dSPACE
NEWS
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Audi – Ahead with AUTOSAR

9 *SOFIA, the flying observatory, is a joint project of NASA and DLR. To develop the safety-critical door closing mechanism, MPC Product, Corp. relied on dSPACE tools.*

12 *Swedish truck and bus manufacturer Scania uses dSPACE Simulator and the Automotive Simulation Models (ASMs) to run automated tests on the ECU networks in its trucks.*

As I've often said before, dSPACE clearly focuses on the automotive industry. But whenever our tools can help, we don't keep something out of our sight just because it doesn't run on four wheels. You'll see this once again in this issue.

Mechatronics is where we came from. Automotives were just one application area among many. The fact that over 80% of our business is now with the automobile industry is due to this area's enormous market receptiveness. This, in turn, is due to the intense pressure to supply innovations, while maintaining high levels of quality and efficiency despite spiraling complexity.

As tool suppliers, we also feel the pressure. We also have to and want to supply innovations. This is why our tools are so highly complex inside – they have so many customer requirements to fulfill. The only way we can bear the weight of this burden is to invest intensively in our employees.

Over the last three years we have taken more than 250 new employees on board in Germany alone, all of them qualified in engineering, computer science, or other technological professions, and most of them working on product development. We had approximately 140 new jobs open in 2007 – and managed to fill 100 of them. This is quite an achievement, considering the current, much publicized lack of engineers. After all, we're looking for the same people as our customers. They also really have their hands full because of the enormous momentum in drivetrain development since the introduction of new regulations.

Germany is not the only country suffering from a lack of engineers, but here is where we feel it the most. And with the number of graduates forecast to decrease, we cannot just sit back and do nothing. We recently launched our ProMINT program (Math, Informatics, Natural Science, Technology). The objective is to stimulate young people's interest in technology at several different levels, and smooth their way to technical fields of study. We have to focus on the long-term and ensure that in 10 years we will have a new generation of engineers, since there's certainly no end in sight to the work ahead. We aim to continue our steady, organic growth, as we have been doing for the past 20 years.

Yes, we've been around for 20 years. This will be given a big celebration in 2008!

Dr. Herbert Hanselmann
President
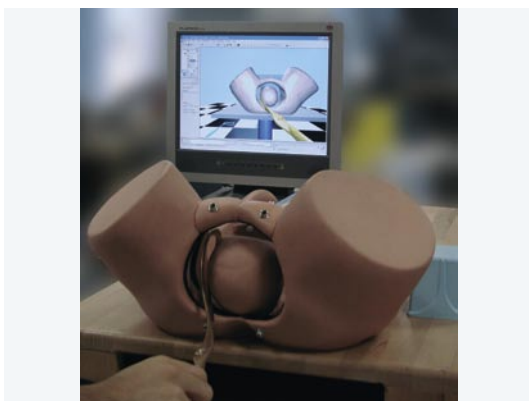
Experience the Hybrid Drive

- **MAGNA STEYR equips SUV with hybrid drive**

- **Hybrid demo vehicle with dSPACE prototyping system**

- **MicroAutoBox and RapidPro control hybrid components**

To integrate components into a hybrid vehicle drivetrain, extensive modification to the electronic and mechanical systems is required in order to ensure the global optimization of all systems by a hybrid drive strategy. MAGNA STEYR and its cooperation partners integrated the new hybrid components in a production vehicle and implemented a control system using a dSPACE prototyping system (MicroAutoBox plus RapidPro). The hybrid demo vehicle HySUV (Mercedes M-class) with a dSPACE prototyping system as the central drivetrain control makes the hybrid drive a reality. MAGNA STEYR and its partners use the demo vehicle as a platform for further optimization of driving behavior, consumption, and emissions.

Drive Systems for the Future

When a combustion engine and an electric drive are combined in a vehicle, the use of optimized operating points for the two propulsion types can greatly improve the vehicle's consumption, dynamics, and emission behavior in comparison with a combustion-engine-only vehicle. MAGNA STEYR worked with MAGNA POWERTRAIN and Siemens VDO to develop modular hybrid drive systems, taking into account the research findings from K-net KFZ, the competence network for "Vehicle Drives of the Future". With the support of the OEMs, hybrid components developed by MAGNA are integrated in the drivetrain of prototypes to investigate the optimization potential of consumption, dynamics, and emissions. The control system and the cross-linking of new components in the drivetrain are implemented with the dSPACE prototyping system (MicroAutoBox plus RapidPro) on the basis of a central hybrid drive strategy. MAGNA STEYR has put this into operation in the hybrid demo vehicle HySUV (Mercedes M-class).

▲ *Hybrid driving experience with the demo vehicle HySUV (a modified Mercedes ML350): The display shows the driver and passengers the torque flow of the three propulsion units.*

Hybrid Components

In the HySUV demo vehicle, the automatic transmission and transfer case of an ML350 (Mercedes M-class) were replaced by an automated manual transmission and a hybrid module (E4WD module). A full hybrid drivetrain with electrical all-wheel drive was implemented in this way. Both the combustion engine and the electric motor drive the rear axle, while the front axle is driven purely electrically. The heart of this modularized drivetrain concept is MAGNA's E4WD module, which consists of two electrical machines with 55 kW each and four hydraulically actuated multi-plate clutches for controlling the torque flow. A 70 kW/360 V lithium ion battery system developed at MAGNA STEYR
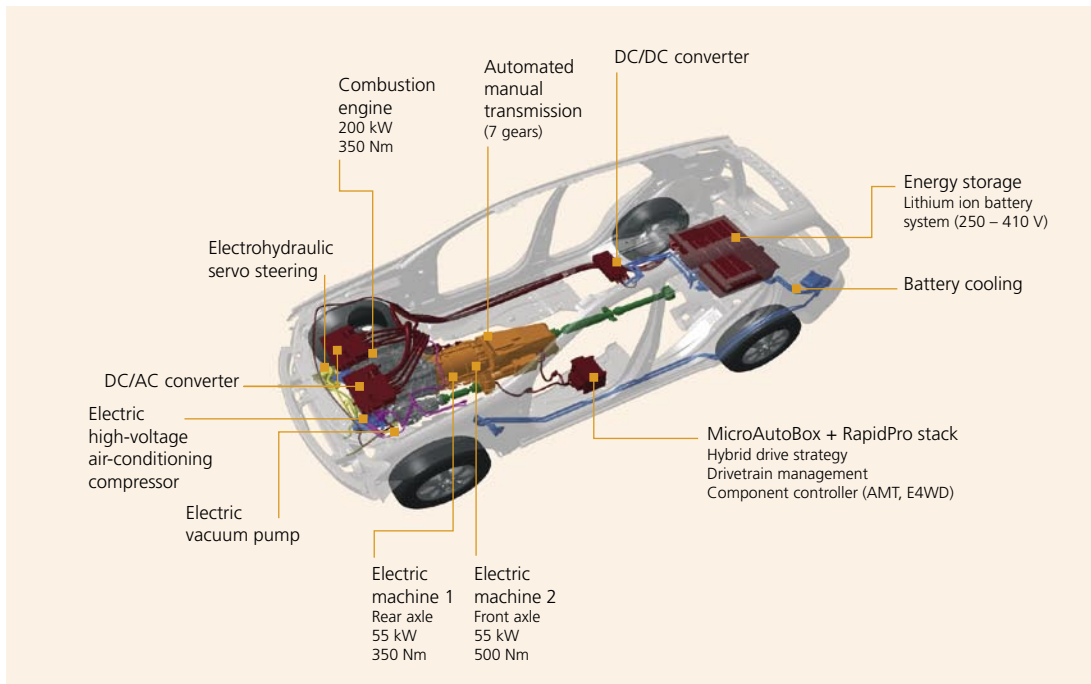
All the components of the hybrid drivetrain in the demo vehicle are controlled via the dSPACE prototyping system (MicroAutoBox plus RapidPro hardware).

provides energy storage. For purely electric propulsion, the accessory aggregates of the combustion engine are replaced by electrically operated components.

Selecting the Prototyping Hardware

The objective was to control all the components of the hybrid drivetrain with just one prototyping system. This objective made tough demands on processing power and hardware interfaces. The MicroAutoBox chosen for this has since become a standard tool at MAGNA STEYR, used for efficient implementation of prototypes for a wide range of drivetrain applications. Internal or external hardware development does not make sense due to the limited development time and the small quantity needed. At MAGNA STEYR, the RapidPro system is therefore used in addition to the MicroAutoBox. RapidPro is a freely configurable, extendable driver hardware solution that meets all of MAGNA STEYR's requirements. The flexibility provided by software- and hardware-configurable signal I/O is an advantage, particularly in early phases of prototype development, when the sensor and actuator systems are not yet completely defined. Together with the diagnostic components that can be integrated into the function software, the proven RapidPro hardware has the reliability needed in order to concentrate on crucial aspects of function development. MAGNA STEYR is using a stack consisting of three RapidPro Power Units and one RapidPro Control Unit (MPC565) for the HySUV demo vehicle.

"The MicroAutoBox has become a standard tool at MAGNA STEYR, allowing us to implement prototypes efficiently for a wide range of drivetrain applications."
Dipl.-Ing. Theodor Schöberl, MAGNA STEYR Fahrzeugtechnik AG & Co KG

RapidPro System Data

- 13 valves controlled via PWM signals, with PWM-synchronous current measurement
- 4 PWM-controlled pumps
- 12 digital inputs for pressure, displacement, and engine speed measurement
- 8 analog inputs for temperature and pressure measurement

Integrated Development Process

From the beginning, the function and software development process is geared to achieving a seamless transition to production development, especially to production code generation. At MAGNA STEYR, TargetLink is used for production code generation. The requirements for this are taken into account as early as configuration management, during the design phase, and in the modeling guidelines and model libraries. The Simulink®/Stateflow® development environment was extended to allow modularization across several
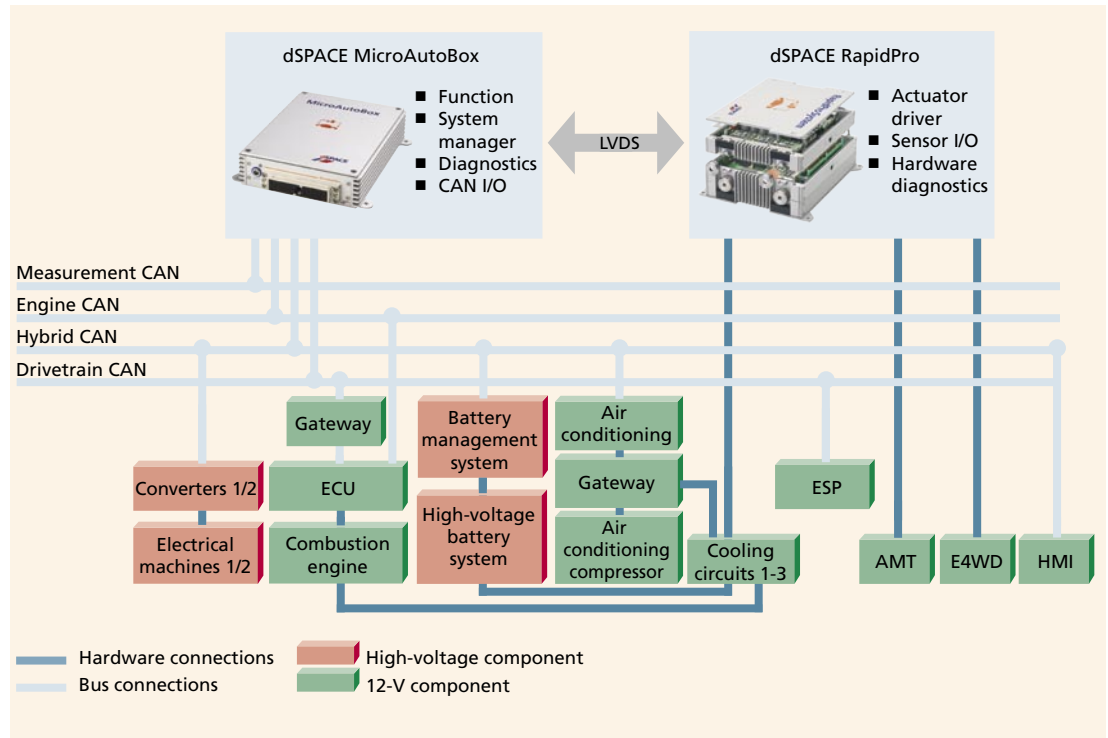
▲ *System architecture: The dSPACE prototyping system networked in the vehicle.*

hierarchy levels, providing a working platform for multiple engineering teams. It also supports variant management for simulation, rapid prototyping, production code and test bench operation.

Function Development

The modular design of the drivetrain components is reflected in the software design. This is scalable to a large number of hybrid drivetrain configurations and covers aspects of customer-specific functionalities in production projects. The control software comprises the functions and interfaces of the entire torque path in the drivetrain, from capturing driver input to selecting the operating point for drive components, to traction-optimized distribution of drive torque, up to component control for couplings, the automated manual transmission, and accessory aggregates. Added to these are central functions for controlling the operating states of components in the drivetrain, and for capturing and evaluating diagnostic information from the function software and the RapidPro stack.

Software Components

- **Driver input capture:**
  The torque required by the driver is determined by the accelerator pedal, the brake pedal, and the gear lever.

- **Vehicle dynamics controller:**
  The traction-optimized distribution of the driver's torque demand to the axles is based on the availability of the three propulsion units.

- **Hybrid controller:**
  The torque distribution and required gear are obtained with reference to efficiency, dynamics requirement, the battery charge status, comfort, and thermal operating conditions.

- **Torque coordinator:**
  Manages the configuration and controls transient processes in the drivetrain.

- **Component control:**
  Controls the components in the automated manual transmission and the E4WD module.

Component Testing

Hardware-related functions like component control and transmission control are tested and optimized on the components in early project phases, using the prototyping hardware. The hybrid controller, representing the core of the driving strategy, cannot be tested until a functioning vehicle is available. Even so, its functionality still has to be validated in early project stages, so a simulation environment has to be provided. This environment was produced by adapting models

Driver input evaluation

Vehicle dynamics controller (traction)

Parameterizable, and modular software for drivetrain and energy management

DCDC

Hybrid controller

Battery management system

Torque coordinator

Combustion engine

DCAC 1..2

Components

ESP

| Clutches 1..4 | AMT | Hydraulics | Lubrication | Cooling |
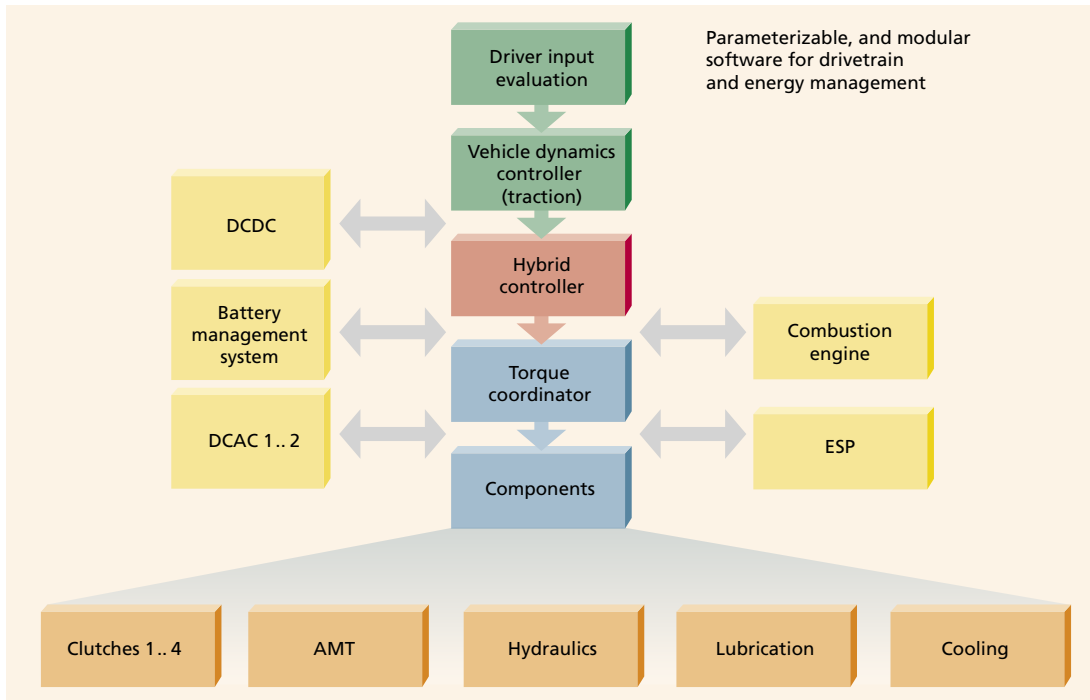
▲ *A large number of software components ensures that the hybrid drive optimally responds to the driver's demand indicated via accelerator pedal, brake pedal, and gear lever.*

