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2/2010

NASA – Radio-controlled test flights

Volkswagen – HIL tests for the Touareg Hybrid

BMW – Predictive thermal management

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Dr. Herbert Hanselmann
President

Back when I was a "private" race car driver with my 60-PS Fiat 124 drifting through curves on country roads without any in-car electronics, I was initially skeptical about the need for any driver assistance system. I remember sitting in a prototype car seven years ago in the USA. Equipped with two MicroAutoBoxes, it demonstrated stop sign recognition, including automatic vehicle stopping. I thought it was a fascinating project for creative engineers – but I was not really convinced that one day this kind of driver assistance technology would be introduced and actually used.

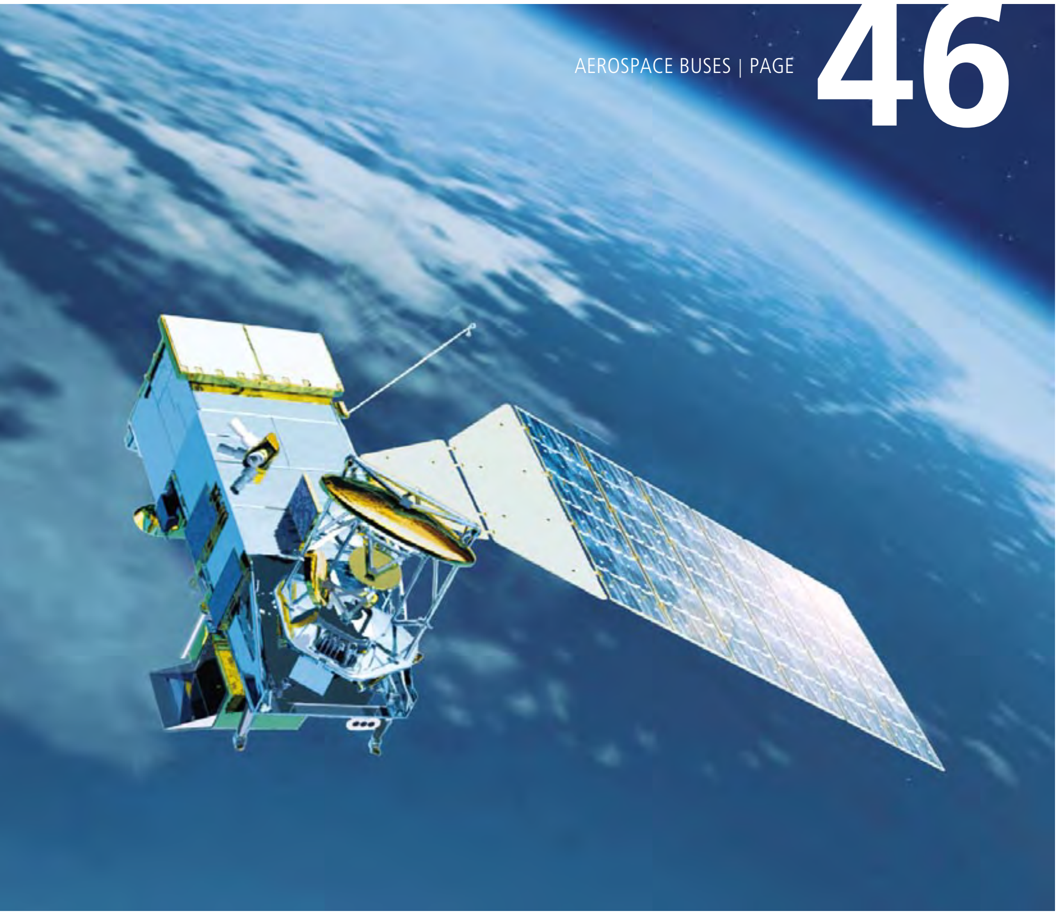
My opinion has changed since then. Not only because I'm getting older, but also because today's driving conditions are much more complex than before. There is a high traffic density, endless traffic lights and signs, long convoys of trucks on highways, and many complicated road stretches.

I still don't use many driver assistance systems myself, but am already a true fan of the radar in adaptive cruise control (ACC).
True, in Germany we hardly have any long-stretch American-style highways where ACC would help avoid the proverbial lead foot. But it does contribute to a higher level of safety on the roads. After all, who can say that he/she is still adequately attentive after hours and hours of traffic congestion to register a sudden halt soon enough? In contrast, ACC always brakes on time. According to studies, the driver has a reaction time of 0.6 to 2.2 seconds, which means an additional traveling distance of up to 30 meters even at just 50 km/h. ACC still needs a bit of work to become perfect, though. Obstacle detection does not reach far enough, and time and again I have noticed abrupt braking in cases where it was not really necessary. For example, when a truck shows up as a large radar reflection, although it is actually in the adjacent lane. Or when somebody cuts into my lane, but obviously does so to accelerate. ACC is not able to evaluate this kind of situation correctly yet. But someday it will.

The system is anyway already useful as it is, especially for drivers who risk losing their licenses due to repeated traffic violations. When the speed limit is kept down to 100 km/h, the ACC is set at 100 plus 'x' km/h. If 'x' is selected in relation to the resulting traffic fine, the driver can rest assured that he/she will not commit any further serious speeding violation. And when automatic compliance with speed limits is finally perfected, the driver will drive as obediently as a choir boy. As a step towards this, traffic sign recognition has already gone into series production. Map-based solutions are another possibility. Just recently, dSPACE laid the foundations for using high-resolution map data that contains lots of additional information. In fact, this kind of driver assistance system is a must-have for my next car.

Dr. Herbert Hanselmann
President

Embedded Success dSPACE



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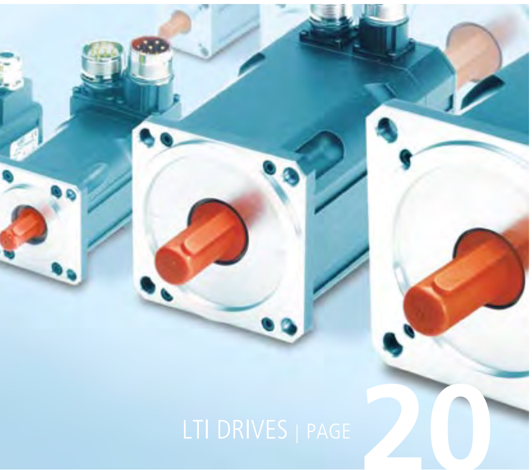
Contents



Customers

Products

Business

Touareg Hybrid – electrified and electrifying

Function integration test for a hybridized powertrain at Volkswagen: There's power in teamwork!

The Volkswagen Touareg has a brand-new hybrid version. Its electric drives, power electronics, and traction battery have caused a significant rise in the complexity of the networked electronic systems. From function development to electronic control unit (ECU) release tests, Volkswagen systematically relies on hardware-in-the-loop (HIL) simulation for functionality verification and quality assurance.

The New Volkswagen Touareg

When it was launched, the Volkswagen Touareg immediately set new standards in comfort and safety with its innovative vehicle functions: such adaptive cruise control (ACC), Side Assist (lane-departure warning), and Rear Assist (parking camera), to name just a few.

The new version of the Touareg continues the company's policy of bringing customer-friendly innovations up to production level and then using them throughout its entire vehicle range. For the very first time, the Volkswagen Touareg is now available with a hybrid powertrain (figure 1) as well as further-developed assistance systems such as a pre-crash system that evaluates data from radar and video sensors.

The full-hybrid powertrain makes tough demands on function and ECU networking. This means that the OEM needs optimal system integration. The OEM is responsible for the final vehicle and has to ensure that all its systems, including ones from different suppliers, are error-free and robust when they run in the overall vehicle.

Reasons for Using a HIL Test Bench

The decision to create a networked hardware-in-the-loop (HIL) test environment resulted from two primary requirements:

- The integration testing of networked ECU functions, especially the hybrid functions, must be set up quickly and dynamically.

- Because only a limited number of prototypes is available in early development phases, there must be a test station that suppliers and specialist departments can use for function development and special tests during development.

Choosing the HIL Test Bench

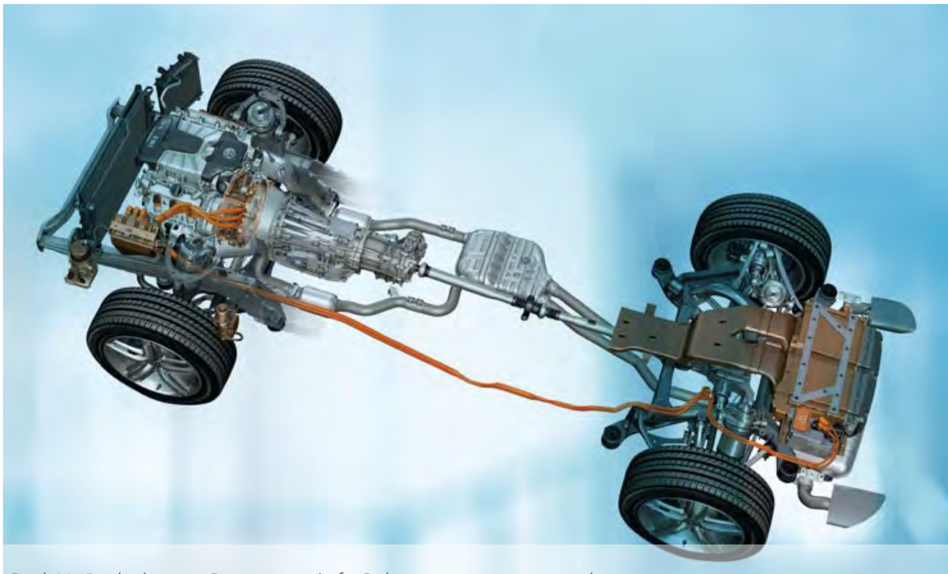
For the first time ever, Volkswagen used a networked HIL simulator to test a hybrid powertrain, with the Touareg Hybrid as the first case this was used for. This called for a strong partner with comprehensive experience in ECUs and simulating electric drive components, and Volkswagen chose dSPACE. Especially in the early test phases in the development process, ECUs are not fully functioning and diagnostics-capable yet, which makes it difficult to put them into operation on the simulator. This is where dSPACE's experience as a HIL development partner comes into play. Their competence in new, innovative bus systems such as FlexRay was the final decisive factor in choosing them as a testing partner.

Volkswagen's Integration Testing and Test Case Creation Process

To handle the complexity of the driver assistance functions distributed throughout the entire vehicle, Volkswagen not only works on real vehicles and test benches, but also systematically uses hardware-in-the-loop simulation. In a multistage testing process, at fixed points in time during the product creation process (PCP) the vehicle's overall status is studied on the integration HIL test bench. These tests are part of overall integration testing. This makes it possible to investigate and verify the interactions between the systems and the external effects of their functions at a high level of test coverage in early development phases.
To determine the vehicle's current maturity with respect to system integration, different test locations such as prototype vehicles or test benches are used during overall integration testing, depending on the test task. The test results from these are bundled and consolidated to provide detailed monitoring of the vehicle's overall integration status. The test locations for specific tests are selected from the available electronics testing facilities (figure 2) according to their suitability and availability.

The ECU tests performed on the HIL test bench focus on selected testing issues (table 1). The HIL tests also support the systematic analysis of any irregularities that emerge from test drives. Thus, the HIL test systems

Figure 1: The hybridized powertrain including the battery module of the Touareg.



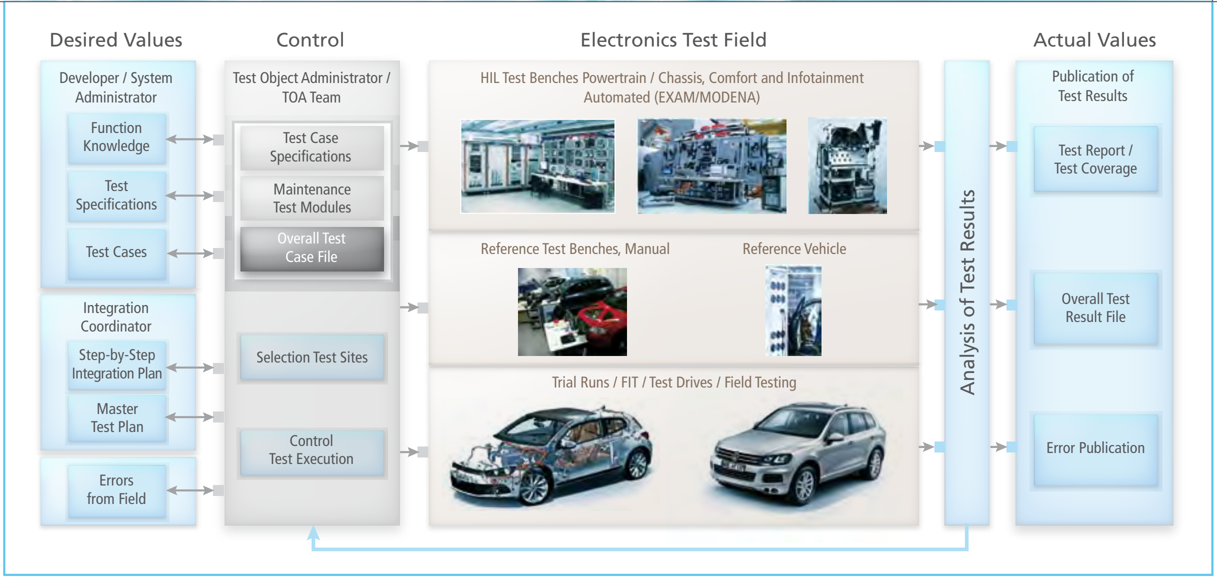


Figure 2: Structure of the electronics testing facilities.

provide considerable technical added value and are used efficiently in the development and release process.

Requirements for the Test System

The basic requirement for the test environment is the HIL test station’s ability to represent all the networked ECU functions that are experienced by customers: for example, when the ECU in the vehicle receives data from sensors and actuators, it must respond without any errors. The networked HIL simulator for the Touareg Hybrid is extremely complex, with 29 ECUs. To handle this complexity, the test bench supplier has to fulfill numerous requirements when commissioning and operating the test bench:

Modularity

Initially, the test station must be designed for three motor variants and the automatic transmission of the Volkswagen Touareg, and be able to switch between them quickly: diesel (3.0 l TDI), gasoline (3.6 l FSI) and hybrid (3.0 l KFSI).

Flexibility

Volkswagen begins HIL testing with the first prototype two years before start of production (SOP). At that point in time, the ECUs are still being developed and subject to system modifications such as sensor adjustments and changes in the plug connectors’ pinouts. These changes need to be made on the HIL simulator quickly and smoothly – and usually despite a lack of mature ECU diagnostics.

> “Without such good cooperation with the ECU developers, it would not have been possible to put the test bench into operation.“
>
> *René Schüler, Volkswagen AG*

Table 1: Test issues for HIL testing.

Test Issue	**Description**
Hybrid ready status	Conditions on which the hybrid must achieve ready status and conditions on which ready status must be prevented.
Coordination of operating states	Conditions for individual operating states such as starting/stopping the combustion engine, electric operation, braking/recuperation, boost function, (charging by generator), transition states.
Driver information and controls for the hybrid	Information on the hybrid given to the driver via instrument cluster and display, energy flow display, onboard computer, recuperation display, warning signals, error messages.
Error responses and substitute measures	Testing the ECU’s desired reactions to inserted failure states.

The NiMH battery is installed in the rear.

> “Answers to questions on functions and the development status of the ECU were usually just a phone call away. And the responsible developer, with all the necessary knowledge, was on hand immediately.“
>
> *Christian Claus, IAV GmbH*

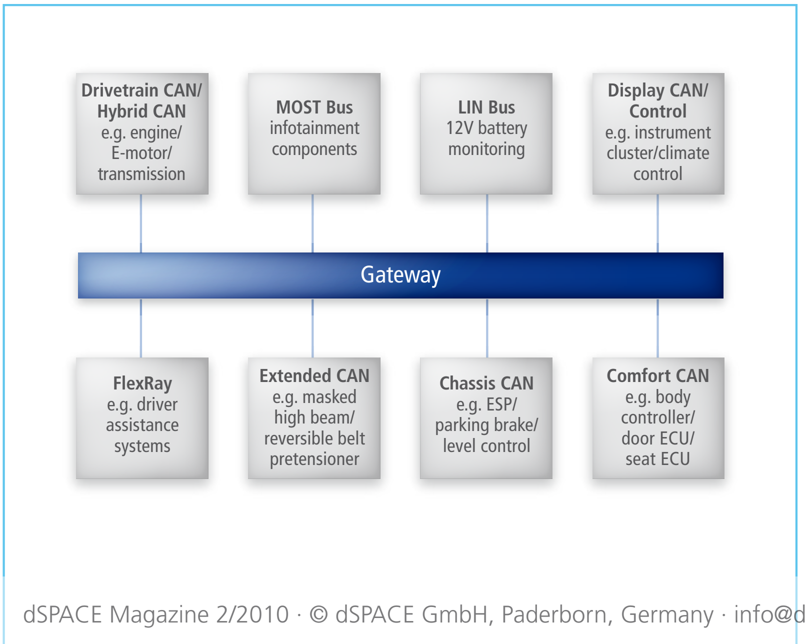
Efficient Software Structures and System Stability

The network simulator used by Volkswagen contributes greatly to function testing and software version release. Any system used for this has to function stably – especially in automated testing. Frequent changes to the drive variants make this more difficult.

User-Friendliness

Not every test bench user must be trained to be a HIL expert. The engineers responsible for specific test objects and the specialist departments/suppliers use the HIL simulator to perform their test tasks efficiently. Efficiency means concentrating on ECU functions without having to acquire in-depth simulator knowledge.

Figure 3: The networking architecture of the Touareg Hybrid.



Structure of the Network Simulator

The simulator for the Touareg Hybrid is designed as a virtual vehicle and covers all vehicle domains. The powertrain comprises the following systems:

- Combustion engine
- Electric motor
- Transmission
- High-voltage battery

These systems are simulated realistically by simulation models, various real parts such as a throttle and injection valves, and high-voltage electronics that emulate the battery voltage.
The HIL system can be configured for three different motor variants and an automatic transmission with different gear ratios and converters. The motor and transmission variants are identified by means of ECU-specific mapping connectors. Finally, the associated model parameters are loaded. This achieves the necessary modularity and flexibility.
For the most part, the ECUs under test are on a test bench setup that was provided by Volkswagen’s test setup service (figure 4).

Bus Systems

The powertrain domain is equipped with various CAN and LIN buses and a FlexRay bus (figure 3). Restbus simulations were set up for all the buses. The CAN buses have a manipulation gateway for main switching and

> “Working with dSPACE, we have learned which requirements and challenges are involved in verifying networked hybrid functions on the HIL simulator. We will be putting this knowledge back into future projects.“
>
> *René Schüler, Volkswagen AG*

local switching. This makes it possible to take each single ECU off the bus and isolate it on a separate bus. The messages received on one bus can be mirrored on the other. This switching method makes it possible to manipulate targeted CAN messages or even delay them at signal level, and also to simulate an ECU failure.

Simulation Models

VW’s own simulation models for the combustion engines and dSPACE’s Automotive Simulation Models (ASM) are used. The hybrid powertrain and the vehicle dynamics are simulated with ASM DriveTrain, ASM Electric Components and ASM Vehicle Dynamics. Because of their open structure, the ASMs were easy to combine with the VW models to create an overall model for the hybrid powertrain. A spindle actuator implemented in the drivetrain model is used to decouple the combustion engine in order to simulate purely electric operation. A battery model from ASM Electric Components is parameterized for nickel metal hydride (NiMH) characteristics and is used for the high-voltage battery. The models have proven to be very robust and enable the simulation of all conventional and hybrid operating conditions such as purely electric driving, hybrid driving, combustion engine driving, recuperation, and coasting. The open models meet the requirements for efficient software structure.

