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dSPACE MAGAZINE

1/2012

Siemens – Steam Turbines in Simulation

Valtra – Virtual Field Test for Tractors

Astrium – Communication via Satellite

We've been seeing the same situation for over ten years: One of the biggest growth problems for many tech companies is getting enough qualified young engineers. This is certainly the case wherever there is a large proportion of research and development, especially in the automotive industry with its entire ecosystem of suppliers and service providers.

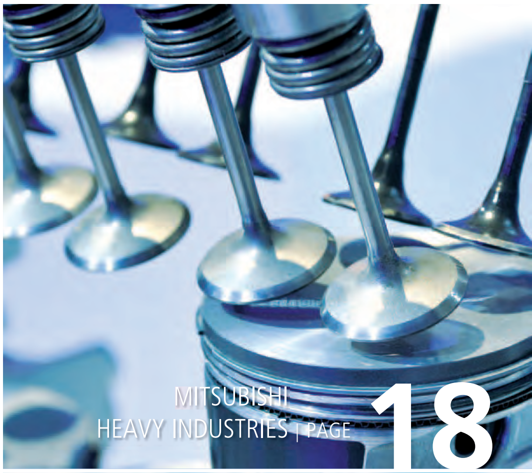
I've mentioned here before that dSPACE has a very high percentage of its employees involved in development. It has always been our strategy to invest strongly in enhancing, renewing and extending our product portfolio. And with few exceptions, we do this on our own initiative without waiting for development contracts. This also enables us to look further ahead than would otherwise be possible. It's an approach with a higher price tag, so you won't tend to find us in the cheap sector. But our customers profit because we don't stagnate, and they appreciate the progress made.

It's a strategy that works. But it needs a supply of skilled professionals: existing products have to be maintained, and new ones are constantly being added. In 2012, we aim to recruit over 100 new engineers, mainly in Germany, but also in the USA, Japan and elsewhere. We're not the only ones, unfortunately. The media is full of headlines like "Porsche to take on 300 engineers in 2012", "Continental looking for 1500 software developers", or in the USA, "General Electric in Michigan adds another 300 to the 850 new engineers already hired". We are certainly successful at recruitment, but it takes a lot of effort – after all, everybody's looking for similarly qualified people from a supply that is much too small.

Amazingly, you will still hear it said, now and then, that there's no lack of engineers. This pronouncement either comes from an ivory tower somewhere or it relates to industries that are having a bad time. The reality is that the competition for talent is in full swing. We score highly with our excellent working atmosphere and with interesting tasks where people learn and grow. And when they have, they sometimes find career doors opening that would otherwise have remained closed. Of course we shed a small tear whenever a dSPACE employee, turbocharged with knowledge and skill, is offered a much-coveted position with one of our best customers. But it also makes us just a little bit proud.

Dr. Herbert Hanselmann
President

Embedded Success dSPACE



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Simulating steam turbines for power generation

1000 MW in the Test Lab

Figure 1: A steam turboset.

Figure 2: Rotor blades of a steam turbine.

Modern digital control systems for power generation steam turbines have very complex control functions. Testing turbine control functionality during commissioning is time-consuming and expensive, so the obvious solution is to use a simulator in the test lab at an early stage of the project. This also has the advantage that critical cases can be tested with no risk to the plant, and any faults can be detected by standardized tests and remedied at an early stage – important factors for ensuring high quality standards.

Modern Steam Turbines for Maximum Efficiency

More than two thirds of Germany's electrical power is produced by steam turbine generators. The situation is similar all over the world, and forecasts indicate that steam turbines will continue to play a significant role in power generation in the future. Reliability and efficiency are essential for maximum economy and minimum environmental impact. With over 40 years of experience, Siemens builds steam turbines ranging from a few MW to 1,900 MW electrical power. Today, with steam turbine temperatures of up to 600 °C and pressures of approx. 275 bar, power generation efficiencies of over 48% can be achieved. The fuel can be utilized even more efficiently with heat extraction. And when a steam turbine is combined with a gas turbine, efficiencies of over 60% can even be reached – a value that was thought to be impossible only a few years ago.

Turbine Control for Increasing Requirements

Reliable operation depends on a modern turbine control system that is engineered for each plant. The complexity of functions has steadily increased: software function plans of over 500 pages are not unusual.

Figure 3: Large steam turbine power plants are automated with the T3000® turbine control system from Siemens AG.

In Germany, ambitious goals for transitioning to renewable energy impose tough requirements on the power plants operating in the electrical grid. The increasing amount of fluctuating energy fed in from regenerative sources rarely matches consumer demand. And because there is a shortage of suitable electrical power storage, power plants have to be able to adjust their output to demand quickly. This requires control technology that can reconcile these requirements with the process constraints of steam turbines. The only way to cope with the complexity and high quality requirements is to use suitable simulators during development and to design the control technology to fit each specific power plant. If the control system has been optimized in the test lab, it can be commissioned more quickly, cutting costs and avoiding life-shortening tests with the actual turbine. Moreover, no power plant operator would ever risk trying out untested control functions on a turbine.

Simulating a Steam Turboset

Testing the control system requires not only a model of the steam turbine, but also models of the generator and the electrical grid, so that all the functions can be tested realistically. A typical steam turbine consists of a high-pressure (HP) section, an intermediate-pressure (IP) section and a low-pressure (LP) section, which together drive a common shaft. The steam produced in the boiler (steam generator) first flows through the main steam valves into the HP section. Then it is superheated again before being fed through the intercept valves to the IP and LP sections. The steam cools in the condenser and the water is fed back to the steam generator via the feed water pump. The generator converts the shaft's mechanical energy into electrical energy and feeds it into the electrical grid via a transformer. The simulation model must therefore contain all these components, plus a simplified model of the electrical grid. This is essential in order to simulate normal operation, from starting up the turbine to its rated speed, to synchronizing the generator with the electrical grid, to loading the turbine to rated power. If other power plants drop out, the steam turbine's performance has to be increased rapidly and automatically

> "The dSPACE Simulator together with the MATLAB/Simulink models fulfills all our requirements. We can easily switch between different turbine types and load a plant-specific parameterization. Now, in the test lab, we can detect and solve problems that would otherwise not have shown up until commissioning."

Michael Schütz, Siemens AG

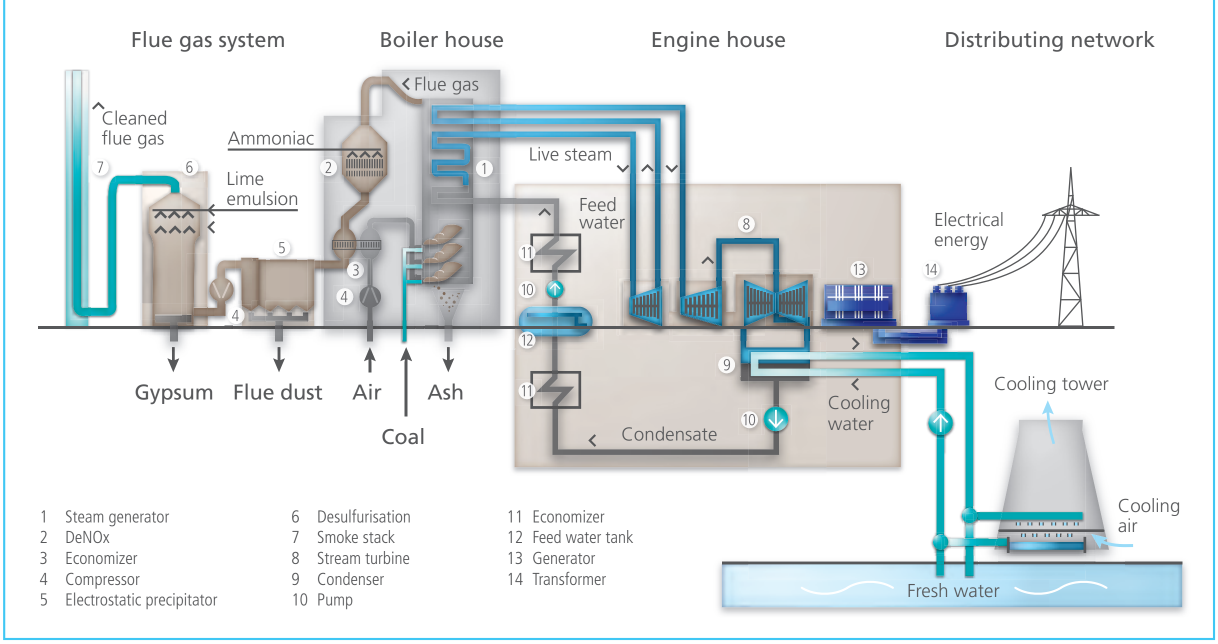


Figure 4: Overview of a modern steam power plant.

to support the grid. If an unexpected malfunction separates the power plant from the grid, load rejection has to be performed without tripping the turbine.

Requirements for the Real-Time Simulator

Siemens engineers drew up specifications for the real-time simulator that would simulate the steam turbine.

- Validated, modularized models of all Siemens steam turbine types
- Simple, plant-specific parameterization
- Real-time capability with a step size of 1 ms for fast transients
- Signal conditioning for direct connection without adjustment to the control system
- Flexible adaptation options
- Convenient human-machine interface for sequence control and documentation
- Interface to MATLAB®/Simulink® for exchanging models and the results of simulation or measurement

The dSPACE Simulator

Siemens chose a flexible dSPACE system. With the DS1005 PPC Board, it is no problem to compute the model of the steam turboset with

Figure 5: To test the digital control system, the simulator and the control system exchange signals such as the speed, power, main steam pressure, and actuation and position feedback for each valve.

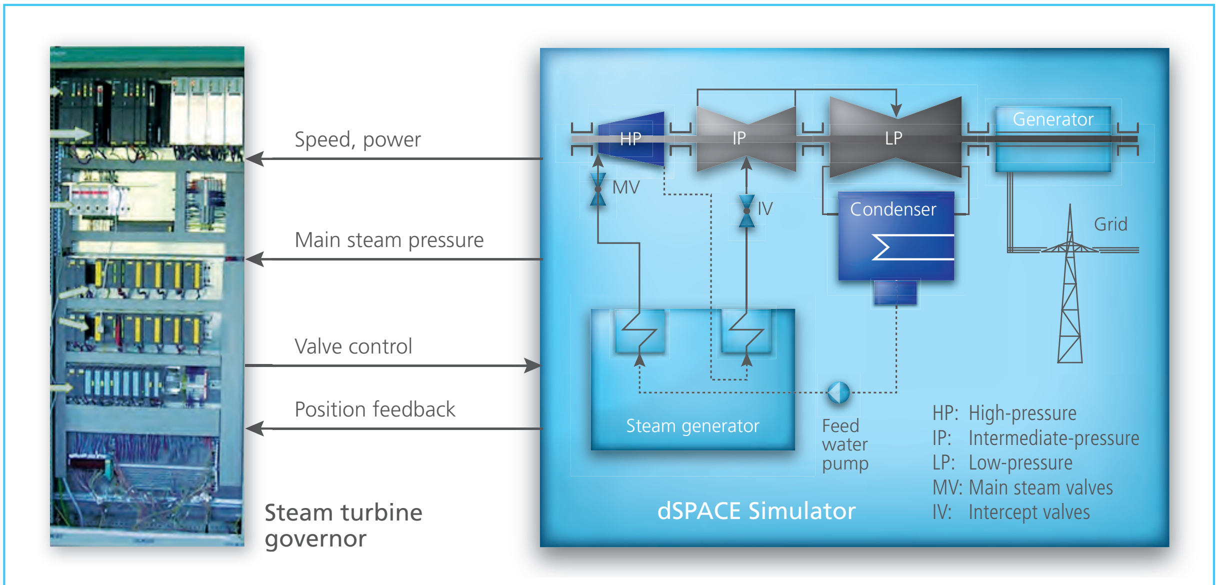


Figure 6: Test lab assembly with simulator in the laboratory.

over 50 state variables at the required step size of 1 ms. Two I/O boards for input and two for output, each with 32 analog channels, provide the numerous analog input and output signals necessary for connection to the turbine control system. Three I/O boards with digital channels supply the turbine's binary signals and rotary impulses. All the boards are installed in a dSPACE expansion box. Buffer amplifiers provide potential separation and adjustment of the analog signals. The digital signals also have electrical isolation and protection.