of the drivetrain and the hybrid components that were used for concept evaluation at the beginning of the project. A parameterizable driver model makes it possible to implement various driving profiles to assess driving behavior during start-up maneuvers, in accelerating and trailing throttle condition, in gear changing, and to investigate system behavior in extreme situations. The resulting model can be executed with the hybrid controller on the MicroAutoBox, allowing the effects of code generation and run-time properties to be studied at an early stage.
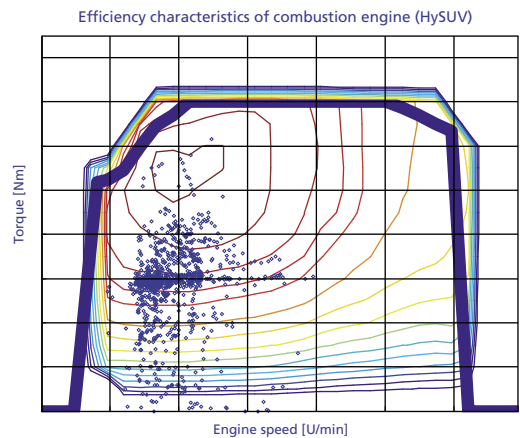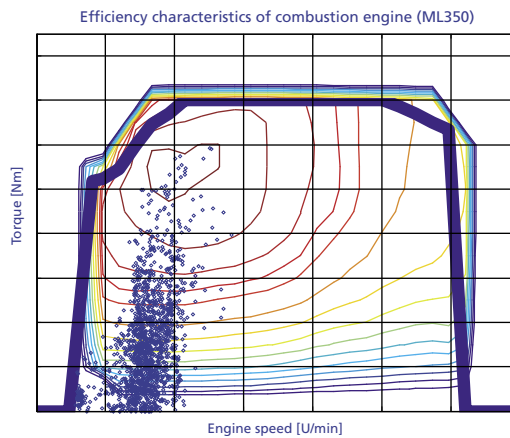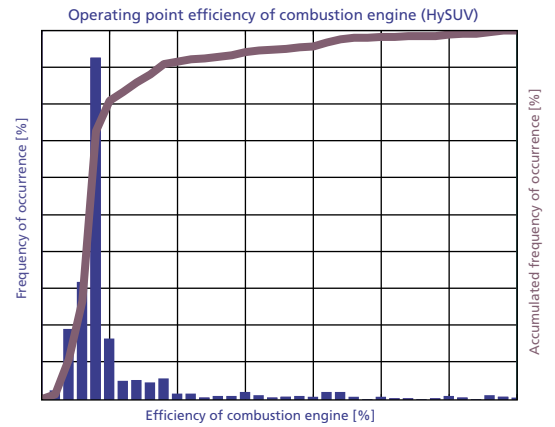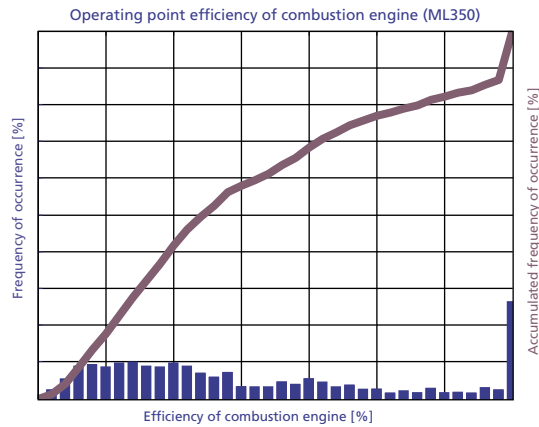
Optimization Steps

The complex calculations needed for the large number of different drivetrain configurations in the hybrid controller, which all had to be computed in parallel, demand considerable processing power. Even though a multitasking system for systematic resource distribution had been implemented, the extensive model pushed the MicroAutoBox to the limits of its performance during the integration phase. However, the CPU execution time guzzlers were identified in the model by studying resource consumption and performing code reviews. Further modeling had to be carried out to enhance code efficiency, in addition to making the optimization adjustments in the code generator (Real-Time Workshop®).

Current Model Data
- 44,000 blocks
- 257,000 lines of generated C code (Real-Time Workshop®)
- Code generation time: 1 h 40 min on a Core 2 Duo 2.67 GHz; 4 GB RAM
- 4.5 MB MicroAutoBox application
- 4 tasks with 95 % CPU load on the MicroAutoBox

Commissioning the Control System in the Vehicle

The system was put into operation in the vehicle step by step. The initial parameter set already showed the positive effect of the operating strategy on the combustion engine's operating point distribution. Operating points with low efficiency are replaced by purely electric operation or load point shifting of the combustion engine. One current focus of commissioning work is on drive-off strategies and boosting. Vehicle development is supported by simulation of the hybrid controller based on adapted simulation models and real measurement values.

Operating point efficiency of combustion engine (ML350)

Operating point efficiency of combustion engine (HySUV)

Frequency of occurrence [%]

Accumulated frequency of occurrence [%]

Efficiency of combustion engine [%]

Efficiency characteristics of combustion engine (ML350)

Efficiency characteristics of combustion engine (HySUV)

Torque [Nm]

Engine speed [U/min]

▲ *Customer-oriented comparison drives show the positive effect of the operating strategy on the combustion engine's operating point distribution. Operating points with low efficiency are replaced by purely electric operation or load point shifting of the combustion engine. The result: An obvious shift in operating points towards the combustion engine's optimum operating range.*

Next Steps

Now that the function software has been successfully implemented and tested, we are in the test drive phase, with the objective of further optimization. The proven modular dSPACE prototyping system gives us the necessary reliability and flexibility. The planned activities include:

- Investigating and optimizing dynamic processes in the drivetrain
- Extending the drivetrain model to study dynamic processes and developing the traction controller in the simulation further
- Optimizing the operating strategy in terms of performance, consumption, and emissions
- Further integrating the brake system into the operating strategy for optimum braking energy recovery

- Developing the lithium ion battery to production level. TargetLink is being used for developing function software for the battery management system.

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A Mach 0.8, 40,000 ft. Challenge

MPC Products Corp., based in Skokie, Illinois, USA, has developed an actuator control system that will be used by NASA to control a drive system for the Cavity Door System that covers a large cavity in the rear fuselage of a modified Boeing 747 housing a large infrared telescope. The telescope is the largest to ever be placed in an aircraft and will aid in the study of infrared light emitted from astronomical objects, including complex molecules, new forming solar systems and black holes. MPC is using several dSPACE tools to design the control software for this very unique project.

▰ **NASA project: Stratospheric Observatory for Infrared Astronomy (SOFIA)**

▰ **Challenge to open and close a cavity door during flight**

▰ **Safety-critical control strategies developed with tools from dSPACE**

MPC Products Corp. is completing the final testing phase on a more than four-year NASA project to develop an actuator control system that will mechanically operate a cavity door drive system (CDDS) for the largest telescope ever to be placed in an aircraft. The reflecting telescope will allow scientists to study distant astronomical objects such as stars, comets, asteroids, forming solar systems and black holes. It is being permanently installed inside of an airborne astronomical observatory – a modified Boeing 747SP referred to by NASA as SOFIA (Stratospheric Observatory for Infrared Astronomy).

Necessity for Stratospheric Observation

With its 2.5-meter aperture, the SOFIA telescope will be capable of making observations that are impossible for even the largest and highest of ground-based telescopes. The telescope, provided to NASA by the DLR (German Aerospace Center), is designed to detect

▲ *The young star L1157 in visible light (left) and an infrared image of the same star (right). In visible light, this star appears black. Credit: NASA, JPL Cal Tech, L. Looney (University of Illinois).*

the infrared light or energy that is emitted from many different kinds of astronomical objects. Most forms of infrared light/energy are blocked by water vapor in the Earth's atmosphere, making it almost impossible to view from ground-based telescopes. But flying at about 40,000 feet above ground, the SOFIA telescope will have the capability to detect infrared light 100 to 1,000 times greater than ground-based telescopes.

Door to the Sky

One of the key engineering aspects necessary to achieve this remarkable observation capability is through the design of the CDDS. The challenge, according to MPC Program Manager Chris Wall, was to design an actuator control system capable of opening and closing the large telescope cavity door on an airplane flying at Mach 0.8 – about 500 mph – at 40,000 feet altitude. In addition to speed and altitude, MPC had to take other load factors into consideration, including ice formation, inertial loads and gravitational forces.

"This has certainly been the most comprehensive software project we've undertaken," Wall said. "Within the next six months, we will be delivering (to NASA) the hardware that will be going on the aircraft to open and close the door system."

MPC Systems Lead Engineer Matt Polley explained that the telescope is run by a computerized control system, which drives electromagnetic motors to move the telescope into position. The doors are required to follow close to the telescope as it moves, relative to the aircraft maintaining position on the observed object. "The control system we designed for the doors con-
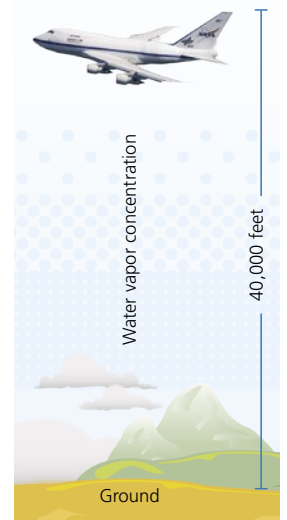
▲ *At 40,000 feet (approx. 12 km), the water vapor has gone down by a factor of about one thousand.*

sists of two redundantly driven actuators commanded by an electronic control unit," Polley said. "Accurate position and speed control are a critical part of the door design. If the door doesn't move correctly, if it moves too fast, or if it goes beyond the set limits, it could damage the aircraft and cause a catastrophe."

Algorithm Design

To develop the actuator control system, MPC's team designed a test set up to simulate the system's opera-

> *"This has certainly been the most comprehensive software project we've undertaken."*
> **Chris Wall, MPC Products Corporation**

tional environment utilizing dSPACE tools. A modular system was established with a dSPACE DS1005 processor board to achieve real-time and high sampling rates, a dSPACE resolver card, a dSPACE encoder card, and a dSPACE DS2201 analog-to-digital multi-I/O board designed for applications requiring a lot of varying I/O types. Polley said the dSPACE tools were used to fine-tune the control design and generate a control methodology for simulating the aerodynamic and gravitational loads that the CDDS will encounter during actual operation. More than 400 system-level requirements had to be taken into consideration as part of the design process. "A crucial element of this project was to simulate the roll and gravitational loads that the actuators will experience during aircraft operation," Polley said. "Because this behavior could

not be defined as a linear function, we had to custom-build a computer system to do closed-loop controls. The system is quite large in terms of the loading, and is more complex than our normal dynamometers, which have lower torque output." "It was a major challenge to wrap our hands around

> *"The dSPACE tools were used to fine-tune the control design and generate a control methodology for simulating the aerodynamic and gravitational loads that the cavity door drive system of NASA's SOFIA program will encounter during actual operation at 40,000 feet."*
> **Matt Polley, MPC Products Corporation**

the software development aspect," Polley continued. "We used dSPACE tools to aid in our development process. The tools are very adaptable and are being used on multiple projects here at MPC."
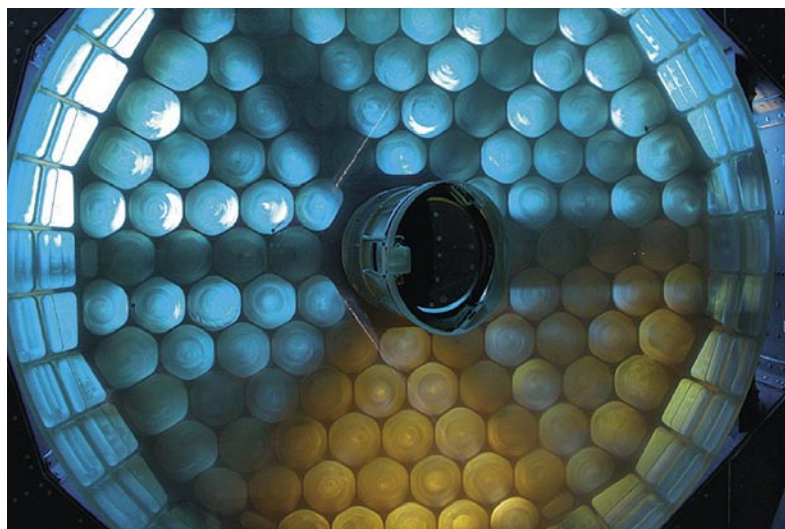
◄ *Sky light seen through the 2.5-meter SOFIA primary mirror. Picture taken before the mirror received its opaque aluminum coating. Foto: Stratospheric Observatory for Infrared Astronomy (SOFIA) Education and Public Outreach (E/PO) Universities Space Research Association (USRA).*

▲ *Boeing 747SP during a test flight. The SOFIA infrared telescope is installed in the rear fuselage.*

Testing Phase

MPC is wrapping up the final production phase of its first development units. The company is preparing to start a "testing only" phase to prove that its actuator control design works by simulating all conceivable conditions that may be encountered while the telescope and CDDS are in operation and airborne. NASA will obtain the equipment and start testing the CDDS independently in August of 2008.

"We have an excellent team in place," Wall said. "We've been working directly with NASA to streamline the software to their expectations. There has been a lot of collaborative effort." MPC will be on site to support NASA with the integration of the Cavity Door System and actuator control system onboard the SOFIA aircraft. MPC will also assist NASA as it prepares to engage open door flight testing, which will result in the first infrared pictures of constellations.

For more information on the SOFIA program, visit www.sofia.usra.edu
For more information on MPC Products Corporation, visit www.mpcproducts.com
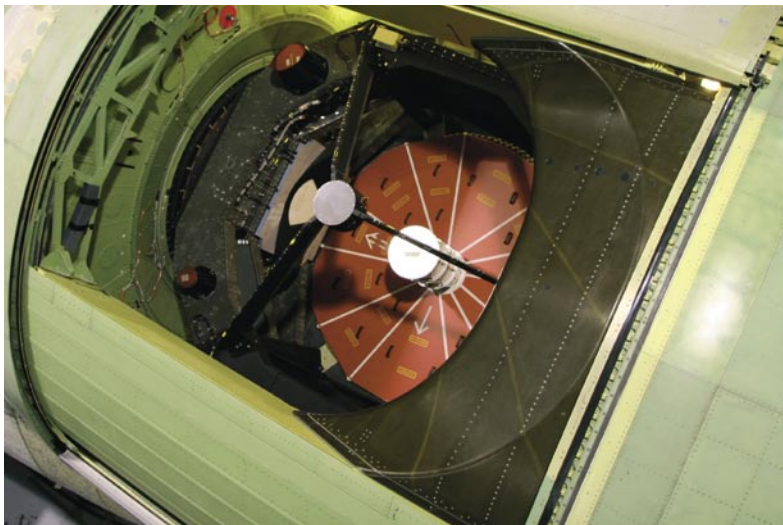
◀ *The telescope that is the heart of NASA's Stratospheric Observatory for Infrared Astronomy is nestled in the SOFIA 747's rear fuselage. The door opens and closes like an eyelid.*
Photo provided by NASA, USRA (Universities Space Research Association), and L-3 Communications Integrated Systems.

ASMs for Complete Truck Electronics Tests

- **Scania tests 33 networked ECUs with dSPACE Simulator**

- **dSPACE Automotive Simulation Models for variant handling**

- **Automated testing with virtual rebuild of buses and trucks**

Swedish heavy truck and bus manufacturer Scania has set up an integration lab to perform automated testing of networked electronic control units (ECU). The integration lab is based on hardware-in-the-loop (HIL) simulators and real-time Automotive Simulation Models (ASMs) from dSPACE. It is a virtual rebuild of a Scania bus/truck, equipped with 33 ECUs and 11 CAN networks. The lab's architecture allows a larger number of possible vehicle configurations to be tested, making it ideal for performing regression tests.

How do you verify the communication between various electronic control units (ECUs) carrying out multiple functions across multiple communication buses? The unavoidable answer, of course, is to conduct in-depth testing. A truck has significantly more variants than a passenger car due to features like dumpers, higher numbers of (driving) axles and different gear types, so efficient variant handling is a key test requirement. For heavy truck and bus

"Although it often takes longer to write a test script than to perform the same tests manually, the ability to run the same test again quickly with next to no preparation saves time for the tester when regression tests are run. This gives us the advantage of reproducibility."
Mikael Adenmark, Scania

▶ *All truck variants have to be tested in depth.*
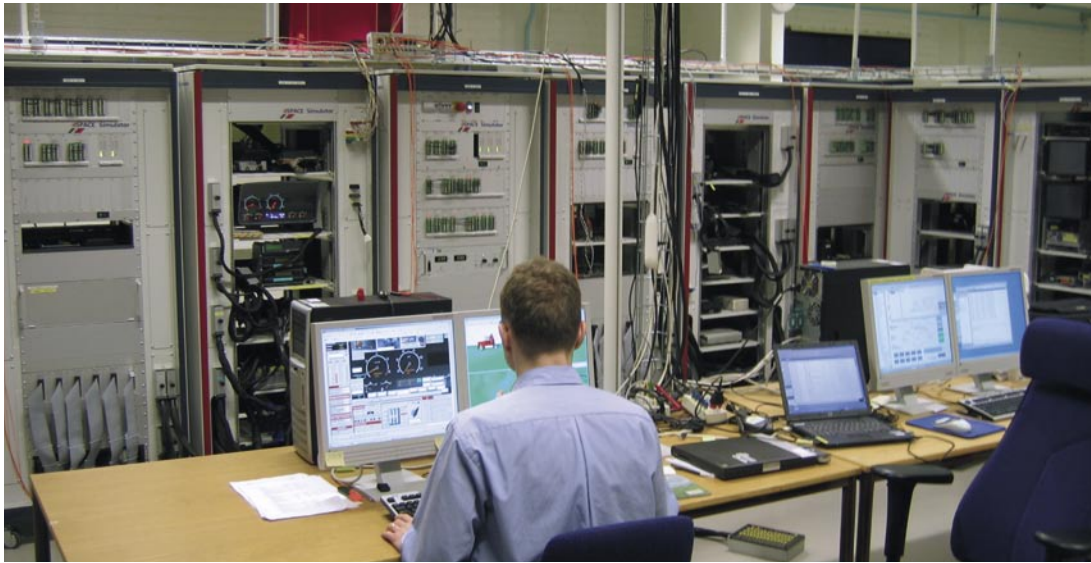
◄ *The networked hardware-in-the-loop simulators used at Scania.*

manufacturer Scania, the sheer volume of testing that is required to evaluate such complex vehicles has made manual testing a virtual impossibility and automated testing a necessity.

