

dSPACE

1/2018

MAGAZINE



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Mission Autonomous Electromobility

The e.GO Mover is a minibus that can be universally extended and used. It can be designed for passenger transport as well as private and corporate cargo tasks. The electric minibus developed by the electric-vehicle startup e.GO Mobile AG in Aachen, Germany, was designed for urban transportation. It is fully electric as well as highly automated and will provide urban app-based mobility solutions to simplify traffic in urban areas. For a smooth integration in urban mobility concepts, the e.GO Mover supports both manual steering by a driver and highly automated operation. The developers of the joint venture e.GO Moove use the rapid control prototyping system MicroAutoBox from dSPACE to develop the vehicle functions, such as propulsion, recuperation, and electric power steering (EPS) control, or the actuators for highly automated driving. This enables them to develop and test driving functions even before the target hardware is available.



“We are using a dSPACE MicroAutoBoxes in the prototype vehicles of the e.GO Mover to develop core functionalities and control the actuators for highly automated driving.”

David Will, Senior Manager Automated Driving, e.GO Mobile AG



“Now is a good time to start a new era at dSPACE.”

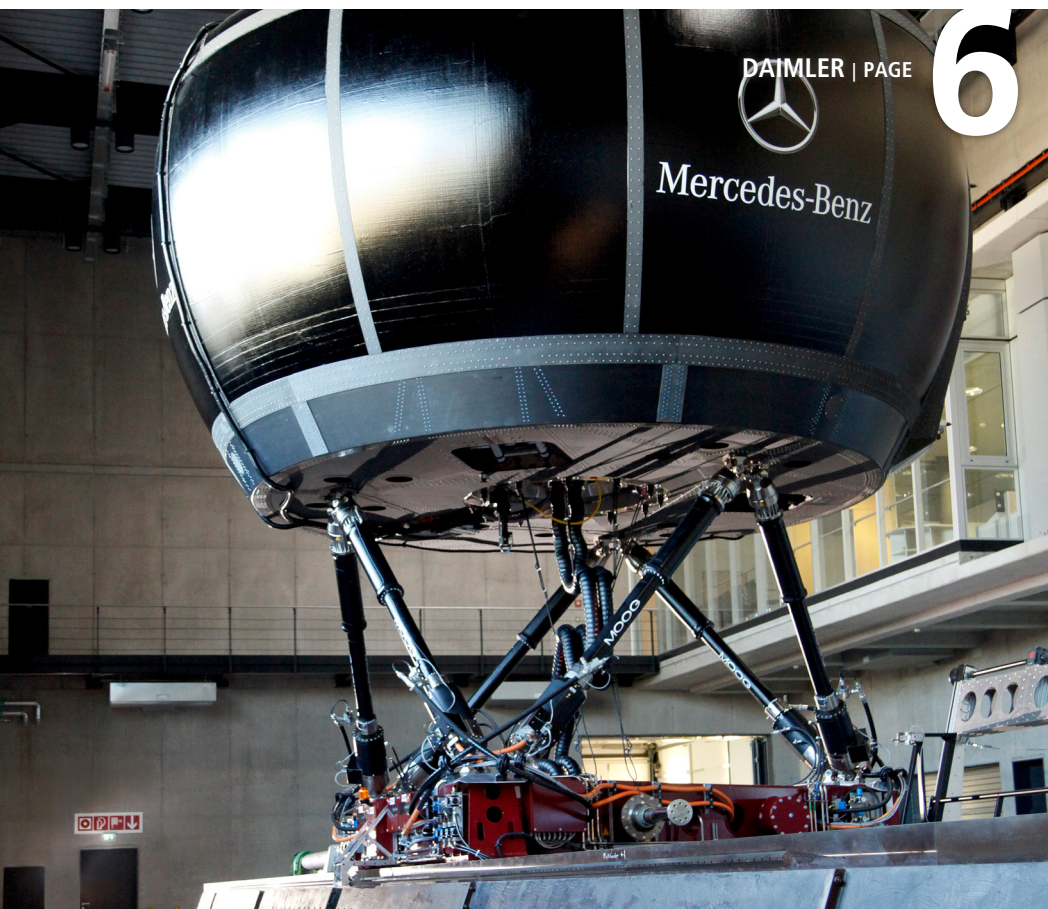
For many years, I have written a small editorial for each issue of dSPACE Magazine. This is my last editorial contribution, because I am putting the management of the company in new capable hands. Martin Goetzler has been the company's CEO since March 1. Until the end of 2018, we will run the company together. Afterwards, Martin will be the sole CEO of dSPACE GmbH as well as the group of local dSPACE companies. The Hanselmann family will remain the owners of dSPACE, and I will still be working in the company, albeit in other roles. dSPACE is turning 30 this year. My background as control systems and electrical engineer and my keen interest in software inspired me to found the company in 1987. I teamed up with three younger colleagues from the university, wrote a business plan, and started to look for financing. And we were successful. The state of North Rhine-Westphalia granted us financial aid and a bank also gave us a loan approval. What has happened since is not easy to grasp, even for me. With the exception of one bump in the road in 2009, a year of economic crisis, it was all only ever onwards and upwards. In the beginning, we could not have imagined how successful we would become. And an end to this growth is not in sight either.

Our business is thriving. We know that we have to tackle some big challenges, because the technologies and applications for which we supply the tools are changing drastically. Therefore, this seems to be a good opportunity to enter the next development stage at dSPACE. I could have remained in my position for another few years, however, I believe it is better to make a change when there is no pressing need for it yet. This gives us the chance to be proactive instead of reactive.

Martin Goetzler does not have a technology degree. However, the existing team at dSPACE consists of many great engineers and technicians who he can and will turn to for support. His strength is the years of experience as a CEO in technology companies, in a very large and a smaller high tech company. This is exactly what dSPACE needs as it keeps growing. I know that Martin places high importance on customer relationships. We have already visited customers together and we are looking forward to giving more customers the opportunity to meet Martin personally. With this in mind, I am looking forward to future developments and continued good cooperation with our customers.

Dr. Herbert Hanselmann

A detailed interview with Herbert Hanselmann and his personal review of 30 years of dSPACE can be found on page 52.



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dSPACE GmbH · Rathenaustraße 26
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Tel.: +49 5251 1638-0
Fax: +49 5251 16198-0
dspace-magazine@dspace.com
www.dspace.com

Responsible in terms of press law:
Bernd Schäfers-Maiwald
Project Manager: André Klein

Authors: Dr. Stefanie Koerfer, Michael Lagemann,
Ralf Lieberwirth, Lena Mellwig, Dr. Gerhard Reiß,
Patrick Pohsberg, Sonja Ziegert

Co-Workers on this issue:

Alicia Garrison, Matthias Deter, Gregor Hordys,
Radoslaw Lapko, Björn Müller, Tobias Schaeffer,
Tino Schulze

Editors and Translators:

Robert Bevington, Stefanie Bock, Anna-Lena
Huthmacher, Stefanie Kraus

Design and Layout:
Jens Rackow, Sabine Stephan

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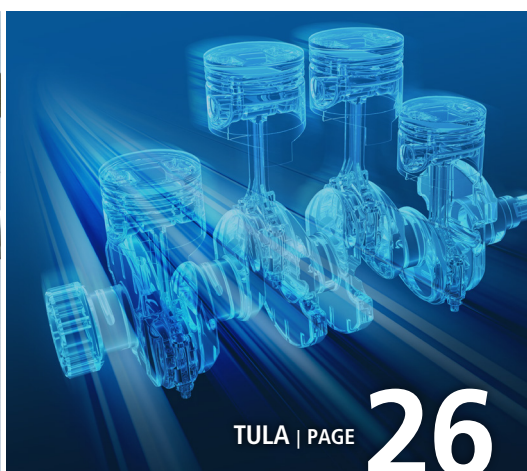
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Flexible Test Track

Testing new driving concepts under reproducible conditions with a hexapod 360° driving simulator

To find and validate concepts for chassis, vehicle dynamics controllers, and advanced driver assistance systems, Daimler AG relies on a driving simulator in addition to test drives on the road. The best thing about it: The test driver and the real vehicle are right in the middle of the action.

The Daimler 360° driving simulator in Sindelfingen, which is used for extensive vehicle dynamics tests, takes up an extremely large factory workshop. It has no less than six legs and can swallow up entire passenger cars. Its pivotable dome is attached to a hexapod (six-legged platform). The six legs that consist of electromechanical spindle actuators can move the dome into a great variety of positions by means of coordinated extension and retraction movements. By combining rail and hexapod movement, the simulator can represent all relevant driving situations as realistically as possible. The design of the motion system dynamics is essentially based on the requirements for vehicle dynamics investigations, extending to the vehicle's limits.

Realistic Driving Situations

While the motion system simulates the acceleration forces, an image generation system visualizes continuous motion. This creates a realistic driving situation for the driver. To do this, multiple projectors create a 360° view for the driver inside the dome. Instead of side mirrors, the vehicle inside the dome has digital displays for the virtual rear view. With the combination of image and traffic simulation software and a complex sound system, a holistic, realistic representation of the entire driving situation and maneuvers is created.

Central Control System

All driver actions, such as the actuation of the accelerator or brake pedal as well as the steering, are trans-

mitted to a computer system that computes the motion of the vehicle in real time and sends the relevant commands to the driving simulator's electronics. The motion system sends the computed vehicle movements to the dome, in which the virtual vehicle subsequently behaves as if it were driving on a real road: When braking, it pitches; when accelerating, the driver is pressed into the seat; and when cornering at high speeds, the driver feels the centrifugal force. The passenger cabins are usually production vehicles whose propulsion unit and wheel suspensions have been removed. The operation is the same as in a real vehicle. When the driver moves the steering wheel, an actuator sets a feedback force at the steering wheel, which is calculated by the vehicle model [1].

Requirements for the Vehicle Simulation

The vehicle model receives the driver input and simulates the vehicle movements in real time. Various simulation programs are implemented to fulfill the different requirements for chassis, vehicle dynamics controllers, and driver assistance systems. The driving simulator has a flexible interface, which makes connecting the vehicle model in different programs possible [1]. For the vehicle dynamics test, it is important to reproduce the vehicle behavior to the extremes. Therefore, the vehicle model must be able to simulate the chassis as accurately as necessary but also as simply as possible. Most of the applied vehicle models do not use structural parts and mountings. Instead, the models are described by look-up >>

An image generation system creates realistic visual impressions in the dome, and a motion system generates the related acceleration forces, for example, when braking and cornering.



tables. This way, the models can provide sufficient accuracy but also remain real-time-capable.

Setting up the Virtual Vehicle

Since 2013, Daimler AG has been using the dSPACE Automotive Simulation Models (ASM) tool suite as a real-time-capable model in the driving simulator to evaluate the handling characteristics of passenger cars during chassis predevelopment. With the driving simulator, it is possible to subjectively evaluate the driving behavior of a chassis design with regard to lateral dynamics. By continuously developing the operating system in the driving simulator and enhancing the ASM model, the test scope has been enhanced. The following tests have become possible during this time:

- *Adjusting the suspension with regard to lateral dynamics*

With the ASM model, it is possible to specify the characteristics of the spring, the stabilizer, and the damper for a chassis system. The characteristics are

tuned by varying the model parameters with respect to subjective criteria, such as agility, yaw behavior, and steering behavior. This allows for evaluating and optimizing the handling characteristics at an early stage when no development mule is available.

- *Subjectively comparing different chassis systems*

In addition to the influence of suspension and damping systems on vehicle dynamics and driving experience, the impact of kinematics, compliances, loading conditions, and the tires is also investigated. With the help of the driving simulator, sensitivity analyses can be performed, for example, to find the influence of bushing stiffness on the self-steering behavior. This analysis is not only useful when developing suspension concepts, but it is also a sensible addition to the real test drive. On the one hand, the adjustment of the chassis parameters, which can be changed only with great effort in a real vehicle,

can be changed quite easily by modifying or replacing the look-up tables and values in the ASM model. On the other hand, the test can be performed more efficiently by simply exchanging the model parameters, because the tester can compare and evaluate the different chassis types without interruption.

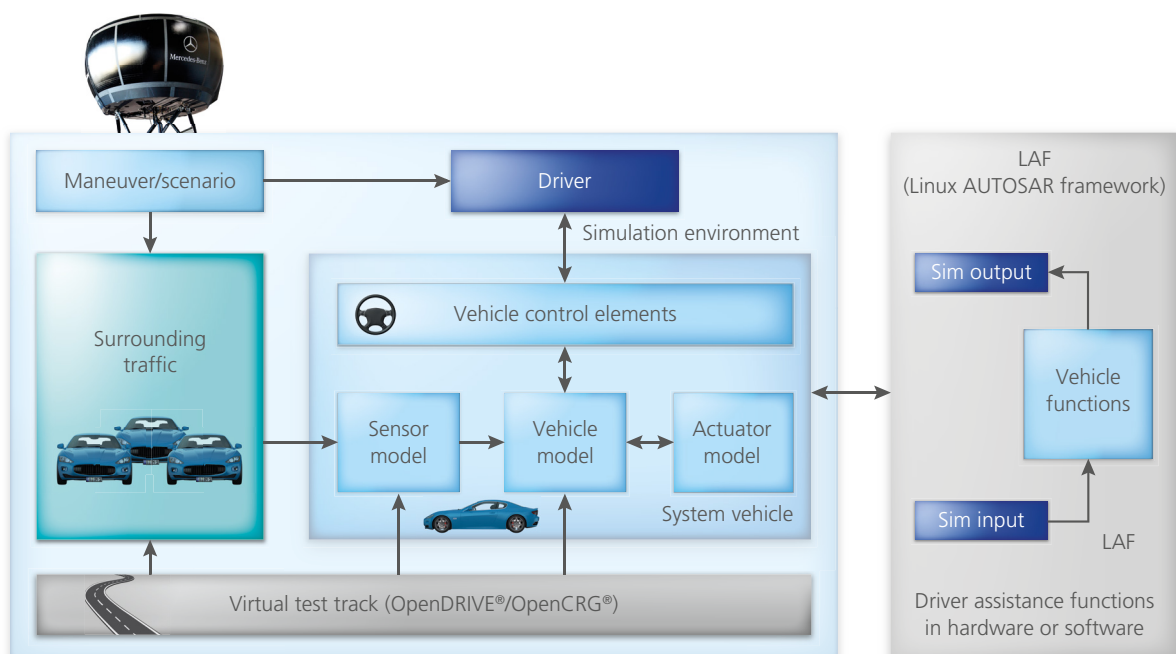
- *Recording the driver reaction during specific driving maneuvers*

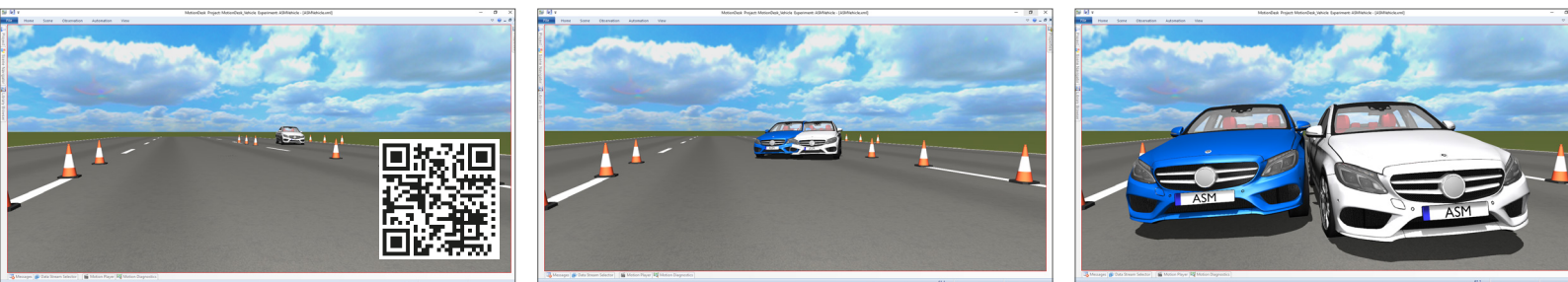
During an offline simulation of a closed-loop maneuver, it is a challenge to accurately model the driver. The driving simulator provides the option to record driver inputs, such as steering wheel angle as well as accelerator and brake pedal position, during the tests. Consequently, the driver model can be optimized on the basis of the recorded data.

- *Evaluating new chassis functions*

Innovative ideas and new concepts for chassis systems to improve driving comfort and vehicle dynamics can be tested and evaluated at the

Schematic setup of the simulation environment to control the hexapod. The vehicle dynamics were implemented with the ASM tool suite.





Superimposed representation of the vehicle behavior of two different chassis types in a step-steer maneuver simulated by the ASM tool suite. Watch the video of the driving maneuver: www.dspace.com/goldMag_20181_steer

“ASM is used as a real-time-capable model for evaluating the handling characteristics of passenger cars during chassis predevelopment.”

Dr. Hans-Peter Schöner, Daimler AG

early stages of the vehicle development without having to design components and set up mules. Both customer and expert evaluations for new ideas and concepts can thus be taken into account at an early development stage and for continued development.

Multistage Test Drives

A test drive in the driving simulator is performed in three steps. At first, the existing multibody simulation (MBS) modeling is transferred to a real-time-capable ASM model. This model is then tested in a fixed-base simulator, i.e., without a motion system, to verify that all variants are numerically stable in all maneuvers. Afterwards, the test is executed. During the test, the test participant successively drives a maneuver with two different chassis variants and then compares the two variants. The evaluations of all variants are documented. In the end, all test results are evaluated and summarized. The chassis variants with the best evaluations are simulated in the MBS model again to have an objective evaluation. The subjective evaluations and their sensitivities can be used as a reference for developing vehicle components and functions.

Summary

By using the driving simulator, it is possible for the automobile manufacturer to test and evaluate vehicles at different development stages. As a result, development times for future models can be significantly reduced. Regarding vehicle dynamics, the road handling, ride comfort, and intervention of control systems can be evaluated quickly and safely. ■

Ruochen Yang, Dr. Hans-Peter Schöner, Daimler AG



See the driving simulator in action: www.dspace.com/goldMag_20181_FSIM

Literature:

[1] Dr.-Ing. Hans-Peter Schöner: “Erprobung und Absicherung im dynamischen Fahrsimulator”; Conference Paper: SimVec - Simulation und Erprobung in der Fahrzeugentwicklung: Berechnung, Prüfstands- und Straßenversuch, Baden-Baden, Volume: 17. Kongress (VDI), November 2014 www.dspace.com/goldMag_20181_SimVec

Dr. Hans-Peter Schöner
Hans-Peter Schöner, Senior Manager for Driving Simulation and Testing Methods at Daimler AG in Sindelfingen, Germany.



Ruochen Yang
Ruochen Yang is responsible for setting up the vehicle model and performing the tests at Daimler AG in Sindelfingen, Germany.





First Automotive Works (FAW) develops the mobility concepts of tomorrow in line with the AUTOSAR standard. The company uses virtual electronic control units (V-ECUs) as well as the prototyping system MicroAutoBox II, the production code generator TargetLink, and the system architecture tool SystemDesk, all from dSPACE, to implement new propulsion technologies on the basis of models and AUTOSAR.



AUTOSAR-based development
for the electric and hybrid
drives of the future

Excellence as a Standard

For new electric and hybrid vehicles, FAW relies on AUTOSAR-compliant controller software to advance the development of electric and hybrid mobility concepts. To this end, FAW initiated and carried out a prototyping project. In the course of this project, existing controller models were migrated to an

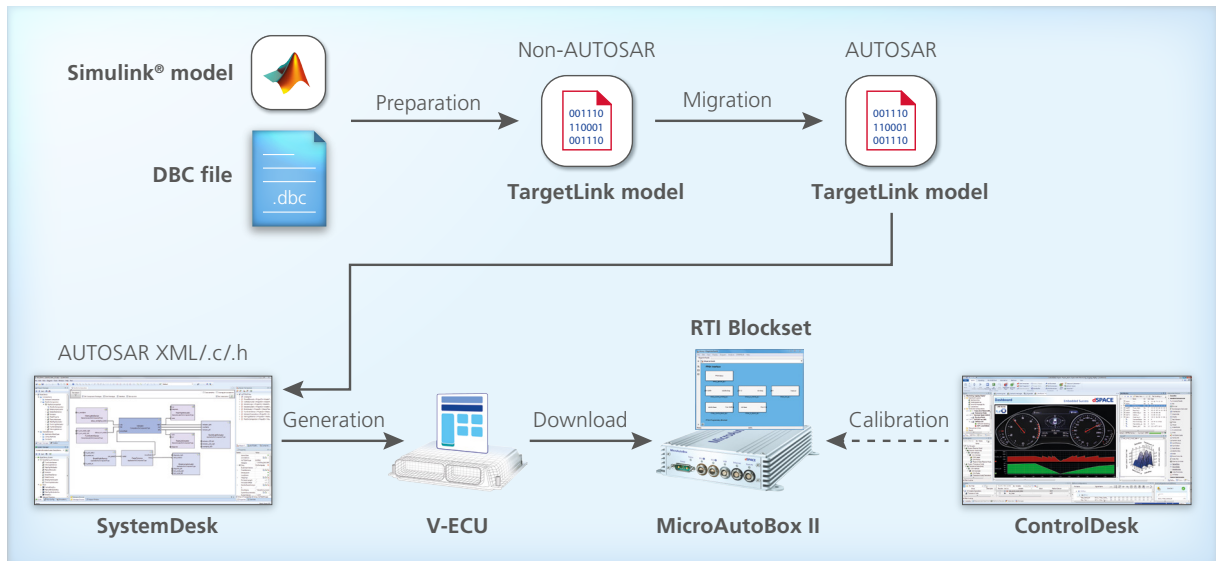
AUTOSAR-compliant format. In addition to the tool-based migration, new functions had to be tested in the vehicle by means of rapid control prototyping, among others. The tool chain FAW originally used was not designed for AUTOSAR-compliant development, so the migration required numerous changes. For example, new tools that

are optimized for AUTOSAR-compliant processes were added to the existing tool chain.