Working with the widely used MATLAB/Simulink software simplifies cooperation with other Siemens departments that are involved in the complex issue of steam turbine control. It also makes it easy to validate the models and parameters by means of measurements made on an operating plant.

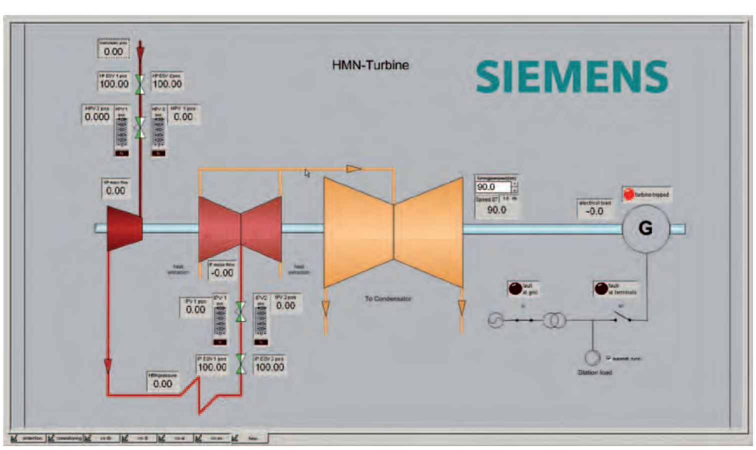
Human-Machine Interface

The simulator was given a dedicated graphical human-machine interface for each plant type, with a bilingual display to meet the requirements of the international power plant market. Turbine ramp-up to nominal speed, generator synchronization with the grid, and load operation are simulated with the aid of switches and inputs on the connected control system. Numerous other features provide comprehensive testing options, both in normal operation and in failure. All signals can be recorded and analyzed.

Passing the Test

A typical test begins by starting up the steam turbine to its rated speed, which is usually 3,000 rpm, corresponding to 50 Hz. When the volt-

Figure 7: All the relevant variables can be monitored with the human-machine interface of a simulator that simulates a turbine with HP, IP and LP sections and valves.



Martin Bennauer
Martin Bennauer coordinates the development of the simulator and is responsible for the steam turbine controller at Siemens AG in Mülheim an der Ruhr, Germany.

Achim Degenhardt
Achim Degenhardt coordinates the development of the simulator at Siemens AG in Erlangen, Germany.

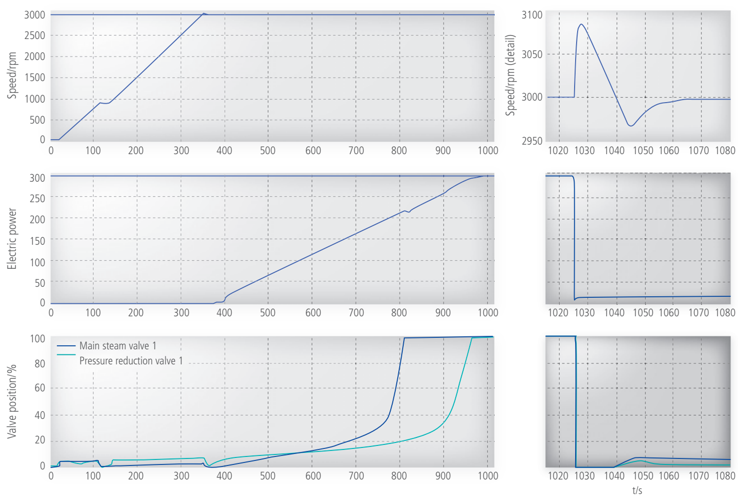


Figure 8: Only slight valve openings are needed to drive the turbine up to its rated speed. The intercept valves are initially closed and open after the main steam valves. After synchronization to the electrical grid, the turbine is loaded to full power (left). When the power plant is disconnected from the electrical grid, the electrical power drops sharply to the low house load (right). Because the valves close quickly, the speed rises to the uncritical value of approx. 103 % before it reaches a steady state with good damping.

age, speed and phase position are correct, the generator can be connected to the electrical grid and the turbine can be loaded to full power. If the steam turboset is disconnected from the electrical grid due to a grid fault while running at full power, the pressure must be reduced to the power plant's house load. The main steam and intercept valves have to be closed fast to avoid impermissible overspeed. At first the quantity of steam within the turbines increases the speed. At the same time the house load of the power plant has to be provided. This depends on keeping the speed within the permitted range. If the valves closed too late, causing impermissible overspeed, protection systems would activate to prevent any threat to the turboset. However, the plant would then shut down and would no longer be able to supply its house load.

Martin Bennauer
Achim Degenhardt
Dr. Rüdiger Kutzner
Patrick Müller
Christoph Schindler
Michael Schütz
Dr. Andree Wenzel

Conclusion

The simulator is also ideal for customer acceptance tests and for training. The complex functions of the digital control system can be optimized and demonstrated even before commissioning. When a plant is modernized, the simulator is flexible enough for quick adjustment, and it helps develop and optimize control functions.
As the next step, the model will be extended by including further control loops. Engineers will also investigate whether testing can be further optimized by test automation.

Dr. Rüdiger Kutzner
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Patrick Müller
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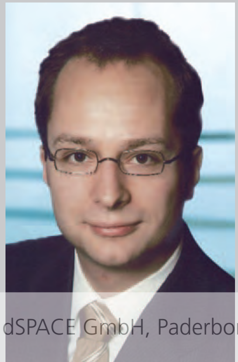
Dr. Andree Wenzel
Dr. Andree Wenzel was team leader for the real-time simulation of steam turbines and generators at Siemens AG in Erlangen. Since February 1, he has been Professor of Power Engineering at the University of Applied Sciences and Arts, Hannover, Germany.





Rapid prototyping meets challenging schedule

Next Generation Satellite Communications

The Air Patrol satellite communication terminal from Astrium Ltd positions antennas with pin-point accuracy at any flight attitude.

Airborne satellite communication systems require the greatest possible antenna positioning accuracy to prevent data loss and data leakage. This is no small challenge in unmanned airborne vehicles, which are constantly in motion and impose rigid constraints in terms of mass, power and volume. Astrium solved this problem with rapid control prototyping tools and support from dSPACE.

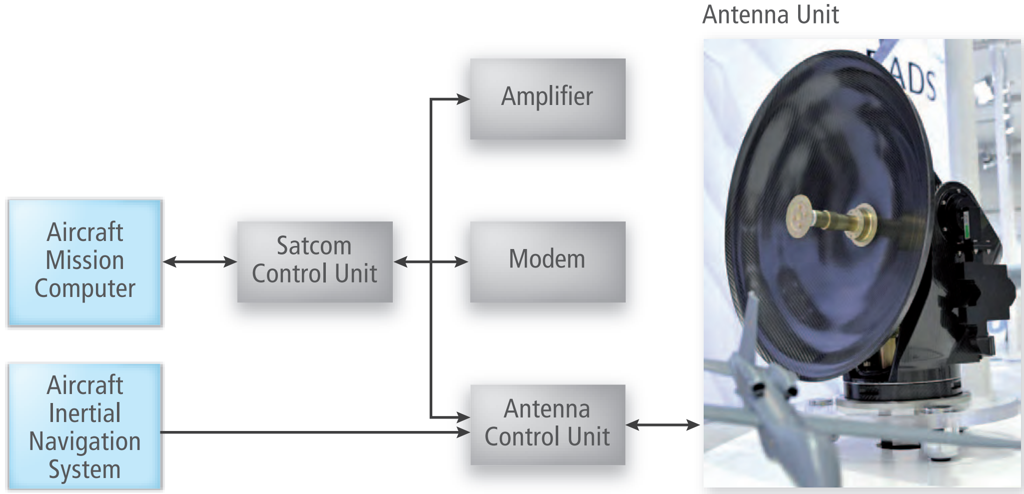


Figure 1: Components of the Air Patrol terminal for precise antenna pointing.

Antenna Control Unit

Building on a heritage of high-quality naval and airborne satellite communication terminals targeted for the defense industry, Astrium Ltd recently launched the first in its Air Patrol series. Covering a range of frequency bands from X to Ka, Air Patrol offers affordable, lightweight, robust and highly efficient satellite communications to a rapidly evolving unmanned airborne vehicle (UAV) market.
Astrium Ltd is responsible for the complete development life cycle of the antenna unit and the corresponding electronics line replaceable units (LRUs). Together, the LRUs and antenna unit perform the following tasks:

- Transmission and reception of radio frequency (RF) signals
- Up conversion and down conversion of frequencies
- Modulation and demodulation of data onto waveforms
- Control output and system monitoring (C&M)
- Antenna stabilization (to compensate for aircraft motion) and corrective motion (to point the antenna at the target satellite)

dSPACE has been key to the timely development of the Antenna Control Unit (ACU), which performs antenna pointing and stabilization.

Challenging Customer Requirements

UAV applications have to meet tough demands, such as harsh environmental conditions and constraints on mass and volume. Flight trials are expensive (due to factors such as airframe adaptation, installation, fuel, insurance and time), thus necessitating the use of numerical simulation as well as hardware-in the-loop (HIL) tests. Many of the target UAV platforms are still under development, prompting a development methodology which eases the successive iteration of hardware interfaces. Demonstration of capability is important to potential customers. With rapid control prototyping, Astrium can present real hardware rather than mere paper designs.

