dSPACE MAGAZINE

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EvoBus, MBtech – Verifying the Maturity of a Bus E/E Architecture

Yamaha – Developing a Self-Navigating Research Boat

Johnson Controls-Saft – Managing the Lithium Ion Battery in the new Mercedes-Benz S 400 HYBRID

Dr. Herbert Hanselmann
President

These are strange times indeed. Automotive industry icons are sinking in chaos, others are going bankrupt. Governments are getting involved as de facto auto manufacturers. Autoworker unions cannot strike anymore because they now own their employers.

I ask myself whether this was really necessary. My honest answer is: No, it wasn't. The overcapacity in the automotive industry is indeed one cause, but this has been evident for a long time. And for quite some time, steps were being taken to gradually reduce it. Fewer brands, step-by-step reduction in capacity. That should have been enough.

No doubt, one inevitable cause is the financial crisis, which spread at a breathtaking pace. For people working in the world of real products and innovation it is shocking and outrageous to see how so-called financial engineers have pushed aside the branch of "real engineering". Instead of real innovations, obscure financial innovations were made. We all could have done without this.

And as if this weren't enough, this all coincides with the fear of CO_2. I wrote about this topic in the last issue of dSPACE Magazine. In light of the combination of these concerns and the widespread faith in quick solutions, it is no wonder that the automobile market is under economic depression. But I am pleased to see that top managers of manufacturing companies and suppliers are now speaking up more often, bring-ing a better sense of reality into the discussion. For example, when they refer to the expected slow start-up curve for electromobility and the related costs. Disillusionment in the political realm and in public opinion might still come.

It is alarming that especially the automotive industry is so stressed, that even this field has reduced its investments in research and development. One would think that in the face of today's technical challenges, the automotive industry would increase its efforts in these areas. But concerns about liquidity and the need to minimize losses are even hitting innovations. Investments are being reduced, shifted, and abandoned not only in the automotive industry. But this is where it is felt the most. We as a tool provider cannot be certain that the electronics and software will be integrated in automobiles at the rate we once knew. And even if so, the number of car model series will not be the same and that probably means less development.

We are getting prepared because the economic recovery will take some time and will progress slowly. The previous level of investments and growth will not return so quickly. In light of the economic crisis, we plan to remain fit for the tasks the future holds for us.

Dr. Herbert Hanselmann
President

Embedded Success dSPACE

IMPRINT

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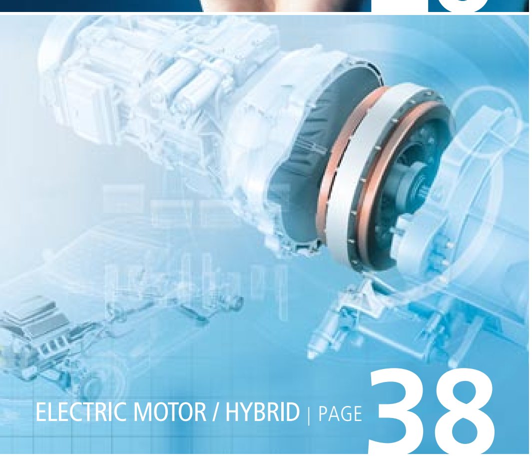


25 Kilograms of Pure Energy

Developing an efficient battery management system for the Mercedes-Benz S 400 HYBRID

25 kilograms: That's the weight of the hybrid battery in the Mercedes-Benz S-Class S 400 HYBRID, which will be launched in 2009. The battery consists of 35 cylindrical, rechargeable lithium-ion batteries and delivers a peak power of up to 15 kW (20 HP). The electric and thermal protection of this little bundle of energy is one of the battery ECU's most important tasks. The ECU's algorithms were developed in a joint venture between Johnson Controls and SAFT. dSPACE TargetLink is used to generate the ECU software.

Mercedes-Benz S 400 HYBRID

The S 400 HYBRID is a mild hybrid in which the electric drive is used for engine start-up, the start-stop function, boosting and energy recovery. To save space, the compact, disk-shaped electric drive is installed in the enclosure of the torque converter, between the engine and the 7G-TRONIC seven-speed automatic transmission. This external rotor motor is a 3-phase rotary current permanent magnet electric motor with a maximum power of 15 kW (20 HP) and a start-up torque of 160 Nm at an operating voltage of 120 V. So much space is saved by installing the hybrid battery in the engine compartment in place of the conventional starter battery that the

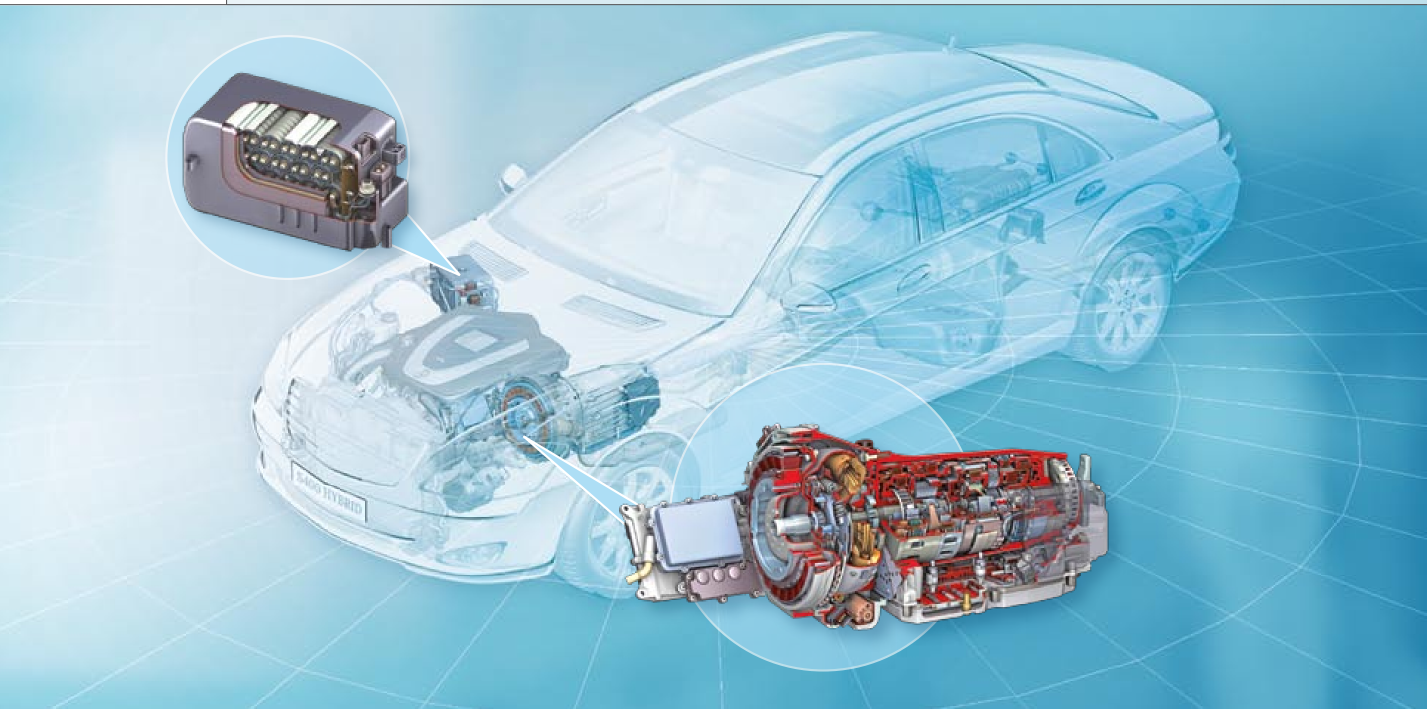


Figure 1: The S 400 HYBRID has a mild hybrid drive. The high-voltage lithium-ion battery is installed in the engine compartment.

vehicle's spacious interior and trunk do not need to be altered (figure 1). The lithium-ion battery is not only an energy store for the electric motor. Via the voltage converter, it is also connected to the 12-volt electrical system that supplies standard consumers such as the headlights and comfort features. Engine start-up is the biggest demand on the vehicle's battery. If the battery charge is low due to self-discharge, low outside temperatures, etc., this is where it first manifests itself. If the charge ever becomes too low, the hybrid system supports jump-starting. The 12-volt lead-acid battery is installed in the trunk. It supplies power to the standard consumers and also the monitoring system for the high-voltage components. Thanks to support from the lithium-ion battery, it can be considerably smaller and lighter.
The combustion engine was specially designed for the mild hybrid. It utilizes the advantages of the Atkinson principle, which increases the engine's thermal efficiency and at the same time reduces fuel consumption and toxic emissions. The disadvantages of the Atkinson principle, such as a relatively low torque in the lower speed range, are compensated by the electric motor.
Comprehensive energy management ensures that all the components in the hybrid powertrain (battery, electric motor, voltage converter) respond optimally to the vehicle's requirements. The electric motor supports the combustion engine during accelerations and acts as a generator with an energy recovery function during braking. Especially during the start-up phase, the hybrid battery provides electric power for the vehicle electrical system via the voltage converter. Moreover, suitable shifts in the working point ensure that the combustion engine always runs in its optimum efficiency range, even in such different situations as cross-country drives and urban traffic.

Cooled Hybrid Battery

The heart of the modular, very compact, very efficient hybrid drive is the new high-voltage lithium-ion battery (figure 2), which was specially developed for use in vehicles. Its essential advantages over conventional nickel metal hydride batteries are greater energy density and higher electric efficiency, plus more compact dimensions and lower weight. The hybrid battery supplies a terminal voltage of 128 V at a maximum current of 200 A in charge and discharge direction. It consists of 35 lithium-ion cells with a nominal voltage of 3.6 V each and a capacity of 7 Ah (figure 3). For cooling, the battery is connected to the vehicle's climate control. Battery cooling always has priority over the driver's air-conditioning settings and can demand full cool-

> "With the production code generator TargetLink, we quickly turned a newly developed controller model into production-level code for a hybrid battery management system."

Torben Materna, Johnson Controls-SAFT

Figure 2: The high-voltage lithium-ion battery weighs 25 kg. It has a high-strength enclosure with integrated cooling.

Figure 3: The high-voltage battery is made of 35 lithium-ion cells.

ing power even if the climate control is switched off.

Battery Management System

The battery management system (BMS) is the control center for all the electric, thermal (physical) and chemical processes in the battery. The BMS is an independent ECU installed in the battery and has the following functions:

- Safety functions (e.g. voltage cut-out)
- Charge indicator (via the instrument cluster, see figure 4)
- Computation of current, voltage, and power limits
- Temperature management
- Monitoring of battery aging
- Balancing (equalizing charge differences)

As well as performing these control functions, the ECU also acts as a black box, i.e., it stores all the battery data permanently so that it can be retrieved via diagnostic functions. To guarantee safe operation at the high voltages and currents, there are numerous safety functions that ensure that the battery's high-voltage contacts are not live unless the battery is in operation. The battery is therefore completely safe to install, transport and store.

Networking the Battery Management System

To do its work properly, the BMS has to intervene in other systems and also fetch data for evaluation from other components. It is therefore connected to all the ECUs in the hybrid branch:

- Energy management (engine ECU)
- Power electronics (electric motor)
- Voltage converter (DC-DC)

To ensure a fast response to errors, the battery and the climate control exchange some messages directly, for example, the battery's cooling requests and the cooling status.

Control Strategy for the Battery

To give the battery cells a long life and make optimum use of their power, the cooling strategies are designed to hold the battery temperature at approx. 30 °C. Under extreme loads, overheating is also avoided by means of current and voltage limits. These features prevent long-term damage and loss of capacity in the cells. The temperature control is designed such that the battery temperature of 50°C is exceeded only in exceptional circumstances (figure 5).
Too-low temperatures, which are particularly likely to occur when the vehicle is not in use, can also damage the battery. During operation, the battery is immediately heated by current flow. If the current load is too high at temperatures below -20 °C, lithium precipitation can occur, which drastically lowers the battery capacity. The vehicle's idle phases are systematically used for recalibration, safety checks and balancing, i.e., equalizing cell charge differences. Balancing is especially important because the battery's life decisively depends on an even charge state in the cells.
To balance the charge levels of all the cells, specific cells are recharged on the basis of load charge analyses. This means that the battery's capacity can always be fully utilized without overloading individual cells (figure 6).

Model-Based Development Process

One of this project's greatest challenges was to combine the know-how of battery experts and the requirements of automotive engineers, and develop a system that guarantees high vehicle availability, while pro-

Glossary

Atkinson principle – Prolonging the expansion phase compared with the compression phase in a four-stroke engine by holding the inlet valve open longer between intake and compression ("fifth stroke"). Result: Greater efficiency and lower consumption.

Boosting – Switching in the electric motor when power peaks occur

Mild hybrid – A hybrid vehicle whose electric motor supports the combustion engine when required, but does not perform propulsion on its own.

Recovery – Storing excess energy in the battery (for example, during braking).

Figure 4a: The vehicle reduces its speed to less than 60 km/h. The electric motor acts as a generator and converts the vehicle's mechanical kinetic energy into electric energy to charge the hybrid battery (energy recovery). The instrument cluster shows this process as a green energy flow towards the battery. The battery is 50 % recharged, and charging continues.

Figure 4b: The vehicle accelerates to over 50 km/h. The electric motor consumes current from the battery and supports propulsion by the combustion engine. The instrument cluster shows the process as a red energy flow towards the wheels. Because of previous energy recovery, the battery charge is now at 51 %.

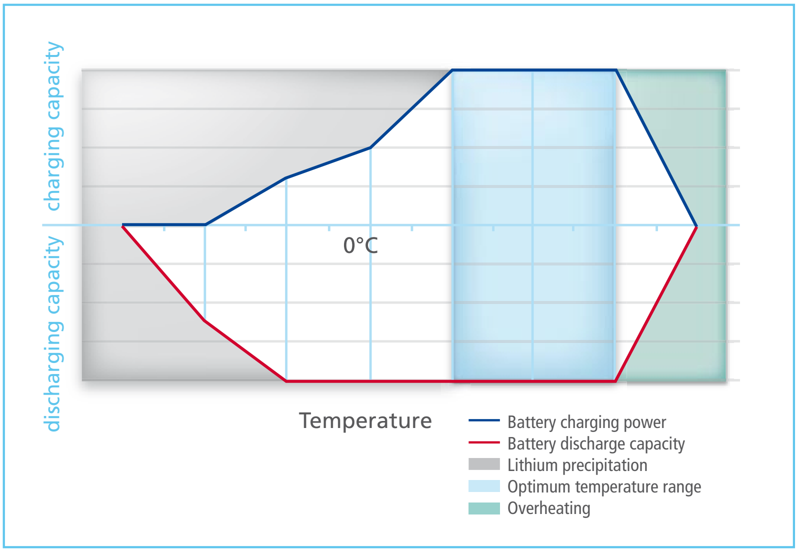
Figure 4c: The vehicle brakes to a standstill (speed 0 km/h; the combustion engine and electric motor are turned off). After this new braking and energy recovery process, the battery's charge has increased to 52 %.

tecting the battery cells at the same time. The task was to take theoretical battery models and cell data obtained under laboratory conditions, and shape them into executable software in such a way that they would be viable in practice, yet still provide sufficient precision. Model-based development and the production code generator TargetLink from dSPACE made it possible to simply integrate existing Simulink battery algorithms and battery characteristics into the controller model, and to use existing Simulink battery models for validation. Because the aim of this project was to design the first-ever control for lithium-ion technology, the controller software had to be developed entirely from scratch, without using legacy code from previous projects. In-house modeling guidelines based on the modeling guidelines published by dSPACE helped to prepare the model for the best possible implementation as efficient production code.
The function developers for the energy management system (EMM) implemented in the engine ECU also use TargetLink, so working with them ran smoothly and coordination between EMM developers and BMS developers in different companies was much easier.

Implementing the Battery Controller

The battery ECU has a TriCore microcontroller from Infineon. To implement the modeled controller software on the ECU, production-capable fixed-point code has to be generated from the model. First all data that had global relevance in the project, such as calibratable variables, was defined in the dSPACE Data Dictionary. The necessary scaling of variables was performed in the model with the aid of the scaling support provided by TargetLink. The fixed-point code was validated by comparing model-in-the-loop (MIL) and software-in-the-loop (SIL) simulations. The run-time behavior and the resource consumption of the codes for the target processor were tested by processor-in-the-loop (PIL) simulation with the evaluation board TriBoard TC1796 (figure 7). Even the very first PIL tests revealed that the code has very good run-time behavior during particularly computation-intensive program parts. The processor with its 150 MHz clock rate continued to fulfill the software's real-time requirements as development continued. TargetLink

Figure 5: The electric capacity of the hybrid battery for charging and discharging processes as a function of battery temperature.



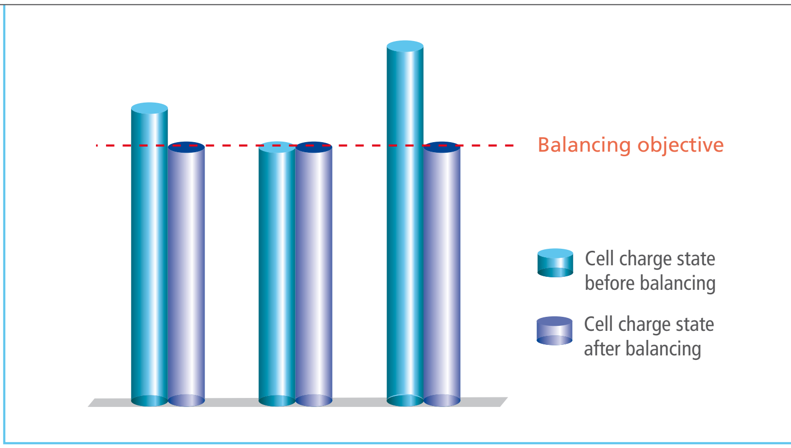


Figure 6: The battery management system equalizes cell charge differences in the background during the vehicle's idle phases, thereby ensuring that all the battery's cells have an optimum charge state at all times.

