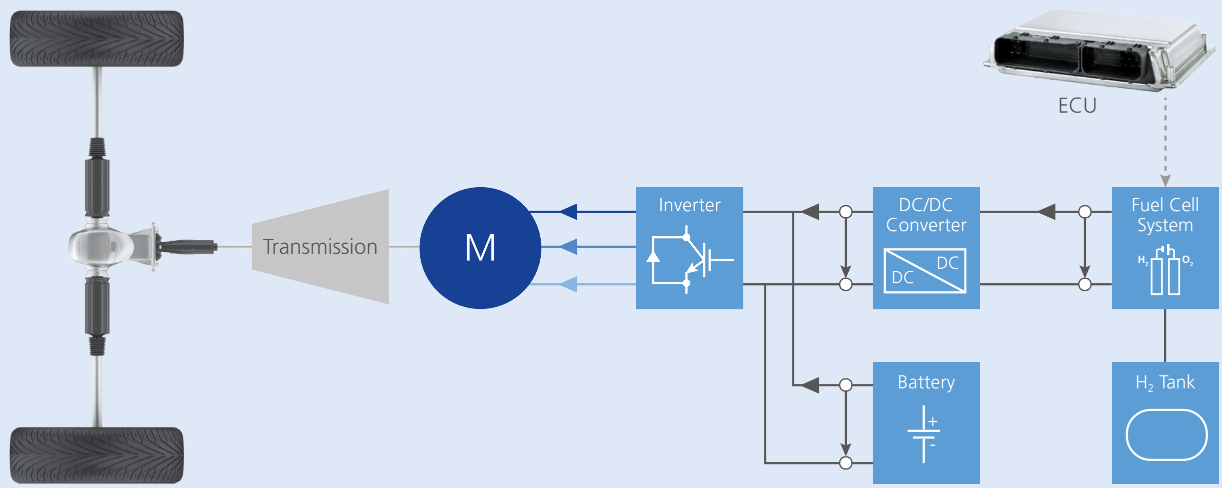
- The properties of the fuel cell are based on the future operating conditions of commercial vehicles.
- The system has a very low hydrogen consumption.
- It features a compact, easy-to-integrate design.
- It stands out due to its exceptional reliability and outputs a constant supply of power.

Development and Test Concept

A suitable fuel cell concept is required to achieve these characteristics, combined with a powerful controller to ensure optimal cell operation. The company decided to create a polymer electrolyte fuel cell, which has especially favorable properties for mobile applications. The controller software was developed in parallel with the fuel cell hardware. For Shangran Power, it was important to obtain information on how the controller works early on and to streamline the design process as much as possible. This is what prompted the company to set out in search of a suitable solution. *"Our developers wanted to test new revision statuses for the controller algorithms and assess how effective they were. Because the hardware was still being developed, we were looking for a suitable development and test solution. We also wanted to use this solution in the release tests for the final electronic control unit,"* explains Liu Fengwei, who is the manager of the electrical and electronic control department. A simulation-based method was discussed in a talk with dSPACE. It turned out that dSPACE had a complete series of solutions for simulating fuel cells and validating controllers. >>



The processes in the fuel cell can be examined precisely during the simulation.



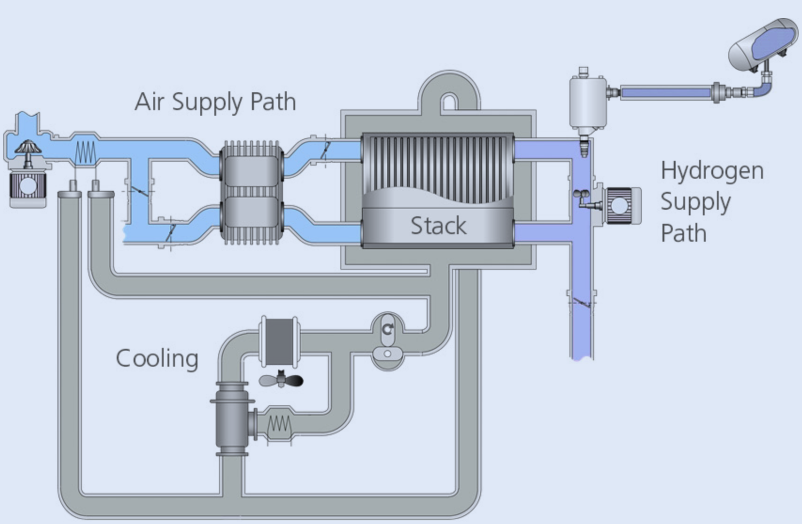
Structure of a powertrain modeled with ASM using a fuel cell to generate electricity.

Virtual Fuel Cell in the Loop

Shangran Power installed this series of solutions in the form of a hardware-in-the-loop (HIL) simulator equipped with the ASM (Automotive Simulation Models) tool suite. This solution makes it possible to realistically simulate a vehicle operated by a fuel cell. It is even possible to examine the behavior of the fuel cell and that of the electric powertrain in detail during the virtual test drives. *"The ASM fuel cell model meets all of our requirements concerning the model quality and real-time capability to simulate the current/voltage behavior, the gas mass flows, and the temperature distribution in closed-loop operation. Together with the HIL simulator, it represents a suitable tool for performing our validation testing effectively and purposefully,"* explains Liu Fengwei in reference to the advantage of the simulation-based method. The precise simulations make it possible for Shangran Power to obtain information about the relative humidity or the diffusion effects of nitrogen and water during early stages of the process. *"We can use the early findings from the simulation to optimize our algorithms for the fuel cell,"* clarifies Zhang Lingxia. He adds: *"The fact that we can quickly confirm the effectiveness of the optimizations is especially valuable."*

Simulation Is Key to Success

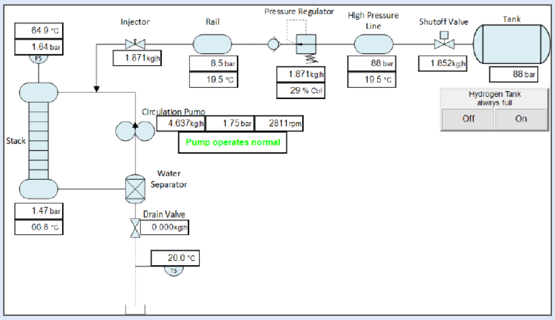
At Shangran Power, four people work with the HIL simulator. Including commissioning, it took roughly two months until all of the developers were well



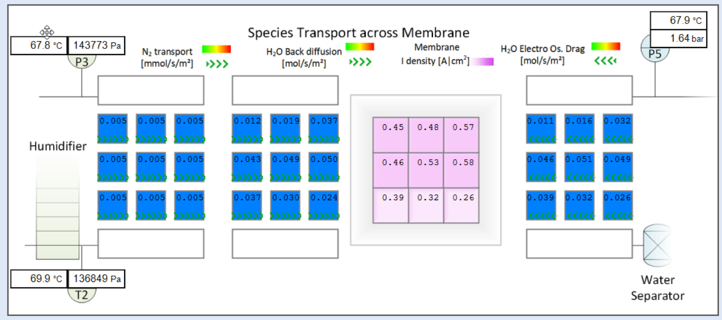
Schematic diagram of the basic components in the fuel cell system.

Picture credits: © Shanghai Fuel Cell Vehicle Power System Co., Ltd.

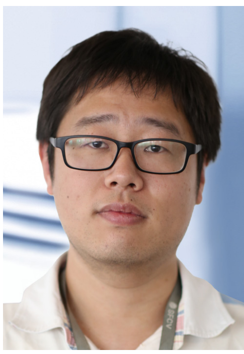
Rendering of the fuel cell successfully developed and validated using a HIL simulator from dSPACE.



Key variables of the virtual fuel cell are depicted clearly during the simulation.



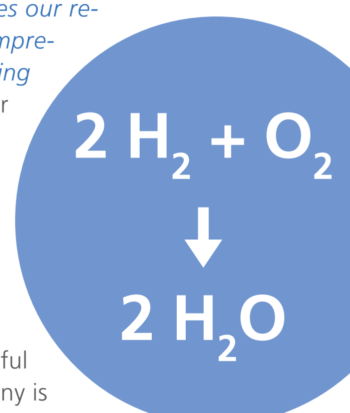
Exact parameterization and analysis of the highly accurate simulated electrochemical processes in the cell.



"The ASM fuel cell model meets all of our requirements concerning the model quality and real-time capability to simulate the current/voltage behavior, the gas mass flows, and the temperature distribution in closed-loop operation. Together with the hardware-in-the-loop simulator, it represents a suitable tool for performing our validation testing effectively and purposefully."

Liu Fengwei, manager of the electrical and electronic control department, Shanghai Fuel Cell Vehicle Power System Co., Ltd.

acquainted with the test system. Now it is part of their everyday work and helps them with their job. For adoption into everyday testing, the ASM fuel cell simulation running on the hardware-in-the-loop simulator had to pass Shangran Power's final acceptance test based on an automatic verification method for the entire operating area. Throughout the test, the simulation was able to meet all safety margins and operate within all limitations set and checked by the controller software. This was clearly evident by the fact that there were no error codes such as 'power level violation' or 'shutdown condition fault' in the controller's software log. Zhang Lingxia describes the benefits they were able to achieve: *"Using the HIL simulator has significantly improved the efficiency of our testing and validation, as well as the reliability of our controller software."* He adds: *"We are very happy with the test solution from dSPACE. It satisfies our requirements for the comprehensive functional testing of fuel cells."* Simulator hardware and simulation models also offer multiple configuration options. Electrical fault tests are used for validation purposes in the subsequent steps. Equipped with a powerful test system, the company is well positioned to promote the electrification of commercial vehicles with reliable components. ■



Courtesy of Shanghai Fuel Cell Vehicle Power System Co., Ltd.

Shanghai Fuel Cell Vehicle Power System Co., Ltd.
In 2001, Shanghai Fuel Cell Vehicle Power System Co., Ltd. (hereinafter referred to as Shangran Power) was established in Shanghai in response to the national 863 Program Major Special Project for Electric Vehicles to achieve the goal of realizing the productization and industrialization of major special projects of electric vehicles.

Polymer Electrolyte Fuel Cell
The polymer electrolyte fuel cell, also known as a proton-exchange membrane fuel cell or solid polymer fuel cell, is a low-temperature fuel cell. Using hydrogen (H_2) and oxygen (O_2), chemical energy is transformed into electrical energy. The electrical efficiency is around 60 percent, depending on the operating point. A solid polymer membrane generally serves as an electrolyte. In order to obtain a technically relevant electrical voltage, multiple cells (ten to several hundred) are connected in series to create what is known as a stack.

Using simulation and automation to consolidate and optimize an aeronautics validation process

Active Vibration Control

Active vibration control systems that reduce the vibrations of the entire rotorcraft fuselage are very complex. Despite this complexity, Hutchinson was able to quickly bring the various control system components to market by using an automated yet flexible test system from dSPACE.

Throughout the last years, Hutchinson's focus has moved from providing customized components to selling fully integrated systems. This strategic trend led to the development of the active vibration control system (AVCS) technology for rotary wing machines, among other things. This technology attenuates the blade-passing frequency vibrations that are felt by rotorcraft pilots and passengers because aerodynamic loads are applied to the blades and transferred to the fuselage. The AVCS is based on several dynamic force generators (actuators) that are integrated in the fuselage, accelerometers distributed across strategic points in the fuselage, a rotor speed sensor providing the reference time, and an onboard real-time controller that analyzes the vibration signals and adapts the output signal to the actuators (adaptive control algorithm). Pilots control the system through a human-machine interface (HMI) with status indicators ('system failure' or 'system ready') and commands that enable vibration control or let the pilot select the comfort mode. All AVCS subsystems are complex mechatronic control systems of proprietary Hutchinson design (figure 1). The actuators are powered by the primary rotorcraft power supply (115 V). Electric unit conversion is performed in the controller.

From Equipment to Systems

This project marked a milestone in the long Hutchinson history, since this was the first time the company was a lead contractor for a complex mechatronics system for the normative aerospace environment that consisted of several line-replaceable units (LRU).
Hutchinson has a long record of developing certified products for the aerospace industry (mostly control and display equipment) with a continuously improving development process. But this project was of much greater complexity, and the validation challenges that had to be mastered by simulation were far greater. Therefore, the company decided to centralize the project validation activities with SCALEXIO platforms, which are tried-and-tested, reliable, high-performance solutions. Hutchinson started using dSPACE tools for its prototyping activities in the 1990s, which led it to trust the more recent dSPACE solutions as well. In the Hutchinson development process, the systems team, the company's point of contact for clients, collected the customer requirements, derived the interface requirements specifications and interface control documents, and performed a safety analysis. Using this information, a functional architecture of an AVCS system was drafted and translated into LRU-level system specifications, the entry point for establishing software- and hardware-level specifications. Therefore, the validation activities were multi-layered in terms of devices under test (AVCS system, LRU, SRU – shop-replaceable unit) and technical team (system, software, or hardware). The flexibility of SCALEXIO allowed the company to successfully and efficiently accomplish its highly complex project. >>

Hutchinson – a journey from equipment to systems for aerospace and automotive customers.

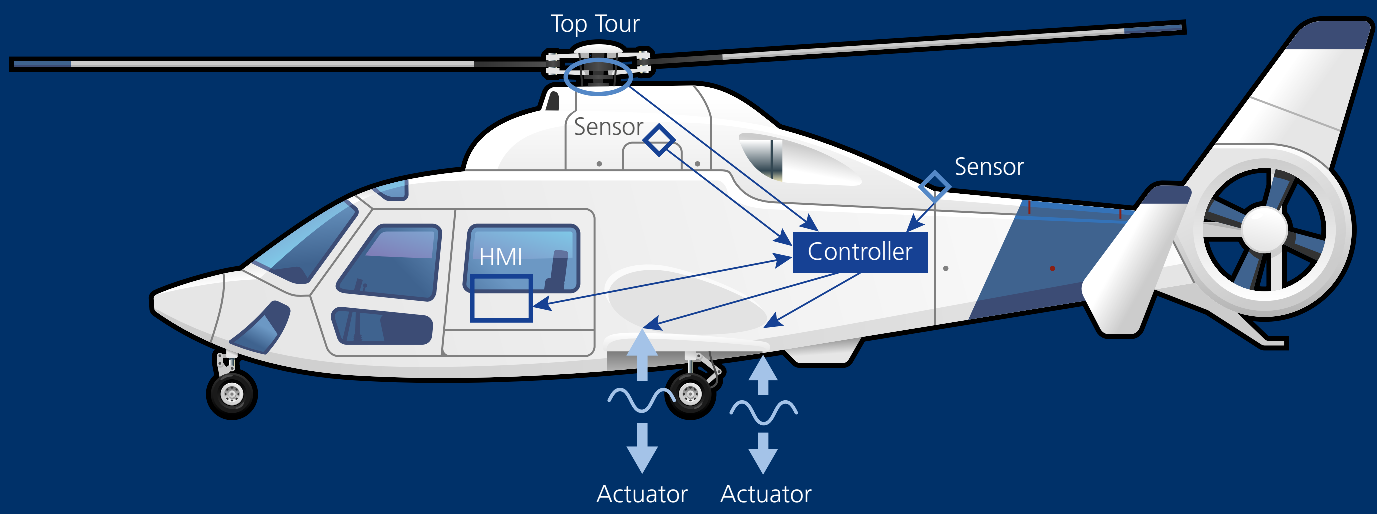


Figure 1: AVCS technology overview.

Team and Tools for Validation

It is standard practice in the aerospace industry to place an independent team in charge of the validation activities. In this case, the role was assigned to a multidisciplinary R&I team of engineers with a background in embedded systems design and validation, predominantly in the automotive industry. They were responsible for designing the required test benches, the validation at the LRU level, SRU level (electronic boards), and software level of both the controller and the actuator. They also performed defects tracking. In terms of resources, two SCALEXIO simulators were available for this project at 50% capacity (one six-slot unit for LRU-level tests and one twenty-slot unit for SRU-/software-level tests). An additional six-slot unit was procured specifically for this project. These platforms were complemented by additional test equipment, most notably a 115 V three-phase power supply and a dynamic external load, connected to the SCALEXIO simulator using standard communication protocols.