Pointing Accuracy to a Few Tenths of a Degree

RF transmissions typically follow a sin(x)/x profile, where power peaks at the center of the beam and gradually reduces moving away from the center. The challenge for the ACU is to ensure that peak power is precisely directed towards a receiving antenna on a satellite in geostationary orbit 36,000 km away from the aircraft. To achieve this, typical pointing accuracies of a few tenths of a degree have to be maintained in the presence of aircraft motion. Aircraft motion is sensed by an inertial navigation system (INS), a standard piece of avionics equipment for aircraft navigation, linked to the aircraft flight control computer through the Air Vehicle Bus (AVB). The ACU has a feed from the AVB, providing the antenna control algorithms with a measure of aircraft motion. The control algorithms induce corrective motion on the antenna to maintain accurate satellite pointing. Antenna motion is actuated by brushless DC motors on the azimuth and elevation

> "dSPACE equipment and technical assistance enabled us to increase customer confidence early in the project."
>
> *Ed Hagger, Secure Satcom Systems*

antenna axes. Antenna position is sensed by absolute encoders on the same axes as the motors. This is fed back to the control algorithms on the ACU. A number of practical difficulties had to be overcome in the development of the ACU, such as noise, bias, quantization, transport delay, measurement bandwidth, actuation lag, saturation, friction, sampling effects, alignment errors, electromagnetic compatibility (EMC) and so on.

Hardware-in-the-Loop Tests

Rapid prototyping and HIL testing allowed an early evaluation of the non-linear effects described above, prompting corrective action where required. The HIL environment provided a means to evaluate the performance of individual pieces of equipment for their suitability in the Air Patrol application. It also provided a way to perform antenna system tests injecting test stimuli. This allowed a direct measurement of the frequency response of the real system, which in turn was used to validate linear models. HIL tests enabled the injection of real or simulated flight data from an aircraft INS, thus providing a simulation of the antenna's pointing performance on a real flight. Setting up the HIL test environment forced an early configuration of the equipment software drivers, which has benefited latter stages of the project. Equipment communication issues were also resolved early in the project. Thanks to the rapid control prototyping methodology, it was possible to test the algorithms for antenna pointing at an early stage, using movable platforms such as 'rocking beds' and land vehicles. These also enabled antenna motion demonstrations for air shows and exhibitions. The process increased our confidence in the system design and, more importantly, increased the customer's confidence. A tangible shift in design reviews was perceived, from "can you build it" to more detailed questions which help to drive the product forwards.

Wide Range of dSPACE Products for ACU Development

dSPACE provided a seamless link from algorithm prototyping in Simulink® to deployment on real-time dSPACE hardware. The relative ease of accessing I/O on the dSPACE hardware enabled effort to be focused

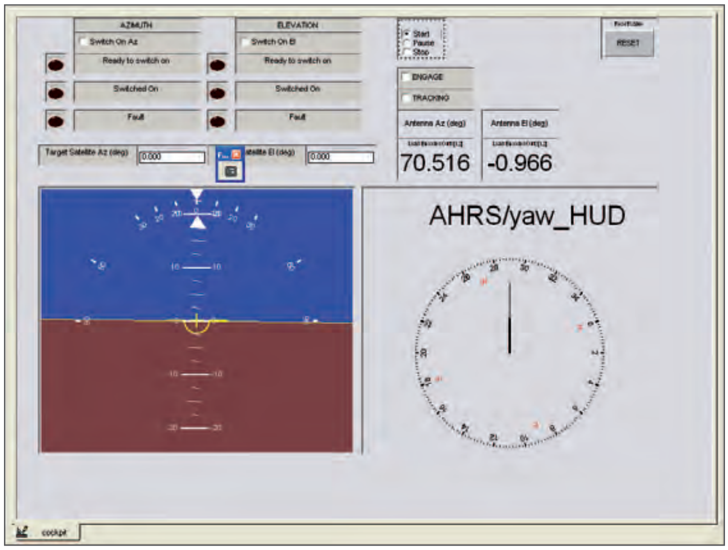


Figure 2: The hardware was controlled and monitored via ControlDesk, dSPACE's experiment software.

on the core antenna pointing algorithms. Various pieces of dSPACE hardware were applied on Air Patrol. During the early phases, the DS1103 proved to be an excellent work horse, with a wide range of I/O that suited our needs and initial limited budget. Several low-cost variants of the MicroAutoBox were deployed for marketing and functional test purposes. The DS1005 was used as the basis of a modular simulator, currently incorporating CAN, RS422, A2D and D2A boards. This solution is expandable to meet our future needs (such as Ethernet or 1553 I/O).

All dSPACE hardware is controlled and monitored via the experiment software dSPACE ControlDesk®. Astrium benefits from the ease of accessing all intermediate variables and parameters in the Simulink model as well as the real-time graphical plotting functionality.

The next step is to target production hardware, which has been developed in parallel with the antenna pointing algorithms. Without the use of rapid prototyping target hardware (such as the hardware offered by dSPACE), it would have been necessary to wait for the completion of production hardware development before being able to test the algorithms in a real environment.

To avoid the need for a detailed specification and handcoding of the algorithms, code is autogenerated using TargetLink. This offers a consistent environment for algorithm development, testing and deployment to production hardware. It has completely eliminated algorithmic errors due to misinterpretation of requirements by giving the algorithm developer ownership of the source Simulink model, which also forms the source of the autogenerated code.

The autocode generation process does not eliminate the need for input from software engineers. Some collaboration is needed between the systems and software teams to agree and define the interfaces with the autogenerated code. Furthermore, I/O drivers and the scheduler are best handcoded or taken from the target hardware board support package.

Why We Chose dSPACE

dSPACE tools have proved invaluable in the rapid prototyping of the Air Patrol ACU. It is difficult to imagine a quicker route to prototyping a real-time embedded con-

Ed Hagger
Ed Hagger is a control systems specialist at Secure Satcom Systems, a division of Astrium Ltd. in Portsmouth, Great Britain.

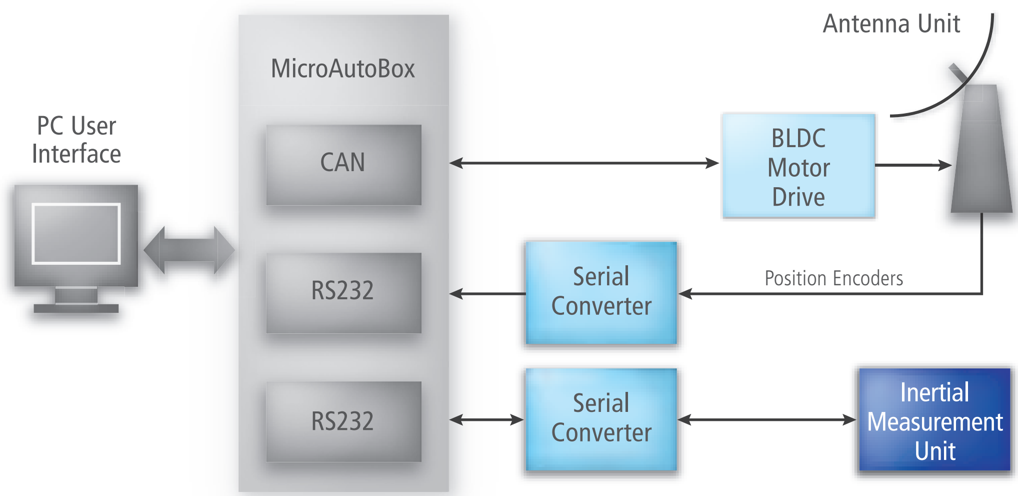


Figure 3: Typical configuration of dSPACE hardware for testing.

trol application. It has promoted an early understanding of the interface issues and performance capabilities of the antenna system hardware elements. TargetLink completes the software development cycle, allowing production-standard software deployment to production hardware. The verification of the generated code is assisted by in-built features such as model-in-the-loop simulation, software-in-the loop simulation and a profiler tool, which tracks the timing of tasks and events during run time. When required, dSPACE engineers have proven extremely knowledgeable and keen to assist in the successful delivery of the Air Patrol product.

Next Steps

Given the ease of adaptation to different applications, our existing dSPACE hardware will continue to provide useful prototyping and test equipment for years to come. Assisted by dSPACE engineers, we are continuing to develop our understanding of TargetLink capabilities as our autocode requirements evolve with project needs. A crucial step will be proving compliance to the DO178B standard. We are confident that TargetLink will accommodate our future requirements. ■

Ed Hagger
Astrium, Secure Satcom Systems

Summary

For smooth radio communications between UAVs, satellites and ground stations, reliable antenna pointing is essential, and it must remain within a tolerance of a few tenths of a degree regardless of aircraft motion. Flight motion is captured by means of an inertial navigation system (INS) and used to compute the commands to the motors that position the antennas. Various disturbance factors have to be taken into account: noise, alignment errors, actuation lag, EMC, sampling effects, etc. In the laboratory, either real or simulated flight data was fed in to simulate the continuous antenna pointing process that occurs in real flight. All the components involved were tested and evaluated with the aid of the dSPACE hardware and software. Finally, the production code for the antenna ECU was generated by means of TargetLink, the production code generator from dSPACE. The dSPACE tools enabled early, realistic evaluation with tangible hardware and contributed decisively to the punctual completion of the system.

Mitsubishi Heavy Industries is researching further optimization of combustion engines with a variable valve test system and engine valve control (EVC) system employing high-speed hydraulic actuators. The EVC system permits any desired valve lift pattern, ensuring highly flexible operation and high engine speeds. A DS1006-based dSPACE multiprocessor real-time system is being used as the experimental control unit.

Variable Valve Control

Variable valve systems are already in use in many mass-production engines. To improve engine efficiency even further, research is underway on the control of intake air volume with inlet valves, elimination of engine knock, and internal exhaust gas recirculation control. Variable valve control can be implemented by various processes, each of which provides a different degree of variability. To achieve further optimizations in the engines of the future, a high degree of freedom is desired in the variable valve system in terms of not only valve open and close timing, lift, operating angle and inlet-exhaust valve overlap, but also in the ability to vary the valve profile itself.

Electric and Hydraulic Actuators

Variable valve controls use either solenoids or hydraulic actuators. Solenoid actuators provide excellent response, but are characterized by small output forces and do not support continuous position control. They are therefore mostly used only for ON/OFF control and are not suited to precise reproduction of lift patterns. In contrast, hydraulic actuators provide high output forces and are readily controlled, but they are generally less responsive and cannot handle high engine speeds. Mitsubishi Heavy Industries have now poured their years of experience in the field of hydraulic control into developing a small, fast hydraulic actuator to be used in an EVC system.

Structure of the EVC System

The EVC system consists of hydraulic actuators (figure 1) driving the valves and fitted to the cylinder head, servo valves to control the flow and direction of the high-pressure hydraulic fluid, sensors and control equipment to control actuator position, a hydraulic pump, and ancillary equipment (figure 2).