AUTOSAR Migration

The basis for the migration to AUTOSAR-compliant development was Simulink models and existing communication descriptions from an orig-

>>



Migration process for the controller software of an AUTOSAR-compatible ECU. The controller software can be tested in the vehicle using the prototyping system.

inally non-AUTOSAR development project. To generate AUTOSAR-compatible software structures, developers at FAW used dSPACE TargetLink as well as a number of TargetLink extensions. One of these extensions is the TargetLink AUTOSAR Migration Tool, which transforms standard TargetLink models that are not AUTOSAR-compliant into AUTOSAR-compatible models at the click of a button. The developers first imported the Simulink models to TargetLink, which converted them to TargetLink models. They were then immediately able to use the models to generate AUTOSAR-compatible code as well as an AUTOSAR software component description. FAW used the flexibility provided by the configuration options of the AUTOSAR Migration Tool to meet their own software architecture requirements. This enabled them to

create AUTOSAR-compatible software components (SWCs), which were then available for other development tasks.

Virtual ECU Generation

The next challenge for FAW was to use the AUTOSAR-compliant software components for in-vehicle tests. This is where virtual ECUs (V-ECUs) and their ability to run on MicroAutoBox II played a decisive role. The architecture software dSPACE SystemDesk is the perfect choice for V-ECU creation. After FAW imported the new SWC and the DBC files into SystemDesk, the tool provided an ECU configuration framework with automation functions. This made it possible to automate the AUTOSAR-compliant configuration and generation of the V-ECUs. These steps and tools enabled FAW to migrate their controller software for AUTOSAR-compliant development.

Preparing the Prototyping System

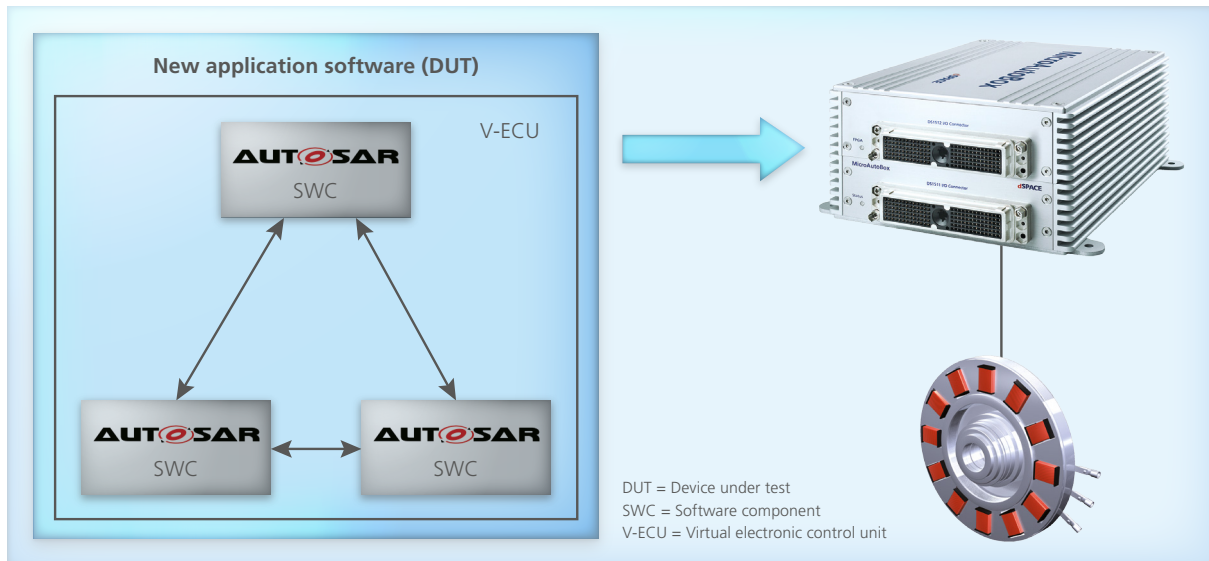
FAW used classic prototyping to test the new controller software in the vehicle to make sure it behaved exactly like the non-AUTOSAR software version. The developers used Real-Time Interface (RTI) blocksets to exchange information between the V-ECU and the MicroAutoBox II. They were also able to use the blocksets to conveniently connect the I/O and signals of the V-ECU with the I/O and communication interfaces of the MicroAutoBox II. Therefore, the MicroAutoBox II took on the role of the ECU in the vehicle during prototyping.

Outcomes and Outlook

FAW successfully completed a core prototyping project on the topic of AUTOSAR-compatible controller software for electric drives. Thanks to the tool-supported AUTOSAR migra-

“The seamless dSPACE tool chain is easy to use and provides the functionality needed so that even less experienced developers are able to migrate controller software to AUTOSAR.”

Guohuang Ji, FAW



The controller software was migrated to an AUTOSAR-compatible structure, which let FAW use it in the vehicle.

tion, the developers were able to focus on the models and new functions. The results of the project are used as the basis for further improvements and will be used in the series production of the controllers. Since FAW was able to achieve the results

with great efficiency, the teams will continue to develop ECUs with the new approach. They will also continue to use the tool chain consisting of the dSPACE products SystemDesk, TargetLink, and MicroAutoBox II. ■

Guohuang Ji, Dali Jiang, FAW

“The production code generator TargetLink played a central role in the implementation of the ECU software and will continue to support us in the new, AUTOSAR-compliant development process.”

Dali Jiang, FAW

At a Glance

The Task

Developing the controller software of future electric and hybrid drives at FAW according to AUTOSAR.

The Challenge

Setting up a tool chain for the AUTOSAR-compliant development and migration of non-AUTOSAR software. Quickly migrating non-AUTOSAR software to AUTOSAR and performing in-vehicle tests.

The Solution

Using a seamless dSPACE tool chain has made it possible to migrate controller software to an AUTOSAR-compliant structure with only little effort and experience. MicroAutoBox II in combination with V-ECUs were used to test the AUTOSAR-compliant software in the vehicle.

Guohuang Ji

Guohuang Ji is Electronic Control System General Engineer for battery management systems (BMS) at FAW in Changchun, China.



Dali Jiang

Dali Jiang is Electronic Control System Development Department leader for BMS at FAW in Changchun, China.



The term 'electromobility' is generally associated with road traffic, where the share of electric vehicles is expected to rise considerably in the coming years. But the well-known benefits of electric drives, such as environmental friendliness, compactness, low maintenance and low noise emissions, are also of great interest for aviation. For example, using electric motors in aircraft can significantly reduce the maintenance work for turbine and piston engines, which is generally high and expensive. Therefore, it comes as no surprise that many aircraft manufacturers and suppliers worldwide are exploring the potential of electric drives for aviation.

ELIAS – All-Electric Flight Demonstrator for Unmanned Tasks

ELIAS (Electric Aircraft IABG AcentisS) is mainly used to test technologies for an unmanned, electric reconnaissance and surveillance system (figure 2). The initial development at IABG and its member ACENTISS started in 2012 when the research center bought an Elektra One aircraft from PC Aero and converted it to the ELIAS system demonstrator with a video camera, data link, and

a ground control station. ELIAS can be operated manually by a pilot or automatically. In the current configuration, the pilot performs take-off and landing. Then, the aircraft automation takes over and flies the plane in a controlled manner according to predefined waypoints, which can be modified during the flight, or according to direct input from the ground station, such as altitude, airspeed, and direction. The aerodynamic control surfaces of the plane are controlled by electric actuators with an integrated electromagnetic clutch. With a simple push of a button, the pilot can take control of the plane at any time. Ground staff can use a joystick at the ground control station to control the sensors that are located below the fuselage, e.g., to pan the camera, infrared sensor or laser rangefinder, or to zoom into the recorded image. In cooperation with Geiger Engineering, ACENTISS developed two dual motors with 30 kW and 40 kW of take-off power, respectively. Each dual motor consists of two motors that drive one propeller via an over-running clutch. If one motor fails, the other motor can continue to drive the propeller, albeit with slightly reduced power. The setup

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Figure 1: Aircraft-in-the-loop simulation is used for comprehensive testing of the flight control algorithms on the ground.





Developing a fully electric
and autonomous aircraft

Electric Take-Off

With ELIAS, ACENTISS GmbH has developed a fully electric plane as a test platform for reconnaissance and surveillance systems. It can be operated with or without a pilot. A MicroAutoBox II from dSPACE is used as the onboard flight guidance computer.



- 1 Electric drive with 20 kW of take-off power and controllable pitch propellers
- 2 Li-ion battery pack
- 3 Avionics – incl. dSPACE MicroAutoBox II as the flight guidance system, inertial reference system, radar altimeter, and satellite navigation system with SBAS¹⁾ support
- 4 Sensors (video camera, infrared sensor, laser rangefinder)
- 5 Electric retractable landing gear
- 6 Data link antenna

¹⁾ Satellite Based Augmentation System – a specialized satellite navigation system for high-precision positioning.

Technical Details

Max. take-off weight	■ 350 kg
Wing span	■ 11 m
Wing area	■ 8.2 m ²
Max. speed	■ 150 km/h
Cruise speed	■ 110 km/h
Max. motor power	■ 20 kW
Max. range	■ >150 km
Max. flight time	■ Approx. 1.5 h

Figure 2: ELIAS setup. An onboard dSPACE MicroAutoBox takes on the role of the flight guidance system.

“MicroAutoBox II is a flexible and reliable onboard flight guidance system. It lets us quickly implement new algorithms to drive innovation.”

Andreas Rohr, ACENTISS

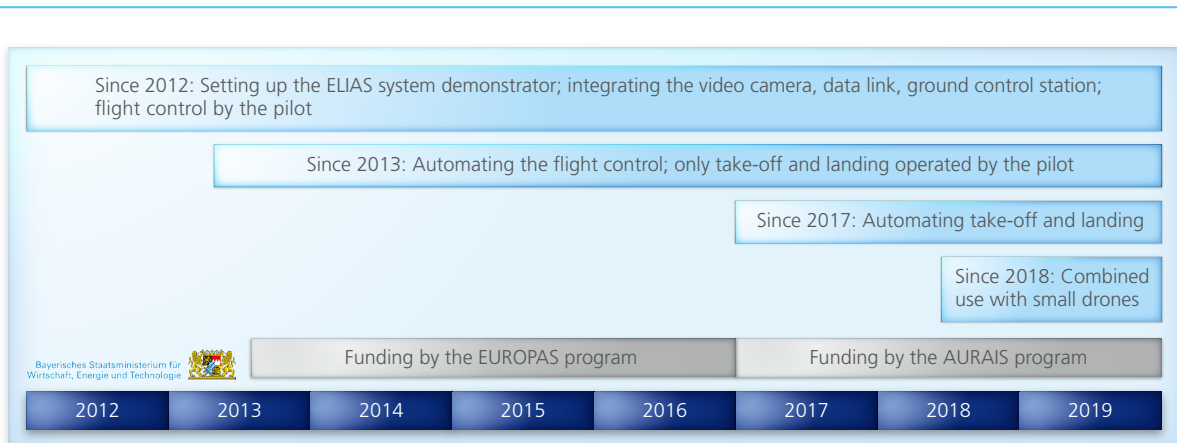
of controllers and Lithium-ion batteries is also redundant. This means that a single motor achieves the level of safety of an aircraft with two motors. Before the in-flight propulsion tests, ACENTISS uses its own motor test bench and the wind tunnel of TU Munich for extensive testing. A prototype of the 40 kW dual motor is currently being used for in-flight tests. The innovative retractable landing gear, which is made of high-strength aluminum, is actuated

electrically. The elastomeric components used for the landing gear make it practically maintenance-free, the only exception being the brakes. The landing gear has already been used for several years. Thanks to the square profile of the suspension strut, complex torsion links are not required.

MicroAutoBox II Guides the Flight
On board ELIAS, a dSPACE MicroAutoBox II performs the core flight

guidance tasks and executes the commands of the ground control station during unmanned flights. The MicroAutoBox II is connected to the flight controller via a CAN-aerospace bus. The flight controller controls the electric actuators for the deflection of the aerodynamic control surfaces as well as the thrust for a stable and safe flight. If required, MicroAutoBox II can be extended by an Embedded PC. A Simulink model

Figure 3: Chronology of the development tasks.



is used on MicroAutoBox II that calculates the trajectories as a function of the specified destination, the captured wind conditions, and the navigation data. It then sends the trajectory to the flight controller in the form of georeferenced waypoints and also transfers altitude and airspeed information. The MicroAutoBox II also controls the retraction and extraction of the landing gear during take-off and landing, respectively, and monitors the state of charge of the batteries. A major benefit is the direct connection between the MicroAutoBox II and MATLAB®/Simulink®, which makes it possible to quickly implement changes to the flight control algorithms. This lets the researchers continuously develop the flight guidance software and adjust it to the different tasks. After the laboratory tests, the software can be loaded to the prototyping system for the aircraft-in-the-loop (HIL/ACIL) simulation and for test flights.

Testing on the Ground and in the Air

To prepare the real test flights in the air, the aircraft is intensively tested on the ground in the ACIL simulation at IABG, the parent company of ACENTISS (figure 1). The engineers not only validate the automatic flight itself, they also test the smooth switching from manual to automated flight mode. The ground control station can be connected to the aircraft via radio or cable.

Supported by Funding Programs

The development of the technology required for unmanned fully electric flight is supported by the Bavarian Ministry of Economic Affairs, Energy and Technology as part of the Bavarian aviation research and technology program. As part of the EUROPAS sponsorship program, partners from the industry and research joined ACENTISS in developing the automatic flight control with flight guid-

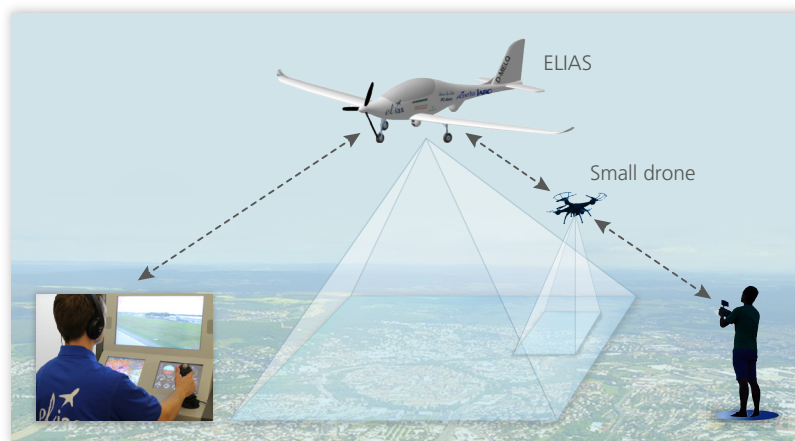


Figure 4: When ELIAS is used with small drones, the aircraft provides a rough overview of a large area and acts as a data link relay for the drone. In contrast to ELIAS, the smaller, more agile drones are able to hover, which is useful for close reconnaissance, and provide more detailed information on the selected area. They can be controlled by pilots in the field or by the ground station.

ance system, the electric retractable landing gear, a 30 kW and a 40 kW dual motor as well as an electronic data link for the connection between the ground control station and the aircraft. The system was successfully demonstrated in a test flight in late 2016. In the follow-up sponsorship program AURAS (All-Electric Unmanned Reconnaissance & Aerial Imaging Airborne System), which started in 2017, the automatic take-off and landing capabilities and a ground control station for the combined use with small drones are developed (figure 4).

Outlook

The current development for the combined use of ELIAS and small drones aims at enabling efficient close reconnaissance (figure 4). At the same time, the compact, mobile ground station is optimized for the future tasks. Test flights are scheduled for 2019 to test the preprogrammed ground-controlled missions with automatic take-offs and landings as well as the combined use with small drones in the field. ■

Dr. Hans Tönskötter, Andreas Rohr, ACENTISS GmbH

Dr. Hans Tönskötter

Hans Tönskötter, Senior Manager Airborne Systems, ACENTISS GmbH in Ottobrunn, is responsible for the development of the technologies of the unmanned electric reconnaissance system.



Dipl.-Ing (FH) Andreas Rohr

Andreas Rohr is an aviation engineer and pilot at ACENTISS GmbH in Ottobrunn. He is responsible for the continued development of the aircraft.

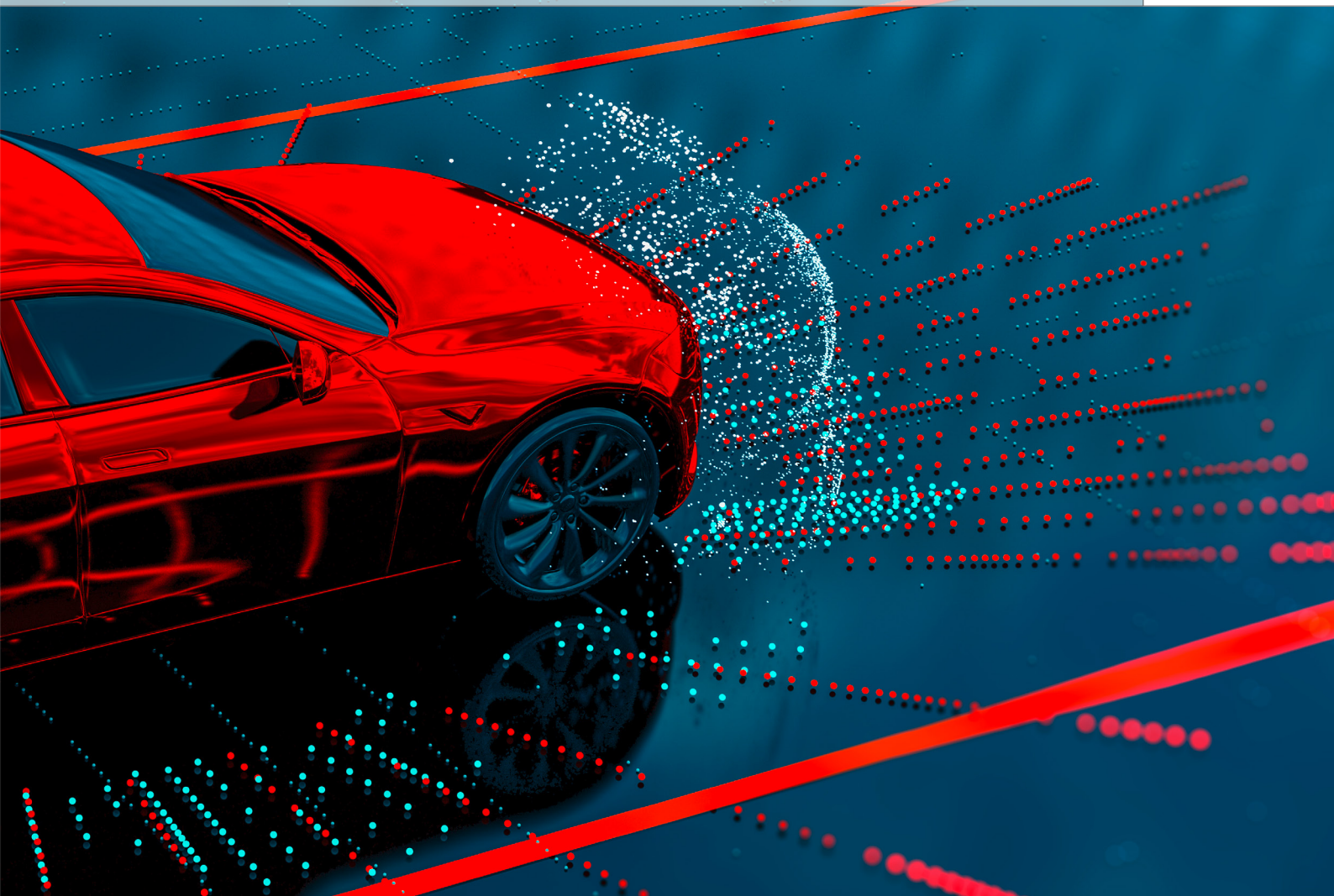


A red car is shown from a rear three-quarter view, set against a dark blue background. The car is surrounded by a complex visualization of sensor data, consisting of numerous small, multi-colored dots (red, yellow, blue, green) and lines that radiate from the car, representing the car's perception of its environment. The overall aesthetic is futuristic and technological.