Torben Materna, Johnson Controls-SAFT Advanced Power Solutions GmbH
Torben Materna is a project manager for software development and developer of lithium-ion battery management systems at Johnson Controls-SAFT Advanced Power Solutions in Hanover, Germany

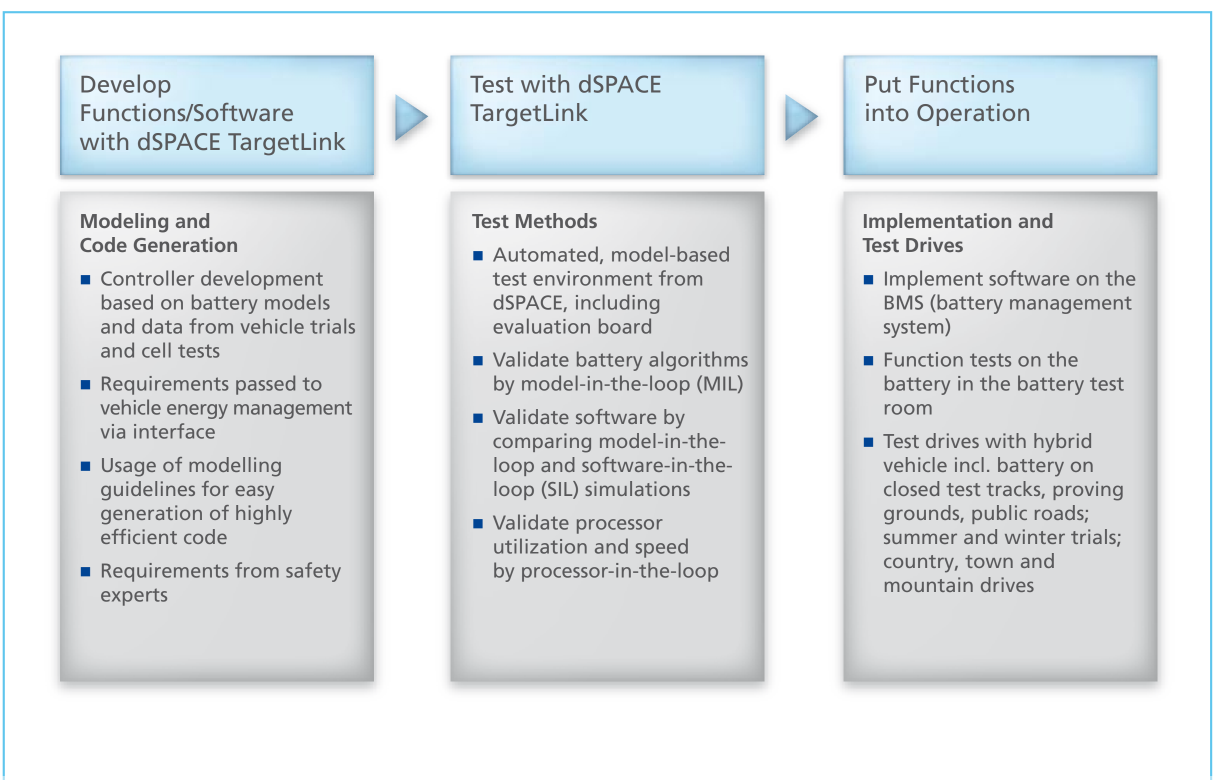
generated approx. 25,000 lines of code for the controller model. The production code generator was no problem to handle and quickly led to production-level results.

Commissioning and Outlook

The battery ECU was first tested on a test bench. Verifying the safety functions and the effectiveness of the temperature control were a particular focus here. Then the system's suitability for public roads, and for summer and winter operation, was investigated in test drives. The hybrid battery plus ECU proved to be a robust system that is able to continuously provide sufficient electric energy. Investigations into using the system in other vehicles are currently underway. The modular design of the software makes it possible to take the battery algorithms that were developed and validated in this project and reuse them in other projects. ■

Torben Materna
Johnson Controls-SAFT
Advanced Power Solutions GmbH
Germany

Figure 7: The main phases in the model-based development of the battery management system (BMS) and the working steps performed in each.



Virtual Bus

Verifying the maturity of a new bus E/E architecture with HIL integration tests

Articulated or double-decker, lowerable, with up to four double doors and a wide range of comfort and safety systems, urban bus or tourist coach: the variations are endless. This also affects the design of an HIL test bench, which has to handle the possible variants and make it possible to switch between them quickly. Together, EvoBus, the MBtech Group and dSPACE implemented just such a test system for ECU validation.

At EvoBus, the world's leading manufacturer of buses and coaches, the main objective is always to give customers what they require. So top product quality is an absolute must. In bus transportation, vehicles must have high availability with very little down time, and a long lifespan. To launch innovations on the market quickly yet still provide only mature, proven systems, it is essential to have an integrated development process from specification to release. And a test chain with a large test depth is vital. The mechanical, pneumatic, hydraulic and electrical systems installed in passenger buses are connected via a central electrical/electronic (E/E) architecture for controlling functions. The integration of these different kinds of systems into an overall vehicle network has to be validated, and the HIL tests used for this are a major component in the development process. Automating the tests provides even greater benefits.
The architecture of a modern coach or bus must be able to bring together a wide range of requirements. These can be anything from a sophisticated articulation control system in an urban bus that has to interact with the brakes, the engine, the floor-lowering feature also known as "kneeling", the assistance systems and the instruments, or even a multimedia system in a tourist coach that gives passengers a choice of entertainment plus a wide range of information on the journey. These numerous different functions and information sources are distributed across several systems, but nevertheless have to function smoothly in a network. Developers have to make sure of this at a very early stage of development, before the systems have been installed in a vehicle, and it makes tough demands on the test environment and the test strategy.

Test Environment and Test Focus

A hardware-in-the-loop (HIL) simulator has been set up for testing functions and diagnostics at the component and network levels. The HIL simulations particularly focus on testing the bus-specific systems and the interactions between the functions of different components. Wherever possible, components that are available from other sections of the manufacturing group are reused. Thus, parts of the HIL test bench, including the simulation models, are copies of other test benches. General test case libraries and test specifications were adapted to EvoBus requirements.

The Challenge of Diversity

Integrating numerous different systems and functions is one challenge to bus and coach development. The enormous number of special features requested by customers is another. This necessitates very short development times for the software modules. Only a few weeks were scheduled for development and testing, from initial requirements to release and installation in the customer's vehicle. At the same time, the EvoBus E/E

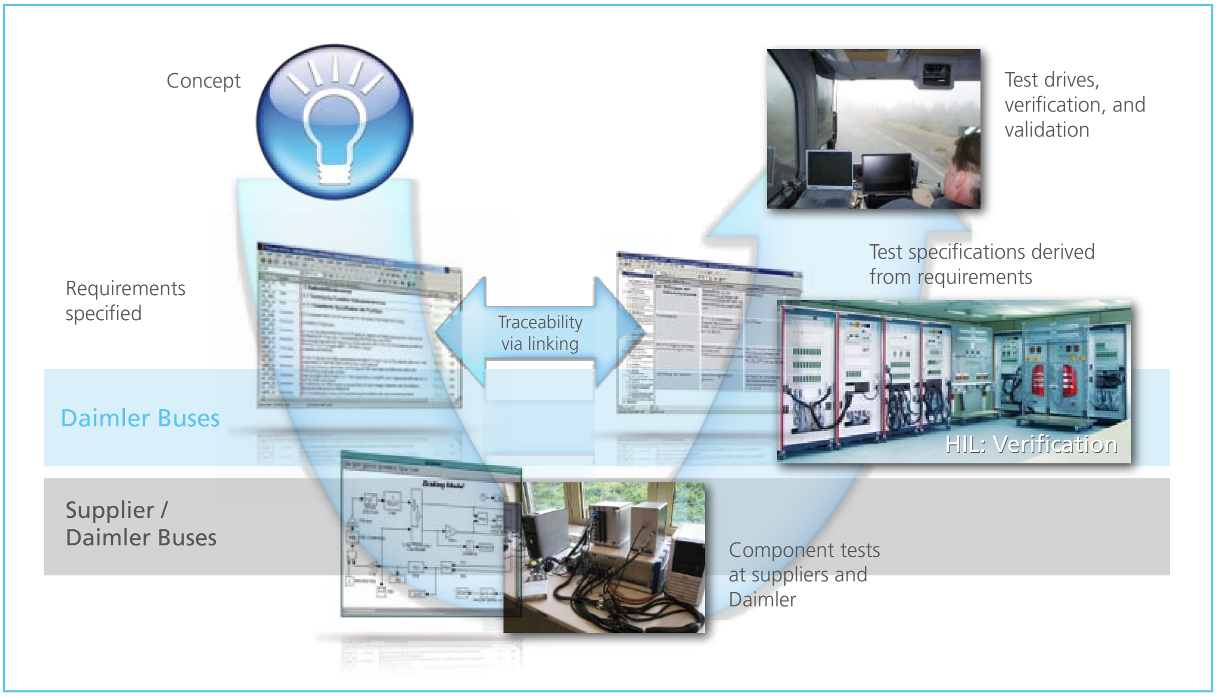


Figure 1: HIL simulation is a standard part of the EvoBus development process.

architecture is a "construction kit" for all integral buses and coaches in Europe. It is used to create the architectures for all other vehicles, from a simple bus with little equipment to a high-end two-level tourist coach or an articulated town bus that is 20 meters long. This diversity is reflected in the ECUs' extensive parameterization and the number of ECU variants, or even sometimes requires completely different ECUs, for example, for different types of transmission. Testing engineers therefore need to be able to switch quickly between different vehicle variants on the HIL test bench. In other words, the model, the ECU network and the parameterization have to adaptable.

> "By using hardware-in-the-loop simulation early in the development process, we are able to establish and validate the ECUs' maturity at an early stage."
>
> *Ian Suckow, EvoBus GmbH*

Motivation for HIL Integration Tests

To achieve high product quality, EvoBus designed its development process for electrics/electronics and diagnostics according to CMMI process models. This means complying with optimum standard processes and continuously improving them. One of the improvement measures is an integrated test chain on the right-hand branch of the development V-cycle (figure 1). As many ECU and ECU software tests as possible are performed by suppliers. EvoBus coordinates and monitors them with a supplier management system. Before the first integration tests on the overall integration test bench, additional internal component tests are performed to verify the networking and diagnostics capability. Their precise nature depends on the system's maturity level and on the software sections being tested. The main focus of integration tests is on verifying functions that are distributed across different systems.

Requirements for Test System and Test Operation

The basic preconditions for smooth test operation are reliable hardware and fast support when problems occur. The test system must be flexibly extensible so that it can cope with additional requirements or new systems. Evobus decided to entrust all testing activities, including setting up the test bench, maintenance, modeling, test implementation and test execution, to a central operator and partner. The partner is responsible for ensuring that the HIL system runs without problems. EvoBus supplies the test specifications; the test results are evaluated jointly by the HIL tester and the function developers. dSPACE produced component specifications and set up the HIL test systems, while the actual operation and model creation were done by MBtech. Carrying out development work at several different locations is an additional challenge, since the developers responsible in each case are often not available on site. It requires standardized procedures, clearly defined processes, seamless documentation and constant communication between everyone involved.

Technical Design of the HIL Test System

To test the functions and ECUs, a complete network of all the systems was reproduced by using 8 HIL simulator racks (figure 2). These comprise the powertrain, interior, and chassis domains. This overall integration test bench makes it possible to simulate all European integral buses from EvoBus. The set-up consists of two multiprocessor systems: 4 dSPACE Simulator Full-Size racks for simulating the powertrain with 5 processor boards for calculating the environment model, and 4 Full-Size racks with 4 processor boards for the interior. The tests for the chassis ECUs were also integrated into the 8 racks. The simulators communicate via Gigalink connections. To distribute the overall computing load across the processors, the environment model can be partitioned, and each partition assigned to a processor node. Altogether, approx. 45 ECUs with 2800 pins can be connected. The simulators for the vehicle's interior are currently being extended by two extra Full-Size racks to allow the simulation of additional systems. When the extension is finished, there will be a total of 10 processor kernels for calculating the model of an urban bus or tourist coach.
One part of the simulator concept is to include bus components in the simulation as real loads. They are connected to the simulator via component assemblies. The real loads include the compressed air system for the brakes, the lighting system, parts of the transmission, and throttles and valves in the engine. To ensure that the HIL system operated smoothly, dSPACE provided the HIL operator, MBtech, with comprehensive hardware documentation.

Brake Simulation with Real Loads

The braking system consists of a central module and axle modulators for the bus's three axles. The ECUs are networked with each other and with the electronic stability program (ESP) via four CAN buses. All the CAN connections can be disconnected separately via a switch matrix and the dSPACE DS4302 CAN Interface Board for use in restbus simulation. To simulate the brake in real time, a real load assembly containing the brake pneumatics with original valves and sensors was connected to the simulator. All 32 pressure sensors and 20 valves in the brake system were connected to the real-time simulation in this way. Realistic simulation of the entire compressed air system would have been considerably more expensive.

Representing the Powertrain

EvoBus offers three types of transmission for its buses and coaches: automatic with torque converter, semi-automatic, and manual. The ECUs for these transmission types are connected to the simulator via coded cable harnesses. This means that it is sufficient to have only one set of I/O resources on the simulator, yet each ECU can be operated with its specific real loads. Changing the test system from one transmission type to another requires only a few simple actions and a change of simulation model.

Interior and Chassis Components

To test the ECUs for the vehicle's interior functions, all the bus-specific components were provided for real-time simulation, including the following:

- Climate system with a variable number of substations
- Variable number of door controls with pneumatic or electric drives
- Electronically controlled spring suspension and damping
- Additional electronic hydraulic steering for the third axle
- Articulation angle control for articulated buses
- 6 MUX modules whose inputs and outputs can largely be configured freely – by digital or analog means, continuously, or by pulse width modulation (PWM).

A total of 1300 ECU pins were connected to the vehicle interior simulators. Sensors or actuators are simulated on 672 of these pins, and electrical failure simulation is also possible on them. Thus, they can be used for switching open circuits, short circuits to supply or to other pins, and short circuits over variable resistances.

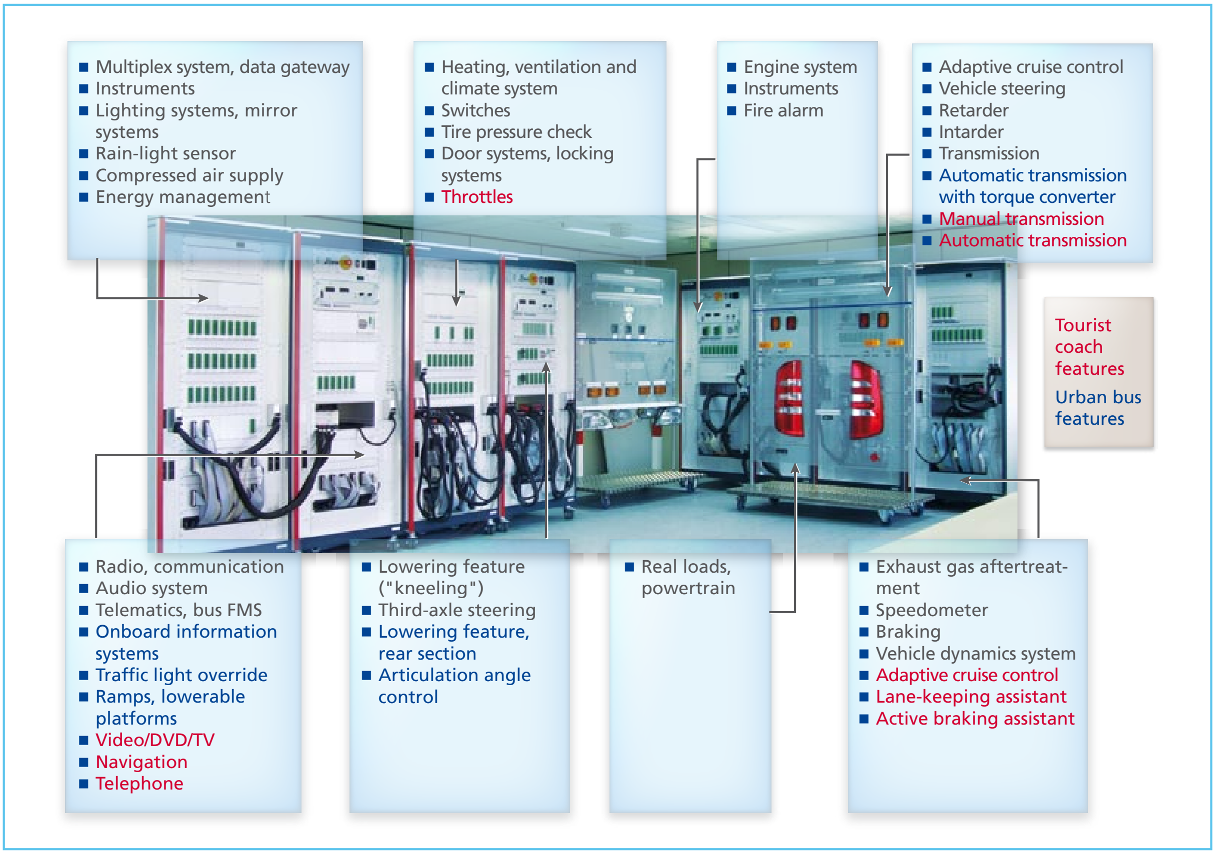


Figure 2: The complete HIL test stand comprises 8 Simulator Full-Size racks and component assemblies for the lighting and brake systems.

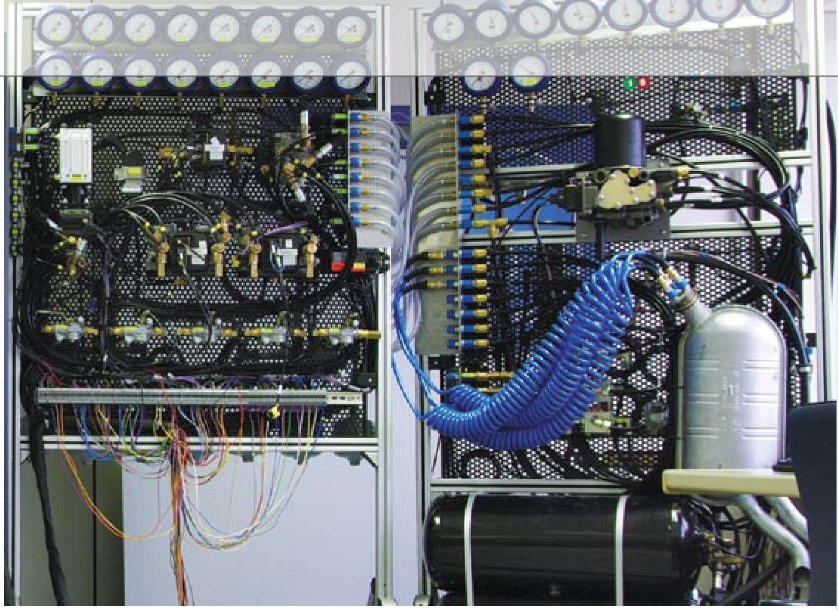


Figure 3: The entire compressed air system in the brakes was recreated with the original valves.

Glossary

Axle modulator – Used to implement the desired brake pressure on the axles.

CMMI (Capability Maturity Model Integration) – Systematic preparation of processes and practices to improve workflows. Maturity level 3 means that projects are carried out according to an adapted standard process and that there is continuous, organization-wide process improvement.