More Efficient Combustion Engines

Variable valve control for a camless engine with fast hydraulic actuators

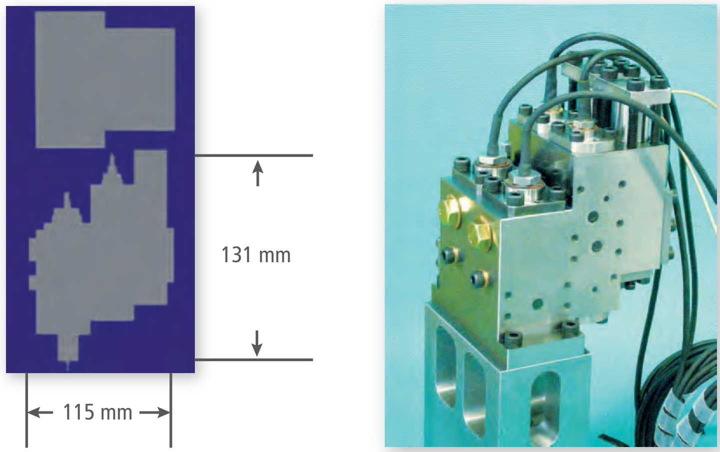


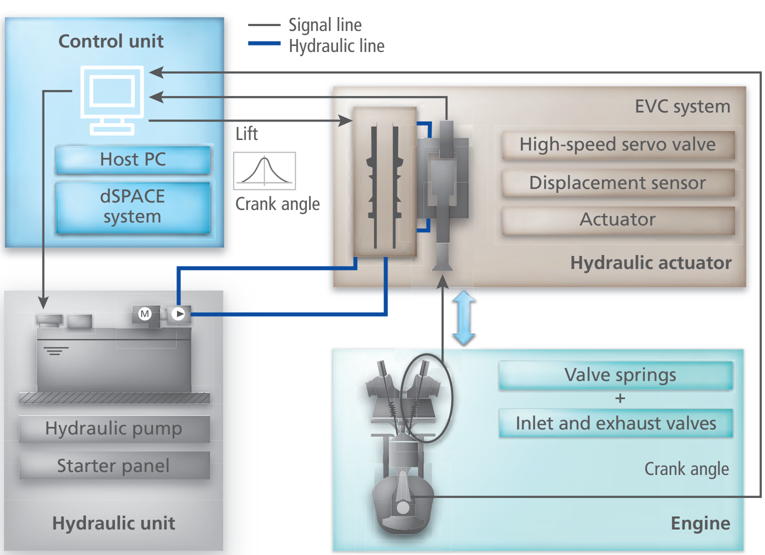
Figure 1: Dimensions (left) and structure (right) of the EVC actuator.

> "Our goal was to develop a dynamic hydraulic actuator. We achieved it quickly with the dSPACE system."
>
> *Ryuji Uehara, Mitsubishi Heavy Industries*

Features and Advantages of the EVC System

The EVC system is characterized by the ability to follow lift patterns accurately and at high speed. This ability is facilitated by dedicated high-speed servo valves and a real-time compensatory control logic.
The servo valve has been developed by Mitsubishi Heavy Industries to operate at a maximum actuator speed of 6 m/s, permitting a valve open-close cycle of approx. 2 ms. The valve improves the ability to follow the lift pattern at high speed, and is small enough to be fitted to small engines.

Figure 2: Schematic of the system configuration of the complete EVC demonstrator, including the control unit.

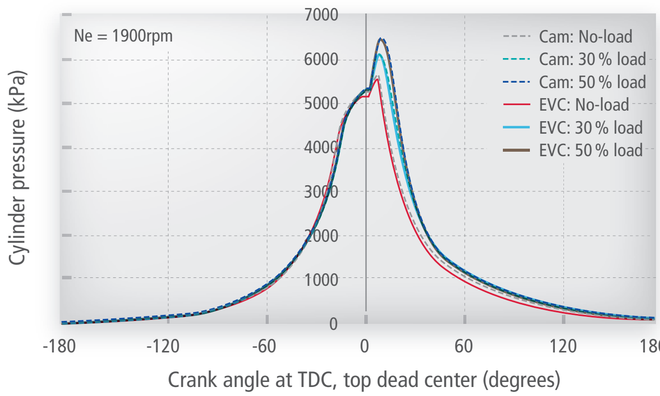


Prototype Control in the Laboratory

The control equipment consists of actuator position control, a digital signal processor to monitor safety – represented by the DS1006-based dSPACE real-time system – and a host PC to set the lift pattern and monitor the system in real time.
The control software for the system was developed in cooperation with Ono Sokki Co., Ltd. Running on the dSPACE real-time system, the software provides actuator feedback piston control and reproduces wave forms with high accuracy, and is also able to handle transient mode operation, e.g., variations in engine speed and torque.
The control also monitors mechanical functions, detecting extreme deviations, proximity warnings and abnormalities in actuator position and engine piston trajectory, and incorporates a range of safety features to prevent valve/piston collisions, etc.

Firing Tests on a Multicylinder Engine

For firing test purposes, the EVC system actuators were fitted to the cylinder head of a 4-valve, 4-cylinder diesel engine.
First, tests were run to compare the cylinder pressure in normal cam-driven operation and in a reproduction of the same lift pattern with the EVC system (figure 3). Results for the two cases are closely matched, verifying that the accuracy obtained with the EVC is comparable to that with nor-



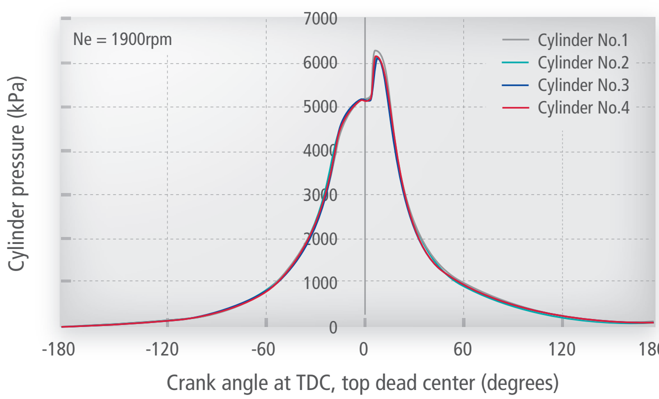


Figure 3: Comparison of cylinder pressures with mechanical camshaft control and EVC system.
Figure 4: Comparison of pressures in all 4 cylinders.

mal cam drive. In the next step, the pressures of all 4 cylinders were compared in EVC mode (figure 4). Differences between cylinders were minimal, and the ease with which the lift pattern was reproduced with the EVC system is clearly apparent. Since the EVC system constantly monitors the crank angle and controls the valve position at high speed accordingly, it is also able to follow the engine speed in transient mode, in which the engine speed is changing. Smooth operation is therefore possible in all conditions during testing, from starting with the starter motor, to stopping with fuel cutoff, to increasing and decreasing engine speeds, all without changing EVC system settings. ■

Ryuji Uehara
Mitsubishi Heavy Industries

Conclusion

Testing the multicylinder engine demonstrated that the EVC system was able to reduce variation between the cylinders, and to reproduce lift patterns to a high degree of accuracy. The application of the EVC system in research on new combustion technology illustrated its efficacy in finding conditions for improvements in combustion within a short time. The dSPACE system used as the experimental control unit offers Mitsubishi Heavy Industries a high degree of flexibility, so that changes and new ideas can be implemented quickly. The system was also convincingly easy to use and stable in operation. The dSPACE system helped Mitsubishi engineers to reduce development times and to improve the thermal efficiency of new combustion technology. Future developments include connecting the EVC system to an engine bench to automatically find optimum lift patterns in response to engine conditions.

Ryuji Uehara
Ryuji Uehara is Principal Engineer at Mitsubishi Heavy Industries, Shimonoseki Designing & Production Department Power System, in Yamaguchi, Japan.

China on the Fast Track

Chinese railway equipment manufacturer uses dSPACE HIL to speed up their Traction Control Unit (TCU) development.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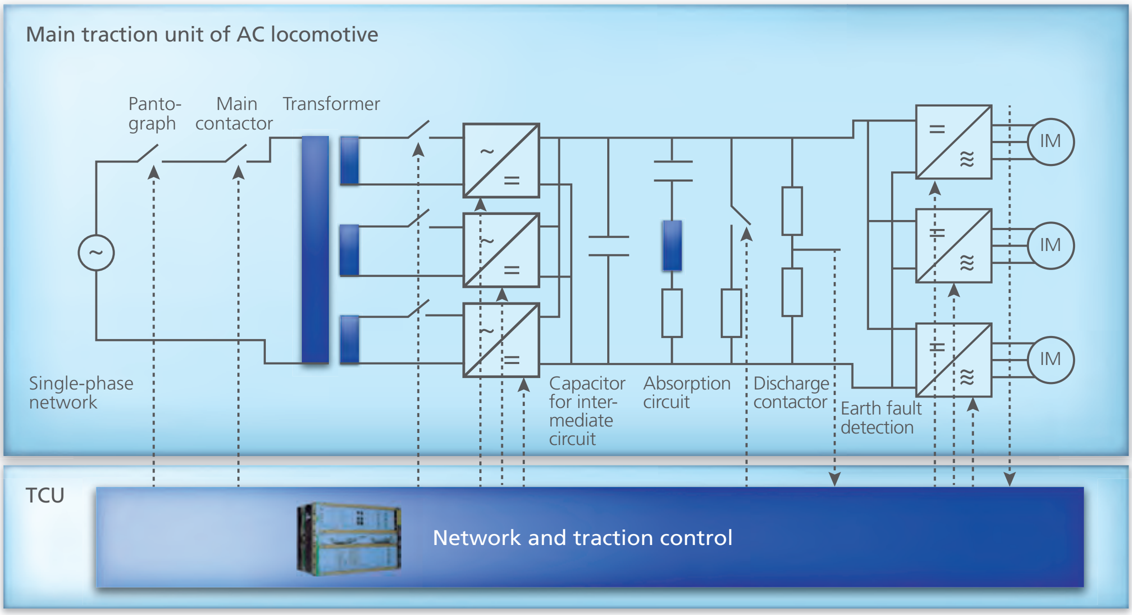


Figure 1: TCU and main traction unit of AC electric locomotives.

Background

China, with its largest population and second largest economy in the world, is revolutionizing its railway, its once obsolete, low-efficient major transportation infrastructure. After only 5 years it has successfully updated the old railway to a very modern and comprehensive system, ranging from metro lines high-speed trains like the TGV and ICE in Europe. This trend also opens up huge opportunities for local railway equipment suppliers. Benefiting from large sum of state subventions, the Dalian Electric Traction R&D Center, a subordinate company of the China Northern Railway (CNR) Group, has recently begun to develop Traction Control Units (TCUs) for AC electric locomotives. In this project, a very critical aspect is the development cycle. And since everything is started from scratch, almost all functions including various diagnosis functions must be thoroughly evaluated and tested; there is no time to set up a full-scale power test bench. Under these circumstances, the Dalian Electric Traction R&D Center decided to use the hardware-in-loop (HIL) approach, well established in the automotive industry, to test their TCU software and hardware.

What is TCU?

TCU is short for Traction Control Unit and is responsible for the optimal operation of the main traction unit of AC electric locomotives.
The main traction unit draws power from an AC overhead line with fixed frequency through pantographs and converts the power to variable frequency AC power to drive the traction electric motors on the bogie (figure 1).
A typical TCU is composed of one part for the line and one for the motor. The line side controls the line's power factor and stabilizes the DC link voltage, the motor side controls the

> "With a dSPACE DS5203 FPGA Board, we can conveniently run our own simulation model at 100 ns to match the real-time simulation data perfectly to the experimental results acquired on the power test bench."