Achieving Top Quality

Early on in the project, the development team made three decisions to attain a high level of quality while reducing validation costs and delays:

- First, their focus was to develop a modular, open-architecture test bench that covered all test requirements. The idea was to configure a functionality (e.g., providing a 28 V power supply) consistently throughout the dSPACE environment (ConfigurationDesk, MATLAB®, ControlDesk, AutomationDesk) so that it could be easily integrated into different SCALEXIO configurations.
- Second, the existing validation process was updated to include the features offered by dSPACE (e.g., automated test reports) as highlighted in figure 2. The validation engineers checked the input requirements identified by the software, hardware, and systems team to write test cases, compiling them in a verification and validation plan before moving to (automatically generated) test procedures with results exported as PDF files.

A line-replaceable unit **(LRU)** is a modular component that is designed to be replaced quickly at any operating location (‘first line’).

A shop-replaceable unit **(SRU)** is a modular component that is designed to be replaced by a technician in a back shop.

> "The flexibility of SCALEXIO systems allowed us to complete our highly complex project successfully and efficiently."
>
> *Julien Mestres, Hutchinson*

- Third, the team placed emphasis on comprehensive automation of the validation activities. Automating the validation activities proved to be beneficial in terms of quality (repeatability of the tests, lower rate of human mistakes), delays (shorter test runs that often run on weekends), and costs (engineers focusing on high-value tasks, such as formal reviews).

System Overview

The AVCS system is composed of the following elements (figures 3-6):

- Actuator LRUs consisting of one control unit board SRU and one power unit board SRU
- One controller LRU consisting of one control unit board SRU, one filtering board SRU, and two power unit board SRUs
- One HMI LRU
- Accelerometer LRUs (hardware only)

Of all these elements, only the HMI and the filtering board were not validated with a SCALEXIO platform as their functional tests were too specific. However, SCALEXIO proved versatile enough to test the remaining LRUs and SRUs. More precisely, the following seven test benches were developed from the open modular architecture described above:

- LRU controller test bench
- LRU actuator test bench
- Software acceptance test bench
- SRU actuator electronic boards (power supply and control) test bench, also used for software acceptance tests
- SRU controller electronic boards (power unit) test bench
- SRU controller electronic board (control) test bench
- LRU accelerometer test bench

Scope of Testing

As usual for SCALEXIO platforms in the aerospace industry, the test benches primarily covered functional tests that typically address the performance of the various LRUs, such as the power consumption of the actuator. They were also used for non-regression software tests after each delivery, with a run time in the range of 40 hours and a degree of automation of 98%. This required >>

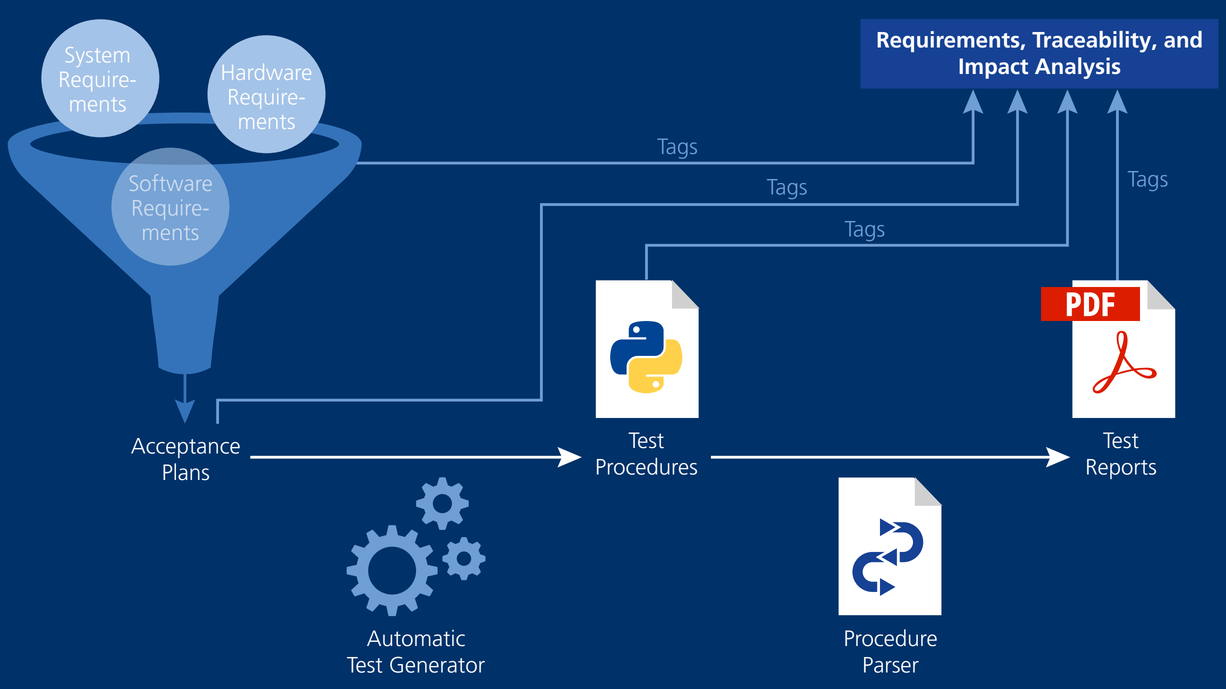


Figure 2: Hutchinson validation process.

Hutchinson active noise & vibration control systems reduce cabin noise (by up to 20 dB for aircraft) and structural vibrations (by up to 30 dB for helicopters and up to 20 dB for automotive applications).

Figure 3: Actuator for dynamic force generation.

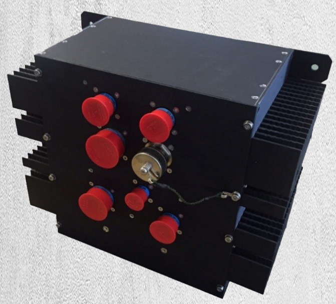


Figure 4: Active vibration control and electrical unit.

Figure 5: Human-machine interface.

Figure 6: Active control sensor.

only a single bed-of-nails test bench because the actuator and the controller are designed around the same digital signal processor (DSP). SRU acceptance tests (which take place after unit and integration tests) on the initial electronic boards and with the official release version, were also automated.

Automating the Tests Procedures

A key element in reducing the time to market was to use a unified framework to validate requirements for the different technical teams (system, hardware, and software). There turned out to be more similarities between the test benches and test procedures than anticipated. Automating the test procedures – a novelty for Hutchinson in an aerospace application – was also a game changer for this project. It has two main benefits. First, it improves the response time of the validation team and its ability to detect defects early. This is especially true for the software team for which automated non-regression tests proved invaluable, helping improve the quality of the software deliveries. Another ingredient for success was the similarity between the test benches. The Hutchinson process, which is assessed according to the capability maturity model integration (CMMI) level 3, comprises three steps in test-bench-based development: specification, architecture, and acceptance tests. Spending time on configuring a SCALEXIO system to validate the controller test bench, for example, proved worth the effort as the company was able to reuse the configuration for the actuator test bench. This is where dSPACE tools, such as AutomationDesk, play to their strengths; They are crucial for the configuration of complex products, systems of systems, where each element has to be tested separately before integrating them (figure 7). With easy-to-create, structured tests, AutomationDesk improved the overall efficiency of validation.

Helpful Features

Hutchinson used the dSPACE configuration and implementation software ConfigurationDesk to configure the hardware, one main reason being the distinct ability to define custom drivers for serial communication. The precise and targeted support they received from dSPACE enabled the company to set up drivers tailored to their requirements where the communication protocol was checked at a low level directly in the C language (message integrity, cyclic redundancy checks (CRC), etc.) before feeding data to the MATLAB® model for more advanced processing and synchronization with other signals. This advanced bus analysis capacity was especially relevant for the LRU integration phase. Another feature that proved equally useful was the scope of available options for crank/cam signals. dSPACE has continuously invested in these advanced functiona-

> "dSPACE tools, such as AutomationDesk, play to their strengths in complex products, where we have to test each element separately before integrating them."
>
> *Dr. Patrick Fayard, Hutchinson*

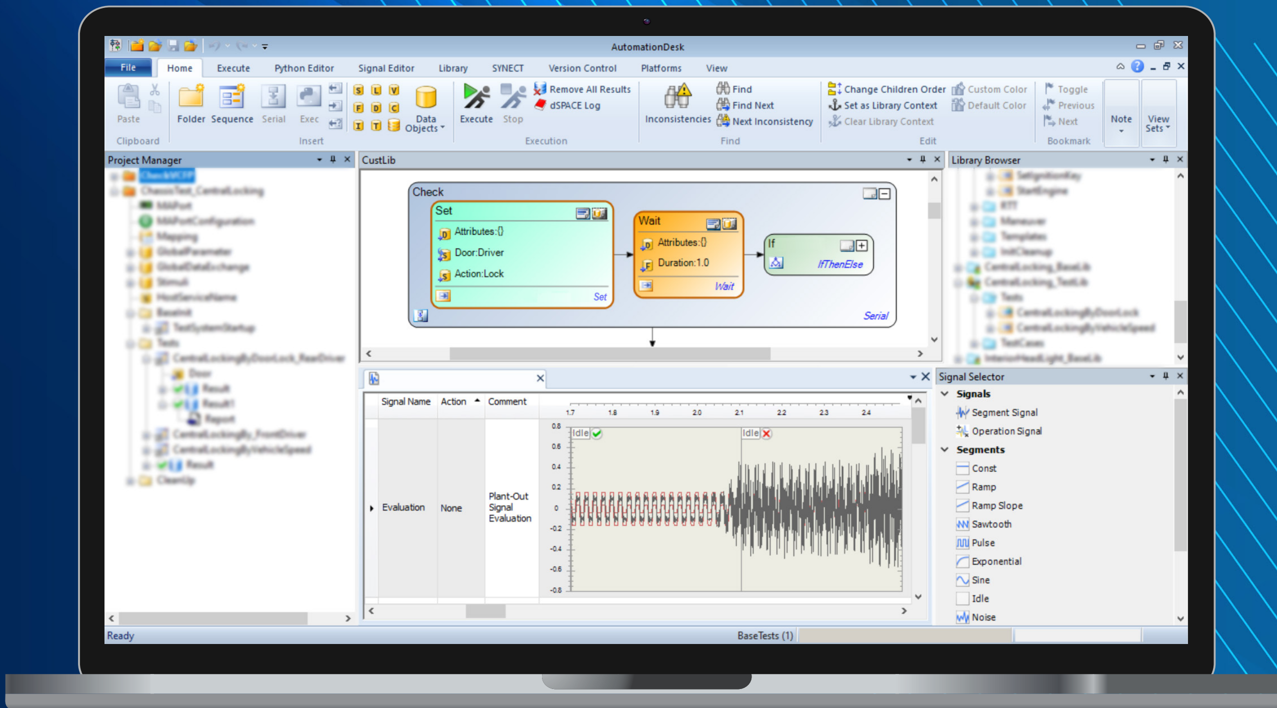


Figure 7: The test automation software AutomationDesk contributed immensely to test efficiency.

lities, which have been used successfully in the automotive industry and can also be applied to aircraft. In the Hutchinson application, the rotor speed sensor plays a pivotal role since it is used as a reference to synchronize the actuator force generation with the vibrations captured by the accelerometers, and the predefined library blocks were a perfect fit for the company's project.

A new generation of the AVCS system, with improved performance and reduced actuator weight, is currently under development. The proven performance of the dSPACE tools gives the technical teams extra confidence in delivering a thoroughly validated product according to schedule. ▪

Dr. Patrick Fayard, Julien Mestres, Hutchinson

Dr. Patrick Fayard

Dr. Patrick Fayard is Verification and Validation Lab Manager and Senior Expert Mechatronics in the Centre for Research & Innovation at Hutchinson in Châlette sur Loing, France.

Julien Mestres

Julien Mestres is AVCS Project Manager & System Engineer and Innovation & Mechatronics Systems Engineering Manager at Hutchinson Aerospace Defense & Industry – Anti-vibrations Systems in Lisses, France.

SmartKai: digital assistance system for docking and casting-off maneuvers

Parking Assistance for Ships

SmartKai is an application-oriented research and development project complying with the funding guideline on innovative harbor technology (IHATEC) issued by the German Federal Ministry of Transport and Digital Infrastructure (BMVI), in which several partners are cooperating:

- **Niedersachsen Ports GmbH und Co.KG (NPorts) –** Germany's largest port operator and coordinator of the SmartKai project. NPorts makes its harbor infrastructure available for the development of SmartKai. Quays and harbor locks with a high risk of accident are good locations for using the system.
- **SICK AG –** Is developing a new, more robust lidar sensor for the project, designed specially for a maritime environment. The sensor uses an adapted light wavelength with a longer range.
- **Humatects GmbH –** Is developing SmartKai's user interface so that ship crews can easily visualize navigation data using a tablet, augmented reality glasses, or projections.
- **OFFIS –** Informatics institute at which the harbor's lidar sensor system for capturing ship positions is being developed.
- **eMIR (eMaritime Integrated Reference Platform) –** Development platform for maritime applications.

Parking assistants have long been a familiar feature in cars. Now ships will soon have something similar. Maneuvering a ship in the confined space of a harbor basin can be difficult due to adverse currents, bad weather, the increasing size of ships, the growing amount of ship traffic, tight schedules, and so on. The result is repeated accidents that cause damage to both the vessels and the harbor infrastructure – and sometimes personal injuries. The SmartKai project aims to prevent this.

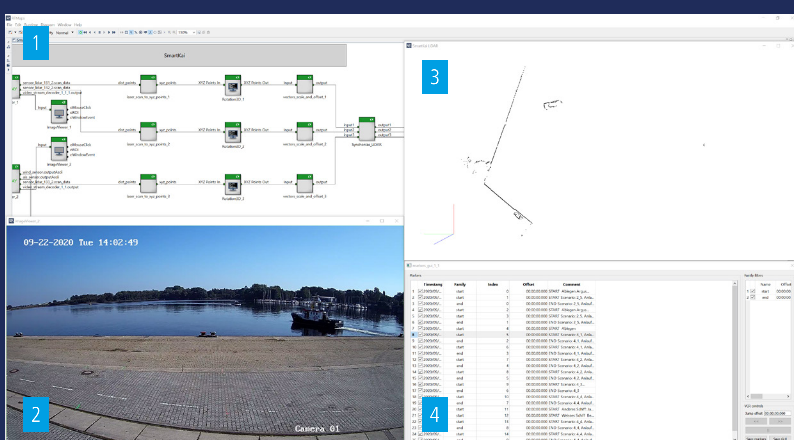
Lidar Sensors in the Harbor Detect Ships

SmartKai is a "parking assistant" for ships. Using lidar sensors mounted on the harbor infrastructure, SmartKai detects the positions of ships during docking and casting off, prepares information from the data, and sends this to the crews and pilots. To gain

>>

SmartKai is a digital assistance system that aims to make damage caused by maneuvering in the tight space of a harbor basin a thing of the past. Lidar sensors installed in the harbor capture each ship's position data, and with the help of the RTMaps software, the data is then prepared for display to the ship's crew.

Figure 1: Setup of the SmartKai prototype at Hannover Quay in Wilhelmshaven. The sensors and processors are spatially separate, so synchronization is vital.



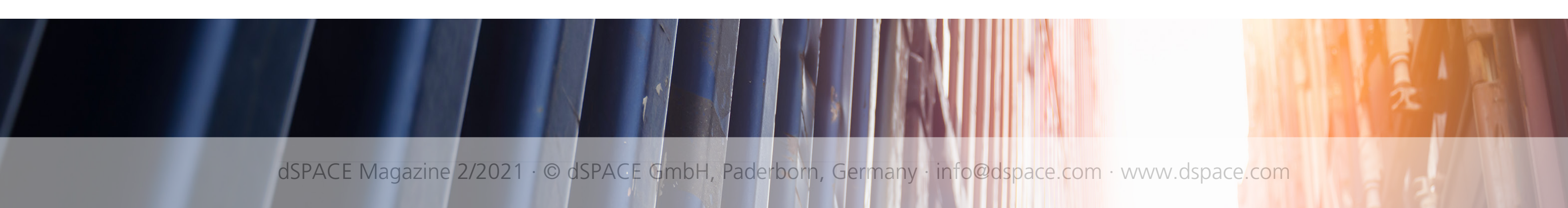
1. Diagram with the different blocks for representing, processing, and synchronizing the measurement data (lidar, cameras, wind, AIS).
2. Live image of the wharfage taken with camera 1.
3. Lidar point cloud of the wharfage, made by combining measurement data from the three lidar sensors.
4. List of recorded test runs.