MUX module – Flexibly programmable ECU

Tri-state – Digital switch elements whose outputs not only have two states (0 and 1) but also a third one known as high-impedance.

> "Together with other forms of testing such as suppliers' tests, internal component tests and test vehicles, the HIL tests provide high system maturity for prototype testing and large test depth."
>
> *Ian Suckow, EvoBus GmbH*

The MUX modules with their variable functions are a particular challenge. MUX modules are special bus and coach ECUs that control numerous electrical consumers, such as roof ventilation, electrical system management, subfunctions of the door control and kneeling systems, coffee machines and water boilers. Each module can drive continuous currents up to 10 A and evaluate tri-state or analog levels at the inputs. For failure simulation, the simulator included the pins of a MUX module with a high-current-capable failure insertion unit (FIU) that can switch failure currents of up to 50 A. In addition, the ECU topology varies from vehicle to vehicle. The MUX modules can therefore be connected to different vehicle CAN buses automatically via a switch matrix.

Special Features of a Bus Environment Model

Realistic models of the environment and the controlled system are indispensable for performing comprehensive function and integration tests in an appropriate simulation environment. All the vehicle's subsystems – powertrain, chassis and interior – have to be included. MBtech was responsible for creating and maintaining the environment models, to which new functions were added during test operation.
The basic model for the urban bus actually consists of two identical basic models for the vehicle's forward and rear sections, which are connected by a joint. Functions such as articulation angle control, third-axle steering and kneeling are important aspects of the chassis model. In contrast, the tourist coach was modeled as a single-section vehicle, so its chassis representation is very different. Engine model is based on individual models for the characteristics of the drag, starting, braking and engine torques, which are added together to obtain the total torque. The braking system is represented by real loads and a real pressure circuit, so only the resulting braking torque and the connection to the modeled powertrain in the environment model have to be calculated.
A characteristic of buses and coaches is that they have different types of doors with a wide range of variations and functions, for example, either electric or pneumatic control. The availability of their functions is especially important in public transportation. Finally, the simulation model also contains representations of the climate system, the switches, and the rain/light sensor.

Testing Process

The approach to implementing tests is based on a reference process, PROVEtech:TP5. This consists of five steps:

- *Test Strategy:* The main objective is to extract an overall system view from all the detail views, and to identify and prioritize distributed functions. A general decision is taken on which test objectives are focused on in which test stage.

- *Test Planning:* Test topics for the integration test are assigned with reference to the testing activities of other test teams such as the ECU supplier and later test drives.
- *Test Specifications:* Work on these began before the test system was set up. They describe detailed test cases for the HIL operating team to work with. In a multi-location development project, they are also indispensable for communication between developers and testers.
- *Test Implementation:* Automated tests are created according to the test specifications.
- *Test Evaluation:* Errors that are found are kept in a central list that is directly linked to the associated requirements, test specifications and test results. Suppliers are informed of errors that concern them, and deadlines and activities for remedying the errors are agreed on.

The statuses of all testing and error-remedying activities are regularly collected in a report so that information on current progress and system maturity at all hierarchy levels is always available.

> "The numerous possibilities for reusing test systems and test cases make it easier to introduce complex network simulators, even for new projects."
>
> *Stefan Abendroth, MBtech Group*

Automating Tests

The MBtech operating team's main task on the integration test bench is to implement and execute automated ECU tests. This involves continuously putting new ECU functions into operation, and also extending and maintaining the HIL hardware, adapting and further developing the environment models, and supporting work on the test system, for example, when measurements or interactive tests are performed. One of the bottlenecks in test automation is the first-time execution of a test with the ECU network. Depending on the complexity of the test case and/or the ECU functions, this can take a long time and require complete access to the test system. The modularity of the HIL system pays off here, as the subsystems for interior/chassis and for the powertrain are separate and can be operated in parallel. The programming of automated tests (figure 4) is initially performed independently of the test system, so test case development and other system support activities can be carried out simultaneously.

Reusing Tests

When the model is changed from the urban bus to the tourist coach, or from one vehicle variant to another, the aim is to reuse as many of the test cases already created and tested as possible. To do so, test automation is based on the Daimler group's tried-and-tested library concept, which uses descriptions of vehicle-specific test parts. The same tests can therefore be used for different vehicle variants by replacing basic vehicle data at a central point in the test. In the long term, this increases the efficiency of test implementation and also makes it easier to compare individual test results.

One Year of Testing Experience

In the first year of its operation, the integration test bench was the place where the various ECUs of the new E/E platform were networked and interacted with one another for the first time. The test bench faced its first major trial when the first complete network integration and first use of the test system were both performed at the same time. Even at this early stage, it was possible to identify and analyze problems in the test objects. In the first year, all the

Left: Ian Suckow, Daimler Buses – EvoBus GmbH, Germany
Ian Suckow is Project Leader for integration and system testing at EvoBus in Mannheim and Neu-Ulm, Germany.

Middle: Stefan Abendroth, MBtech Group, Germany
Stefan Abendroth is head of Commercial Vehicle Testing at MBtech Group in Sindelfingen, Germany.

Right: Martin Müller, dSPACE GmbH, Germany
Martin Müller plans and designs HIL simulators that are tailor-made for specific customers at dSPACE's Project Center Stuttgart, Germany.

systems were successfully run in a closed loop, including two extremely demanding subsystems – the powertrain and the chassis – and complex environment models. Virtual test drives can be implemented under laboratory conditions in this way, even including brake interventions by an ABS and complex driving maneuvers. Previously specified test cases were implemented and automatically executed in test bench operation. Automated regression tests are performed on new sample versions of the ECUs and bug fixes. The test results from the simulator allow early function validation for the whole network with a large test depth. The maturity of the system network is enhanced by the entire integrated development process, which takes a lot of the load off the testing of prototype vehicles and promises to deliver high product quality for the series. Used in conjunction with an operator model for operative testing, which relieves ECU developers of the duty of operating the very complex test system, the HIL integration test has earned itself a permanent role in bus E/E development.

The integration test bench is currently being extended for testing additional systems in tourist coaches. EvoBus is preparing to use HIL tests for additional safety systems and alternative drives such as hybrid and fuel cell functionalities in the future.

Ian Suckow, Daimler Buses – EvoBus GmbH
Stefan Abendroth, MBtech Group
Martin Müller dSPACE GmbH

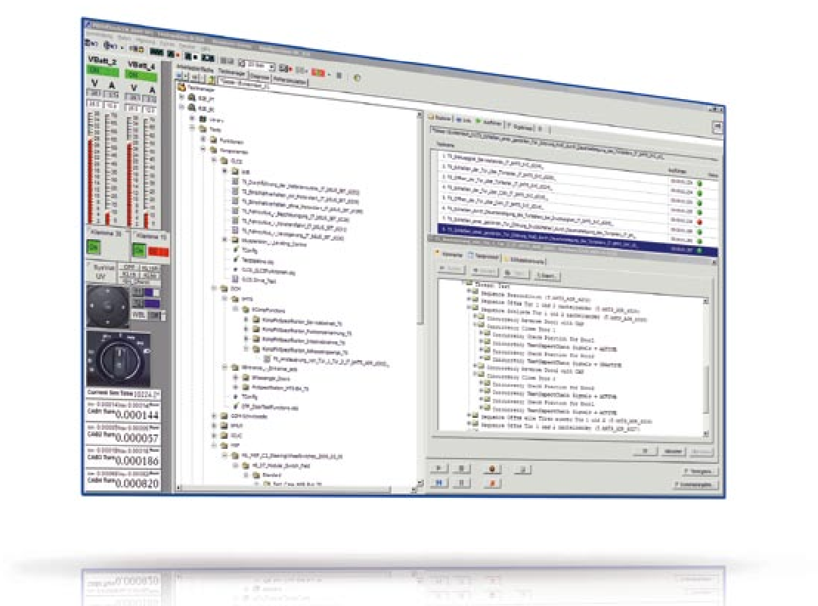


Figure 4: The PROVEtech:TA test software from MBtech.

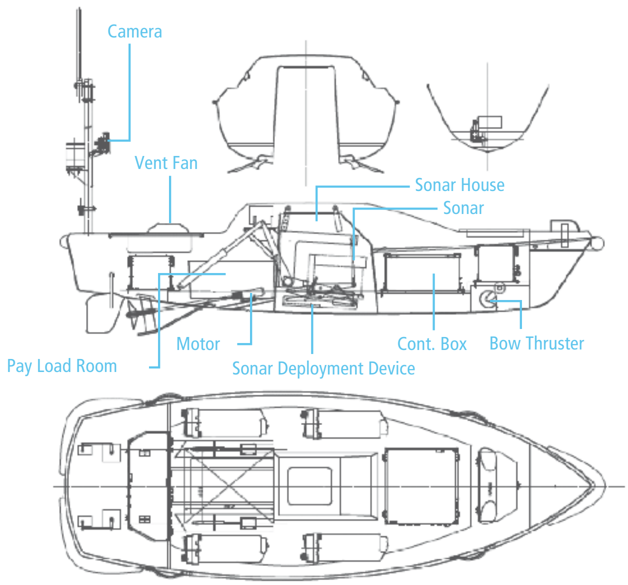
Summary

- HIL simulation used in parallel with ECU development for a bus E/E architecture
- Early virtual test drives made possible by smooth interaction between the environment model and the simulator hardware
- Frontloading error detection in the testing process shortens development and test times

Developing a self-navigating research boat with MicroAutoBox on board.

MicroAutoBox Ahoy!

The Yamaha Motor Corporation, Ltd., is developing an unmanned marine vehicle (UMV) which can be used for numerous measurement and observation tasks. A dSPACE MicroAutoBox performs all the tasks involved in navigating and steering the vehicle.



Principle Dimension

Length over all (without fender)	2.85 m
Breadth	0.98 m
Main motor	RE40 150 W x 2
Reduction gear ratio	3.5
Displacement	170 kg
Battery	lithium ion battery 24Ah x 4
Endurance	3 hrs
Max. speed	4 kt
Cruising	3 kt

The boat provides enough space for various observation devices and also a sufficient current supply.

Why Unmanned Boats?

As a first step, Yamaha Motor Corporation started to develop unmanned land vehicles and the initial version of the unmanned electric observation boat, based on a jet boat. The development of the current UMV version started in 2005. The objective was to produce a vessel that would be able to navigate autonomously using GPS and bearing angle data, and also perform various observation and measurement tasks. This kind of boat makes sense in dangerous locations, and it is also ideal for executing lengthy, monotonous measurement sequences – unlike people, who can get tired and make mistakes, especially in adverse weather conditions.

> “The MicroAutoBox means that the control algorithms can be implemented smoothly and executed in real time. dSPACE prototyping systems have a good reputation in all model-based development activities at Yamaha.”
>
> *Tsuyoshi Kamiya, Yamaha Motor Co., Ltd.*

Sonar and Underwater Camera

The UMV can investigate and monitor its environment acoustically (by sonar) and visually (by underwater camera). The forward-looking DIDSON sonar device from SOUND METRIC can be lowered into the water from a hatch at the bottom of the vessel and used for a wide range of tasks. Typical applications include surveying the beds of lakes, rivers, and the sea; monitoring the silt in reservoirs; testing water quality; and locating submerged objects, for example, to keep harbor shipping lanes clear.

An underwater camera can also be used in addition to sonar. The boat transmits all its data in real time by radio. Its support team on land can use this data, plus the data from the integrated GPS, to follow the UMV’s observations live.

Changing to a dSPACE System

The present UMV is an extended, optimized version of its predecessor. In order to avoid obstacles, the UMV needed new tracking algorithms to detect obstacles, generate its evasion route, and follow the complicated generated route. Since the new, more complex control algorithms might overload the old system resources, our engineers decided to upgrade the old system completely. Yamaha Motor chose a dSPACE prototyping system based on a MicroAutoBox to ensure that model-based development would be an efficient control development process. A PC receives the obstacle detection data and generates an

Typical Use for the UMV: Studies on Water Quality on Hokkaido

In cooperation with the Center for Environmental Science and Disaster at the Muroran Institute of Technology, Yamaha Motor is performing experiments with the UMV on Lake Utonai and the Bibi River on Hokkaido. The objective is to improve methods of measuring water quality. Up to now, the measurements were made manually from a canoe. Now the UMV automatically and autonomously runs the entire measurement program for surveying a target location, except for in an adverse environment. This saves research teams a lot of time and money. The UMV's activities on Hokkaido produced a lot of valuable results:

- Data and practical experience for optimizing measurement procedures
- Testing the communication system under real-world conditions. In the open countryside, the range is up to 2 kilometers.
- A precision of 2 meters in following the preprogrammed navigation route on unmanned voyages up- and down-stream.

evasion route; the MicroAutoBox precisely controls the generated tracking route. As a result, the UMV also provides an effective test environment for control logics, as it can find errors easily.

The Decision to Use a dSPACE System

As engineers searched for a suitable new system, they originally considered a PC-based solution as another candidate. However, after real-time capability and model-based development were identified as the decisive requirements, the ultimate choice was for the dSPACE system, since it guarantees a stable, reliable test environment. Moreover, dSPACE

Various observation instruments can be lowered into the water amidships (the photo shows a sonar device).

With a total length of only 2.85 meters, the boat easily fits into a small van to travel to its working location by road and is no problem to launch.

products already proved their value in other Yamaha divisions. Since the dSPACE system was known to be reliable, other systems were not even evaluated. The MicroAutoBox played a major role in simplifying and speeding up development processes.

> "Thanks to ControlDesk's easy-to-use, intuitive graphical interface, we quickly familiarized ourselves with using it."
>
> *Hirotaka Aoki, Yamaha Motor Co., Ltd.*

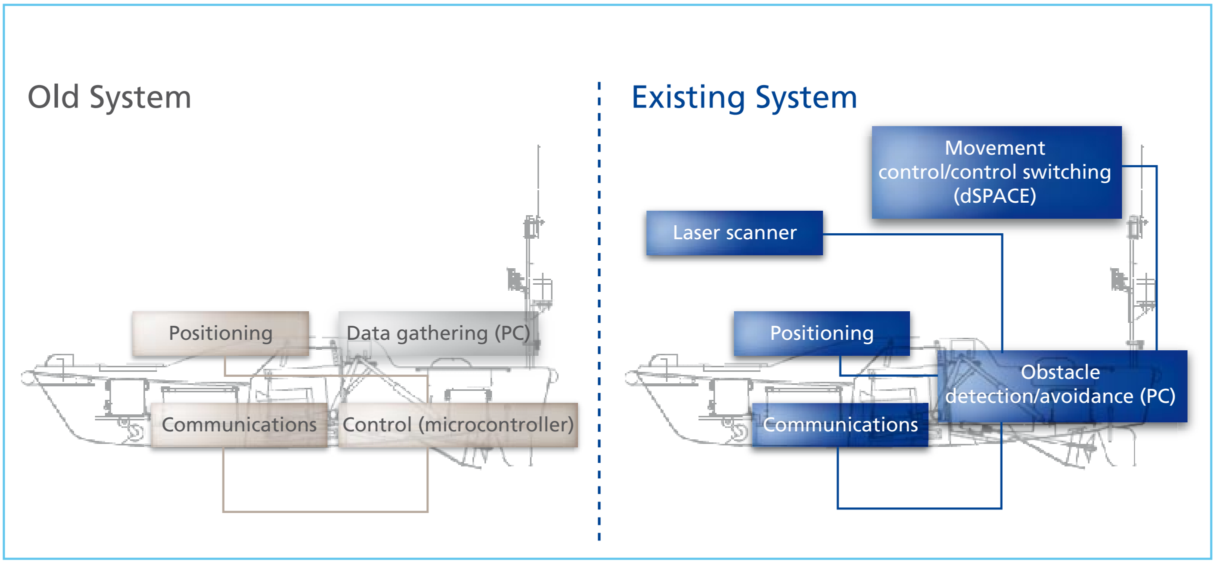
MicroAutoBox at the Helm

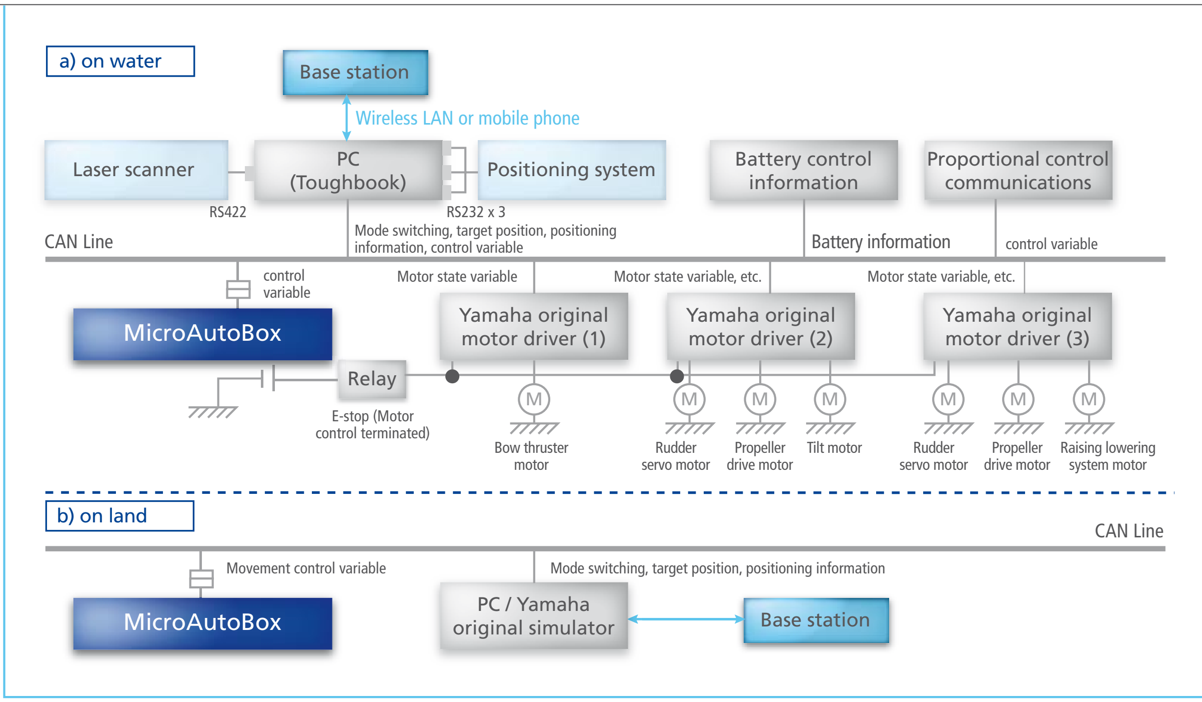
The dSPACE prototyping system receives position data from a GPS system connected to a PC. The MicroAutoBox uses the data to perform navigation calculations and sends the input data for steering the UMV to the motors (propeller drive motor, bow thruster motor, and rudder servo motor) via a motor driver that was specially developed by Yamaha. All the components exchange data via a CAN bus. To develop new control algorithms without using the actual boat, a Yamaha simulator is connected to the MicroAutoBox.