Developing Features for
ADAS and Autonomous Driving

Sensor-Based Driving

P3 has developed an Autonomous Data and Analytics Platform for Testing (ADAPT) to help customers evaluate the implementation of features for ADAS and autonomous driving. These include vision-based features and features for testing sensors as well as sensor configurations and algorithms. ADAPT leverages RTMaps software to verify and validate ADAS and algorithms for autonomous driving.



As emerging trends are ushering in a period of fundamental transformation across the transportation industry, P3 helps OEMs and suppliers prepare for the future by providing effective strategies. Their aim is to bring new connected services and technologies for autonomous driving to the marketplace. In the area of ADAS and the development of autonomous vehicles, P3 provides a range of services including:

- Development of technology roadmaps and business strategies
- Benchmarking for global products and mobility services
- Definition of functional system and subsystem requirements
- Functional safety analysis (ISO 26262)
- Rapid prototyping (HW/SW)
- Data strategy and data analysis
- Agile program management and launch

To demonstrate its capabilities in this area, P3 North America, a subsidiary of P3, recently unveiled its ADAPT vehicle, showcasing advanced driver assistance systems (ADAS) and features for developing autonomous vehicles. ADAPT stands for Autonomous Data and Analytics Platform for Testing.

Considerations for Autonomy

P3's first step was to consider which sensors, software, and hardware would have to be tested in the future. The P3 engineers determined that tests must support a comprehensive range of sensors as they expected there might be various configurations of vehicles of SAE Level 3 or higher. They set a goal to create a modular vehicle that offers the option to mount a variety of sensors. P3's aim is to deliver real-time static and dynamic data in a

robust and reliable setup – independently of the existing weather or traffic conditions. The P3 engineers conducted a benchmark study to review a variety of different sensor options, including a surround view camera, forward-looking camera, peripheral view camera, mid/long-range radar, lidar, short-range radar, and ultrasonic sensors. Additionally, they evaluated common communication interfaces (e.g., USB, Ethernet, CAN). For demonstration purposes, P3 decided to incorporate scanning and solid-state lidars, ultrasonic sensors, forward-looking cameras, and forward-looking radar in the vehicle, which did not have to be all-inclusive.

Design Specifications

To conceptualize, design, and model desired ADAS features for the demo vehicle, P3 turned to model-based

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P3's ADAPT demo vehicle features a data logging PC with RTMaps software and a set of sensors (lidar, ultrasound, forward-looking camera, forward-looking radar).



systems engineering, which supports the development of system design specifications. This engineering approach included identifying functional and software testing requirements (i.e., model-in-the-loop [MIL], software-in-the-loop [SIL], hardware-in-the-loop [HIL], etc.), as well as creating the vehicle and feature architecture models. All of these aspects support the verification and validation of

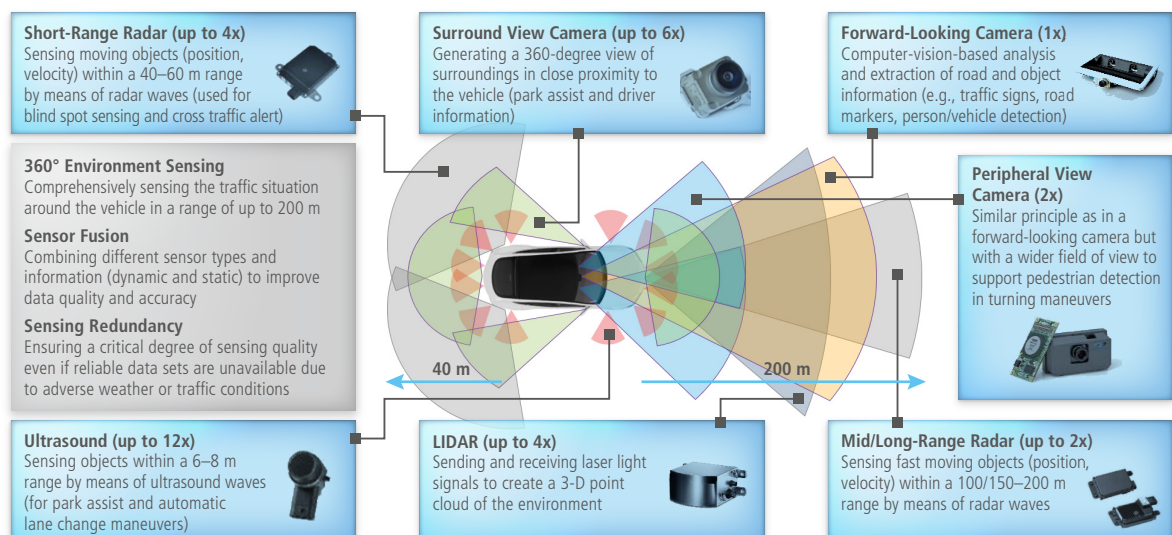
production software and hardware. P3 engineers identified hazardous scenarios and set appropriate system safety goals. From this initial assessment, engineers defined system and technical safety requirements for implementation.

Equipping the Vehicle

With a good understanding of the functional safety requirements, P3

engineers began with installing the measuring and test equipment. They mounted the various sensors to the vehicle. They prepared sensor connectors and wiring according to the desired layout and interface elements, and they installed PCs to log data derived from the sensors. Some of the important aspects that they kept in mind while equipping the vehicle with the instruments included:

Autonomous vehicle systems involve a complex suite of sensors, software, and hardware.





Solid-state lidar mounted on the vehicle roof.



Power management, I/O, data logging, and processing units housed in the vehicle trunk.

- Incorporating sensors with common communication interfaces (e.g., USB, Ethernet, CAN)
- Creating a schema of the vehicle to consider all possible sensor locations and expansions that might be added
- Mounting sensors in both invasive (e.g., bumper rails) and non-invasive spaces
- Integrating the vehicle with reliable power management to support additional equipment and multiple configurations
- Expandable storage that supports the largest sensor packages and test scenarios
- Providing easy access to all equipment with enough space for expandability while keeping sufficient room for passengers and maintaining the safety and integrity of the vehicle
- Ensuring optimal cable routing that

is resilient enough to handle environmental stresses and constant use but short enough to reduce data loss

- Preventing interference with existing sensors (e.g., blocking other sensors' fields of view, network interference, electrical noise)

Setting up the Data Logging System

Gathering accurate real-time data is vital for the proper operation of ADAS and functions for autonomous driving. With this objective in mind, P3 engineers made a list of conditions they wanted to be conscious of when setting up their data logging system. Some qualities they sought to incorporate included:

- Understanding how the sensors interface and communicate with each other

- Enabling data processing for required live visualization (e.g., converting radar data from range, angle to (x,y,z))
- Synchronizing data handled in real time or according to the GPS clock
- Monitoring sensor communication (P3 uses RTMaps watchdog blocks to ensure data is captured)
- Saving raw data (for testing modified algorithms in a playback diagram)
- Saving processed data (to save time on playback after testing)
- Ensuring that sensors operate properly via component interaction (P3 uses RTMaps to provide necessary information, i.e., CAN messages, yaw rate, etc.)

Managing Sensor Fusion

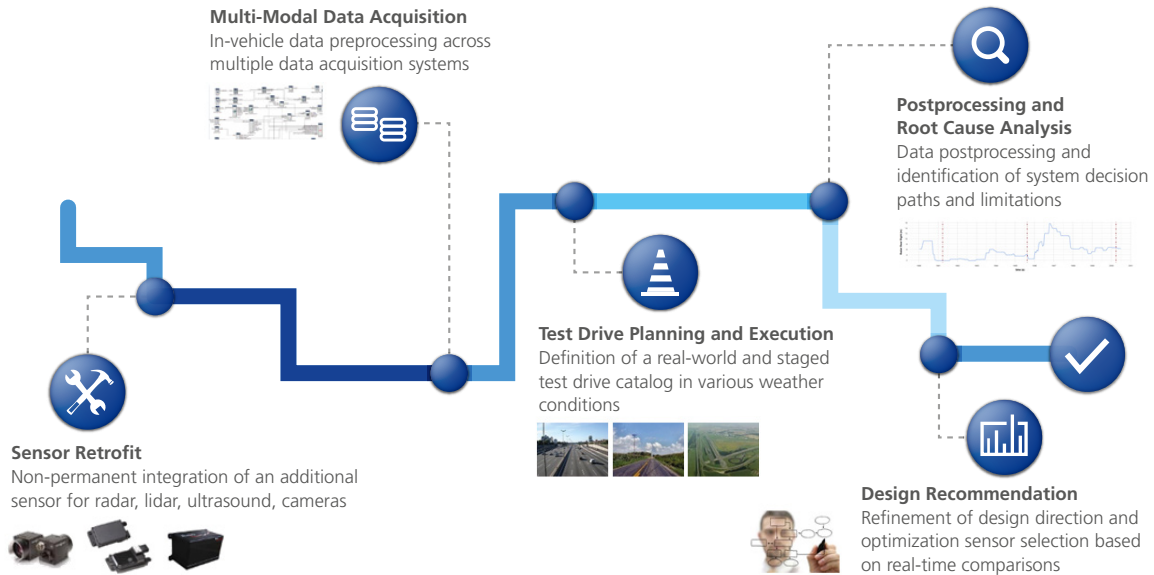
With a clear plan of how to set up the data logging system, P3's next step was to find a way to process

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"We have been using and recommending dSPACE MicroAutoBox and ControlDesk to enhance the robustness of ADAS and autonomous driving prototypes. This allows prototype systems to operate in near-automotive-grade conditions."

Modar Horani, Managing Principal of Systems Engineering at P3 North America

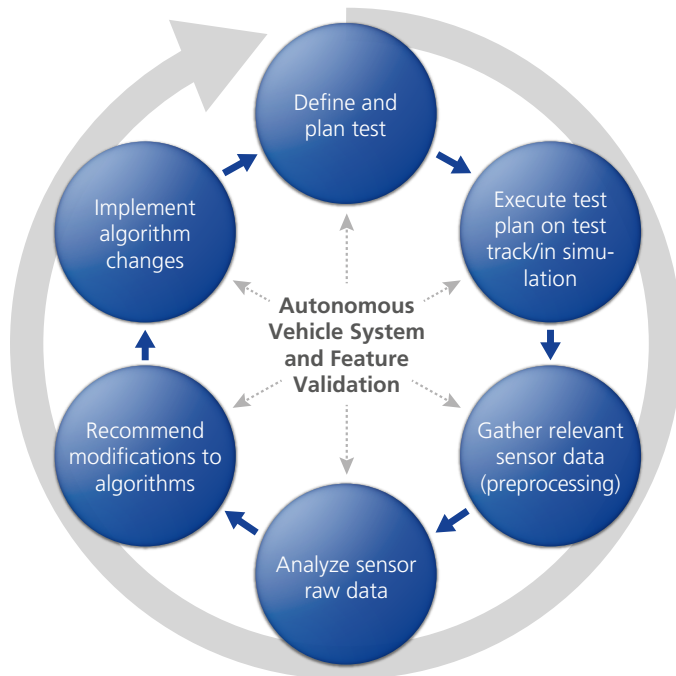


Milestones in setting up and refining an autonomous vehicle system.

and manage the data collected from the various sensors. P3 set out to establish an in-vehicle data preprocessing system that can handle multiple data acquisition systems. The ADAPT platform is designed to accelerate the development of new autonomous driving (AD) and ADAS features as it combines everything that is necessary for the efficient, robust, and reliable testing of sensors, sensor configurations, and algorithms. This platform allows for gathering real-world data for benchmarking and data analytics purposes. It also enables OEMs and Tier 1s to test different configurations of hardware and software in real-time, dynamic driving conditions. ADAPT is equipped with RTMaps (Real-Time Multisensor applications), a software platform created by Intempora and distributed by dSPACE. RTMaps enables data collection in real time and testing of data processing algorithms. The platform's powerful real-time execution performance enables it to handle time coherency among numerous software tasks and the high bandwidth of raw data streams. Modar Horani serves as Managing Principal

of Systems Engineering at P3 North America. He leads a team of systems engineers who support clients (OEMs and Tier 1s) in developing functional requirements for systems and sub-

systems, functional safety analyses (ISO 26262), and rapid prototyping (HW/SW). Horani explained that RTMaps allowed P3 to record data from a relatively large set of sensors



Important steps for planning tests and analyzing data of autonomous vehicle systems.



“We are very pleased with the capabilities offered by RTMaps. The performance was seamless and logging was reliable.”

Modar Horani, Managing Principal of Systems Engineering at P3 North America

including cameras, lidar, radar, CAN, GPS, IMU, and ultrasound. He also stated that RTMaps connected well to the dSPACE tool chain. “Its simple interface makes it easy to use and you can rapidly modify the existing environment,” Horani said. “To ensure the proper operation of sensors, RTMaps lets us send control signals to the sensors, and the built-in watchdog package helps to ensure valid data is being input to the logging diagram. Overall we are very pleased with the capabilities offered by RTMaps. The performance was seamless and logging was reliable.”

Test Planning and Analyzing Collected Data

Once their demo vehicle was successfully equipped with sensors and a data logging system, P3 set out to identify a series of driving tests to be executed, the final goal being test completion without errors. The test drives were designed to achieve the following goals:

- Confirming system readiness and sensor calibration
- Gathering data from various road, weather, and traffic conditions of interest
- Verifying the performance of certain algorithms under test

A careful design of experiments was performed to identify the most suitable experiment environment and variable factors. Some of the variations of interest included gathering sensor readings from normal to adverse

weather conditions. For example, collecting data from sunny, rainy, snowy, and foggy days while driving on the same section of a highway. GPS tracking allowed for aligning the recorded data and identifying the corresponding challenges when dealing with

adverse conditions. Some test drives were performed on a dedicated proving ground facility to establish verified ground truth. Ground truth data is required to calibrate both the sensor and algorithm outcome. P3 was able to collect significant streams of real- >>



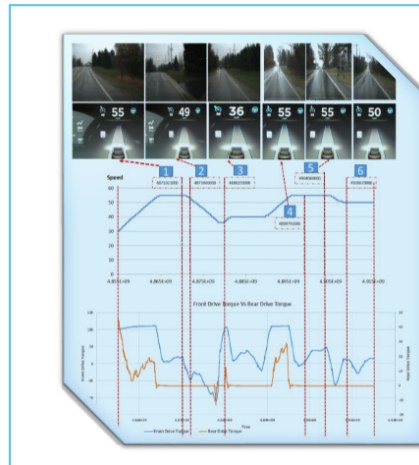
To merge various sensor signals and perform the relevant processing algorithms in real time, RTMaps and MicroAutoBox took over crucial roles.

time data from the various sensors to evaluate sensor functionality.

Modifying Algorithms

Using the data collected from the demo vehicle sensors for various driving tests, such as forward and rear collision avoidance as well as lane departure warning, engineers initiated rapid prototyping to evaluate findings and their impact on system performance. They were able to identify errors and modify and implement various ADAS algorithms to improve the performance of the demo vehicle.

A dSPACE MicroAutoBox II prototyping unit and the dSPACE ControlDesk experiment software were among the tools used to modify and implement the ADAS algorithms. Horani explained that MicroAutoBox II was easy to use and integrated well with major model-based development tools (e.g., MATLAB®/Simulink®) to accel-



Validation and verification with RTMaps and further solutions: Early confirmation by means of reviewing and analyzing whether all safety requirements are correctly implemented.

erate the implementation of new and innovative concepts. “We have been using and recommending dSPACE MicroAutoBox II and ControlDesk to enhance the robustness of ADAS/AD prototypes,” Horani said. “This allows

prototype systems to operate in near-automotive-grade conditions.”

Using RTMaps

Beyond the demo vehicle, Horani said P3 had leveraged RTMaps for

Data analysis of raw and processed sensor data with RTMaps.

the verification and validation of ADAS algorithms in two scenarios:

- 1) On the road, where algorithms are running on the car's PC and live data is collected and visualized, and
- 2) in the lab, where the collected data is used as input to verify the performance of algorithms under development.

Additionally, Horani said RTMaps was helpful for several projects with algorithms that were developed in various programming languages (e.g., Python, C, MATLAB) and required integration. "RTMaps has a good native selection of packages for interfacing sensors," Horani explained. "However, customer requirements often dictate the use of proprietary sensors outside of the native packages. The tools provided by RTMaps facilitate the development of custom packages."

What is Next for P3?

After validating its functional autonomous vehicle system, P3 is well positioned to work on future ADAS and autonomous vehicle development projects. The company is looking to expand the capabilities of its Autonomous Data and Analytics Platform for Testing (ADAPT) to include additional sensors for various applications, such as V2X communication. They are also evaluating implementations of vision-based ADAS features. P3 provides management consulting and innovative engineering solutions that accelerate the development of mobility products and services. Their combination of management support, consulting services, and engineering solutions enables them to understand what it takes to implement new technologies with speed and agility. In North America, their focus areas are autonomous, connected, and electric mobility in

addition to new mobility services and digital transformation. P3 has almost 4,000 consultants and engineers across more than 40 locations worldwide working to develop and implement innovative solutions to today's complex technology challenges. The successful implementation of the ADAS evaluation platform extends P3's services and capabilities to support both the development and validation of features for ADAS and autonomous driving. The ease of use and modularity of the platform make it relevant to the complete development cycle from early research and prototyping to product development, integration, and validation. P3 is deploying this platform globally to accelerate the transition towards the future of autonomous mobility, which is safer, greener, and connected. ■

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At a Glance

The Task

Setting up a demo vehicle that is based on a data and analytics platform for autonomous driving to help customers evaluate the implementation of ADAS and features for autonomous driving. The platform comprises vision-based features and the testing of sensors, sensor configurations, and algorithms.

The Challenge

Gathering accurate real-time data is vital to the proper operation of functions for ADAS and autonomous driving. Therefore, various sensor inter-

faces and communication protocols have to be supported and their signals must be processed in a synchronized manner. Monitoring sensor data, saving raw and processed data, and a flexible routing of signals are crucial to verify the performance of algorithms under test.

The Solution

P3 relies on RTMaps and MicroAutoBox to connect to and record data from a relatively large set of sensors, including cameras, lidar, radar, CAN, GPS, IMU, and ultrasound. RTMaps enables data collection in real time and

testing of data processing algorithms. The platform's powerful real-time execution performance enables it to handle time coherency among numerous software tasks and the high bandwidth of raw data streams. The MicroAutoBox II prototyping unit was used in combination with ControlDesk to modify and implement the ADAS algorithms and perform them in the vehicle in real time.



Watch the video demonstrating the data analysis with RTMaps.
www.dspace.com/go/dMag_20181_P3

“**T**here has to be a better way.” – This is the mindset of Tula Technology, and this innovative engineering company has succeeded in solving an engine design challenge that the automotive industry has grappled with for decades. That issue is how to achieve individual engine cylinder deactivation. The creative minds at Tula have developed a software-based approach that combines advanced digital signal processing, algorithms, and sophisticated powertrain controls to automatically manage when a single engine cylinder should deactivate (skip) or activate (fire) to meet the torque requirements of the driver. Their solution is called Dynamic Skip Fire (DSF®) technology.