Figure 2: The RTMaps interface for processing and visualizing the collected measurement values.

a precise idea of their ship's position and maneuver it safely, all the crew on board needs is a tablet, called the portable pilot unit (PPU). Moreover, if there is an accident, SmartKai makes it possible to find out what caused it. Another plus with this system is that no complex, expensive installations are needed on board, because the sensor and computing technology is installed permanently in the harbor.

First Prototype in Wilhelmshaven

The first step was to test the system with no disturbing effects, so Niedersachsen Ports (NPorts) installed it at Hannover Quay in Wilhelmshaven, an almost completely closed harbor area with almost no currents or tides (figure 1). Three 2-D lidar sensors from project partner SICK were the



> "For us, RTMaps is the right software for capturing, accurately time-stamping, synchronizing, processing, and forwarding the measurement values from our sensors."
>
> *M.Sc. Jan Mentjes, OFFIS*

basis for SmartKai. In addition, environmental sensors (for wind data and visibility) and an AIS receiver were installed (AIS = Automatic Identification System, an internationally standardized radio system for exchanging navigation and other vessel data). Two cameras for visual monitoring were mounted at strategic points on the quayside. All the sensors are connected to two industrial PCs (IPCs) in mobile boxes on the quay. These collect, save, and process the measurement values from the sensors.

Processing the Measurement Values with RTMaps

For a safety- and time-critical system like SmartKai, reliability and processing speed are essential. The specific challenge is to assign accurate time data to the captured measurement values and synchronize the processing instances, which are spread over a wide area. So the obvious course was to use the RTMaps software (Real-Time Multisensor Applications), which was created for just such scenarios where users have to collect, time-stamp, synchronize, and replay data from different sensors (figure 2). To handle the challenges posed by the SmartKai project, there is an RTMaps run-time instance on each of the industrial PCs. In addition, all the RTMaps instances are synchronized with one another to ensure that the system is real-time-capable. Another of the project's main aims is to store all the incoming data permanently to make it available for further development and evaluation of the system. After over a year in operation, an extensive collection of lidar, camera, and AIS and wind data has been collected. RTMaps is also able to replay this data synchronously.

Wide Range of Scenarios Tested Extensively

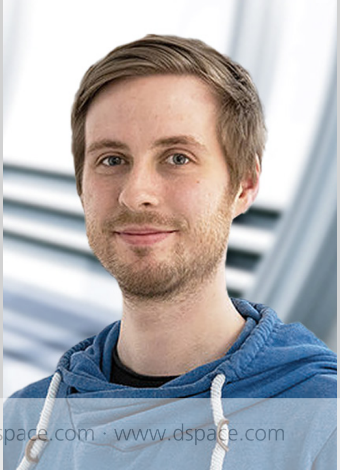
In September 2020, the system in Wilhelmshaven underwent its first three-day field test with more than 20 scenarios. These were oriented to the regulations issued by the International Maritime Organization (IMO), as well as to requirements stated by pilots. The research boat Josephine (belonging to OFFIS e.V.) and the survey ship Argus (NPorts) were used for the test (figure 3). The sensor measurement values were saved via RTMaps and appropriately annotated. Data on the start and end times of the scenarios, plus details of any issues or events such as passing ships, were saved in the RTMaps EventMarker format so that the data could be used for the further development of the system. Following that, the system continued in operation through winter 2020/2021 and summer 2021. Docking maneuvers under harsh weather conditions are of particular interest because they can show the effect of the weather on the lidar measurement values. Throughout the entire test phase, data was continuously captured, time-stamped, and saved via RTMaps.

Tests to Be Completed in 2021

The project is designed to run for three years (project end is November 2022), and the next step will be to install another system in a different location, this time Europa Quay in Cuxhaven. The focus there will initially be on the effects of currents and the weather, and how they might make docking difficult. Seven more lidar sensors have been added to the system for this in order to cover the 300-meter-long quayside. The system will be completely tested and evaluated for the first time in the test campaign planned for the end of 2021 in Cuxhaven. ■

Figure 3: The research boat Josephine (belonging to OFFIS e.V.) and the survey ship Argus (NPorts) during a test run in Wilhelmshaven.

M.Sc. Jan Mentjes, OFFIS
M.Sc. Jan Mentjes, research associate in the institute's transportation division, OFFIS e.V. – Institute for Information Technology, Germany.



Validating ultrasonic-based parking assistance

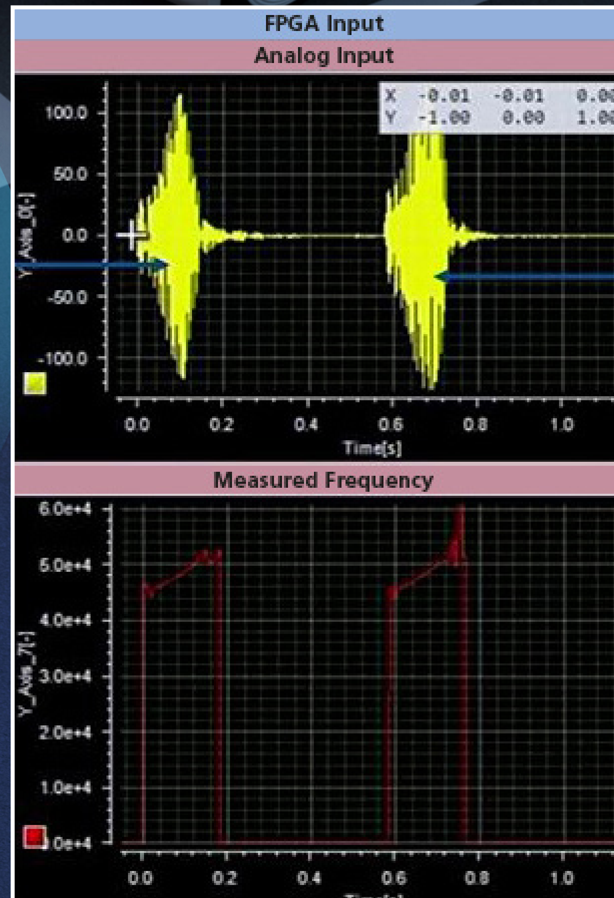
Sound Waves in the Control Loop

Ultrasonic sensors play a significant role in the field of parking assistance systems. CATARC provides a service for validating ultrasonic-based systems using a simulator from dSPACE.

One of the greatest challenges for road users and especially for new drivers is parking: maneuvering cars into tight parking spots can often be both frustrating and time-consuming. Assistance systems can reduce the driver's workload by taking over the entire parking process: Depending on the degree of automation, the digital assistant drives the vehicle partially or entirely on its own. To do so, the assistance system detects the vehicle's surroundings and controls the actuators for braking, driving, and steering.

Near-Field Monitoring for Parking Procedures

The sensors of the assistance systems monitor what is known as the near field: the area directly surrounding the vehicle. Typically, ultrasonic sensors are used for this purpose. As displacement sensors, they are capable of measuring the distance of the objects from the sensor by cyclically emitting short, high-frequency sound impulses and receiving the reflections from the surroundings. The distances can be calculated based on the difference between the time the impulses are sent and received. The following also holds true for modern near-field monitoring: Sensors love company. On their own, ultrasonic sensors and other sensors deliver relatively blurry or "noisy" data. Only after comparing the results with other sensors is it possible to obtain a reliable picture of the surroundings. This multisensor recording is even more important as vehicles on the road become more autonomous. Due to the high likelihood of collisions when parking, such systems must have passed extensive validation tests before they can be approved for a vehicle.



Sensor chirp and simulated reflection.

Maximum Flexibility When Testing

Test drives cannot cover the entire validation task. Many different test cases have to be evaluated up to the collision, and the behavior of the assistance system has to be adjusted accordingly. A simulation-based process offers the necessary flexibility for the variation between tests. However, stimulating the sensors and assistance systems simultaneously with plausible environment data poses a challenge.

Criteria for Selecting the Test System

Among other services, the technology company CATARC is specialized in validating and approving a wide range of parking assistants that automobile manufacturers would like to operate in their vehicles destined for the Chinese market. The different structures of the parking assistants call for special requirements with regard to the test system:

- **Flexibility:** to provide all required interfaces and map the relevant signals appropriately
- **Automation:** to easily create test cases and their variants and apply them in a replicable manner
- **Availability:** Due to the high test volume, the test system must be available at all times.
- **Reporting:** detailed test reports for individual parking assistants
- **Economic efficiency:** to ensure cost-effective operation from acquisition to maintenance despite the high flexibility

Based on this set of requirements, CATARC probed the market for test systems.

A Test System for Parking Specialists

After evaluating various test systems, CATARC decided on a solution from dSPACE. The test software is based on a HIL simulator, which makes it possible to integrate ultrasonic and camera sensors into the control loop.

Integration via simulation: This is done using an over-the-air (OTA) approach for ultrasonic sensors (USS). A sensor box contains all of the vehicle's ultrasonic sensors and supplies them with the necessary operating voltage and signals from the simulator. A reflector, which is also connected to the simulator, is positioned across from each USS. It receives the signals from the

>>

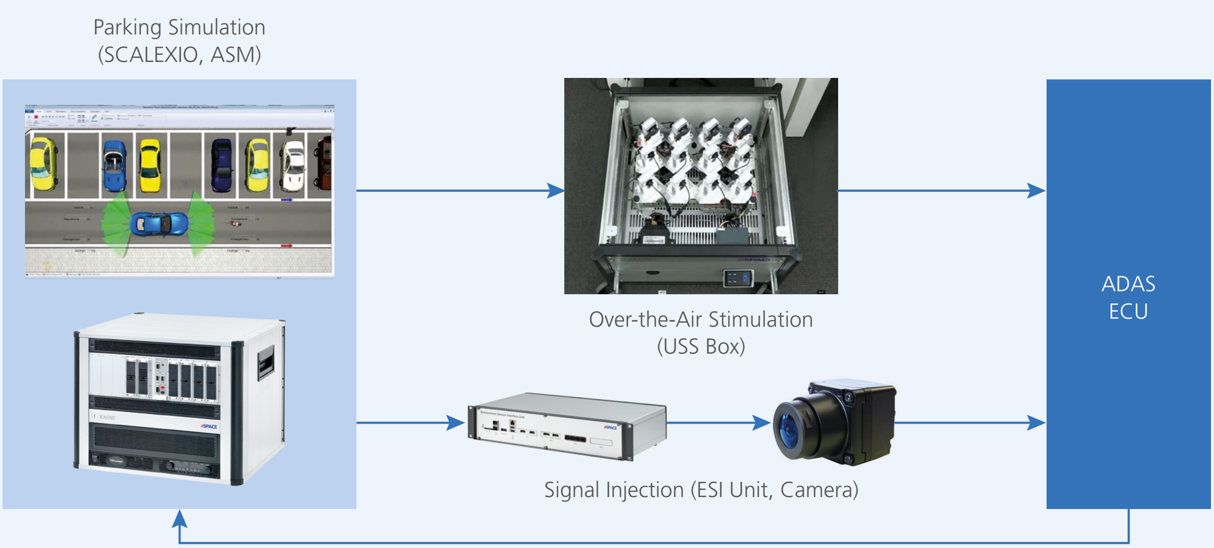
USS and sends them back with a delay based on the distance calculated from the simulation. Thus, the ultrasonic sensors are stimulated entirely by means of simulation, delivering the calculated distance signals to the assistance system. Parking assistance systems consisting only of ultrasonic sensors can be fully tested and validated using this method.

Integration via data feed: The HIL simulator can also be used for parking assistance systems that feature a camera sensor as well. Because these sensors are designed for a panoramic view and feature a detection angle greater than 180°, an OTA approach, in which the sensor records a flat monitor, is not appropriate. In this case, the simulation data is fed directly into the sensor. This is done with the help of the Environment Sensor Interface (ESI) Unit from dSPACE, which prepares the raw sensor data so that it can be fed directly behind the camera's imager chip, for example. As a result, the validation covers all of the sensor's processing stages. The sensor data required to stimulate and feed the sensor is obtained from a simulation and supplied simultaneously.

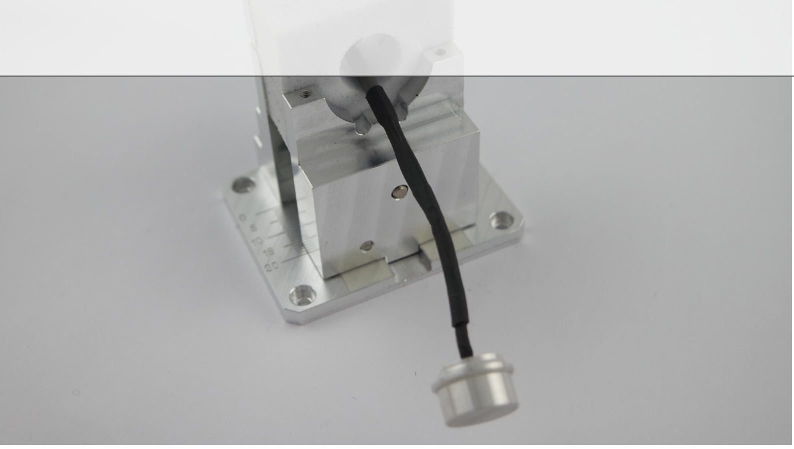
Learning from Mistakes: Virtual Collisions Are Allowed

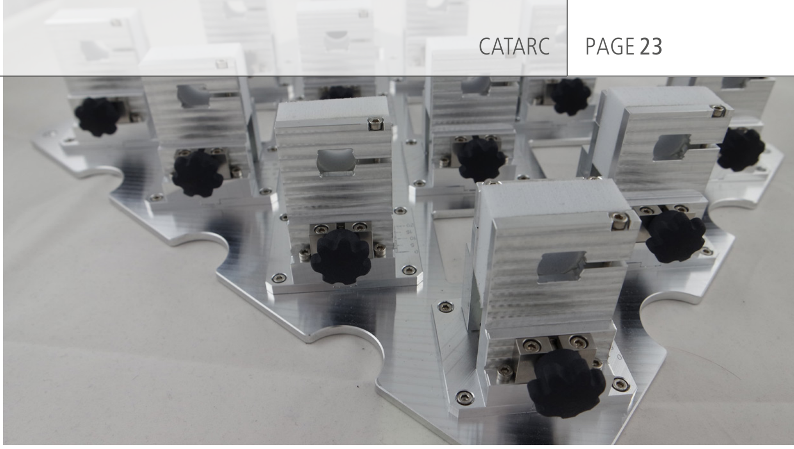
All of the data relevant to the sensors is acquired from a traffic simulation carried out using the ASM (Automotive Simulation Models) tool suite. ASM makes it possible to create any number of scenarios interactively and simulate them realistically. For parking assistance systems, these scenarios might include parking bays, parking spots, or urban regions, which can be designed as needed. Furthermore, it is possible to simulate road users including pedestrians, and obstacles that have to be detected while parking. The sensors can even be positioned easily: Their positions inside the virtual test vehicle can be assigned intuitively via a graphical user interface. The predefined tests are then performed

> "The flexible and automated simulator from dSPACE plays a key role in developing and approving parking assistance systems for the Chinese market."
>
> *Quanzhou Liu, CATARC*



Structure of the simulator for validating parking assistance systems.





"The dSPACE simulation models from the ASM tool suite make it possible to create any number of scenarios intuitively and simulate them realistically."

Zhanqi Li, CATARC

automatically. Test parameters such as distances and speeds can be changed at any time during the test until a virtual collision, which is particularly useful. Thus, the test engineers at CATARC can generate numerous test cases and ensure a high test coverage using the parameter variations.
In addition, the HIL simulator can replay recorded sensor data during test drives. This data is supplied via the sensor box and ESI unit to the USS and camera, exactly like the simulation data.