Stepping up Development Activities

The initial stage of developing the unmanned boat focused on the demands of this boat size, as well

Direct comparison between the present UMV (right) and its predecessor (left). The major features of the new boat were obstacle detection integrated into the overall system, and expanded system resources.



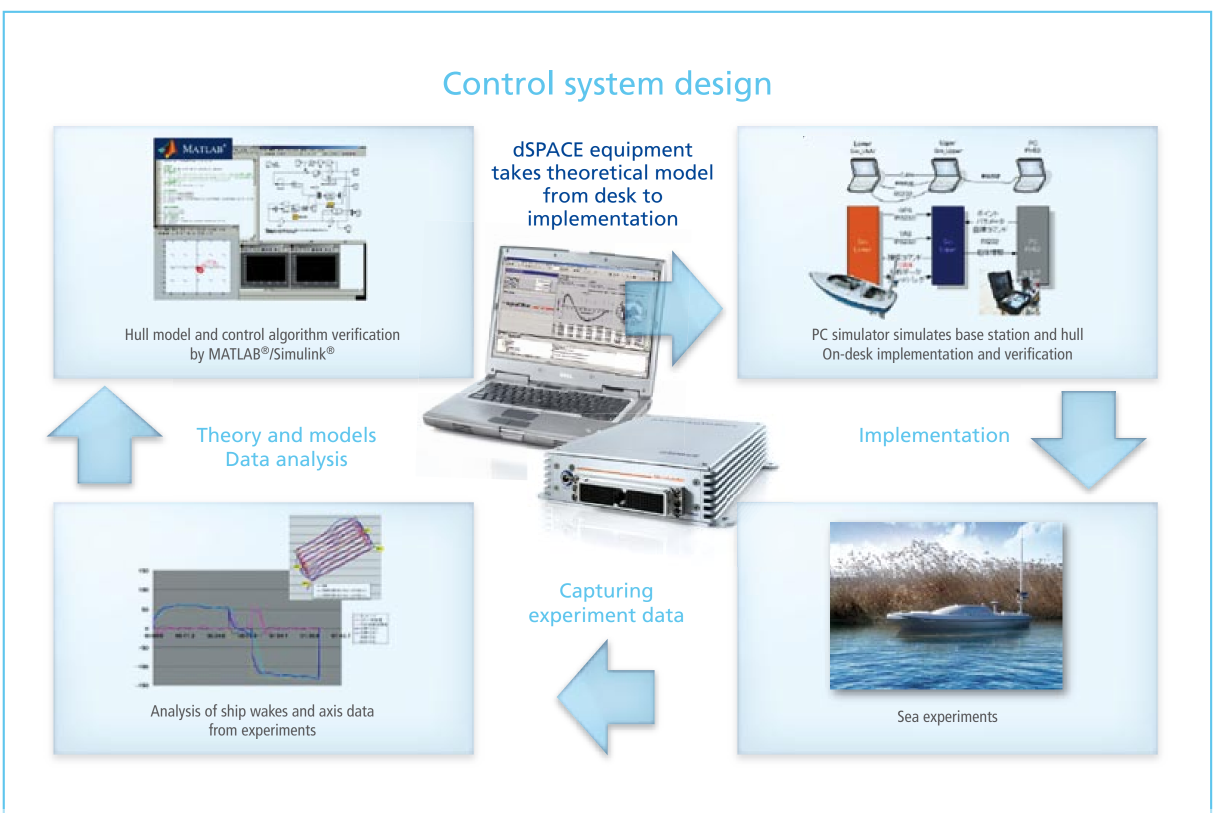


a) Schematic of the UMV's control system. To control the boat, the MicroAutoBox uses GPS data and data from an on-deck laser scanner that scans the immediate above-water environment for obstacles. All components communicate via CAN bus.
b) To develop control algorithms on land, a Yamaha simulator plays the part of the boat.

as researching the next challenge. Now that promising results have been obtained, the development team can concentrate on research and further technical development. Yamaha Motor will intensify its development work on the complex UMV control in the future, once more relying on dSPACE's robust prototyping systems. ■

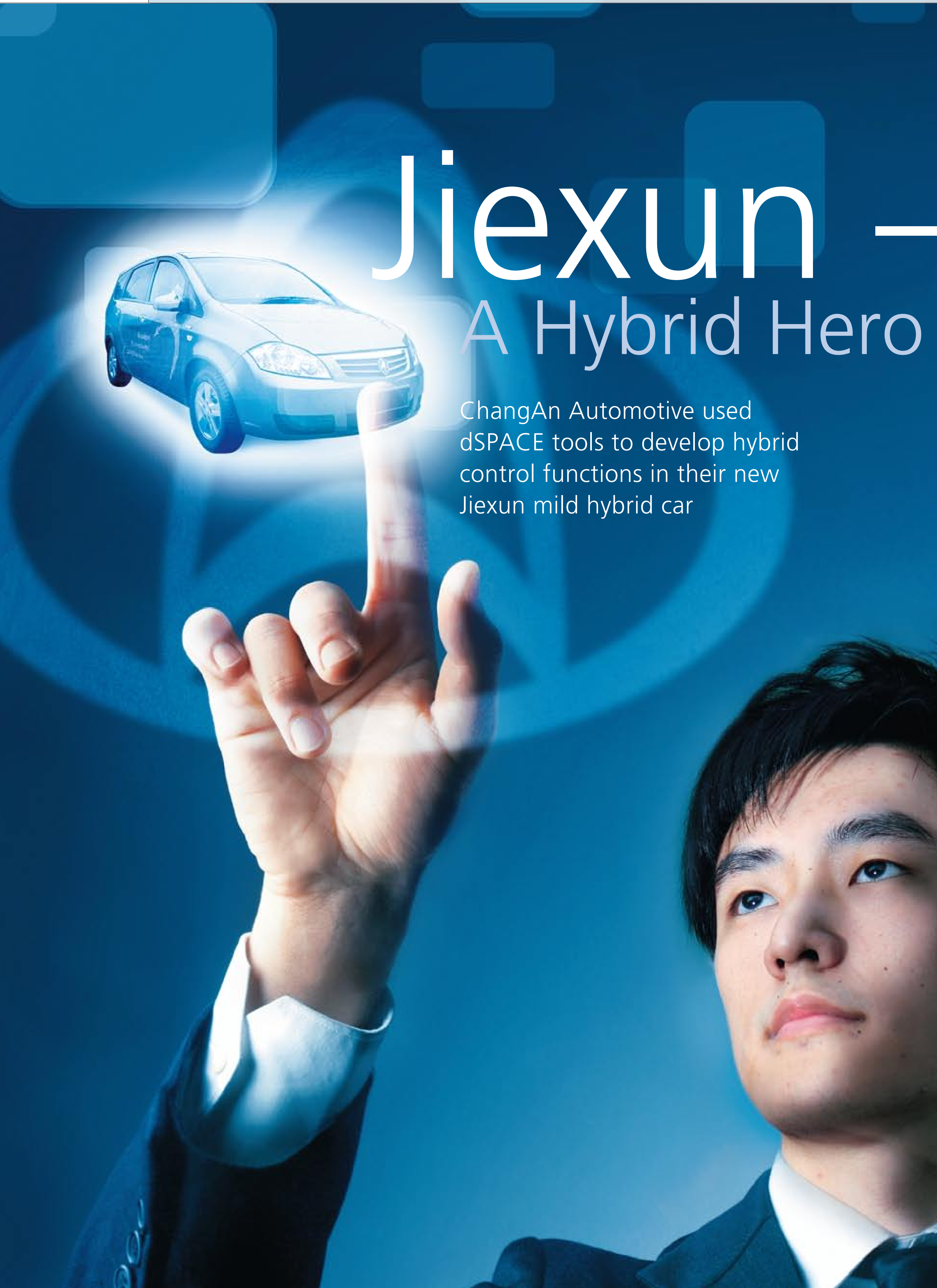
Tsuyoshi Kamiya, Hirotaka Aoki,
Yamaha Motor Co., Ltd., Iwata, Japan

The development and implementation process for the control system. The model-based control algorithms are tested and refined by repeated tests on the water and on the Yamaha simulator.



Jiexun – A Hybrid Hero

ChangAn Automotive used dSPACE tools to develop hybrid control functions in their new Jiexun mild hybrid car



Lower emissions and more fuel economy: the Jiexun mild hybrid.

Hardware-in-the-loop testing at ChangAn Automotive.

The new ChangAn Jiexun mild hybrid car successfully rolled off the production line in December 2008 – containing a comprehensive hybrid controller strategy developed with dSPACE tools. During the 2008 Beijing Olympic Games, ChangAn already provided several pre-production hybrid Jiexuns as taxis and a press fleet. About 80% of the hybrid controller strategy's code was generated with dSPACE TargetLink. ChangAn also used dSPACE MicroAutoBoxes and dSPACE Simulator for successful controller development and testing.

Reducing Emissions and Saving Fuel

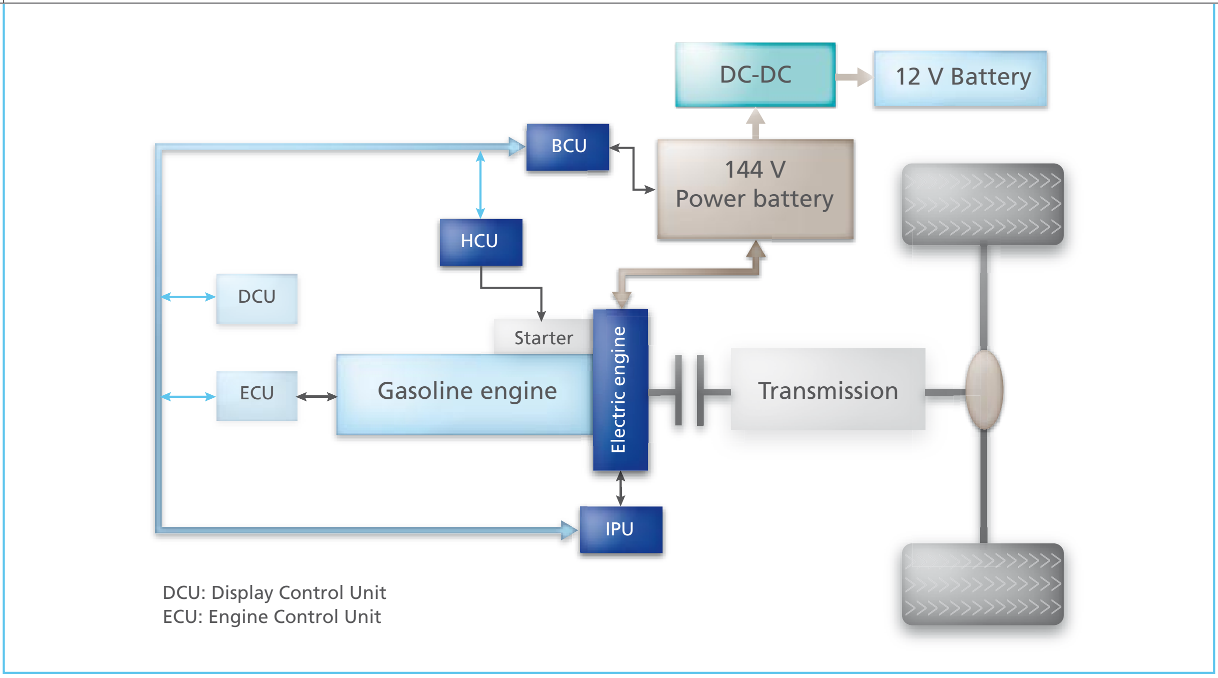
Following the Chinese market's needs for lower-emission and more fuel-economic passenger cars, ChangAn launched the "Jiexun" (杰勋: hero + glorious deed; pronounced: jié xūn [d̥ʑiɛ ɕyn]) hybrid project in late 2005, working closely together with several cooperating partners. As a mild hybrid car, the Jiexun offers features such as electric engine based parking (while the gasoline engine is in idling mode), power assistance and regenerative braking. Unlike full hybrid cars, the current Jiexun hybrid version does not offer autonomous electric driving yet. However, a full hybrid version with autonomous gasoline and electric engines is under development and will soon be introduced onto the Chinese market.

The fuel consumption of the current mild hybrid Jiexun averages 6.8 l/100 km or 34.6 miles per gallon (city traffic and expressway combined), and the emissions meet the Euro IV standard, which is in the process of becoming a standard in the P. R. China. During the 2008 Beijing Olympic Games, the Jiexun helped make the idea of a green, high-tech Olympics a reality. In Beijing, some 25 pre-production mild hybrid Jiexuns served as taxis and a press fleet during the games. ChangAn also provided 1,000 mild hybrid Jiexuns to the City of Chongqing and became the city's official partner for the Olympic project "1,000 vehicles for each 10 cities", which was initiated to demonstrate green technologies to a wide audience.

Developing New Control Units

The development project for the ChangAn Jiexun mild hybrid car consisted of three major phases of development with the respective outputs A, B and C sample (a func-

> "We developed the new control algorithms of the Jiexun mild hybrid control strategy with TargetLink. 80% of the code was generated automatically by TargetLink."
>
> *Dr. Ling Su, ChangAn Automotive*



The hybrid powertrain system of ChangAn's hybrid car contains three newly developed control units: the hybrid control unit (HCU), the battery control unit (BCU), and an intelligent power unit (IPU).

tional sample vehicle, a performance sample vehicle, and an end-product sample vehicle). The project focused especially on the multi-energies management system, the battery system technology, and the electric engine technology. ChangAn developed a new hybrid control unit (HCU) as the superordinate controller, as well as a battery control unit (BCU) and an intelligent power unit (IPU).

The Jiexun was one of the first hybrid cars developed in China. The hybrid components that are used are also brand-new. ChangAn developed most parts of the new control units necessary for a hybrid vehicle by themselves (with assistance from engineering partners) instead of buying units from suppliers, because their major goal was to establish an autonomous development and production chain for hybrid cars for future Chinese car generations, and to master the new technologies by themselves. An efficient, application-tailored tool chain is a key requirement for such tasks. ChangAn relied on the dSPACE tool chain during the entire development process, and will continue to use dSPACE tools in future high-demand projects.

> "Compared to competitors' code generators, ChangAn found the TargetLink-generated code to be of higher quality and efficiency."
>
> *Dr. Ling Su, ChangAn Automotive*

Jiexun's Hybrid Electrical System

To create a mild hybrid, ChangAn integrated an electric engine into the Jiexun, in addition to a gasoline engine. The electric engine is controlled via the IPU, which also contains strategies for coupling the electric engine and the gasoline engine, such as torque distribution in different situations. The power for the electric engine is supplied by a dedicated battery pack. ChangAn uses a nickel-metal hydride battery pack, allowing a maximum voltage of 200 V and a maximum current of ±200 A. The operating output of the battery pack is 144 V. It is connected on the one hand to the electric engine and on the other via a DC-DC converter to the car's 12 V onboard power supply, which in turn is backed by a 12 V battery. The battery management for both batteries is implemented on the BCU. The HCU acts as a superordinate controller.

Development Process and Development Tool Chain

To develop and test the controller software and the control units, ChangAn relied on a model-based design process from beginning to end. The software for the new vehicle controllers was developed from scratch, following typical steps such as function design, rapid prototyping, ECU autocoding, hardware-in-the-loop (HIL) testing and ECU calibration. The control functions were designed in MATLAB®/ Simulink®. To develop and test the control strategy on in-vehicle tests, and to generate test signals during the platform reliability tests, ChangAn intensively used the dSPACE MicroAutoBox, in combination with peripheral circuits for sensor and actuator connection. To verify the function strategy and test the CAN-based communication and the

"To develop the controllers of the new Jiexun hybrid vehicle, we relied on a dSPACE tool chain during the whole development process, and we will continue to use the dSPACE tools for further demanding projects."

Dr. Ling Su, ChangAn Automotive

software logic, ChangAn employed dSPACE Simulator, with dSPACE ControlDesk as the experiment software. The simulation models were partly in-house from ChangAn, and partly provided by an engineering partner. The test automation was done by an engineering partner, using dSPACE AutomationDesk. For measurement and calibration tasks, ChangAn used dSPACE CalDesk plus a further calibration tool. This seamless tool chain helped achieve the development goals on time.

From Function Design to ECU Software

To develop software for the performance sample vehicle, TargetLink served as the main development tool and for automatic C code generation from Simulink blocks. Model-in-the-loop (MIL) testing was intensively used to test the submodules of the controller model. MIL testing as a "front loading" activity brought ChangAn valuable quality improvements and saved time in the subsequent process steps. Via software-in-the-loop (SIL) testing, ChangAn compared the behavior of the generated code with the MIL testing results. Finally, ChangAn prepared the code for the S12XDP512 microcontroller with the help of processor-in-the-loop (PIL) simulation. TargetLink's comprehensive simulation techniques were a highly effective accelerator for the project.

Comprehensive HIL Tests

To test the HCU, the ECU, the IPU and the BCU simultaneously and automatically, ChangAn used dSPACE Simulator again. Numerous test cases were run. For example, ChangAn simulated the overall network behavior in the case of sudden voltage changes, and simulated failure events in the CAN communication network. Once again, the test automation was done by an engineering partner, using AutomationDesk. The final calibration was done with CalDesk plus a further calibration tool. ■

Dr. Ling Su
ChangAn Automotive
P. R. China

Conclusion and Outlook

ChangAn aims to master the core technologies in the field of hybrid drives with independent development capabilities, and to formulate a complete development and production process for hybrid cars. The emerging hybrid technologies and their integration into vehicles are a challenge: many software and hardware elements need to be developed from scratch, as there has been no precedent in China so far. dSPACE tools helped the company take an enormous step in hybrid car development. ChangAn has set up a professional research and development team to tackle key technical problems by fully utilizing and integrating resource advantages both at home in China and abroad. ChangAn plans to further apply dSPACE products for the development of electronic control units, hybrid cars, pure electric drives, fuel cell technology, solar energy technology, etc.

Higher, Faster, Further

Active damping control for turntable ladders

Turntable ladders nowadays are required to go higher, faster, further – and be safer. Lightweight construction is the key to achieving these goals. But there is a problem: The new lightweight ladders tend to suffer from bending oscillations. The Institute for System Dynamics at the Universität Stuttgart in Germany used dSPACE tools to develop an active damping control for the manufacturer IVECO MAGIRUS Brandschutztechnik.