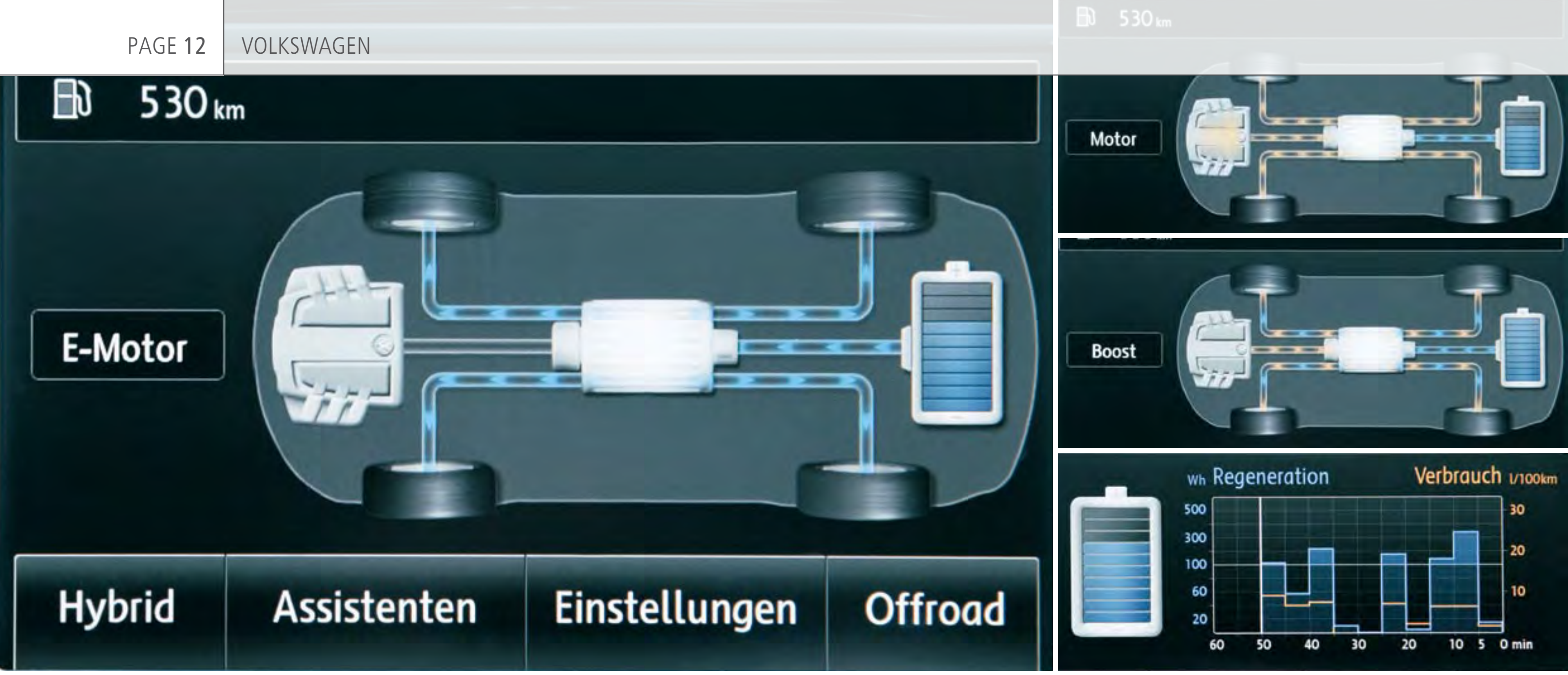
Battery Simulation and Emulation

To test the battery management system (BMS), the high-voltage battery’s terminal voltage and the voltages of the battery cell clusters have to be emulated. A controllable 400-volt power supply and several galvanically isolated DC amplifiers are available for this. The simulation of cell and battery behavior uses the battery model from the ASM Electric Components, which controls the power supply and the amplifiers. This system provides reliable representation of the on/off currents, the charging and operating behavior of the NiMH energy store, etc. To isolate the high voltages and protect operating personnel, the high-voltage electronics are installed in the simulator as a sealed system.

Simulating the Electric Motor

The electric machine, which has an output of 38 kW in the Touareg, is simulated by a three-phase-current motor model from the ASM Electric Components. Evaluation at signal level is sufficient for testing the electric motor ECU. The interfaces between the signal and the output electronics were opened up physically for this. The pulse-width-modulated (PWM) signals to control the power electronics (IGBT) are measured with a PWM Measurement Solution and processed in the motor model. The model provides position and current signals that are passed to the ECU via interface boards (DS5202 PSS, DS2102). This means that the ECU can be tested in a closed control loop.

Figure 4: The simulator and the test setup in the laboratory.



Driver information display with energy flow indicators for purely electric driving, charging, boosting, and battery regeneration and fuel consumption.

Operation and Experience

Once again, the process of putting the simulator into operation showed that as vehicles become more complex, closer cooperation between testers, test bench operators and – most importantly – developers is essential. A project like this cannot be carried out without the know-how of ECU developers from the individual specialist departments and their readiness to support commissioning. The same applies to subsequent test bench operation, as this is the only way to quickly and efficiently carry out changes to the ECU software or hardware and the resulting changes in test bench requirements.

> "The Automotive Simulation Models (ASM) from dSPACE guarantee solid, reliable simulation of the Touareg Hybrid's electrical components."
>
> *René Schüler, Volkswagen AG*

In addition to the supporting developers, a resident engineer from dSPACE helped to make the modifications and to adapt the HIL simulator to new situations. There is always on-site support from HIL experts, and direct contact with dSPACE's development department is also guaranteed.

Because of the high dynamics and modularity of the test setup adaptations, it is always possible to run the current ECU versions in the integration test phases described above. In addition to checking the networked functions for ACC, Side Assist, ESP, etc., the test focused on hybrid coordination. This mainly concerned testing the driver information and the driver controls for the hybrid functions, along with correct responses to failures and plausible selection of driving states.

Outlook

Volkswagen plans to extend the HIL test bench for future Touareg motor

René Schüler, Volkswagen AG

René Schüler is Project Manager for HIL simulation for the Touareg Hybrid at Volkswagen in Wolfsburg, Germany.

Christian Claus, IAV GmbH

Christian Claus, a project engineer, was a significant contributor to the HIL testing of the Touareg Hybrid at Volkswagen.

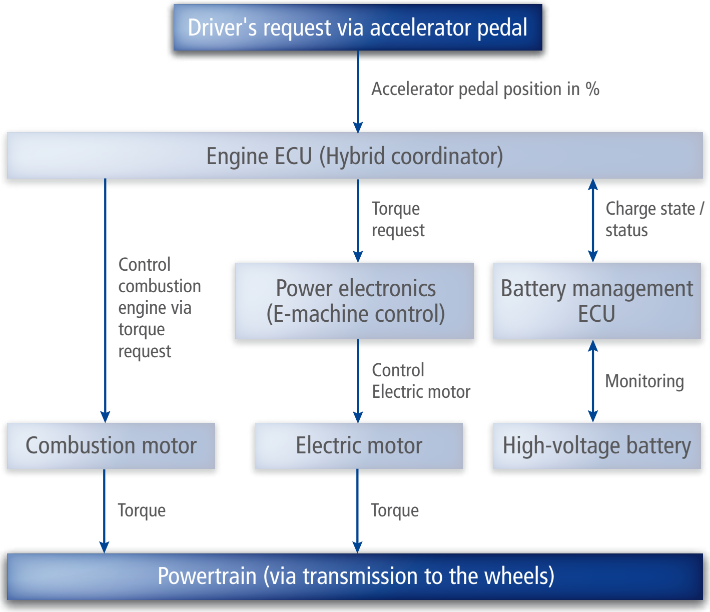
variants. This will involve integrating new combustion engine models and setting up ECU identification via mapping connectors. High resolution environment simulations for virtual test drives will also be added to the HIL test environment so that ECUs for advanced driver assistance systems (ADAS) can be included in simulation. The sensors (camera, radar) in these systems will have to be stimulated appropriately for this. ■

René Schüler,
Dr. Marcus Brand
Volkswagen AG
Christian Claus
IAV GmbH
Germany

Example of a Networked Function in the Touareg Hybrid

The engine ECU not only controls the combustion engine, it is also the hybrid coordinator. Its task is to coordinate the torques in the powertrain and to monitor the participating ECUs, such as for battery management and power electronics.

When the driver depresses the accelerator pedal, this tells the engine ECU the desired torque. The engine ECU uses this torque (desired acceleration/speed), and also the system status, the temperatures and the battery charge state (SOC), to decide whether to initiate electrical driving, combustion engine driving, or a combination of the two known as “boosting”.



Conclusion

The dSPACE HIL simulator immensely helped during function verification when the Volkswagen Touareg was developed. Even after the initial start of production, the test station is being used for further versions and vehicle enhancements. Because setup times are very short, it was possible to test several motor variants in the integration testing phases. Working with dSPACE, we have discovered the requirements and challenges involved in the verification of networked hybrid functions on the HIL simulator. We will be putting this knowledge back into future projects. Volkswagen firmly believes in close cooperation between automotive brands to verify functions with networked HIL test benches. The successors to the Volkswagen Touareg, the Audi A8 and the Porsche Cayenne are based on modular longitudinal platform technology (MLP, also known as MLB). This led to the goal of using standardized HIL test bench equipment, ideally with a uniform hardware and software structure from standardized vehicle technology. One of the reasons for choosing dSPACE for MLP testing was dSPACE’s extensive experience working with Audi (the leading MLP developer). Working together, Audi, Volkswagen and Porsche are planning, implementing and commissioning the test stations, utilizing all the synergies inherent in closely related vehicle projects. In addition to HIL technology, successful cooperation on test case creation, test case automation (the in-house tool EXAM) and error tracing has also evolved.

Looking forward

Predictive thermal management optimizes efficiency and dynamics

Mobility in Transition

Mobility as we know it today will not stay this way for ever. Under threat from the world's increasing energy requirements, limited fossil fuel resources, political crises and uncertain energy prices, mobility will undergo changes in the medium term. Legislators all over the world have responded with measures to limit fuel consumption and reduce CO_2 emissions. More than 90% of the world market is already subject to regulations on fuel consumption and CO_2. The legislation was not formulated and passed down to the last detail yet, but the general direction is clear: Over the next 10 years, car makers will have to reduce fuel consumption and CO_2 emissions by a further 25 - 30%. Anyone failing to meet this objective will face paying severe fines or will be unable to obtain approval for their products.

New Approaches to Combustion Engines

These tough reduction targets cannot be reached by classic development of the engine alone. The BMW Group therefore began to systematically analyze every single physical actuator and assess their effects on the energy balance.
The combustion engine will continue to play the dominant role as the main power convertor in a vehicle and is therefore undergoing intensive further development.
One decisive factor will be to cut vehicles' fuel consumption in typical customer driving without losing the dynamics of a premium brand vehicle. One promising approach, and part of the BMW EfficientDynamics strategy, is to integrate predictive information on the road ahead, with speed and curve profiles, and also hills or gradients, etc., into the thermal management of a conventional combustion engine. A prototype produced by the BMW Group demonstrates the benefits of predictive thermal management.

Modern Vehicle Thermal Management

Modern cooling system controls have requirements-driven thermal management that unites efficiency, dynamics and comfort while at the same time ensuring thermal operating reliability. Electrifying the actuators in the cooling circuit (figure 1), combined with whole-vehicle control strategies (implementing the increased degrees of freedom in the controlled systems), is already enabling functionalities that go far beyond the original purpose of cooling:
The core function of BMW's thermal management is to select operating modes within the engine control functions. For example, after a cold start a warm-up mode is activated to bring the engine up to an efficient operating range quickly. Because the electric coolant pump is decoupled from the engine speed, this mode produces a static coolant to reduce heat transfer from the combustion chamber walls to the coolant and hence the engine warms up faster.

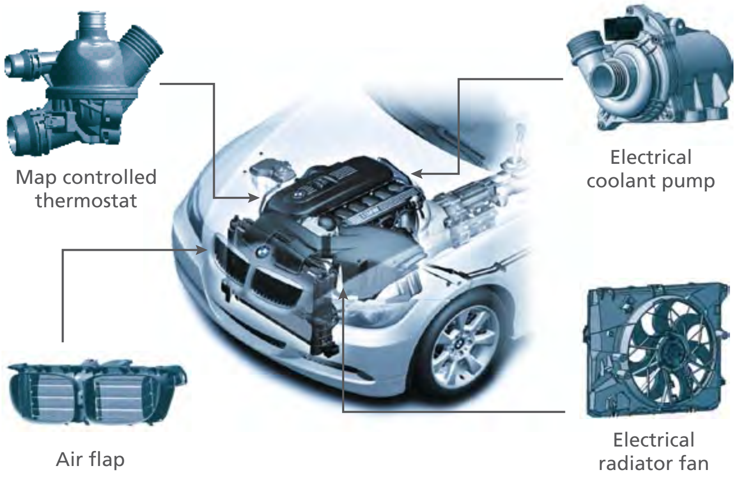


Figure 1: Electrified actuators in the cooling system (source: BMW, International Technical Training).

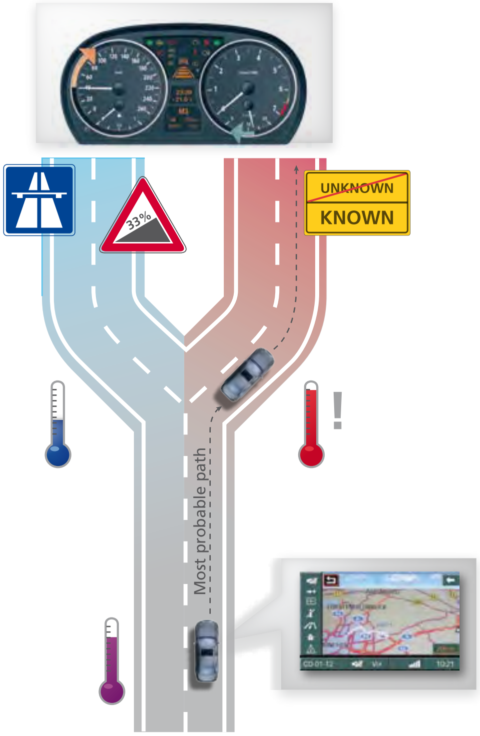
Situation-Dependent Control Strategies

When the warm-up phase has been completed, the engine control computes the coolant requirement in accordance with the driving situation. The conventional control strategy attempts to reconcile two conflicting objectives: It has to reduce the internal friction by increasing the engine and coolant temperatures, but at the same time it must not compromise the thermal reliability standards. The entire engine performance range is determined by the operational maps in combination with fixed thresholds. These influence the fluid temperature and cooling temperature, which in turn determine the cooling system operation modes for the conventional thermal management control. The associated cooling levels range from consumption-oriented operation (ECO operation) with considerably reduced cooling and higher coolant temperatures, to highly dynamic operation. This highly dynamic operation mode provides maximum cooling at significantly reduced coolant temperatures under high engine loads. Depending on the situation, the operating strategy currently used in production vehicles can result in unnecessary adjustment of the requested cooling power. This is especially evident, for example, at intersections in an urban environment, where the conventional thermal management system takes preventive measures to compensate for the additional heat gain caused by sudden acceleration. The energy required to reduce the coolant temperature is wasted in this case. Thermal reliability always has top priority in the control strategy because the current driving situation is primarily fed into the control system.

The Limits of a Situation-Driven Approach

The BMW Group evaluated test drives with respect to cooling system behavior and identified application cases for predictive control. Typical application cases are acceleration from a standstill at intersections, brief accelerations on country roads, or when the engine is turned off. Even with only a slightly dynamic driving style, these influences can cause conventional thermal management to leave ECO operation due to the conventional reactive control directly responding to the current driving situation. When the driver briefly hits the accelerator pedal, the cooling power rises so that the cooling temperature drops, even though this is not always necessary, for example, in an urban area.

Figure 2: Idea and approach of predictive thermal management: The engine and the cooling system are systematically preconditioned according to the most probable path. This example shows an uphill stretch of freeway with a low temperature and an urban driving situation with a high temperature.



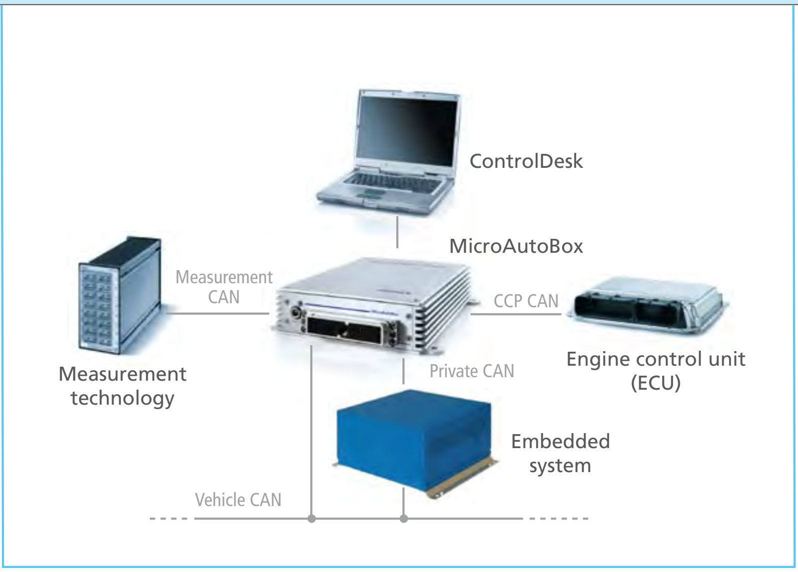


Figure 3: Hardware and communication structure in the experimental vehicle.

Predictive Operating Strategies

The analysis and evaluation of data on the road ahead is called the electronic horizon. Predictive thermal management uses the electronic horizon to intelligently prevent inherent inertia depending on the driving situation. The electronic horizon can also precondition the engine and the cooling system. The driving situation is further differentiated by using driver types ranging from steady to sporty (figure 2). The required cooling power can be better estimated and regulated through predictive information, which is used to classify the acceleration with respect to duration and possible maximum end speed. In this case, maintaining ECO operation reduces fuel consumption. This helps to avoid a higher load on the actuators such as the electrical coolant pump. During the short acceleration action, the raised temperature level can be maintained without exceeding the limits of the cooling system.

Predictive Adjustments for Improved Dynamics

Predictive thermal management enables predictive adjustment of the cooling power and the engine temperature, so that the engine is preconditioned for upcoming higher performance requirements. These have a greater impact on cooling requirements in order to maintain optimum engine performance. The extent of predictive intervention can be selected according to the driver type and the type of transition between different driving situations. Predictive conditioning performed by thermal management has a positive effect on knock behavior, engine cylinder charging, etc. These can considerably enhance the dynamics of the vehicle, for example, when it is driven onto the freeway in a sporty manner.

Prototype Vehicle Setup

To verify the feasibility of the concept vehicle, the thermal management division within the BMW Group prepared a prototype based on a production BMW 335i for the application cases described above. The electronic horizon in the prototype vehicle was developed by BMW Forschung und Technik GmbH. The Intelligent Learning Navigation (iLeNa) project offers extended functionalities compared with current off-the-shelf navigation solutions. One of the extra functionalities is the learning application knowledge database, which can store the actually driven road profiles, for example, habitual speed patterns, and not only the official speed limits from a digital map. A destination and route estimator uses stored driving patterns to calculate the most probable path even if the driver has not activated the navigation system.
To determine the position and perform map matching, iLeNa accesses the vehicle's GPS antenna via the vehicle bus. An automotive-capable embedded system with an MS Windows operating system (figure 3)

Glossary

ADASIS – Advanced Driver Assistance Systems Interface Specification, ADASIS Forum on the Internet: www.ertico.com/en/activities/safemobility/adasis_forum.htm

ADAS RP – Advanced Driver Assistance Systems Research Platform. Development platform for map-based driver asistance systems from NAVTEQ.