Real-Time Integration Lab

To implement a more efficient and systematic means of testing networked ECUs, Scania developed a state-of-the-art, real-time integration lab, where ECUs can

"By using the Automotive Simulation Models from dSPACE across many simulators we can quickly and reliably parameterize our virtual trucks."
Mikael Adenmark, Scania

be integrated into a virtual truck. The ECU testing process, which was formerly done manually, is now carried out with a Python-based test framework. The system includes 33 networked ECUs for such important system functions as brake management, all-wheel drive, crash safety, engine management and climate control, and 11 CAN networks for inter-ECU communication to accommodate different engine and vehicle configurations. The volume of testing variants that Scania is able to evaluate in this new, automated environment is substantially greater, since loops can be created to run the same tests for all variants. Although it often takes longer to write a test script than to perform the same tests manually, the ability to run the same test again quickly with next to no preparation saves time for the tester when regression tests are run. Having the test variants recorded and ready for reuse

gives Scania the advantage of reproducibility. Another major benefit of Scania's integration lab is the ease with which new software versions can be uploaded, since these are often provided by external suppliers with differing release dates. As new versions can be immediately uploaded across the whole system, the integration lab makes an excellent resource for testing, in terms of both quality and quantity.

Network Simulators

The heart of the Scania integration lab includes five Full-Size hardware-in-the-loop (HIL) simulator racks from dSPACE and associated ECU racks for mounting test devices. The racks are equipped with various I/O devices. Several processor boards are connected via Gigalink cables, so that the Integration Lab is a comprehensive multiprocessor system. All the ECUs and connections are outlined in a 50-MB Simulink® model. All the tests are visualized by MotionDesk, the 3-D online animation software from dSPACE, which gives a realistic view of the moving truck's behavior. This environment has enabled Scania to bring a much wider range of vehicle variants into its testing loop, which in turn has greatly increased our understanding of how certain conditions impact connected ECUs with distributed functions.

Simulation Models

Two of the five simulator racks are dedicated to the integration testing of powertrain and mandatory truck ECUs (e.g., gear boxes, engine control units, instrument clusters, the visibility system and the coordinator system). As simulation models for

the tests, Scania uses the Diesel Engine Simulation Package and exhaust gas aftertreatment models from dSPACE's Automotive Simulation Models (ASMs). The engine model can handle different engines, e.g., a 5-cylinder 9-liter, 6-cylinder 12-liter, and 8-cylinder 16-liter. The gearboxes can be manual transmission, manual automated transmission with up to 16 gears, or different automatic transmission systems. The

> *"With automated testing on dSPACE Simulator, the possibilities increase since loops can be created to run the same tests for all variants, where applicable."*
>
> **Mikael Adenmark, Scania**

models make it easy to adjust parameters to the truck specifications and simulate the tested truck type in real time.

Two further simulator racks are dedicated to the testing of vehicle dynamic ECUs (e.g., brake management, air processing, suspension management, all-wheel drive, locking and alarm, bus chassis, and body work system). The ASM Diesel Engine Simula-

tion Package and the ASM Vehicle Dynamics Simulation Package for Trucks were used for testing all the networked truck ECUs. The vehicle model can simulate trucks or buses with two or three axles. One or two of the axles can be driven axles. The last simulator rack is dedicated to the testing of body ECUs (e.g., heater, infotainment, climate control, crash safety, audio, clock and timer systems). Simulation models developed by Scania were easily be integrated into the test system. By using ASM also for another powertrain simulator, Scania expects to efficiently exchange model parts and parameterization sets between the different systems.

CAN Bus Systems

To realize smooth communication between so many ECUs always is a challenge. Scania vehicles perform their main communication via three global J1939 CAN buses with 250 Kbps. The ECUs are connected via 11 CAN networks, for example for the drivetrain, the comfort systems, and inter-ECU communication. Each ECU can be connected to one of the doubled buses or completely disconnected.
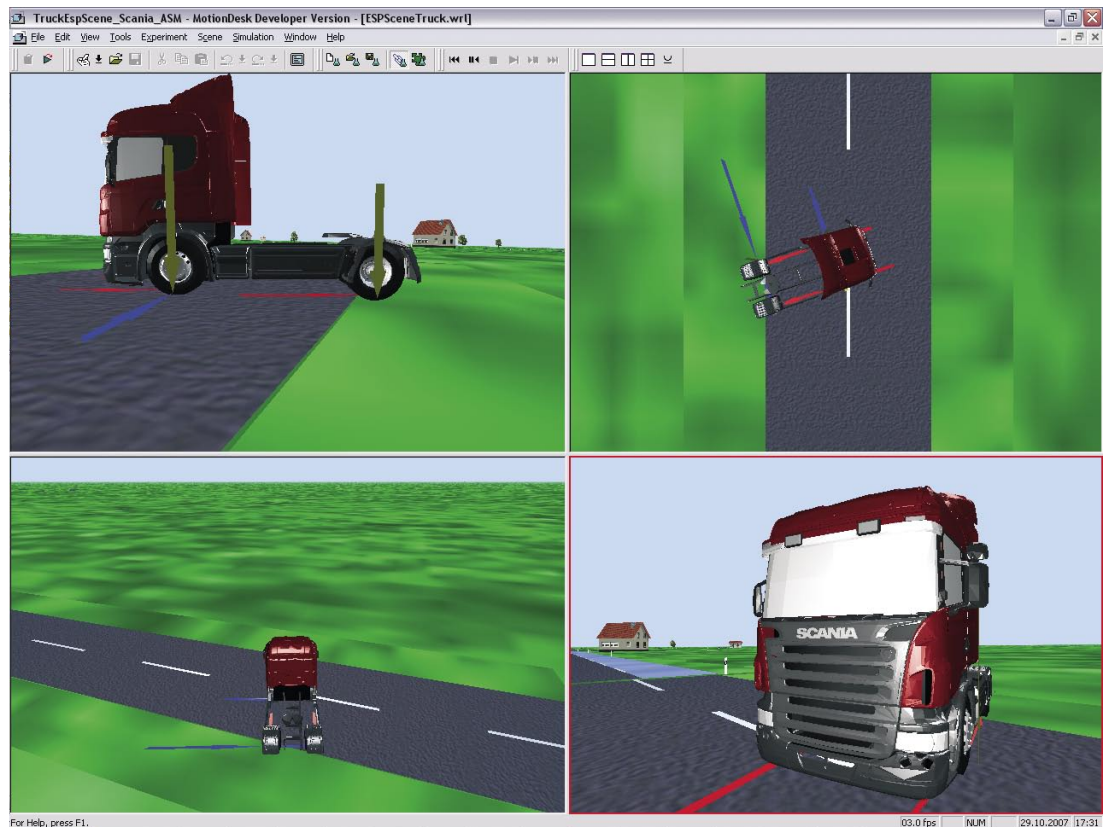
▲ *MotionDesk screenshot showing a test drive.*
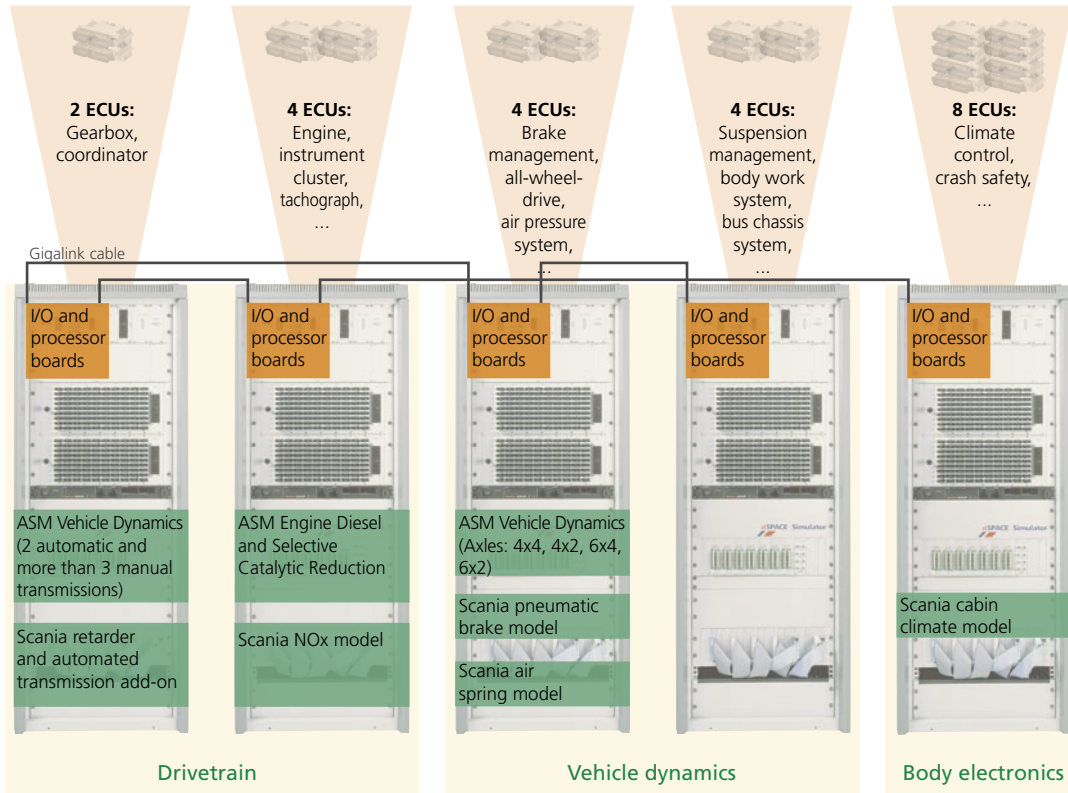
▲ *Schematic of the overall ECU network.*

Scania is presently using its integration lab to perform:

- CAN communication testing to verify that the correct CAN messages are sent, in the correct interval time, when all ECUs are connected to the CAN network.
- User function testing to gauge reliability.
- Robustness testing to determine how ECUs are affected by exceptional conditions (e.g., how the communication between ECUs is affected when system voltage is reduced or when the ground connection in one or several ECUs goes bad).
- Diagnostic testing to pinpoint ECUs sensor failures or defective electrical connections.

Benefits of the Integration Lab

The integration lab demonstrates that dSPACE Simulator technology is capable of handling huge vehicle networks far more complex than those of passenger cars. Script-based testing enhances reproducibility, which will be useful for further tests, and integrating our own simulation models offers great flexibility,

The ability to conduct regression testing on multiple ECUs across distributed functions with interchanging variants has greatly simplified Scania's process for developing and testing ECUs.

Mikael Adenmark
Scania CV AB, Södertälje
Sweden

Glossary

Regression tests –
Repetition of a test part or all test sequences to ensure that new modifications do not affect formerly tested components.

J1939 CAN buses –
Vehicle bus standard, used for communication and diagnostics between vehicle components.

Integration Lab –
Combination of real existing ECUs and a virtual truck model for testing the network and communication of the ECUs.

Doing It All With CalDesk

- **CalDesk used in steering system development**

- **Correlated measurement data capture from different sources**

- **Tool chain from a single supplier**

To help the development of steering systems run as smoothly as possible, ZF Lenksysteme GmbH, Germany, has set up an environment consisting of various dSPACE tools. The CalDesk measurement and calibration software performs several tasks in the set-up: It provides access to various hardware devices and displays different measurement data in correlated form. dSPACE NEWS spoke to Andreas Stöffler, a member of the software development team at ZF Lenksysteme GmbH, about the advantages of CalDesk.

Mr. Stöffler, what kind of work does your department do?
Our task is to test electrical power steering systems, some of them active. We do this by exposing the original components – the ECU and the servo motor – to the same conditions they would meet out on the roads. We simulate the torques and forces that affect the steering and study the reactions of the ECU and servo motor.

What does your working environment consist of?
First of all, we have a dSPACE hardware-in-the-loop (HIL) simulator. This supplies the simulation data to the steering system under test and in return receives a variety

of measurement values from the steering system. To run and manage the tests, we use the AutomationDesk test automation software from dSPACE and the DOORS® requirements management tool from Telelogic. The

> *"The measurement and calibration software CalDesk from dSPACE makes it simple for us to measure and display data from different sources simultaneously."*
> **Andreas Stöffler, ZF Lenksysteme GmbH**

two tools are coupled via the dSPACE Connect&Sync Module, which helps us keep track of the tests and their results. Finally, CalDesk gives us simultaneous access to the simulator hardware and the ECU, and also displays all the processes on a shared time basis.

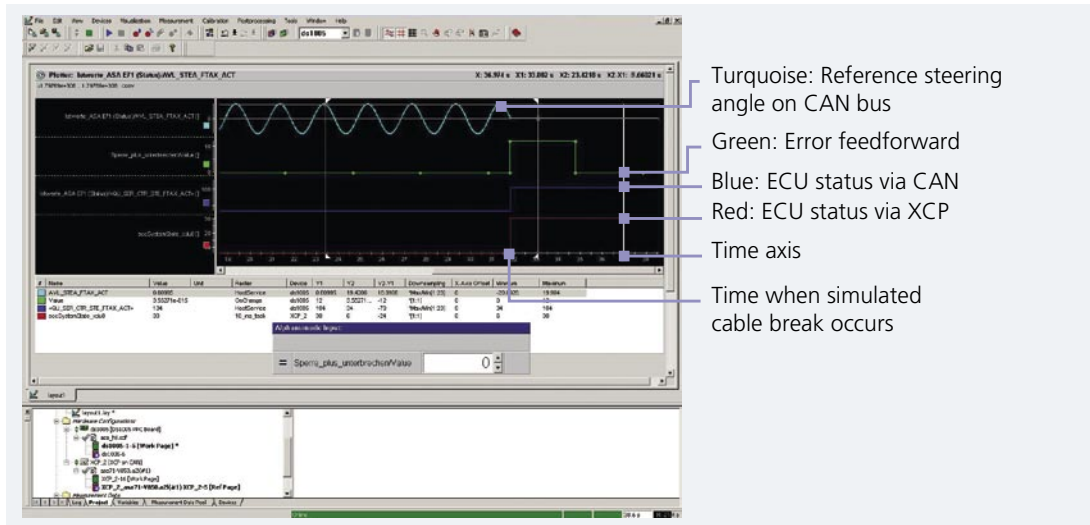*Which particular CalDesk functionalities do you mainly use?*
With its various add-on modules, CalDesk makes it possible to tailor suitable CalDesk environments for a wide variety of scenarios. We are using CalDesk with the Automation Module, the Prototyping Module, and the Diagnostic Module.

What do you use these CalDesk modules for?
The Automation Module lets us automate and remote-control measurement, calibration, and diagnostic tasks via AutomationDesk. The Prototyping Module gives us access to the DS1005 Processor Board from dSPACE, which we use as the real-time simulation platform in our HIL systems. So with CalDesk in the loop, we can capture data from the ECU and the HIL simulator simultaneously and output them on a single time axis. Lastly, we use the

▲ *Andreas Stöffler, member of the software development team at ZF Lenksysteme GmbH: "We can now use CalDesk to handle a lot of tasks that we formerly required several tools for."*

Turquoise: Reference steering angle on CAN bus

Green: Error feedforward

Blue: ECU status via CAN
Red: ECU status via XCP

Time axis

Time when simulated cable break occurs

◄ CalDesk plot of a simulated cable break in a steering system: The moment the cable breaks, the ECU switches to "Error". ECU-internal variables are measured via XCP, while the CAN signal and error feedforward are recorded in parallel via the DS1005 board.

Diagnostic Module for actions such as accessing the ECU's fault memory and reading out the ECU's device ID.

### Could you give us a typical example of how you use CalDesk?

Let's take safety testing of the steering function as an example. If there were a short circuit in the motor phases, the motor could lock up and the ECU would have to react to this within milliseconds and switch power away from the phases. We activate the electrical fault with AutomationDesk. At the same time, we use CalDesk to measure the fault activation in the simulation model and the ECU's reaction. The measurement data is automatically analyzed in AutomationDesk, and the reaction time is evaluated. The CalDesk Diagnostics Module reads the trouble codes in the ECU and compares them with the expected values.

This procedure means that we automatically test all possible combinations of electrical faults. A separate report including a signal plot is produced for each test case, and if an error occurs, it is passed on to the responsible function developer.

Where does CalDesk help most?

One feature we find particularly useful is the ability to view the processes in the HIL simulator and in the ECU on a shared time axis, and to adjust parameters simultaneously. In addition, CalDesk can perform all kinds of tasks that we formerly needed several tools for – such as diagnostics, calibration tasks, measuring via CCP and XCP, and CAN monitoring. Moreover, we can reuse existing tests in other projects, since not every OEM requires us to connect their own diagnostic tool to our automation system.

What are the advantages of the dSPACE tool chain?