Valuable Findings from the Test

The test system can be used to quickly test new functions and validate complete controllers. Moreover, it is possible to evaluate the system limits, for example, the actual minimum and maximum distances, early on by means of simulation. The ability to repeat any abnormalities that were detected and recorded during the test drive is especially valuable.
The test solution has been adapted brilliantly to CATARC's range of services to offer the flexibility required to easily integrate ultrasonic sensors and ECUs from various manufacturers. In general, only a few parameters have to be adjusted for this purpose.
Currently, the simulator is being used by a team of 30. It took roughly three weeks of training until they could use it efficiently. The test system has come to play a key role in everyday testing. Especially in the field of automated driving, including valet parking, the simulator ensures that the functions are safe before they are used in a real test drive. This is possible because the wide range of dangerous scenarios is simulated realistically using the simulation tools supplied by dSPACE. Furthermore, the tools from dSPACE help speed up testing and streamline the validation tasks by allowing for end-to-end validation, from the sensors and ECU to the driving.

More Innovation, More Testing

The development of parking assistance systems is progressing rapidly. Communication systems between vehicles and their surroundings (V2X) are being integrated and new sensors are becoming increasingly relevant. Therefore, there are plans to add V2X validation to the test system. Further testing requirements might arise with regard to radar sensors. Because radar test benches from dSPACE already play an important role in other contexts at CATARC, the integration of such a test system is being considered. ■

Quanzhou Liu, Zhanqi Li, Pengfei Jia, CATARC

Quanzhou Liu
Quanzhou Liu is Director of the Electronic Control Development Department at CATARC in China.

Zhanqi Li
Zhanqi Li is senior manager of the Simulation Development and System Verification Group at CATARC in China.

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Liver4Life perfusion machine preserves donor livers for up to one week outside of the body

Back to the Future

With funding from Wyss Zurich, an interdisciplinary group of researchers from ETH Zurich and the University Hospital Zurich has developed a device that significantly extends the life of donor livers outside the human body by simulating a range of bodily functions. A dSPACE MicroLabBox performs the central control tasks.

The demand for donor livers has been growing drastically for years, quickly outstripping the number of organs available. Every successful liver transplant effectively prolongs the life of a patient. This is why it is important to use all available donor livers optimally. The healthier the liver or partial liver, the better the chances are that the patient will be able to return to a normal life. This is even more likely if it is possible to preserve the donor liver longer outside of the body. And that is exactly what the new perfusion machine does.

PERFUSION: Artificial circulation for organs

A Race Against Time

With the perfusion machines currently available on the market, donor livers can be preserved for transplantation for a maximum of 24 hours. In order to extend this time, ideally to up to a week, an interdisciplinary team of researchers consisting of surgeons, engineers, and biologists started developing an innovative perfusion machine in mid-2015 as part of the Liver4Life project. It simulates numerous bodily functions and provides a donor liver with an environment that is as similar as possible to the conditions present in a human body. As a result, livers can not only survive up to one week outside of the body, their condition can also be improved considerably, which opens up a variety of new perspectives for future transplants. For example:

- Reliably estimating the quality of the donor livers based on measurement data
- Improving the quality of previously damaged livers
- Potentially regenerating parts of a liver in the future
- Making autologous organ donations possible

Ultimately, the available donor livers can be used much more efficiently

as a result, or they are not even required in the first place (in the case of an autologous donation).

Nature as a Role Model

In order to preserve a liver outside the body, it used to be common practice to pack it in ice, known as static cold storage, to reduce the metabolic processes to a minimum. However, to achieve the goals described above, it is necessary for all biochemical processes in the donor liver to continue as if it were still in the body. For this purpose, the metabolic functions of the liver had to be described in detail from a medical perspective so that engineers could then implement the requirements in a machine. Five key functions in particular were identified for long-term perfusion: controlling the glucose metabolism, preventing hemolysis (the rupture of red blood cells), discharging waste, controlling the supply of oxygen through the perfusate (fluid used for the artificial perfusion of organs, blood in this case), and simulating diaphragm movements (figure 1).

New Habitat for a Liver

In the human body, the liver is fed through two blood vessels, in which both the blood pressure and the share of oxygen, hormones, and nutrients in the blood vary.
Outside of the body, the Liver4Life perfusion machine takes care of all this. If the donor liver is connected to the machine, it is not simply fed a standard supply of nutrients, neurotransmitters, and oxygen. Instead, this supply is adjusted to the liver's needs. Waste produced by the liver metabolism is discharged by means of dialysis or as bile. The fluid leaving the liver is fed back into the system. To make sure the liver feels "at home", a series of sensors transmit the data that is used as a basis to adjust the supply to the liver via various actuators.
In addition, sensors monitor its condition at all times. What is more, an artificial diaphragm simulates the movements of a real diaphragm to protect the liver from pressure necrosis (tissue dying as a result of constant pressure). Such a setup requires various subcircuits, which all have to be carefully calibrated (figure 2).

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"The MicroLabBox controls how the sensors and actuators interact with each other. In doing so, it takes over the function of the brain by coordinating the simulation of the different organs."

***Dr. Dustin Becker, ETH Zurich, Wyss Zurich, Zurich, Switzerland,** helped develop the system as part of his dissertation and is responsible for implementing the medical requirements in the machine.*

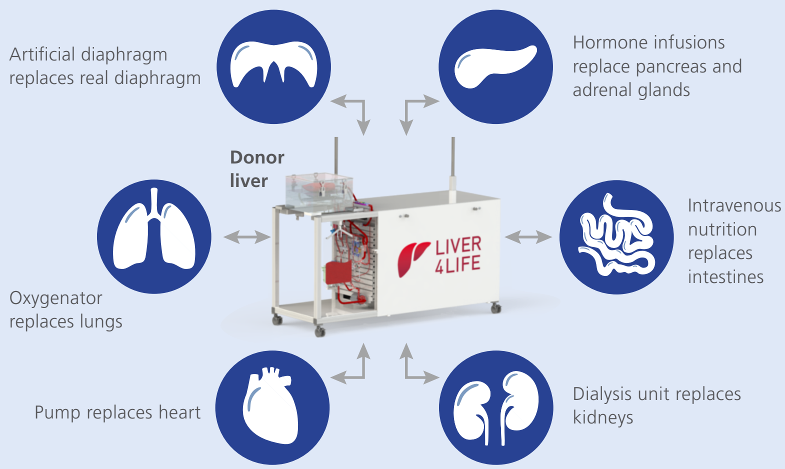

Figure 1: In order to maintain the metabolic processes of a donor liver, the functions of various organs have to be simulated by the perfusion machine.

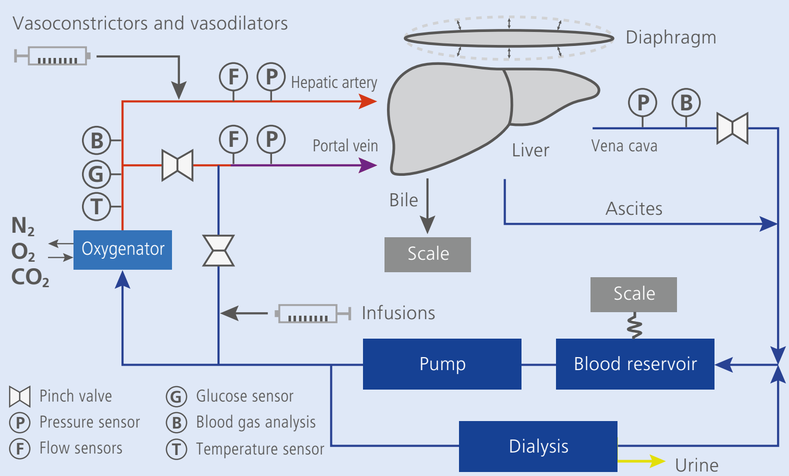

Figure 2: Simplified diagram of a perfusion machine.

Multiple Functions, One Control Unit

A MicroLabBox serves as the control unit used to simulate the brain functions required in this context. One of these boxes is being used at ETH Zurich in the field of automotive developments, which means they already had experience using it. The MicroLabBox stood out due to its flexibility and high computing power. The MicroLabBox acts not only as an I/O interface for the communication between sensors and actuators, but also as the central computation unit (figure 3). The work is supported by the dSPACE experiment software ControlDesk, which makes it possible to access real-time applications while they are running. As a result, it is possible not only to monitor the supply parameters of the liver but also to influence them actively when a donor organ is connected to the machine.

Better Simulation for Better Quality

The perfusion machine considerably expands the possibilities of maintaining the metabolic functions of a donor liver outside of the human body (table 1). What are the next steps after these promising results? Clinical studies are now required to demonstrate that even mediocre livers can actually be transplanted after undergoing the perfusion process. The metabolic data delivered

"When it's a matter of survival, there are no 'pretty good' results. The decision as to whether or not a donor organ can be transplanted, for example, has to be definitive and reliable. The perfusion machine, supported by the MicroLabBox, makes it possible to make decisions like this."

Dr. med. Dilmurodjon Eshmuminov, University Hospital Zurich, Zurich, Switzerland, Department of Visceral and Transplantation Surgery, *contributes his medical expertise to the project team and is responsible for defining the medical requirements.*

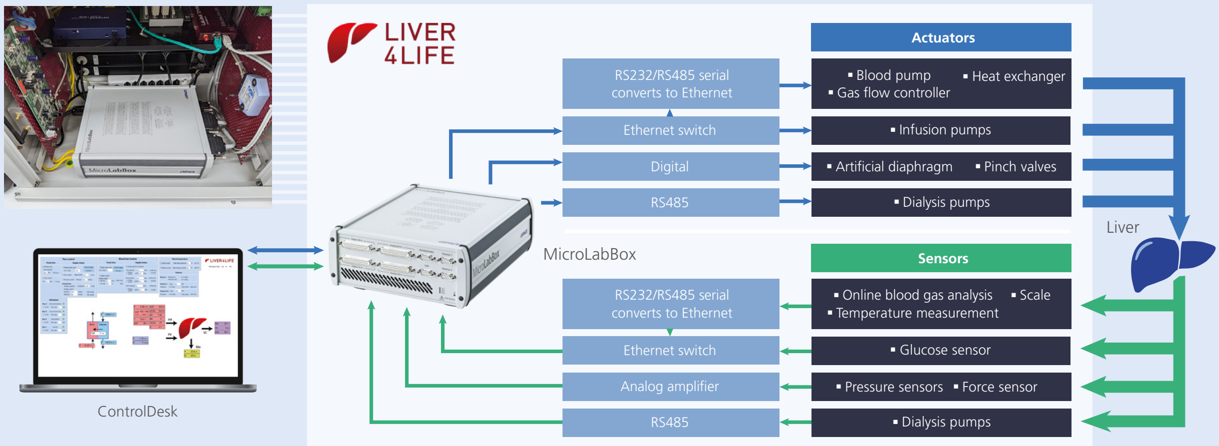

Figure 3: Function of the MicroLabBox as the "brain" of the perfusion machine.

Table 1: Possibilities for monitoring and controlling liver functions offered by perfusion machines available on the market compared to those offered by Liver4Life.

Device/Function	Task	Details	Commercial perfusion machines	Liver4Life long-term perfusion system
Liver chamber	Safe liver storage		x	x
Pump	Continuous flow in portal vein		x[1]	x
	Pulsatile flow in hepatic artery		x[1]	x
Pressure and flow sensors	Continuous pressure and flow monitoring	Hepatic artery	x	x
		Portal vein	x	x
		Vena cava	x	x
Oxygenator	pH control with individual O_2, N_2 and CO_2 gas supply to oxygenator	Gas supply	x	x
		Heat exchanger	x	x
		Individual gas supply for pH control in blood		x
Blood gas analysis	Monitoring of blood gases and other critical parameters during long-term perfusion	Hepatic artery	x	x
		Portal vein		x
		Vena cava		x
Physiologic portal vein oxygenation	Prevention of hyperoxygenation and reduction of vasoconstriction, physiologic portal vein saturation			x
Online glucose sensor	Real-time glucose monitoring			x
Feedback-controlled infusions of insulin/glucagon	Automated correction of blood glucose level within predefined limits			x
Feedback-controlled dialysis system	Metabolic waste removal, acid-base balance, control of sodium and electrolytes, hematocrit control			x
Diaphragm simulation	Movement of liver to prevent pressure necrosis			x
Continuous evaluation of response to vaso-active substances, insulin, and glucagon	Continuous viability assessment			x

1) *Waveform and pulse shape of flow and pressure unknown for conventional machines*

by the perfusion machine could provide a reliable evaluation of the organ quality. In the long term, the liver's enormous capacity to regenerate itself will also be used so that one donor liver can benefit multiple patients at once. It would also be conceivable – for example, with cancer patients – to remove healthy parts of the liver, regenerate them in the Liver4Life machine, and retransplant them as a replacement for the diseased organ. This would not only potentially save the patient's life, it would also save them from having to take medication for the rest of their life to prevent their body from rejecting a new organ. A donor liver would not be required in this case. Thanks to the new perfusion machine, there is a renewed hope that more lives can be saved by making better use of quality donor livers or even with autologous organ donations. ■

On the left: Untreated liver
On the right: Liver prepared in the Liver4Life perfusion machine

Courtesy of ETH Zurich, the University Hospital Zurich, and the Wyss Zurich Institute

Visionary Trucks

Developing, prototyping and validating an automated camera- and radar-based braking system for commercial vehicles

Shaanxi Automobile Group Co., Ltd. is equipping its vehicle fleet with cameras, radars, and an advanced emergency braking system to give its customers the highest possible level of safety. To develop the software more efficiently, the company relies on RTMaps, a development and execution environment for multisensor applications from Intempora, a dSPACE company.

"With RTMaps, we control extensive, complex sensor data and can use it in a targeted and synchronized way to efficiently develop and validate our algorithms."

Junjie Bai, Shaanxi Automobile Group Co., Ltd.

Whether in city centers or on rural roads, truck drivers always have to keep an eye on traffic, traffic lights, and road signs, while watching out for pedestrians and cyclists. But even the most attentive drivers struggle with the large blind spots and long braking distances of their commercial vehicles, which weigh several tons. Driver assistance systems provide vital support in reducing the number of traffic accidents and protecting drivers as well as other road users: They warn drivers if a collision is imminent. If the driver does not respond, the system automatically initiates emergency braking.

Reliable Algorithms for Vehicle Safety

Yiran Zhang, head of the electric control division explains, "Shaanxi Automobile Group aims to further strengthen its leading role İn the field of intelligent connected commercial vehicles in China. To this end, we are pushing ahead with the development of an advanced emergency braking system (AEBS).

Our goal is to develop a safe and reliable AEBS algorithm characterized by a high correct-recognition rate and a low false-recognition rate. We will bring this algorithm into series production for our wide range of vehicles," adds Yiran Zhang. The AEBS includes a control unit with intelligent cameras and millimeter-wave radars.

The Challenges of Multisensor Data

At the outset of the project, the developers used recorded CAN messages from the sensors to test the algorithm implemented on an ECU. This approach quickly reached its limits due to increasingly complex test data and a growing number of corner cases that had to be analyzed in detail. The developers then formulated requirements for a powerful test environment:

- Synchronous playback of all sensor data to ensure correct, time-correlated data fusion
- Synchronous visualization of the test scenarios with recorded motion images to quickly assess the output of the fusion and detection algorithms
- Easy localization of relevant test data in a large data pool
- Efficient handling of large amounts of data

Mastering Complexity

Shaanxi Automobile Group selected RTMaps, a development and execution environment for multisensor applications as it meets all of the above challenges. It was also found to be suitable to support the design and validation of advanced and complex software functions.

Junjie Bai, responsible for the development of the perception algorithm reports, "When started working with RTMaps, it was a night and day difference compared to the initial approach. With RTMaps, we control extensive, complex sensor data that we can synchronize to develop and validate our specific algorithms."

First, the developers used RTMaps to synchronously record large volumes of sensor data during measurement runs. This includes the original video of the webcam, the audio signal of the microphone, the target lists of the intelligent camera, and the millimeter-wave radar in the form of CAN messages.

The developers then integrated the AEBS algorithm in the RTMaps graphi-

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The advanced emergency braking system is being rolled out to the many truck platforms in the fleet of Shaanxi Automobile Group Co, Ltd.

Advanced emergency braking system (AEBS)
The system warns the driver of an imminent collision with a slow-moving or stationary vehicle ahead. If necessary, it can also hit the brakes to prevent the collision or reduce the speed of impact.

Shaanxi Automobile Group Co, Ltd
With approximately 13,000 employees, Shaanxi Automobile Group Co, Ltd. is one of the larger employers in the People's Republic of China. The company manufactures trucks. The manufacturer's headquarters are located in Xi'an, Shaanxi.

cal development environment and put it into operation with the recorded data.