BMW EfficientDynamics – A strategy used by the BMW Group to achieve what was previously thought to be unachievable: the reduction of fuel consumption and CO_2 emissions with a simultaneous increase in vehicle dynamics and engine power. Or to put it another way: Squeezing every last drop of fun out of every drop of fuel.

GPS – Global Positioning System is a global navigation satellite system for determining position and measuring time.

Map matching – Matching a found position to the geographical data on a digital map.

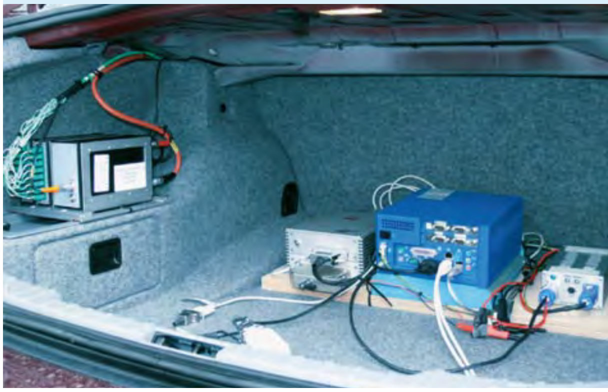


Figure 4: Hardware setup in the experimental vehicle: measurement devices, MicroAutoBox, embedded system, voltage supply (from left to right).

forms the hardware environment of the navigation platform. This is based on the NAVTEQ development environment for map-based driver assistance systems (ADAS RP).

Controller Structure and Function Logic

A CAN interface with the CAN Calibration Protocol (CCP) was installed between the BMW thermal management system partitioned on the engine control (DME) and the MicroAutoBox.
The controller structure and the function logic of the predictive thermal management system was designed with MATLAB®/Simulink®/Stateflow from The MathWorks® and implemented on a dSPACE MicroAutoBox in the vehicle (figure 4).
Existing measurement technology, such as for temperature and voltage capture, was easily integrated into the Simulink® model and coupled with the MicroAutoBox by reading in the appropriate DBC configuration file via the dSPACE RTI CAN Blockset.

Function Blocks of the Predictive Thermal Management

The predictive thermal management comprises several logical function blocks (figure 5). The Reconstructor is the interface to the iLeNa and processes the data packets sent via the CAN bus. The communication protocol used for this is an ADASIS protocol that has been adapted to BMW-specific requirements. Because the electronic horizon is transmitted cyclically to reduce the load on the vehicle bus, there is a memory block that functions as a buffer and an interface for thermal-management-specific situation evaluation. The profiles for the type (from the digital map) and the expected speed (from the iLeNa knowledge database) are filtered with respect to the situations described above and transferred to the actual predictive function logic together with distance data. The logic evaluates the situation horizon with respect to the current position and calculates the extent and timing of control interventions by the thermal management system. Finally, the validity of the preview and additional current vehicle parameters are used to prioritize the function interventions or to switch the system to the production ECU behavior.

> “With predictive operating strategies, we can specifically precondition the engine and the cooling system to increase dynamics and efficiency.“
>
> *Mathias Braun, BMW Group*

The evaluated information on current and upcoming environment situations is displayed by dSPACE ControlDesk together with the conventional and predictive thermal management operating strategies and the consumption effects in the vehicle.

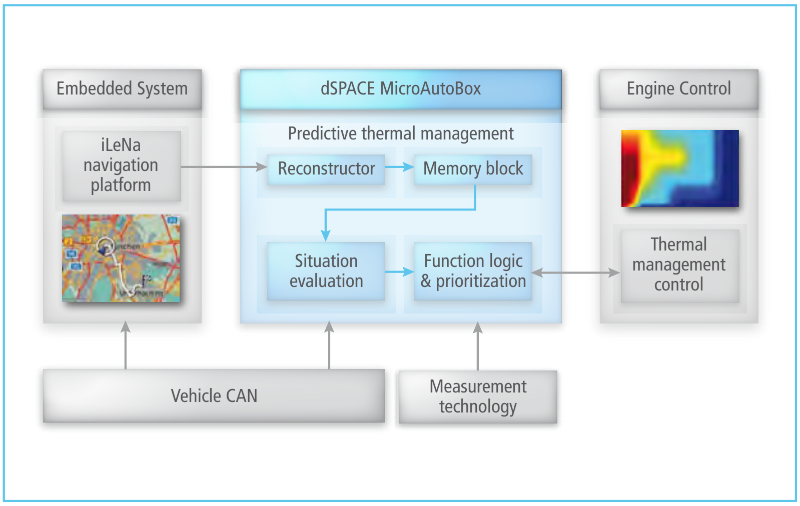


Figure 5: Software and control structure of the predictive management.

Results of Fuel Consumption Reduction

Networking the thermal management system with the vehicle navigation system allows the intelligent, simultaneous further development of a vehicle’s efficiency and dynamics. A more homogeneous coolant temperature behavior at a raised temperature level can be implemented for typical customer in-town driving. The load on the vehicle’s electrical system is reduced by avoiding unnecessary spikes in the requested cooling power, and fuel consumption is also reduced in a range of up to 1% simply by ad-

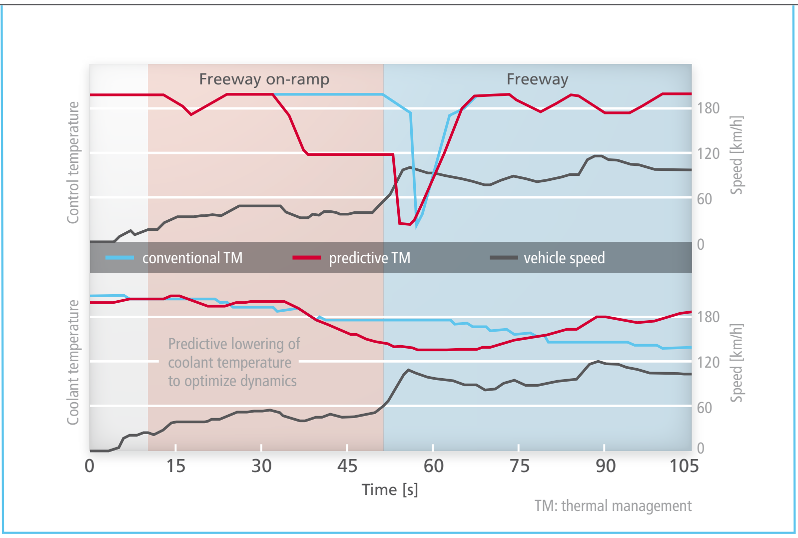


Figure 6: Comparison between controls for conventional and for predictive thermal management.

justing the operating strategy, i.e., without using additional components. This is another important future strategy alongside numerous others in the overall BMW EfficientDynamics package.

The Achieved Increase in Dynamics

In the second application case described here, predictive thermal management allows the engine temperature level to be raised at low loads without increasing the risk of exceeding temperature limits during the transition to higher load points. Moreover, it was found that preconditioning the engine by predictive reduction in the temperature level (figure 6) can also bring about increased dynamics. These effects are measurable in the acceleration phase, especially in naturally aspirated engines and their typical intermediate accelerations (e.g., elasticity at 60 - 120 km/h), and are in a range of 3 - 5 % in the uncharged BMW 6-cylinder in-line engine.

The positive effects of predictive thermal management are less obvious in turbo-charged engines. This is due to the in-cylinder charge being dependent on the operational process of the turbo-charger. However, at full engine load, the predictive temperature reduction can increase the efficiency of the turbo-charged engine by selecting a more favorable ignition angle, which in turn optimizes the in-cylinder combustion. ■

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Dr. Matthias Linde,
Dr. Andreas Eder,
BMW Group
Dr. (RUS) Evgeny Kozlov,
ALTRAN Technologies

Summary and Outlook:

Thermal management in a conventional powertrain was intelligently further developed by adding a predictive component. With a Series 3 BMW as a basis, initial control strategies were implemented in a prototype, and their functionality and potential were verified. Networking different ECUs to use information that already exists in the vehicle results in increased efficiency and increased dynamics, as was seen from the example of predictive thermal management.

The networking of navigation domains has been a benefit to driver assistance systems such as Adaptive Cruise Control and speed limit displays. Progress in navigation systems with respect to the quantity and quality of information in the digital map (even if navigation is not activated) opens up the potential for predictive functions for optimum control of the energy and heat flows in vehicles.

In addition to predictive thermal management, there are other possibilities, such as computing the driving range of purely electric vehicles more precisely. These would be ideal additions to the BMW Group's successfully implemented BMW EfficientDynamics strategy.

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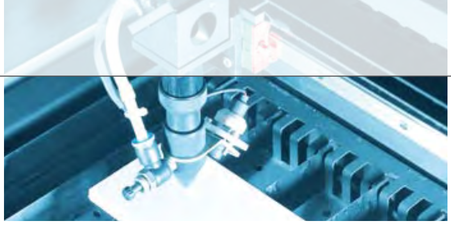
Automated software tests on a HIL simulator

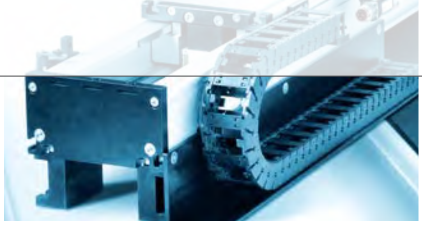
Electric Drives

Efficiently Virtualized

Controlled electric drives are a key technology in numerous engineering applications. Handling so many applications calls for a high degree of flexibility, especially for servocontrollers in industrial automation. And with all the possible configuration options for the servocontroller software, there is a high number of variants, involving an enormous testing workload. With automated testing on a HIL simulator, these tests can be simplified and accelerated significantly.

LTi DRiVES GmbH in Germany develops, produces and distributes servocontrollers for electric drives with performance ranges from a few hundred watts to 250 kW. In addition to operating in classic automation technology, drive products from LTi serve such different application areas as medical technology, wind farms and high-speed drives. And more than ten years ago, LTi also started equipping diesel-electric industrial trucks with custom-developed inverters. No matter what the field is, the level of software in elec-





tric drives is getting higher, while innovation cycles are getting shorter. So it is extremely important to execute the software tests for servocontrollers efficiently.

One Servocontroller for All

The core functionality of any servocontroller is to control the current, rotary speed and position of various motor types such as direct-current, synchronous and asynchronous. The ServoOne server controller from LTi has numerous additional functions that users can configure for a wide variety of applications. Figure 1 shows software function modules that are typical for a servocontroller, all requiring extensive testing. Obviously, the large number of variants and the broad functionality involve an enormous testing effort. Against this background, automation regression tests in the software modification promise enormous savings.

> “The HIL simulation technology provided by dSPACE is an important aid to quality assurance and development cost reduction at LTi.”
>
> *Dr. Harald Wertz, LTi DRiVES GmbH*

The Challenge: Real Parts

The software must be tested intensively not only in isolation, but also in interaction with a large number of hardware configurations. Different power stages, different types of motors and encoders, and different field bus and technology option boards can all be combined in different ways. Test bench tests require extensive setup work, such as performing the electrical and mechanical installation of the inverter and motor when real hardware is used. This not only prolongs the software release process, but also ties up valuable test bench capacity.
Many of the test conditions for using real parts in software tests are safety-critical, so they pose another challenge. Such conditions apply when critical errors are tested, such as overcurrent, overvoltage, overspeed and overtemperature.

The Solution: HIL Simulation

The solution for testing extensive software functions and hardware configurations is hardware-in-the-loop (HIL) simulation. This replaces the necessary controlled systems and real parts with simulation models, so that most of the setup work otherwise performed during testing is unnecessary. A HIL simulation can run under automated control, so testing can be done around the clock. Test automation is especially helpful with routine tests for verifying compliance with standardized field bus profiles such as CANopen, SERCOS and CAN J1939. Technical safety approval procedures also require that test sequences with error simulations are reproduced repeatedly. This too is immensely simplified by test automation.

Simulation Hardware Setup

All the simulator’s components are integrated in a mobile cabinet (figure 2). A dSPACE system is used as the platform for real-time simulation. It consists of a processor board (DS1005), two I/O boards for simulating electric drives (Electric Motor HIL Solution) and a CAN interface board (DS4302). The connection technology and signal conditioning

Figure 1: Typical software components of a servercontroller.

between the dSPACE system and the electronics in the object under test were planned and implemented by LTi. The cabinet also contains an industrial PC, which acts simultaneously as the field bus master and as the host for the test automation software. To give the simulator maximum versatility, boards for control parts taken from different drive products can be integrated in the cabinet as test objects. This is done by using a pull-out tray and a standardized adapter that has robust plug connectors with a high pin count.

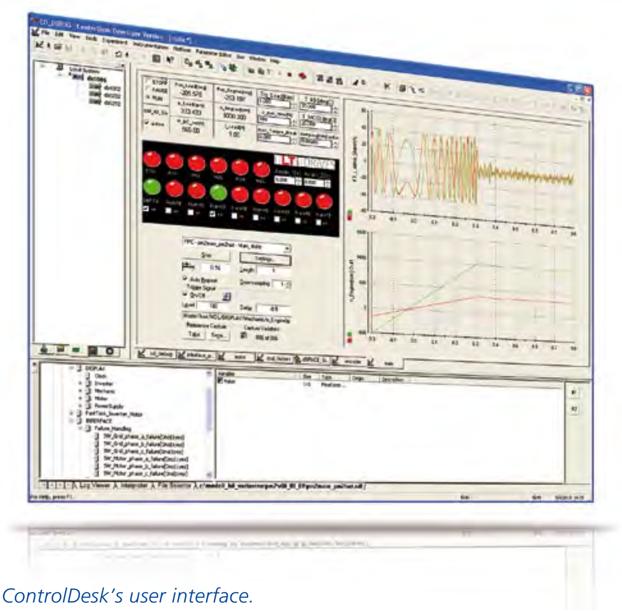


Figure 3: ControlDesk's user interface.

Figure 2: The assembled HIL simulator.

Simulation Models

The simulation model for the controlled systems was created in Simulink®. It was based on models from dSPACE's ASM Electric Components Library, such as synchronous and asynchronous machines and power converters. With their open structure, the models were easily adapted to LTi's requirements. Components from the SimPowerSystems Toolbox from The MathWorks® were also used, for example, to simulate three-phase networks in real time.

Drive Peripherals

Because of the high dynamics of the real plant, the real-time simulation of power electronics and electric drives makes very tough demands on the simulation system. The EMH board that dSPACE developed specially for the HIL simulation of electric drives has a series of intelligent I/O channels. The integrated FPGA (field-programmable gate array) executes I/O processes with a high time resolution. These include analyzing the PWM control signals generated for the power stage by the control electronics and generating the digital and analog signals that arise during position encoder simulation. The EMH board can simulate not only the usual analog resolver and encoder systems, but also TTL incremental encoders such as encoders with the serial transmission protocols SSI, EnDat2.1® and Hiperface®. The protocol of the serial encoder systems can also be parameterized flexibly to represent all common encoder types.

Test Automation

dSPACE ControlDesk is used for interactive work with the HIL simulator (figure 3). The automatic tests are implemented in the Python script language. Easy access to the simulator and the object under test from the host computer is implemented by using appropriate Python libraries created by dSPACE and LTi.

Comparing Simulation and Reality

To assess the quality of the real-time model, first the parameters of an 11-kW synchronous motor were determined on a real test setup, with the aid of the drive's integrated autotuning function. Following this automatic controller design, the step responses of the current and motor speed control were measured. Then the HIL motor model was parameterized with the motor data identified on the real hardware, and the step responses were recorded with identical controller parameterization for the object under test on the HIL simulator. This resulted in good consistency between the respective processes (figure 4).

Outlook

The HIL simulation of electric drives in real time can be performed at a high quality level with the powerful dSPACE hardware and simulation algorithms that are specially designed for it. The precision of the real-time model is so good that even the most demanding control investigations can be carried out. LTi also found other interesting possible uses for the HIL simulator in addition to automatic execution of software tests for server controllers:

- Optimization of control parameters for customer applications to prepare and speed up on-site commissioning
- Early testing of software prototypes to run hardware-related tests on control functions
- Early evaluation of the design data of special motors for hybrid and electric vehicles in terms of control technology. ■

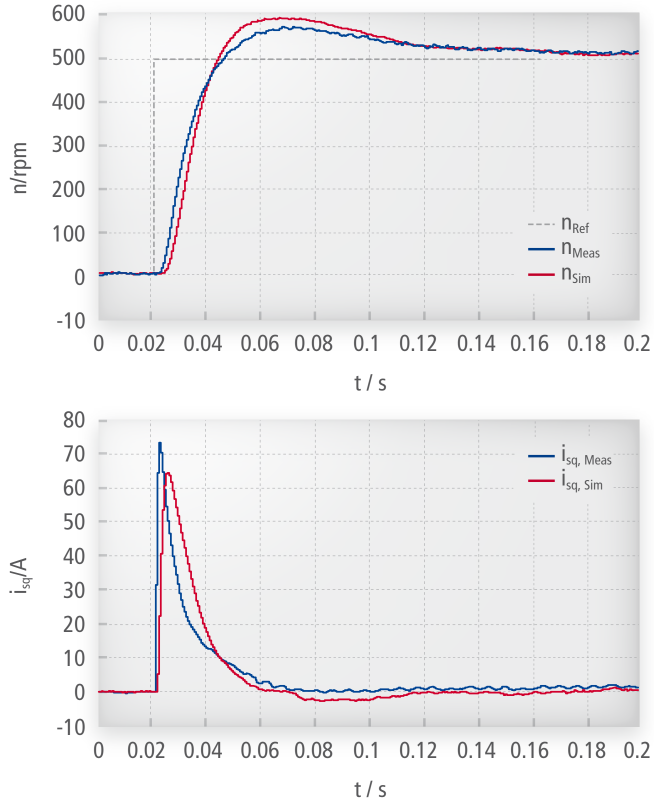


Figure 4: Comparison between motor speed control in HIL simulation (red) and in a real test setup (blue), each with a sampling rate of 125 µs.

Dipl.-Ing. (FH) Thomas Küsterarent,
Dipl.-Ing. Jens Schirmer,
Dr.-Ing. Harald Wertz,
Dipl.-Ing. Ulrich Schumacher
LTi DRiVES GmbH, Unna
Germany

Pictured left to right are:

Dipl.-Ing. (FH) Thomas Küsterarent
develops the software framework for test automation.

Dipl.-Ing. Jens Schirmer
develops the real-time models.

Dr.-Ing. Harald Wertz
is the head of software development.

Dipl.-Ing. Ulrich Schumacher
is Project Manager for the HIL software test project.

NASA’s Top Model

Subscale UAV for test flights under extreme conditions

Aerobatic displays thrill spectators with maneuvers that push the aircraft to their limits. NASA is researching even more extreme flight situations with its unmanned aerial vehicle (UAV).

At its Airborne Subscale Transport Aircraft Research facility, called AirSTAR for short, NASA is using an unmanned aerial vehicle (UAV) to study flight situations that would be too dangerous and too expensive with a real aircraft. The role of the flight control computer is played by a dSPACE system which communicates by radio.