Dynamic Skip Fire

With DSF technology, the engine control system automatically turns individual fuel cylinders on or off to meet the vehicle’s power requirements with the most efficiency. In contrast to conventional methods of cylinder deactivation, Tula’s Dynamic Skip Fire algorithms fire between 0% and 100% of cylinders in a near continuum. This operation reduces fuel consumption through a substantial reduction in pumping losses, higher combustion efficiency, and an improvement in catalyst management during deceleration. DSF technology gives drivers the power they need, but keeps the engine running at optimal efficiency. This solution can reduce fuel consumption and CO₂ emissions by 10-15%. General Motors (GM) has taken notice of this fuel economy technology. The automaker has invested in Tula, as have

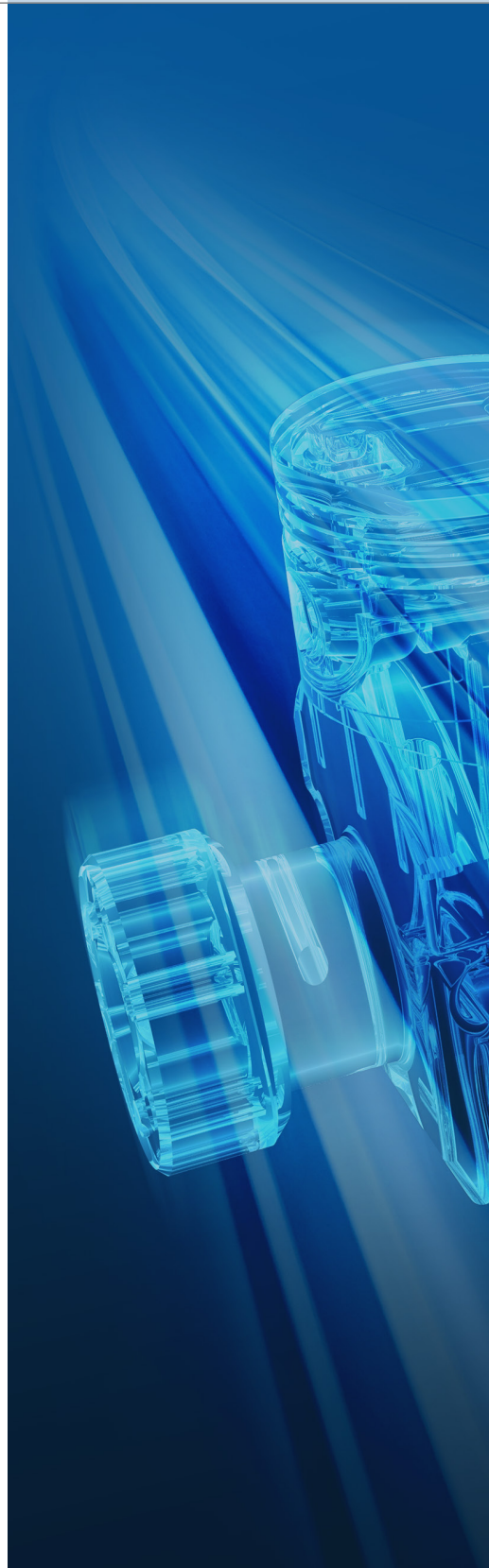
other companies including Delphi, Sequoia Capital, Khosla Ventures, and Sigma Partners. Delphi is a strategic Tier 1 partner of Tula as well.

Pursuing Automated Testing

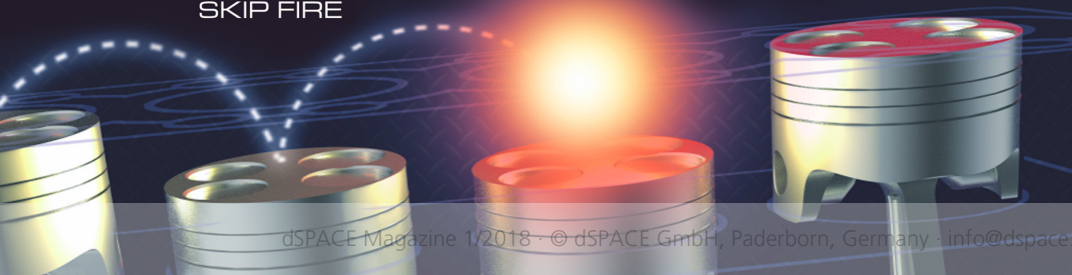
Tula has been fine-tuning its DSF solution since 2008, when the Silicon Valley technology company was established in San Jose, California. The company has since received 52 patents and currently has over 70 patents pending. Tula first contacted dSPACE in 2009, when the company set out to explore embedded software development and electronic control unit (ECU) testing options. Today, Tula has established an automated testing platform that incorporates several dSPACE tools, including MicroAutoBox II for rapid control prototyping, RapidPro for signal conditioning, a hardware-in-the-loop (HIL) system for simulating and testing engines, ControlDesk for controlling the experiment, SystemDesk for modeling architectures and systems, and AutomationDesk for writing and updating standardized tests and recording and sharing test data. To further expand on its automated testing capabilities, Tula has most recently adopted a virtual validation environment and added dSPACE VEOS, a simulation platform for virtual validation, to its laboratory.

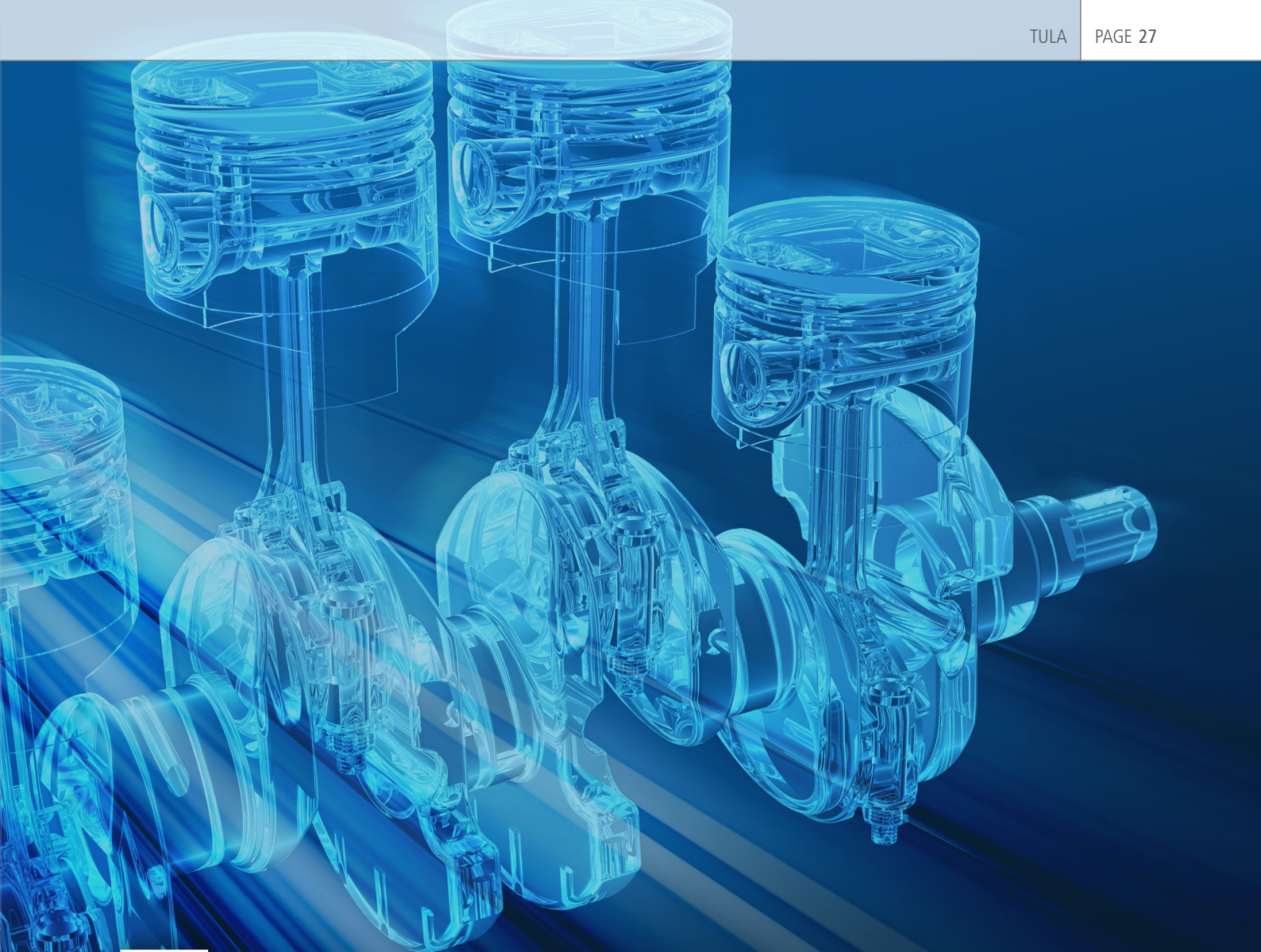
Faster Validation and Earlier Bug Detection

The desire to complete validation tasks faster and find bugs earlier in the software life cycle are two of the main drivers that motivated Tula to pursue virtual validation in 2016. Alfred >>



DSF
DYNAMIC
SKIP FIRE





Faster

Completing validation and verification activities in half the time with virtual validation

Engine Validation

Can you execute testing activities faster without the physical hardware? Tula, a Silicon Valley technology company, has seen a 50% reduction in time required to complete validation and verification activities since establishing a virtual validation environment.

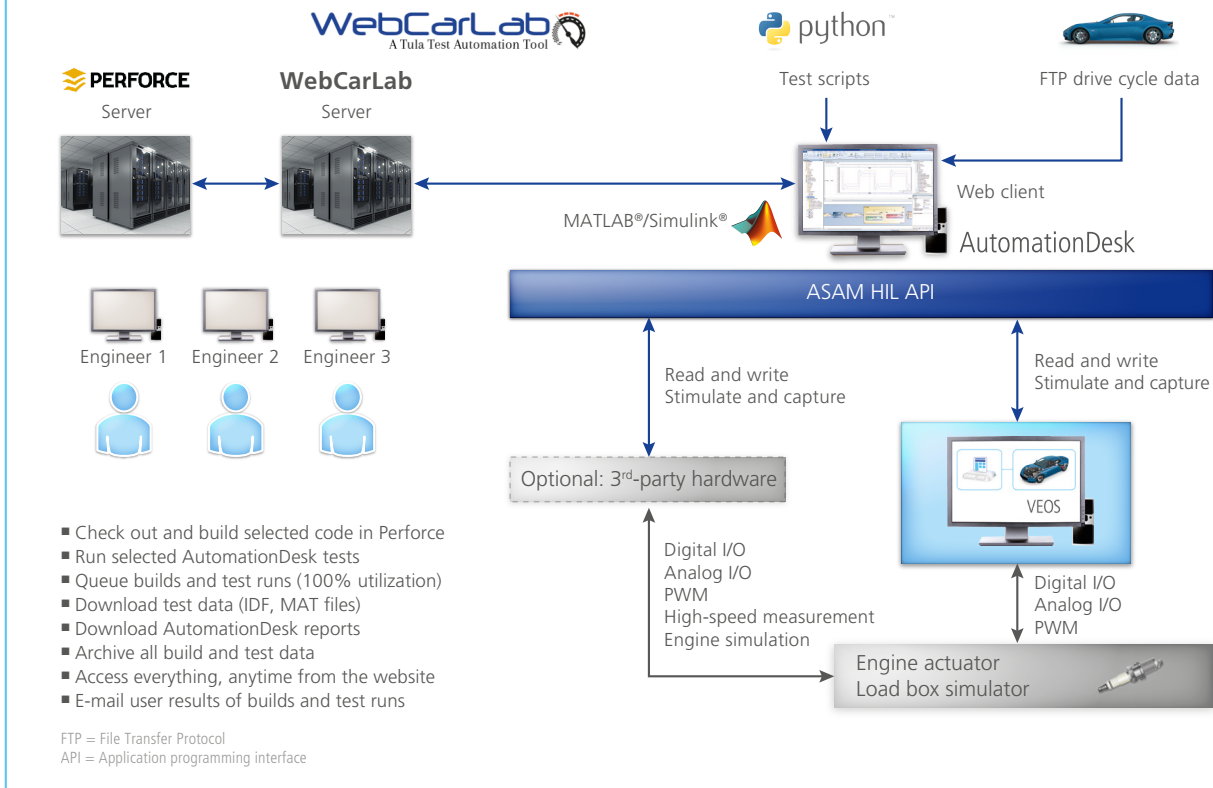
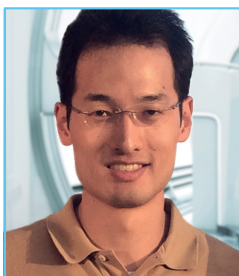


Figure 1: In Tula's new validation and verification infrastructure, all code and test scripts are organized in dSPACE AutomationDesk and executed using the PC-based simulation platform dSPACE VEOS.



“We have found that it is generally faster to validate software early in the development process using just your PC and VEOS.”

Alfred Wong, embedded software and systems engineer, Tula Technology, Inc.

Wong, an embedded software and systems engineer for Tula, explained that their process for verifying and validating updates to software was time-consuming due to multiple dependencies. This issue, coupled with the challenge of managing multiple customers with different hardware and time limitations stemming from having to share the HIL bench among team members, prompted the company to seek a better alternative. Tula's main objectives in establishing a virtual validation environment were to:

- Reuse existing tests developed with AutomationDesk
- Execute validation and verification tasks in a virtual setting, without the physical hardware
- Reduce costs and maintenance time

Advantages of the dSPACE Tool Chain

Tula turned to the dSPACE virtual validation tool chain because it promised to fulfill all objectives. One of the main components of this solution is the simulation platform dSPACE VEOS. The soft-

ware runs on a standard PC and gives engineers many new options for developing new functions and validating, verifying, and testing ECU software in a entirely virtual environment. Since implementing its virtual validation platform, Tula has met all of these goals and is seeing impressive results. The company reports that it has cut its validation and verification (V&V) process time by more than 50%. Tula credits much of these time savings to their newfound ability to execute tests in a virtual environment – without the physical hardware.

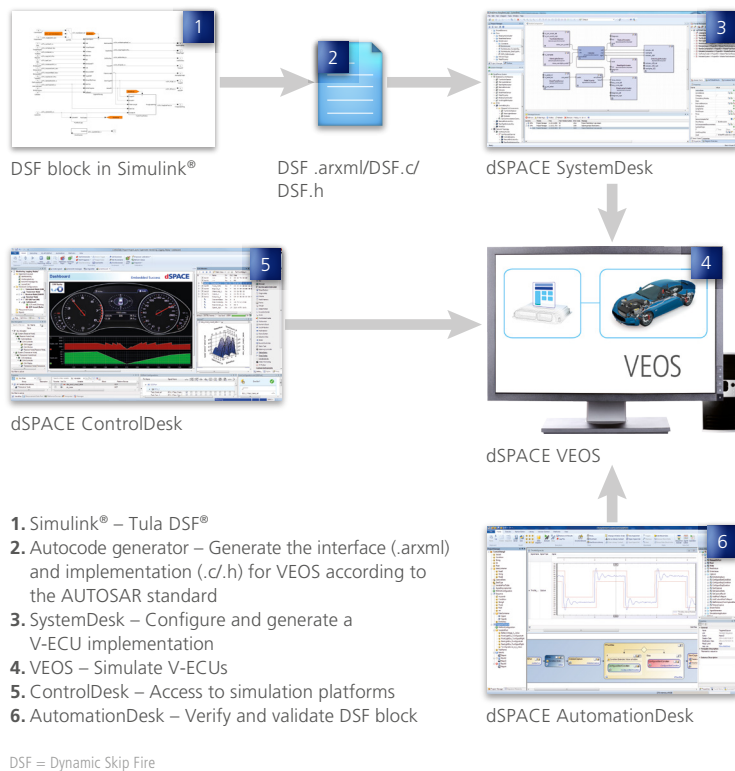


Figure 2: Typical workflow for generating V-ECUs with Tula's DSF functions and simulating them on VEOS for testing.

Applying Virtual Validation to a Simulink® Block

Tula is using virtual validation for its Dynamic Skip Fire (DSF) technology. Specifically, Tula is applying virtual validation to its DSF algorithm Simulink® block. The generated DSF algorithm is running on a virtual ECU over an FTP cycle as input, and the outputs are recorded. Tula then compares the recorded outputs (software-in-the-loop) against the expected outputs (model-in-the-loop) to determine if requirements have been met. "Virtual validation saves us time, finds bugs early in the software life cycle, and frees up our HIL bench," said Wong. "It gives us confidence in our software, prior to deployment on the engine and vehicle."

Bending the Learning Curve

Tula had to face a learning curve in setting up its virtual validation plat-

form. Some setup challenges they successfully managed included importing Tula software into the virtual environment, creating physical models for hardware components, and starting tests with the same initial default values. Tula used a signal generator to create input values that would otherwise be generated from the hardware components. They also set the initial values to default and waited for the software to reach a steady state before injecting stimuli. Wong clarified that virtual validation does not replace their use of MicroAutoBox II for function prototyping, but it complements the process by allowing them to reduce their time spent in the HIL environment. "We are using virtual validation on our development PC to verify functional requirements early in the software life cycle," said Wong. "It is less expensive than physical hardware, and it frees up our physical

Tulas Virtual Validation Environment

Tula's virtual validation environment includes the following tools:

- SystemDesk for modeling architectures and systems, and generating virtual ECUs (V-ECUs)
- VEOS for simulating the V-ECUs
- MicroAutoBox II for rapid control prototyping
- RapidPro for signal conditioning
- A hardware-in-the-loop (HIL) system for simulating and testing engines
- ControlDesk for controlling the experiment
- AutomationDesk for writing and updating standardized tests and recording and sharing test data

hardware for other work." For its next customer project, Tula plans to utilize virtual validation as well. ■

With the kind permission of Tula Technology, Inc.





Quick Start

From 0 to 30,000 revolutions
in 2.6 seconds

How do you start a helicopter engine so fast that it can be used as a redundant safety engine for emergencies? The Chair of Turbomachinery and Flight Propulsion at the Technical University of Munich uses regulated compressed air to reduce the start time by up to 90%.

For safety reasons, modern helicopters generally have two turboshaft engines. This redundancy ensures that if one of the engine fails, the other engine provides the necessary power to maintain the helicopter flight or to begin a precautionary landing procedure. Therefore, multi-engine helicopters generally have excess engine power as the combined performance of both engines is usually required only during take-off and landing, while flying at high speeds, and during the ascent. At all other times, the simultaneously running engines operate only in a partial-load range, in which the fuel consumption is comparably high (figure 1). An optimized strategy for operating the engines now intends to lower fuel consumption.

Idea: Reducing the Fuel Consumption

The plan is to switch off one engine in a controlled manner (intended single-engine operation, ISEO). This requires a higher power output of the remaining engine, which improves

the specific fuel consumption. As a result, fuel consumption and exhaust gas emissions decrease. This procedure is particularly useful for longer flights at continuous speed, for example, for supply flights to offshore platforms or long overland connecting flights. Research shows that up to 21% of fuel can be saved at the current state of technology.

Problem: Loss of Power

Since only one engine is used when flying in ISEO mode, this also entails a reduction in flight safety. If the running engine causes any problems, the second, previously inactive, engine cannot take over immediately, because starting the engine can take up to 26 seconds with a standard starter generator. During this start phase, the main rotor of the helicopter continues to rotate only in autorotation. This means the rotation is caused merely by the air flow of the descending helicopter. At the same time, the helicopter significantly loses altitude. Assuming that the typical rate of descent is 15 m/s, this can be more than 400 m.

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It is only after this time span that the restarted engine provides sufficient power again. The loss in altitude, which must be taken into account when flying in ISEO mode, means a limitation to the usable flying range and could be avoided by a faster engine start.

Solution: Reducing the Engine Start Time

Smaller helicopter gas turbines are usually started with a battery-operated electric motor. Because this type of starter system is optimized for weight, it can only provide a limited acceleration torque for the shaft of the core engine, the gas generator. The transmission gear between the electric motor and the engine is not designed for higher torques. Thus, to shorten the start phase of the engine, other methods are needed. One of the concepts directs a powerful jet of compressed air to the trailing edges of the radial compressor blades of the core engine to quickly stimulate shaft rotation (figure 2). This method is very effective, because most turboshaft engines in helicopters have a large leverage at the core engine shaft.

Objective: Reliable Self-Start

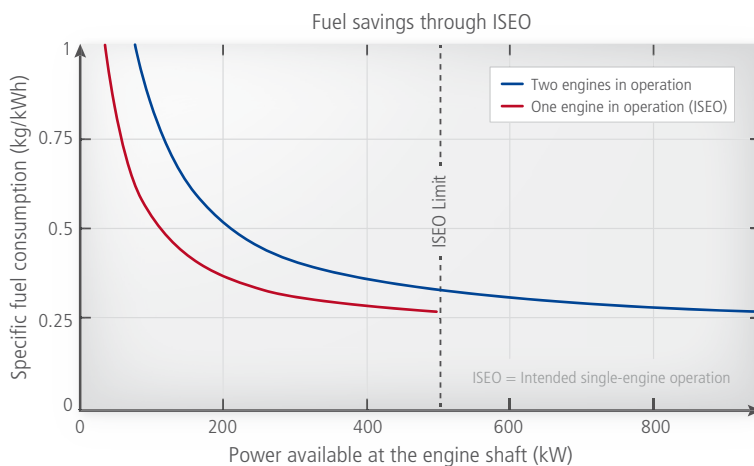
It is vital that the quick-start system is completely reliable. In addition, the reduction in start time must be significant enough to justify the additional weight of the quick-start system in the overall ISEO concept. Aside from the analytical calculations, the research team at the university also carries out experiments with this type of system. For this, it uses an Allison 250-C20B turboshaft on a testbed in the Chair's laboratory. For the first functionality test, a modified radial compressor enclosure was designed with five integrated de Laval nozzles (specially shaped nozzles for high air flow speeds). At first, a 13-bar compressed air supply on the testbed provided the nozzles with air. In a second step, a 200-bar compressed air tank was used.