Efficient Workflows in RTMaps

"With RTMaps, we can quickly replay real sensor data, both raw data and CAN messages, and start replay from any point in time. This is particularly useful for developing the fusion and perception algorithms," says Junjie Bai. The team reports an easy-to-use yet efficient workflow in RTMaps: The tool allows the selection of input signals for the AEBS algorithm – in this case, the original sensor messages captured on the CAN bus, and further sensor signals are key variables of the algorithm. The original video can be used in RTMaps to visualize and check the respective driving situation, while the audio signal reproduces the alarm signals in the vehicle. "Thus, the developer is always informed about all recorded aspects that occurred during a driving situation," concludes Junjie Bai. Furthermore, parameters can be added to the algorithm to calibrate and optimize it. Particularly relevant sensor data, such as test cases for testing behavior in specific situations or so-called corner cases, can be extracted and is then available as validation data for subsequent algorithm optimization.

Fast Evaluations of Sensors

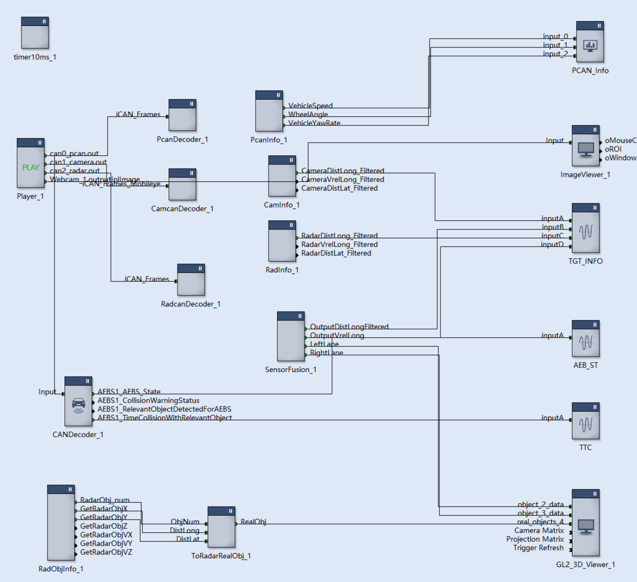
For some of the commonly used sensor types, the performance of different sensor makes has to be compared before algorithm development begins. RTMaps lets developers evaluate and visualize the target lists of the sensors, allowing for an easy comparison and a quick selection of the most suitable sensor.

Support of Multiple Programming Methods

Developers often use multiple programming environments to write complex algorithms: for example, C/C++ to build the basic structure, Python for image processing, and Simulink® for the application layer. The open and flexible code development environment of RTMaps supports this multifaceted approach and allows developers to collaborate efficiently despite different programming methods.

Efficiency Gain in Development

At Shaanxi Automobile Group, three developers work with RTMaps. It took approximately three weeks to familia-



An RTMaps diagram illustrates the graphical, block-based way of working in RTMaps.

Drivers often find themselves in situations where assistance systems provide valuable support.

Picture credits:
© Shaanxi Automobile Group Co., Ltd.

"Using RTMaps improves the efficiency of algorithm development by more than 50%. This shortens the time to market."

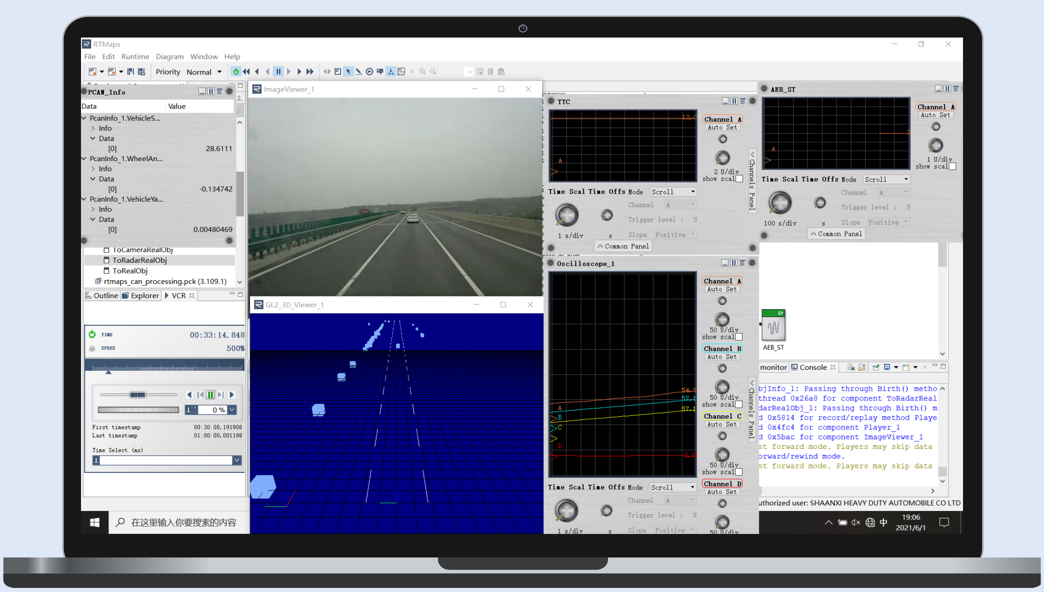
Yiran Zhang, Shaanxi Automobile Group Co., Ltd.

rize the team with the software's main features, and now RTMaps plays a central role in the development and validation of perception and fusion algorithms. Yiran Zhang summarizes, "RTMaps is the core tool for the rapid, targeted development of AEBS. Offline validation of algorithms with real data helps quickly identify problems and develop solutions. This reduces development time, effort, and cuts costs. Using RTMaps improves the efficiency of algorithm development by more than 50%. This shortens the time to market."

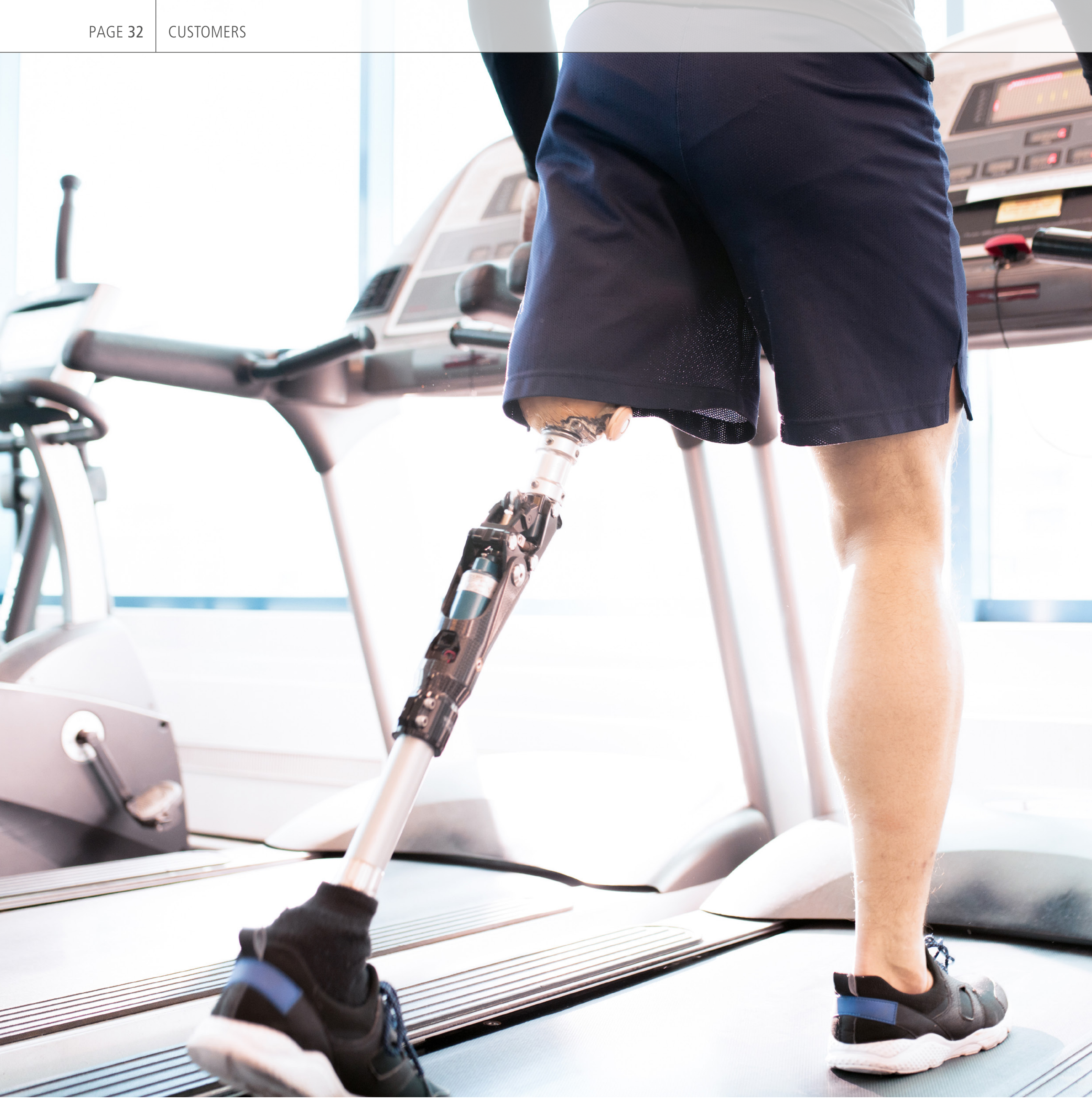
Safe Vehicles Ensure Customer Recognition

The algorithm developed and validated with RTMaps is intended for the Shacman X6000, X5000 vehicle platforms. In the next step, RTMaps will be used to develop the adaptive cruise control and adaptive speed control algorithms. This way, Shaanxi Automobile Group aims to meet the requirements of its customers, generate added value for them, and take on the leading role in the industry. The developers are certain: Reliable functions for automated driving will win their customers' favor. ■

Courtesy of Shaanxi Automobile Group Co., Ltd.



RTMaps provides detailed insights into sensor data and algorithm behavior.



Reimagining prostheses for improved walking

Regenerative Power

Electric mobility is also an exciting topic in medical technology. Find out how recuperation and advanced control technology help people concerned get ahead.

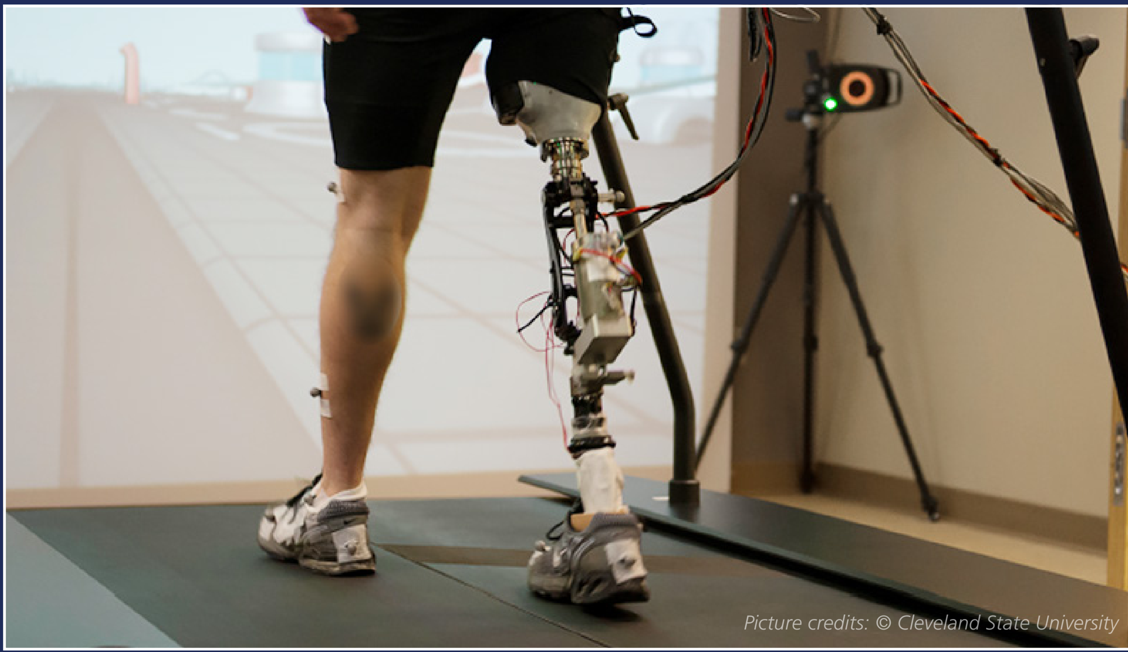
Lower-limb amputees typically use passive (non-powered) prostheses, which provide support but are unable to produce assistive forces for key activities, including walking and ascending slopes. Because of this, amputees who wear passive prostheses have a significantly larger metabolic energy demand in comparison to able-bodied people.
Power prostheses are powered by electric motors. They address the limitations of passive devices by providing a sense of freedom and the ability to walk longer distances with reduced effort. But these devices are limited by their high power consumption.
A research team from Cleveland State University and the Louis Stokes Cleveland VA Medical Center received funding from the U.S. National Science Foundation to search for a solution that will greatly expand the range of use and naturalness of motion possible with these devices.
The team developed a prosthesis prototype that features energy regeneration technology with super-capacitors as energy storage elements. The team developed a powered knee prosthesis and an advanced energy-optimal control system. It is their hope that the prosthesis will not only operate for a longer period of time but will facilitate a more active lifestyle by enabling faster walking speeds and, eventually, the ability to climb stairs.

Energy Regeneration May Be Key

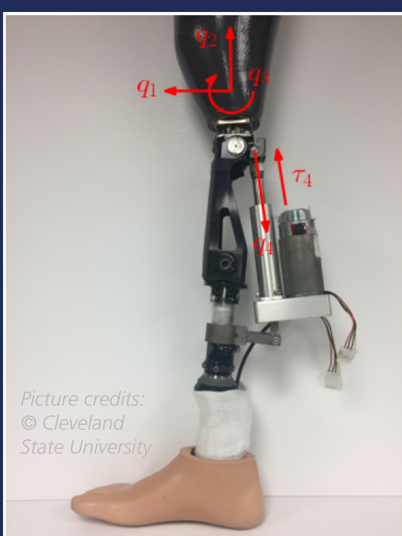
According to Professor Hanz Richter, the biggest obstacles with these devices are their high electrical demand and the complexity of the actuators that are required to control movement. Today, most electrically powered prostheses only support walking at an average pace and may have to be recharged several times a day.
The research team developed a control method that allows for seamless transitions between the different gait phases for walking, including different walking speeds and a range of varying inclining and declining slopes, based on self-modulated impedance control and energy regeneration technologies.
Energy regeneration technology has the potential to reduce energy usage in motion systems. This technology is based on the recovery, storage, and reuse of surplus energy associated with motion cycles. Regenerative braking is commonly used in electric vehicles to improve energy efficiency. The same method can be applied to a powered prosthesis. Natural gait involves periods of surplus energy at the knee joint.
While passive prostheses act as a brake and dissipate this energy, the regenerative prostheses developed by Prof. Richter can store and reuse surplus power without compromising the naturalness of the motion. Thus, energy regeneration can extend battery life, making a prosthesis more practical for daily use.

Issues with Traditional Powered Prostheses

Most electrically powered prostheses use finite state impedance controllers, mechanical springs, and dampers to replicate the motion of the knee and ankle joints. The prosthesis is divided into a series of gait states, represen- >>



Test subject walking with the prosthesis prototype.



Prosthetic knee prototype.

tative of the balance and coordination that is required to complete a walking stride. For each gait state, a separate impedance controller is used. These controllers are triggered by sensors placed on the prosthesis. Control parameters are tuned for each state to match the different walking speeds and walking patterns of individual subjects.

Typically, these prostheses have a five-state controller that operates at 3 or 4 different walking speeds and the controller parameters require tedious impedance scheduling. For instance, 5 walking gait phases with 3 gains each and 3 speeds imply 45 gains to be tuned. In contrast, the team used a continuous impedance modulation scheme based on axial shank force, allowing for a substantially reduced control parameter space.

Energy-Regenerative-Powered Transfemoral Prosthesis

The research team developed a prototype to demonstrate their ideas on energy regeneration and self-modulated impedance control.