Turntable ladders, the most distinctive item of equipment used in fire rescues and firefighting, can reach working heights of up to 55 m. Once a ladder's base is in position, the ladder itself has to reach rescue height in minimum time. Modern vehicles take far less time for this than the standard of 180 s that applies to the 30-meter ladders generally used in Germany. The extensible ladder is mounted on a hydraulic turntable and can be raised and tilted by two hydraulic cylinders. A 30-meter telescopic ladder can span more than 17 m horizontally – this is called outreach – and a load of up to 300 kg can be transported in the cage. With their requisite lightweight construction and considerable length, turntable ladders have limited flexural stiffness. So when they move, flexural vibrations are induced. External forces like the wind and load variations caused by the people in the rescue cage also cause vibrations. The usual way of countering this effect is to greatly reduce the speed of motion – which is far from ideal in an emergency rescue. Moreover, slow deflection movements impair the safety and comfort of the ladder.

Joint Research Project by the Institute for System Dynamics and IVECO MAGIRUS

Active damping of these flexural vibrations is therefore the main focus of a research project that has been running continuously since 1998, in close cooperation between the Institute for System Dynamics and IVECO MAGIRUS. Active damping control has been one of the standard features of the new CS ladder series (CS = computer-stabilized) since 2001. Combined with a memory function, it is one of the main reasons why the CS

IVECO MAGIRUS DLK 23-12 CS with rescue cage in action.

models have been so successful. Active damping control gives the CS ladders from IVECO MAGIRUS a unique selling point on the market. More than 700 vehicles with CS in their name are now in action worldwide. And the Institute for System Dynamics is continuing its cooperation with IVECO MAGIRUS, performing ongoing research and development to make the control even more effective. Now the third generation is just coming up to production level. It actively damps not only the fundamental frequency of the vibration, but also its harmonic frequencies.

> "The ControlDesk software provides numerous options for editing and managing various experiments, setups, and measurement signals simply via drag & drop."
>
> *Nico Zimmert, Institute for System Dynamics, Universität Stuttgart*

The Ladder's Movements

The operator controls the ladder's movements from the console on the vehicle or in the cage. The bending vibrations are captured by two different sensor systems. One of them consists of strain gauges on the ladder set not far from its mount. These detect the material strain caused by the ladder bending and output the elongation in its longitudinal and lateral directions. The other system consists of gyroscopes at the tip of the ladder. These measure the changes in its position, or more precisely, its rotational speed, in all three spatial directions. The vertical and horizontal deflection, and also the torsion of the ladder, are obtained from these two measurement systems by model-based analyses. Incremental encoders on each rotational axis are used to determine the angles of elevation and rotation. The ladder's current length is also ascertained by means of incremental encoders. The processor captures all the turntable ladder's states from the sensors immediately. It condenses and evaluates the incoming data, and converts it into suitable control signals for the hydraulic drives via model-based controller modules – all in a fraction of a second. The ladder's movements basically follow the operator's inputs. At the same time, its bending vibrations are actively suppressed by hydraulic drives, with a gentle counter-control that is hardly perceptible to the operator.

IVECO MAGIRUS DLK 55 CS with elevator and rescue cage ready for operation.

Advantages of Active Damping Control

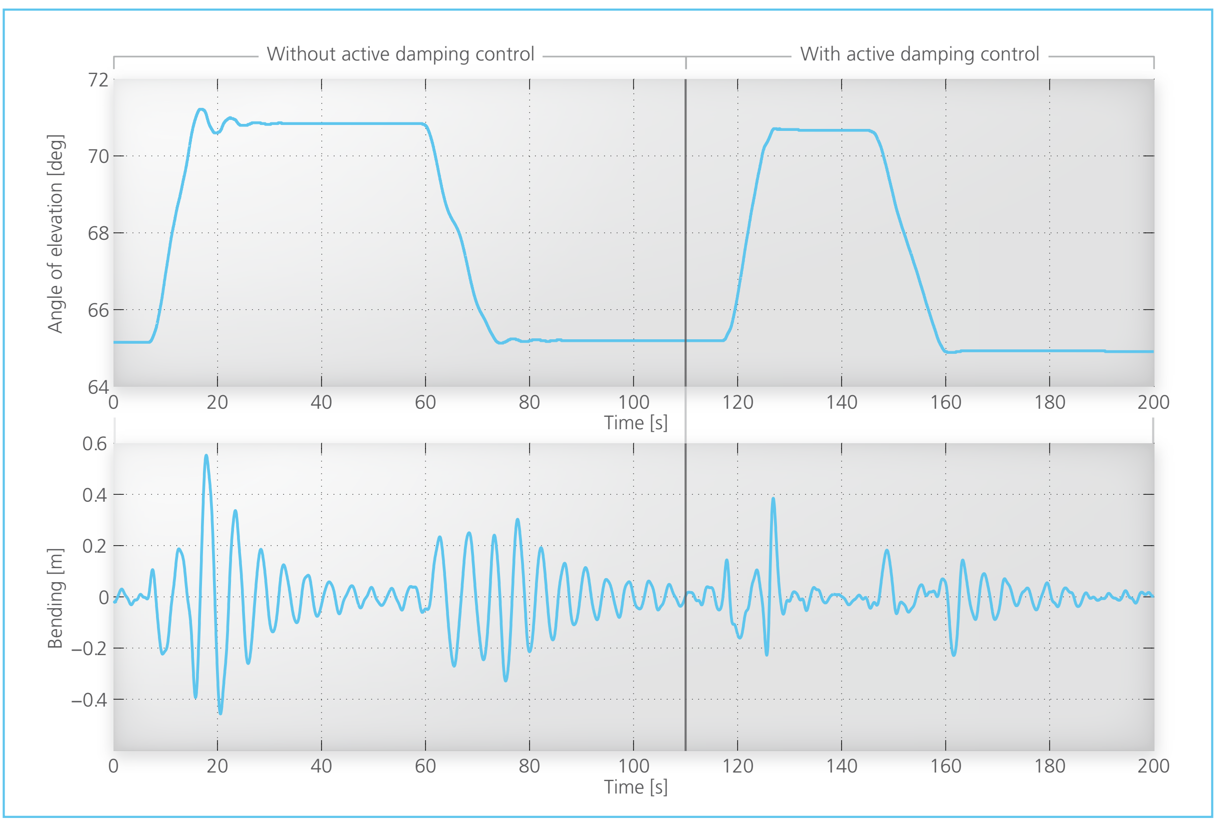
Using the active damping control software increases the stiffness of the overall system, making it possible to reach the rescue position much more quickly and safely. The speed of motion can be increased because reducing the bending and weight also reduces the dynamic forces. Moreover, because it is systematically designed to be lightweight, the vehicle has a low total weight. This means a longer outreach can be achieved from the same base. A rescue cage can hold only three to four people, so a memory function was developed for rescuing several people from the same rescue point. The operator specifies the trajectory between the rescue point and the ground during a teach-in operation. This trajectory can then be repeated within a preset tolerance and at maximum speed. The operator can specify at any time whether the trajectory should be repeated at maximum speed or more slowly. He or she can even stop the ladder at any point and reverse the direction of its trajectory. This provides great flexibility for work at the rescue location.

Model-Based Development

The active damping control was developed by model-based design, and all the control laws are available in analytical form. This means that the algorithm can always be adapted if parameters such as the ladder's length and payload are changed. The control has two degrees of freedom, that is, there is a feedforward control and a feedback control that can be designed separately. The feedforward control is designed so that only a minimum of bending or vibrations are induced in the ladder. The feedback control uses the sensor data to compensate the bending vibrations that occur despite the feedforward control, e.g. due to external disturbances. In the new

The Benefits of Active Damping Control:

- Greater safety for people and machine by reduced bending and other vibrations
- Faster ladder motion (especially with the memory function)
- More precise positioning
- Longer outreach and enhanced stability due to additional weight savings
- Greater comfort



Comparison of deflection at the ladder's tip and of the elevation angle of a DLK 55 CS while being raised at approx. 50 m ladder length, without and with active damping control.

IVECO MAGIRUS DLK 55 CS with elevator and rescue cage ready for operation.

generation of the active damping control, the higher eigenfrequencies of the ladder are also actively damped.

Test System Setup

During the design phase for the active damping control, we use a dSPACE prototyping system based on a DS1103 PPC Controller Board. The board communicates with the vehicle's ECU via the CAN bus and reads out all the necessary measurement data. The CAN communication can be set up quickly and simply with the dSPACE RTI CAN Blockset. During this phase, dSPACE's ControlDesk software provides numerous options for editing and managing various experiments, setups, and measurement signals via drag & drop. We use these to run experiments capturing static and dynamic variables so that we can identify parameters for model-based control design. Then we develop the control algorithms in the MATLAB®/Simulink® environment and study their functionality and the initial design by means of simulations.

The next step is to test the algorithms on the actual vehicle, using the DS1103. The hand lever signals from the operating console are read, appropriately manipulated, and then transmitted to the ECU via CAN. This procedure lets us run intensive tests, fine-tune the control, and implement a new controller concept quickly and with very few hardware adaptations.

The TargetLink production code generator is used to implement the algorithms on the vehicle's ECU. The microcontroller in the ECU uses fixed-point arithmetic, so TargetLink automatically generates fixed-point source code in ANSI-C in the algorithms. The autoscaling tool, together with the ability to simulate algorithms in both floating-point arithmetic (by model-in-the-loop simulation) and fixed-point arithmetic (by software-in-the-loop simulation), make it possible to verify the algorithms

> "With the dSPACE prototyping system, we can develop and test the active damping control quickly."
>
> *Nico Zimmert, Institute for System Dynamics, Universität Stuttgart*

dSPACE Products in Use:

- DS1103 PPC Controller Board as a controller module in the vehicle control during development
- Real-Time Interface to integrate the bus and additional measurement devices during identification
- RTI CAN Blockset for communication with the vehicle CAN
- ControlDesk to experiment with the active damping control
- TargetLink for autocoding to port the control algorithms to the microcontroller hardware
- Autoscaling tool to scale the fixed-point calculations automatically

early in the design phase. And with the extensive simulation functions, it is easy to scale the complex mathematical calculations. dSPACE's integrated tool chain guarantees fast, consistent portation of the algorithms from the MATLAB/Simulink environment to the ECU.

Conclusion

The research project is an example of successful cooperation between a university institute and an industrial company. The Institute for System Dynamics not only plays a role in developing the technology, but also provides support throughout the project, from the prototype and the preproduction vehicle to the production vehicle. Product-related innovations can be designed efficiently, quickly, and successfully for both sides in this way.

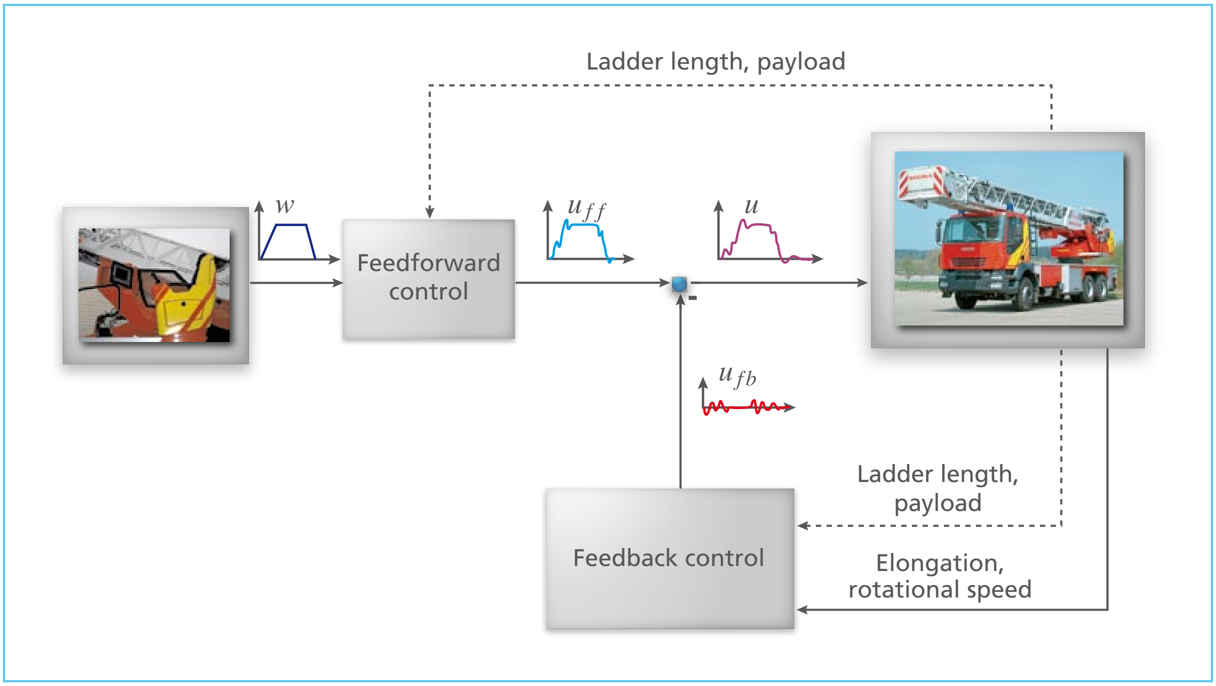
Nico Zimmert, Prof. Oliver Sawodny, Institute for System Dynamics, Universität Stuttgart; Reinhard Keck, Christoph Lauterjung, IVECO MAGIRUS Brandschutztechnik GmbH, Ulm, Germany

The Institute for System Dynamics

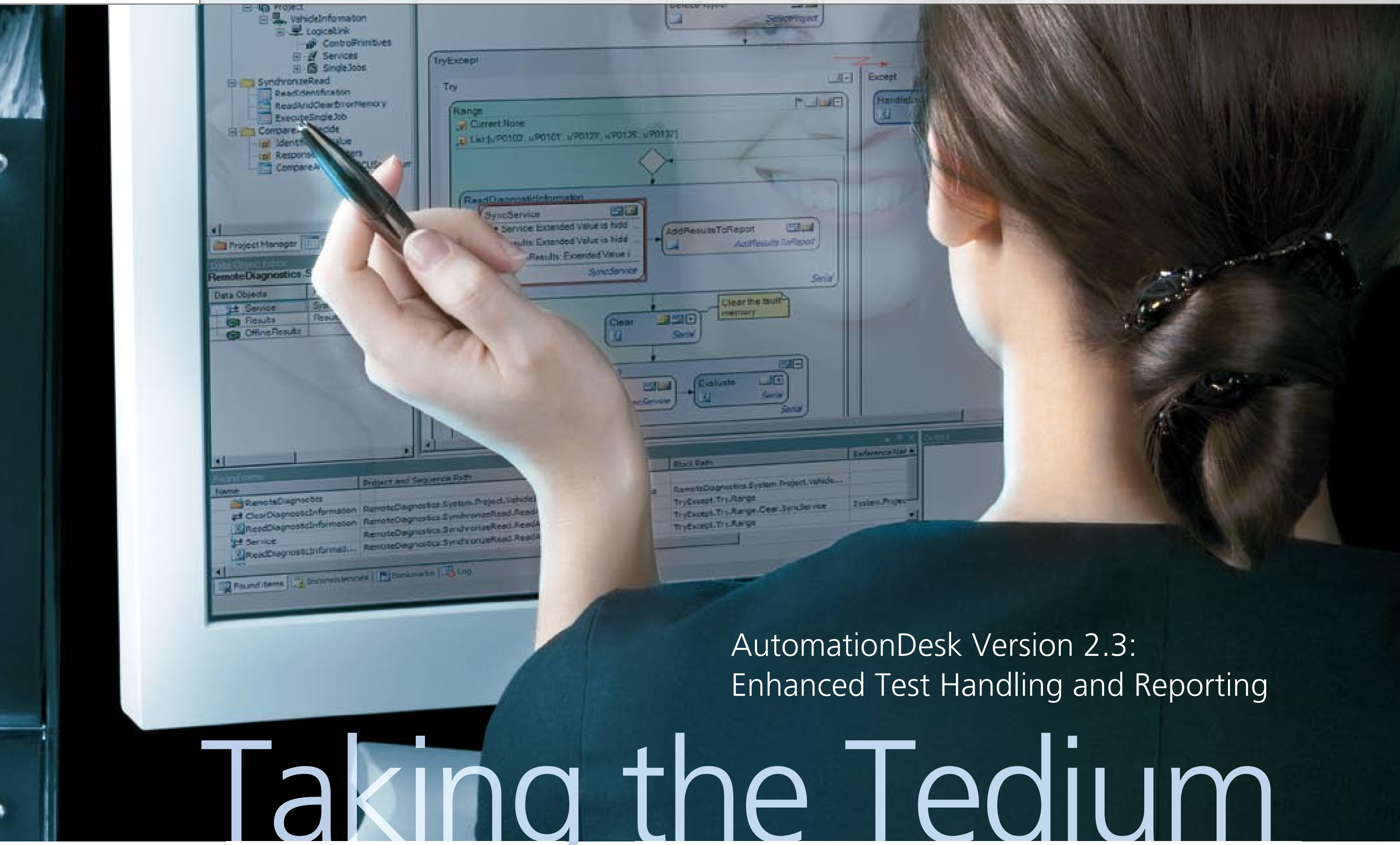
Research at this institute at Universität Stuttgart is mainly concerned with analyzing the dynamics of systems. The researchers use methods from system theory, modeling, simulation, control engineering and optimization, which they develop further. They study systems from widely differing fields, such as mechatronics, process engineering, traffic regulation, and biology. The result is an interdisplinary scenario that integrates all sorts of different sciences. It is characteristic of the institute that it not only performs basic research on developing methods, but also investigates how to implement the methods in automation engineering.

IVECO MAGIRUS Brandschutztechnik

At six locations throughout Europe, IVECO MAGIRUS produces a wide range of vehicles and equipment for fire protection and disaster control. With more than 1,300 vehicle units sold a year, IVECO MAGIRUS is one of the world's largest providers in this sector. The MAGIRUS brand is the global market leader for turntable ladders.



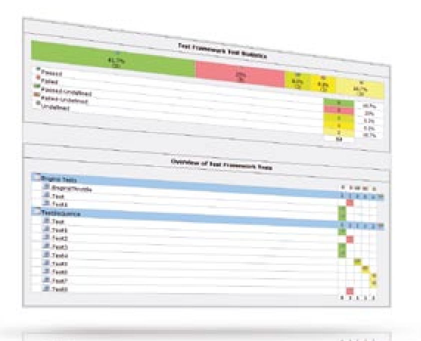
How the 2-DOF control works: The ladder length and the payload are parameters that vary over time and are used to adapt the control.