Requirements and Challenges

Handling the high air pressures and optimizing the reaction time of the engine control unit poses exceptional challenges. On the one hand, every hundredth of a second counts during the quick start. On the other hand, the controlled components

- 1 High-pressure turbine: Depressurizes the hot gas from the combustion chamber and subsequently drives the compressor and, via a transmission, the attachments. Maximum rotational speed approximately 50,000 rpm.
- 2 Low-pressure turbine: Depressurizes the hot gas after the high-pressure turbine and subsequently uses a transmission to propel the helicopter rotors. Maximum rotational speed approximately 30,000 rpm; continuous power: 298 kW.
- 3 Compressor: Consists of six axial stages and a radial power stage. Maximum air rate approximately 1.5 kg/s; maximum pressure build-up: 1:7. Supplies compressed air to the combustion chamber.
- 4 Pot-shaped combustion chamber with injection elements and ignition plug.
- 5 Fuel metering unit, controlled by the dSPACE system.
- 6 Electric starter motor for the normal engine start.
- 7 Exhaust gas diffusor, depressurizes the exhaust gas to the ambient pressure.
- 8 Electromagnetic eddy current brake, controlled by the dSPACE system. Simulates helicopter rotors and subsequently the power requirements of the helicopter.
- 9 Air supply of the engine.
- 10 Bottle of compressed air (max. 230 bars, 15 l), supplies the compressed air required for a quick start.

Figure 1: Instead of two engines working at an unfavorable partial load, only one engine works at a higher load when using ISEO, which means it operates in a more fuel-efficient range. As a result, operating only one engine achieves the same performance as two simultaneously operated engines and uses less fuel.



must work quickly and accurately. The calculated quick-start time is only three seconds, during which the engine accelerates from standstill to 30,000 revolutions per minute. This corresponds to 60% of the designed rotational speed of the core engine. During this interval, the controller must perform various control and monitoring tasks. They include controlling the fuel release valve when a certain rotational speed is reached or sending the signal for closing the compressed air valve, for example. Safety-critical values, such as the gas temperature at the rear of the combustion chamber, must also be monitored. Since the test operation requires setting

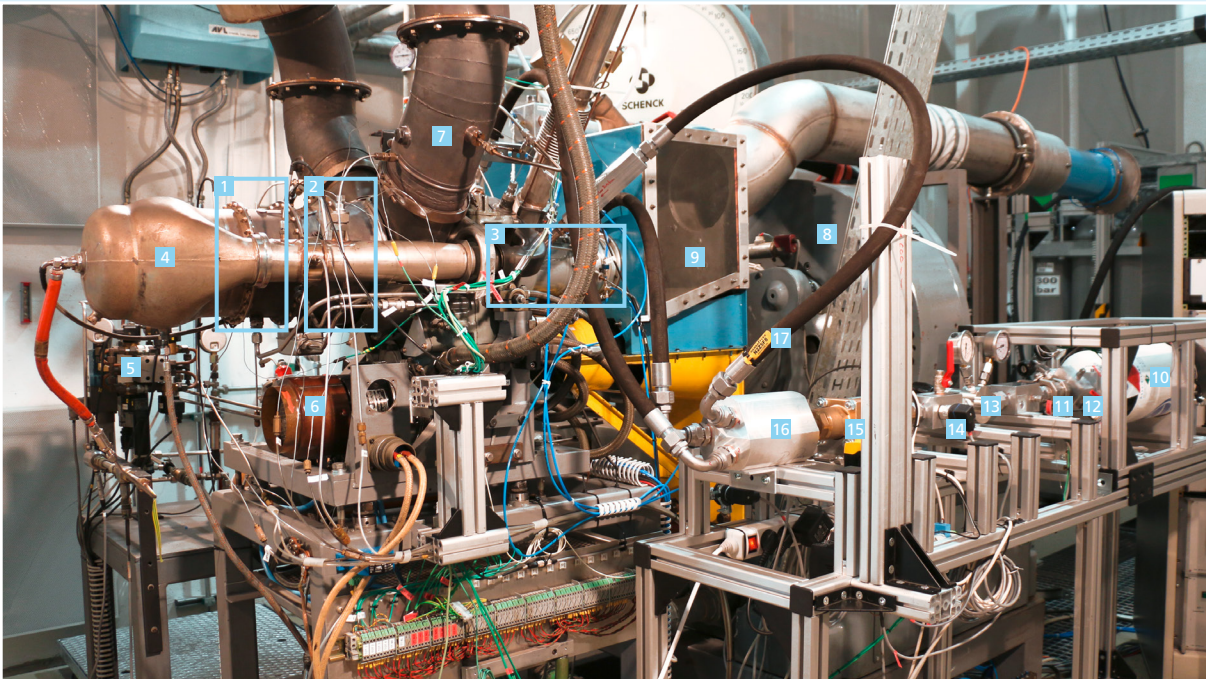


Figure 2: Overview of the testbed with the Allison 250-C20B turboshaft engine.

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|--|--|--|
| <p>11 Ball valve for closing the main pressure line when filling the bottle.</p> <p>12 Adapter for the bottle filling valves as well as pressure and temperature measurement.</p> <p>13 Adjustable pressure regulator for maintaining a fixed output pressure at the nozzles.</p> | <p>14 Adapter for controlled pressure release during maintenance work and for pressure as well as temperature measurements.</p> <p>15 Coaxial valve for releasing the compressed air for the quick start, controlled by the dSPACE system.</p> | <p>16 Distributor block for the three nozzle supply lines.</p> <p>17 Connecting tube of the nozzles.</p> |
|--|--|--|

“The open and powerful dSPACE real-time systems let us use MATLAB/Simulink to quickly and efficiently implement and use new control features.”

Martin Kerler, Technical University of Munich

various quick-start parameters, a graphical user interface such as dSPACE ControlDesk is extremely beneficial, because it offers a multitude of options to configure instruments, displays, input masks, etc. (figure 4).

Predeveloping a Control System

The team at the university performed model-in-the-loop tests to test the quick-start control system beforehand. For this, they added a model

for the start phase to the existing quasi-nonlinear real-time-capable state-space model of the engine in MATLAB®/Simulink®. On the basis of the measurement data, the team extended the normal operating range of the engine by a range between standstill and engine idle. They used a numerical 1-D simulation of the actual quick-start system to define the essential system values, such as quick acceleration torque, and to derive important control parameters

from them, for example, the valve opening times. These values were included in additional quick-start control algorithms. Among these algorithms are also specifications for the amount of fuel that has to be injected so the core engine can be accelerated rapidly by the hot gas generated in the combustion chamber. These early tests helped solve potential problems during the fully automated quick start and validate the related control algorithms. The next step is

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to implement the quick start in the trial engine.

Setting up an Integrated Control System

For the engine control, the team at the university used a dSPACE system that consisted of a DS1007 PPC Processor Board with a dual core, a DS2103 Multi-Channel D/A Board, and a DS2002 Multi-Channel A/D Board in a PX10 Expansion Box. The 32 channels of the output and input boards provide sufficient capacity for extensive control and monitoring tasks at the engine and the quick-start system. The controller, which was modeled in Simulink, was distributed to the two cores of the processor board. One of the cores pre- and postprocesses the output and input values and monitors the engine parameters. It also integrates the virtual Simulink engine model, which thus runs simultaneously with the real engine. The second core is responsible for the actual control tasks. This way, it was possible to implement a controller update rate of 1 ms. Using dSPACE ControlDesk, the team created a graphical user interface to control and monitor the engine and

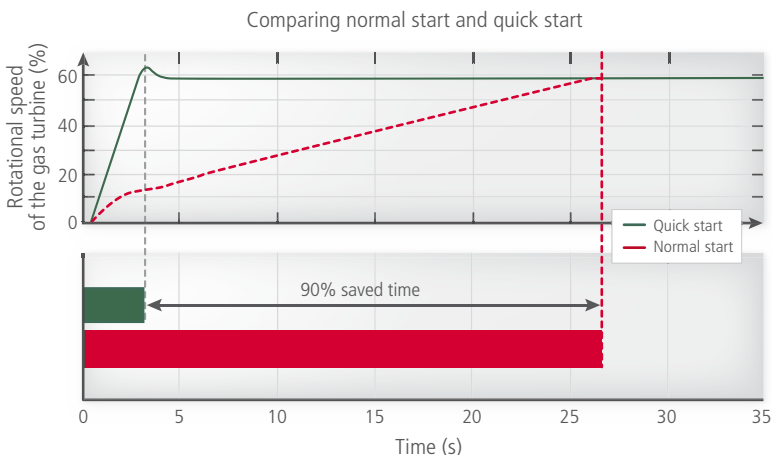
the quick-start system. The user interface also allows for changing control parameters during engine operation without having to recompile the engine controllers. For over 20 years, the combination of a regularly updated dSPACE system (hardware plus ControlDesk) and MATLAB/Simulink has become a powerful development tool for test and research activities on the testbed at the university. The system also offers sufficient reserves for continuing development tasks, which means it can be used in the long term.

Results of the First Test Runs

The aim of the first test runs on the engine with an independent 200-bar compressed air supply system was to achieve a fast and above all safe and reproducible engine start. The time interval during which compressed air nozzles are switched off is particularly interesting, because the compressor of the engine moves towards normal operation in only a few milliseconds. After the first test run, the team adjusted a few parameters, which lead to a stable transition from the non-stationary acceleration process to stationary idling. The quick-start system

- 1 Display of the engine state
- 2 Display of the fuel consumption
- 3 Alert display for engine parameters
- 4 Control of the engine in an emergency
- 5 Normal control of the engine
- 6 Activating/deactivating the quick-start system
- 7 Activating/deactivating the ignition plug
- 8 Activating/deactivating the electric starter motor
- 9 Selecting model- or hardware-in-the-loop simulation
- 10 Selecting the source of the compressed air
- 11 Selecting normal or quick start
- 12 Selecting the control of the engine: helicopter simulator or test bench
- 13 Setting the engine limits
- 14 Display panel for warnings regarding important engine parameters
- 15 D/A display for commands sent to the engine and the quick-start system
- 16 A/D display for input measurement values for the FADEC (full authority digital engine control)
- 17 Control panel for the bleed air valve
- 18 Control panel for the electromagnetic eddy current brake
- 19 Control of the pump detection logic
- 20 Additional displays and selection elements for the FADEC

Figure 3: Comparison of a normal start (red) and a quick start (green) of the gas turbine. A quick start reaches 60% of the maximum speed within 2.6 seconds. Compared to the 26 seconds required by a normal start, this reduces the start time by 90%.



reduces the engine start time by 90% at a typical ambient temperature of 20 °C, i.e., from 26 to only 2.6 seconds. At the same time, the core engine accelerates to 30,000 revolutions per minute. The pressure inside the compressed air tank decreases from 200 to 100 bar and 1.52 kg of compressed air is consumed.

Summary and Future Prospects

This test run was able to reliably implement quick engine starts for a 300 kW turboshaft engine with an independent compressed air supply. The start times achieved exceed the predicted values and theoretically can be reduced further. The focus of ad-



Figure 4: The graphical user interface of dSPACE ControlDesk clearly displays the extensive control and display parameters for the engine tests.

“dSPACE ControlDesk lets you clearly display all measurement values and control parameters that are relevant for operating the engine. The great flexibility of ControlDesk lets you implement new ideas fast.”

Martin Kerler, Technical University of Munich

ditional research is now on thermodynamic combustion processes during quick start, the influence of the system operation on wear and tear and the life cycle of a complete helicopter powertrain. Moreover, the university team wants to test compressed air systems with higher pressures and a new nozzle geom-

etry. The goal is to test a weight- and volume-optimized variant that can be integrated into a helicopter. The dSPACE system used for the entire development and test process has proven itself and contributed significantly to the success of the tests. ■

Martin Kerler, Technical University of Munich

Martin Kerler

Martin Kerler was a research associate at the Chair of Turbomachinery and Flight Propulsion at the Technical University of Munich, Germany, until the end of September 2017.

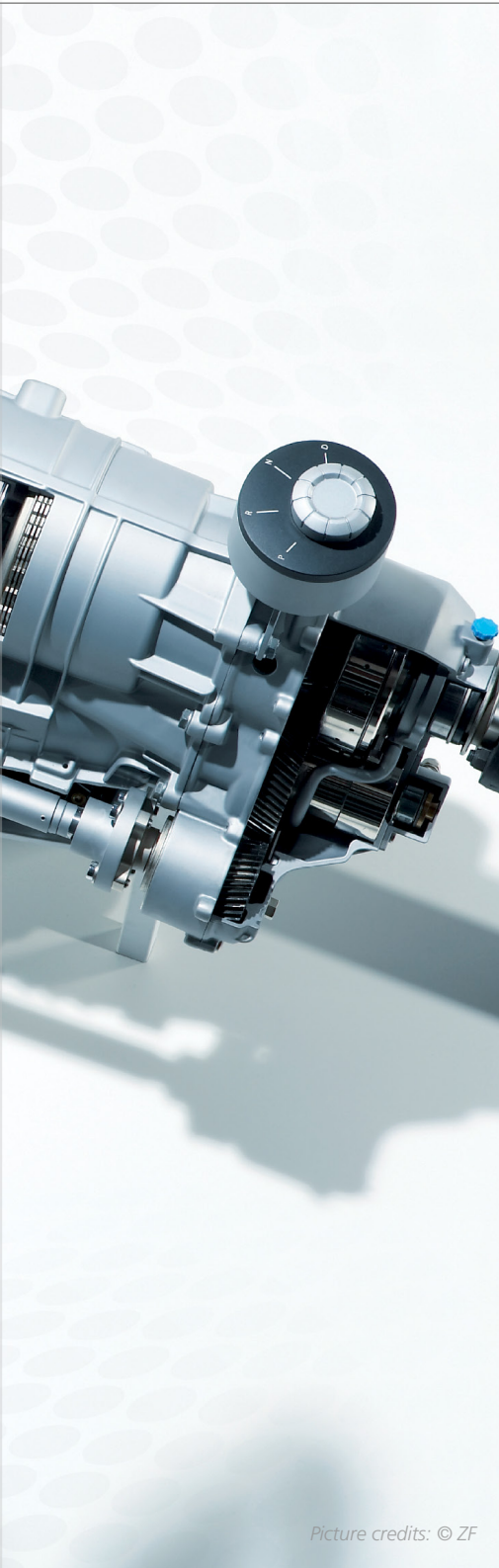




Simulated test drives
and real loads put ZF
drivetrains to the test

Virtual Torque

The ZF technology group is increasingly using virtual solutions to test and validate new real drivetrains in the early development phases. To this end, highly dynamic test benches realistically simulate the test track, the entire vehicle and even the driver. The ASM tool suite from dSPACE is used for this purpose.



Picture credits: © ZF

Drivetrains in modern vehicles are becoming increasingly modular in design, making it possible to accommodate a large number of drive types. In addition to automatic, dual clutch, manual, and automated manual transmissions, today's vehicles feature a broad range of hybrid configurations as well as purely electric drives. A further distinction can be made between central drives, drives near the axle, and in-wheel drives. Test benches must therefore be able to perform reproducible and reliable tests on all of these configurations. This requires the vehicle simulation model to be open and easy to modify.

Reasons for Drivetrain Test Benches

ZF uses highly dynamic test benches to test a drivetrain's functions and life cycle as early on as possible. Such test benches make it possible to test the entire real drivetrain in a simulated vehicle. The aim is to plausibly simulate various drivetrain and vehicle configurations. These simulations must be as realistic as possible so that all loads (load collective) that occur during a real test drive as well as the vehicle behavior in all of its possible features and configurations are covered. Only then can the drivetrain be realistically evaluated and optimized on the test bench. During the analysis, it is important to simulate the behavior of the active components in the vehicle, such as the interaction between the propulsion engine and the transmission. This ensures that the gears can be shifted either comfortably or dynamically, depending on the driver's preference. The behavior of different drivers is equally relevant, i.e., whether they drive the vehicle cautiously or sportily.

Simulations must also realistically reflect the pedal actuation and the steering wheel's movement.

Simulation as a Solid Basis

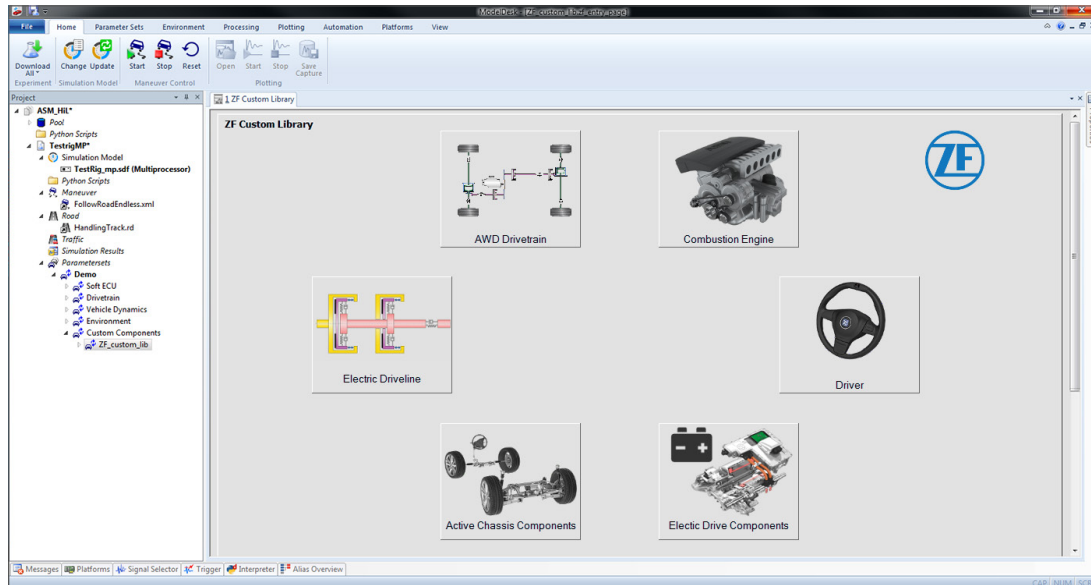
When designing the highly dynamic test benches, ZF first had to find a suitable solution for vehicle simulation. This meant the engineers had to build a virtual vehicle whose dynamic behavior is suitable for controlling the test bench. This is typically done using a real-time simulation model that can be flexibly configured and parameterized for all required vehicle types. After the evaluation of technical, economic, and process-related factors, the Automotive Simulation Models (ASM) tool suite proved to be the most suitable choice. The main benefit of ASM, aside from the open model structure, is that it can be used without an additional simulation environment, which eliminates extra license fees.

Setting up the Virtual Vehicle

The virtual vehicle that was built in ASM covers front-wheel, rear-wheel and four-wheel drives as well as all hybrid and electric drive Model. The ASM Vehicle Dynamics model is equipped with the desired vehicle dynamics features. To simulate drive units with gasoline or diesel engines, ZF uses a proprietary model that is seamlessly integrated into the model environment. An environment model based on the ASM Environment model enhances the simulation with roads and their various attributes, such as surface conditions, inclines, and gradients. The ASM Traffic model is also part of the simulation so that surrounding traffic can be taken into account. Other models from the ZF library were integrated into the overall vehicle model, for example, a steerable rear >>

“To optimally use active drivetrains, we perform realistic test drives using the ASM tool suite.”

Oliver Maschmann, ZF



An overview page in ModelDesk provides convenient access to the customer-specific model libraries.

axle or active shock absorbers. ASM's open structure made it particularly easy to integrate the ZF models. For instance, the developers were able to access exactly those signals that were required for the components they had developed.