The dSPACE tools are optimally coordinated, so we do not have the typical interface problems that arise with a mixture of tools from different suppliers. Also, we get support for our entire test environment from a single

AutomationDesk
■ Test automation

CalDesk
■ Measurement
■ Calibration
■ Diagnostics

HIL Simulator

ECU
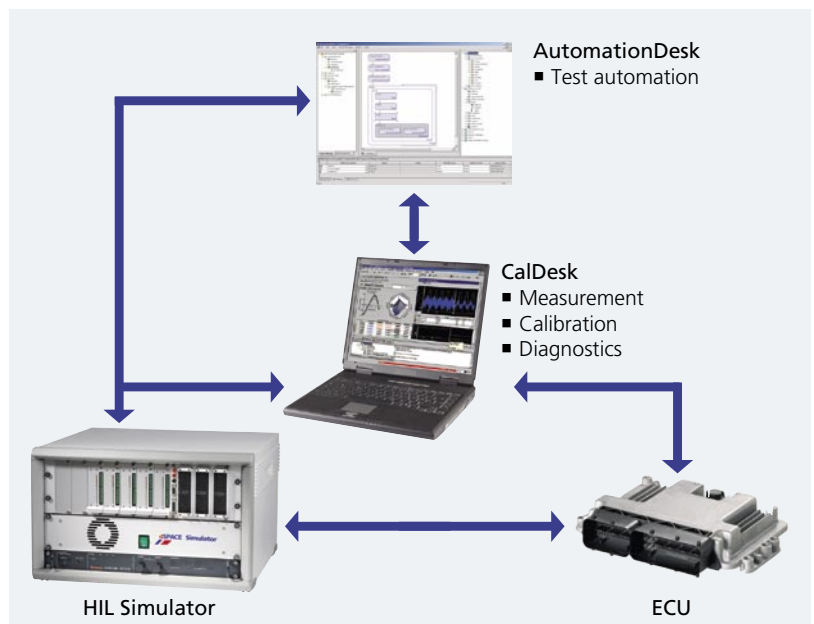
source. All in all, this saves us quite a few working steps, and we have a lot more time for tackling other tasks.

Have you any plans for the future?

One of our requirements for the future is support for XCP on FlexRay. We would also like to use automated ECU flashing during test runs.

Mr. Stöffler, thank you for talking to us.

▲ Interacting with the tools that are used, CalDesk plays a central part in measuring and outputting various measurement values.

Making Childbirth Safer

- French robotic medical research project

- Innovative childbirth simulator for training obstetricians and residents

- Practicing diagnostic and therapeutic manipulations

Obstetricians and residents (trainee doctors) learn most of their craft in the delivery room itself. If problems occur during a birth, they use forceps and vacuum extractors to solve them, but this increases the risk of injury to mother and child. The only way this risk can be reduced is by years of practical experience. Soon, however, obstetricians and gynecologists will be able to hone their skills outside the delivery room, trying out manipulations on a new birth simulator called BirthSIM. ControlDesk and MotionDesk from dSPACE's experiment software family are used to control and visualize simulated birth complications.

The patented birth simulator, BirthSIM, is being jointly developed by the Laboratoire Ampère of the Institut National des Sciences Appliquées (INSA) and the Hospices Civils de Lyon, both in Lyon, France. It teaches trainee obstetricians and residents how to handle instrument placement when complications occur during birth.

The Structure of BirthSIM
BirthSIM has electromagnetic sensors with 6 degrees of freedom. 3-D visualization shows images of the pelvis interior, including the position of the baby and the movements of the instruments. The control system, with the DS1005 PPC Board at its core, processes the data captured by the sensors. To be more precise, it picks up the data on the forceps' position, calculates the position of the forceps model by MATLAB®/ Simulink®, and passes the information to MotionDesk, which registers the forceps' trajectory and then replays the scenario on the monitor. BirthSIM consists of the following components:

- Static mechanical system: anatomical models of the mother's pelvis, the pelvic floor muscles, the baby's head, and real forceps.
- Dynamic mechanical positioning system: for modifying the baby's position in the womb.

- Two monitors: The first is for the instructor. It runs with ControlDesk to visualize and parameterize the birth complications to be simulated. The second works with MotionDesk and gives obstetricians in training the opportunity to observe the movements of their instruments inside the pelvis in real time. Visualization is performed from several perspectives.

BirthSIM Indispensable to Training
To date, there are no comparable anatomic simulators for obstetrics that provide a comprehensive learning program for training obstetricians and residents on a mechatronic basis. To close this gap, our team from the Laboratoire Ampère conceived and developed the BirthSIM simulator, with the aim of replacing existing

Ampère

http://ampere-lab.fr
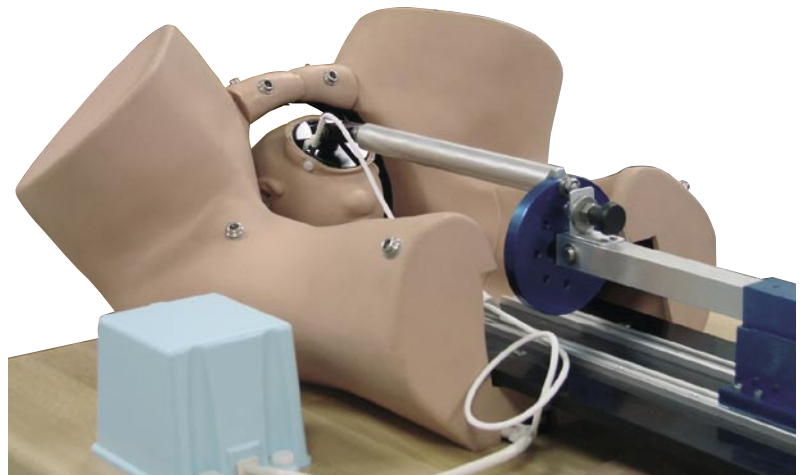
▲ *A mechatronic system developed at the Laboratoire Ampère positions the baby's head in the pelvis by rotation and translation.*

obstetric simulators with it. BirthSIM is a new type of simulator that gives obstetricians and residents a means of practicing instrument use, so inexperienced delivery room staff can be trained without endangering the health of patients.

## BirthSIM's Current Development Status

At its current stage of development, BirthSIM helps to train the following manipulations:

- Diagnostics via internal examination through the vagina
- Analysis and reproducibility of actions involved in using forceps, via an interface developed with MATLAB/Simulink
- Evaluation and analysis of forceps handling according to criteria selected by the medical team
- Learning to apply forceps in the right place, without harm to baby and mother, supported by MotionDesk visualization

BirthSIM in the Future

The prototype of the simulator has been available in the Centre Hospitalier Universitaire de Lyon Sud of the Hospices Civils de Lyon since June 2007. Dr. Olivier Dupuis, specialist gynecological obstetrician, has made it part of the curriculum for gynecologists. Meanwhile, the Laboratoire Ampère is continuing work on developing the simulator. The goal is to position the baby's head in the birth canal by moving and rotating it. Simultaneously, an electropneumatic system will reproduce the expulsion forces that occur during birth (contractions and the mother's intentional pressure). Obstetricians can then learn to synchronize forceps traction with the mother's natural expulsion forces. Initial results already showed that an obstetrician who trained on BirthSIM applies far less force to the baby's head during a forceps birth, the overall effect of which is to make the delivery procedure safer and less risky.

Pr. Tanneguy Redarce, Ass. Pr. Minh Tu Pham
Ass. Pr. Xavier Brun, Dr. Richard Moreau
Laboratoire Ampère – UMR, CNRS 5005
INSA de Lyon
Dr. Olivier Dupuis, Hospices Civils de Lyon –
Centre Hospitalier Lyon Sud France
France
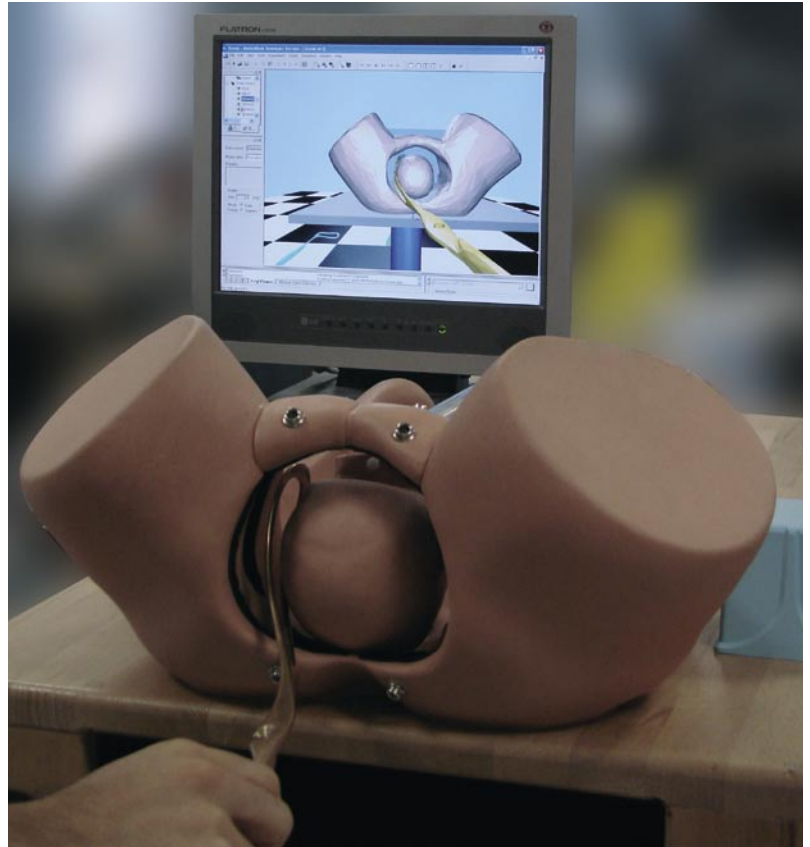
▲ *Obstetricians and residents can practice using forceps on BirthSIM.*
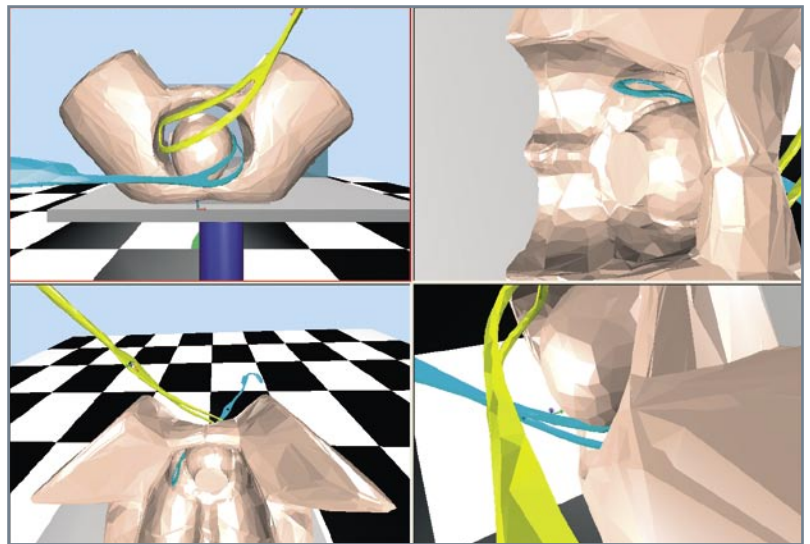
▲ *On-screen monitoring: MotionDesk visualizes forceps insertion from several perspectives. The 3-D visualization is useful for analyzing the handling and for recording typical mistakes.*

Systematic AUTOSAR Migration

- Audi developing AUTOSAR software for shock absorber control

- Setting up an efficient tool chain

- Modeling and generating AUTOSAR-compliant software with TargetLink

The AUTOSAR standard offers new solutions for mastering increasing complexity as the number of different technologies, functions, and most of all, variants continues to grow. In addition, it ensures that software components are easy to reuse. Audi implemented a shock absorber control that complies with the AUTOSAR concept. This project provided important insights on setting up a tool chain in which TargetLink, dSPACE's production code generator, is used for modeling and generating AUTOSAR-compliant ECU software.

The Challenge of Complexity
There are several ways of handling the complexity of ECU development. Approaches based on suitable software architectures and standardized hardware platforms look promising. The AUTOSAR standard's role here is as a manufacturer-independent starting point for designing software architectures. OEMs' concentration on designing AUTOSAR software components (SWCs) will enhance the quality of software due to the ease with which they can be reused.
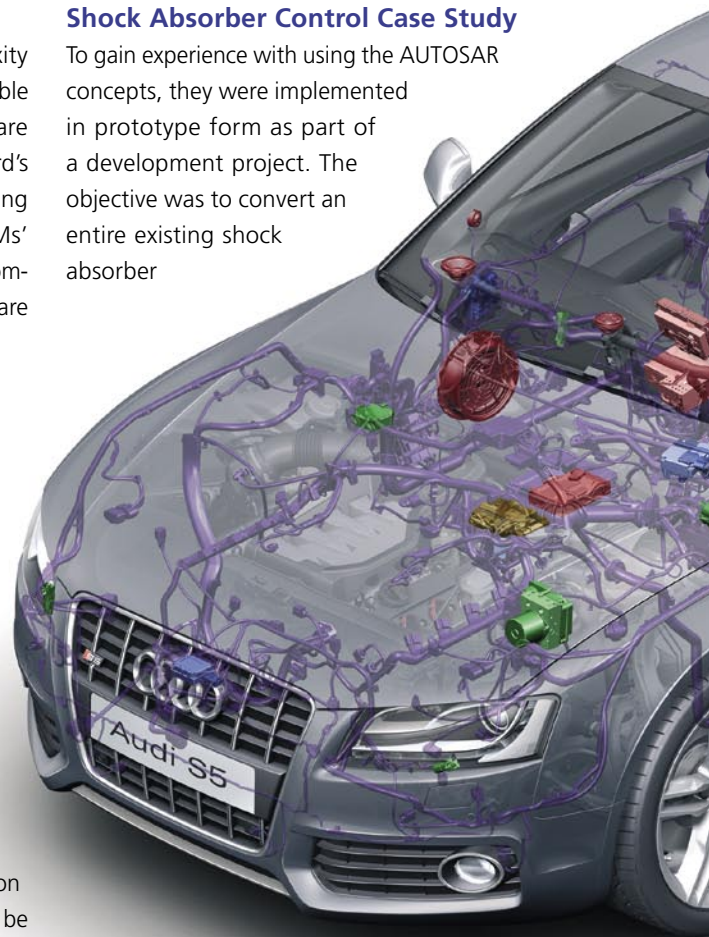
Easy to Reuse
Because all function logics are encapsulated in AUTOSAR-compliant software components, items such as the processing algorithms for sensor data can be reused in different projects and with reference to different processor-specific requirements, without the code having to be adapted. This means that automobile manufacturers not only save costs, they also save time when launching new projects.

Systematic Abstraction
Systematic abstraction of the system architecture means that explicit decisions on how the application software will be deployed on ECUs do not have to be made until a late stage of a project. This means that the logical software architecture can be designed at a very early stage, independently of hardware architecture. Individual functions can be moved from ECU to ECU at will, giving developers the freedom to perform function distribution or integration whenever they want: For example, they can delay it until after an intensive internal testing or exploration phase.

Shock Absorber Control Case Study
To gain experience with using the AUTOSAR concepts, they were implemented in prototype form as part of a development project. The objective was to convert an entire existing shock absorber control system into AUTOSAR-compatible software components by means of TargetLink, and to test it on a production-close vehicle as the prototype development platform.
The control consists of four body acceleration sensors, four distance sensors, and four continuously

controlled shock absorbers. A central ECU evaluates the sensor signals and calculates the shock absorber control, taking into account further vehicle dynamics variables such as the steering angle, yaw rate, brake signal, lateral acceleration, vehicle speed, and engine torque. The ECU receives these variables from the vehicle's CAN bus. The ECU communicates with the active shock absorbers via a FlexRay bus.
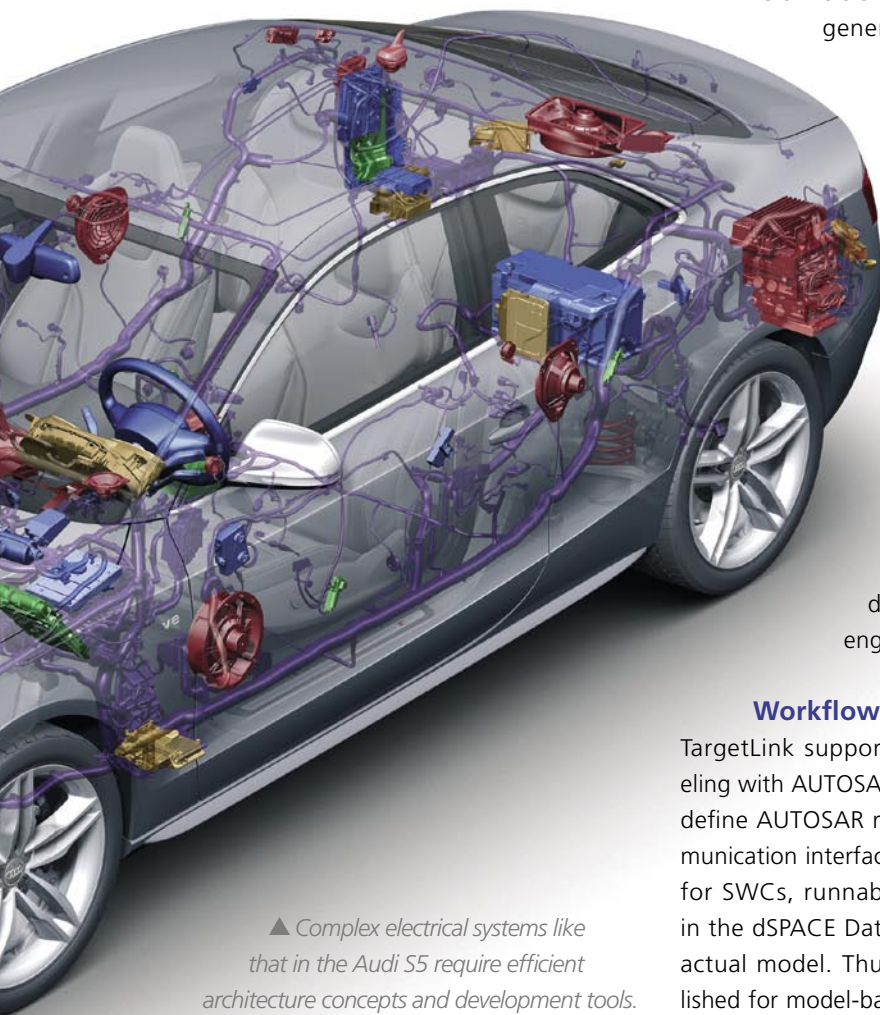
A Prototype Development Environment

The tool chain currently in use is based on AUTOSAR Release 2.0. Standardized file formats allow

▲ *Complex electrical systems like that in the Audi S5 require efficient architecture concepts and development tools.*

dedicated tools to be created. These make it easy to analyze other aspects of the overall system, such as time behaviors in the ECU. The following tools were used:

- ◢ TargetLink for model-based development and automatic production code generation for AUTOSAR SWCs

- ◢ Elektrobit's EB tresos® for configuring the AUTOSAR-compliant basic software (e.g. OS) and generation of the RTE
- ◢ Configuration tools for the FlexRay stack
- ◢ Production-close ECU prototypes

Model-Based Development of SWCs

From the point of view of function developers, the most important tool in an AUTOSAR tool chain is the modeling tool. It lets them implement and model their ideas simply, using tried and tested processes.