Congqian Xu, staff engineer of HIL team, CNR

Figure 2: The HIL rig contains a TCU under test, signal conditioning unit and dSPACE modular hardware (DS1005, DS5203, DS5001, DS5101 and DS2302).

inverter and traction motors to achieve the required torque and speed.

Why the HIL Approach?

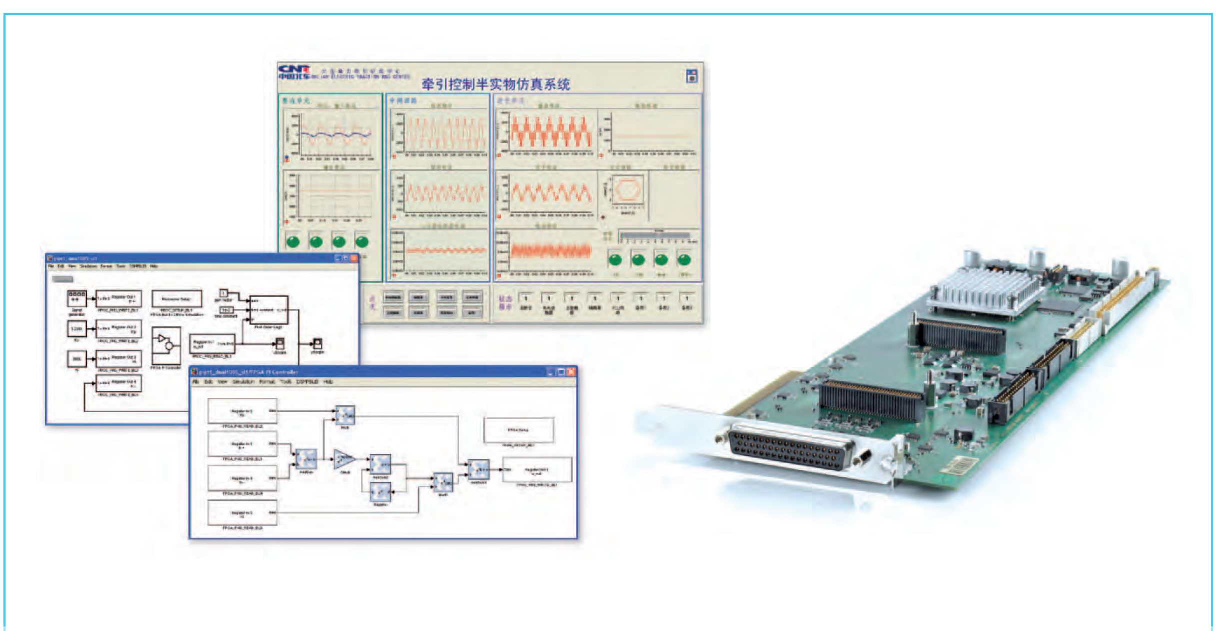
As in the automotive industry, HIL simulators quickly established themselves as very efficient, indispensible tools in the development and verification of locomotive controller software. Major international players such as Bombardier, Alstom and ABB use HIL systems to develop and test the complex TCU software. After carefully studying the experience of international competitors and the automotive industry, the Dalian Electric Traction R&D Center of CNR included HIL simulators in their entire development process in order to detect software and hardware bugs in the early stage of development (figure 2).
Unlike chemical processes in the combustion engine, the electromagnetical process in the electric traction unit can be accurately simulated thanks to a precise set of analytical equations. So it is possible to include HIL simulator in the early stage of TCU development to verify the controller functions, like evaluating the effect of different modulation methods on motor torque in different working conditions. Since power devices such as IGBTs (Insolated-gate bipolar transistor) are implemented in the model, the engineers don't have to worry about high voltage equipment being harmed by faulty gating signals.

The Challenges Met

In simulating power electronic systems and drive systems like an elec-

> "We decided to use a dSPACE HIL simulator as it already has proven its value in the broad range of the automotive industry."
>
> *Xiangdong Che, head of the electric traction department, CNR*

Figure 3: The plant model is graphically implemented in Simulink® with RTI FPGA Blockset and Xilinx® System Generator blocks.



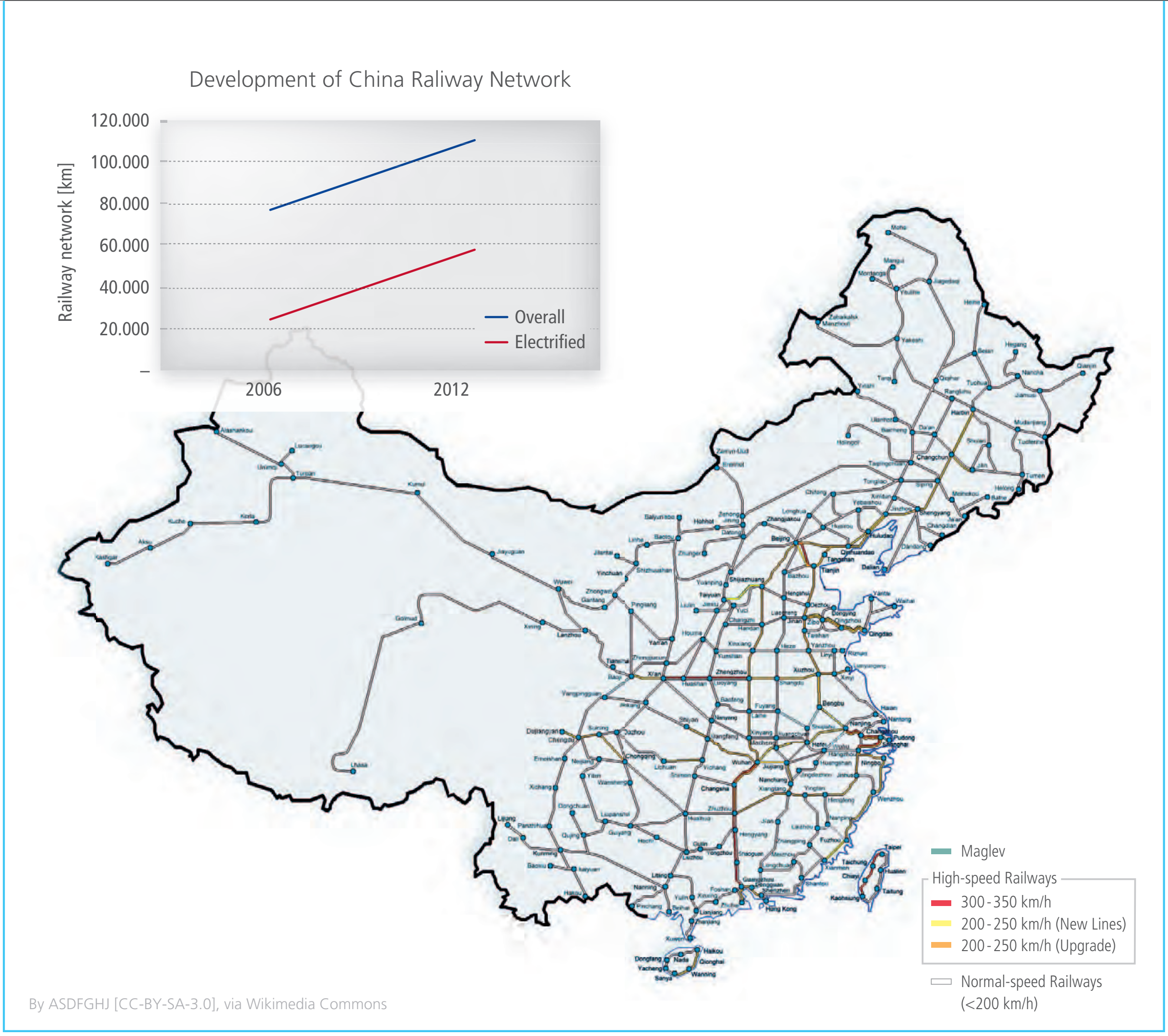
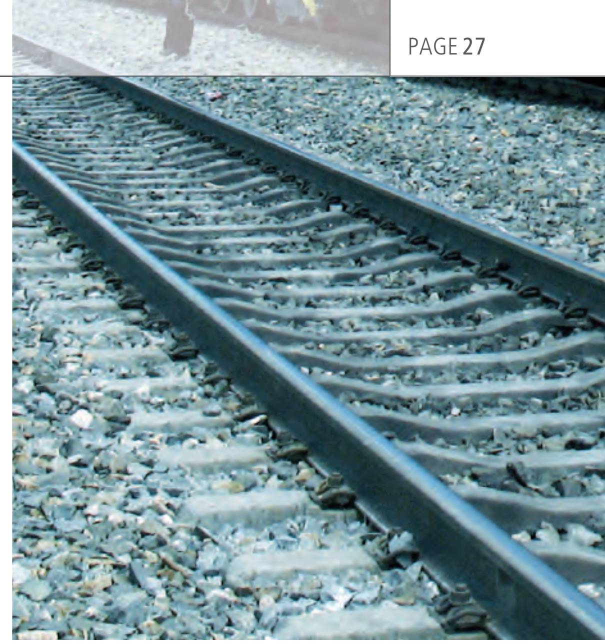


Figure 4: Over the last 6 years, the Chinese railway network has more than doubled its electrified railways.

> "A further advantage of a dSPACE simulator in locomotives is that we could utilize it in the very early stage of development, not only in the integration test."
>
> *Xiangdong Che, head of the electric traction department, CNR*

tric locomotive traction unit, the most challenging problem is the sampling of high-frequency power switch gate signals. If, for example, the inverter and traction electric machine is to be simulated on the real-time computer, the sampling error of gating signals will accumulate in the calculation of machine fluxes, leading to very poor simulation results. This error occurs at each gating signal transition and gets worse when the ratio of sample time to the switching period of gating signals becomes higher. Based on experience, a very satisfactory simulation result for an HIL test would be achieved with the ratio of 1/100. This means the time step of real-time simulator should be 1 µs in order to sample a 10 kHz gating signal, which is fairly common in the highly dynamic control of electric machines.

This time step requirement poses a great challenge to HIL vendors because it is impossible to run simulation models on any CPUs with such a small time step. Even parallel computing cannot solve this problem with current technology. So recently, FPGA-based solutions were brought forward to counter this problem, and this achieved very good results. However, in most of the commercial solutions the reconfiguration of the computing hardware must be done



by the HIL vendors and not all the customers are comfortable with the hardware description language VHDL or Verilog coding, let alone hardware synthesis technologies. The newly released dSPACE DS5203 FPGA Board offers a good opportunity to solve both problems elegantly. With the help of dSPACE RTI FPGA Programming Blockset and Xilinx System Generator, CNR could conveniently build the simulation model in Simulink, compile and synthesize it in bit streams and then download them in the board, all automatically. The FPGA reconfiguration could be done in a graphical environment without any knowledge of VHDL or Verilog coding. The Electric Traction R&D Center utilized this feature and ported their original model to the FPGA model running on DS5203 board without much effort (figure 3). The powerful FPGA device Xilinx Virtex 5 on the DS5203 provides the possibility to implement very large, complex models on the FPGA device. After some optimization, the Electric Traction R&D Center of CNR successfully implemented the complete main traction unit, including 3 4QC converters, 1 DC link, and 3 inverters and 3 traction electric machines on a single DS5203 board. With the help of the FPGA's parallel computing feature, the main electric traction unit can be executed at a 100 ns time step, yielding very accurate real-time simulation results. ■

Dr. Xizheng Guo
Congqian Xu
Xiangdong Che
China Northern Railway

Result and future plans

Since the dSPACE HIL simulator is used at a very early development stage and much less power test bench involvement is needed for algorithm verification, the TCU development cycle has been shortened dramatically: TCU software and hardware testing under various working conditions can be now easily implemented without the danger of harming power devices or machines.