Scaling Effects: Smaller, Stronger, Faster

In an effort to improve aviation safety, engineers at NASA are looking to understand flight dynamics in abnormal and upset conditions and design automation systems that can help to maintain safe controlled flight. Loss of control can occur when events such as structural damage, hydraulic failures, or icing build-up have so changed the vehicle's performance that traditional autopilots fail and pilots are faced with highly coupled controls and oscillatory or even divergent handling characteristics. To study these flight conditions, a subscale UAV was designed and integrated with a highly automated ground station for piloted testing. Because the UAV is scaled down to 1:18 the size of a full-scale transport aircraft, the test model responds much more quickly to pilot inputs than a full-scale vehicle. However, with a careful structural design that scales the mass distribution and density along with the geometry, these subscale vehicles retain the dynamic coupling and response characteristics of the full-scale system. Flight test results from these vehicles can be scaled in time (by the square root of the scale factor) to predict full-scale dynamic behavior. This retains relevance to the target application of commercial transport aircraft, but allows experiments to be conducted which have more risk and may incur much larger structural loads than would be feasible on a full-scale aircraft.

Figure 1: Test flights with the UAV (here in front of the mobile ground station) serve to optimize the functions for flight control computers in passenger planes.

1. Navigation display, top-down view of location, heading and range limits
2. Aircraft configuration display, surface positions, engine settings, and test-card details and system status indicators
3. Primary heads-up display, a synthetic, out-the-window view overlaid with airspeed, altitude, g-load, flight-path information, and warning indicators
4. Secondary NAV display (redundant for safety)
5. Secondary HUD display (redundant for safety)
6. Analog ground-based tracker camera view
7. Analog in-flight nose camera view
8. Discrete mode selection switches, to invoke failure emulation and control algorithms

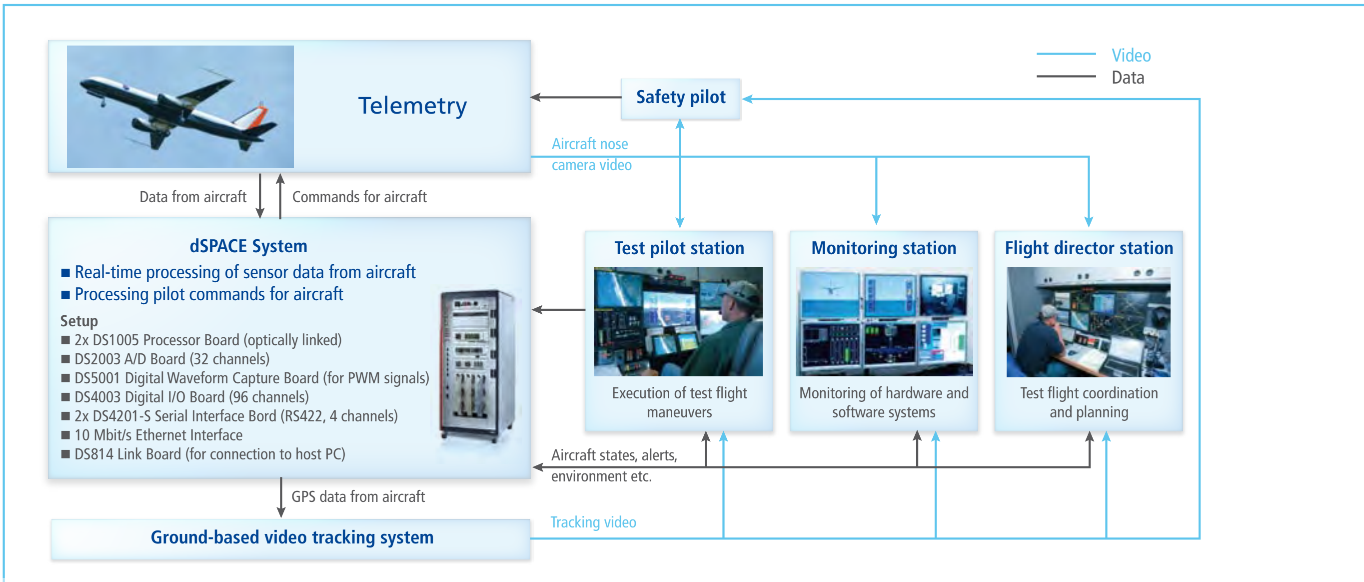
Figure 2: The test pilot's station. Communicating with the UAV by radio, the dSPACE system performs all the ongoing real-time computation tasks so that the test pilot can fly any desired maneuvers realistically from the ground.

Flight Control with the dSPACE System

Although the aircraft is small, the algorithms NASA is interested in testing can be quite large. Advances in control theory and real-time system identification are typically made at the researcher's desktop, with algorithm prototypes implemented in a model-based simulation tool like MATLAB®/Simulink®. One goal of the AirSTAR program was to reduce the amount of time required to rehost these algorithms to a real-time system for flight testing and provide ample computing power for researcher code. By doing this rehosting process quickly, it is possible to provide real-world test results during an early stage of technology development, where they can inform and influence the direction of ongoing research. This capability was provided by employing a dSPACE system on the ground that communicates with the vehicle over a high-bandwidth telemetry link.

In addition to the UAV itself, the AirSTAR test facility includes a mobile ground station for piloting and monitoring the vehicle. The ground station's computer systems consist of a multi-CPU dSPACE unit and several connected workstations for display generation and data logging. One CPU of the dSPACE system has the "ship systems", which handle pilot inputs (discrete, analog and PWM I/O), manage the telemetry stream to and from the aircraft (RS422 serial), and calibrate and process data to drive real-time displays (UDP). The second dSPACE CPU is dedicated to research control algorithms which are invoked during the flight under both nominal and failed vehicle configurations. These control algorithms are routinely swapped out for different flight experiments, and implement code developed and prototyped in Simulink using a simulation model for

Figure 3: Schematic of the mobile AirSTAR test facility. The flight control system installed on the dSPACE system receives telemetric data from the UAV and sends pilot commands and other parameters to the UAV. For a closer look at one of the three control stations (the test pilot station), see figure 2.



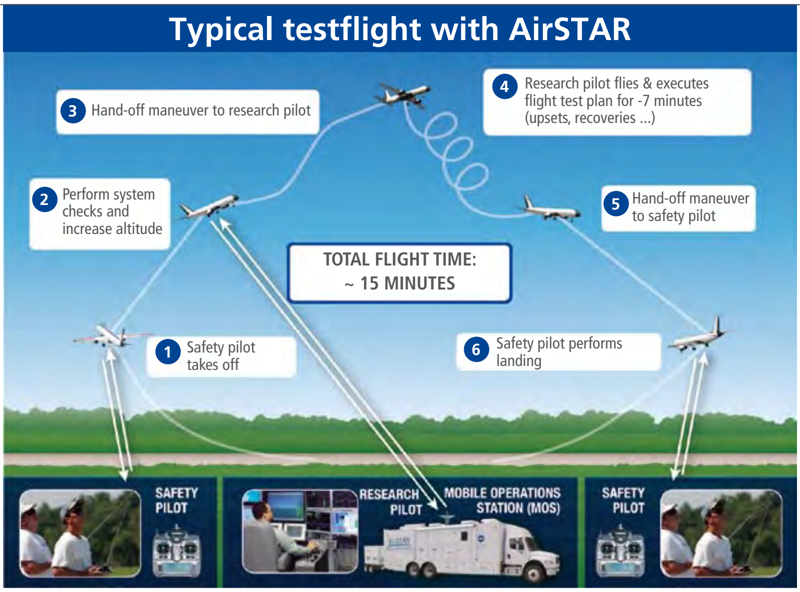


Figure 4: A typical test flight procedure. The main focus is on investigating loss-of-control scenarios and appropriate recovery maneuvers.

the vehicle. The use of a secondary CPU for this code not only provides a high level of computing power but also allows the master CPU to monitor and isolate any software faults, including code lockup, segmentation faults, or unbounded behavior, and automatically revert to a ship-system controller. The telemetry stream provides over 70 channels of raw data at 200 Hz, but with real-time calibrations, corrections and the calculation of derivative variables, this data set grows considerably. Over 500 variables at 200 Hz are streamed to disk via the dSPACE host PC optical link, including 75 variables provided to document internal variables to study the control algorithms during flight. This data set is available as a MATLAB file within minutes of landing, providing researchers with an opportunity to understand test results and if necessary modify test plans during flight test deployment.

> "The dSPACE system provides the performance required by the complex real-time computations during test flights with the UAV."

Tommy Jordan, NASA Langley Research Center

A Typical Test Flight Procedure

The UAV can make flights lasting about 15 minutes. A second pilot, the safety pilot, in visual contact with the vehicle, performs the take-off and landing phases, and hands off the UAV to the test pilot only after a specific altitude has been reached. The test pilot runs through the flight program in the remaining time, piloting the vehicle from the simulator-like displays in the mobile ground station. As part of the NASA Aviation Safety Program, the declared aim of the test flights is to especially analyze what are called loss-of-control scenarios – extreme flight situations combined with the failure of onboard systems – and to evaluate suitable recovery maneuvers. The test pilot can choose to fly with the support of the flight control system or without it. He or she can also feed in freely configurable failure scenarios, which lock up control surfaces or destabilize the vehicle's dynamic response. To avoid exceeding the UAV's structural strength, a load protection algorithm monitors thrust and control surface settings and can limit inputs in emergency situations. In addition, the safety pilot always has overriding control of the test flight – the ability to intervene at any time and take over control of the UAV from the test pilot.

Summary and Outlook

NASA uses the AirSTAR test facility to perform test flights with a UAV for investigation of abnormal flight situations, including loss of control, that cover a large proportion of fatal accidents in commercial aviation. The ground-based flight control system is implemented as a dSPACE system. It processes the measurement values collected by the UAV and also the test pilot's flight commands in real time, supports the generation of data for flight displays, and records test data for post-flight analysis. Future plans for the system include an expansion of test conditions, algorithm complexity, and the introduction of different vehicles into the system. Due to its flexible design, the ground processing system can accommodate these changes with very little modification to its architecture and software. ■

Tommy Jordan
NASA Langley Research Center
USA

Tommy Jordan is AirSTAR project manager at the NASA Langley Research Center, USA.

AVL Raptor:
Hungry for Engines

A rapid prototyping controller for combustion engines

AVL Raptor provides the customers of the entire AVL group with a quick, flexible way of creating and testing the control of complex engine configurations for demonstration and calibration purposes. The solution is based on models developed by AVL using dSPACE prototyping hardware. Models from customers and suppliers can also be included.

Rapid Prototyping for Complex Engine Controls

Engine controls help to meet a wide range of engine requirements: Current and future emission limits have to be met, fuel consumption has to be further reduced, all driving states and driving styles require optimum support – and all this has to be achieved as inexpensively as possibly. Technologies such as variable valvetrain, variable geometry turbo, and direct injection with multiple injections increase the degree of freedom, and requirements like these are what gives engine controls their high internal complexity. In the final analysis, they consist of thousands of parameters and submodels, and calibrating these takes an enormous amount of time. Calibrating the controller on a test bench can easily take up to 12 months, not including the time needed for performing in-vehicle calibration in winter and summer tests, and on the dynamometer test bench. For mass-produced engines and commercial engine controls, such a comprehensive procedure is both necessary and efficient. Performing rapid prototyping for demonstration purposes and for test operation of engine ECU software requires much faster and more flexible solutions, however. For cost efficiency, production controllers are precisely tailored to the target application, but prototyping systems for test purposes require flexible I/O, high processing power, support for managing complexity (achieved by testing subsystems or by using fewer input variables), the ability to perform offline simulation, and the ability to generate code quickly for tests with prototyping hardware.

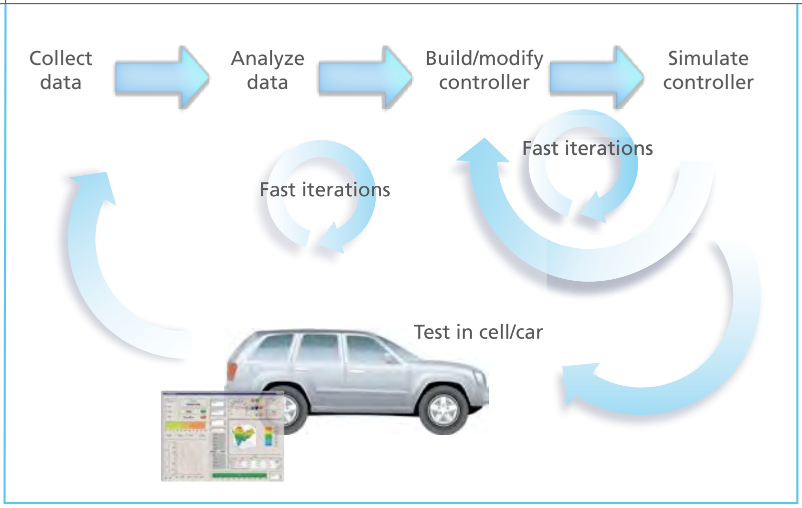
Platform for Rapidly Developing Engine Controls

AVL has a long history of developing engine controls for production, both for OEMs and for Tier 1 manufacturers. The AVL Raptor tool set is a result of this extensive experience. The platform can be used for normal algorithm development as well as rapid prototyping. It gives the developer an environment where the functionality is tested offline using the model-in-the-loop environment, or online using the rapid prototyping controller. The simplicity with which the platform can be used offline and online really increases the pace of development, as the entire system is tested with all the interactions, not just one function with synthetic input.

AVL Raptor: Save Time Prototyping

AVL Raptor gives the international customers of AVL a complete rapid prototyping controller for test operation of engine ECU software, based on dSPACE RapidPro hardware, dSPACE MicroAutoBox, and models by AVL and models provided by customers and suppliers. Even though a production controller is often available and accessible, it is in many cases too complex or has limited I/O, so a rapid prototyping controller like AVL Raptor is an ideal solution. AVL Raptor is a complete engine controller, including a fully developed torque structure and a basic operating system, and the software is module-based, with every module in its own library. This is combined with a user interface where the user selects the modules needed for the build, making it very easy to add a component such as a new actuator or even to switch completely from a gasoline to a diesel controller. The controller uses in-cylinder pressure for closed-loop feedback control and is suitable for test bench and in-vehicle operation. It is so modifiable that it can be

AVL Raptor offers a complete rapid prototyping controller for test operation of engine ECU software, based on dSPACE RapidPro hardware, dSPACE MicroAutoBox, and models by AVL and those delivered by customers and suppliers.



AVL Raptor: Rapid prototyping controller for offline simulation, test bench and vehicle tests.

> “The flexibility of the dSPACE RapidPro system combined with the AVL Raptor environment enables us to significantly accelerate even very complex development tasks of our customers.“

Richard Backman, AVL Södertälje Powertrain Engineering AB

used for any engine type. With AVL Raptor, AVL and their customers can achieve 90% of the desired final state in only 10% of the time that calibration normally takes. This is ideal for demonstration purposes, for example, when new technologies are adopted.

AVL Raptor: Model Integration and Simulation

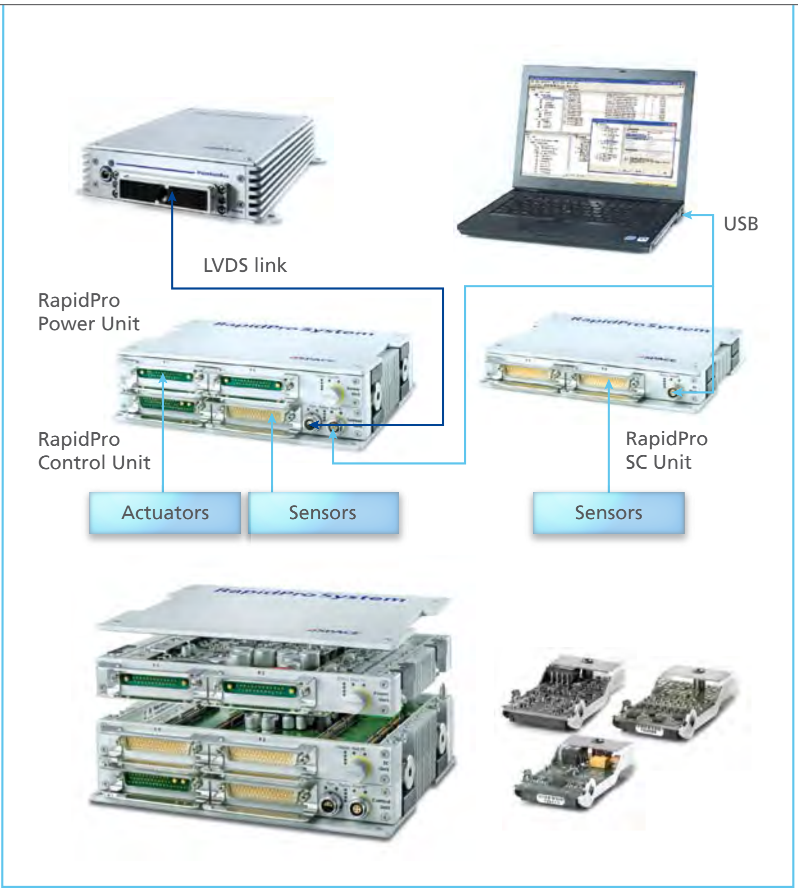
AVL provides a complete model-in-the-loop environment for running through an entire NEDC (New European Driving Cycle) offline. This environment comprises an engine model, a combustion model, a transmission model, a driver model, and a sensor and actuator model. Customers can also use other models as alternatives to those developed by AVL. The simulation time for the model and controller is faster than real time, but if there is no engine for which data can be generated to the models, AVL offers the use of advanced simulation tools, so that controller strategies can be simulated and implemented for an engine before that engine even exists. For example, it is possible to use AVL Boost for such applications. With the help of dSPACE RapidPro, the development team collects the input data and analyzes it, then builds the controller, tests it offline and compiles it, finally loading it to the real-time hardware (dSPACE MicroAutoBox). It is also possible to validate and verify production code parts on the proto-

Hardware and Configuration of the AVL Raptor

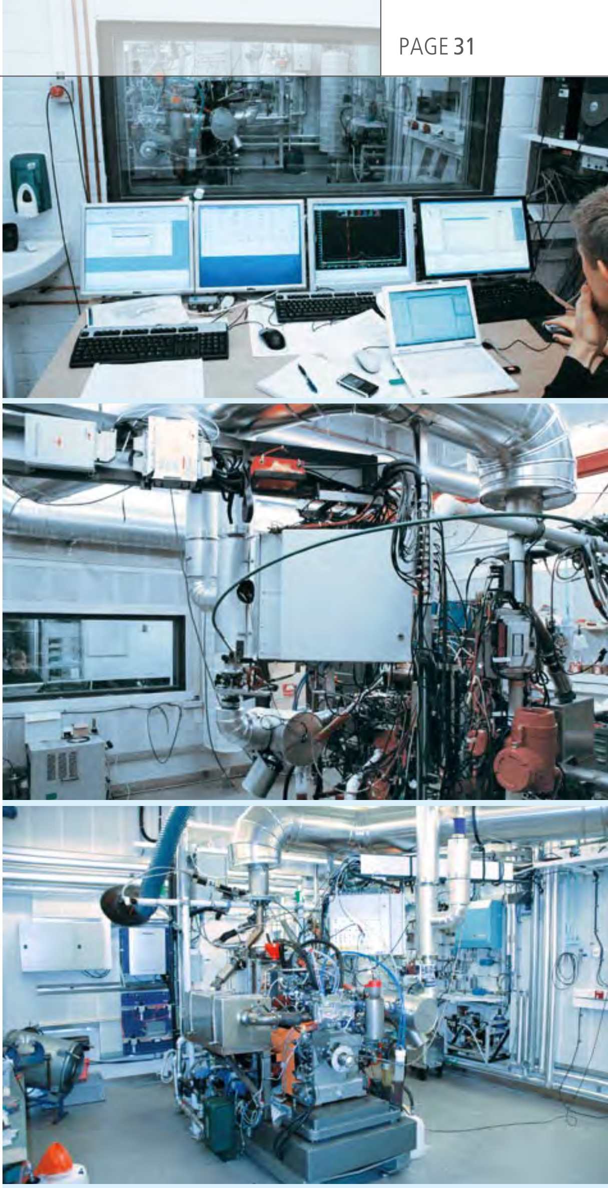
- MicroAutoBox
- RapidPro hardware
- Typical sensor/actuator connections (customer-specific):
  - Half bridge
  - High-pressure fuel pump
  - High-pressure injector actuator (multiple injection)
  - Injection actuator (multiple injection)
  - Support for up to 12 cylinders with additional angle-based control
  - Various crank-angle decoders
  - Camshaft phaser support
  - Lambda sensor
  - Temperature sensor
  - CAN communication using DBC files
- Complete vehicle interface
- Cylinder pressure interface

Richard Backman
Expert, Advanced Engineering Controls & Software, AVL Södertälje Powertrain Engineering AB, Sweden

Jonas Cornelsen
Development Engineer, Advanced Engineering Controls & Software, AVL Södertälje Powertrain Engineering AB, Sweden



dSPACE hardware used for AVL Raptor.