As of Version 2.2, dSPACE's production code generator TargetLink supports the design of AUTOSAR software components as well as conventional model-based development, and allows the corresponding target code to be generated automatically. Because communication and hardware connections are abstracted, function developers can concentrate fully on the actual application. To take production aspects into account from the beginning, it is advisable to give the function developers support from design engineers.

Workflow with TargetLink

TargetLink supports AUTOSAR-compliant modeling with AUTOSAR blocks, which make it easy to define AUTOSAR runnables and model the communication interfaces. The AUTOSAR-specific data for SWCs, runnables, interfaces, etc., is stored in the dSPACE Data Dictionary and linked to the actual model. Thus, the entire workflow established for model-based design with TargetLink can also be applied to developing AUTOSAR software. Once an AUTOSAR function model has been designed, it can be simulated and tested with TargetLink at the model (MIL) and the software (SIL) level.

As well as generating the AUTOSAR-compliant code, TargetLink automatically produces the AUTOSAR software component descriptions.
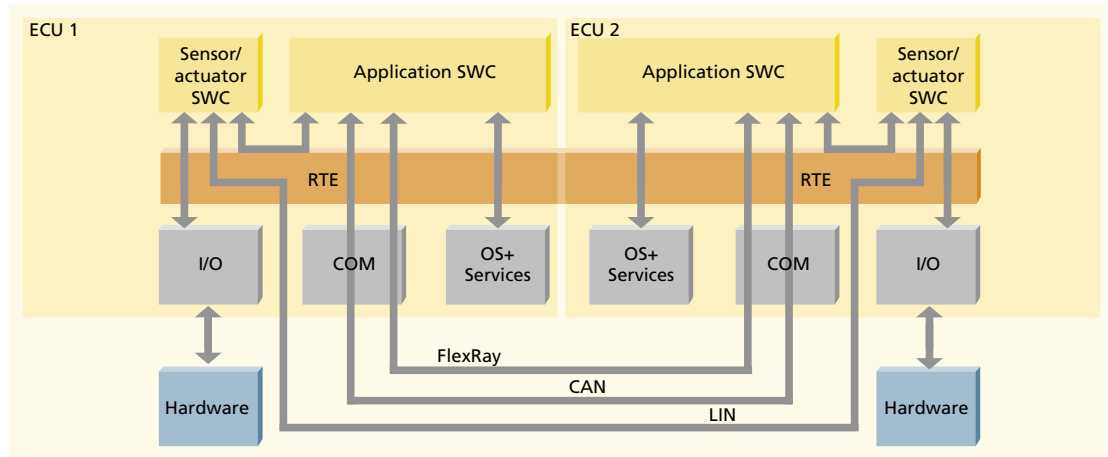
▲ *Basic AUTOSAR structure. Several SWCs are distributed on two ECUs. The RTE allows the SWCs to communication independently of the specific I/O hardware and bus that are used.*

The shock absorber control is subdivided into several AUTOSAR software components, each comprising several runnables. In this specific case, communication between interrunnables was used intensively, though the AUTOSAR standard currently supports this only for scalar variables. Thanks to an Audi-specific TargetLink extension, however, the function developers can also work with vector signals, which TargetLink converts into code patterns for scalar variables. This simplifies the modeling process and also ensures compliance with AUTOSAR.

Implementing the AUTOSAR Software

As part of SWC implementation on the ECU, the AUTOSAR operating system was configured and the run-time environment (RTE) was generated by EB tresos. To generate the RTE, the software component descriptions generated by TargetLink were imported into EB tresos, and the RTE was generated on the basis of the information in them. The last step was to configure the FlexRay drivers, which are in the basic software. The Infineon TriCore microcontroller family was used to set up the prototype hardware because of its good performance and broad-based connec-
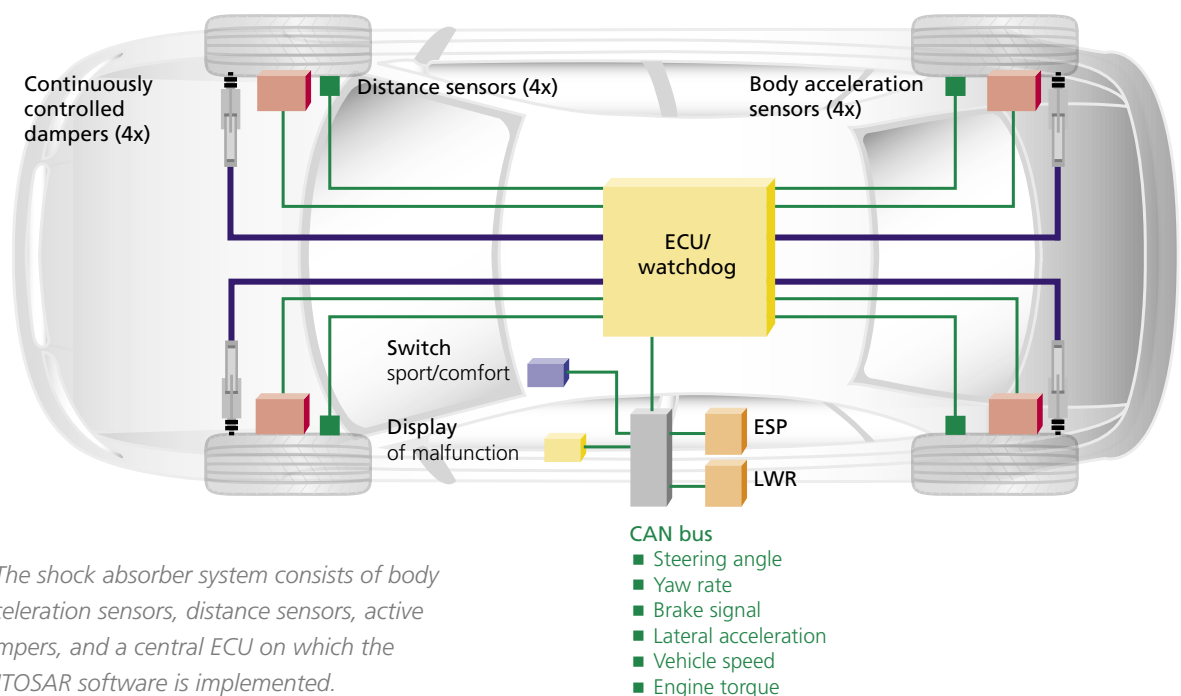
▲ *The shock absorber system consists of body acceleration sensors, distance sensors, active dampers, and a central ECU on which the AUTOSAR software is implemented.*

tions to typical automotive peripherals. These so-called "engineering device" microcontroller derivates provide a powerful data interface for the necessary tests and for instrumentation tasks.

Successful function implementation on the production-close ECU was verified both in test drives and in tests on the simulator. These also clearly showed that the AUTOSAR-compliant code generated by TargetLink meets the production requirements on size and run-time behavior.
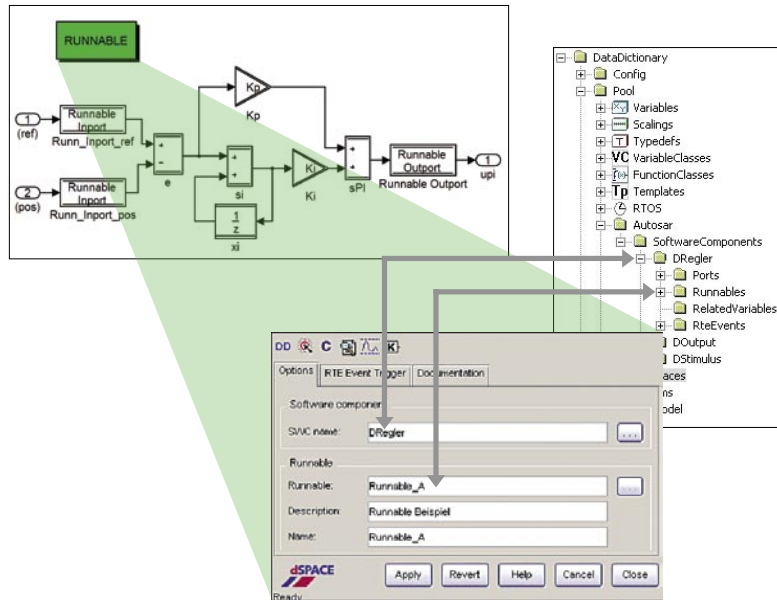
▲ With TargetLink, the AUTOSAR specifications stored in the dSPACE Data Dictionary can be linked directly to the model.

Tool Chain Know-How

The experience gained is being invested to set up an AUTOSAR tool chain for function developers to develop new vehicle features close-to-production and with high efficiency.

> *"The support given to the AUTOSAR standard by dSPACE tools and close cooperation with dSPACE enable us to introduce AUTOSAR successfully."*
> **Dr. Karsten Schmidt, AUDI AG**

As a tool for model-based development and automatic code generation, TargetLink addresses the design of individual, clearly defined software components. The SystemDesk architecture tool is an obvious choice for overall system design, as it closes the gap in the systematic design of software systems. In addition, modeling and analyzing the temporal relations in single ECUs and in the overall system looks likely to grow in importance.

The Charm of the AUTOSAR Idea

As the advantages described here show, the AUTOSAR idea offers numerous options for increasing the efficiency of function development. A production-close framework can be used at an early stage in the development process, thereby minimizing potential difficulties in cooperation between OEMs and suppliers. Interaction between different tools is the 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.

*Dr. Karsten Schmidt
Frank Gesele
AUDI AG
Germany*

Dr. Karsten Schmidt is responsible for the further development of the AUTOSAR tool chain in the chassis section at Audi.

Frank Gesele is team leader for vertical dynamics and proprietary software development in the chassis electronics section at Audi.

Flexible Configuration

- Joint project between Volkswagen AG and University of Paderborn

- Hardware-in-the-loop system

- Testing ESP and EPS systems

A joint project between Volkswagen AG and the Professorship for Control Engineering and Mechatronics at the University of Paderborn, Germany, has developed an integrative hardware-in-the-loop system. This consists of two HIL subsystems, each complete in itself, which can be used either separately or together as an overall system for validating the functions of networked chassis control systems. Designed using the model-based approach, the HIL system can be configured flexibly and is ideally suited for use in the automotive industry.

Hardware-in-the-Loop in Automobile Development

The sheer number of ECUs is not the only reason why in-vehicle electronics are becoming more complex: Networking between ECUs is another cause.

The automobile industry is therefore working intensively on setting up new development processes and testing methods to master this rapidly growing complexity.

Hardware-in-the-loop (HIL) simulation is playing a major role in all this as a proven method of testing ECU software. Together with Volkswagen AG, the Professorship for Control Engineering and Mechatronics at the University of Paderborn has developed an HIL system for testing the control functions of either individual or networked ECUs, and also, to a great extent, verifying vehicle dynamics under real-time conditions.

One HIL System – Different Configuration Options

The HIL system is hierarchical in structure and designed for validating the two chassis control systems ESP (Electronic Stability Program) and EPS (Electric Power Steering – the electromechanical power steering in VW vehicles). It consists of two subsystems:

- HIL simulator with an ESP ECU
- HIL component test bench with a real steering module and an EPS ECU

HIL Simulator in an ECU Network

The two subsystems can run separately and can also be combined to form one overall HIL system. The overall HIL system with the ECUs for ESP and EPS supports the development and testing of the entire ECU network. To create the overall HIL system, the two HIL simulators and the individual ECUs were coupled
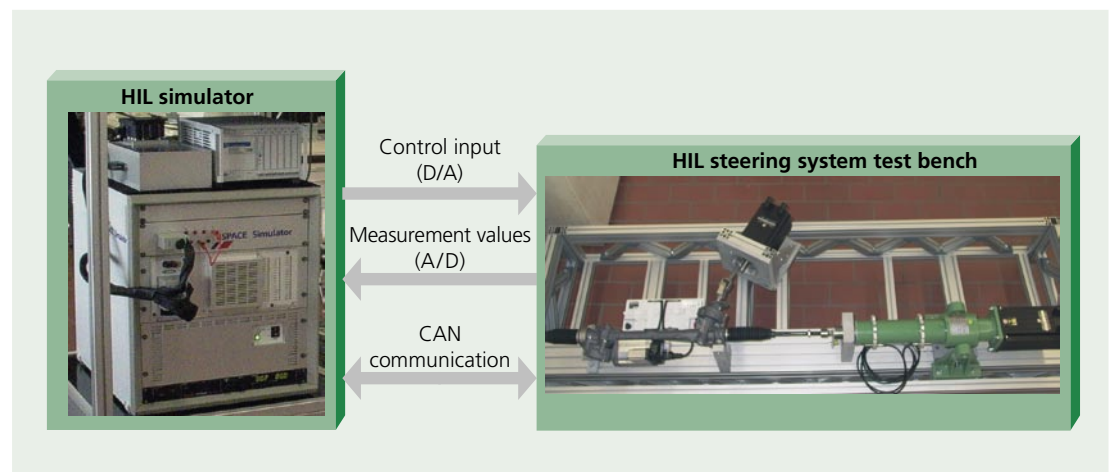
▲ *The integrated HIL system with steering system test bench: real steering module, EPS ECU, actuator, sensor, and mechanical steering system.*

via the DS830 MultiLink Panel. The coupled HIL system is mainly for investigating the inter-action between several ECUs. One example is tests on a vehicle's elec-trical system aimed at ensuring safe behavior if voltage drops occur when several energy consumers in the vehicle are all running simultaneously. The effects of the ECU, the power electronics, and the electric motors on other electrical devices are analyzed. The plausi-bility of the CAN signals between different ECUs can also be verified in this HIL system.
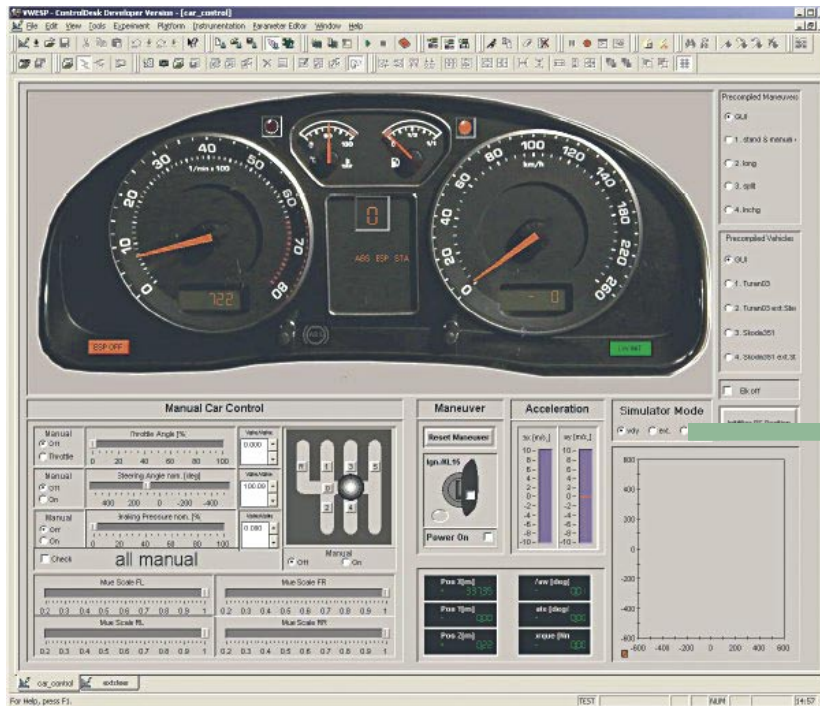
Set mode
- ○ *ESP simulator*
- ⊙ *EPS steering system test bench*
- ○ *ESP+EPS*

▲ *Configuration options on the test bench: This user interface was created with the ControlDesk experiment software. Developers can monitor measurement signals and operating states as well as run tests.*

Combined HIL Simulator with Test Bench

Increasingly, ECUs are not only networked with one another for testing, but also connected with a real system component. Thus, when new control functions are tested and validated, not only the ECU itself can be present in hardware form; the constellation can also include essential vehicle components. In many cases, these components come straight from the sup-plier, and they are often highly complex: for example, the entire mechatronic steering module including the mechanical steering system, actuator, controller, and sensor. It is not really possible to create a model for such a component, as many suppliers are not pre-pared to disclose their know-how. Thus it cannot be studied as a component model in the HIL simulator software. The solution is to include the real compo-nent module in an HIL test bench, and let the module communicate with other subsystems and ECUs via defined interfaces.