Implementing a Graphical User Interface

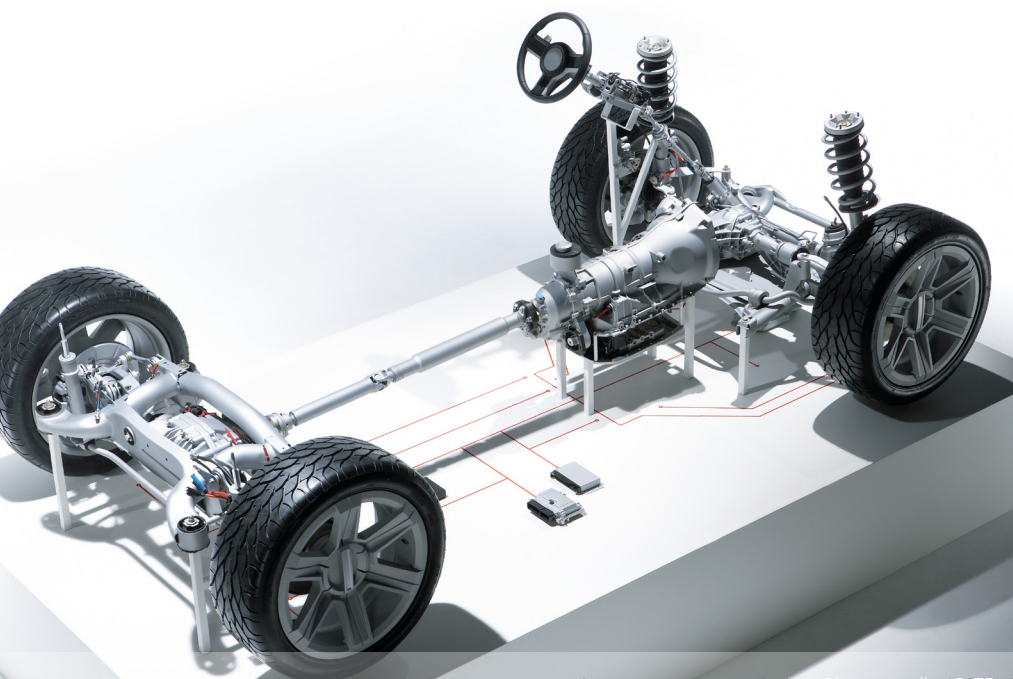
Since test benches along with their simulation environment are needed

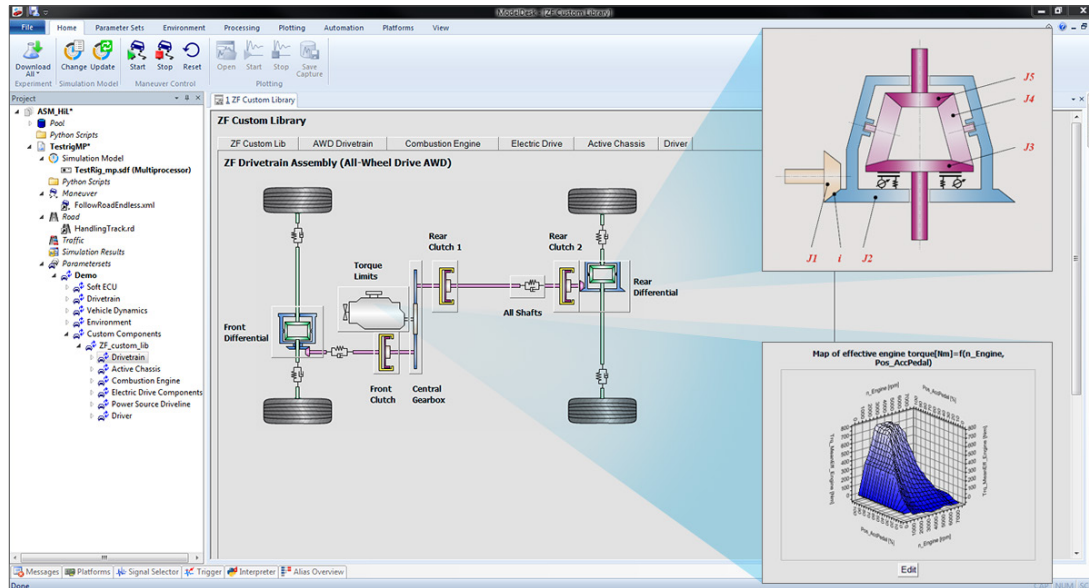
at several locations with identical setups, they must be easy and intuitive to use. To meet this requirement, ASM is equipped with dSPACE ModelDesk, which provides a graphical user interface for parameterizing and configuring the models. Moreover, the developers can execute prepared test programs and simulations using only one user interface. This process can be comfortably controlled by a script and thus easily automated.

ModelDesk can be used for all ASM libraries. For the proprietary models in the ZF library, the developers can automatically generate suitable user interfaces. For this, ModelDesk contains a parser that analyzes a model and then automatically generates a functional framework that contains all parameters, maps and interfaces for tool automation. ModelDesk provides this framework as an HTML website. Cascading Style Sheets (CSS) help implement all created user interfaces uniformly and according to ZF's design requirements. The manual effort for this is very low, which means all pages can be created in one day, even if the libraries are more extensive.

Preparing for Deployment

After the simulation environment is set up, it must be validated. For this purpose, the developers used benchmark measurements from a real vehicle. The simulated vehicle must return the same results (yaw rate, longitudinal acceleration, lateral acceleration) under the same conditions (speed, steering angle, etc.). In addition, a driver model is used that has been extended and optimized according to ZF's requirements. The goal





The contents of customer-specific model libraries are displayed clearly and can easily be changed.

was to ensure a plausible, realistic actuation of the pedals and the steering system. The PC-based simulation platform dSPACE VEOS enables developers to start up the entire setup virtually at their desks before testing on the test bench. If required, all processes as well as the test case can be executed significantly faster than in real time. This is very useful if the developers have to simulate long test drives of hundreds of kilometers because they complete them within a few minutes. Combining ASM and VEOS also offers advantages regarding a consistent and efficient development process. Thanks to the open architecture, any number of Functional Mock-up Units (FMU) or ideas for functions can be used in Simulink, even if they are only rough drafts. Another advantage is that it is easy to integrate measurement data into the simulation. The processing function in ModelDesk is recommended for this because it can be used to prepare the data accordingly.

Evaluation and Next Steps

The installed ASM tool chain for simulating vehicle dynamics enables ZF to take an important step towards realistically testing drivetrains on the

test bench. The models meet the demanding requirements regarding cycle time and accuracy on highly dynamic four-wheel test benches, for example. Moreover, the simulation has proven to be suitable for testing drivetrains using customer software by means of automated, closed-loop driving of load collectives on the test bench. During these test drives, comfort criteria can also be analyzed, for example, during drive-off. The system is continuously enhanced to make larger road networks and traffic flows available during the automated test runs. The tool chain is available internationally: It can be purchased locally at the various ZF development locations worldwide. The proprietary libraries allow users to create an identical test bench configuration at all ZF locations, thus ensuring identical use. ■

Oliver Maschmann, ZF

Requirements for a Drivetrain Test Bench

Simulated components:

- Active chassis with steering
- Combustion engine with hybrid module
- Active rear axle kinematics
- Vehicle dynamics
- Longitudinal and lateral drivers
- Soft ECUs

Required flexibility:

- Using real and emulated drivetrains
- Active components in the drivetrain (active axle differential, switchable four-wheel drive, differential lock, etc.)
- Modular interfaces in the drivetrain for additional configurations

Oliver Maschmann

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





Where Am I?

Environment recognition
using SLAM algorithms

To make the vision of autonomous driving a reality, it is important to always know the vehicle position within its environment at any given time. This is also required if no detailed map or satellite navigation is available. In these cases, SLAM algorithms offer a smart solution.

Knowing the exact position of a vehicle in its environment is an important prerequisite for autonomous driving. The most common solution is using precise maps and satellite or inertial navigation systems (inertial measurement units, IMUs)

as well as navigation with dead reckoning (location recognition using the direction of movement and velocity). However, for the foreseeable future only a patchy network of detailed maps will be available and the precision of satellite-assisted positioning

is also often not sufficient. Simultaneous localization and mapping (SLAM) algorithms offer a solution to this problem. These algorithms use data from environment sensors, such as lidar, to generate a 3-D map of the entire vehicle environment



Using SLAM Algorithms in RTMaps

Augmented LiDAR 3D SLAM algorithms from Dibotics are available in a preconfigured component library for the multisensor development environment RTMaps (Real-Time Multisensor applications, refer to the info box "Profile: RTMaps from Intempora"). RTMaps is integrated in the dSPACE tool chain. SLAM algorithms are perception and localization algorithms based entirely on sensor data. They require neither sensor fusion nor odometry (position estimation based on the propulsion system, for example, wheel rotations). Based on the data of only one lidar sensor, the SLAM algorithms generate a 3-D model in real time by combining a large number of data sets. The 3-D model can then be viewed from different perspectives and also contains a classification of the detected objects (figure 1). At the same time, the vehicle is located in this environment. Afterwards, the environment model forms the basis for subsequent steps in the development of applications for automated driving, for example, trajectory planning and motion control. A simple example for using the SLAM library in RTMaps is replaying sensor data that was captured during test drives. On the simple and intuitive principle of block-based development, the required components are first added to a diagram from the component library in RTMaps via drag & drop. Afterwards, the components are parameterized on the basis of dialogs and in a last step connected as desired via a data link. The application can then be executed and tested simply at the click of a button. For this, the raw data saved

to the storage medium is replayed via a replay block and transferred to the SLAM and segmentation algorithms. The algorithm outputs are graphically displayed by means of 3-D visualization blocks. The perspective of the 3-D model can be changed during the operation using the mouse. Thanks to the multithreading capabilities and the efficient memory management of RTMaps, algorithm execution is highly performant despite the algorithms' complexity.

Developing Functions for Autonomous Driving in the Vehicle

For fast prototyping and testing the algorithms in the vehicle, the application must be connected to real environment sensors. This is done by simply replacing the replay block in the RTMaps diagram by a component for capturing sensor data. The development environment provides various interfaces to connect cameras, radar, lidar, and vehicle buses. It also issues time stamps to provide time-correlated capturing, processing, and replay of sensor data. For the development of functions for autonomous driving, information from the generated 3-D environment model is often processed by using specific algorithms, for example, for situation analysis or trajectory planning. These algorithms can be integrated in RTMaps as self-defined components in C++, Python, or even Simulink® code. When integrating self-defined algorithms, the developer can use SDK Wizards in Windows® and Linux as well as numerous code examples for support. The required data exchange with the control algorithms that are executed on the in-vehicle development plat-

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and locate the vehicle in this environment. The more data is available on the current environment, for example, from rough map data that can be compared to and aligned with the captured 3-D data, the more precisely the algorithm will work.

RTMaps supports developers with all important steps for creating algorithms for autonomous driving and with the development on embedded platforms.

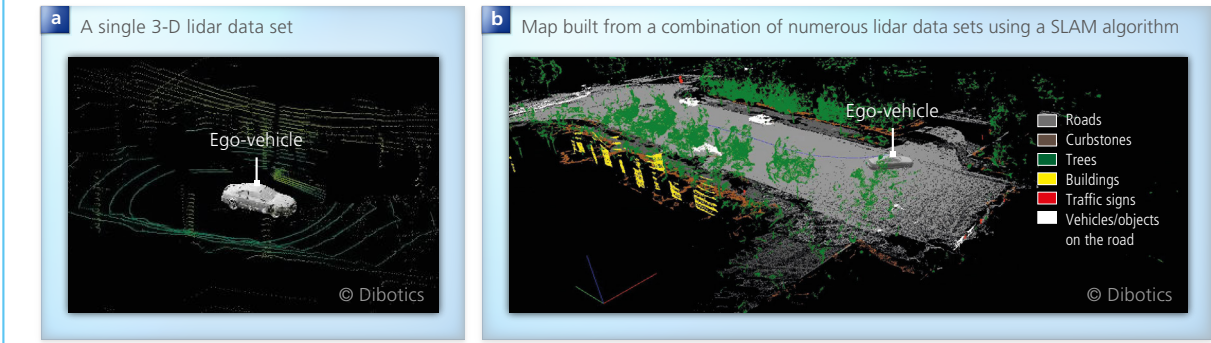


Figure 1: Comparing an individual, unprocessed lidar point cloud (a) and the 3-D map built from numerous lidar data sets (b) demonstrates the effectiveness of SLAM algorithms.

form dSPACE MicroAutoBox can directly be done, for example, for motion control. A special component library helps with the seamless integration of RTMaps in the dSPACE tool chain and ensures a time-synchronous data transfer using dSPACE real-time platforms.

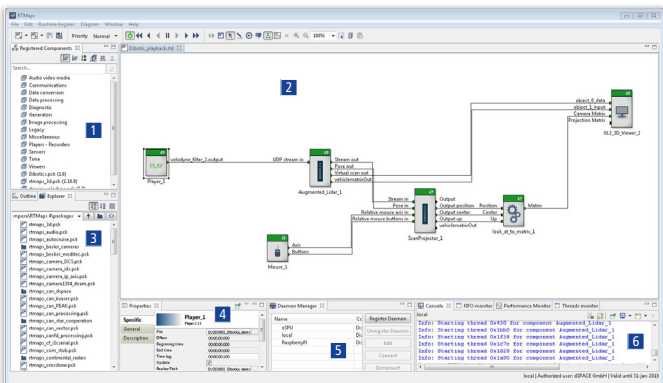
Working Continuously – from the PC to the Embedded Platform

The available resources of a development platform, such as computing power or hardware acceleration, can influence the run-time behavior of complex algorithms. Therefore, developers often have the desire to develop on the target platform as early as possible. Regardless of which plat-

form they choose: Thanks to the convenient tool support of RTMaps, they can always work in their familiar work environment on the PC. The Remote Studio Connector (figure 3) enables them to process and execute RTMaps diagrams via a TCP/IP connection directly from the desired platform without having to attach a keyboard, mouse, or monitor. The environment also automatically makes the working environment more convenient because the developers can always work in the component libraries that are suitable for the selected system and they can load and save the applications directly from the data system of the selected platform. Moreover, the parameterization

options also enable loading and starting the desired application in the run-time environment immediately when the target platform is switched on. By adding support for embedded platforms to RTMaps Studio, the prototyping of functions for autonomous driving reaches an unprecedented quality, because the developers can simply and conveniently work on the embedded platform from the familiar environment of their PC. ■

Figure 2: The user interface of RTMaps. The modular development environment allows for easily processing a large variety of multisensor applications. To do this, comprehensive component libraries are available



- 1 **Component library** – Displays the registered/available component models in the RTMaps environment. These component models are categorized by function (sensors, viewers, image processing, etc.).
- 2 **RTMaps diagram** – Used to create application diagrams. The elements used in this example are a block for replaying lidar data, Dibotic components for SLAM and segmentation, mouse control for setting the perspective, and the 3-D visualization.
- 3 **Explorer and Outline** – Explorer: Offers a view of the local directory on the computer. It generally shows a directory with packages that can be registered in RTMaps. Outline: This view shows the entire diagram space for an overview and quick navigation.
- 4 **Properties** – Lets the user set the different parameters for the current diagram.
- 5 **Daemon Manager** – Lets the user connect to embedded platforms and open, process, and execute remote diagrams.
- 6 **Console** – Provides information on various subjects, such as commands, component messages, warnings, and errors.

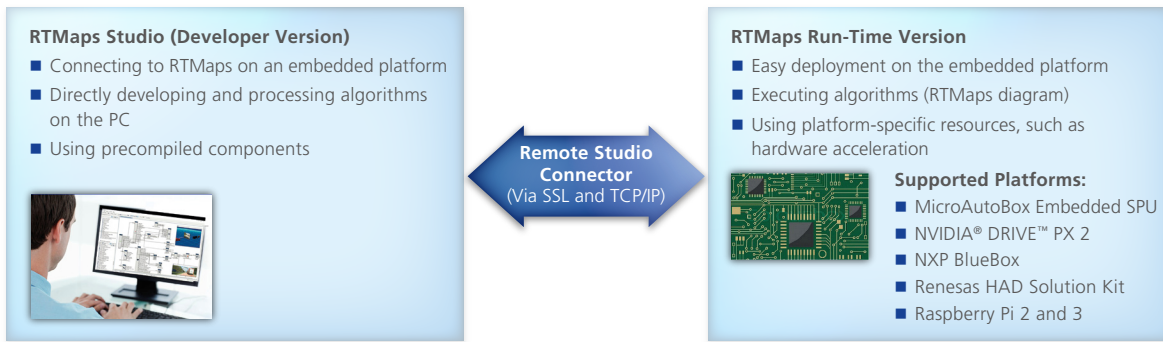
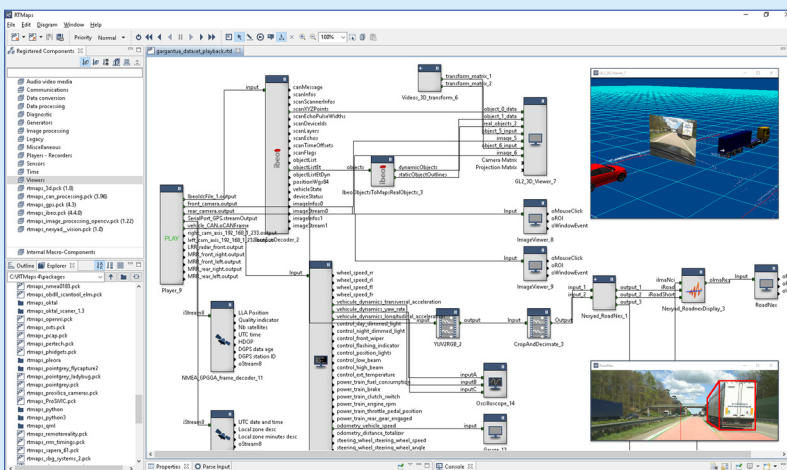


Figure 3: RTMaps with Remote Studio Connector gives developers access to the world of embedded prototyping on various embedded platforms without having to leave their usual work environment on the PC.

Profile: RTMaps from Intempora



Seamless Integration in the dSPACE Tool Chain

To integrate RTMaps in the dSPACE tool chain, dSPACE offers an interface blockset that is specifically designed for real-time systems and the PC-based simulation platform VEOS. ControlDesk can also be easily connected with RTMaps to parameterize the developed applications, for example.

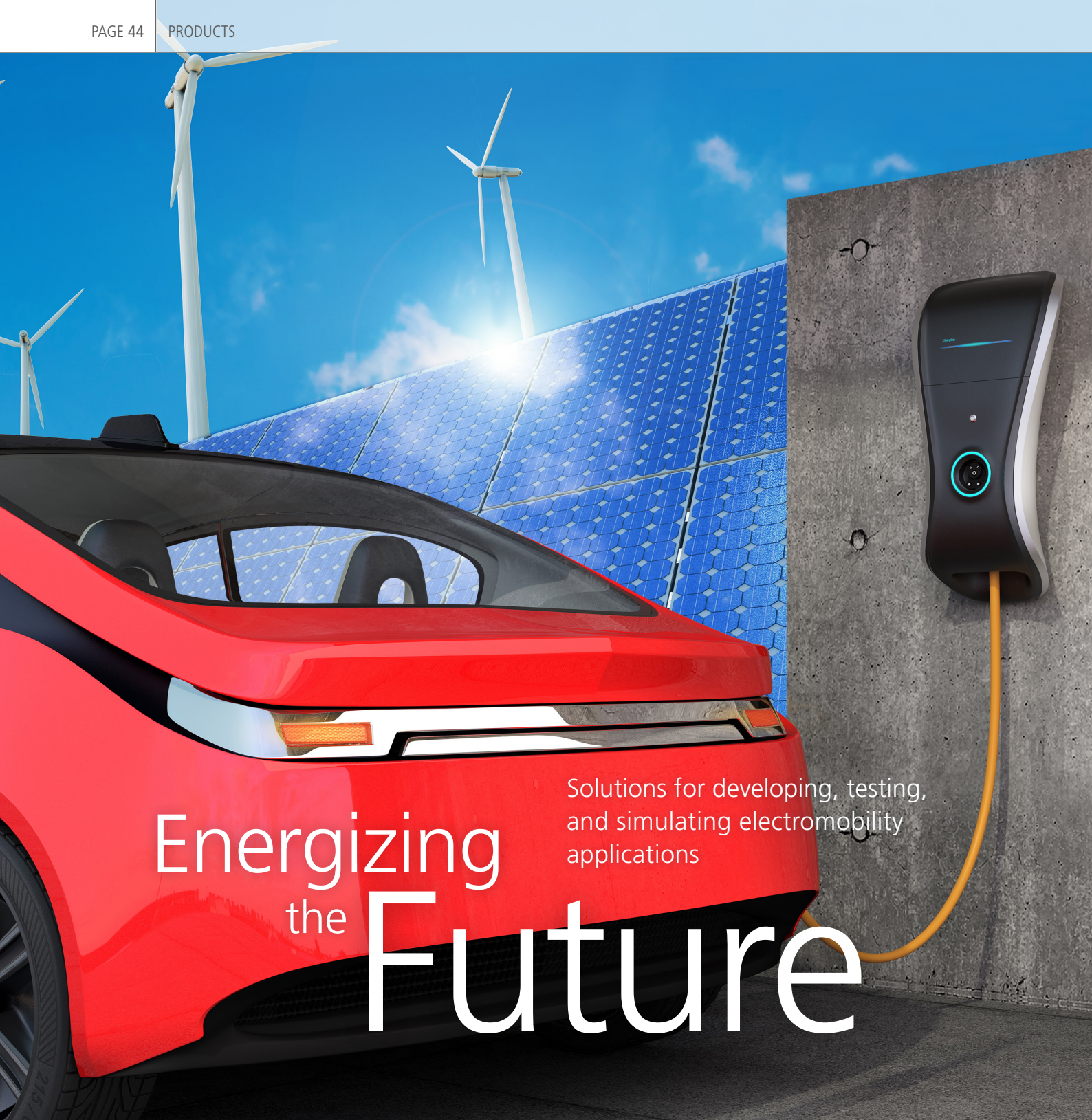
NEW: Prototyping Directly on Embedded Platforms

RTMaps with Remote Studio Connector now allows for even faster prototyping of applications on embedded platforms for highly automated driving. Perception and fusion algorithms are therefore developed directly and conveniently on the target platform from the familiar RTMaps development environment on the remote PC, without having to connect mouse, keyboard, and monitor to the embedded platform.