Their prototype consists of a passive ankle and a powered knee joint. The knee joint is actuated by a DC motor with a leadscrew and a crank-slider mechanism. An ultracapacitor (also known as a supercapacitor) is used as an energy storage element instead of a battery, providing an efficient means of storing and reusing energy. The ultracapacitor is lightweight and durable and has high power densities and the ability to rapidly charge and discharge without damage, in contrast to batteries.

Another key design element of their prototype is the control method they have devised. The team developed a novel varying-impedance control approach that drives the prosthesis in both the stance and swing phase, while explicitly dealing with energy regeneration. The control method varies the impedance of the knee joint based on the amount of force exerted on the shank and promotes energy regeneration by precisely injecting a designated amount of negative damping into the system.

"This approach provides a natural vari-

"The powerful dSPACE system not only supports us in modeling and simulation, but also lets us streamline the transition to real-time applications."

Professor Hanz Richter, Department of Mechanical Engineering Cleveland State University

ation in the impedance of the knee and leads to far fewer tuning parameters compared to some other approaches," said Professor Richter. "Additionally, the controller allows walking at different speeds without the need for retuning. With a simple adjustment, the same tuning can be used for different subjects."

Validating the Control Method

To validate their control method, the team installed a variety of sensors on the test prosthesis to gather data on the control method and to evaluate its overall performance. A volunteer amputee was recruited, and trials were conducted. To obtain feedback on the control strategy, the motor position, which is kinematically related to the knee angle, was measured by an encoder to compute velocity. Additionally, two strain gages were installed and then calibrated to produce shank force measurements. The voltage of the ultracapacitors was then measured for use as feedback as part of the semiactive virtual control method developed by the team.

To evaluate the energy regeneration capacity of the prosthesis, sensors were installed on both sides of the motor driver to measure input and output currents. The voltage applied to the motor, as well as the ultracapacitors, were recorded. The combined measurements provided information on the overall power usage and the efficiency of the motor driver.

A dSPACE system was used for the centralized data acquisition, control, and display for the prosthesis and its control system, at a rate of 1 kHz. Real-time control computation was implemented in a Simulink block diagram where some code was executed by embedded MATLAB® blocks. Digital filtering with a 24 Hz cutoff frequency was applied to all measurements. A tether cable was connected between the user and the dSPACE system. According to Prof. Richter, the dSPACE system and Simulink compatibility greatly helped the team focus on the control algorithms, rather than on the implementation details. In particular, the transition from modeling and simulation to the real-time deployment were streamlined.

Trials on a Treadmill

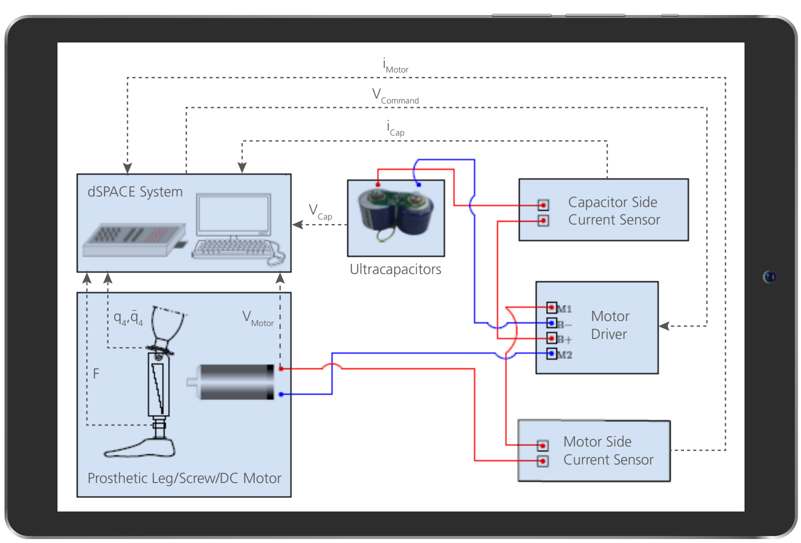
After completing initial validation tests, the team began a series of human trials. During tests with a 35-year-old male amputee walking at three different speeds on a treadmill – slow (0.6 m/s), preferred (0.75 m/s) and fast (0.9 m/s). Through this trial, the control method was validated and energy regeneration was achieved under the test conditions. A 10-camera passive marker motion capture system recorded 26 markers placed on standard anatomical locations. The force plates of the split belt treadmill measured ground reaction forces for each side.

Regenerated Energy provides Power to the Knee Joint

In summary, the team observed that the tuning process was relatively easy – tuning was completed in a matter of minutes while conducting the test. They also observed energy regeneration taking place, providing power to the knee joint when needed. However, the team realized that further improvements in energy regeneration are possible. Though the project has concluded, additional funding would allow the team to focus on the stability of the controller and improve energy losses that were detected in the first prototype.

The data collected from the trials for a human-side evaluation and the results will be featured in an upcoming full-length paper in the Medical Engineering and Physics Journal.

Courtesy of Cleveland State University



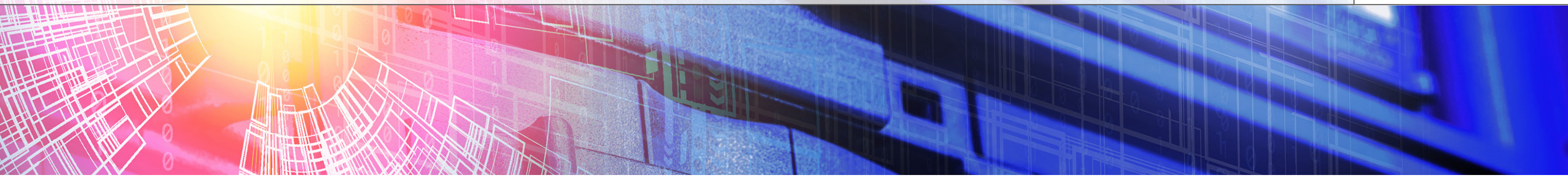
An overview of the prosthetic leg system indicating power and information paths.

Efficiency and quality of the data pipeline for autonomous driving

Fueled by Data

An optimal data-driven development solution consists of a fully integrated pipeline for the continuous development of the machine-learning-based functions needed for autonomous driving. However, there is a multitude of bottlenecks awaiting in the development process, such as inconsistencies in formats and interfaces, which are a common source of project delays. dSPACE ensures that you successfully master your data pipeline challenges with the right technologies, methods, and outstanding expertise.

The reliable operation of an autonomous vehicle is a highly complex task due to the endless complexity of the real world and the corresponding vehicle environment. Traditional problem-solving approaches, such as simple logic comparisons in the form of "if-then-else", are not sufficient. The number of conditions is countless. A completely different approach had to be adopted by developers to tackle these complex issues. This approach focuses on the implementation of automated parameterization of a general model with the help of example use cases, rather than solving the problem with the highest accuracy and completeness through manually written code. The more data is fed in, which is often described as training, the closer the parameterization result will get to the expected result, and the safer the vehicle becomes. This is a relatively efficient way to prepare an autonomous vehicle for reality without having to define its complete "universe" in code beforehand – which would be impossible. Therefore, the development process is called data-driven, or data-centric instead of code-centric. For development, this means that we have to adapt the processes to the data instead of routing the data though the exist-



ing process. Thus, the data, the data pipeline, and the accompanying tools become the center of the development process.

Advanced Data Logging in the Vehicle

The starting point of the data pipeline is the vehicle. It collects all the data which is then used in the process. At the vehicle level, the data sources are all sensors, buses, and networks that transmit information from internal vehicle sensors and ECUs. The vehicle and the data collection system are also the first place where much can be done to optimize the data pipeline. First, the in-vehicle infrastructure and architecture of the logger itself must support data transmission from I/O interfaces to data storage as fast as possible and without data losses. Second, not all of the recorded data will be needed. Only a smaller part of the data is really valuable and will have impact. So why not dismiss the superfluous data at a very early stage in order to save storage and time? Alternatively, only the valuable data is recorded and stored while the superfluous data is dumped. This means that we need a technically powerful and flexible data logging system, and also functions between recording and storage that ensure that only the right data is stored. This is where the dSPACE solution for smart data logging comes into play. It consists of data logging hardware and software, data ingestion and management software, and accompanying services. A central component of this solution is the AUTERA product family, which is tailored for data logging in demanding ADAS/AD applications. It can be combined with RTMaps, a lightweight but powerful development and logging software, and with RTag, a mobile tagging application. dSPACE also has the technology and know-how to filter and reduce recorded data volumes to a relevant subset. Our artificial intelligence experts will be happy to help. If desired, dSPACE and its partners can also assist you with a dedicated vehicle equipment and data acquisition service.

Data Ingestion – Making Data Available to the Developers

The data ingestion pipeline is a part of the data pipeline which ensures that the data flows from the vehicle to the software and test engineers quickly and in the right quality. This is the second stage in the data pipeline where we will increase efficiency and quality. Even if the data has already been intelligently filtered during recording, there is usually still room for data reduction. Camera data, for example, is particularly memory-consuming. Data can be reduced further by using more computational power and non-real-time processing. This can be done outside the vehicle, where more energy is available. If the data has not been filtered before in the vehicle, there is even more to do in the ingestion step to reduce the data volume. Efficiency can only be improved if all data that is not needed, or that is corrupted or incomplete, is simply not ingested. The data would only take up space without any added benefit. If this quality check is not performed in the vehicle, the ingestion pipeline is another pipeline stage where it can be implemented to minimize the required storage, thereby saving costs. Quality control includes, among others, format checks, error checks, and consistency checks. Further reduction of data can be achieved by understanding the content of the data. Therefore, processing of the data and extracting certain metainformation takes place in the ingestion pipeline as well. It not only allows filtering and data reduction, but it also improves search and data organization. The generation of map and sensor previews allows for visualization and speeds >>

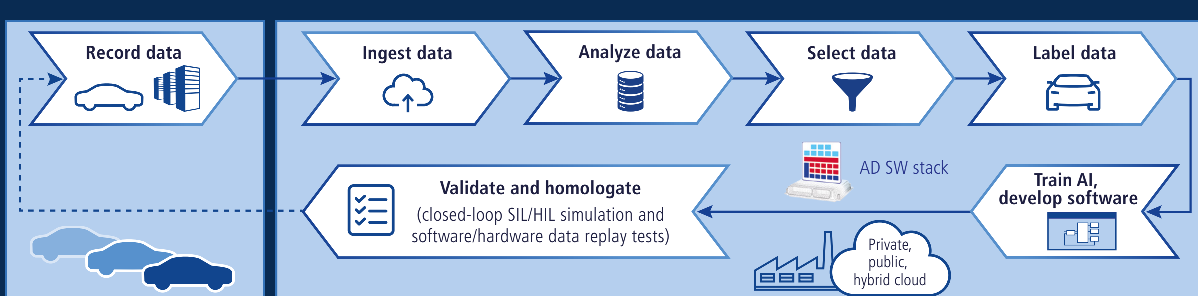


Figure 1: The data pipeline and the cycle of data-driven development (simplified view).

Figure 2: The dSPACE AUTERA hardware lets you meet even highest data acquisition demands. As powerful yet easy-to-use data logging software, RTMaps offers flexible configuration options.

up responsiveness in data access. Previews can be automatically anonymized to also comply with GDPR regulations. dSPACE offers a comprehensive solution for data ingestion. The high-bandwidth AUTERA Upload Station with its hot-swappable AUTERA SSDs ensures a speedy data upload. IVS from Intempora integrates native transmission protocols and the framework for plugging-in customized processing modules for data ingestion steps. By default, quality checks, redundancy reduction, preview generations, and tagging modules are included. The annotation services offered by understand.ai, a dSPACE group company, helps you label selected data rapidly and with the highest quality, even for very large data volumes. And finally, the UAI Anonymizer as an identity protection anonymizer removes more than 99% of all identifiable faces and license plates, and it is GDPR-, APPI-, CSL-, and CCPA-compliant by design.

Testing: Safety First

Autonomous vehicles must function properly in all imaginable and unimaginable traffic situations. Automated testing plays a particularly important role, as only a fully tested vehicle and vehicle software can be trusted on the road. There is a wide range of test methods applicable depending on the development stage. dSPACE products provide solutions to integrate and apply these methods smoothly into the overall testing and homologation process for each platform and new vehicle model.

Data replay testing (a.k.a. reprocessing), which means replaying recorded sensor and bus data to a system under test and evaluating its output against ground truth data, has established itself as a key test and validation methodology in ADAS/AD. Such a testing methodology provides an efficient and cost-effective way to analyze the behavior of autonomous vehicles with data from real driving situations, which is the key for full safety assessment of the vehicle. Data access and its synchronous streaming are crucial aspects for data replay, which makes it a main part of the data-driven development pipeline. The methodology can be applied as a pure software (SW) data replay test early in the development process, or as a hardware (HW) data replay test later in the process after system integration. Software data replay usually does not operate under real-time constraints and can run faster than real time to facilitate quick accuracy checks. Moreover, it can be performed long before a hardware prototype is available. Hardware data replay on the other hand involves deploying a central computer or sensor ECU, which is connected to the test system and is

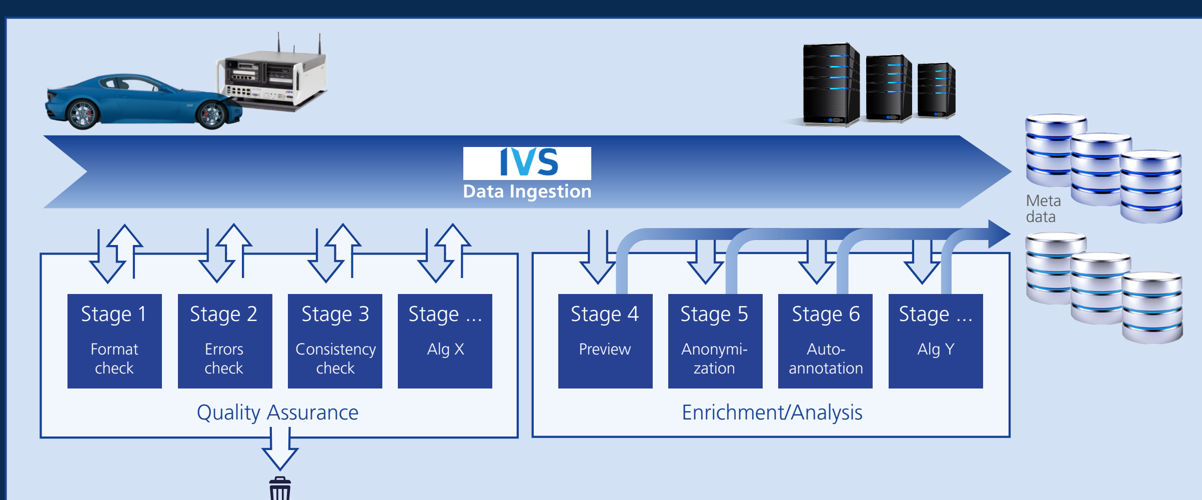


Figure 3: The data ingestion pipeline makes sure that high-quality, enriched, and – optionally – anonymized data reaches the developers.

fed with recorded synthetic or real data. This makes it possible to test the hardware, the electrical interfaces, as well as the software in the conditions closest to on-road testing. Data replay tests can be further enhanced by inserting failures and manipulating the data streams. More and more, cloud services are used for data replay testing. dSPACE and its partners offer outstanding solutions for data replay tests based on public cloud, on-premise and hybrid cloud infrastructures. The dSPACE data replay portfolio includes a multitude of tools to best fit your needs, including SCALEXIO, the modular real-time system for accurate bus and network interfaces; the Environment Sensor Interface (ESI) unit, the powerful FPGA board for sensor interfaces; VEOS, the offline simulator for early-phase (virtual) ECU simulations; and RTMaps, the state-of-the-art data parsing and streaming software. In addition, there is IVS, the data management software for easy accessibility to the recorded datasets of interest. All of these tools are integrated to provide fully automated test solutions that let you perform continuous 24/7 tests against thousands of driven and synthetic kilometers.