Easy Handling of Real-Time Hardware

To put the HIL system into operation and communi-cate with it, the Simulink®/Stateflow® models were quickly and automatically implemented on the dSPACE

real-time hardware (DS1006 Processor Board) via the Real-Time Interface (RTI). This screenshot shows a part of the user interface that was created with the ControlDesk experiment software. There is a Set Mode function for easy switching between the three con-figuration options. In addition, important system and controller parameters can be programmed and syn-chronized with the operating states, making it easy to access system and controller parameters online. The simulation can be addressed interactively to feed in suitable driving maneuvers (µ-split, lane changing, etc.).

Summary

This article describes the development of an integra-tive hardware-in-the-loop system for validating the control functions of single or networked ECUs and also, to a large extent, for verifying vehicle dynamics under real-time conditions. The only way for the auto-mobile industry to master the rapidly growing com-plexity caused by networking and the large number of ECUs is to use the new development processes and testing methods.

Turbine Tweaking on Virtual Aircraft

- **Real-time simulation of a complex aircraft model**

- **HIL simulation with turbine emulator in the loop**

- **Optimization of turbine controller model**

The Air Force Research Laboratory (AFRL) is taking advantage of hardware-in-the-loop (HIL) simulation with dSPACE Simulator to develop and optimize the propulsion systems for the next generation of aircraft. Real-time simulation of turbines and aircraft models performed together with real turbine hardware components opens new possibilities for turbine engine controls. The optimized algorithms allow aircraft to achieve higher altitudes, faster speeds, lower fuel consumption and lower heat rejection into recirculated fuel.

Aircraft power demands continue to grow with the increase in electrical subsystems. These subsystems directly affect the behavior of the power and propulsion systems and can no longer be neglected in system analyses. The performance of the whole aircraft must also be considered with the combined interactions between the power and propulsion systems. The larger loading demands placed on the power and propulsion subsystems result in thrust, speed, and altitude transients that affect the whole aircraft. This results in different operating parameters for the engine. The complex models designed to integrate new capabilities have a high computational cost.

HIL Opens up Integrated System Analyses

Using a hardware-in-the-loop (HIL) analysis with real time integration of the aircraft/propulsion system has revealed tremendous potential. This method provides a significant reduction in computational runtime, and the airframe/turbine engine model has proved usable in an HIL environment. This also allows a more complete analysis of the interactions between engine loading and aircraft performance by including some real hardware components.

To determine the system-level consequences of these kinds of capabilities, the Air Force Research Laboratory (AFRL) is diving into integrated system analyses via advanced modeling and HIL simulation techniques.

"Propulsion, power and thermal subsystems on these types of aircraft need to be tested and analyzed to identify interdependencies and any possible adverse interactions," says AFRL senior electrical engineer and physicist Peter Lamm. "Through advanced real-time simulation with turbine prototype hardware components, we can predict the interdependencies and address adverse interactions prior to costly hardware prototyping."

Virtual Representation of Aircraft

The AFRL has set up a real-time HIL simulation test facility – a virtual representation of an aircraft turbine engine and power system – to explore subsystem interactions between propulsion, power and thermal systems. To take parameters such as ambient pressure, ambient temperature and airspeed into account, the simulation is complemented by a real-time aircraft simulation.
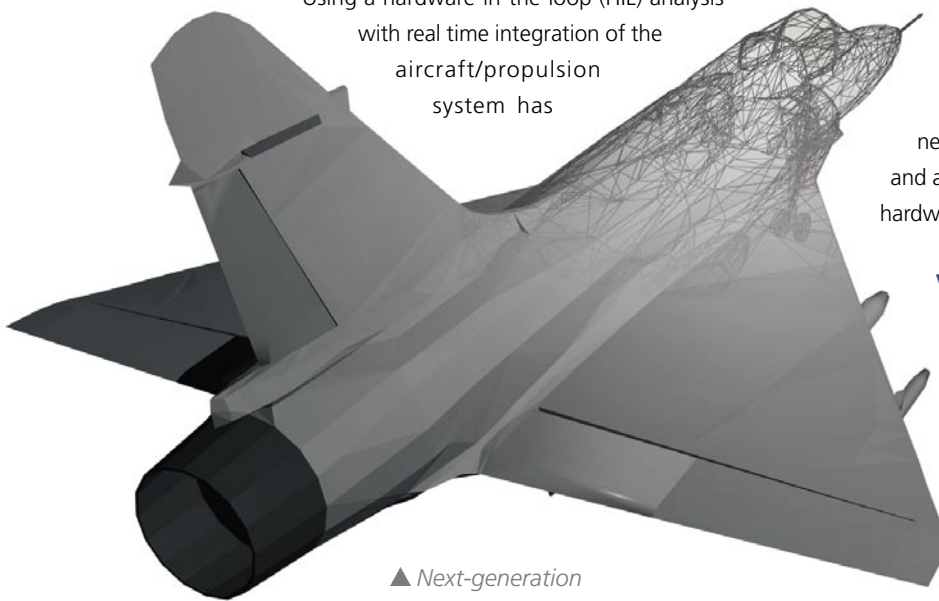
▲ *Next-generation aircraft will benefit from optimized turbine engine controls developed with the aid of dSPACE Simulator.*
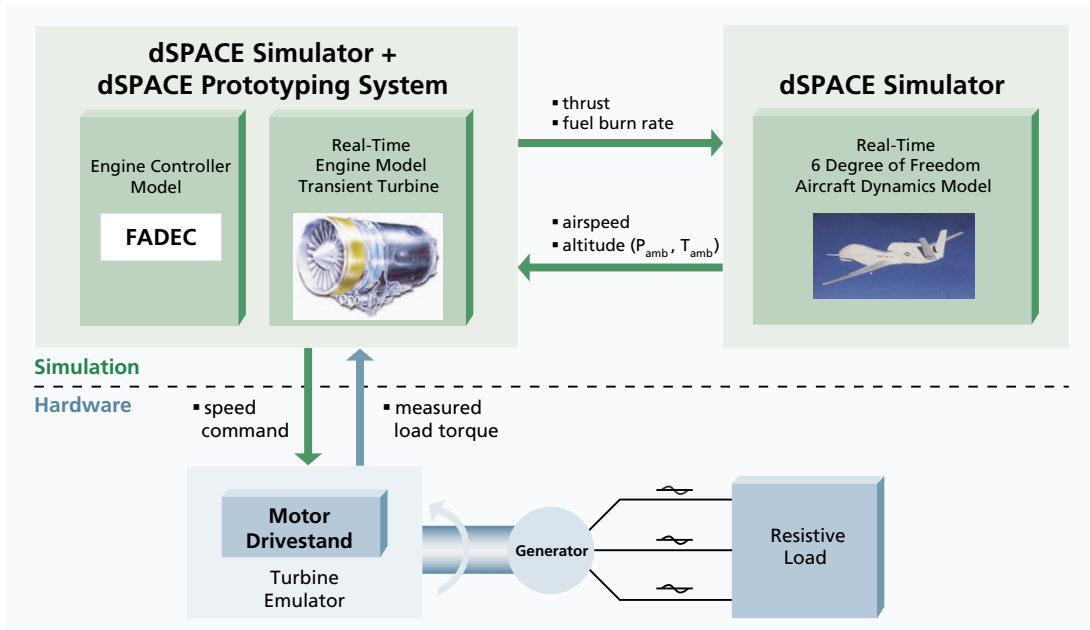
▲ *Two dSPACE Simulators and a prototyping system are used to perform the controller model and the models of the aircraft systems in real time.*

The test-bed includes four main components:

- Turbine engine dynamic and aircraft simulators, comprised of a dSPACE Prototyping System and a dSPACE Simulator (HIL)
- Generic turbine engine model, aircraft model and FADEC (Full Authority Digital Engine Control), developed in a MATLAB®/Simulink® environment
- Aircraft engine spool emulator, consisting of a motor drivestand, speed control and torque feedback
- Electric power system, containing an aircraft test generator and a load bank

Combination of Controller Model and Controlled System in Real Time

The dSPACE simulation environment comprises 3 systems: The generic turbine engine, aircraft, and FADEC models run as self-contained real-time models. The FADEC is performed on a dSPACE Prototyping System; the turbine model and the aircraft model (a full 6-degree-of-freedom aircraft dynamics model including rotation and translation in 3-D space) run on two dSPACE HIL simulators.

Variant Simulation Runs

Aircraft, propulsion, and power system modeling have been investigated with this system. Various experiments were performed using the low pressure (LP) generator as the

hardware component in the loop. Significant non-linear, transient variations occurred when the power loads were applied and removed. These simulations produced different results than those which assumed constant altitude

> *"The results achieved with dSPACE Simulator validate the capability of HIL experimentation in avionics and provide the opportunity for significant propulsion configuration studies with minimal cost."*
> **Peter Lamm, Air Force Research Laboratory**

and airspeed. These variations could cause the engine to surge, making it vital that transient events are modeled and analyzed with aircraft dynamics. Lamm comments, "These results validate the capability of HIL experimentation in avionics and provide the opportunity for significant propulsion configuration studies with minimal cost."

HIL Investigations Deliver Better Performance Results

Lamm is convinced that the potential of HIL investigations opens new possibilities for turbine engine controls, and could provide a means of tweaking the performance of the turbine engine, allowing aircraft to achieve higher altitudes, faster speeds, lower fuel consumption and lower heat rejection into recirculated fuel.

Customer-Oriented Vehicle Measurements

- Recording driver behaviors

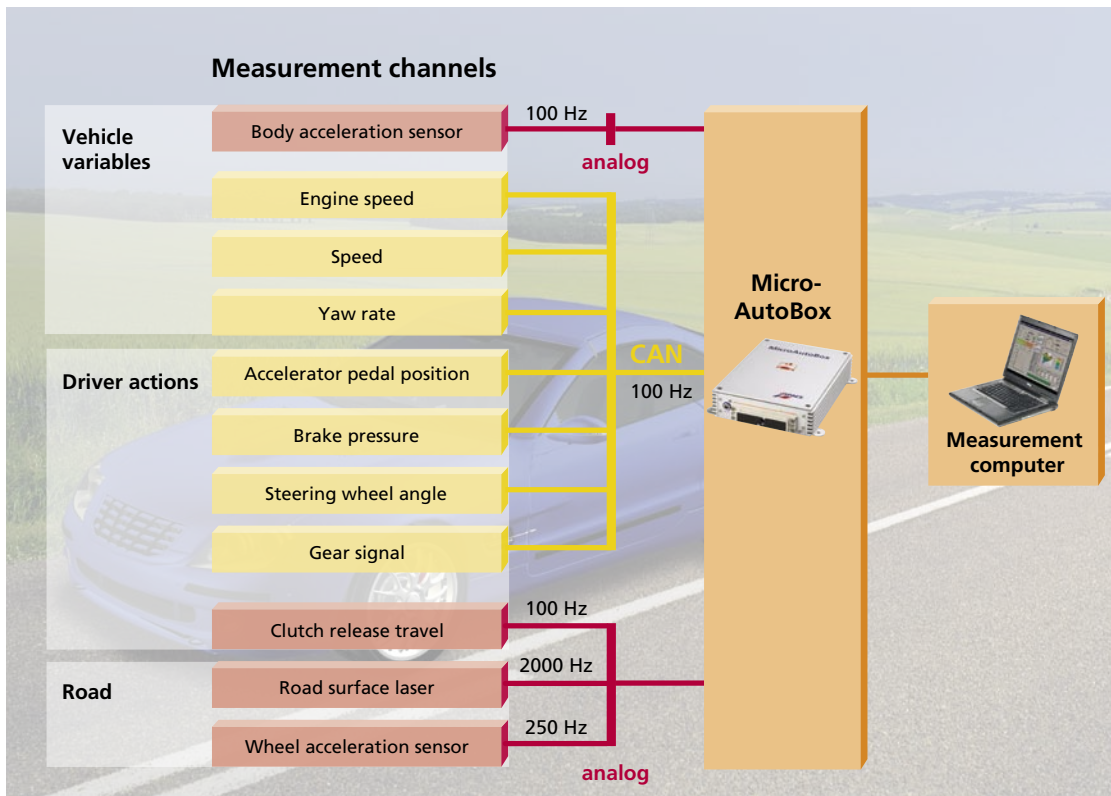- Statistical data processing for simulating load spectra

- Endurance-test-capable measurement system MicroAutoBox

▼ *The MicroAutoBox records the measurement channels at different sampling rates.*

More and more, life cycle tests on vehicles and vehicle components are being moved forward to the simulation phase, rather than performing later hardware tests. Reliable information is needed for designing component strength, and this includes a precise knowledge of customer behavior. To obtain this information, the Institut für Fahrzeugtechnik (Institute of Automotive Engineering, IAE) at the Technische Universität Braunschweig, Germany, is using dSPACE MicroAutoBox to capture driver actions and driving environment parameters. Statistics derived from this measurement data make it possible to simulate customer-imposed stress at an early development stage.

The stress that inflicts maximum damage on a component and therefore causes minimum durability, called the representative load spectrum, is a key factor in many optimization objectives in vehicles. For example, requirements optimization and efficient vehicle testing are very closely connected with the load spectra that are used. With this in mind, we at the IAE have developed a method that lets us identify the representa-tive load spectra by using a simulation environment. The advantage is that operating loads for the chassis, drivetrain, body, etc. are captured systematically. For the simulation, we draw on an extensive database of vehicle measurements, so we can include all the customer-relevant conditions that a vehicle is subject to, subdividing them systematically into driver, road and vehicle (what we call the DRV method).

Measurement channels

Vehicle variables		
Body acceleration sensor	100 Hz	analog
Engine speed		
Speed		
Yaw rate		

Driver actions		
Accelerator pedal position	CAN 100 Hz	
Brake pressure		
Steering wheel angle		
Gear signal		

Road		
Clutch release travel	100 Hz	
Road surface laser	2000 Hz	
Wheel acceleration sensor	250 Hz	analog

Micro-AutoBox

Measurement computer

Capturing Characteristic Driving Behavior

The dSPACE MicroAutoBox captures CAN variables such as the accelerator pedal position, steering wheel angle, gear, and brake pressure for various customer types, along with analog measured variables, such as the clutch release travel. At the same time, it records data on the state of the vehicle and the driving environment, so that driver actions can be correlated with particular vehicle and environment properties. As well as vehicle acceleration in three spatial directions,

velocity, and engine speed, the MicroAutoBox also captures, via laser measurement, the height of the road surface irregularities the vehicle drives over. Measuring both tracks provides data on the road surface, so that the stress on the chassis, body, and exhaust system can be assessed. The volume of collected data is manageable, as the individual measurement channels can be recorded at different sampling rates. Using Real-Time Interface from dSPACE, we created Simulink model subsystems for recording the driver's actions at 100 Hz, wheel carrier acceleration at 250 Hz, and road surface irregularities at 2000 Hz. The data was recorded via the experiment software ControlDesk.

▲ *The entire measurement equipment fits in the trunk of an SUV.*

Driver Statistics Used for Simulation

The obtained measurement values are the basis for simulating driver, vehicle, and road (DRV simulation). Individual driving maneuvers in the time histories are identified, and the significant parameters are collected in statistics. The simulation environment developed by the IAE reconstructs the driving maneuvers from these statistics and uses them to control a virtual vehicle.

> *"Natural driver behavior is only possible if the test persons are unaware of the measurement equipment in the vehicle. The compact size of the dSPACE MicroAutoBox 1401 makes it ideal for concealed installation, without compromising its performance and versatility."*
> **Hermann Kollmer, TU Braunschweig**

The primary criterion for reconstruction is the orientation speed profile (OSP). These driver statistics describe the vehicle speed at the end of an accelerating or braking maneuver as a function of current speed. They comprise data on the driver's desired speed, and also map the volume of traffic, traffic routing, speed limit, and other road characteristics. Combined with statistics on the accelerator pedal position, gear speed, and brake pressures, this allows customer use of a virtual vehicle to be simulated in simulation runs of any desired length. To determine the operating load spectra, the vehicle model contains detailed mapping of individual assemblies or components (such as the transmission, car body, chassis, or exhaust system) so that the forces occurring during vehicle operation can be calculated. The results of the simulation are operative load spectra for different customer types, which are weighted to obtain the representative load spectrum.

Reliable Information

Our project partners are very satisfied with the results that they obtain from the simulation, since these give vehicle manufacturers and automotive suppliers reliable information on vehicle stress by customers at an early stage of development. This has a very positive effect on project costing and scheduling.