AutomationDesk Version 2.3:
Enhanced Test Handling and Reporting

Taking the Tedium out of Testing

Creating and executing tests, and then evaluating them, can be a tedious routine task. To make the tester's job as easy as possible, we have extended AutomationDesk, our test and automation software. Numerous aspects of its user interface and handling have been revised and enhanced.



The statistics on the test results provide quick information on the current status of the software quality.

Simplified Test Development

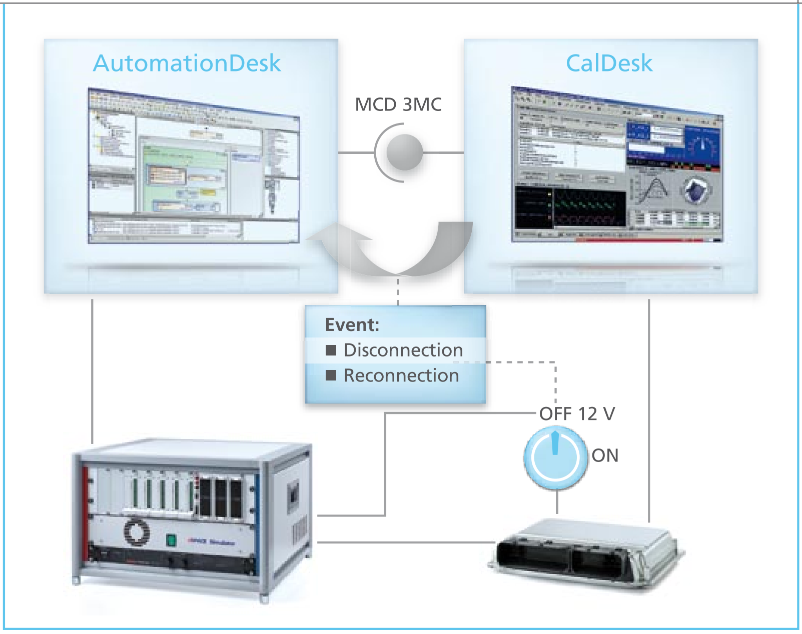
The new AutomationDesk makes it much easier to verify test sequences – even while they are still being developed. To switch out a test step or sequence, a user can simply comment it out, and then switch it back in again just as easily. Being able to switch off specific sections this way is extremely useful during test development, and facilitates error-finding.

Comprehensive Test Report

When test execution is complete, AutomationDesk can generate a report showing which test sequences were executed successfully and which were not. Each report begins with statistics on all the test results. The user can then ask for a more detailed report to be output, including the statistics, or use the statistics alone. These present all the important results in a concise form, making it easier to evaluate and assess the software quality of the electronic control unit (ECU) under test.

Enhanced Process Integration

Smooth cooperation between our individual software products is important to us at dSPACE. So we have enhanced the interaction between AutomationDesk and CalDesk, dSPACE's measurement and calibration software. For example, if the connection to an ECU is lost during a HIL test, CalDesk reports this to AutomationDesk via the MCD 3MC interface. The ECU can be disconnected intentionally by switching it off manually, or accidentally due to an error. The purpose of intentional disconnection is usually to test how the rest of the system behaves if one ECU fails. The test can be made to



CalDesk and AutomationDesk interact closely in the test process.

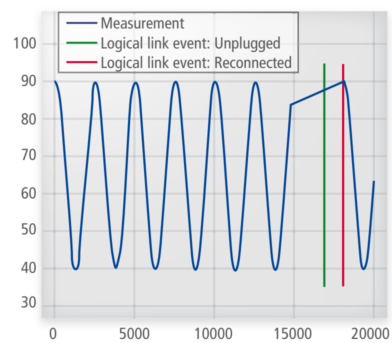
AutomationDesk is constantly being extended to meet all users' new requirements.

react to the ECU's disconnection, and if necessary also to its reconnection. The points in time when this occurs are shown graphically in the test report.

There is also an extended COM-API to facilitate access to AutomationDesk from the outside. Users can create, read, and parameterize all the available data objects, and they can also execute test sequences. This means that tests can be automated and executed with different parameterizations.

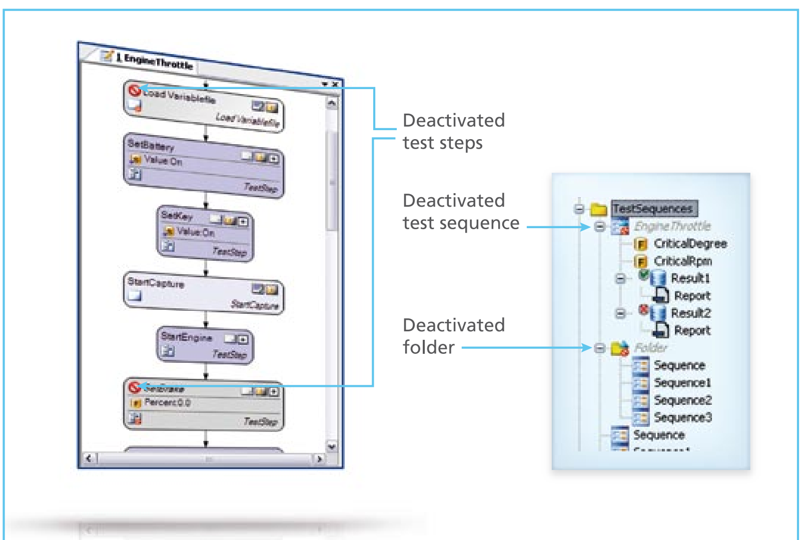
Managing Real-Time Tests

AutomationDesk comes with several different libraries containing ready-made test steps that support a wide range of applications. Now a new, special library has been added to



The test report documents the disconnection and reconnection of an ECU.

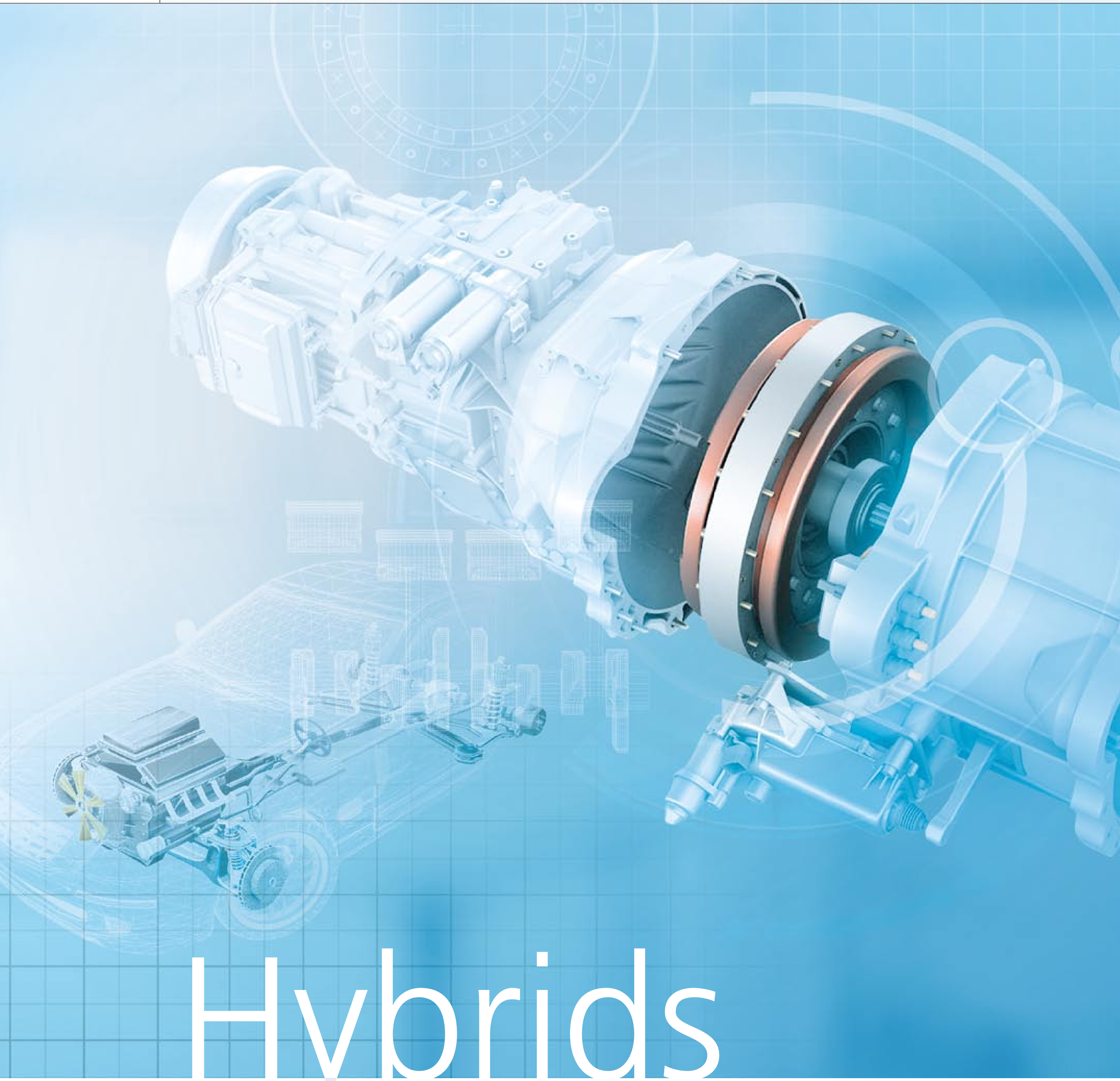
simplify the management of real-time tests in AutomationDesk test sequences. These can now be loaded to the hardware-in-the-loop simulator and executed via special test steps from within an automated test. Users can view the test status at any time.



Test steps and test sequences that are commented out are deactivated. They are highlighted in the graphical test sequence and the library structure, and ignored in test execution.

Testing in Real Time

Another new library, RS232 Real-Time Library, allows direct access to the on-board RS232 interfaces of the dSPACE DS1005 and DS1006 processor boards. So when users want to address a simulator's RS232 interfaces, they no longer need Real-Time Interface (RTI) blocks in their models or scripts on a PC. This means that the RS232 data exchange can be configured completely from within a real-time test and controlled under real-time conditions. ■



Hybrids under Control

Developing and Testing ECUs for Hybrid Drives and Electric Motors

A current goal for vehicle developers is to reduce CO_2 emissions yet maintain a high standard of driveability. For many car makers, hybrid drives are one solution. What challenges do they face? What products give them support? dSPACE provides the answers.

When a vehicle's combustion engine is supplemented by an electric motor, either the existing electronic control units (ECUs) need additional functions, or completely new ECUs have to be added. Electric motor ECUs are characterized by extremely dynamic behavior, which means short sampling times and control loops in signal capture. Function development has to take this into account, and so do the tests. dSPACE provides comprehensive hardware and software for this.

Function Development

Efficient function development means being able to try out and test new algorithms flexibly, without having to think about how to implement them on the target platform. dSPACE prototyping systems can represent either parts of the ECU under development, or even the whole ECU. For example, they might represent the top-level central hybrid controller, or they might directly control the auxiliary units required for hybrid operation, such as gasoline and water pumps.

Prototyping with dSPACE

When a dSPACE prototyping system is used for function development, users are not bound by the restrictions that will be imposed later by the ECU itself. Instead, they have high computation performance and enormous memory capacity. They can transfer new functions to the prototyping system from a MATLAB®/ Simulink® model with push-button

ease in dSPACE Real-Time Interface (RTI). This makes it possible to perform fast iterations.
Moreover, dSPACE prototyping systems can also be used in the actual vehicle, so that functions can be verified not only in the laboratory, but also in actual driving operations.

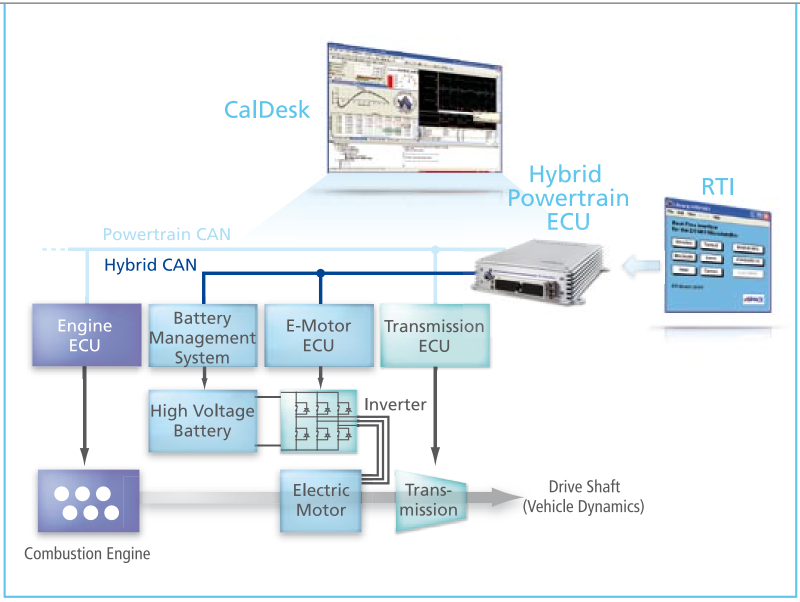


Figure 1: The dSPACE MicroAutoBox is used as a central hybrid ECU during development.

Typical Use Scenarios

1) Developing a hybrid controller:
The dSPACE MicroAutoBox is ideal for developing a top-level, central hybrid controller (figure 1). It has the necessary bus interfaces – CAN, LIN, FlexRay, etc. – and also additional I/O. It is just as easy to run in ECU networks as an actual ECU, so it integrates seamlessly. And with its small, compact design, it can also be installed in the vehicle.

2) Electrifying various auxiliary units:
Electrifying the various auxiliary units requires a modular, scalable system for integrating new functions or ECU software into existing ECUs. This is where the dSPACE AutoBox comes in (figure 2). Used together with the signal conditioning and power stage modules of the dSPACE RapidPro system, it provides a completely configurable solution. Control signals for block/sine commutation, I/O interfaces for Hall sensors and encoders, are available to users. Sensorless processes are supported by precise measurements of powertrain voltages and motor currents. Measurements and parameters can be changed during run time with dSPACE CalDesk. This measurement and calibration software is optimized for in-vehicle use on a notebook.

Testing ECUs for Hybrid Drives

To test the new ECU functions, the ECU is connected to a hardware-in-the-loop (HIL) simulator that simulates the rest of the hybrid drivetrain. The modular design of dSPACE simulator hardware allows users to set up different types of hybrids such as:

- Serial and parallel hybrid drives
- Micro hybrid drive with starter and generator
- Mild and full hybrid drives

HIL Tests with dSPACE

In a typical simulator setup for hybrid drives, the transmission, engine, and battery simulations are implemented in different simulators. These contain two parallel CAN networks – a drive CAN and a hybrid CAN. The drive CAN connects the standard ECUs, such as those for the engine or the transmission. The hybrid-specific ECUs communicate via the hybrid CAN (figure 3). ECUs that are not yet available are represented in these networks by restbus simulation so that an entire vehicle can be simulated.
To achieve the short sample times required for electric motors, the

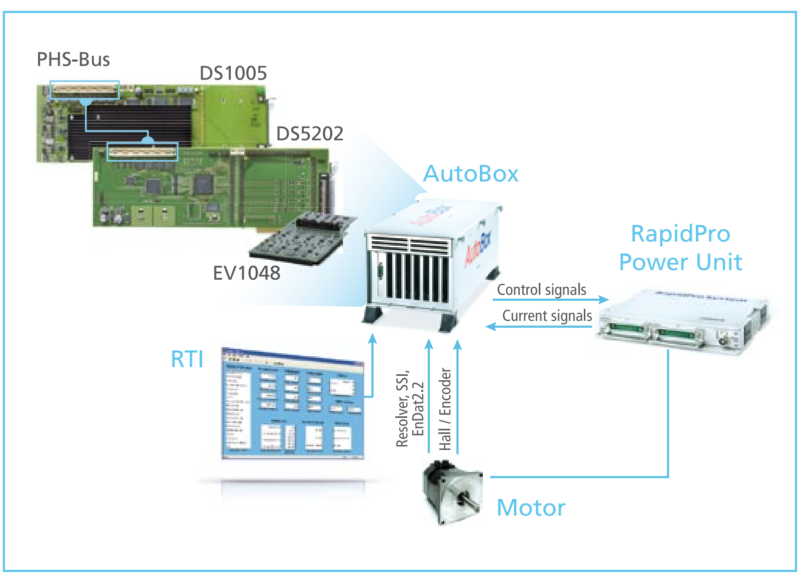
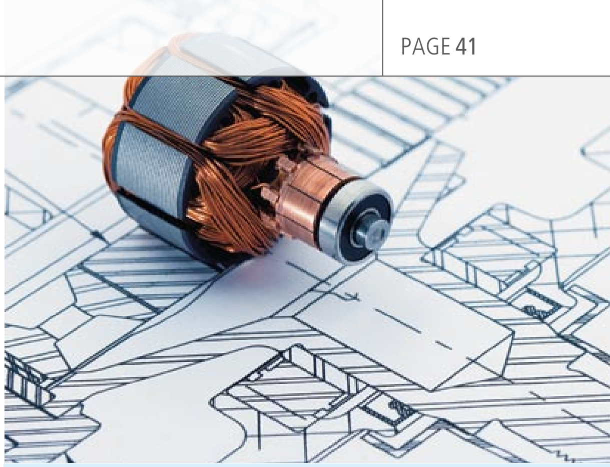


Figure 2: The dSPACE AutoBox can be flexibly adapted to the requirements of different electric motors.



dSPACE's mature products support the development of ECUs for hybrid drives from the first design to the final test.

signals have to be preprocessed. dSPACE offers its PWM (pulse width modulation) and PSS (position sensor simulation) solutions for this. These interact closely with the processor to calculate the electric motor model. If the ECU under test requires precise current behavior, the dSPACE Electronic Load Module is used. This feeds the real current to the ECU. To control the module, parts of the electric motor model are moved out to the dSPACE FGPA Board to be calculated.

Simulation Model

Real-time simulation models are indispensable for HIL tests. dSPACE's Automotive Simulation Models include an Electric Component Library especially for electric motors. The model components from the library can be integrated into existing models. Simulating battery behavior and integrating electric motors into a hybrid vehicle are just two of the library's typical applications. ■

Further Developments

At dSPACE, we are constantly expanding our product range, and strongly believe in modularity. An upcoming example: RapidPro will soon have new modules for controlling brushless motors.
Our goal is to continue supporting developers in the future, from the initial function design to the final integration test. To ensure we are the ideal development partner, dSPACE is dedicated to providing innovative products.