Data Augmentation

A challenge is not only to prepare autonomous vehicles for situations that were already covered in previously recorded data, but also to confront them with completely new and unknown scenarios for which there is no real data at all. This is especially important for testing corner cases, which are impossible or too risky to test in reality. Artificially created data from sensor-realistic simulations is used to extend a test data set. The traffic scenarios and environment can be created from scratch or by synthesizing a real traffic situation and manipulating its parameters.
A second method to extend the test data set is to use recorded data and manipulate it in a way which adds synthetic traffic participants with realistic behavior to the situation. dSPACE products already support the manipulation of real scenarios, especially the solution for scenario generation developed by dSPACE and understand.ai. The solution lets you transfer recordings from real test drives to the simulation and perform thousands of tests of safety-critical and realistic driving scenarios with dedicated hardware and software conveniently as a simulation. These scenarios can be changed and extended artificially, which is very useful in scenario-based testing where a great number of scenarios have to be executed. The dSPACE solution for sensor-realistic simulation, AURELION, is a new, powerful tool not only for cloning but for manipulating reality in simulation. dSPACE also provides methods for generating artificial training data that will dramatically decrease development costs.

Seamlessly Integrated

As shown above, dSPACE, its group companies, and partners support the entire data pipeline with seamlessly integrated tools, ensuring a smooth data flow. With dSPACE tools and dSPACE expertise, you can keep your data pipeline running even during critical phases of your development projects. ■

Would you like to talk to one of our experts?
Just contact us: info@dspace.de

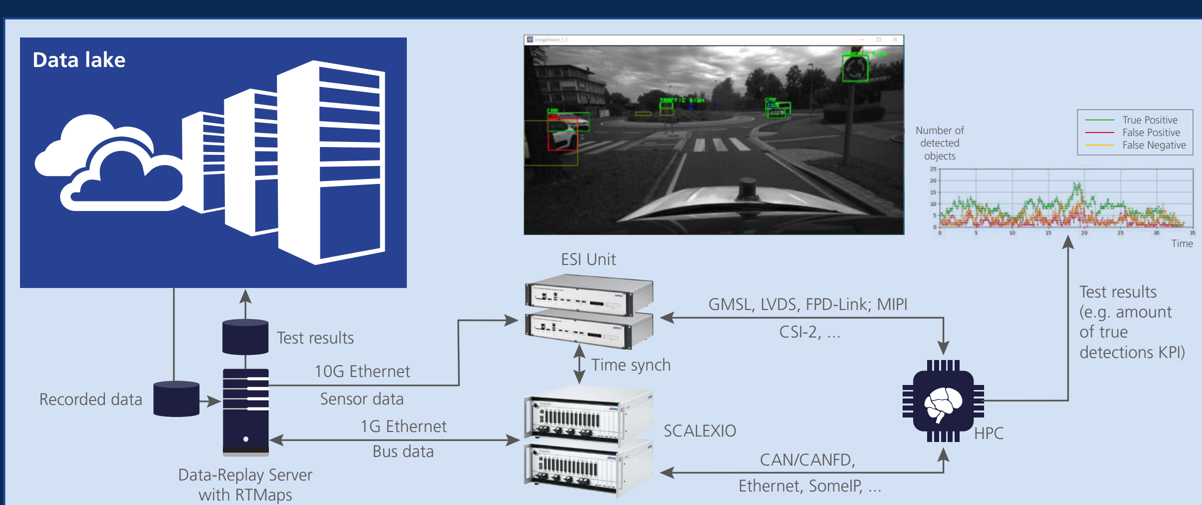


Figure 4: Data replay testing in a data center.

Enter simpliCity

SIMPHERA – the new web-based solution for convenient and efficient validation of functions for autonomous driving

Simulation environments that replicate situations for autonomous driving are like a virtual planet on which a vehicle has to master innumerable traffic situations. It is just such a digital world that the SIMPHERA software provides, adding to the already broad range of dSPACE products for simulation and validation.

It is Tuesday morning. Function developer Belle Fisher powers up her computer and accesses her company's simulation environment via the web browser. The environment notifies her about a new test scenario that is planned and available, which her colleague Yang Yu in China has prepared. The scenario is ideal for evaluating the algorithm for highly automated driving that Belle and her team are currently working on. So she integrates it into her simulation, uses it to test the algorithm, and optimizes the algorithm based on the insights gained from automated validation. The result is a validated new version of the algorithm.

Later in the day, sensor specialist Roni Cohen in Israel integrates the model of a new radar sensor into the simulation environment. The sensor was selected as an alternative on the basis of the manufacturer's data, to improve steering behavior in specific corner cases. Belle can immediately equip her virtual test vehicle with the sensor model and select the relevant corner cases as test cases, which she then uses for simulations testing whether the desired improvement is really achieved.

The results are convincing.

At the team meeting the next morning, the vehicle control project manager asks for an integration test to be run to investigate the behavior of the whole vehicle including the new sen- >>

SIMPHERA is a web-based solution that offers flexible user access and exciting technologies.

sors. So Belle runs a simulation with over 1,000 test cases, all generated by automatic parameter variation. And thanks to multi-instance simulation in the cloud, the development team gets the results just after lunchtime. They can now be compared with the results of previous simulations to identify any changes.
With the new improvements, the vehicle control meets its defined requirements. The team now has a newly validated version of the vehicle control.
Following successful validation by software-in-the-loop (SIL) test methods, the team tackles the next validation step: determining how the vehicle control behaves under real-time conditions, using the actual hardware. A service provider is tasked with implementing the software on the ECU, which is being developed in parallel. To test the ECU under real-time conditions, the service provider uses the same simulation environment as the development team and accesses the same test suites to select suitable test scenarios. In SIMPHERA, the service provider selects a hardware-in-the-loop (HIL) simulator as the test platform. This degree of integration, with test artifacts that can be directly reused, enables an efficient and reliable validation process. **If you can relate to any or all of these cases, our new cloud-based solution for simulation and validation is exactly what you need. Read more to discover what SIMPHERA can offer for your own tasks.**

What is SIMPHERA?

In short: It is a completely new concept, a web-based cloud software solution for simulating and validating autonomous driving.
SIMPHERA has been specifically designed with the aim of getting your autonomous driving innovations on the road faster. The software brings them to life at an early stage and helps you analyze them and handle their complexity. How? By giving you easy access to powerful functions for simulating the vehicle dynamics, traffic, and more. So you can trial new algorithms, such as for vehicle control, in a virtual world: simpliCity. Developers can do this by completing reproducible, deterministic test drives with a virtual vehicle in a virtual environment. The vehicle, the environment, and the tests – or traffic scenarios as they are called in this context – can all be freely defined and imported. The virtual world of simpliCity is so versatile that any desired corner cases can be replicated to guarantee broad test coverage. And because the cases are easy to parameterize, new variants can be generated to increase test depth.
After each simulation run, users are given a detailed and informative analysis of the ve-

> "SIMPHERA is extremely well designed. There's nothing comparable on the market."
>
> *Opinion of a German OEM*

hicle behavior. For example, you can identify the speeds at which emergency braking leads to a collision.

The Three Cornerstones of Efficiency

SIMPHERA gives you an easy and intuitive way of creating, performing, and evaluating highly realistic, deterministic simulations. Its user interface provides role-based user guidance:

- **Prepare:** Define vehicles, create scenarios, and manage the functions under test
- **Simulate:** Simulate the vehicle interactively with selected scenarios and the functions under test
- **Validate:** Create test suites, use parameter variation to perform large numbers of concrete test cases, and analyze the results

This structured procedure guides you through a workflow that avoids errors and enhances efficiency. Moreover,

the highly integrated solution ensures that everyone works on the same data, so nothing "falls through the gaps" between one team or person and another. It is also transparent, letting everyone involved see the various work products.

Whenever, Wherever: Worldwide Collaboration

Wherever the users and the IT infrastructure might be located, SIMPHERA is there, too – as a web-based solution in the cloud or on your company's server cluster, it can always be accessed directly. Meeting the needs of every user and ideal for worldwide, shared use. There's no lengthy installation work, you only need the license and off you go. You can set up distributed

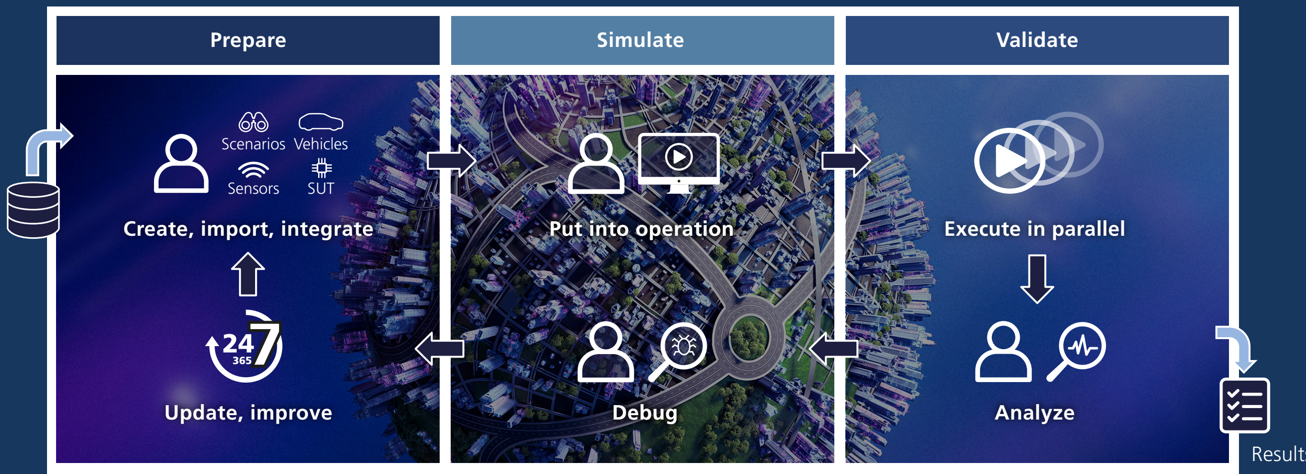
Access whenever, wherever for global, collaborative use

teams and implement efficient processes, then collaboration can commence.

Scenario-Based Testing

Scenario-based testing means that particular driving situations can be generated automatically, with specific traffic constellations and unusual road user behavior that push the driving functions to their limits. The situations are replicated in the virtual test environment and can be run through repeatedly to test the driving functions in complete safety. These scenarios can also be abstracted to make them parameterizable, so innumerable "concrete" scenarios can be generated from one "logical" scenario via parameter variation – to further increase test cover- >>

Validating functions for autonomous driving with integrated scenario-based tests.



SIMPHERA's integrated workflow supports efficient end-to-end validation.

Scalable cloud-based testing for faster results and broad coverage

age. SIMPHERA has a library of relevant driving situations (Euro NCAP, ALKS, etc.), which can be extended in whichever way required.

Scalable Tests in the Cloud

To be absolutely certain that driving functions perform safely in any situation that might occur on the road, the volume of testing required can easily get out of hand. Especially when the number of test cases and variants skyrockets, SIMPHERA shows its strengths. For example, tests can be scaled by means of parallel execution in the cloud. And even if extra work is required for test coverage and test depth, you can still keep your projects on schedule. With the support of SIMPHERA, you can uphold the quality and completeness of validation at all times, thereby ensuring that the algorithms are reliable and the vehicles safe.

Automatic Creation, Execution, and Evaluation of Tests in the Cloud

Once the setup is ready, the process is simple, and any function developer can use SIMPHERA to test their algorithms quickly. The Linux Docker containers are automatically orchestrated in the background by using Kubernetes (a system for automating the deployment, scaling, and management of containerized applications). After that, the individual simulation jobs are automatically assigned to the execution nodes. The user does not have to intervene. Once the jobs have run, SIMPHERA provides a clear overview of the results.

Seamless Testing on SIL and HIL Platforms

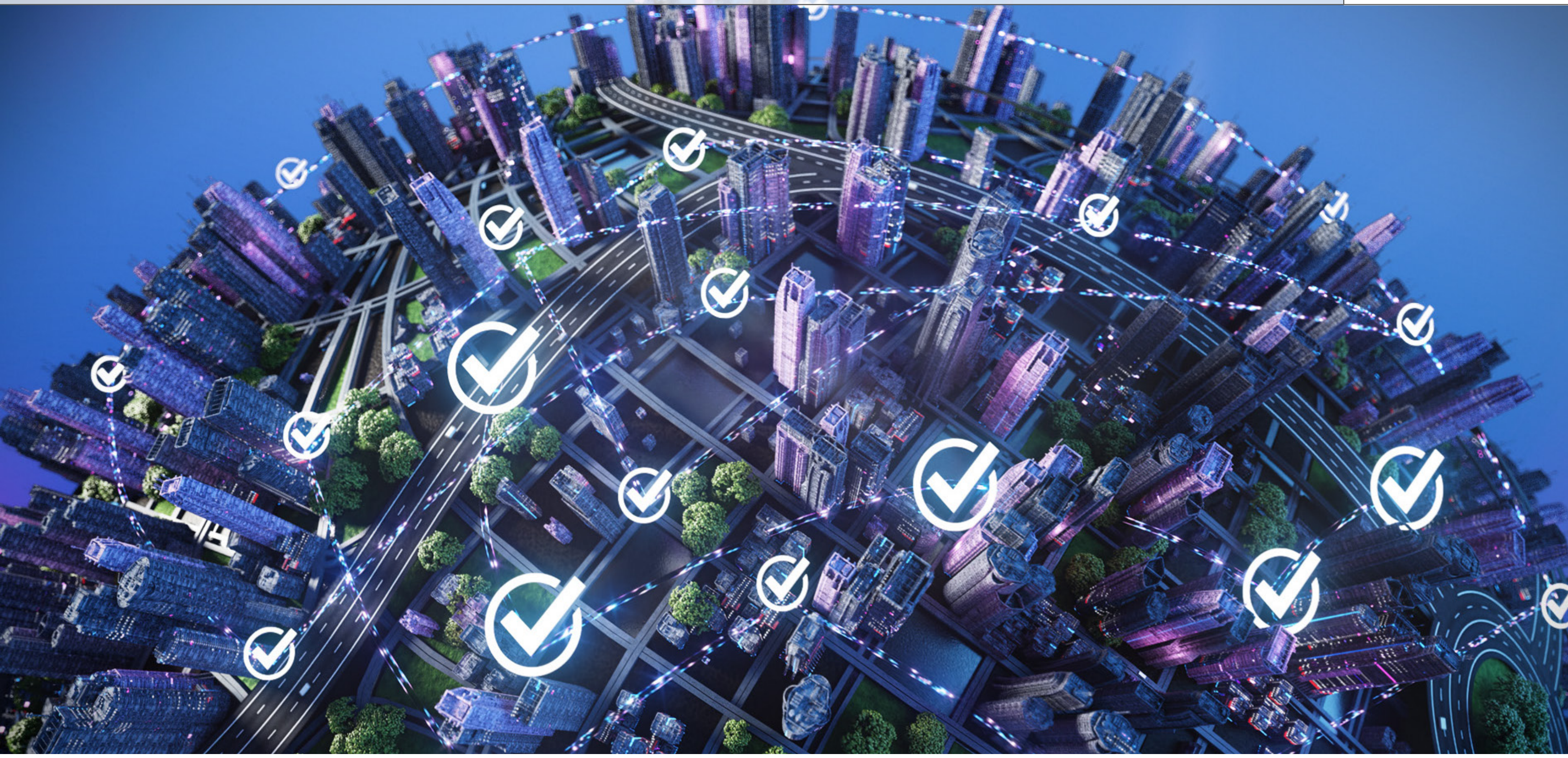
The validation of ECU software begins with early software-in-the-loop (SIL) tests and continues on through to hardware-in-the-loop (HIL) tests that check and validate the behavior of the ECUs and the vehicles under real-time conditions. SIMPHERA gives you

Benefits of SIMPHERA

Platform-independent – Wider use

Quick access – Save time and money

Worldwide use – Collaborative development



With simple, web-based access, SIMPHERA is ideal for distributed development.

The basis for simulation is test scenarios that are either synthetically defined or generated from real sensor data and imported.

Guided workflow –
Faster onboarding

Ease of use –
Wider acceptance

Easy SIL/HIL transitions –
More efficient process

Scalability –
Better test coverage


Scalable tests in the cloud for faster results and broad coverage.