In future projects, customer-oriented vehicle measurements will be extended to countries with bad road conditions. And we will again count on MicroAutoBox, the reliable and endurance-test-capable measurement system.

Hermann Kollmer
Andreas Janßen (research assistants)
Prof. Ferit Küçükay (Director)
Institute of Automotive Engineering
Technische Universität Braunschweig
Germany

Glossary

Representative load spectrum –
Causes the minimum permitted component life in customer vehicle use and is therefore the assessment criterion.

OSP –
Statistics for describing and reconstructing speed profiles.

DRV method –
Systematic approach for identifying driver, road (driving environment), and vehicle.

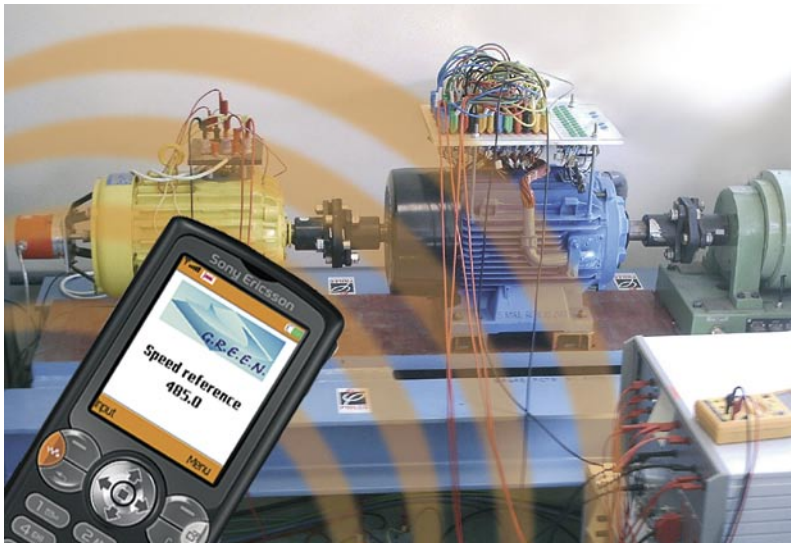# Wireless Vector Control of Induction Motor

- **Extending a DS1104 controller board with a Bluetooth module**

- **Implementing C code on the dSPACE hardware**

- **Developing control software for mobile devices**

The 'Groupe de Recherche en Electrotechnique et Electronique de Nancy (GREEN)', France, performs research in the field of electrical machines. Using an experimental setup based on a dSPACE DS1104 R&D Controller Board and a Bluetooth module, a wireless control of an induction motor is achieved. The project serves as an example of how control algorithms created with the C programming language can be implemented on the dSPACE hardware. The complete code is available online.

The implementation of control algorithms into digital signal processor (DSP) systems can be a challenging task for electrical and control engineers. While their daily business is in the area of applying control methods and modelling control systems, they are often not used to translating the models into

▲ *5.5 kW experimental bench with the double star induction motor controlled by a mobile device.*

code lines to be compiled for a digital signal processor (DSP). We from GREEN know that dSPACE successfully puts a lot of energy into fulfilling the requirement of easy implementation processes. dSPACE provides dedicated Simulink® blocks linked in Real-Time Interface (RTI) to the hardware of dSPACE's processor boards. Compiling the model and code generation is then transparent to the user.
While this satisfies most users, it may be insufficient for cutting-edge, highly demanding end-users.

Register Programming

For special demands, dSPACE provides the Real-Time Library (RTLib), a C runtime library that is a sublayer of RTI. This allows users to write the control code directly in C language and call the RTLib functions to access the DSP board hardware. This way, the user has the ability to fully control the run of his/her program that is executed on the floating point PowerPC. dSPACE also added a library feature to change the firmware that is factory flashed into the slave DSP (the fixed point

▲ *CommDSP: the Windows PC version of the remote control software ...*

◄ *... the Pocket PC version.*

TMS 320F240), resulting in a completely flexible and customized code. We performed some development there and chose to present a method of generating 6 fully independent Pulse Wide Modulation (PWM) controls for double-star induction motors, thanks to the "user function" feature.

Bluetooth Interface

RS232 Connection

DS1104 R&D Controller Board
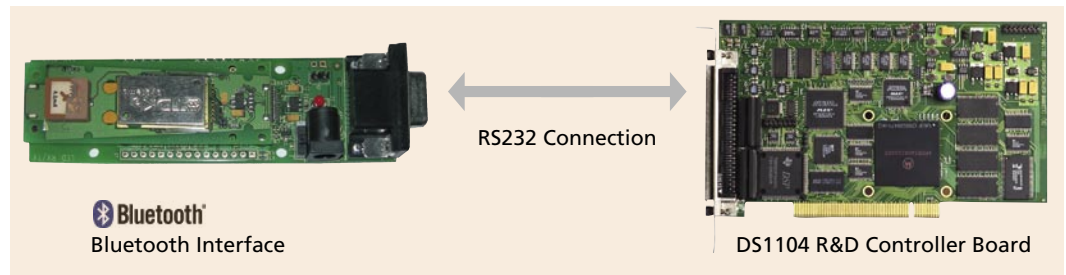
Getting Wireless

We also developed software that uses the Universal Asynchronous Receiver Transmitter (UART) serial port of the DS1104 to allow remote control of the program being run on the DSP board. In fact, the program listens to commands coming from the UART and interprets them as changes in the motor speed and position references. Simply by adding a Bluetooth® interface to the UART, we obtain wireless control.

Remote Control Software

For wireless remote control, one has to write the part of the software for the remote device. In our case this is a program called CommDSP. We developed a Windows® operating PC application, PDA (PocketPC)

> *"Due to the open interfaces we could easily extend the dSPACE hardware with a Bluetooth device to realize wireless control."*
> **Lotfi Baghli, Nancy Université**

application and Midlet application for Java enabled mobile phones. The PC and PDA CommDSP programs are written in C language. For mobile phones, the most common language is Java with a special SUN edition for resource limited systems called Java ME (Mobile Edition). The code developed uses the MIDP 2 profile which is the standard for mobile phones nowadays. In our case, we used the Eclipse 3.0 Integrated Development Environment (IDE), an Eclipse ME plug-in and the Sony Ericsson Software Development Kit (SDK) to generate the jar files of the Midlet. These tools are free and very powerful. CommDSP, running on the PDA or on the phone, establishes a Bluetooth connection to the device that is wired to the DSP UART. The information can be sent from the PDA or the phone to the control board. The 5.5 kW induction motor of our test bench is then at fingertip control with the mobile phone keys.

Full Wireless Control

Bluetooth is suitable for data exchange in such high electromagnetic disturbed environments because of its high carrier frequency and communication protocol and layers. Authentification and pairing of Bluetooth devices are welcomed security features. Our code implements a full vector control (IRFO) of an induction motor with IP/Fuzzy controllers. It permits current, speed and position control and flux weakening for high-speed operating. This code, which runs on the dSPACE PowerPC, listens to the remote device commands, and also to commands coming from the conventional dSPACE ControlDesk platform. The code developed for this profect is available on our web site:

http://www.baghli.com/dspace.php

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Groupe de Recherche en Electrotechnique et
Electronique de Nancy
GREEN - CNRS UMR 7037
Nancy Université, Vandœuvre-lès-Nancy, France

▲ *The Bluetooth module is connected via RS232 serial bus to the UART of the dSPACE DS1104 controller board.*
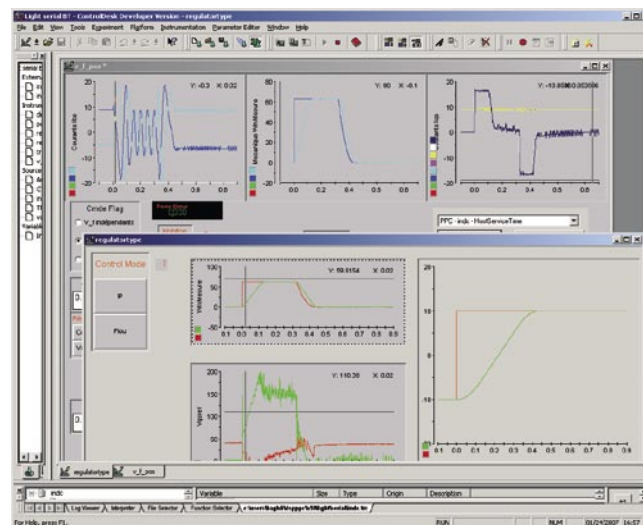
▲ *ControlDesk view of program variables showing a 20 rad position step of a 5.5 kW induction motor under vector control.*

The Electronic Eye

◢ **Hardware-in-the-loop simulation with integrated camera**

◢ **Automated visual instrument checks**

◢ **Reduced testing workload**

A new test system put into operation by dSPACE performs automatic visual checking of an instrument cluster. The system consists of a dSPACE Simulator Mid-Size, a camera, and a Cadillac STS 2006 instrument cluster. The hardware-in-the-loop (HIL) system plus camera makes it possible to perform comprehensive tests on vehicle electronics and replaces the error-prone checks made by human beings. This makes the system very suitable for real-time-tests on instrument clusters.

Hardware-in-the-loop (HIL) simulators from dSPACE have been used for testing dashboard instruments for ten years now, like at AUDI AG, for example.

▲ *The camera (right) "observes" the instrument cluster and passes the signals on to the HIL simulator.*

As in-vehicle functions grow in number, driver information systems grow in size. Integrated tests are therefore an increasingly necessary part of instrument testing. To give drivers comprehensive information, modern vehicles are equipped with highly sophisticated display instruments, infotainment systems and navigation systems. Not only important vehicle data such as driving speed, engine speed, fuel level and coolant temperature are displayed, but also maintenance periods, tire pressure, failed lamps, kilometers driven, inside and outside temperature, etc.

Greater Testing Workload

Display instruments are open control loops in which the vehicle data is output to the display, but no electronic feedback is available to report on the functions under test. Thus, until now function testing for indicator needles, messages, and signal lamps has had to rely on visual observation, known as man-in-the-loop testing. These tests have enormous disadvantages in terms of their reproducibility, their resolution regarding the times and positions of the changes observed, and the number of instruments that can be observed simultaneously. Moreover, the human eye soon tires and is easy to deceive. The solution to this challenge is to introduce automated visual tests as part of hardware-in-the-loop (HIL) simulation.

HIL with an Electronic Eye

In a test project, engineers from dSPACE connected a dSPACE HIL simulator with a high-resolution camera that "observes" a Cadillac STS 2006 instrument cluster. The displays were also reproduced via ControlDesk,

▲ *ControlDesk provides a photorealistic image of the instrument cluster.*

dSPACE's experiment software, so that changes could be recorded, displayed, and if necessary replayed. To create realistic test scenarios, various Automotive Simulation Models (ASMs) from dSPACE were used, for example, for the engine, transmission, driving behavior, driver, and environment. The simulation model for the tests was created in Simulink®. The dSPACE Real-Time Interface (RTI) provides the connection between the dSPACE hardware and Simulink. The HIL simulator emulates the sensor and ECU inputs for the displays.

Test Execution

AutomationDesk, dSPACE's test automation software, is used to create and run the tests. AutomationDesk simplifies the creation of test cases and makes it possible to automate test execution. While the HIL simulator simulates sensor signals according to the test scenarios, the camera's image capturing and image processing software evaluates the needle positions and other display elements by means of algorithms. Whenever changes occur, such as needles moving or signal lamps lighting up, the camera software converts the measured values into angular values and sends them to the HIL simulator via an RS232 interface. The simulator software translates this data into scalar variables, for example, vehicle speed and engine speed. Changes can take place very rapidly, so the observation and testing processes have to be in real time. This is particularly important for registering signal glitches that only show up as tiny needle movements or flickers in signal lamps, and which can occur at any time. ControlDesk's virtual instrument display indicates both the measured values and the reference values. Both values are stored in a list that AutomationDesk accesses to perform test evaluation. When the test has completed, the software produces a test report in either PDF or HTML format.

Speed vs. Resolution

Initial test runs show that HIL simulation with integrated image capturing and image processing is very well suited to testing instrument panels in real-time. However, there are restrictions with regard to the simultaneous requirements for speed and resolution. Tasks such as needle position capture and needle angle determination require a high resolution, while signal lamp observation requires a high frame rate. Users have to find their own trade-off between these two requirements, depending on what they want to observe.

Instrument cluster monitoring can also be applied to other information systems such as climate control displays and automatic parking systems.
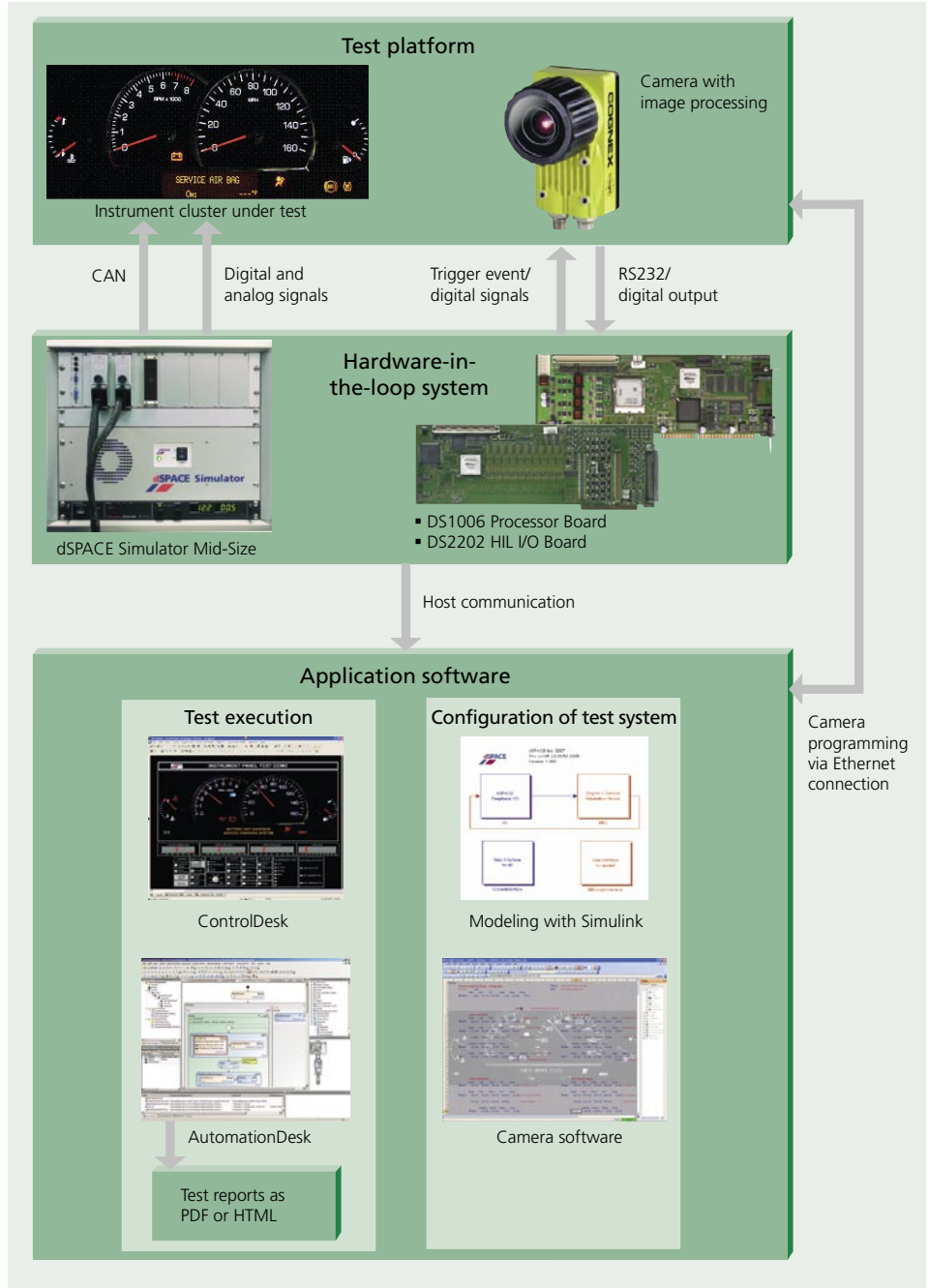
▲ *Schematic of the test set-up for automated instrument checks.*

CalDesk 2.0: Simply More Flexible

- ◤ **Easier and faster to use**

- ◤ **New interfaces – LIN bus and XCP on Ethernet**

- ◤ **Numerous new functionalities**

CalDesk 2.0, the new version of dSPACE's universal measurement, calibration and diagnostic tool, will soon have a new look. Its revised user interface has numerous convenience features to make your work easier and faster. The tool has many new functionalities and enhancements and can be used more flexibly in different ECU projects – for example, due to its new support of the LIN bus and XCP on Ethernet.

Simply Easier

CalDesk Version 2.0 has a reworked user interface based on the latest Windows technology.

There is a new instrument library, so you can create complex layouts by assigning instruments to your working environment via drag & drop. Variables from the variable list are assigned just as easily, via mouse or keyboard.

When you configure instruments yourself, you can put them in a library of custom variants, so you do not need to reconfigure them every time you use them. CalDesk 2.0 lets you edit layouts without having to switch to a special edit mode. To make your work even easier, the menu structure has been reworked and the shortcut keys are now displayed in menus and tooltips.

New control bars at the edge of the screen let you quickly display or hide tool windows like the instrument library or the variable list, so you have the whole screen area for the optimal display of instrument layouts.