Encouraged by the current success in TCU development, the Electric Traction R&D Center plans to purchase more DS5203 boards to test the TCUs of larger-scale railway vehicles. It is also under discussion to purchase several full-size HILs to implement a full-scale virtual train to test networked electronic controllers for the high-speed CHR trains.

Congqian Xu
Congqian Xu is a HIL test team staff engineer in the Electric Traction R&D Center of the China Northern Railway (CNR) Group in Dalian, China.

Dr. Xizheng Guo
Dr. Xizheng Guo is an eDrive scientist and the HIL system development leader of CNR in Dalian, China.

Efficiency in the Field

Regular gear shifts are becoming rare in modern tractors. When Valtra's Direct tractors work the fields, their continuously variable transmission (CVT) keeps the optimum speed range to increase fuel economy and efficiency.

To find the optimum CVT, Valtra requested the Technical University Tampere, Finland, to evaluate the CVTs available on the market. The university team used a newly developed static calculation model to visualize the attributes of various CVTs as a tractive force/speed diagram. They also looked at the efficiency of the hydraulic converter in relation to overall efficiency, calculating the pressure level of the hydrostatic converter, and the torques and speeds of all rotating parts. Thus it was easy to compare the attributes of the different gear constructions. The research showed that no CVT completely fulfilled Valtra's high demands, so Valtra decided to develop its own.

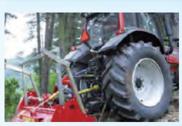
CVT Requirements

Valtra identified the following requirements for a high-performance, high-efficiency CVT:

- Robust design
- Easy operation
- Various adjustment and control options with automatic help functions
- Minimal changes to Valtra's existing transmission concept

Continuously variable transmission with power-split driveline for more power and lower costs

Figure 1: In Valtra's Direct tractors, the ideal work area for the task at hand can be selected. The speed range for each begins at 0 km/h and offers stepless speed adjustment, even in reverse.

	 **Work Area A:** Heavy pull/ special crop	 **Work Area B:** Field work	 **Work Area C:** Fast work	 **Work Area D:** Road transport
0-9 **A** 0-18 **B** 0-30 **C** 0-50 (40) **D** 0 km/h 50	For the heaviest work, like low speed tillage or special crop harvesting. Ideal when maximum pulling force is needed continuously, or when the most precise speed adjustment is required. Extremely high pulling forces with power take-off (PTO) driven trailers.	Universal field work range. Ideal from seeding and faster tillage to various forage operations. Easy control of different operations (like harvesting speeds) essential. Also suitable for work such as transport through forest.	Ideal for transportation across fields. Suitable for many local services. Efficient start-up with heavy loads.	Ideal for road transport at high speeds.

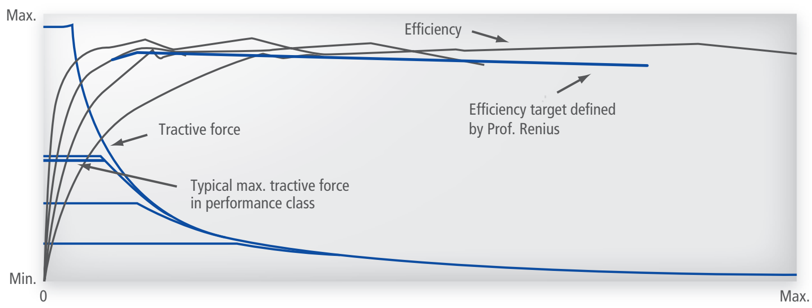


Figure 2: Full-load transmission efficiency. The achieved efficiency meets the target defined by Professor Karl Theodor Renius. Professor Renius was a professor for agricultural machines at the Technische Universität München, Germany, with an international reputation for his contributions to tractor research and technology transfer and his role in agricultural engineering education.

> "Using the dSPACE HIL simulator meant that we had the freedom to consider all the possible variants."
>
> *Ville Viitasalo, Valtra Oy*

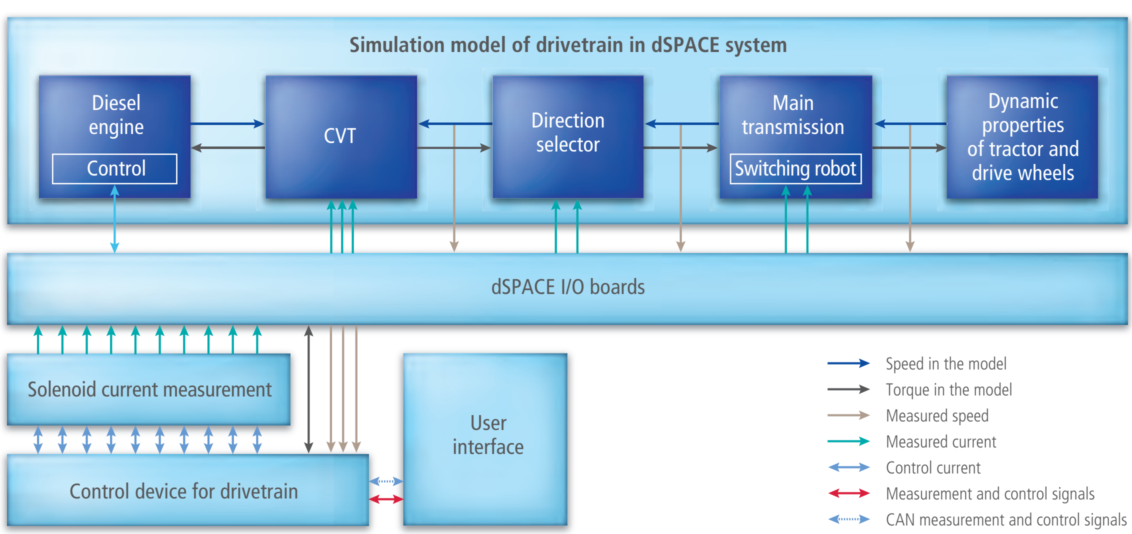
- Cost-effective production and operation
- Suitability for arctic conditions
- Long service life
- Easy maintenance

The best solution out of hundreds of possible variants was selected with the help of the static calculation model.

Different Driving Strategy for Each Work Area

Valtra analyzed tractors' different operating modes and developed an optimum driving strategy for each work area. All driving strategies start at 0 km/h and accelerate continuously until they reach the maximum speed. The CVT consists of a power-split driveline which has been fitted with a Linde Hydrostatic Drive. Shifting between the different work areas is done via a multi-plate clutch. A powershift direction selector makes smooth start-up and change of direction possible at driving speeds less than 10 km/h in work areas A and B. The main gears for all work areas can be selected at the touch of a button and the actual gear change is performed by a robot. The selected drive design achieves optimum efficiency for each work area and fulfills the efficiency target defined by Professor K.T. Renius (figure 2).

Figure 3: The dSPACE HIL system supports Valtra in testing control algorithms for the CVT.



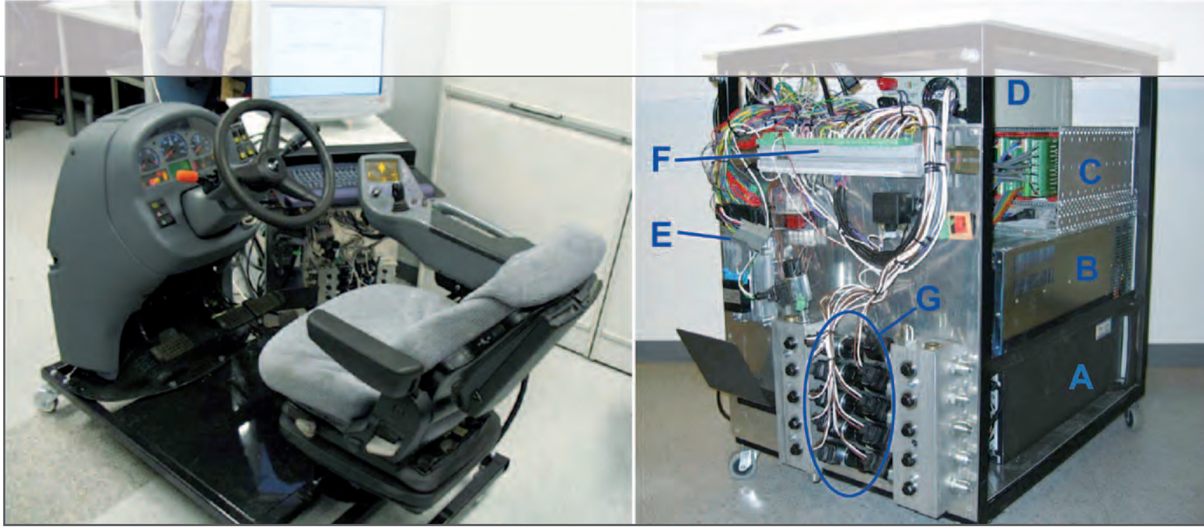


Figure 4: HIL user interface and system (A – PC, B – dSPACE AutoBox with processor and I/O boards, C – transformer, D – power supply, E – drive-train control, F – connector strip, G – solenoids).

> “This project has shown that cooperation between university and industry can produce excellent results.”
>
> *Dr. Mikko Erkkilä, Technical University Tampere*

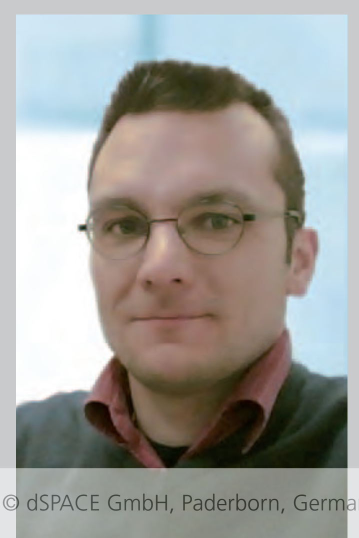
Developing the CVT Control with HIL Simulation

To develop the drive control for the new CVT, a dynamic drivetrain model was created, covering everything from the diesel engine to the pulling tractor wheels. Valtra built a hardware-in-the-loop (HIL) system based on this dynamic model and used it to develop the control algorithms and program the drivetrain control. The HIL system consists of a dSPACE processor board that runs the simulation model and several dSPACE I/O boards. The control signals are measured and converted to digital values to control the simulation model. Some control and measurement signals are transmitted through the CAN bus according to the SAE J1939 standard. The HIL simulator makes it possible to test the control device under realistic conditions at the developer’s desk. Errors and hazardous situations can be checked extensively to improve the control’s safety. ■

Dr. Mikko Erkkilä,
Technical University Tampere, Finland
Ville Viitasalo, Valtra Oy

Dr. Mikko Erkkilä
Dr. Mikko Erkkilä wrote his dissertation “Modeling and Simulation of CVT Drive Lines” at Tampere University of Technology in cooperation with Valtra Oy. He is now technology coordinator at Hydac Oy in Vantaa, Finland.