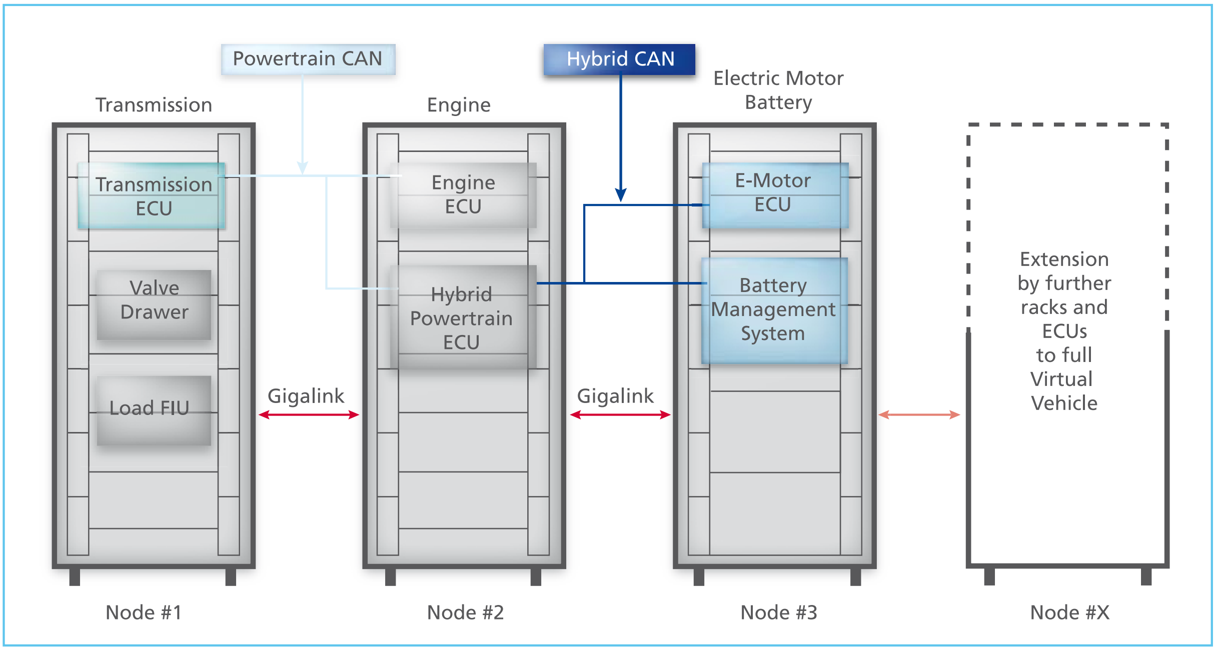


Figure 3: Example setup of an HIL test system for a hybrid drive.

EcoCAR: The NeXt Challenge Goes Green

Next Generation Automotive Engineers Develop Sustainable Mobility Technologies

dSPACE tools will aid students in developing production-ready prototypes that demonstrate their "green" vehicle architectures.

For the EcoCAR Challenge the U.S. Department of Energy (DOE) assigned a three-year pilot project to 200 students from various universities. The teams must develop a production-ready prototype vehicle and demonstrate the implementation of their "green" vehicle architecture.

GM provided a Saturn 2009 VUE which the students are converting for greater eco-friendliness.

Some of the world's most original inventions can be traced back to the college campuses and research laboratories of the academic community. It is within this environment – where students and faculty members can interact freely and exchange ideas – that technological innovation is born at a grassroots level.

> "I'm really excited that dSPACE is able to help EcoCAR teams by donating mid-size simulators and other tools to streamline our controls development. The HIL will save us time, and many, many headaches."
>
> *Alex Koch, team captain EcoCAR, University of Waterloo grad student*

Exploring and Developing Sustainable Vehicle Solutions

Since 1987, the DOE has sponsored 45 North American collegiate advanced vehicle technology competitions.

The competitions, organized and managed by Argonne National Laboratory, a DOE research and development facility, have been highly successful. Past events have resulted in student-developed technologies for increased fuel economy, reduced petroleum usage, reduced greenhouse gas (GHG) emissions, reduced NO_x emissions, and more. All of these technology areas are fundamental objectives for the DOE in its initiative to champion sustainable mobility.

Greater Performance for Green Power

In May of 2008, the DOE – along with sponsor General Motors (GM) – announced the onset of its newest competition – EcoCAR: The NeXt Challenge. Nearly 200 students from 17 North American universities were selected to participate in the three-year competition, which kicked-off in August 2008 and ran through June 2011.

Each participating team was challenged to re-engineer a 2009 Saturn VUE compact crossover SUV (donated by GM), with the following objectives:

- Reduce petroleum energy consumption on the basis of a total fuel cycle well-to-wheel (WTW) analysis
- Increase vehicle energy efficiency
- Reduce criteria gas and WTW emissions
- Maintain consumer acceptability in the areas of performance, utility and safety

In support of EcoCAR's "green" theme, students must strive to achieve vehicle designs that meet California Air Resources Board (CARB) zero emissions vehicle (ZEV) regulations. Teams are encouraged to integrate lightweight materials, improve aerodynamics, and utilize alternative fuels such as ethanol, biodiesel and hydrogen.

A Taste of Real-World Engineering

The EcoCAR Challenge is funded and supported by a network of 30 sponsors who are providing money, hardware, software, training and support. Students are not only gaining access to state-of-the-art tools and equipment, but they are in direct contact with their sponsors who provide hands-on technical support and industry insight.
The EcoCAR Challenge drives the exchange of technology and incites

innovation through the establishment of student-industry partnerships with program sponsors.

Additionally, to give students real-world experience, the teams are required to model their vehicle designs to the GM Global Vehicle Development Process, which includes stipulations for engineering practices, resource allocation and deliverables.

Another aspect of the EcoCAR Challenge is focused on educating youth about engineering as a career path. Teams are encouraged to plan outreach events throughout the year to give students at all levels – elementary, middle, high school and college – insight into the field of engineering and its important role in developing innovation. Outreach efforts are also aimed at educating the general public about EcoCAR and technologies that support sustainable mobility.

Even people in politics have become aware of the competition. California's Governor, Arnold Schwarzenegger, made a surprise visit to the GM exhibit at the SAE World Congress to learn more about the EcoCAR Challenge. He spent some time listening to Kent Helfrich, Powertrain Executive Lead for EcoCAR and Director for Powertrain Software Engineering at GM, talk about the EcoCAR program.

Dedicated to Learning

University of Waterloo grad student Alex Koch says he is definitely up to the EcoCAR Challenge. Upon completing his undergrad degree last year, Koch received an attractive job offer, but he turned it down to pursue the university's graduate program and participate in EcoCAR as team captain.

"This challenge is as close as you can get to advanced vehicle development," said Koch. "There are late nights and early mornings and it's all driven by an underlying feeling that we (the students) are contributing to something big – something worthwhile – something that will make a difference."

Green Success

Green Competence with dSPACE Products

dSPACE has been an active partner to the automobile industry for over two decades, supporting research and development on new drive technologies. dSPACE products have played an important role in optimizing downsized engines, developing electric vehicles and hybrid drives (micro, mild, and full hybrid), and designing hydrogen vehicles with fuel cell drives and many other innovations.

For further information, see www.dspace.com

Arnold Schwarzenegger visiting the GM exhibit at the SAE World Congress, learning more about the EcoCAR Challenge.

> "The level of tools, technology, and training available are opportunities that many engineers do not have access to and will open many doors for graduating students."

John Robbins, computer engineering graduate student, Mississippi State University

John Robbins, a computer engineering graduate student at Mississippi State University, concurred that the EcoCAR competition is highly valuable to students.
"I absolutely enjoy every minute I spend on EcoCAR projects," Robbins said. "The level of tools, technology, and training available are opportunities many engineers do not have access to and will open many doors for graduating students."

Getting Eco-Friendly Vehicles Ready to Go

As a platinum-level sponsor, dSPACE has donated a suite of tools to enable students to develop and deploy advanced control strategies, simulation, vehicle integration and testing activities. Additionally, dSPACE has assembled a team of engineers to serve as dedicated technical mentors to the EcoCAR teams that are utilizing dSPACE equipment in their application projects. Tools donated by dSPACE include:

- MicroAutoBox/Rapid Prototyping Systems with ControlDesk (a graphical experiment management software program). These tools will be used as supervisory controllers.
- Mid-Size hardware-in-the-loop (HIL) simulators for testing new control algorithms.
- CalDesk for measurement and calibration of the dSPACE and non-dSPACE controllers.
- SystemDesk for planning, implementing and integrating complex system architectures and distributed software systems.
- TargetLink for automatic production-quality code generation.

Students received training on HIL simulators and other dSPACE tools during January workshops.

Communication and Control via dSPACE MicroAutoBox

"I'm really excited that dSPACE is able to help EcoCAR teams by donating mid-size simulators and other tools to streamline our controls development," said Koch. "The dSPACE simulator will help us to identify many issues that otherwise wouldn't be noticed until the vehicle testing phase. The HIL will save us time, and many, many headaches."

Koch said his team is using the MicroAutoBox as the primary vehicle controller in their platform vehicle. "It will let us communicate and control all of the new hybrid power train components that we will implement over the next year," he said. "The ControlDesk software, used with the MicroAutoBox, will definitely streamline our troubleshooting and calibration process and it's extremely easy to use."

Robbins said the dSPACE HIL and MicroAutoBox have given his team the freedom to try any approach for controlling and simulating their vehicle.

"dSPACE's tools give us the ability to turn our ideas into experiments. This is exactly what we need," he said. "Additionally, dSPACE training is top notch, and their tools are some of the best documented in the industry."

Developing a Green Vehicle Architecture

Over the three-year duration of the EcoCAR Challenge, teams must fully design and develop a production-ready prototype vehicle and successfully demonstrate the implementation of their chosen "green" vehicle architecture.

During a press conference held at the Washington Auto Show, Washington D.C., in February 2009, the teams announced their chosen architectures. They will pursue Extended Range Electric Vehicles (EREV), Plug-in Hybrid Electric Vehicles (PHEV), Full Function Electric Vehicles (FFEV) and Fuel Cell Plug-in Hybrid Electric Vehicles (FCPHV).

While these architectures represent different technology solutions, every vehicle design must:

- Have plug-in capability.
- Use state-of-the-art lithium ion battery technology, so the vehicles can store more electricity.
- Lower energy consumption.
- Use a renewable energy source that displaces petroleum consump-

Several teams visited dSPACE Inc.

tion, which significantly reduces the amount of greenhouse gases emitted from the vehicle's tailpipes.
- Have team architectures that retain the safety and real-world performance characteristics of production vehicles that consumers demand.

What Counts

Strong emphasis is being placed on using best-practices methodology and tools to develop control algorithms. Students will incorporate model-based development, rapid control prototyping (RCP), software-in-the-loop (SIL) simulation, and hardware-in-the-loop (HIL) simulation. This environment will enable students to implement complex control designs quickly, and to test them early against real-time simulations before they are introduced to the actual vehicle.

"Over the past two decades, we have seen a remarkable evolution in the sophistication and complexity of automotive technology," said Kristen De La Rosa, Director of Advanced Vehicle Technology Competitions, Center For Transportation Research Argonne National Laboratory. "To stay industry relevant, the competition program has also evolved dramatically, by utilizing the latest cutting-edge technologies and engineering practices. The dSPACE tools, for example, allow teams to develop HIL simulations of their vehicles where they can test and validate advanced in-vehicle hybrid system controllers before the actual vehicle designs are assembled."

During an EcoCAR Winter Workshop held in January, students received tools, equipment and training to ramp up performance modeling, control system design and simulation activities.

Making Eco-Friendly Transportation Usable

EcoCAR Competition Finals for the conclusion of year one activities were held June 7-13, 2009, in Toronto, Canada. A panel of judges assessed each team on their use of model-based design tools to ensure the proper fit of components into prototype vehicles and the functionality of electrical, mechanical and software systems. The teams were also judged on how effectively they used SIL and HIL simulation to develop controls and subsystems and on their educational outreach efforts.

The overall winner was The Ohio State University, followed by the University of Victoria and the Mississippi State University. All three winning teams used dSPACE's hardware-in-the-loop and rapid prototyping tools. Other awards were made for the best design, the best technical report, the best presentation, and so on. dSPACE also presented its Embedded Success Award to three teams that designed their vehicles with dSPACE equipment.

In years 2 and 3 of the EcoCAR Challenge, the teams will implement their vehicle designs through the build out of a working prototype vehicle.

For more information on EcoCAR, visit www.ecocarchallenge.org. ■

10 Years of TargetLink

Milestones in a Success Story

Automatic production code generation is one of the decisive phases in developing electronic control units and embedded software. Since its launch in 1999, the automatic production code generator TargetLink has been an amazing success story. The automotive industry regards TargetLink as its established autocoder.
Its automotive applications cover every area of a vehicle: powertrain, chassis, driver assistance, comfort, active and passive safety systems, and so on. And for several years now, it has been used to develop safety-critical aerospace systems.
In fall 2009, TargetLink will look back on ten years of market success. Come with us on a journey through time as we show the milestones since 1999!

Safety-critical application: cabin pressure control for the A380.

Daimler's engine ECU development department relies on TargetLink.

TargetLink supports AUTOSAR software components.

1999

The Revolution: Straight from Simulink® Model to ECU

With its launch in fall 1999, TargetLink revolutionizes the development of electronic control units (ECUs): Production-ready code can be generated from the controller model and transferred directly to the ECU at the touch of a button. Handcoding is now obsolete. The first production projects begin before the year ends. With TargetLink, Daimler completes a research project for a hybrid truck in only 3 months.

2001

Top Benchmark Results Impress the Entire Industry

TargetLink's excellent benchmark results cause a sensation. International automotive manufacturers and suppliers are impressed. Moreover, the production code generator now has an added attraction as the "missing link" between function model and ECU: It closes the major gap in the development process and ensures seamless integration. TargetLink is also valued in the off-highway sector: An international manufacturer of agricultural machines uses TargetLink to develop tractor transmissions and other control components.

2003

Entire Departments Rely on TargetLink

TargetLink is now a valuable tool in large project teams, where it blends seamlessly into the development process. The new "programmer" is now a full team member, for example, at Daimler. The company has switched its entire engine ECU development department over to automatic production code generation with TargetLink.

2000

On the Road: TargetLink Code in Production Vehicles

TargetLink attracts widespread interest in the automotive industry. OEMs and suppliers worldwide begin evaluation and pilot projects, and use the results in actual production.

Nissan launches an engine control component for the 2000 Sentra, the first TargetLink-developed product to go into production. The results of this project and others are impressive.

2002

The First Safety-Critical Aviation Application

The aviation industry has particularly strict safety requirements. TargetLink has made its mark on aviation – in projects like the cabin pressure control from Nord-Micro:

- Code certified according to aviation's highest safety standard, DO178B Level A
- Development time cut by 50%

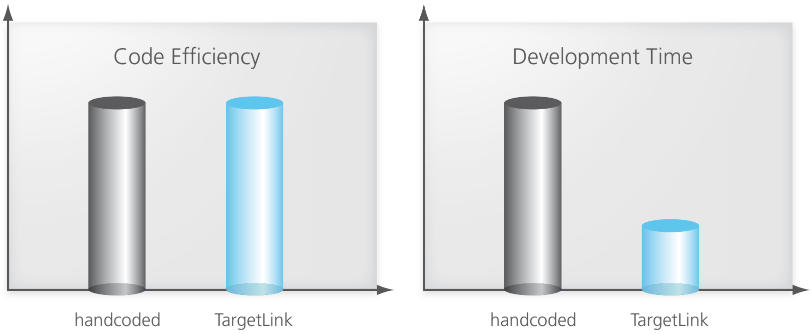
The new cabin pressure control is installed in a number of passenger planes, including the Airbus A380.

2004

New Features: More Than Just a Code Generator

Now with powerful new extra functions, TargetLink is setting new standards.

- dSPACE Data Dictionary for managing the data sets of complete ECU applications
- Production-level implementation of OSEK and multirate modeling
- Code coverage analyses and incremental code generation



Top benchmark results win over industry.

2005

The Best in Test

Model-based development is gaining ground, and so is automatic production code generation. TargetLink wins over new users and new application fields at an impressive rate. BMW is yet another major OEM who chooses TargetLink after evaluating the various production code generators on the market.

2007

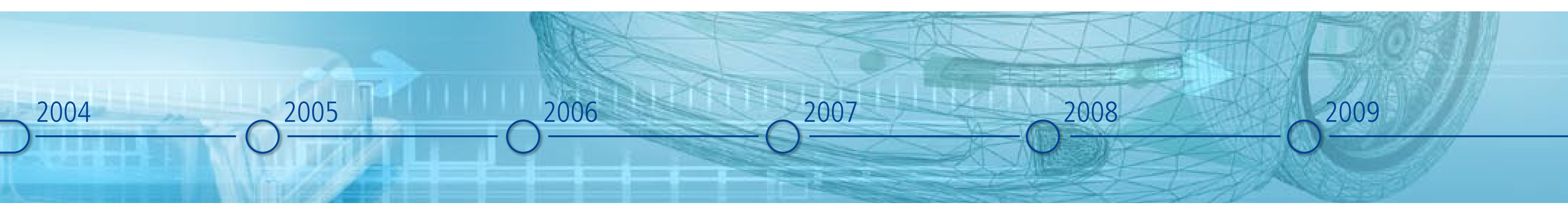
MISRA Modeling Guidelines for TargetLink

The Motor Industry Software Reliability Association (MISRA) publishes official modeling guidelines for TargetLink. TargetLink is the first autocoder ever to have such guidelines, reinforcing its position as the world's leading production code generator in the automotive industry. The guidelines particularly address aspects of functional safety.

2009

The No. 1 for Professional Code

Ten years of success. TargetLink is being used in numerous industries all over the world. The automotive industry regards it as its established code generator. TargetLink also looks back on several successful years in developing safety-critical aerospace systems (see the customer report "Maximum Safety", dSPACE Magazine 1/2009).



2006

TargetLink Supports AUTOSAR

For the first time ever, a code generator bridges the gap between model-based design and production-ready, AUTOSAR-compliant ECU software. TargetLink provides extensive support for modeling, simulating, and generating code for AUTOSAR software components.

2008

TargetLink 3.0: The Winning Combination

The best of both worlds: With its newly designed blockset and its tried and tested features, TargetLink 3.0 provides even closer integration with MATLAB®/Simulink®, so that numerous Simulink third-party tools can be used for TargetLink models. TargetLink 3.0 also supports model referencing to facilitate modular, distributed development processes.

TargetLink is also valued in the off-highway sector.

Five Stars for dSPACE

Mechatronics Demands Top-Notch Software Quality

The demands on today's embedded software are high. And the requirements on the development software and the testing software are just as tough. What does this mean for dSPACE products? Dr. Hans Joachim Rabe, Head of Product Development at dSPACE, explains.