AVL Raptor including a dSPACE system can control, for example, a single-cylinder test bench for gasoline engines with a fully flexible valve system.

typing hardware by means of wrapper code. For automatic tests, AVL uses the experiment software dSPACE ControlDesk in conjunction with Python scripts. AVL uses AVL Raptor in offline simulation, on a test bench, and in vehicle tests. Around 99% of all bugs in a new controller are found by simulation alone.

In Action

AVL Raptor is already running in numerous projects. At AVL in Södertälje, a dSPACE system controls a single-cylinder test bench for gasoline engines with a fully flexible valve system. The KTH Institute of Technology (Kungliga Tekniska Högskolan) in Stockholm is operating a comparable test bench for diesel engines, and Linköping University and Lund University are planning multicylinder test benches for gasoline engines. A demo vehicle for using AVL Raptor on the road will be available soon.

Great Application Potential

AVL Raptor enables AVL and their customers to create any conceivable, complex engine configurations, develop them in closed-loop simulation, and demonstrate them in a vehicle. This also includes technologies such as homogeneous charge compression injection (HCCI) and hybrid drives.
The rapid prototyping controller makes it possible to calibrate standard functions at a point in time when the production controller does not yet exist. AVL Raptor can also be used to run endurance tests on engines, again before the production controller even exists. AVL Raptor is especially well suited to research and teaching in the field of combustion engines. ■

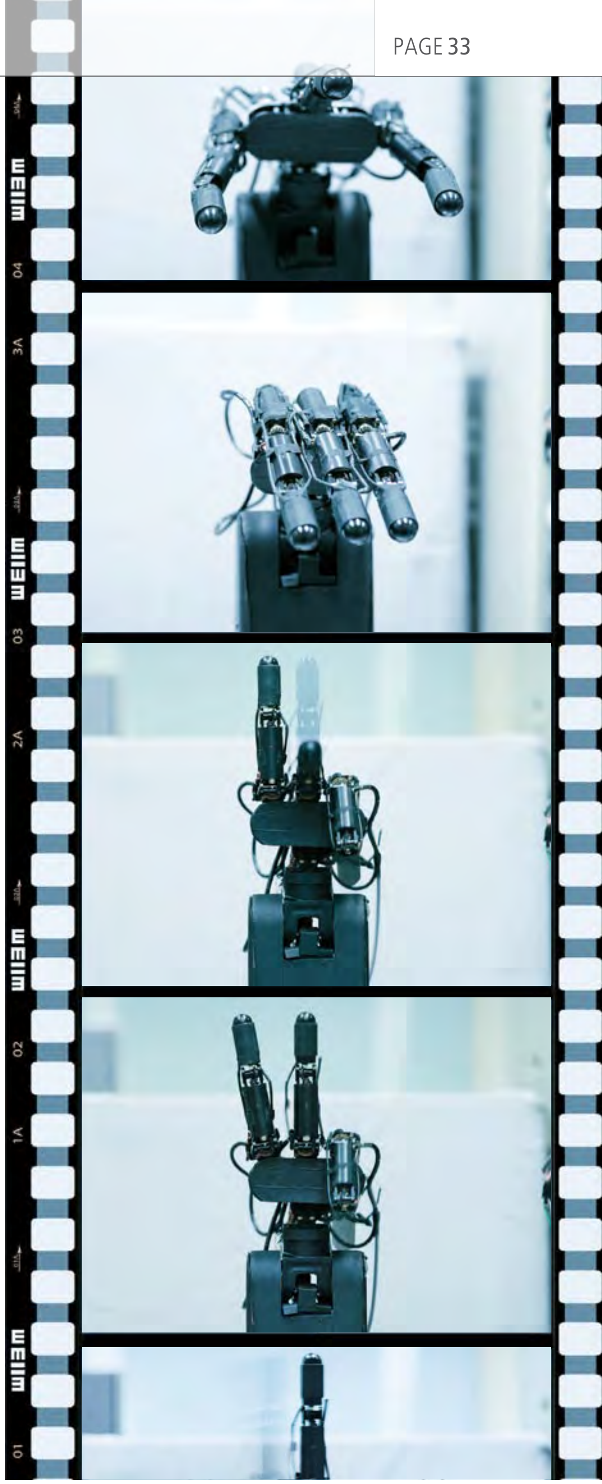
Richard Backman,
Jonas Cornelsen
Advanced Engineering
Controls & Software
AVL Södertälje Powertrain Engineering AB
Sweden

Conclusion

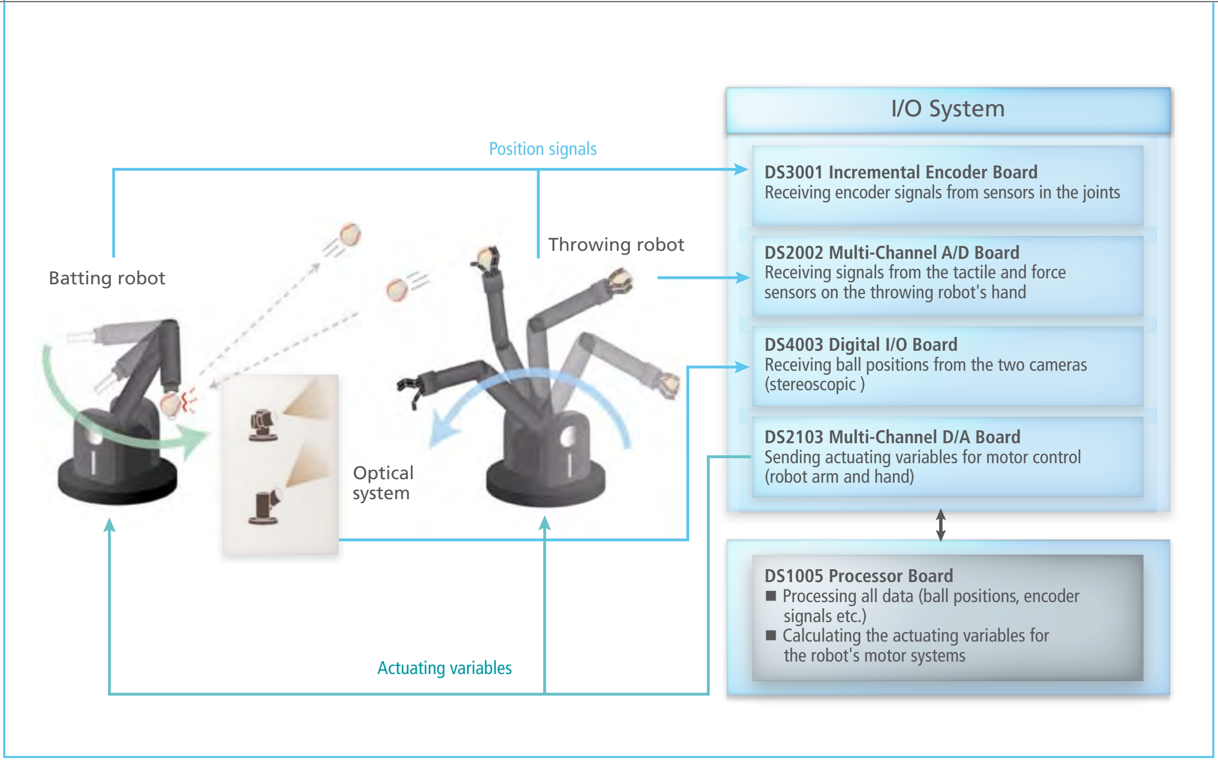
- AVL Raptor: dSPACE RapidPro and dSPACE MicroAutoBox as a powerful rapid prototyping system for engine ECU software
- Flexible model integration, flexible engine configurations
- Calibration work for demonstration and test purposes dramatically reduced
- Prototyping platform for verifying production code algorithms

Home Run in Lab

Baseball-playing robot system demonstrates perfect and quick pitching and batting technology



Ultra-high-speed robots are expected to open up new fields of applications. With extremely high kinematic performance and stupendous cognitive capabilities, they surpass the human processing ability and challenge the limitations of machines. A project based on two robots at the University of Tokyo demonstrates the state of current research.



The throwing and batting robots are arranged like baseball players. The dSPACE system evaluates signals from sensors and a stereoscopic camera via several interface boards to calculate the motor control values.

Human Cognitive and Kinematic Abilities

In contrast to conventionally developed computers, the human brain is highly adaptable. This is because the brain is not a closed system comprised of the nervous system, but an open system that obtains information from the outside world through a very large number of sensory organs. It uses multiple kinematic control functions to affect the outside world, and it can also increase its adaptability and learning ability through the exchange of information with the outside world.
Pianists, circus acrobats and jugglers are examples of the ability to perform highly flexible, reliably harmonized cognitive and behavioral functions.

The Ultra-High-Speed Robot

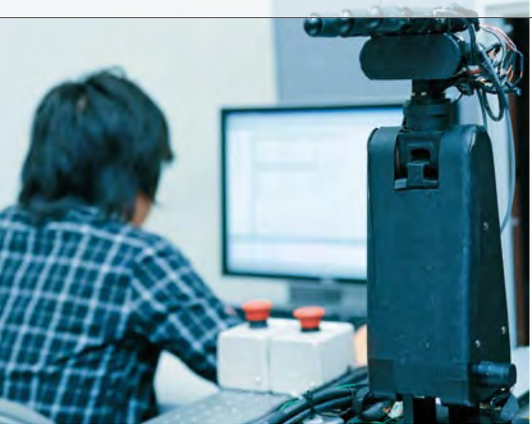
The aim of a research project at the University of Tokyo was to construct an ultra-high-speed robot system capable of far exceeding human or conventional robot performance.
To achieve the speed performance, the specifications included the following components:

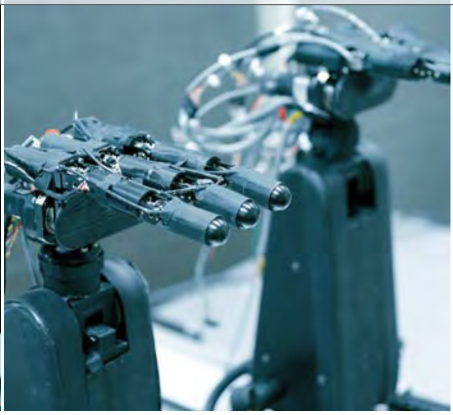
- Optical system capable of processing the image data – including taking, sending, and calculating images – within 1 kHz.
- Lightweight robot hand with three fingers – the lowest number for stable manipulation – featuring miniature motors with high torque-to-weight ratio.

> “With the modular hardware from dSPACE we were able to set up a robust, high-performance real-time system for our high-speed robots.”
>
> *Dr. Taku Senoo, University of Tokyo*

System Design

The system built in this research project consists of a robot arm, robot hand, optical system, several sensors, and a real-time control system based on dSPACE hardware. Around the tips of the fingers of the hand are film-type tactile sensors, while force sensors are fitted to the joints of the fingers, allowing data relating to contact with objects to be obtained at 1 kHz. The high-speed hand, jointly developed with Harmonic Drive Systems Inc., can open and close 180° in 0.1 seconds. The optical sensors and processors of the optical system were developed with Hamamatsu Photonics K.K. Designing the camera head as an active vision system with a 2-DOF (degrees of freedom) mechanism able to pan and tilt allows tracking control that can keep an object in the center of the field of vision as with the movement of the human eyeball. The stereoscopic vision based on two active vision systems allows reconstruction of three-dimensional shapes. The control software for download to dSPACE system was developed using MATLAB®/Simulink®.





Baseball Experiments

In the experiments, one robot plays the role of the thrower (pitcher), while the other plays the batter. In throwing, steadily migrating the speed peak time from shoulder to fingertips increased energy propagation efficiency and resulted in a high-speed, smooth swing. In batting, distributed control of the motion of swinging the bat at high speed and the motion of following the ball made it possible to respond to and strike a curve ball while swinging at high speed.

Score

The result was a system in which a batting robot situated 3.9 meters from a throwing robot was able to hit the ball back with a swing time of 0.2 seconds. Using its fingers like a human, the throwing robot was able to control the release timing instantaneously and the direction precisely to hit the ball into the strike zone. It was also possible to pitch the ball to any set target point. As the batting robot adjusts the bat trajectory every 1 kHz in accordance with the three-dimensional location data calculated by the active vision systems, the ball can be hit back even if it is a curve ball or just randomly thrown. In this experiment, because the distance between the two robots was short (the laboratory was small), the pitching speed was limited in accordance with the batting swing time. But calculated to the distance between the actual pitcher mound and home base (18.4 meters), in theory it would have been possible to hit the ball at 300 km/h.

Role of the dSPACE System

The role of the dSPACE system was to receive the sensor data, calculate the motion trajectory between the throwing and the batting robots, and forward instructions to the motor driver. A modular approach with an expansion box was used and proved to be an extremely convenient way to create a large-scale system. ■

Dr. Taku Senoo
University of Tokyo
Japan

Dr. Taku Senoo
Dr. Senoo is a Project Research Fellow at the University of Tokyo, Department of Creative Informatics and Graduate School of Information Science and Technology.

Outlook

In the future, ultra-high-speed robot systems will be used in accumulating and systematizing a range of skills. In our laboratory, we already achieved dexterous high-speed manipulation tasks such as pen spinning, dribbling a small ball between two fingers and catching ultra-small objects by actively using non-contact and unstable states. Controlling these basic skills is expected to lead to the creation of new forms of robot operation involving dynamic motion rather than conventional forms of robotic operation where tasks are performed semi-statically while constantly maintaining a state of contact with the object.

Demo video at
www.dspace.com/goto?cv

Superbike Success from the Electronics Lab

As an official partner to BMW Motorrad Motorsport, BMW's motorcycle motorsports division, dSPACE has brought the Superbike World Championship circuits into the lab.

The BMW motorcycle motorsports team is in the fast lane. Since 2009, BMW Motorrad has been competing in the Superbike World Championship, and with success. After safety, racing's number one priority, reliability is a major issue – especially in the engine controls for racing machines. BMW Motorrad relies on dSPACE to validate the quality of their completely self-developed electronic control units.

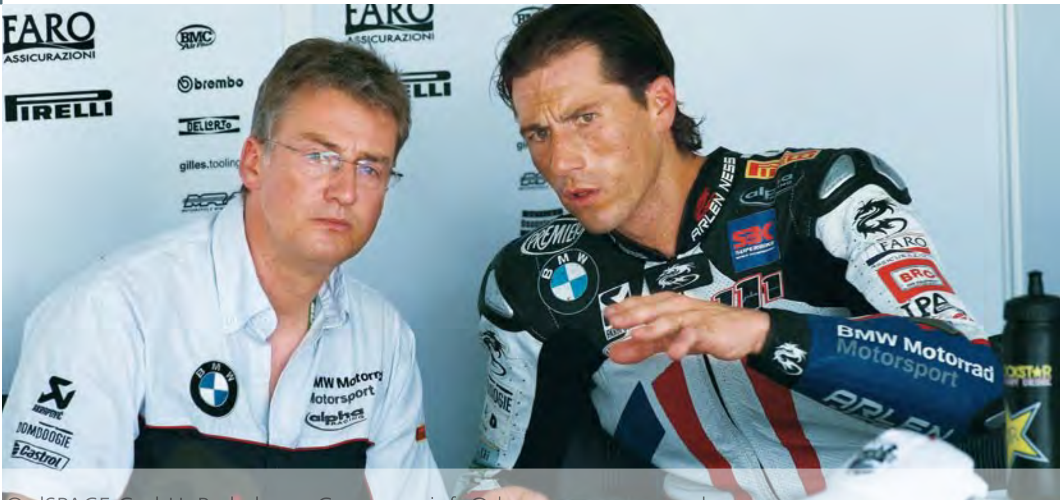
Motorsports Center of Excellence

Even though BMW Motorrad looks back on 87 years of racing tradition, in the Superbike World Championship the company is a newcomer. The BMW team stood at the World Superbike starting-line for the first time in 2009, with the S 1000 RR racing machine. In Stephanskirchen near Rosenheim in Upper Bavaria, Germany, BMW and alpha Racing jointly set up a motorsports center of excellence to further develop the racebike. BMW development engineers are responsible for ensuring that the S 1000 RR competes well in the World Superbike class.

Electronics Development at BMW Motorrad

Electronics development is one of BMW's core competencies in the field of motorsports. The self-developed engine control, the RSM5 (Racing Sport Engine Control, 5th Generation), plays a major role in the Superbike project. From selecting the processors and components to designing circuit boards and programming low- and high-level functions, all the work steps are performed at BMW Motorrad. This enables the team to respond quickly and flexibly to new requirements imposed by the test tracks and race

>> Continued on page 39



BMW rider Ruben Xaus deep in concentration with racing engineer Wolfgang Martens shortly before the race in Portimão, Portugal.


Ernst Henne

Milestones

in BMW Motorrad's 87 Years of History

Chief designer Max Friz developed BMW's first motorcycle, the R 32, in **1923**.

In **1933**, Ernst Henne's team brought home the European Offroad Championship title on 33-HP, R16-type Boxer machines in Wales. Offroad races were used to try out innovations. Both telescopic forks and the first BMW rear-wheel suspension passed the acid test of six-day events before being installed in production models.

In **1937**, Ernst Henne achieved a world speed record of 216.75 km/h. The record was unbroken for 14 years and brought BMW worldwide respect as a motorbike manufacturer.

In **1963**, the BMW competition machines made a technological breakthrough with their new chassis, whose ride stability set new standards on US highways. It was later integrated into the 5-Series in **1969**.

BMW's first Superbike success came in Daytona, USA, in **1976**. The American Steve McLaughlin won the AMA Superbike event in an exciting photo finish against his team colleague.

The R 100 RS launched by BMW in **1984** was the world's first production motorcycle with a full fairing. The development work had focused on aerodynamic aspects and on protecting the rider from the wind and the weather.

Frenchman Hubert Auriol, nicknamed "the African" because of his navigation talent, won the Paris-Dakar desert rally, the toughest rally in the world, for BMW in **1981** and **1983**.