Ville Viitasalo
Ville Viitasalo is head of the transmission team at Valtra Oy in Suolahti, Finland.



Conclusion

The static calculation model is a powerful tool for developing new transmission and drivetrain concepts. Simulation-aided design tools plus steady-state, dynamic and HIL simulation models all make it possible to reduce design time and cost. More time and effort can then be used for virtual and field testing, and for increasing the functionality and reliability of the machines. Cooperation between university and industry went well. The meeting of practical skills and theoretical knowledge produced excellent results.

Students at the Universität Stuttgart are developing an electric race car with an innovative battery management system

A Winning Formula

The E0711-2

Motors:	2 permanent magnet synchronous motors, each 50 kW
Control:	MicroAutoBox II
Recharcheable batteries:	Lithium polymer pouch cells with 588 V
Weight:	266 kg
Acceleration:	0 to 100 km/h in 3.0 s

Formula Student has very strict rules on the safety of electrically powered race cars. GreenTeam Uni Stuttgart guarantees safety by using dSPACE technology to develop their high-speed vehicle.
The new dSPACE MicroAutoBox II controls the vehicle dynamics, monitors the safety system and controls the battery management.

The GreenTeam in Formula Student Electric

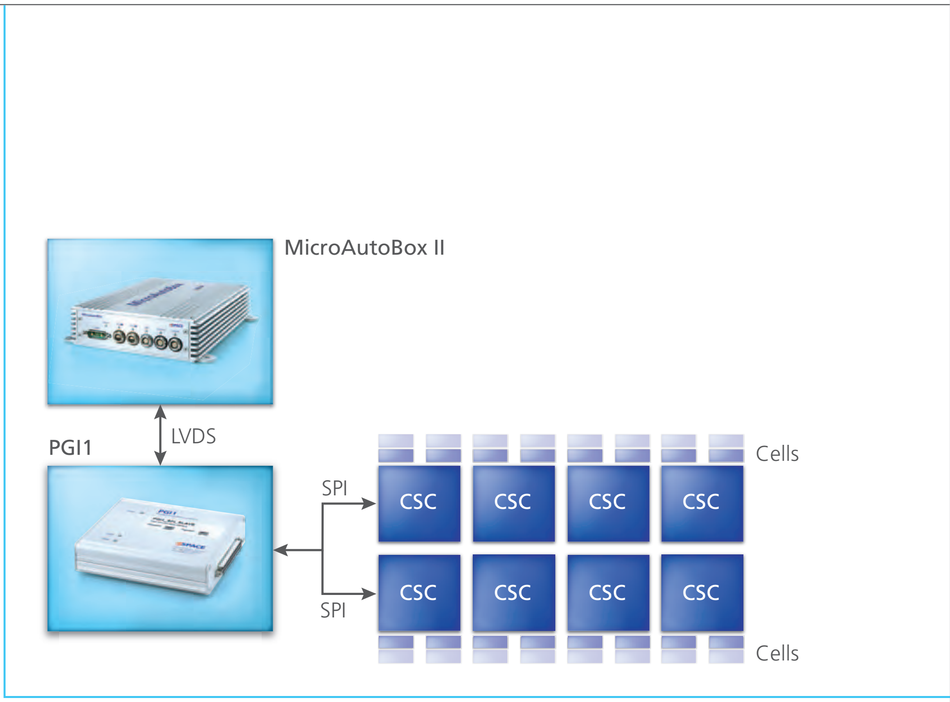
GreenTeam Uni Stuttgart is a non-profit organization with over 30 active student members who develop and build electric race cars according to the rules of Formula Student Electric. What's special is that the entire development process, from the idea and design for the car to parts manufacture to prototype assembly and testing, is carried out by the students themselves.
Founded in 2009, the team's goals are to develop a Formula Student race car with a purely electric drive and to actively participate in Formula Student Electric competitions.
To develop their first electric race car, the students optimized and modified the racing team's combustion engine-driven 2008 world championship vehicle, the F0711-3. Their main focus was on integrating the electric motor, the high-voltage battery and the necessary control system.

Electrical Vehicle Components

The E0711-2 race car that was developed for the 2010/11 season has two 50-kW electric motors, type AMK DT7-80-20-POW, installed longitudinally, which drive the rear wheels independently of each other. The required operating voltage is supplied by a high-voltage Lithium polymer (LiPo) battery. It has 8.4 kWh capacity with a maximum voltage of 588 V and an energy density of 180 Wh/kg. The batteries in the Stuttgart race car are arranged in three series of 140 sequentially switched cells, giving the vehicle three independent batteries connected in parallel.

Functions of a Battery Management System

A battery management system (BMS) controls the electrical and thermal processes in a battery of several connected, rechargeable cells that have to be monitored and controlled. In automotive technology, a BMS also controls different vehicle operating states, optimizes the battery's lifetime and performance, and if necessary puts it into a safe state.
For example, if the vehicle is switched off, the BMS goes into sleep mode. If the vehicle is in waking mode (programmable cyclically), the BMS can monitor variables such as voltage, current strength and temperature



Battery management system: The dSPACE MicroAutoBox II is connected to the dSPACE interface module PGI1 via the LVDS bus and controls the BMS. Via SPI buses, the PGI1 receives information from the cell supervisory controllers that monitor the individual cells.

for irregularities or failures. These are transmitted to the driver and the racing team in real time so that they can take appropriate action.

Requirements for the Battery Management System

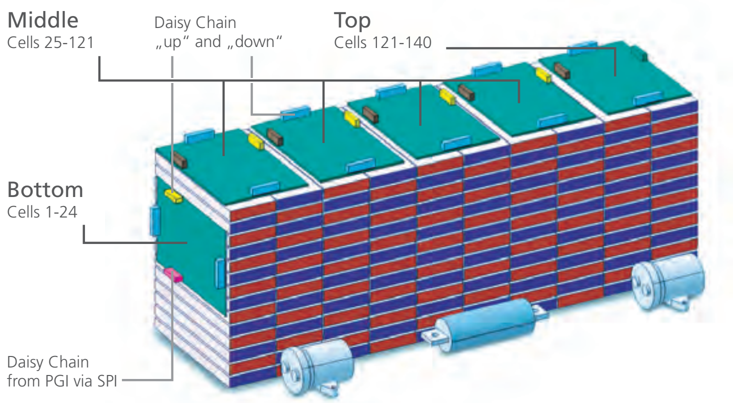
The rules of Formula Student Electric Germany (FSE) state that the battery system in the E0711-2 race car must switch off automatically if its cells are working outside the specified parameter limits. To cover the BMS' entire functional scope, other input variables must also be captured and evaluated in order to optimize battery management. These include the voltages and temperatures of the individual cells. States such as overcharging, deep discharge, overcurrents, short circuits and the ambient temperature also have to be captured. This minimizes the risk of a weak or failing battery cell affecting the other cells in the series-connected system, which would impair overall performance. This is especially important in Formula Student Electric, because the battery in an electric race car has to keep going till it reaches the finish line without recharging, even in a long-distance (22 km) race.

Conception of the BMS

This is the approach the team uses to ensure the battery operates reliably: The consumed power is controlled as a function of temperature T and state of charge SOC. Overcharging and deep discharge are prevented by interval control: The charging process is interrupted at the top limit (4.2 V), and then all the cells are balanced to the lowest

> "With the MicroAutoBox II and the dSPACE Programmable Generic Interface, we can capture and control the high-voltage battery's elementary variables precisely."

Leonardo Uriona, E0711-2 Team Leader



The bottom battery module (BOT) contains battery cells 1-24, the middle modules (MID) contain battery cells 25-121, and the TOP module contains battery cells 122-140. The bottom module forms the interface to the dSPACE PGI1 module via the SPI bus. The top module ends the daisy chain of the bus system that transports the data.

Edward Eichstetter (left)
Edward Eichstetter is team leader for the overall vehicle in the GreenTeam Uni Stuttgart, Germany.

Leonardo Uriona (right)
Leonardo Uriona is team leader for the overall vehicle electronics in the GreenTeam Uni Stuttgart, Germany.

voltage. As soon as all the cells have the same voltage, another attempt is made to charge them up to 4.2 V. The charging process continues in this iterative fashion until all the cells have reached their maximum SOC. At the bottom charge limit (3.5 V), the system calculates the expected voltage drop so that the battery load does not go below the minimum.
The BMS can use the SOC curves, the temperature and the kilometers still to be driven in order to calculate how much power can be released.

It does this with the dSPACE MicroAutoBox II.

dSPACE Technology in the Race Car

The MicroAutoBox II is the computing center for the battery management system. It monitors the overall system and processes the information from the dSPACE Programmable Generic Interface (PGI1) via a low-voltage differential signaling (LVDS) bus. The PGI1 then communicates with the individual cell supervisory controllers (CSCs) via the Serial Peripheral Interface (SPI).
The battery cells and various control mechanisms are evaluated by a BMS model based on a dSPACE engineering solution. The dSPACE-supported battery management system has proved a success for GreenTeam and will be used in the same form in actual competition. The high reliability of the vehicle functions is demonstrated by the racing team's many wins with their second-generation electric race car.