Powerful Development Environment for Multisensor Applications

RTMaps from Intempora, which dSPACE has been distributing since 2016, is a modular software development and run-time environment for complex multisensor applications that play an important role in certain areas, such as autonomous driving, robotics, and the aerospace industry. Comprehensive component libraries let the developers accurately cap-

ture, synchronize, and process data from various sensors (camera, radar, and lidar). User-specific components can be developed in C++, Python, or as Simulink code and easily integrated. Even complex algorithms, such as OpenCV, Augmented LiDAR 3D SLAM from Dibotics and the support of NVIDIA DriveWorks is available. RTMaps offers unique multithreading capabilities and efficient memory management on PC- and ARM-based platforms.



Energizing
the

Future

Solutions for developing, testing,
and simulating electromobility
applications

Electromobility has long become a complex industrial branch that encompasses much more than just the electric vehicle. Based on dSPACE's long-standing experience, the company provides a well-engineered product portfolio and innovative solutions that cover the entire range of electromobility applications – from energy generation and distribution, to charging stations, to energy storage systems.



There is no ignoring electromobility in this day and age. Each OEM and supplier designs their own electric vehicles and required components. Stricter regulations on emissions and an increasing demand from countries such as China open up profitable market opportunities. Electromobility has three core topics:

- Electrifying the vehicle, including driveline, energy storage systems,

and auxiliary units, such as the steering system

- Establishing a charging infrastructure
- Creating and distributing the electrical energy

dSPACE has been active in the area of electric drives for years. For example, in 1997 we worked with Adtranz to develop an electric locomotive drive, and in 1998 with ABB to develop a hardware-in-the-loop simulator for

the simulation of power electronics. We have continuously broadened our product range for electromobility on the basis of these and many other projects. It now covers all required development steps – from function development to production code generation to testing and simulation.

Electric Vehicles

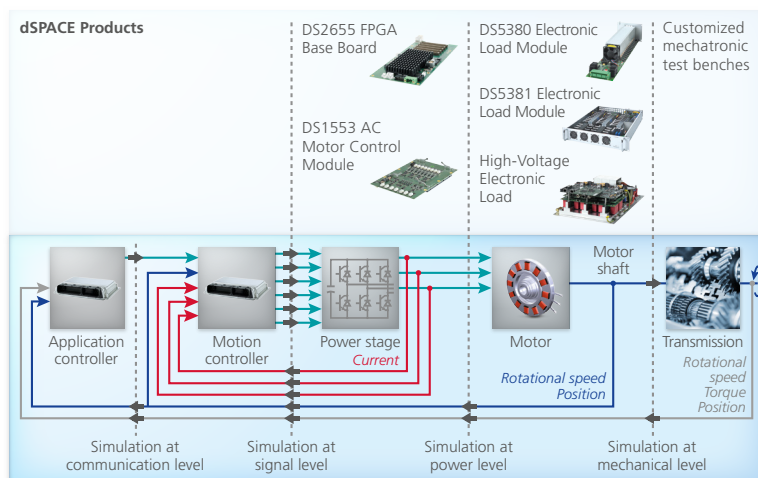
Electric Motor

Unlike combustion engines, electric motors are much more dynamic and generate high torque even at low rotational speeds. Their power ranges from a few Watts to several hundred kW. To meet the high dynamic requirements, the dSPACE portfolio includes powerful FPGA platforms, which can also be integrated in **MicroAutoBox II** or the **SCALEXIO systems**. To do this, the **DS2655 FPGA Base Board** was added for the SCALEXIO systems, for example. Users can either use existing FPGA models, such as the **XSG Electric Components Library**, or program the FPGA themselves by using the **RTI FPGA Programming Blockset** or the **XSG Utils Library**. To perform validation under realistic conditions, dSPACE provides electronic loads to emulate electric motors that support tests at power levels of 100 W to 500 kW (figure 1). The processor-based real-time simulation of components of the vehicle electrical system is made possible with the dSPACE **ASM Electric Compo-**

nents Library. Synchronous motors can be connected to the FEM tool JMAG® to simulate nonlinear effects. The supported applications vary from electric drives and inverters for close loop control to complete automotive electrical systems including a battery,

starter-generator, and alternator. Furthermore, control engineers can use the **XSG AC Motor Control Library** to access preconfigured implementations and engineering approaches for the development of drive control functions. >>

Figure 1: The HIL simulator can be used to access the electric motor ECU on different levels. Whether on the signal, power or mechanical level – dSPACE has a wide product range for each test case.



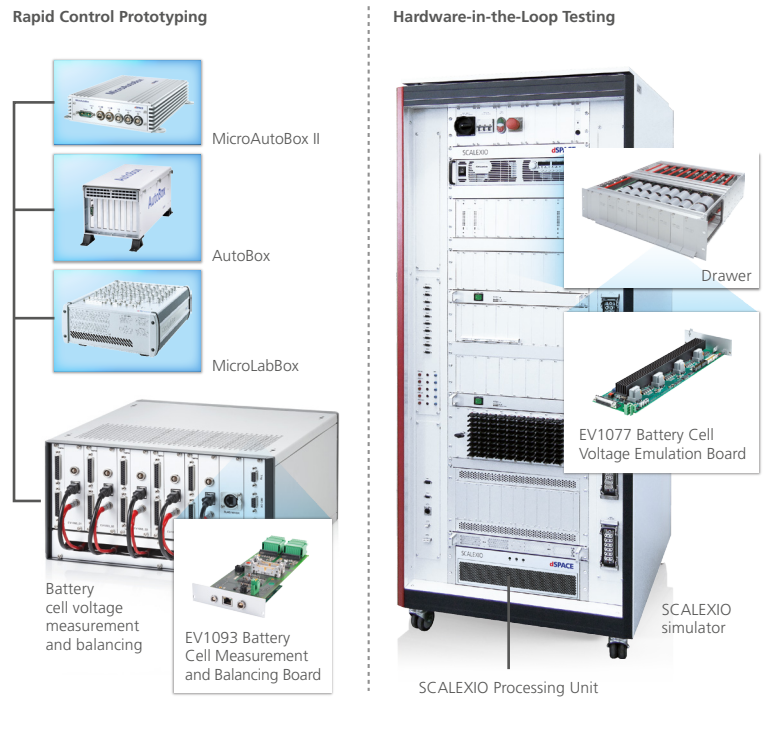


Figure 2: The products for battery management range from compact systems that can also be used in the vehicle to large systems for testing the entire vehicle.

Battery System

The battery management system (BMS) is a central component of every electric vehicle, because it maintains the battery performance during the entire battery life cycle. The BMS ensures that each cell voltage is in the optimum working range. dSPACE offers dedicated hardware for developing BMS functions, such as the **EV1093 Battery**



Figure 3: The compact, robust housing makes RapidPro ideal for use in the vehicle, in the laboratory, and on the test bench.

Cell Measurement and Balancing Board

A single board can control up to 24 real battery cells. The more boards you use, the more battery cells can be controlled. The EV1093 can be used either in a laboratory system or in a vehicle with a suitable housing. To validate BMS ECUs, the HIL test system has to provide the simulated cell voltages and temperatures with high precision. The **EV1077 Battery Cell Voltage Emulation Board** makes it possible to inject voltages in the range 0 to 6 V. Damaged cells can be emulated in the same range as well.

Power Electronics

Power electronics are a key technology for electric vehicles. Some of the components used in electric vehicles are frequency converters for the electric drives, DC/DC converters for adjusting the different voltage levels and chargers for the interface

between the power grid and the vehicle. To test these systems as realistically as possible, the test system must be able to respond in microseconds. For the fast and convenient development of functions for DC converters, dSPACE provides the **RapidPro system**, including a range of modules for configurable signal conditioning and power stages. During HIL tests, the **dSPACE Electrical Power Systems Simulation Package** enables the real-time simulation of topology-based power electronics models that were designed with Simscape Power Systems™ (Specialized Technology) by MathWorks®. The FPGA-based simulation has low latencies and supports step sizes of 2.5 μs. Preconfigured FPGA applications make it easier to start a project because they require neither FPGA-specific knowledge nor specialized software. More complex models can be split and computed on multiple processors or FPGAs simultaneously, so it is possible to simulate them in real time as well.

Electronic Auxiliary Units

In electric vehicles, all auxiliary units must be designed for operation with electric power. Typical units include electric power steering (EPS), electric brake systems, and electronic brake servo. Since these are safety-critical systems, mechanical tests are indispensable and must be performed in addition to tests at the signal and power level. dSPACE provides customizable **mechatronic test benches** that can be used to perform realistic test drives under laboratory conditions to test the behavior of the systems. With suitable simulation models, it is possible to test actuators for EPS applications under realistic conditions, for example. The dSPACE systems range from small rotary test benches for laboratory use, to large test benches for complete steering systems.

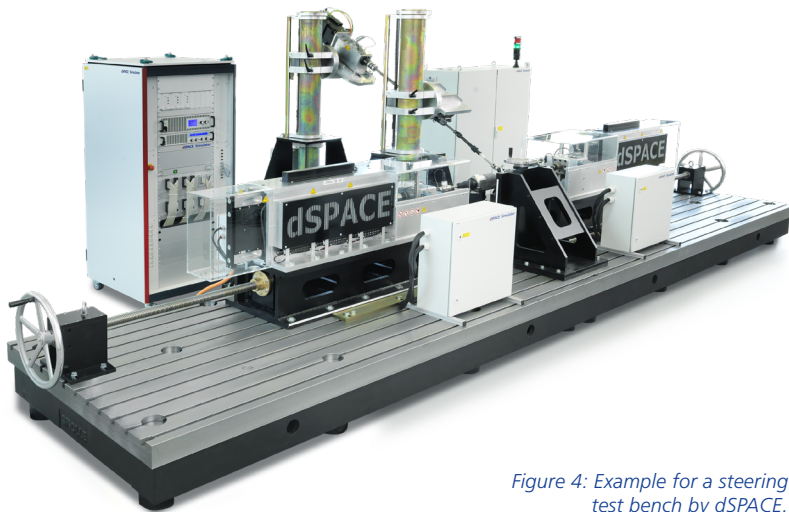


Figure 4: Example for a steering test bench by dSPACE.

More Information

For more example use cases with dSPACE products, go to www.dspace.com/go/dMag_20181_emobility

If you would like to learn more, you can request the dSPACE poster on electromobility: www.dspace.com/go/sales

Charging Stations

There are many different manufacturers of electric vehicles and the respective charging technologies on the world market. While the vehicle battery is charging, the vehicle and the charging station communicate to shorten the time required for

charging and to exchange information, for example, on the technological fine-tuning between the vehicle and the charging station, on aspects of safety, and on payment options. Different standards apply to the charging technology in different

regions of the world, e.g., CHAdeMO in Japan, ISO 15118 in Europe and the US, and GB/T in China. dSPACE offers solutions that can be integrated in the HIL test system and that help to test the different communication protocols.

Energy Generation and Distribution

Electromobility uses energy from a variety of sources, such as wind and solar energy as well as, for the time being, energy from conventional power plants. Coordinating the energy distribution is therefore becoming more complex, one reason being that energy from renewable sources is subject to daily and seasonal fluctuations.

To ensure a stable power grid, it is essential to precisely control the frequency and the power factor. The growing number of electric vehicles also imposes stricter requirements on energy management systems and the communication between them. With the dSPACE **Electrical Power Systems Simula-**

tion Package (EPSS), a wide range of energy generation and distribution systems can be simulated on the dSPACE systems. When used with the dSPACE RCP systems, the

software package enables users to create a model-predictive control of an energy distribution system and simulate the entire energy system. ■

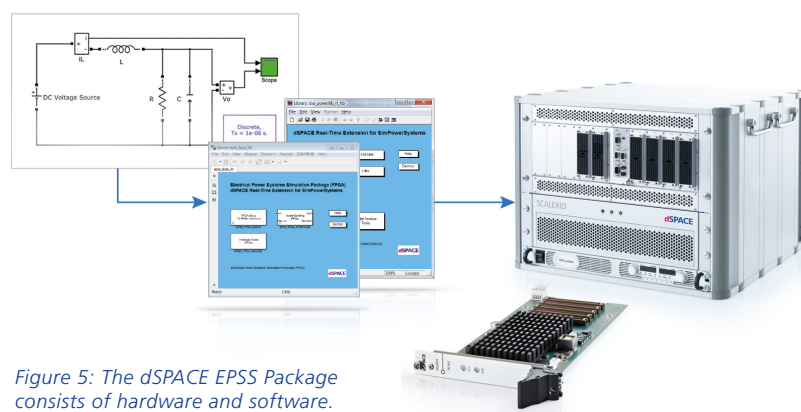


Figure 5: The dSPACE EPSS Package consists of hardware and software.

Automotive Ethernet
in the dSPACE tool chain

Not Your Average BUS



The Ethernet network standard has many advantages over classic bus systems and is increasingly being used in the automotive industry. The dSPACE tool chain already widely supports Ethernet, modified for use in automotive applications, with ever more possibilities.



Photo: Harald Czekała, www.fotoharry.de

With each new vehicle model, manufacturers try to outbid each other in terms of assistance systems, connectivity, and features. This multiplies the volume of data transferred between the electronic control units (ECUs). By the time today's assistance systems are extended with complex functions for partially or fully autonomous driving, the bandwidth of "classic" automotive bus systems will no longer suffice. The Ethernet network standard is the answer to this problem. Having been adapted to the new environment, this technology can also be used in vehicles, where it is called "automotive Ethernet" (see info box). The current bandwidth of up to 1000 Mbit/s by far exceeds that of CAN/CAN FD (<10 Mbit/s), FlexRay (10 Mbit/s), and MOST (up to 150 Mbit/s). In addition, Ethernet supports a large number of protocols on different layers, some of which (such as SOME/IP) were designed and standardized specifically for in-vehicle use. This makes it possible to use it in different forms (optimized for bandwidth or real time) for a wide range of applications.

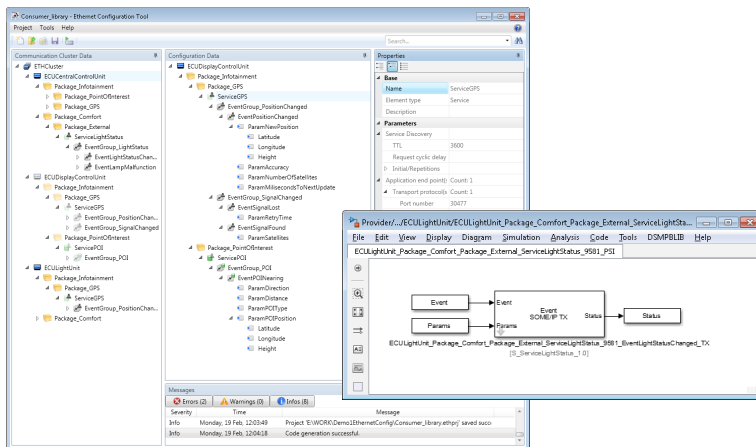
dSPACE Tool Chain – Ready to Go

The dSPACE tool chain already supports automotive Ethernet in many applications. The support is spearheaded by the versatile SCALEXIO systems for rapid control prototyping

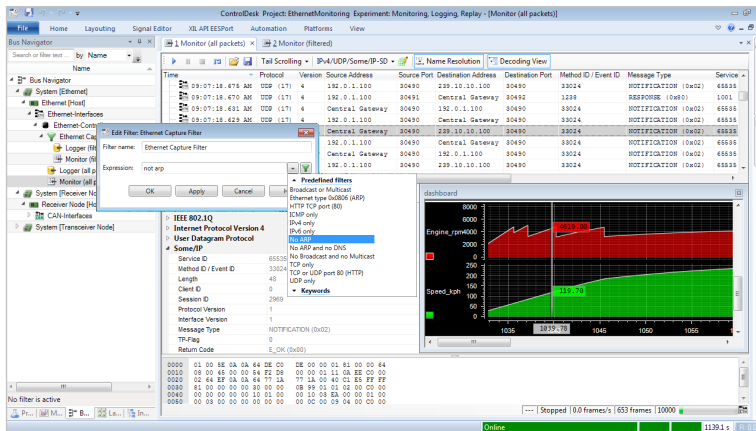
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A wealth of possibilities: Automotive Ethernet provides multiple software layers above the physical layer. They can be used for an application-specific combination of protocols, such as SOME/IP, AVB, and TSN.



Implementation: The Ethernet Configuration Tool lets developers efficiently and conveniently set up and configure automotive Ethernet applications. The latest AUTOSAR standards can also be considered.



Monitoring: The Bus Navigator in dSPACE ControlDesk can be used for easy monitoring and recording of Ethernet traffic. The built-in Ethernet filter makes it possible to limit data capturing to individual Ethernet package types. The Time Cursor in ControlDesk lets you easily compare recorded Ethernet communication with other buses and measurement data.

(RCP) and hardware-in-the-loop (HIL) applications, for which a range of Ethernet boards with up to 5 ports will be available. For in-vehicle prototyping, the newest members of the MicroAutoBox product line, the Embedded PC with an Intel® Core™ i7-6822EQ processor and the upcoming Embedded SPU, can be equipped with up to 6 automotive Ethernet ports. In addition, numerous dSPACE hardware products feature conventional Ethernet ports, which can be used for different automotive Ethernet speeds by means of a media converter. The ports of the upcoming SCALEXIO Ethernet boards (DS6333-PE/CS) even have a modular design, so they can be configured for both conventional Ethernet and native supported automotive Ethernet with different speeds (100 Mbit/s and 1000 Mbit/s).

Implementation

A service-based network simulation for the Ethernet SOME/IP protocol can be set up on the basis of FIBEX or AUTOSAR communication descriptions with the Ethernet Configuration Package. It is part of the dSPACE Ethernet Configuration Package, as is the Ethernet Configuration Blockset, which provides the Simulink blocks required for implementation on the supported hardware. By providing AUTOSAR-oriented support, relevant safety and security mechanisms are easily implemented. This includes end-to-end protection, secure onboard communication, and global time synchronization, which is particularly important for driver assistance systems.

Recording and Visualization

To round off the support for automotive Ethernet in the dSPACE tool chain, it is possible to flexibly monitor the different Ethernet protocols. The central tool for this is the optional Bus Navigator Module for ControlDesk. When combined with automotive-



Automotive Ethernet

Automotive Ethernet is a modification of the established Ethernet network standard, designed specifically for in-vehicle applications. A new physical layer was added to meet the requirement of cost-effective wiring via an unshielded twisted pair (UTP) cable without violating existing requirements, such as electromagnetic compatibility. Two bandwidths are currently standardized for automotive Ethernet: 100BASE-T1 (also known as BroadR-Reach) and 1000BASE-T1 (Gigabit Ethernet, i.e., 1000 Mbit/s). Other bandwidths ranging from 10 Mbit/s to 10 Gbit/s are currently being developed. If there is no native automotive Ethernet support, conventional Ethernet interfaces can be converted to 100BASE-T1 and 1000BASE-T by means of media converters.

As the software layers of Ethernet can easily be separated, an application-specific mix of different protocols can be used. This includes scalable service-oriented

middleware over IP (SOME/IP), audio-video bridging (AVB), and time-sensitive networking (TSN). The SOME/IP protocol was specifically designed for in-vehicle use and is part of the AUTOSAR specification. With a service-based communication concept and dynamic service discovery, it provides maximum flexibility with limited protocol overhead. SOME/IP is already being used by a number of OEMs and has been established as the standard for transferring control information between ECUs. The AVB protocol combines several IEEE-802.1 standards. It covers various requirements for time synchronization, delay, and jitter for data streaming. This is also a point of reference for the TSN protocol, which contains even more standards of the IEEE-802.1 group and is used especially for time- and bandwidth-critical applications. In contrast to AVB, however, not all IEEE specifications in TSN have been officially adopted as standards yet.

With the dSPACE product range, automobile manufacturers are already well-equipped for automotive Ethernet.