Why do development tools for embedded software have to meet such extraordinarily high requirements?
With embedded software, especially in safety-critical applications, there must be absolutely no failures. With an ESP controller, for example, you can't just tell the driver, "Could you please wait a bit till the controller reboots, then we'll have another go at braking." Embedded software and its hardware have to function perfectly. These rigorous requirements mean that the software used for development and testing – in this case dSPACE software products – also has to fulfill enormously high requirements. Applications outside the automotive industry are also highly complex and make extremely high demands on tool quality. In a word: We're equipped for anything.

What does software quality mean at dSPACE?
At dSPACE, software quality doesn't just mean having very few errors or passing formal requirements and approval tests. In the face of high customer requirements, we take a much wider view of quality. When we develop a product, we apply comprehensive quality guidelines for designing dSPACE products and associated services from the word go.

What do the dSPACE Quality Guidelines actually look like?
The catalog of criteria includes not only the "classic" best practices for software development, but also addresses software usability and customer support, plus support of industry standards, documentation, and training for our users. Our Quality Guidelines have helped us shape the open tool chain that our

> "If you find an error early, you can often repair it at minimal expense."

customers need and that we provide, ensuring that dSPACE products can be combined with third-party products. The automatability of our tools is also a major goal right from the outset of development work.

What part does automation play in today's development processes?
In many fields, fast development cycles and a zero-error policy result in our customers having to run countless tests within an extremely short time. So the components in the tool chain have to communicate with each other directly and allow automated interventions. Intermediate manual activities would be impossible in many areas because of the work and time they require.

How is automatability reflected in dSPACE tools?
Users expect the necessary automation options and interfaces to be on board dSPACE products – as indeed they are. The TargetLink Automation API, the CalDesk Automation Module, and ControlDesk's automation features are just a few examples. And we also have a powerful automation tool: AutomationDesk. Moreover, if our customers so request, we can provide experienced engineers who carry out the automation and development of processes and tests as an engineering service.

How are dSPACE software products tested?
More than a third of the effort of all our projects is spent on product testing. Unit tests, regular build runs, integration tests, usability tests – our products are really run through the mill. And we ourselves use our products' extensive automation features so that we can test an enormous number of scenarios and variants before a product goes out to the customer. We couldn't cope with the vast number of tests without a very high degree of automation.

How important is testing in general these days?
When computer scientists come to us for job interviews, I'm always amazed that their universities have taught them a lot about software development, algorithms, architectures, etc., but told them almost nothing about software tests. But the fact is that if you find an error early, you can often repair it at minimal expense. The selfsame error, discovered at a later stage, can endanger an entire project. I often get the impression that educational institutions treat testing as an additional nuisance and regard actual program development as the essential activity. In reality, though, the twin arts of test development and test execution both require immense skill and expert knowledge. All testers at dSPACE therefore have ISTQB certification (ISTQB = International Software Testing Qualifications Board).

What parts of the software development process require the greatest investment?
In addition to actual software development, there are three areas that involve the most work: collecting and consolidating requirements, developing the necessary, frequently innovative concepts and architectures, and comprehensive software testing.

> "Developers, especially experienced ones, put themselves in the customer's shoes and scrutinize their own work results with a critical eye."

How are dSPACE's high quality standards reflected in the engineers' qualifications and work methods?
At dSPACE, we make high demands on our employees' expertise and soft skills, to ensure that customers get the quality of products and services that they require. And by the way, we regularly see what high standards dSPACE people set for themselves: Developers, particularly experienced ones, put themselves in the customer's shoes and scrutinize their own work results with a critical eye. This attitude is invaluable, especially in customer support. It's no coincidence that customer satisfaction surveys have given us top grades for our support services for years.

Thank you for speaking to us.

Up and Running with the Right Standard

Scenarios for introducing the AUTOSAR standard: case studies from industry

The starting situation with regard to developing electronic control units (ECUs) is probably similar in almost every case: Development methods have been introduced, tool chains and processes are in place and in action. These are occasionally optimized – but obviously never revolutionized if it can be avoided. After all, the main goal is to put new products on the market quickly and successfully, using efficient tools and processes, and not to waste time fiddling with the infrastructure. Then along comes a new standard which impacts numerous development areas, and it is not always convenient.

To help them master complex software architectures, developers were actually asking for the very solution principles that the AUTOSAR standard incorporates. But before they can introduce the standard, they have a whole barrage of questions to answer.
Can we continue using our mature function software and models? We've developed elaborate ECU network communication – is it still usable? Do we need a team of developers to carry out AUTOSAR projects in parallel to conventional development? What tools do we require, and will any of our old tools be obsolete? What's the best strategy for software development: redo as much as possible from scratch, or aim for maximum reuse? Questions without end.

Scenarios That Help

To find viable approaches to introducing AUTOSAR, we will be looking at some scenarios that have proven their value in practice Because company and project conventions vary, no two starting situations are ever exactly the same. These scenarios are therefore simply suggestions for how specific requirements might be met, though some basic preferences do emerge. The approaches are based on projects that were actually carried out in various companies. The very fact that each approach is different shows how important it is to find the right one for each situation.

Quintessence of AUTOSAR

AUTOSAR is a multi-layered standard that:

- Identifies the description elements for designing the system and the architecture.
- Defines a data exchange format for describing these elements.
- Introduces a layer concept of ECU software architecture with interface conventions.
- Describes a framework methodology for software development according to AUTOSAR.

As a result, it can affect very different parts of any project. And in view of the standard's enormous scope, it is most likely to be introduced step by step.
One question has to be answered before anything else is done: How do we go about producing AUTOSAR-compliant descriptions?

Scenario 1: Bottom-Up Approach

There are two prerequisites for smooth production of AUTOSAR descriptions: ECU software develop-

ment must already comply with company or project specifications, and suitable guidelines and structuring approaches must exist. Signal lists, modules and parameters are stored in Microsoft® Excel® spreadsheets, A2L files, graphical models, or other formats.
To migrate existing application software to an AUTOSAR project, existing data catalogs can be converted to the AUTOSAR format. This step needs to be performed just once. If the data catalogs have been structured well and maintained consistently, this step is not difficult, and can be performed automatically via tailor-made scripts.

Example: Engine Control

A project run by the supplier Magneti Marelli S.p.A. is an example. In concrete terms, the task was to migrate the entire software of an existing engine ECU to AUTOSAR and then reimplement it on that ECU. To do so, Magneti Marelli extracted (from the existing ECU data) all the information needed for reconstructing the software architecture and scheduling, and transferred it to the dSPACE SystemDesk architecture software by means of scripts. The company's developers worked together with dSPACE to carry out the migration, which took about half a year.[1]

> With AUTOSAR, we don't start again from scratch; we just speak a different language.

Scenario 2: Instrumental Alternative

Scenario 1 can be modified so that both AUTOSAR and classic development can be carried out. The existing models, C code and data catalogs are preserved, along with their associated tool chains. The existing descriptions are "instrumented" to provide intervention points for switching between descriptions of AUTOSAR implementations and descriptions of classic implementations. These intervention points can be inserted at code level, for example, in the form of macros for access functions, or at model level, for example, by using the dSPACE TargetLink AUTOSAR Blockset with downstream generation alternatives.

Scenario 3: Top-Down Approach

Another approach takes the architecture level as its starting point. First the system is planned, and then behavior modeling is performed for the functions. The software development process makes systematic use of the AUTOSAR description formats. Developers use authoring tools such as SystemDesk for modeling software components or central databases for managing all the project data. Scenarios 1 and 2 are incorporated into this scenario and can be represented by it, but its salient feature is its holistic strategy.

Example: Body ECU

To introduce the standard, the carmaker Daimler AG systematically divided the software architecture into an application part and a basic software part, which communicate with one another via a defined interface. The AUTOSAR standard was the basis for defining this interface. The basic software and the standard software architecture were also based on an established standard core and were supplemented by selected AUTOSAR software services. This initial procedure ensured that the ECU was network-compatible with ECUs developed by the classic method. This allows AUTOSAR technology to be introduced step by step.[2]

Benefits of AUTOSAR

Once AUTOSAR-compliant descriptions are available, they can be used in processes, tool chains and methods in innovative new ways.

Data Exchange

One of AUTOSAR's strengths is data exchange between OEMs and suppliers. Project conventions can be based on a single standard, as Daimler AG discovered in its first AUTOSAR production project: "The prerequisites for broader, process-safe use of model-based development are a uniform, supplier-independent software architecture and a standardized description of the metadata."[2]
The AUTOSAR standard fulfills these prerequisites and even provides benefits within the same company, such as a supplier with an international presence. Software modules that were uniformly produced according to a standard like

> The better the structure that was defined for previous processes and methods, the easier it is to migrate to AUTOSAR.

AUTOSAR can be retrieved from a central repository and reused in exactly the same way in all regions and countries.

Tool Coupling

AUTOSAR also facilitates tool coupling, making it easier to link software components in an authoring tool such as SystemDesk with function descriptions in a tool such as MATLAB®/Simulink® or TargetLink. The same applies to coupling the authoring tool with tools for configuring the basic software.
"Interaction between different tools is one key to successful implementation of the AUTOSAR idea. dSPACE provides an excellent basis for this in the form of TargetLink and SystemDesk, together with defined file formats and open interfaces."[3]

Offline and Online Test Process

Not only the design process has additional new options with AUTOSAR, but also the test process. When a formal description of the application software according to AUTOSAR is available, the software modules can be simulated at an early stage via a system design tool. Audi Electronics Venture GmbH performed virtual integration of a networked control system with SystemDesk. The system was systematically simulated and analyzed on a PC by means of test automation. One possible future scenario is for parts of the offline simulation to be reused for ECU testing on a simulator.[4]
The test process can additionally incorporate not only the application software, but also services for the platform software, such as diagnostics services. This is demonstrated by a project at Daimler AG for validating diagnostic functions in very early development phases. Test vectors from conventional diagnostic tests are applied to offline simulation with SystemDesk. Following simulation, the virtual fault memory was evaluated and the error entries were checked for plausibility.[5]

Summary

The development of modular and distributed control systems requires unambiguous definitions of interfaces, languages and protocols. The AUTOSAR standard provides solution principles for developing these efficiently. Scenarios demonstrate the main approaches to introducing AUTOSAR. Case studies show how these approaches can be applied in development projects and what benefits they provide. The AUTOSAR introduction projects prove that even large-scale projects are manageable if there is seamless tool support.
Would you like to know more about the application and benefits of AUTOSAR in your projects? We would be happy to advise you: info@dspace.com

AUTOSAR Literature

[1] *Alessandro Palma, Luigi Romagnoli, Walter Nesci, Magneti Marelli: Engine Management the AUTOSAR Way – Magneti Marelli migrates ECU software to the AUTOSAR standard. Source: dSPACE Magazine 2/2008*

[2] *Christian Dziobek, Dr. Florian Wohlgemuth, Dr. Thomas Ringler, Daimler AG: AUTOSAR in the Development Process – Procedure for Introducing Model-Based AUTOSAR Function Development into Production Projects. Source: dSPACE Magazine 1/2008*

[3] *Dr. Karsten Schmidt, Frank Gesele, Audi Electronics Venture GmbH: Systematic AUTOSAR Migration. Source: dSPACE NEWS 1/2008*

[4] *Dr. Karsten Schmidt, Dipl.-Inf. Stephan Reichelt, Dipl. Ing. Marko Maleuda, Audi Electronics Venture, Dr. Dirk Stichling, Dr. Oliver Niggemann, dSPACE GmbH: Seamless System Tests: From Virtual Integration to Network Tests. Source: ATZelektronik 06/2008*

[5] *Matthias Kohlweyer, Valentin Adam, Daimler AG, Heinrich Balzer, University of Paderborn, Oliver Niggemann, Dirk Fleischer, dSPACE GmbH: Using Simulation to Verify Diagnosis Algorithms of Electronic Systems. SAE Paper No. 2009-01-1043, Detroit, USA*

MicroAutoBox Features at an Especially Attractive Price

dSPACE now offers the new MicroAutoBox 1401/1507, a particularly low-priced variant of the well-established prototyping unit for several gateway and bypassing applications. The new MicroAutoBox 1401/1507 has a standard processor unit with full high-end processor performance, and the CAN, LIN and FlexRay bus interfaces seen in the “large” MicroAutoBox 1401/1505/1507 together with a bypass interface. The difference is that it goes without the standard I/O. This new “light” variant, with its numerous high-quality MicroAutoBox features, is the cost-effective solution for many different applications. In combination with RapidPro’s intelligent I/O subsystem it is ideal for engine management systems and similar applications.

Honda Aircraft Company Chooses dSPACE Simulators

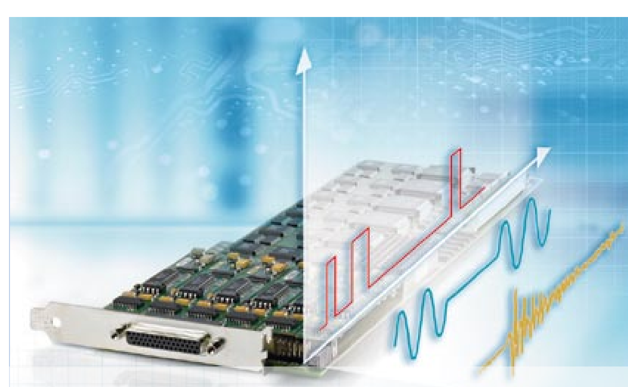
Honda Aircraft Company, Inc., has awarded a contract to dSPACE Inc. to provide turn-key hardware-in-the-loop (HIL) simulators for the HondaJet Integration and Test Facility (ITF). HondaJet is the first aircraft to be developed by Honda Aircraft Company, a subsidiary of Honda Motor Company, Ltd.

Honda Aircraft Company will utilize dSPACE simulators for automated integration testing of aircraft electrical and avionics subsystems. Production aircraft subsystems and Line Replaceable Units (LRU) will be tested against high-fidelity flight dynamics models, engine models and engineering prototypes running on networked dSPACE HIL platforms. dSPACE HIL Simulators provide systems engineers with a complete testing framework for the integration of networked electronics, with support for a wide range of aircraft configurations. A comprehensive suite of tools facilitate model-based design, automated testing and automated failure insertion. The environment offers a fully customizable human interface, automated traceability to requirements, and automated reporting and documentation.

Signal Generation Made Easy

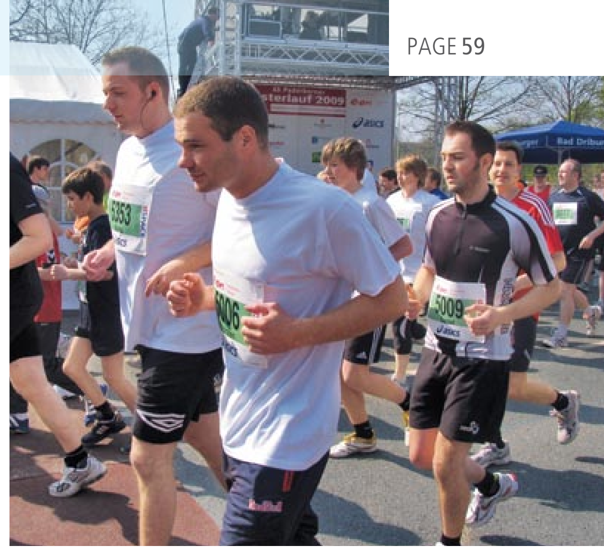
The DS2302 Direct Digital Synthesis Board – the ideal device for efficiently generating and measuring complex signals when testing electronic control units – now has more options to generate demanding signal forms such as those required for intelligent wheel speed sensors. The new APU slave interface (APU = angular processing unit) for each channel on the board, together with the Fast Analog Capturing Module, an optional extension, provide even more precise measurement of injection control voltages. This makes it easier to calculate the injection quantities for direct-injection engines, even with variable valve lift.

The board’s enhanced performance boost is derived from its enlarged memory and from new signal processors (TMS320VC33) that push its speed up to two and a half times faster than that of its predecessor.



63rd Paderborn Easter Run – dSPACE is on the Move ...

As in past years, dSPACE lined up again at the annual Paderborn Easter Run, Germany's oldest road race. The atmosphere was fantastic. Over 8,000 runners altogether gathered at the starting line. And dSPACE took 3rd place in the 5 km Company Cup. All in all, 62 dSPACE employees ran in various disciplines in the race. Carrying on their traditional support, dSPACE was once again the sponsor of the Handbike Race. The winning handbikers received their prizes at the dSPACE pavilion, enjoying the beautiful sunshine and the festivities.



Green Is the Color of the SAE 2009 World Congress

"Racing to Green Mobility" is this year's motto for the world's largest event in automotive technology. It's what everyone is talking about – whether they're discussing networking, exchanging know-how, or presenting the most recent developments. Honda, this year's host, declared eco-friendly automotive technology as the main concern for the entire automotive industry. dSPACE was also present – with the motto "Green Success" – at the SAE, held from April 20 - 23 in the Detroit Cobo Center. Interested visitors gathered vital information on the newest trends in dSPACE's development environment, such as tools for AUTOSAR-compatible development and hardware-in-the-loop technology for hybrid vehicles.

This year, approximately 16,000 guests from 49 countries visited the 4-day SAE congress.

dSPACE SARL has moved.

dSPACE's branch in France has moved into a new office facility. Support and training for new dSPACE products and increasing engineering activities such as HIL simulator commissioning and ECU test campaigns have led to a demand for more space. dSPACE SARL is certain that customers will also appreciate the new facilities.

The new address is:
dSPACE SARL
7 Parc Burospace
Route de Gisy
91573 Bièvres Cedex
France

Please let us know your opinion on the quality of the dSPACE Magazine. Just fill out the enclosed reply card and return it to us. You can also use the card to order any other information by post. Thank you!

You can also give us your feedback online. For further information, visit www.dspace.com/magazine

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

Driving for Precision

Electric drives are everywhere. In golf carts and medical devices. Locomotives and wind power generators. Rolling mills and hybrid cars. And there are more of them every day. When you develop and test electronic control units for them, you're up against several major challenges. Like fast sampling rates, short control times, and accurate synchronization. Plus the need for the utmost precision. But with dSPACE on your side, problems like those aren't problems at all. Our rapid prototyping tools help you quickly develop and optimize single functions.

We provide exactly the right products and solutions for simulating electric drives and testing their ECUs. And with a dSPACE hardware-in-the-loop simulator, no ECU error ever escapes detection – in function tests, system tests, or network tests. From flexible dSPACE development systems and special hardware for electric drives to unparalleled experience in building complete systems, dSPACE is here to accelerate your drive to the future.

Embedded Success **dSPACE**