The Variable Array: A New All-Round Instrument

The instrument set itself has also been extended. The new Variable Array instrument has various configuration options, and is practically an all-rounder. Input fields, bitfields, sliders, status LEDs and the new Push, On/Off and Check buttons can be combined flexibly in just one instrument. With further options such as an integrated value range check, the Variable Array provides a space-saving overview of all the relevant information at a glance.

Simply More Versatile

CalDesk is now being used as a universal measurement and calibration tool in widely varying scenarios in the modern ECU software development process. Version 2.0 provides a whole range of new options for this:
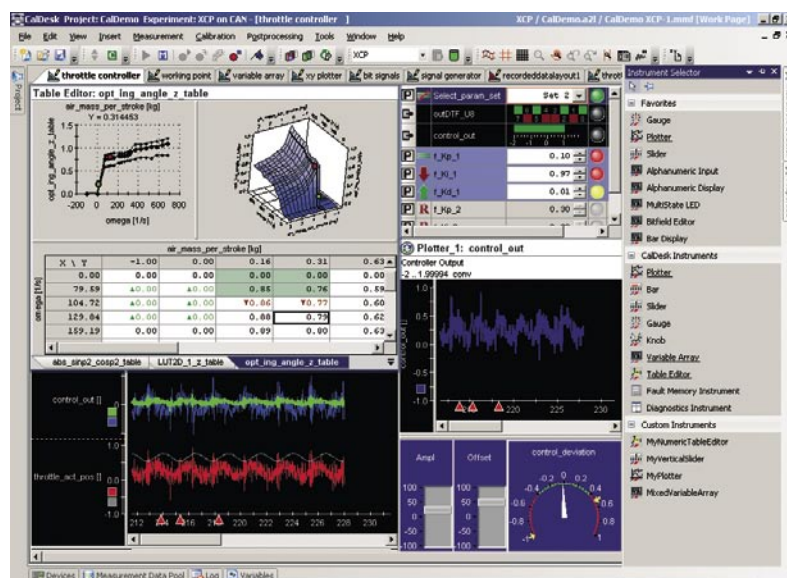
▲ The new user interface of CalDesk 2.0 is designed for higher efficiency, with new features such as an instrument library.
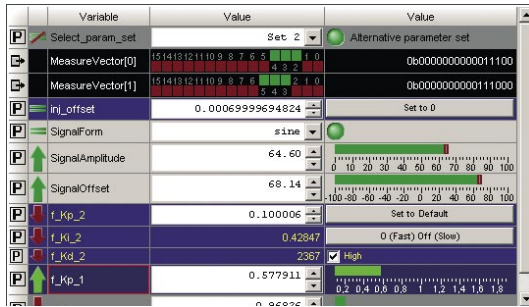
▲ *The new Variable Array opens up new options for instrumenting variables.*

Recording Signals on the LIN Bus
The Local Interconnect Network (LIN) bus has become a standard at many OEMs. CalDesk 2.0 supports you in measuring and recording its physical signals, which are described in an LDF file.

XCP-on-Ethernet Support
XCP-on-Ethernet interfaces are growing in importance, not least because of their high measurement bandwidth. CalDesk 2.0 supports protocol variants TCP/IP and UDP/IP for XCP on Ethernet.

Calibrating ECUs Without Dedicated Data Segments
CalDesk 2.0 lets you calibrate ECUs that do not have separate memory areas for calibration parameters. To do so, you can upload and download only those calibration variables which are connected to instruments in CalDesk. You also now have the option to change variables which are defined as measurement signals in the ECU description file from within CalDesk.

Instrumentation with Identifiers from ODX Files
With CalDesk 2.0, diagnostic data (identifiers) from ODX files can also be used on measurement and calibration instruments. You can then perform simple measurement and calibration tasks on ECUs via the diagnostics interface instead of the calibration interface.

Further New Functions
Test drives typically produce measurement files that are several hundred megabytes in size. Frequently, however, only specific time intervals or even just selected signals are relevant for evaluation purposes. In this situation, CalDesk 2.0 provides an option for saving the precise time intervals and signals displayed in the Plotter instrument to a new measurement file – with or without data reduction. Thus, these measurement files contain only the information you really want and are manageable in size.

There are further enhancements and new functionalities in just about all areas of CalDesk 2.0:

- Undo/Redo of parameter changes and displaying the change history
- Data recording via automation Interface
- Faster change of software versions
- Improved dataset manager
- Hex editor
- GMLAN support for ECU diagnostics

Numerous new features make work with CalDesk much easier and therefore much more efficient. CalDesk 2.0 continues dSPACE's strategy of providing one tool for a wide range of application scenarios in the modern ECU software development process.

Thus, XCP on FlexRay is already under development and will be available for the first customer projects in the course of this year.
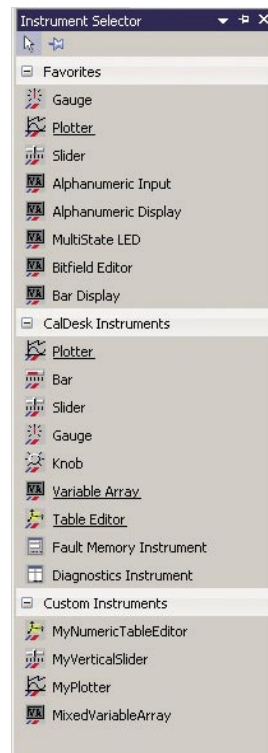
◀ *The new instrument library, shown here with custom instruments preconfigured by the user.*
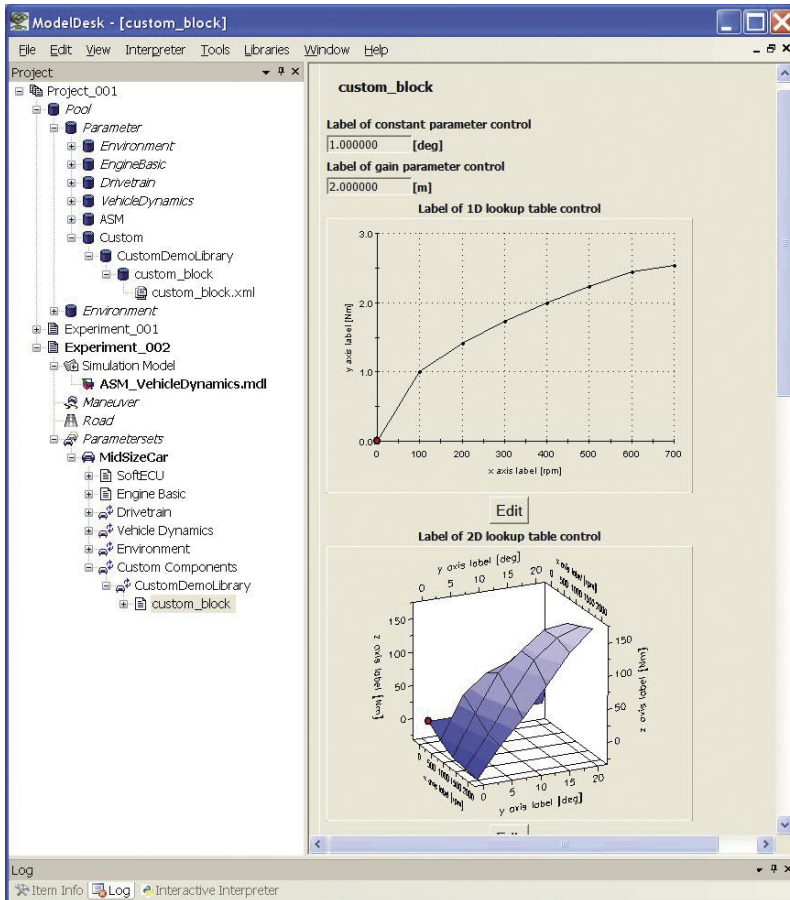
Parameter Control Center

- ◢ **Graphical parameterization of custom models**

- ◢ **Central parameter management**

- ◢ **Efficient parameter management**

▼ *A custom parameter page created by ModelDesk.*

What distinguishes the Automotive Simulation Models (ASMs) is their open design philosophy. Users can view the models right down to Simulink block level, and even modify them or add their own models to them. This open, flexible approach is now made even more convenient and efficient with Version 2.0 of ModelDesk, the parameterization software. ModelDesk now detects models that were modified or added by the user and offers graphical parameterization functions for them.

Custom Library User Interfaces

So that ModelDesk can handle custom models, modeling has to comply with a few easy-to-follow ASM design rules. The main one is that if a variable needs to be parameterized in ModelDesk, it must be contained in a masked Simulink subsystem and parameterized via a mask parameter. The masked subsystems are stored in a Simulink library. Intuitive names can be assigned to the

▲ *Declaring parameters as masked variables with names, units, and initial values.*

parameters, along with the units to be displayed by the user interface. ModelDesk supports scalar, vectorial, and table-based parameters.

The new Simulink library can be registered in ModelDesk. If a model loaded to ModelDesk contains components from the registered library, the parameters from the library are displayed on screen. There is a separate parameter page for the parameters of each subsystem.

Central Parameter Management

When an experiment containing custom models is loaded, ModelDesk displays them in the same way as standard ASM parameters. Users can simply select the model components from the Model Navigator and parameterize them graphically on the automatically generated parameter pages. Now that support for user-specific models has been added to ModelDesk, it can be used to manage all experiment data and all parameter sets.

TargetLink Reloaded

The new version of our production code generator TargetLink that comes with Release 6.1 emphasizes code efficiency and AUTOSAR support. The code that it generates is now more efficient than ever, particularly where vector signals are involved. The new version also supports AUTOSAR standard 2.1 and the current The MathWorks Release 2007b.

⬦ **Efficient code for vector signals**

⬦ **Up-to-the-minute AUTOSAR support**

⬦ **Flexible selection of MATLAB version**

AUT⦿SAR

Enhanced Code Efficiency

TargetLink 2.3 is particularly geared to maximizing code efficiency in production applications. Even though efficiency was already very high, it has been made even better by the following optimizations:

⬦ As an option, code for blocks with vector signals can be generated as loops instead of single statements, which considerably reduces ROM consumption. TargetLink identifies vector sections that have the same characteristics and creates loops for them if a specified threshold is exceeded.

⬦ To avoid unnecessary intermediate variables at the borders to atomic subsystems, code optimization now appropriate analysis functions.

⬦ The procedure for analyzing whether to calculate individual blocks in every time step has been refined. This saves execution time, as more blocks can be moved to conditionally executed branches.
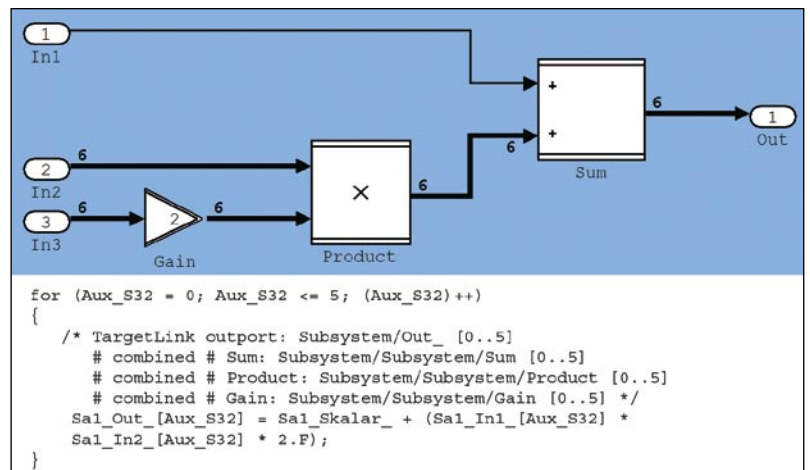
Support for AUTOSAR Standard 2.1

In response to the growing importance of AUTOSAR, TargetLink 2.3 includes the following new features:

⬦ Support for AUTOSAR 2.1 in addition to Version 2.0 SP3, particularly addressing calibration and measurement

⬦ Mode switch events for switching ECU modes during the execution of AUTOSAR runnables

⬦ Code efficiency of implicit sender-receiver communication enhanced by optimizing out superfluous stack variables

Choice of Four MATLAB® Versions

One of TargetLink's useful features is that a single version supports several MATLAB versions. This greatly benefits you as a user, as you can:

⬦ Use the same TargetLink version for different MATLAB versions – in different projects, for example.

⬦ Upgrade MATLAB without having to install a new TargetLink version.

⬦ Upgrade TargetLink without having to install a new MATLAB version.

⬦ TargetLink 2.3 supports the last four releases: R2006a+, R2006b, R2007a+ and R2007b.

Further enhancements include options for generating table code without a map structure and automatic adjustment of the references to a dSPACE Data Dictionary object when it is renamed or moved. Target simulation support for the Infineon XC2000 processor in conjunction with the TASKING compiler round off the new version.


```
for (Aux_S32 = 0; Aux_S32 <= 5; (Aux_S32)++)
{
    /* TargetLink outport: Subsystem/Out_ [0..5]
     # combined # Sum: Subsystem/Subsystem/Sum [0..5]
     # combined # Product: Subsystem/Subsystem/Product [0..5]
     # combined # Gain: Subsystem/Subsystem/Gain [0..5] */
    Sa1_Out_[Aux_S32] = Sa1_Skalar_ + (Sa1_In1_[Aux_S32] *
        Sa1_In2_[Aux_S32] * 2.F);
}
```

▲ *TargetLink 2.3 can roll the code generated for blocks with vector signals into loops.*

Bypassing: XCP on Ethernet (UDP/IP)

dSPACE will soon add XCP on Ethernet (UDP/IP) to its portfolio of bypass interfaces for ECU function development. This new high-speed communication interface between dSPACE prototyping hardware and a real ECU is made possible by an extended Real-Time Interface (RTI) Bypass
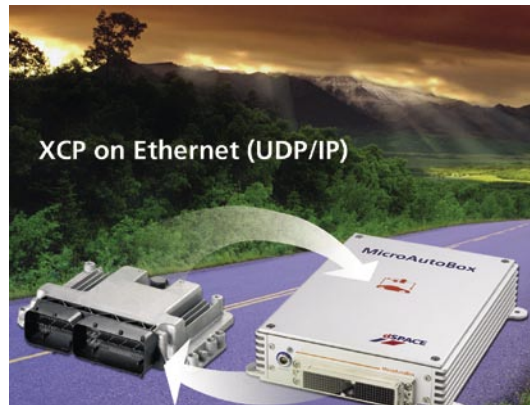
Blockset and a special connection cable with integrated LVDS-to-Ethernet converter. Nowadays ECUs are increasingly equipped with an XCP on Ethernet interface, and the dSPACE bypass solution can be used on such ECUs without any modifications. The new LVDS-to-Ethernet connection cable allows existing prototyping hardware with LVDS interface to be reused. In addition, Ethernet is also supported by the dSPACE XCP Service. (Release date: *www.dspace.com/goto?release*)

RTI: Model Referencing

The dSPACE Real-Time Interface (RTI) will soon support model referencing (The MathWorks feature) in single-processor models. If you have models in separate files, you can integrate them into other models via model referencing and generate code for them incrementally. With support for model referencing, the Real-Time Interface (RTI) for the automatic implementation of MATLAB®/Simulink®/Stateflow® models on dSPACE hardware now makes development processes even more flexible and modular. (Release date: *www.dspace.com/goto?release*. For details on the extent of support provided, please inquire at dSPACE).

Summer Camp at Technische Universität Braunschweig

At a summer camp held at the Technische Universität Braunschweig, Germany, last September, students were set the task of developing a comfort system for passenger vehicles. 16 students from the fields of electrical engineering, computer sciences and mechanical engineering took part, along with representatives from various companies that were supporting the project. Petra Nawratil, dSPACE, reported on products and trends and gave students a glimpse of her work as a product engineer. dSPACE is very committed to projects of this kind, which aim to stimulate young students' interest, and sponsors and advises students providing them with individual career perspectives.

User Conference 2007 – India

On September 21, 2007 over 150 participants came to the dSPACE User Conference in Bangalore, India. At the Hotel Le Meridien they participated in detailed lectures by dSPACE customers. General Motors and Visteon gave insights into their current automotive development projects in India. Further lectures showed how dSPACE tools are being used in the fields of aerospace and mechatronics.
dSPACE extends its thanks to all participants and lecturers for their interest and enthusiasm. A special thank-you goes to our Indian distributor Cranes Software International Ltd. for excellently hosting this event.

Events

dSPACE participates in trade fairs and conferences throughout the world. Come to one and get to know us and our solutions. We're looking forward to meeting you!

For the dates, visit *www.dspace.com*

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- Hardware development
- Applications
- Technical sales
- Product management

Current offers at *www.dspace.com/goto?jobs*

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- ControlDesk
- RapidPro
- Rapid Control Prototyping with CalDesk
- TargetLink
- dSPACE Simulator MidSize
- AutomationDesk
- Real-Time Testing
- RTI CAN MultiMessage Blockset
- Hardware-in-the-Loop Simulation
- ASM Vehicle Dynamics Simulation
- ASM Engine
- CalDesk

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Papers

"Trends and Perspectives in Automated ECU Testing"
Dr. Klaus Lamberg, dSPACE GmbH

"Parameterizing User-Defined Models Graphically"
Holger Krumm, dSPACE GmbH

"Building Bridges – Standardized Data Interchange in the ECU Development Process"
Joachim Stroop, dSPACE GmbH

More publications are available at *www.dspace.com/goto?info_downloads*

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