Ethernet-capable hardware, such as SCALEXIO, with the soon-to-be-available Ethernet simulation on the PC-based simulation platform VEOS, or with the PC Bus interfaces, the Bus Navigator Module provides convenient handling of all Ethernet packets in the network. Even today, automotive Ethernet traffic can effortlessly be monitored and recorded in ControlDesk. In the future, dSPACE will also provide a dedicated Ethernet Bus Instrument. This will enable users to create tailor-made layouts with just a few clicks. The Time Cursor in ControlDesk can be used to quickly compare the recorded Ethernet data traffic with other measurement data or protocols, such as CAN, LIN, and

FlexRay. The built-in Ethernet Capture Filter makes it possible to limit data capturing to individual Ethernet packets. For dSPACE Release 2018-A, a tree view for the decoding of Ethernet communication and a function for improved name mapping of individual Ethernet packets were implemented.

Conclusion

The growing demands on bandwidth and the high number of supported protocols will strengthen the position of the Ethernet standard in automotive engineering. It is good news for automotive engineers that the dSPACE tool chain already contains a number of hardware and software products

that support the new standard in many use cases. In the future, dSPACE will continue to expand its support for automotive Ethernet. ■



30 years ago, dSPACE accelerated the introduction of mechatronics and electronic control units by means of fast control technology. Since then, dSPACE tools have become a fixture in development departments all around the world. Soon-to-be-leaving CEO, Dr. Herbert Hanselmann, explains his career path.

Did you ever imagine that you would be the CEO of dSPACE for 30 years?

No, I did not. Back in the days, I did not have this type of vision. My first idea was to provide other engineers with a then unique technology. Growing the company from 4 to 20 employees seemed attainable and entirely sufficient at first.

Did you have a back-up plan in case dSPACE would not work out?

All the founders probably could have found a good career as engineers somewhere. In my head, I had already said goodbye to my position as a lifetime civil servant-type associate at the university to either start working in the industry or to become a full professor. There were plenty of alternatives.

How did you come up with the name dSPACE?

At dSPACE I am known for my love for

acronyms. Digital Signal Processing and Control Engineering described what we wanted to do. Back then, everybody knew the database software by the catchy name dBASE. From there, it was a small step to come up with dSPACE. Today, I would choose a different name. The constant assumption that we work in space flight gets old after a while as does continuously having to spell out the name. In the early days, I had a collection of letter



Being the CEO of dSPACE
for 30 Years – A Retrospective

envelopes that had a funny address on them. My favorite was: "Dora Siegfried Paula Anton Cesar Emil, followed by the street address", etc. We received those because this is how we spelled our name on the phone.

You have had so much success. Were there any failures? You can admit it now.

Thankfully, nothing ever went really wrong. There was one product that was not all that successful despite our extensive market research. We would have had to challenge a competitor in the market, for which we were too late. We also underestimated the inertia of customers. If a customer is not happy with a product, yet it works somehow and the competitor quickly fixes certain deficits, the newcomer does not stand much of a chance.

There are reports that you might have successfully fixed a squeaky shopping >>



cart with your car's oil dipstick. How much of an engineer can or must a CEO be?

It was not a shopping cart. It was the dolly for some measuring equipment that I had to wheel into the Ritz Carlton in Detroit. But some time later, I soldered something for a customer in Japan. In the past, customers often used to say that it was noticeable that the company had an engineer CEO. It was meant as a compliment, but this was years ago. With the current size of the company and the large number of talented technical leaders, an engineer CEO is no longer as important.

In your opinion, what were the oddest customer projects that used dSPACE

equipment for testing?

Our dSPACE Magazine always provides great exotic examples. One is the childbirth simulator, another one a tool for cutting into the human skull bone. I also fondly remember the hydraulic seismic damper on a skyscraper roof in Japan. Or a ride in Disneyland. There is nothing odd about cars, however. Everything about cars is serious.

What is the secret to the dSPACE success?

At the beginning it was particularly important that we, the mechatronic engineers, spoke our customers' language. We sometimes even helped them solve problems along the way that were a long way from the focus of our product range. It was always

important to combine multiple disciplines, namely control engineering, electronics, software, and physics. We earned the reputation that our equipment worked and did not require much post-engineering to finally do what it was supposed to do. Mistakes happen, but we always do our utmost to not leave our customers out in the rain. Good support is not a cost item, it is a matter of engineer ethics and of winning customer loyalty. A decisive factor is also that we are not afraid to put a lot of work into our tools to give the customer the best technology and that we do not slow down our efforts to constantly invest in our product portfolio. This last point is currently becoming very important again in view of the great technological changes.

Examples of dSPACE's presence in the early days and what became of it

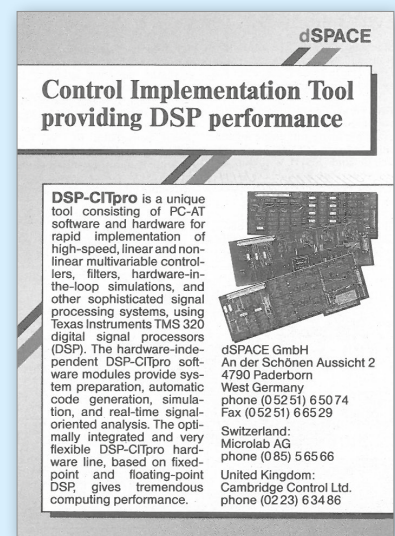
The first paper by dSPACE



In the early days: dSPACE messages and product promises 30 years ago.

In 1988, an article in the Elektronik magazine first drew attention to the newly-founded dSPACE company. Topic: "Control of fast mechanics with DSP".

Product display 1990



Today: Current user statements about the solutions offered by dSPACE.

Aavid Amthor from the TU Ilmenau explains what this means in practice today:
 "The dSPACE hardware and software helped us achieve the high sampling rate needed for fast, nanometer-precise positioning."

One of the first dSPACE product ads. The offer: An integrated solution that consists of system software, processors, and I/O for particularly demanding control tasks.

It is good to know that users appreciate us and our products. Franz Hangl from IABG:
 "The seamlessly integrated development environment from dSPACE lets us carry out projects efficiently."

Your successor as CEO is Martin Goetzeler, somebody who has vast experience in managing a company. How did you eventually choose him?
I had an idea of a succession plan. And I wanted to start implementing it in 2018. Yet, I changed my plans when I saw the opportunity to get Martin on board. I have known him for 15 years. He is not an engineer, but this is not important. dSPACE has enough engineers. Martin is an experienced expert in managing technology companies. I expect he will make the company even more professional, start pushing topics that have been on the backburner, and continue growing the company.

How hard is it for you to let go? What will life after dSPACE look like?

Ask me about letting go at the end of the transition phase, that is at the beginning of 2019. But it is already very nice that I no longer have to deal with certain tasks on my own. Martin has really rolled up his sleeves and got to work. Life after dSPACE will not be idle for me, because I am not leaving the company entirely. I am only leaving my position as the CEO of dSPACE. The company will continue to be family-run, which means there will be sufficient jobs for me to do as the owner and in supervisory roles. Moreover, we also want to introduce the next generation of the family to the company. I am sure I will not be bored in my private life either. I have gone without much traveling, boating, and relaxing for way too long. Okay, we will have

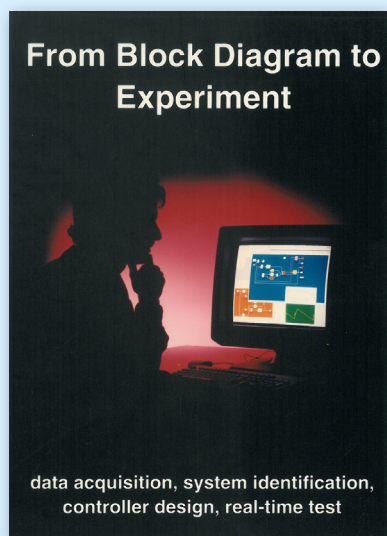
to see about the relaxing part.

What is your wish for the future of dSPACE?

That we can further expand our market position and grow in line with market requirements. I would also like to see the company gain some new momentum. But most of all, I want to keep our good reputation or even improve on it. ■

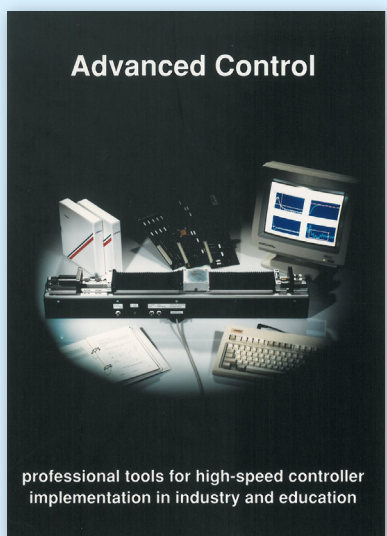
Thank you very much for the interview.

Poster for a trade fair



How to get from design to implementation as quickly as possible? One of the first trade show posters focuses on one of the most important tasks for dSPACE tools.

The performance message



When good is not good enough. dSPACE messages and products have always been aimed at those who simply expect more.

From customers, for customers



The first issue of dSPACE NEWS in 1992. dSPACE regularly lets its customers share their experiences in the magazine and report on exciting projects.

Prof. Trumper of Massachusetts Institute of Technology summarized it as follows:

"By facilitating rapid experimental implementation of controllers, dSPACE tools allow us to focus on the research challenges without becoming bogged down in implementation details."

A statement by Kay Kochan, Helmut-Schmidt-University Hamburg:

"With the modular hardware concept from dSPACE, we can tap into computing performance with virtually unrestricted scalability, and use it to develop systems that can be executed in real time despite high sampling rates."

We received the following opinion in the 2017 reader survey:

"I am very happy with the customer magazine as well as the dSPACE products and their product support."

Developing Safety-Relevant Functions for AURIX™ 2nd Generation

The AURIX™ 2nd Generation microcontroller family launched by Infineon provides advanced functionalities for safety-relevant applications, among others. As of dSPACE Release 2018-A, the dSPACE tools Generic Serial Interface (DCI-GSI2), ECU Interface Manager, and RTI Bypass Blockset support the AURIX™ TC3xx by bypassing, measurement and calibration as well as for other scenarios that require access to ECU-internal functions and variables. The dSPACE ECU interface products are therefore a central component for developing and testing classic embedded applications, such as engine and transmission control, as well as safety-relevant



applications. This includes steering and brake systems as well as sensor-

based applications for autonomous driving and electromobility. ■

Python 3 in the dSPACE Tool Chain

In April 2020, the Python Software Foundation will discontinue the support for Python 2. Consequently, dSPACE will change the Python distribution of its software tools to the current version, Python 3, as of dSPACE Release 2018-B. Python is one of the key programming languages for dSPACE products and plays a vital role when it comes to automating ControlDesk with its integrated Python interpreter, writing real-time tests, and working with AutomationDesk. dSPACE customers who are affected by this migration will receive comprehensive support in the migration



process. For information on changes between Python 2.7 and Python 3.6 as well as migration notes for dSPACE tools, they can consult the Python 3.6 Migration Guide available for download on the dSPACE website. For questions about the Python migration, dSPACE Support will be the point of contact. The migration to Python 3 will provide customers with important

benefits, such as full, long-term support, less complex structures, full Unicode support, and more efficient standard functions. ■

The Python 3.6 Migration Guide for download:
www.dspace.com/go/dMag_20181_Migration

Link to the Support form:
www.dspace.com/go/dMag_20181_Support



Find us on social media.
www.dspace.com/go/socialmedia

MotionDesk – Visualizing Realistic Lighting Conditions

In dSPACE Release 2017-B, we enhanced the visualization engine of our 3-D visualization software MotionDesk comprehensively, which, among other things, offers an improved simulation of realistic lighting conditions. With this, MotionDesk takes another significant step towards being a tool that can address all use cases in the development of advanced driver assistance systems. The new illumination model not only lets you visualize environments more realistically, it also adds scenarios with special lighting conditions, such as night drives, to the test range.

Numerous New Features for Camera-Based ECUs

The new software features are particularly important for developing and testing camera-based ECUs and for the sensor simulation used for this. Camera-based systems are able to recognize the realistic 3-D animations from MotionDesk, which can thus be used as the basis for various tests. Typical areas of application are the development of lane keeping assistants and autonomous emergency

braking systems as well as systems for lane detection and traffic sign recognition.

Realistic Lighting Conditions Day and Night

MotionDesk offers numerous configuration options to precisely simulate real scenarios. It is now possible to change the shape, the color, and the intensity of all light sources involved in the model, such as headlights, street lights, and the ambient light. Moreover, the light sources can be attached to any object in the model. This flexibility ensures well-lit simulated environments and individually adjustable lighting conditions. The sun can be positioned in MotionDesk on the basis of a simple ephemeris model. This lets you simulate changing lighting conditions, such as sunrise and sunset. The ambient light and the shadows change dynamically, depending on the selected values for the position of the sun. To be able to test real headlights in real time, the simulated vehicles can be equipped with different headlight models in



MotionDesk, simply by loading different luminance distributions for the relevant headlight. In combination with the Automotive Simulation Models (ASM) that dSPACE offers, you can test various use cases, for example, for developing adaptive front lighting systems (AFS).

Additional Lighting Effects in the Works

Introducing the new illumination model is only the first step in the continuous development of MotionDesk and heralds the start of a range of software changes and enhancements. Improvements, such as sun glare, road reflections, and atmospheric influences are planned for the next versions of MotionDesk. With this, the dSPACE 3-D visualization software is well equipped for future requirements that result from developing advanced driver assistance systems. ■



Watch our video of the new illumination model:
www.dspace.com/go/dMag_20181_MotionDesk



dSPACE MotionDesk now lets you individually adjust the lighting conditions of the test scenario and tailor them precisely to the related use case. Therefore, the 3-D animations in MotionDesk are ideally suited for developing various applications in the area of advanced driver assistance systems and autonomous driving, for example, for adaptive front lighting systems (AFS).

ConfigurationDesk and Bus Manager – More Efficiency for RCP and HIL Applications

The new version of ConfigurationDesk, the implementation software for SCALEXIO systems, boasts new comfort- and efficiency-enhancing features. The main novelties are a task-specific user interface, an even tighter integration with Simulink® and the optimized Bus Manager, which can be integrated as an add-on.

Task-Specific User Interface

A new, context-sensitive navigation bar provides different view sets, which always display precisely the functions required for the current work step. This gives users a better overview and lets them focus on specific tasks at a time.

Tighter Integration with Simulink

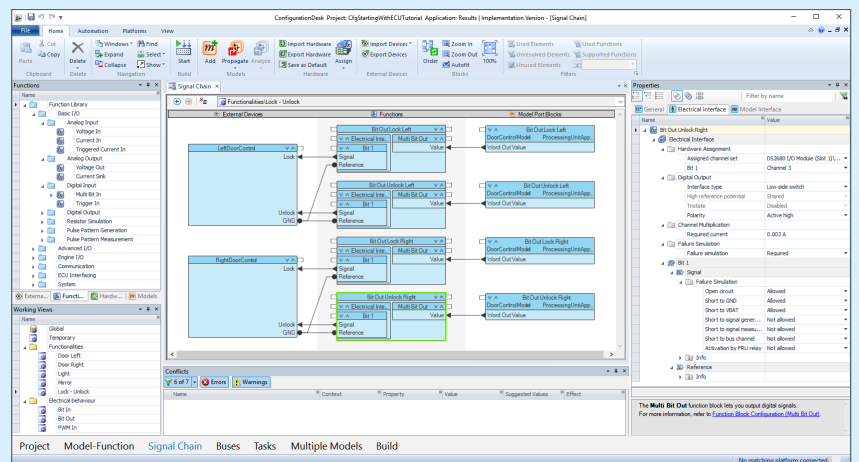
The interaction and information exchange between ConfigurationDesk and Simulink has been further enhanced. For example, it is now possible to create a new ConfigurationDesk project with Simulink, and the build process for the entire system can be started from the Simulink model. With just one click, the user can switch from the model port blocks in Simulink to the relevant point in ConfigurationDesk and vice versa. It is also possible to transfer changes made to the model interface in ConfigurationDesk to the relevant Simulink model.

Optimized Bus Manager

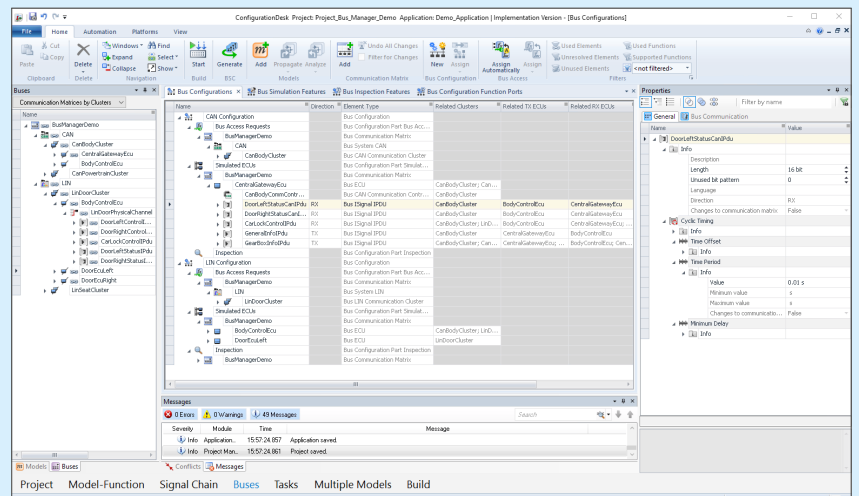
The dSPACE Bus Manager is the central tool for simulating the bus communication on dSPACE systems. It also improves efficiency and convenience by providing a clear overview of imported communication matrices and allowing for a configuration via drag & drop, without programming skills. An automation interface and update functions let users quickly adjust existing con-

figurations to new requirements. The new version also offers new features for bus communication inspection and manipulation. This includes functions for modifying frames and signal values, inspecting raw data, and simulating counters. The import of communication matrices has also been enhanced: In addition to existing for-

mats, the new standards AUTOSAR 4.3.1 and FIBEX 4.1.2 are also supported. ■



ConfigurationDesk is an intuitive, graphical configuration and implementation tool for behavior models and I/O function code on SCALEXIO hardware.



The Bus Manager lets users import communication matrices, display them in a clear structure, and modify them

dSPACE on Board

Discover intriguing and innovative applications, achieved with dSPACE development tools

Personal Pilot

BMW demonstrates the future possibilities for interaction with a level-5 autonomous vehicle. From calling the vehicle with a smartphone to conveniently operating it with a tablet from the backseat, the future scenarios are exciting and manifold. An AutoBox in the trunk of the car is part of the intelligent control system.



Photo credits: © DPCcars

The vehicles of the future can operate like personal taxi cabs.
www.dspace.com/go/dMag_20181_BMW



Photo credits: © DPCcars

A peek into the "training facility" for autonomous vehicles. The industry-proven AutoBox is on board in the trunk.

Growing Tomatoes in Space

The mission of the compact satellite Eu:CROPIS (Euglena Combined Regenerative Organic-food Production In Space) is to find closed life support systems under conditions prevalent on the moon and Mars. Specialized greenhouses are used to grow tomatoes that are connected to other biological systems. The German Aerospace Center (DLR) is using a dSPACE Simulator to test the Attitude and Orbit Control System (AOCS).



Photo credits: © DLR

Eu:CROPIS is used to evaluate the cultivation of plants in space.
www.dspace.com/go/dMag_20181_DLR



A dSPACE Simulator in a PX20 Expansion Box supports the tests of the attitude and orbit control system AOCS.

Demonstrator for Autonomous Driving

The Virtual Vehicle research center has been granted official permission to conduct test drives with autonomous vehicles in Austrian road traffic. This permission also applies to a demonstrator vehicle whose computing platform includes a MicroAutoBox Embedded PC. The vehicle explores deep learning techniques, which means that the vehicle is "trained" until it can independently drive on a road.



Photo credits: © Virtual Vehicle

The demonstrator vehicle can independently follow a road trajectory.
www.dspace.com/go/dMag_20181_VV

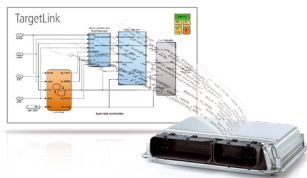


Photo credits: © Virtual Vehicle

The MicroAutoBox is part of the autonomous drive control.
www.dspace.com/go/dMag_20181_VV2



Learn more about these applications online, via videos, photos, and reports:
www.dspace.com/go/dMag_20181_REF_E



Production code generation



Development



Testing



Simulation

Electromobility – Complete Development and Testing with dSPACE

With advanced function development and test systems, dSPACE products make it possible to develop, simulate and test electronic control unit (ECU) software for all areas of electromobility and generate production code for it. Whether it's for electric motors, power electronics, batteries, electrical networks, or the charging infrastructure – You get everything from a single source. Trust in dSPACE's years of experience and one-stop solutions.

Be a pioneer – with development tools by dSPACE.