> "SIMPHERA is a very complete tool."
>
> *Opinion of a Japanese OEM*

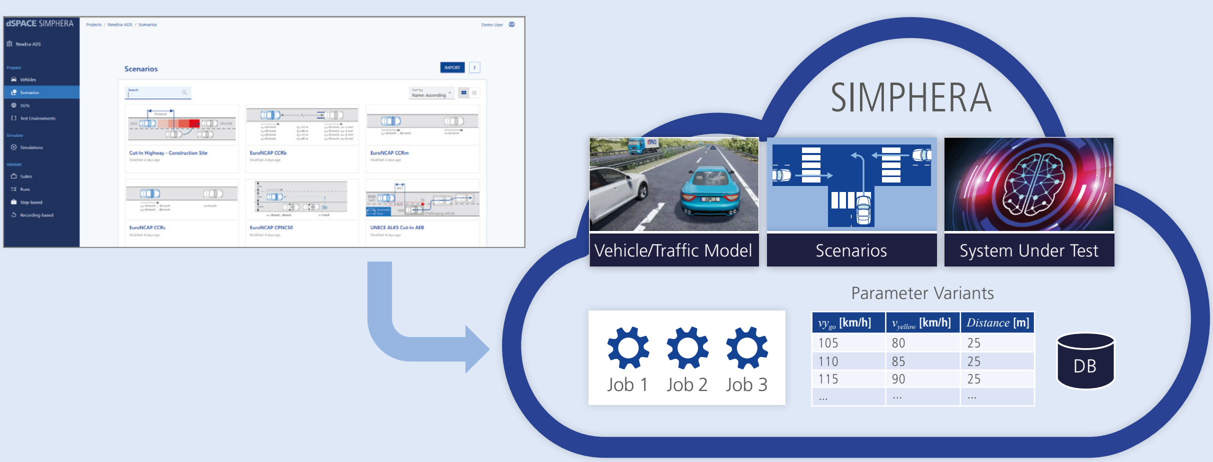
access to both of these test platforms. This provides a fundamental benefit: Test artifacts can be reused for both SIL and HIL with no need for conversion between different platforms. This reduces errors, saving both time and costs. It is also a fundamental precondition for traceability and homologation.

And last but not least, having one single integrated environment for all validation activities enhances development efficiency. Thus, SIMPHERA is an end-to-end solution for simulating and validating ECU software and ECUs.

Complete Open Framework for Maximum Test Coverage

SIMPHERA's philosophy is to ensure coverage-driven validation with measurable reliability. It does so by providing vital features such as mass validation and robustness tests. The industry-proven technologies in SIMPHERA, such as validated simula-

Once the user has selected a cloud platform, SIMPHERA takes care of the entire cloud-based test execution.



End-to-end solution for simulation and validation: SIL and HIL tests with reusable models, scenarios, tests, and interfaces.

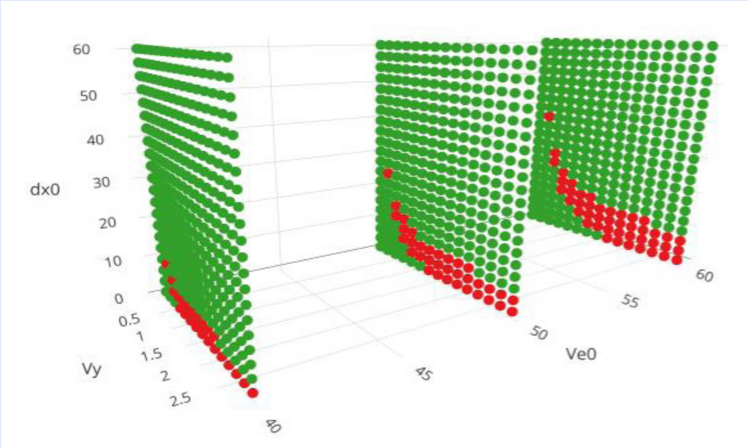
tion models and established simulation platforms, ensure high reliability, particularly when it comes to validating that the software under test functions correctly. Consistent data management, even between SIL and HIL tests, is an elementary prerequisite for traceability and homologation. In addition, SIMPHERA is open and flexible, letting you integrate partner solutions from the field of homologation.

SIMPHERA: The Next Steps

SIMPHERA is being developed in close cooperation with pilot customers. This ensures that it has precisely the right features that the industry urgently needs when validating driver assistance systems and functions for autonomous driving. And there's already a full agenda for further functions. The next items on the list include deep integration of realistic sensor simulation, and additional test methods. dSPACE would like to invite you, as a customer, to join in the agile development of SIMPHERA and help ensure that your requirements and wishes are completely fulfilled. ■

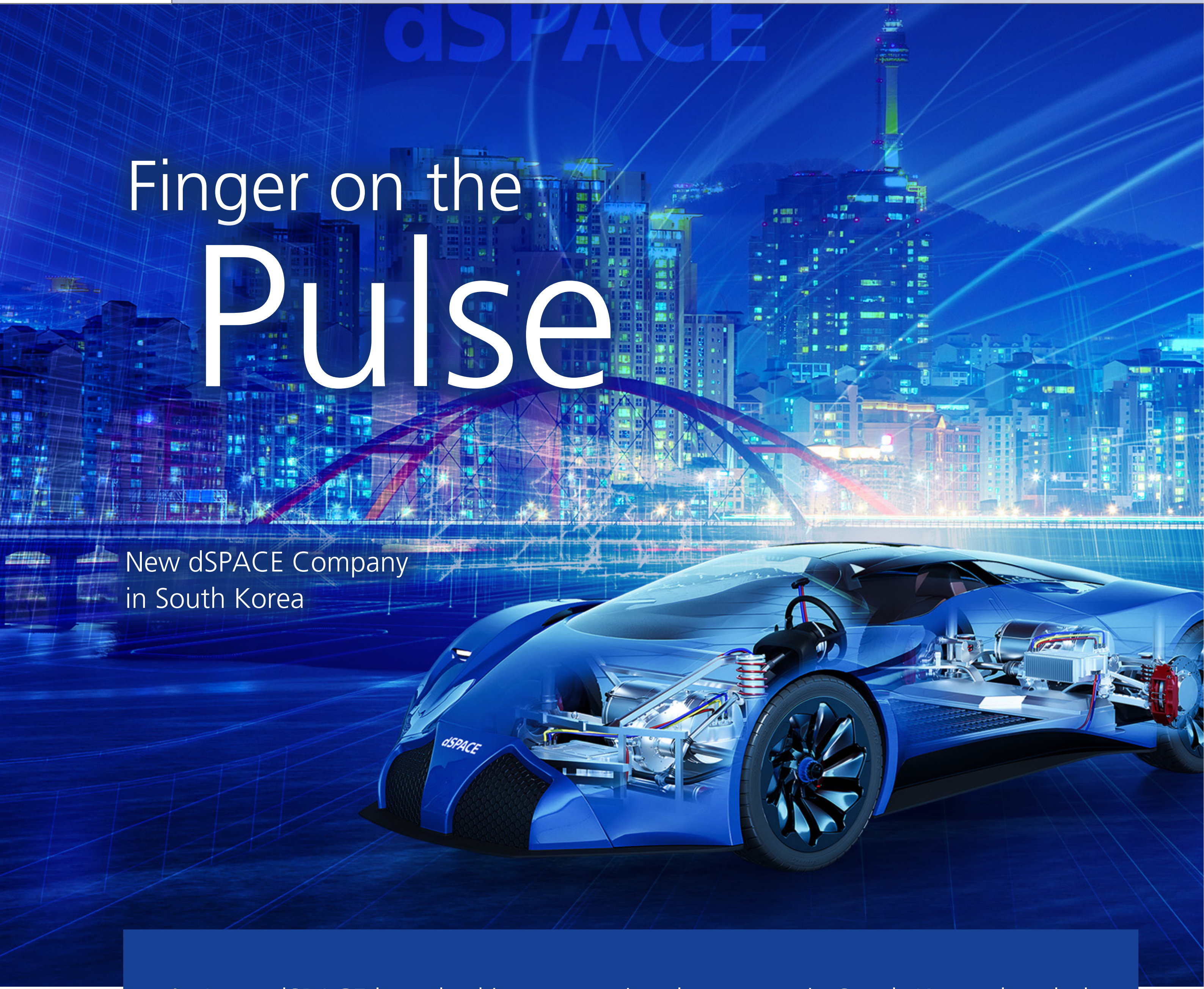
Seamless SIL/HIL test transitions: a fundamental precondition for easy traceability and homologation

Test reports show the simulation results.



Finger on the Pulse

New dSPACE Company in South Korea



In June, dSPACE launched its own regional company in South Korea, headed by Martin Wöhrle. In this interview, he explains why having your own local presence is so important, what his own connection with Korea is, and what kind of a start the new company got off to.

dSPACE has long had a presence in Korea, through partners. Why set up our own company?

Quite simply because South Korea is one of the world's major markets for mobility and automotives. Korean companies have an incredibly fast pace of innovation. And as a leading partner in simulation and validation, we need our finger on the pulse of the times. Our new company, headquartered in Seoul, will let us take our know-how – as a partner in simulation and validation – directly to customers, and support the dynamic change occurring here with solutions for autonomous driving, electromobility, and digitalization.

How well-established are solutions from dSPACE on the Korean market?

The dSPACE brand is well-known and already has a good reputation. Distribution partners have been selling our test solutions in South Korea for more than two decades, during which time the solutions have been used in vehicle development with great success.

Requirements are becoming increasingly complex, and we now need to provide direct support if we want to give the Korean market tailor-made solutions. So dSPACE Korea Co. Ltd. will also offer engineering and consulting services, plus training and support. Drawing on existing customer relationships, but also on new strategic partnerships, we will be able to develop and support the Korean market systematically.

You've taken on the job of heading up dSPACE Korea. What takes you personally to Korea, and to dSPACE?

I've been living in Korea since 2015. For the first three years, I set up and managed BMW's fifth international R&D facility. Korea is one of the world's most innovative countries, and has enormous potential from a technological point of view. The country fascinated me and my family, so when I had an offer from Hyundai – to develop a strategy for future technologies and establish the organizational preconditions for access to global top technologies for the Hyundai Motor Group – we decided to stay here. And my initial contact with dSPACE early this year immediately brought back fond memories. Around 15 years ago, at BMW in Munich, I introduced model-based software development plus associated modeling guidelines and tool chain validation. We used TargetLink with great success, combined with MATLAB®/Simulink®, to generate production code for an ASIL-C ECU in vehicle development. But coming back to the present: Setting up a national company for a technology leader is obviously an exciting challenge, and I found it irresistible.

The team is also new, but many of them are already familiar with dSPACE solutions. Does that make things easier at the beginning?

We've taken on 20 sales and engineering experts from our long-term distributor. That has smoothed the transition in many ways. Among other things, we were able to simply migrate customer relationships and technical know-how to our new distribution company. So we're productive from the get-go and can offer customers a seamless transfer. In the meantime, we have taken on ten additional employees and started to make plans for expat specialists to come here.

What's the first thing on dSPACE Korea's agenda?

Martin Wöhrle is CEO of dSPACE Korea.

Korea has massive subsidy programs that are driving ahead technological change in the fields of digitalization, electrification, and automation of mobility. Our new products fit this scenario perfectly; we can give start-ups and also established companies in Korea the support they need. We're developing a local market strategy so that working with dSPACE headquarters, we can put together a customer-oriented and market-specific portfolio. In parallel with this, we are also working on expanding our network.

Are there any areas where Korean dSPACE customers can expect to receive particular support?

I see electromobility and automated driving as being the main focus in Korea. Our customers are increasingly pushing digitalization and virtualization in order to remain competitive in a global market. With our professional solutions, engineering services, indeed services for all phases of development, we offer our Korean customers that decisive added value they need.

Thanks for the interview.

Powerful Propulsion

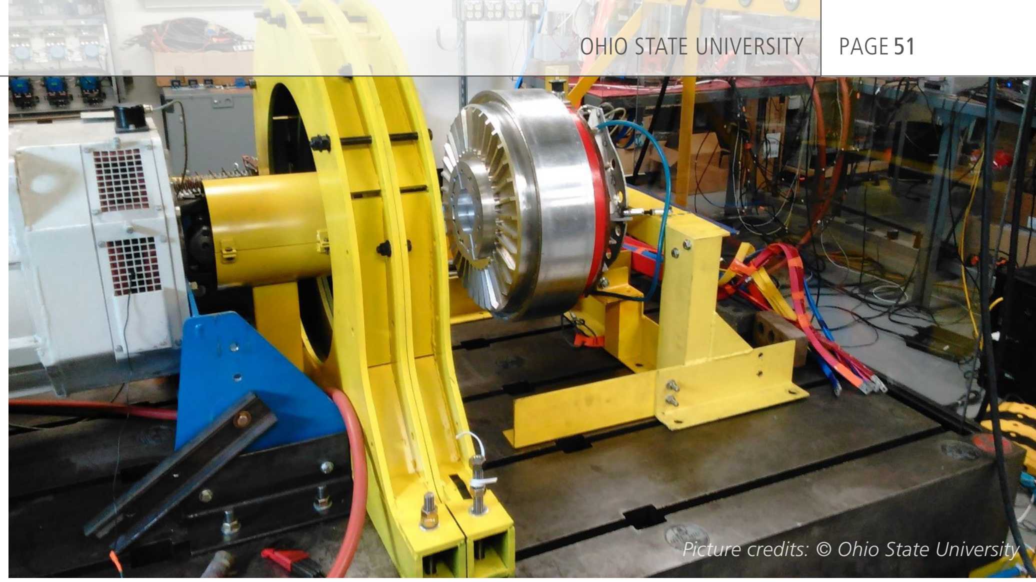
An electric motor concept break several world records

How do you push the envelope in electromobility? A team of researchers developed an induction motor that is lighter, more efficient, and safer than conventional AC motors, yet powerful enough to propel a large passenger aircraft.

Dr. Codrin-Gruie Cantemir and his research team at Ohio State University took on the challenge of designing a new type of 10 MW ring motor. The new design may prove to take hybrid electric propulsion systems to a new level in terms of performance as well as fuel and energy savings. The concept was derived after receiving a NASA research grant to design an electric machine that would be five times lighter and more efficient than any motor in production but would also have a propulsion system powerful enough to transport a large aircraft.

The electric motor design features a unique tuned coil with variable cross section windings, which achieves direct contact between the coils and the coolant. This enables stator magnetic field production at high frequencies while keeping specific high-frequency losses in solid conductors at a minimum. As an induction machine, it operates as an outrunner. Due to its compact size, it weighs less than a permanent magnet (PM) motor, which is most commonly used in high-end electric machines, yet it produces more torque and power than a PM motor.

To ensure a high degree of operational safety, the OSU electric motor does



Shown here is a smaller version (1 megawatt) of the 10-MW ring motor concept. It includes unique features which produce torque and power without the use of commonly used permanent magnets (PMs).

not use conventional copper conductors or wire insulation. Dr. Cantemir and his team observed that in certain situations, aluminum behaves better as conductor material, so they swapped out copper for aluminum. One of the best features of the motor design, and what Dr. Cantemir refers to as the "cherry on the cake," is that their solution does not require electric wire insulation. This is significant because this insulation is the number one cause of electric motor failure.

Test Demo Breaks World Records – Right out of the Gate

During preliminary testing using a 1 MW ring motor version of the conceptual design, OSU set two world records. The first record was for absolute normalized continuous power density. The second record was for continuous power density in an induction motor. The team broke these records by achieving a constant state of continuous power for the induction motor running at a reduced performance level.

"This technology may end up serving a plethora of propulsion applications, from small passenger aircraft to medium and large jets (e.g., 737 or 787) and pretty much any marine application, from pontoons to nuclear aircraft carriers," said Dr. Cantemir.

Performing Control Tests with the dSPACE MicroAutoBox

As high-power motors are usually the "victims" of inherent limitations coming from the power electronics, Dr. Cantemir said their focus turned to increasing the power level towards the high end of the rpm range using a very rare technique generically called synchronous modulation (in contrast to conventional asynchronous modulation).

Two dSPACE MicroAutoBoxes were used to test the continuously sliding synchronous modulation (CSSM) technique, as well as the control algorithms. One dSPACE MicroAutoBox was used to control the motor, and another MicroAutoBox was used to control the load (another motor operating as a generator).

"The dSPACE systems enabled us to implement these two new techniques, greatly improving the outcome," said Dr. Cantemir. *"Even more, because these new techniques have never been done previously, obviously dSPACE enabled us to open a new door in the field."* ■

Courtesy of The Ohio State University

The MicroAutoBox was used to develop and test the new control algorithms.


Samar Aidrus, Development Engineer at dSPACE
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