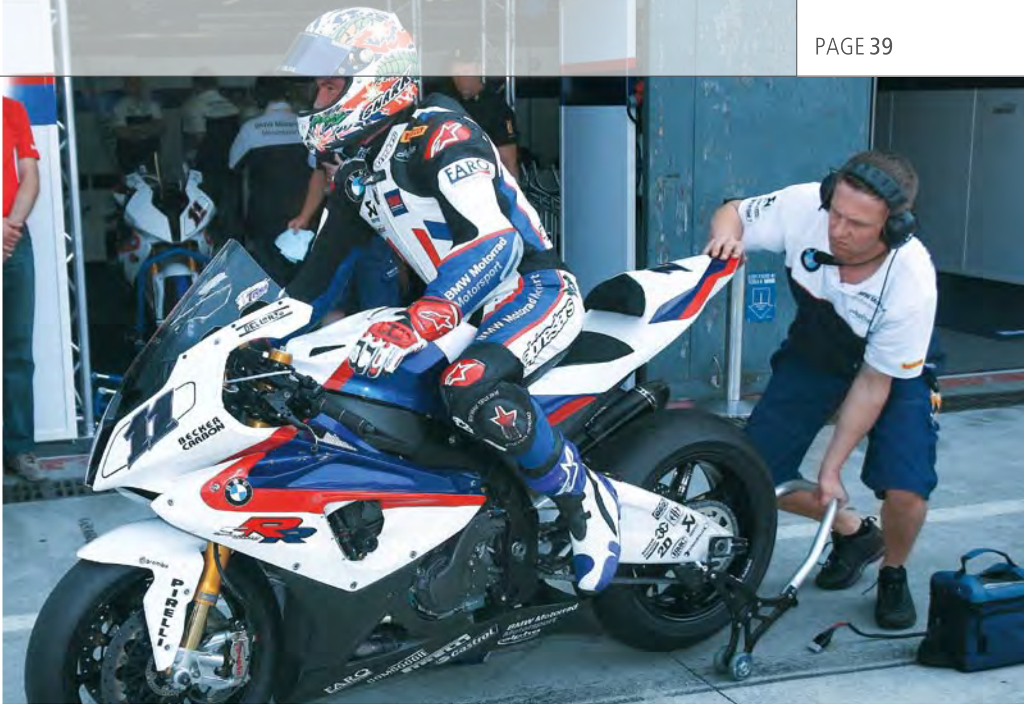
In **1988** BMW was the first manufacturer in the world to market an electronic, hydraulic antilock braking system (ABS) for motorcycles.

At INTERMOT **2004**, BMW presented the K 1200 S, their first transversely mounted four-cylinder engine. Its 167 HP (123 kW) took BMW Motorrad into new power dimensions.

The team first competed in the Superbike World Championship in the first race in Phillip Island, Australia, in **2009**. The BMW S 1000 RR production machine has innovative features such as a 2.5 kg lightweight racing ABS and dynamic traction control that permits slip depending on the lean angle.

In **2010**, BMW riders Troy Corser and Ruben Xaus were among the first ten at the Superbike event in Portimão. Troy Corser took 4th place at the race in Valencia, BMW Motorrad's best World Superbike class result to date. More exciting races on legendary race tracks such as the Nürburgring and the circuit in Imola will follow.

Daytona



Last check on the superbike before the race. Even BMW pilot Troy Corser gets a bit nervous.

>> Continued from page 37

tracks. For example, over 14 software versions were created and driven for the 28 worldwide Superbike races on the 14 days of the 2009 season.

Top Priority: Reliability

Electrics and electronics make a bike not only fast, but also reliable. “To finish first, first you have to finish.”: The BMW racebike team embraced this motto and chose to use a dSPACE Simulator Full-Size as a hardware-in-the-loop system to test the ECUs, including running automated tests under dSPACE AutomationDesk (Figure 1). The simulator primarily performs three main tasks:

- Automated quality assurance of ECU hardware
- Automated, individual ECU calibration
- High-level software development with the aid of a complete vehicle model

> “BMW Motorrad’s development philosophy is to find problems before they reach the test track or even the race track.”
>
> *Ralf Schmidt, BMW Motorrad*

Automated Quality Assurance

To put the RSM5 engine control on the track absolutely reliably and to reproduce it easily for small production runs, the quality of the ECUs must be validated by automatic testing. Errors in the electronics are not acceptable, because any possibility of failure on the race track or test track must be excluded.

After each hardware and software change, the ECUs undergo a test program lasting almost two hours on the dSPACE HIL test bench. The inputs for the tests are simulated on the simulator, and the outputs such as ignition and injection signals are read back via the simulator. These signals are then compared with the calculated values of the ECU that the simulator sends to the ECU via the ASAM MCD-3 interface. The permitted deviations are evaluated, and then documented and archived in a test log of over 100 pages. If a channel is above a predefined deviation limit, the entire ECU is taken apart completely in an intensive test to hunt down the cause and fix the error. This approach is the only way to ensure the quality of the hardware and software reliably and continuously, and has given the systems their extremely high standard.

Automated, Individual ECU Calibration

Because only very small quantities of the ECUs are produced, production tolerances can occur, for example, in the gain and offset values on some analog input channels. To eliminate these deviations, the simulator performs automated measurements on each ECU. This is done with AutomationDesk, where a test protocol is implemented to apply specific signal voltages to each individual input channel on the ECU. Each voltage value is transferred from the ECU to the simulator via the ASAM MCD-3 interface, and the deviation is logged. Then an individual binary calibration file is automatically created with MATLAB® and written to the ECU’s flash memory.

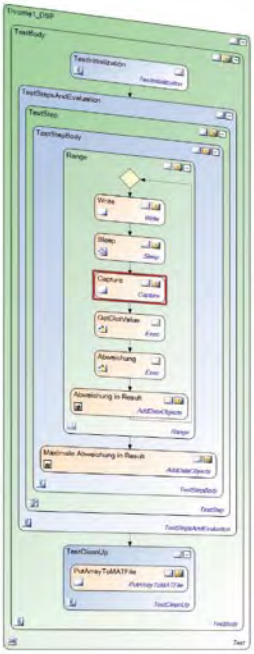


Figure 1: AutomationDesk provides a graphical user interface for creating and modifying test projects and test sequences.

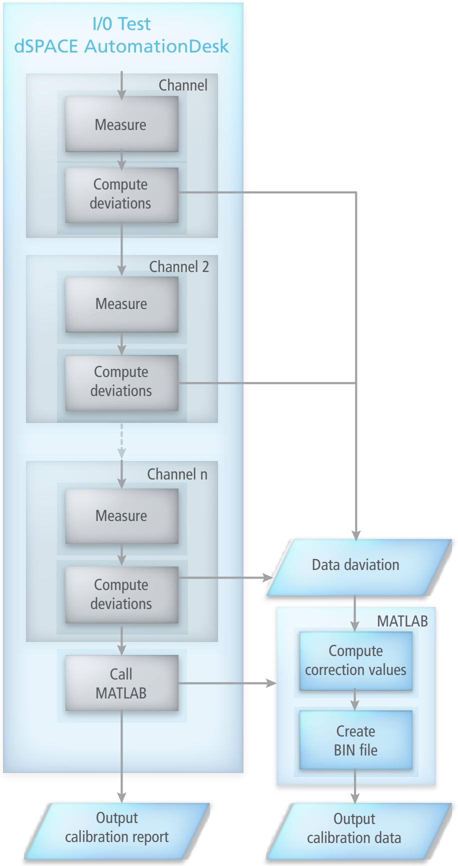


Figure 2: Finding the correction values with the ECU calibration system consisting of flexible hardware and scalable software for measurement, calibration and diagnostics tasks.

Laboratory test on BMW Motorrad Motorsport's RSM5 engine ECU with the dSPACE HIL test bench.

Functions in the ECU software use this calibration data to compensate for component tolerances in each individual ECU. Even BMW Motorrad's two professional riders Troy Corser and Ruben Xaus noticed the resulting quality boost and gave very positive feedback on the identical reproduction of the ECUs (figure 2).

Developing a Complete Vehicle Model

At the end of 2009, work started on developing a special vehicle dynamics model for the racing version of the BMW S 1000 RR in MATLAB/Simulink®, initially focusing on the vehicle's longitudinal dynamics. The objective is to generate a representation of a real vehicle that is as realistic as possible to simulate complex control functions, such as traction control, launch control and wheelie control, in the laboratory. The development laboratory in Stephanskirchen gives the team ideal conditions for this. The center brings together the know-how of experts from the engine and chassis fields, and also from the alpha Racing team, who all provide input for a representation of a real vehicle that is accurate in every detail. This saves a lot of time and money that would otherwise be spent on items such as track time, i.e., on renting the race track, staff and equipment.

The Race Track in the Lab

With the numerous test runs made by the S 1000 RR and the 28 races in the 2009 World Superbike season, the powerful data logger integrated into the RSM5 engine control ECU captured an enormous volume of recorded data, which can now be used as stimuli for the vehicle's newly developed model:

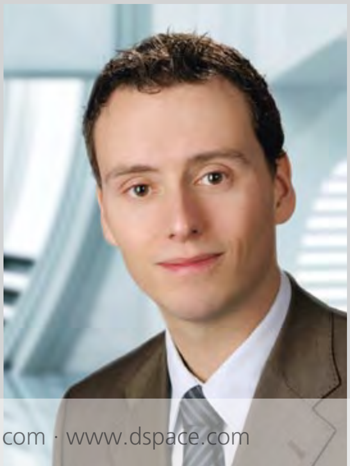
- Throttle grip
- Steering angle setting
- Hydraulic pressure of front- and rear-wheel brakes
- Gear position
- Force on the gear shift lever
- Start button
- Emergency stop switch

The first laboratory experiments showed that the model values calculated for the longitudinal dynamics are virtually identical with the real values in the racebike. The simulation covered legendary circuits such as Nürburgring, Monza and Valencia, which are all venues for the Superbike World Championship and therefore available as a data collection for simulation with the dSPACE simulator.

The Challenge of Lateral Dynamics

Lateral dynamics are the most difficult block in the vehicle model. The vehicle dynamics of a single-track vehicle are extremely complex due to constantly changing tire contact force caused by the bike rider shifting weight. Only a precise model of the vehicle's center of mass location can represent these dynamics. For example, during

Ralf Schmidt,
BMW Motorrad Motorsport
Electrics/Electronics Development
Munich, Germany



Superbike S 1000 RR – Technical Data:

Engine displacement:	999 cm³, four-stroke, four-cylinder, liquid cooling
Transmission:	6 gears
Power:	> 200 HP at >14,000 min^{-1}
Bore x stroke:	80 x 49.7 mm
Compression ratio:	14:1
Dry weight:	162 kg
Front-wheel suspension:	Öhlins upside-down telescopic fork, ø 43 mm
Rear-wheel suspension:	Öhlins TTX

> "Automated ECU quality assurance has become indispensible at BMW Motorrad, because the two attributes of complete reliability and identical reproduction of ECU controls are absolutely essential."

Ralf Schmidt, BMW Motorrad

acceleration the rider moves his or her body weight forward to counteract the rising front wheel, known as a wheelie. During tight cornering, the steering angle causes the vehicle to lean into the turn by up to 65 degrees. The tire contact force and the resultant possible force transmission of the engine depend to a very high degree on the rider's weight shifts. The aim is therefore to create a realistic model of these actions to ensure the BMW team's continued success in the World Superbike class.

Looking Forward to World Superbike 2010

BMW riders Ruben Xaus and Troy Corser aim to deliver constant results in the 2010 season. Their team has set itself the goal of improving the electrics and electronics in the S 1000 RR and also the simulation models as a major contribution towards the S 1000 RR's success in the Superbike World Championship. ■

Ralf Schmidt
BMW Motorrad Motorsport
Electrics/Electronics Development
Munich, Germany

Superbike rider Ruben Xaus and racing engineer Wolfgang Martens feel good about the S 1000 RR's performance.

Formula Student is a well-known international competition that judges not only speed but, more importantly, know-how. With the 2010 season about to begin, dSPACE visited the UPBracing Team at the University of Paderborn in Germany for an inside look at ongoing development work. The team is focusing on extending the electrical and electronic components, even including an electronic clutch.

Behind the Scenes

The UPBracing Team is fine-tuning new components for its racing car to gear up for the 2010 season of Formula Student.

Formula Student Opens Doors

There is hardly a German university without a Formula Student team. The Association of German Engineers (VDI) began holding the Formula Student Germany competition in 2006. Since then, it has grown into a major project, watched with interest and great respect by universities and the automobile industry alike. Participating students find that it opens doors for them, as partner companies in their recruitment processes proactively search for students with Formula Student experience. So it is no surprise that in the last few years, the available starting slots in Formula Student Germany were taken up within minutes of registration opening.

The teams are constantly improving, and the standard of competition in Germany is also getting higher, even though it already enjoys a reputation as the fairest but most demanding competition in comparison with other countries. Every year, the organizers raise the competition's level of difficulty, ensuring a continuous professional development process which the UPBracing team fully embraces. With the help of dSPACE products, the young engineers have again come up with exciting innovations to impress judges and spectators at the Hockenheimring this summer.

Faster and Lighter with Electronics

Creativity and teamwork are key when Paderborn's up-and-coming engineers plan new vehicle components and then test, build and measure them after weeks of research. To hold their own against the 77 other registered teams, this year the UPBracing team is mainly concentrating on three new features that will reduce the weight of their self-designed racing car, the PX210, and also boost its horsepower.

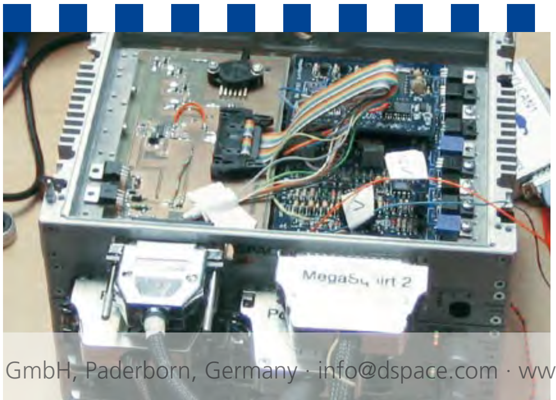
> The fifth injector ensures that fuel is used more efficiently and adds an extra 5 HP.

Structured Cable Harness

In its predecessor, the PX208, each cable is installed and shielded individually, which makes it more difficult to correct any faults that occur. The new vehicle has a structured cable harness that provides quick access. Design work on the new cable harness is very complex and extensive, as each individual connection has to be thought out in advance, and every time a component's position is changed, the entire cable harness has to be rebuilt. The result is impressive: The vehicle's overall weight is slightly reduced, its faults are easier to find, and its reliability has been improved.

The Fifth Injector Adds 5 HP

The installation of a fifth injector has also brought greater power and efficiency. The E85 fuel used by the UPBracing Team has a high heat of vaporization. To use the effect better and to allow the air in the cylinder to start cooling even earlier, the



students installed a fifth injector at the start of the air duct. By injecting fuel into the air duct, the air can be cooled down from 30 °C to 5 °C, improving the supply to the cylinder at high engine speeds. Because the fifth injector needs different injection values, which cannot be adjusted by the engine ECU, the engineering students are using dSPACE's RapidPro system. RapidPro works simultaneously with the same algorithm as the engine ECU and guarantees that all five signals are parallelized and synchronized. The results are more efficient fuel utilization and a power increase of 5 HP.

Hand Clutch

A normal manual transmission car has three foot pedals: the clutch, the brake, and the accelerator. But in the compact PX210, it is difficult for the pilot to reach the middle pedal. So this year, the brake in the PX210 is on the left, the accelerator is on the right, and a hand lever on the steering wheel activates the electronic clutch. When the clutch lever on the steering wheel is moved, the data is passed electronically via a CAN bus to the RapidPro system, which controls the clutch motor. Initially the drivers were very skeptical of this system which is also used in professional Formula One race cars, but soon became enthusiastic. The start-up is smooth, the vehicle handles very well, and there is a good driving feel.

Teamwork and Dedication

Overall, Formula Student is much more than just a design competition for the students. It gives competitors an opportunity to run through the entire process of constructing a product prototype and to get to know important real-world workflows, from the original idea to development work to final manufacture. “We are working just as if we were in a real company,” explains UPBracing team member Denis Wachsmann. Teamwork and interdisciplinary communication play a major role. The different workgroups such as mechanical engineering, IT and accounting constantly have to coordinate with each other and develop a feel for the work that others are doing. “The main thing is not personal victory, but success for the entire team,” adds his team colleague Felix Langemeier.

In the races too, both the participants and the spectators soon realize that fairness and sportsmanship are important components in the competition. The organizers aim to promote soft skills as well, so Formula Student has its own award for these qualities. Even if every team wants to win, the students are not meant to use their elbows, but to lend a hand if another team needs help. 99.9 % of the work done by the young engineering students is learning by doing, and they show enormous creativity and commitment. So a 60-hour week is no exception, as the students are constantly searching for new challenges and are immensely ambitious in their innovative planning. Even so, Formula Student's main aim is the same as ever: fun and enthusiasm for motorsports. ■

The Countdown Has Begun

The UPBracing team still has quite a bit to do before the race begins, and the time left before they get a taste of Formula One racing this summer is shrinking fast. And this year, the students are not only competing at the Hockenheimring from August 4 to 8: They will also be at the starting line at Formula Student Austria.

dSPACE is addressing the unique and demanding requirements of aircraft and satellite development and testing, through new interface boards. Extra channels and features, and new blocksets, have been added to the interface boards for avionics buses ARINC 429 and MIL-STD-1553. And there is now a new interface board for ARINC 717. These solutions are ideal in modular dSPACE real-time systems for hardware-in-the-loop (HIL) testing and rapid control prototyping (RCP) in the aerospace industry.

Testing Aerospace Buses Flexibly and Easily

To run integration tests of several electronic control units (ECUs) with HIL simulators in aerospace applications, a large number of bus channels are required on one interface board, configuring the bus communication for the tests has to be made as easy as possible, and all the properties of the buses under test must be supported. Component tests with one ECU on an HIL simulator partly have different requirements, because bus nodes that are not available during the tests have to be simulated additionally. Here too, though, there needs to be an easy way of defining the bus communication. With MIL-STD-1553, the special bus structure also has to be taken into account, as it includes a bus controller, up to 32 remote terminals and a bus monitor. In HIL tests for components, the bus controller has to be simulated, and for integration tests, it is mainly the remote terminals.

The new aerospace bus solutions from dSPACE fulfill all these requirements. This is because they were

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) is collecting, disseminating and processing data about the Earth's weather, atmosphere, oceans, land, and near-space environment. dSPACE tools have been used for subsystem development and integration.

Avionics for High Flyers

With the new interface boards, dSPACE systems are well prepared for avionics development.


Photo: Lockheed Martin


Photo: Eurocopter


Photo: Honda Aircraft


© ESA – D. Ducros

Examples of aircraft and spacecraft developed using dSPACE tools and interface boards: Lockheed Martin F35, Eurocopter EC145, Honda Jet, ESA METOP (from top to bottom.)

Overview of the New Hardware

Product:	Carrier Board:	Extension Module:
MIL-STD-1553	DS4504 PMC	QPM-1553 from GE Intelligent Platforms
ARINC 429	DS4501 IP	IP-429HD-88P from GE Intelligent Platforms
ARINC 717	DS4501 IP	IP-717-HBP from GE Intelligent Platforms

developed in close cooperation with leading aerospace component and system manufacturers. The new interface boards are being used successfully in the Joint Strike Fighter (F35) program, the NPOESS program (a US environmental satellite), and other projects.

> Users can conveniently access the entire functionality of the avionics interface boards by using the graphical blocksets.

Solution for an Integrated Development Process

The new solutions for MIL-STD-1553, ARINC 429 and ARINC 717 are based on industry-proven modules from GE Intelligent Platforms, in PMC and IP form factor. These modules are integrated into the dSPACE Peripheral High-Speed (PHS) bus via dSPACE PMC and IP carrier boards, which are optimized for high-performance real-time operation. This configuration means that developers can utilize the very short latencies of dSPACE's modular hardware with the advantages of industry-proven bus system boards from other providers. This constellation can be employed to set up seamless, traceable development processes running straight through from model-based development to release tests for controllers on an HIL simulator. For easy connection of the bus interfaces, dSPACE provides special blocksets. These are the interfaces to the real-time model (plant model for HIL tests or controller model for RCP applications) and provide a graphical environment for intuitively configuring communication. It is not necessary to program the interface boards at the deep protocol level. Their functionality can be used conveniently for the individual buses with the help of the appropriate Real-Time Interface (RTI) blocksets from dSPACE. One feature that deserves special mention is that configuration files are used to configure bus communication, making it easy to change the parameterization of the models in Simulink®.

MIL-STD-1553

The new interface board has four doubly redundant channels that comply with the current MIL-STD-1553 A/B Notice II. Each of the four channels can be user-configured independently of the others as one of the terminal devices specified in the standard: bus controller, remote terminal and bus monitor. Thus, the new interface board can be optimally utilized for developing

DS4504 PMC Carrier Board with installed QPM-1553 module from GE Intelligent Platforms. Next to it are the QPM-1553, IP-429HD-88P and IP-717-HBP modules (from right to left).

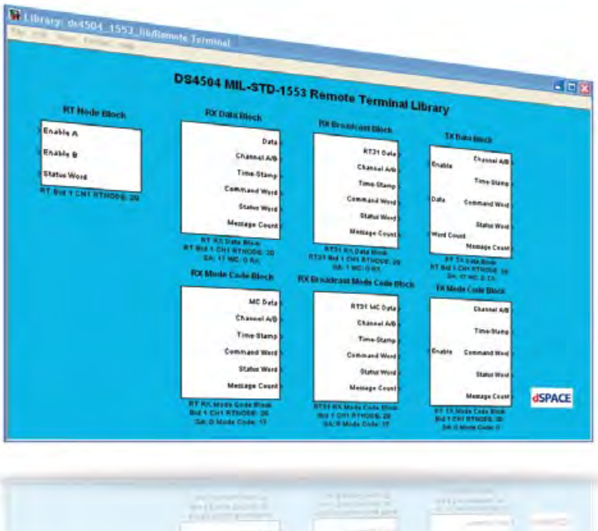
sophisticated components and for testing complex networks.

An essential component is the RTI blockset. Newly developed by dSPACE, this contains a library with send and receive blocks for remote terminals. The blocks in it give users complete access to the channels' functional behavior, their physical level, the transmitted messages, and status information. In addition to the message contents, the outputs of the receive blocks also make time stamps, commands, status messages and message counts available in the real-time model. The blocks can be used to simulate up to 32 remote terminals on an MIL-STD-1553 bus and enable users to set subaddresses, the word count, mode codes and broadcast messages for each remote terminal. Both the physical bus level and the transmission behavior can be manipulated to perform error testing. For physical tests, the bus output voltage can be either predefined or fed in from the outside.

For tests on the transmission behavior, the times for no-response timeout and late-response timeout can be set. A special feature is that if a channel is configured as a bus monitor, the messages to be monitored are not only available in the real-time model, but can also be sent to a PC via Ethernet.

ARINC 429 and ARINC 717

dSPACE's new interface board for ARINC 429 is ideal for testing entire avionics networks, including communication between a very large number of bus nodes. With up to 32 send and 32 receive channels, it has twice as many channels as its predecessor. One outstanding feature is the completely redeveloped blockset, which facilitates the configuration of bus channels enormously. The configuration files that are used define all the properties of the ARINC labels: data format, start bit, data length, scaling factor and SDI filter. This makes it very easy to change the labels. With the data from the configuration files, the ARINC messages are generated automatically in the real-time models by means of Encode and Decode blocks, and payload data can also be extracted from the received ARINC messages. To perform the all-important tests for erroneous bus transmission, errors can be inserted for bit-count, inter-message-gap and parity errors. ARINC 717 buses are another frequent component in network tests with ARINC 429 buses, allowing data transmission between the Digital Flight Data Acquisition Unit (DFDAU) and the Digital Flight Data Recorder (DFDR) to be tested. There is now also a dSPACE interface board for these buses, offering the same advantages as the ARINC 429 interface board. ■



Library of remote terminal blocks for the new DS4504 MIL-STD-1553 interface board as an example of dSPACE's Real-Time Interface

Summary

The new interface boards for MIL-STD-1553, ARINC 429 and ARINC 717 have graphical user interfaces and work with a database, making communication configuration intuitive and easy. Used in conjunction with dSPACE's fast, modular real-time systems, they are ideal for developing and testing components and systems for aerospace applications. Not surprising, since they were developed in close cooperation with leading aerospace companies.

Developments on the Electronic Horizon

An integrated development environment for map-based driver assistance systems

Modern, map-based driver assistance systems are one way to solve the challenges posed by the road traffic of tomorrow. Efficient development of these systems requires a tool chain featuring flexible and configurable access to map data throughout all development phases. To meet the challenges of the tasks involved, NAVTEQ and dSPACE have coordinated their development tools.

The Road Traffic of Tomorrow

The automobile industry will face great challenges in the future. High traffic density, driver stress and information overload are making it increasingly difficult to drive and keep the general overview in traffic. On top of this, due to demographic change the number of older road users will increase. This is why road safety is a major focus of numerous discussions, as is the reduction of CO_2 emissions.

Motivation for Driver Assistance Systems

Modern driver assistance systems are an important way to solve these challenges. They help the driver keep track of the traffic, and can contribute significantly toward greater safety and reduced energy consumption. Many of today's driver assistance systems require a reliable detection of the vehicle environment. Information from radar, video, or ultrasonic sensors is the foundation of numerous applications such as adaptive cruise control, lane departure warning systems, and parking assistants. In the future, advanced driver assistance systems (ADAS) will intervene in the driving process more intensively and autonomously. For example they will influence braking and steering maneuvers, which will give drivers even more support in traffic.

Map-Based Driver Assistance Systems

One fundamental concept of advanced driver assistance systems is to capture not only short range information from the vehicle environment but also long range data on the road ahead based on high-quality digital maps and the current vehicle position. This detailed knowledge of the road ahead, such as slopes, road curvatures and speed limits, opens up the potential to create numerous new applications that enhance driving safety and CO_2 reduction. Predictive cruise control, overtaking and curve speed warning assistants, and intelligent concepts for energy and thermal management ("Looking forward", BMW Group, page 14), are just some examples. In general, these systems are called map-based advanced driver assistance systems (map-based ADAS).

Fundamentals: The Electronic Horizon and the Most Probable Path

To make information on the road ahead available to driver assistance

Map-based driver assistance systems utilize map attributes for the road ahead (i.e., of the most probable path) and predictively control various vehicle functions.

Digital map

Electronic horizon
- Slopes
- Curvatures
- Speed limits
- Lanes

Vehicle

Four major factors govern how mobility will evolve in the future: environment, safety, traffic and demographics.

> The dSPACE tool chain supports the seamless development of map-based driver assistance systems.

systems, an electronic horizon is needed which can be evaluated during driving in real time. The electronic horizon is a kind of virtual sensor that uses map data from a digitalized road map, the current vehicle position, and the vehicle's direction of travel to provide attributes of the roads ahead. This includes topographical data such as slopes and curvatures, and information on the traffic infrastructure such as traffic signs and the number of lanes.

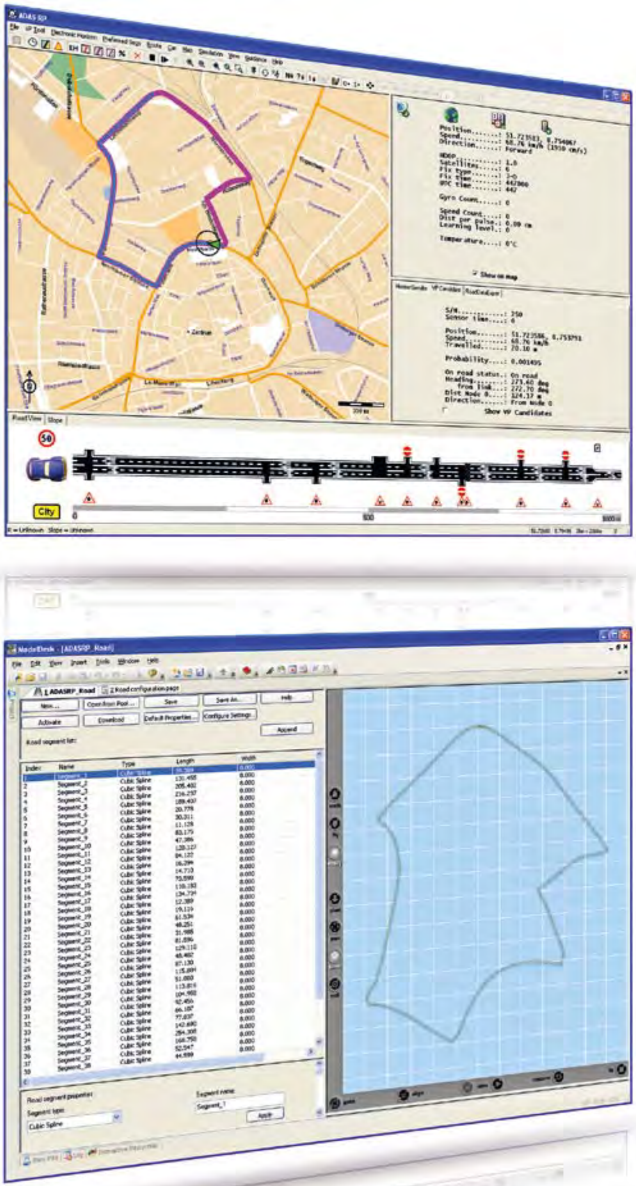
The electronic horizon is periodically broadcast by a horizon provider via the associated vehicle bus. For this, the horizon provider constantly calculates the route along which the vehicle will likely travel. This route is called the most probable path (MPP). If the driver has selected a route in the satellite navigation system, that route is used as the MPP. If navigation is not activated, various heuristics are used to determine the MPP. These algorithms use static map attributes as well as dynamic vehicle states, such as the speed or a direction indicator signal. This method is also applied if a special cost-optimized eltronic control unit (ECU) without a user interface is being used instead of a satellite navigation system. The driver assistance functions receive the attributes from the electronic horizon and evaluate them. For example, a predictive energy management system uses data on slopes and speed limits, while adaptive headlight systems and curve speed warning assistants evaluate the road curvature.

NAVTEQ/dSPACE Tool Coupling

The right tools are needed to quickly implement new concepts, try them out in a vehicle, and test the production software. NAVTEQ and dSPACE have coordinated their efforts and have created an integrated development and test environment for map-based driver assistance systems.

NAVTEQ ADAS RP Development Environment

The ADAS Research Platform (ADAS RP) from NAVTEQ is a development environment for map-based driver assistance systems that runs on Windows® PCs. ADAS RP provides basic functions such as the visualization of maps, route planning and the indication of the vehicle position in respect to the digital map. It also serves as a horizon provider and sends the MPP and all the selected attributes for example via a network service. The ADAS RP development environment can be adapted to application-specific requirements by plug-ins, for example, to send the MPP via a proprietary protocol.



A route from NAVTEQ ADAS RP (above) is exported as a route to dSPACE ModelDesk (below).

dSPACE Tool Chain for Map-Based Driver Assistance Systems

The dSPACE tool chain supports the major development phases in the model-based software development of map-based driver assistance systems. A specially created Simulink® blockset performs data exchange with ADAS RP and can be used for PC simulations and for real-time applications. The supported development phases include the following:

- Function development and offline simulation on a PC with the Automotive Simulation Models (ASM) and the ModelDesk parameterization software
- In-vehicle rapid control prototyping (RCP) with MicroAutoBox or AutoBox
- ECU testing by hardware-in-the-loop (HIL) simulation with the dSPACE Simulator and ASM

Coupling the Development Tools

The dSPACE tools are coupled to ADAS RP by file export and by the User Datagram Protocol/Internet Protocol (UDP/IP). For example, a navigation route can be exported as a road for the driving simulation. During simulation (PC/HIL) or rapid control prototyping, data is exchanged bidirectionally via UDP/IP. The receiver function blocks of dSPACE's ADAS RP blockset provides the Simulink model the electronic horizon received by the ADAS RP. The sender function blocks transfer the vehicle position simulated by ASM as GPS coordinates to ADAS RP. In an RCP application, sender function blocks take the information on the vehicle position, which was received by the vehicle's sensors, and transfer it to the ADAS RP. ■

Sinisa Durekovic, NAVTEQ

We would like to thank Sinisa Durekovic of NAVTEQ for his kind support in producing this article. Mr. Durekovic is in charge of application-specific further development of ADAS RP at NAVTEQ in Sulzbach (Taunus), Germany.

Application Examples:

An Integrated Development Process for Map-Based Applications

Function Development and PC Simulation

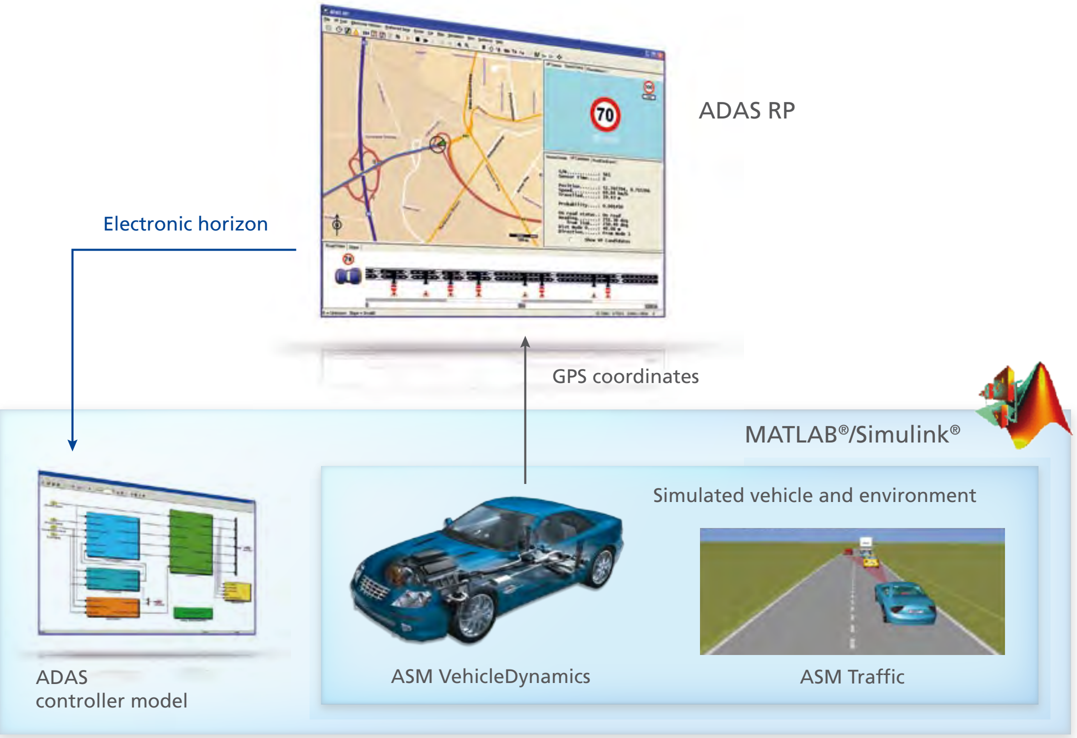
The Task
In model-based function development, new ECU functions have to be tried and tested in a virtual environment at an early stage. Map-based assistance systems need a virtual vehicle and a virtual environment consisting of roads and, if necessary, other road users .

Development Environment
ASM VehicleDynamics is an open MATLAB/Simulink model. It is equipped with the ModelDesk parameterization software to enable the vehicle, roads, and maneuvers to be defined and configured. The ADAS RP development environment provides the electronic horizon. The two tools are coupled by a network service and can run together on one Windows PC.

Roles and Signals
A route defined in ADAS RP is exported to ASM VehicleDynamics for use as a road in simulation. During the driving simulation, the vehicle follows the road at a variable speed that is determined by the maneuver. Its position is sent to ADAS RP cyclically in the form of GPS coordinates. ADAS RP computes the electronic horizon for these coordinates and sends it to the simulation model. The attributes are available to the ADAS algorithm for evaluation.

The Benefits

- Map data used in early development phases
- Driving simulations on realistic roads



Application Examples

Rapid Control Prototyping (RCP): In-Vehicle Function Development and Tests

The Task

Developing, testing and optimizing software for map-based ADAS in a vehicle. The ADAS prototype has to be integrated into the vehicle like a real ECU, and communicate with the vehicle's bus systems (such as vehicle CAN). It must be possible to configure the electronic horizon flexibly.

Development Environment

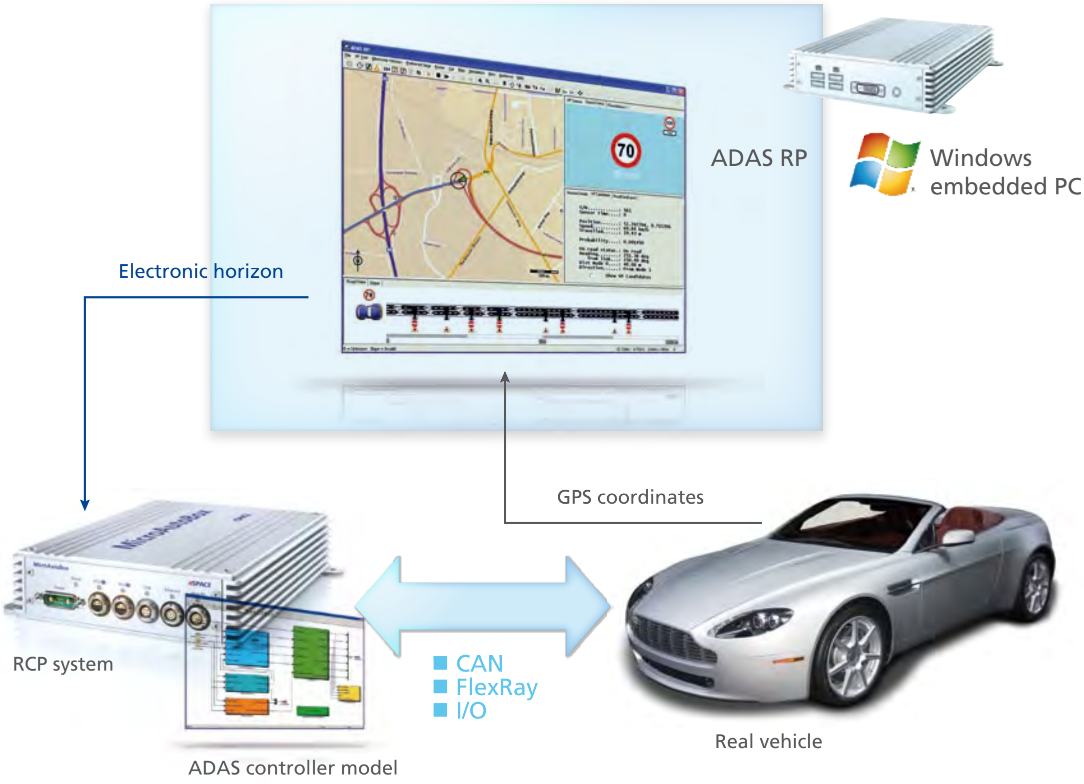
MicroAutoBox and AutoBox are compact prototyping solutions for executing computing-intensive embedded software and integrating it in a vehicle's electrical system. They can be configured with all the interfaces necessary for map-based driver assistance systems. In a typical case, the sensors of the vehicle provide the GPS coordinates. If required, a sensorbox with high-quality sensors for position finding (GPS antennas, gyroscopes) can also be used. ADAS RP evaluates this position data and provides the electronic horizon for the real vehicle position.

Roles and Signals

Position data from in-vehicle sensors or a dedicated sensor box (e.g. from NAVTEQ) is acquired and transferred to ADAS RP. This matches the vehicle's position to the digital map and broadcasts the electronic horizon (MPP + road attributes) once per second. The dSPACE system, which is connected via Ethernet, receives the data and decodes it with the ADAS RP Blockset. The electronic horizon is then available to the algorithm under test on the MicroAutoBox or AutoBox.

The Benefits

- Map-based assistance systems tested and optimized under real driving conditions at an early stage
- Communication tested in the vehicle's electric/electronic system



ECU Testing by HIL Simulation

The Task

As part of the development process, control and diagnostic algorithms of new software versions of the map-based ADAS ECU have to be tested on a HIL simulator. For production release, network tests also need to be performed with the vehicle's ECUs.

Development Environment

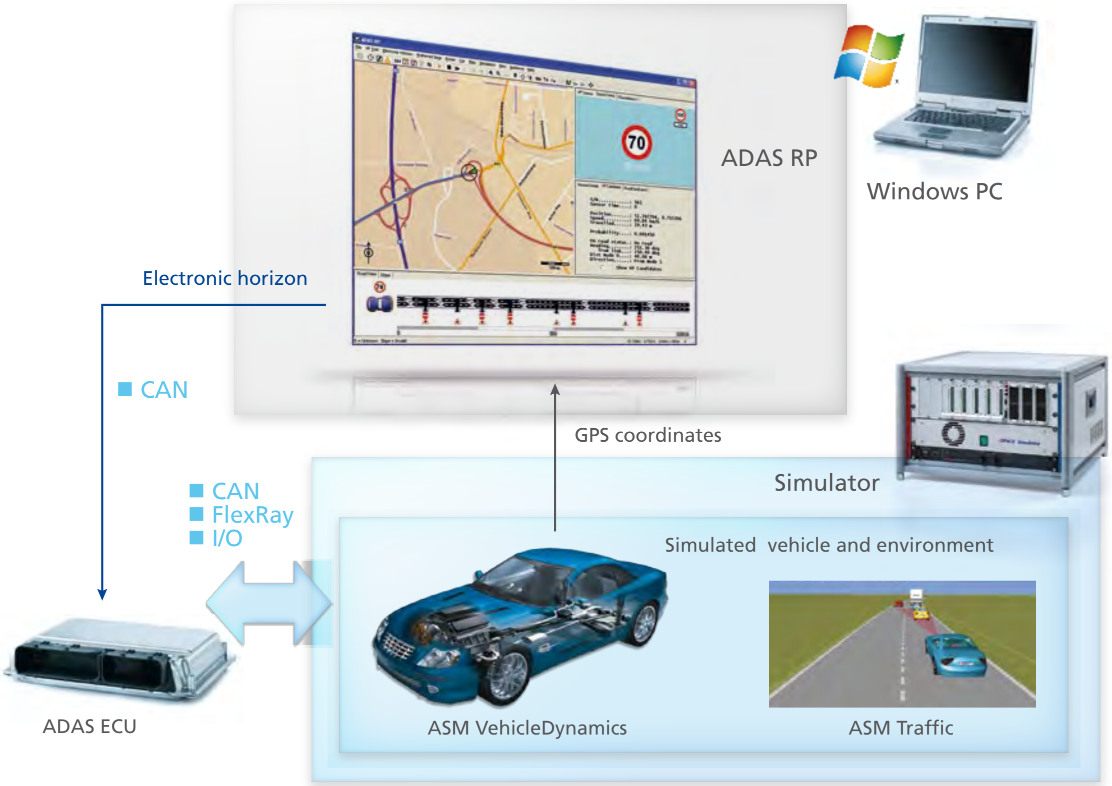
Together with the ASM Vehicle Dynamics model, the dSPACE HIL Simulator provides the virtual controlled system for the production-ready ADAS ECU. It can be equipped with all the interfaces and simulation models needed to simulate a complete vehicle and its environment in real time. The electronic horizon is provided by ADAS RP on a Windows PC. ModelDesk is used to parameterize the vehicle model and create roads and maneuvers for the test cases.

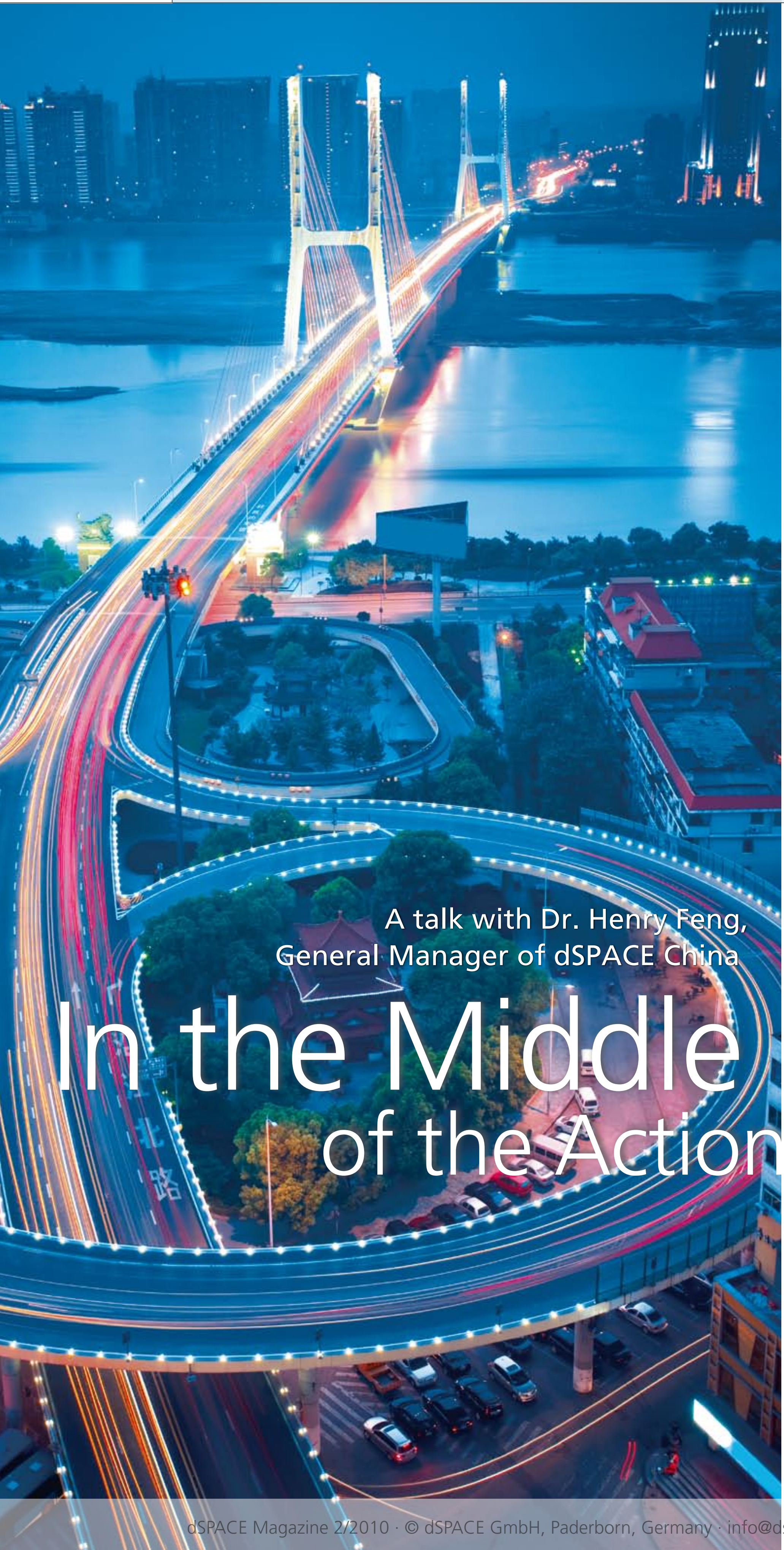
Roles and Signals

A road exported from ADAS RP is available on the dSPACE Simulator. The vehicle's position (GPS coordinates), speed, and direction of travel are computed in the simulation model and passed to ADAS RP via Ethernet. ADAS RP calculates the MPP for the vehicle's position and sends it (for example, via CAN) to the map-based driver assistance ECU together with the attributes of the electronic horizon. Thus, the map-based ADAS ECU can be tested in a closed control loop. In addition, the usual test methods for testing ECUs automatically and reproducibly are also available.

The Benefits

- Automated, reproducible test cases
- Function testing and diagnostics testing on the component and network levels





A talk with Dr. Henry Feng,
General Manager of dSPACE China

In the Middle of the Action

With 13.8 million vehicles sold in 2009, China is now number one among the world's largest car markets. Yet only 1 Chinese person in 70 has a car. So in a country with 1.3 billion inhabitants, there is still plenty of buying potential. With the launch of its own subsidiary in this dynamic market, dSPACE is right in the middle of the action.

How do customers benefit from dSPACE China?
dSPACE has been working together with a distributor on the Chinese market for over ten years. To specify today's large-scale systems, put them into operation, and integrate them into development processes, developers need continuous, direct communication with the tool vendor. So since February 2010, our customers in China are exclusively supported by our new office in Shanghai. This gives them direct engineering services, qualified on-site contact partners, and easier communication.

What kind of qualified people does dSPACE China have?
Our company offers comprehensive, competent service for consulting, engineering, support and finance. We have field application engineers and consultants who directly support customers from the initial idea to project implementation. The responsible engineers are qualified dSPACE experts who gathered experience in the engineering and development departments at dSPACE's headquarters in Germany. We are continuously expanding this team with automotive specialists who have extensive experience with dSPACE projects.

You were born in China and lived in Sweden for many years. How did you come to work for dSPACE?
I founded dSPACE's Swedish distributor, Fengco, in 1995 together with two embedded control experts. So I have known the core business extremely well for over 15 years. I'm very glad that I can now contribute my know-how to dSPACE China and to the Chinese customers.

What characterizes the Chinese market, and how does dSPACE China respond to it?
Over 100 Chinese manufacturers have government licenses to produce automobiles. About 50 of them are actually producing automobiles, and 5 of them develop their own vehicles and electronics. The Chinese market is in flux. We see lots of joint ventures and changes taking place. Right now, 10 huge OEMs are currently producing 90% of the cars in China. To develop a feel for market dynamics, you have to be on site. dSPACE is right in the middle of the action. We have to respond fast to our customers' requirements and quickly exchange ideas with them.

What is the current trend in the Chinese automobile industry?
Hybrid and electric vehicles are a major focus. The Chinese government is investing around six billion Euro in developing alternative forms of propulsion. The issue of fuel efficiency, with lower fuel consumption and CO_2 emissions, is firmly rooted in the minds of Chinese engineers. With dSPACE's tools, they can put their ideas into practice much more quickly and reliably protect their complex electronic systems from errors.

What does your typical workday look like?
Our customers' satisfaction is our top priority. Their projects are given total support, from the start to the turnkey solution. I'm at the hub, where everything comes together. Engineering, sales, logistics and finances have to be well coordinated to ensure customer-friendly solutions with maximum transparency. This would not be possible without a competent team and a network of trust with industry.

> Over 100 Chinese manufacturers have governmental licenses to produce automobiles.

What are your primary goals for dSPACE China?
We want to grow, we want to open up the market for dSPACE, we want to give our customers the best possible service.

Do you take dSPACE home with you?
Yes *(laughing)*, there are days when I work up to 15 hours, and that makes it difficult to switch off and relax. But it gives me immense satisfaction to lead a professional team to serve the Chinese customers.

Thank you for talking with us.

Reunited Under One Roof

An eXcellent New Building

Christian Saalbach, Hardware Development:
"With the new building, communication has improved tremendously. Shorter communication paths mean you get the really important information faster, and you are more closely involved in the development process."

Britta Dorn, Human Resources:
"Especially in Human Resources, we often need to have just a quick word with someone, rather than lengthy meetings. Since we started working in the new building, we can discuss more things directly and personally, instead of phoning or writing standard e-mails. Things are a lot easier."

Michael Strugholz, Direct Sales:
"What I find exciting about the X building is that you get to know people in the product management and product development departments much better. Thanks to the building's design, we meet in the hallway, in the elevator and at lunchtime and can make new contacts quickly."

Farewell Technologiepark! At the beginning of 2010, dSPACE relocated to its new X-shaped headquarters in Paderborn, taking 5,650 pieces of furniture and 12,000 moving boxes along. Futuristic, spacious, communicative - these three adjectives perfectly describe the new building. dSPACE is no longer spread over ten buildings in three different Paderborn locations. All employees now work together on one single campus.

H + X = dSPACE HQ

The dSPACE site, measuring 33,000 m² in the center of Paderborn and just a few minutes from the central train station, is home to an H-shaped building and the new X-shaped one. The engineering, logistics, electronics production, purchasing and technical sales departments already moved to the 5,400 m² H building in 2006. Construction of the X building, the new corporate headquarters, started in the winter of 2008 and, after completion of the tight schedule, it was ready for occupancy in January 2010. In addition to company management, it contains the administration, sales, marketing communications, product management and development departments.

Modern and Filled with Light

Everyone close at hand – instead of always writing e-mails or calling on the phone, our employees prefer talking to each other in person. With a meeting room on every wing of each floor, it’s no problem to call ad-hoc meetings. Transparency and openness are the central concepts of dSPACE architecture. Each office has a clear window wall facing outside, and an opaque window wall to the corridor. All this light creates a naturally pleasant working atmosphere, and the sunny, spacious central lobby with its open stairwell and glass elevators highlights the building’s modernity.

Low Energy Consumption

dSPACE is setting new standards in energy efficiency. A low-tech climate system constantly feeds water of a suitable temperature through pipes in all the ceilings. Called concrete core activation, this feature supports the heating system in winter and cools the rooms in summer.

Comfort for Employees and Visitors

dSPACE also has a new parking facility with six levels and over 530 parking slots. A free-standing cafeteria with 1,600 m² of floor space is equipped for 800 employees and guests, and can also host large events. ■

Einstein Microscopic

Researchers at Stanford University recently made the most precise test of Einstein’s general theory of relativity there has ever been by measuring the frame-dragging effect. Frame-dragging is an extremely tiny warp in spacetime that occurs near rotating masses such as planets. To measure it, a satellite was launched into Earth orbit in 2004 with four spherical gyroscopes onboard. The electronic control for the gyroscopes’ suspension had previously undergone comprehensive testing, including a test setup consisting of a DS1005 Processor Board, diverse I/O boards and the experiment software ControlDesk (as reported in dSPACE NEWS 1/2002). According to Einstein, if the spin axis of each gyroscope is aligned with a guide star at the start, after a full year in orbit it will show a minimal deviation. This is caused by various relativity effects, including frame-dragging, which makes a difference of approx. 1/40,000,000th of a degree. To give an idea of size: 1/40,000,000th of a degree is the angle of a pin head seen from 1000 km away. After several years of evaluating data, the researchers finally succeeded in detecting this microscopically small change in the gyroscopes’ angle at the end of 2009. They had verified the existence of the frame-dragging effect.

Simulating Exhaust Systems

International standards are constantly lowering the accepted levels of nitrogen oxide in diesel engine exhaust. Compliance with these tougher limits is not possible without electronically controlled catalytic converters. Selective catalytic reduction (SCR) systems that use urea injection (with AdBlue or diesel exhaust fluid, DEF) are an especially effective solution. Simulating the control algorithms plays a vital role in the development of these systems.

The dSPACE **ASM Diesel Exhaust Model** provides a complete virtual diesel exhaust aftertreatment system. In addition to the submodel for urea injection (the SCR system), it includes further submodels for a diesel oxidation catalyst (DOC) and a diesel particle filter (DPF). The simulation model can be used throughout the development process, from controller design in Simulink® to ECU testing on a dSPACE simulator.

A special feature of the model is that users have complete access to all its Simulink blocks. They profit from being able to view the modeled functions and adapt them to specific requirements themselves. The exhaust model’s individual components (DOC, DPF, SCR) can be combined in different ways and optimally configured for the aftertreatment system under test.

MicroAutoBox II: New Processor Board for Greater Performance

The new generation of MicroAutoBox includes a completely redesigned processor board with a clock rate of 900 MHz that provides considerably more processing power and faster boot times in rapid prototyping applications. Other new features are a powerful Ethernet host interface and a real-time-capable Ethernet bus interface for connecting external devices such as measuring systems or PCs. The system still has its well-known features such as compact design and passive cooling, and its mechanical robustness has even been enhanced. The models and cable harnesses from previous MicroAutoBox applications can all be used with it. Operating the new MicroAutoBox requires the current dSPACE software release. Additional I/O variants are planned for MicroAutoBox II for the end of 2010.

EcoCAR Competition – Year Two

The second year of the EcoCAR Challenge ended in an impressive display of design accomplishments by engineering students. 16 North American university teams revealed their functioning prototype vehicles at the end of May 2010.

The top five finishers, all of whom designed extended-range electric vehicles (EREV), were:
1. Mississippi State University
2. Virginia Tech
3. Pennsylvania State University
4. University of Victoria
5. Ohio State University

Four of the top five teams used dSPACE systems to simulate their vehicle architectures and develop and test their control strategies.
At the closing ceremonies of EcoCAR Year Two, dSPACE presented three teams with an "Embedded Success Award". It recognizes EcoCAR Challenge teams who demonstrate the most effective use of dSPACE HIL equipment. The first-place winner was Ohio State University. Second- and third-place honors were presented to Mississippi State University and the University of Victoria.
dSPACE continues to sponsor the EcoCAR competition. The final year of the EcoCAR Challenge culminates in the spring of 2011, when the participating universities will compete for first-place honors by delivering near-production prototype vehicles.
dSPACE congratulates all of the teams of the EcoCAR Challenge on their great achievements! ■

Optimized for Commercial Vehicles: New J1939 Support

dSPACE has extended its development tools **RTI CAN MultiMessage Blockset** and **ControlDesk** for use in commercial & off-highway vehicles. Version 2.5.1 of the blockset lets users configure extensive restbus simulations for J1939, a protocol frequently used in the commercial vehicle field. The blockset supports the transport protocols Broadcast Announce Messages (BAM) and Request to Send/Clear to Send (RTS/CTS) Messages, so among other things it can transfer large volumes of control information and diagnostic data. The J1939 network management (address claiming) means, for example, that address conflicts can be solved and ECU addresses can be changed during run time.
From ControlDesk 3.6, the integrated Bus Navigator supports the J1939 network protocol. There are special new layouts containing J1939-specific information such as message priority, parameter group number (PGN), and source and destination addresses. A tailor-made gateway layout is also available for J1939.

The handling of the layouts in the Bus Navigator has been improved for all bus systems, so that previously created bus layouts can now be opened much more quickly. ControlDesk 3.6 is also optimized for replaying CAN logging files several megabytes in size.
The new RTI CAN MultiMessage Blockset 2.5.1 and ControlDesk 3.6 are available with dSPACE Release 6.6. ■

System Architecture | Rapid Prototyping | ECU Autocoding | HIL Testing | ECU Calibration

Rapid AUTOSAR with the dSPACE RTI AUTOSAR Package

The AUTOSAR standard is becoming increasingly important, especially in rapid prototyping and HIL testing. With the RTI AUTOSAR Package, you can easily integrate your existing AUTOSAR software components into the familiar MATLAB®/Simulink® environment, simulate them, and execute them on our real-time hardware.

Whether developing functions or tests, you can run AUTOSAR software components with your dSPACE system however and whenever you want. No complications and no hassle. Get on the fast track now!

Embedded Success dSPACE