Development Progress

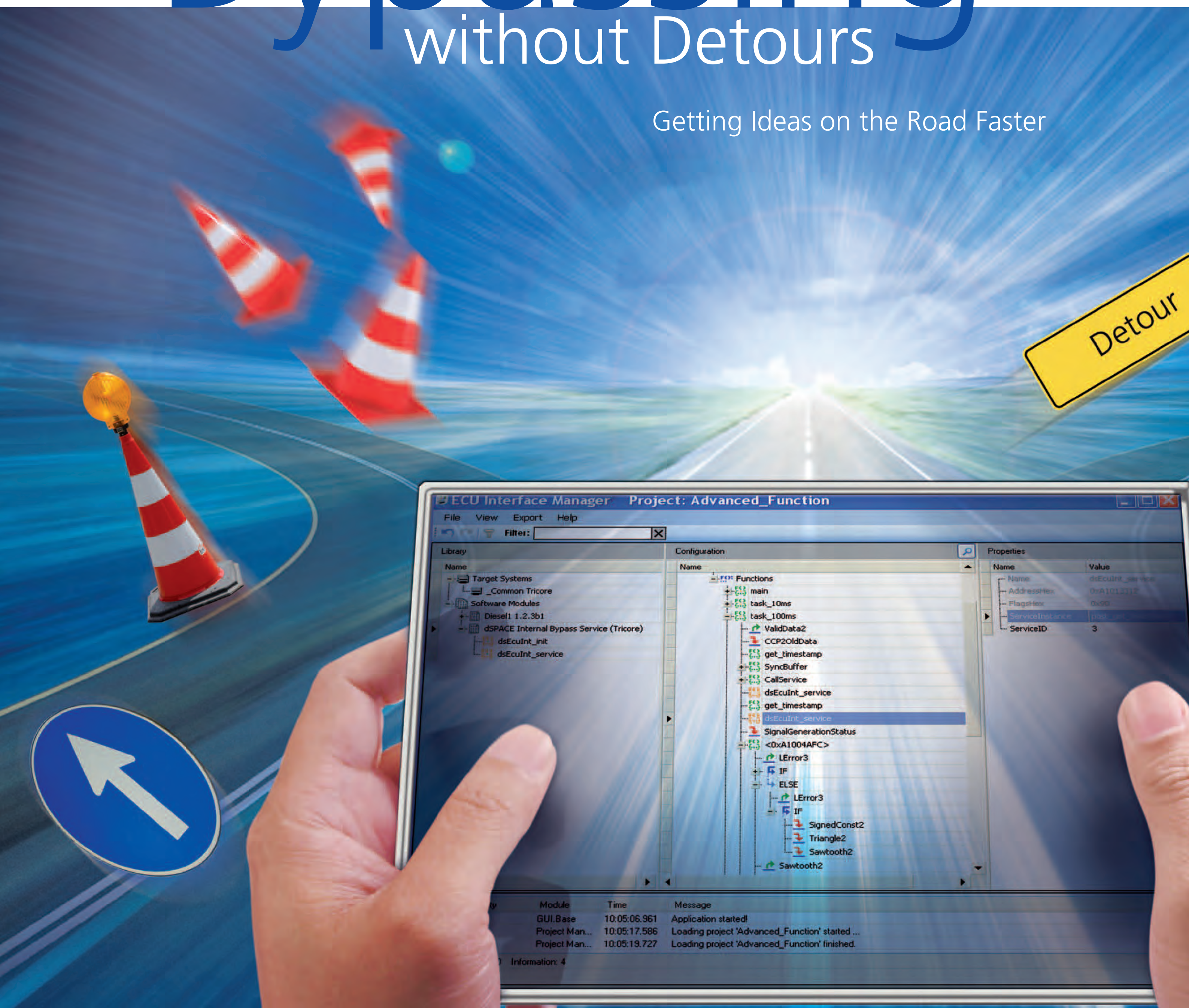
The GreenTeam Uni Stuttgart has already taken 3 top places in 4 competitions. In 2010, they won the overall victory in Germany and in Italy. The team showed its determination again in 2011, winning second place in Italy.
These successes inspired the team to compete on the Hockenheimring in Germany and in Italy every year with the E0711-2, a newly developed and improved race car. The team also aims to take part in other international competitions.
In the meantime, GreenTeam is busy working on the E0711-3, the third generation of their self-developed electric race cars. ■

Edward Eichstetter
Leonardo Uriona
GreenTeam Uni Stuttgart

Bypassing

without Detours

Getting Ideas on the Road Faster



The ECU Interface Manager and the internal bypass option extend dSPACE's portfolio of tools for fast function development and service-based bypassing. Function calls can now be inserted directly into the compiled ECU software, and new ideas can be implemented directly on the target ECU. No ECU source code or build environment is necessary.

New Challenges

Nowadays, it is unusual to develop completely new ECU software for new vehicle generations: existing code is adapted instead. Service-based external bypassing, in which a rapid prototyping system running in parallel to the ECU computes new functions, is a proven method for this approach. The supplier has to integrate the necessary interfaces (called bypass hooks) in the ECU software as service calls in the source code. This process usually involves an iterative consultation process between the OEM and the supplier, and in some cases additional, previously unplanned software adaptations become necessary during a project. For the vehicle manufacturer, this can mean long project run times and high project costs.
AUTOSAR ECUs present additional challenges, because if software components are developed by the vehicle manufacturer or by project partners and then made available to the ECU supplier for integration into the overall software as object code, the ECU supplier is usually not able to change the components by inserting bypass hooks.
Even though current driving forces behind innovation, such as electromobility, CO_2 reduction and road safety, are pushing up the need for suitable prototyping development environments, budget restrictions are often an obstacle. Affordable starter systems are increasingly in demand. At the same time, developers soon come up against the limits of using the external bypass method to create fast control loops.

The Answer: Extended Tool Chain

dSPACE offers the answer to these challenges: an extended tool chain for function development with the bypass method. Besides their current solutions for external bypassing on high-performance rapid prototyping systems, dSPACE now also supports internal bypassing, also known as on-target prototyping. With an integrated development environment in MATLAB®/Simulink®, software functions can be developed directly on the existing ECU, using its free RAM and flash memory resources.
A new tool is also available: the ECU Interface Manager. This enables end users to integrate bypass hooks for internal and external bypassing into the compiled ECU software. Thus, special software versions from the ECU supplier are no longer needed.

Benefits of Service-Based Bypassing

dSPACE offers various services for internal and external bypassing, providing the following benefits:

- *Bypass hook configuration in the modeling environment*:
  If an ECU software version with service calls (bypass hooks) is available, the modeling environment lets developers define which bypass functions to start with

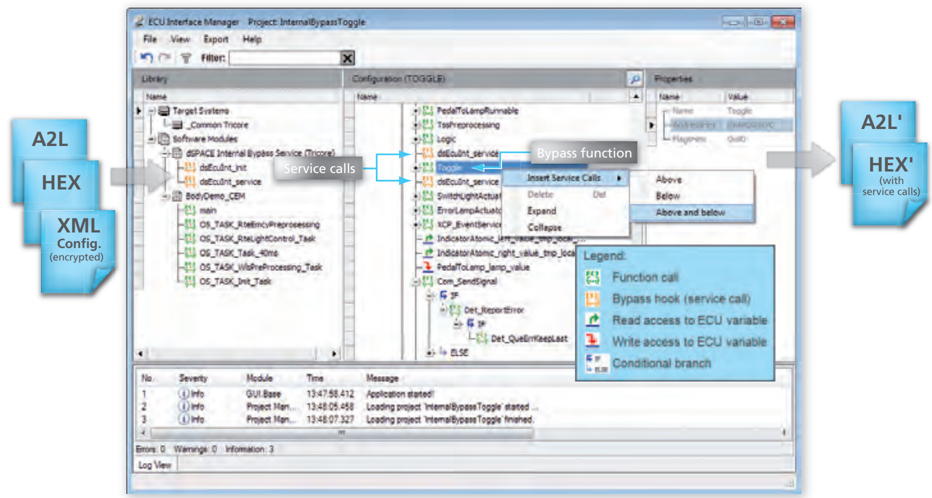


Figure 1: Fast integration of service calls via the ECU Interface Manager.

which bypass hook, and which ECU variables to read and write.

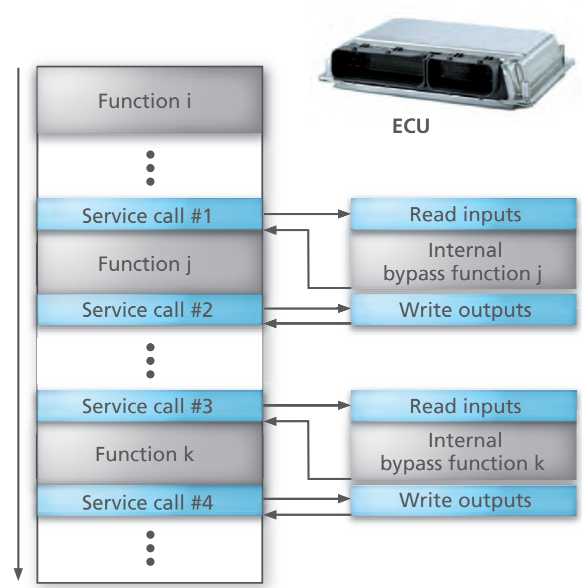
- *Data consistency:*
  When several ECU variables are read and written, double buffer mechanisms can ensure data consistency. This option is especially important if the execution of the bypass function and the reading of input values and writing of output values take place in different ECU tasks.
- *Safety:*
  There are various safety mechanisms, including error counters with automatic bypass hook switch-off and plausibility checks before writing variables.

Integrating Service Calls into the Compiled ECU Software

In internal and external bypassing, the ECU Interface Manager can integrate service calls into the compiled ECU software (hex file) without any changes to the ECU source code. Very little information is needed in addition to the hex file and the associated ECU variable description (A2L file): just information such as the details on free RAM and flash memory areas and entry points for the hex code parser, which the ECU supplier usually provides in an encrypted XML configuration file.

The ECU Interface Manager analyzes the hex code to find function calls, accesses to ECU variables and conditional branches. The configuration file defines which information the end user will be able to see in the ECU Interface Manager. Filter and search mechanisms locate dedicated variable accesses and function calls in the program sequence. After specifying the service call positions, users can intuitively insert the service calls into the ECU code and generate modified A2L and hex files at the push of a button. Access to the ECU supplier's build environment is not necessary. With this method, it takes end users only a few minutes to independently integrate the bypass hooks into the ECU software. Thus, changes to the original software status can be limited to a specific bypassing task, thereby minimizing memory

Figure 2: Example implementation of internal, service-based bypassing using two bypassed ECU functions.



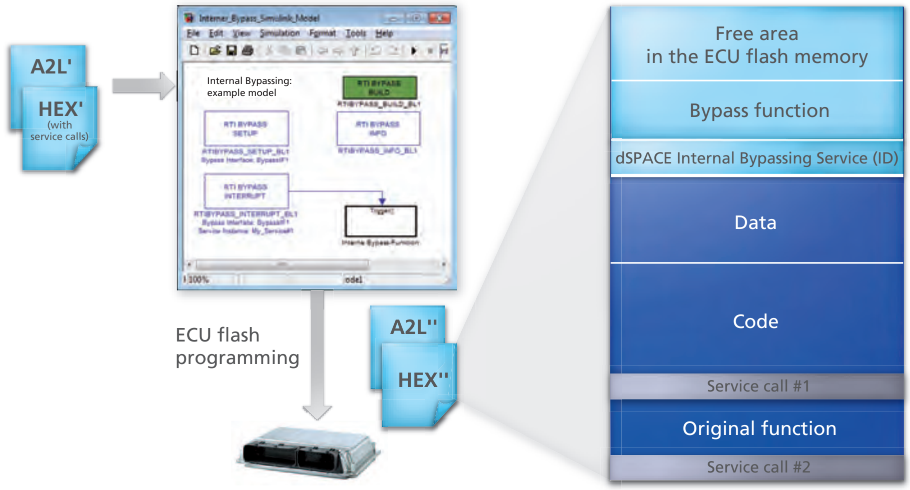


Figure 3: Developing a software function directly on the ECU with the new internal bypass option for the RTI Bypass Blockset.

requirements and effects on the ECU's run-time behavior. For example, in typical applications, bypass hooks for internal bypassing with Infineon TriCore™ microcontrollers require 32 bytes in ECU RAM and 2 kBytes in the ECU's flash memory.

On-Target Prototyping

The new internal bypass option for the RTI Bypass Blockset supports model-based function development directly on an ECU. It even allows users to switch between external and internal bypassing without changing the function model. For example, if the ECU's RAM and flash memories are too small during internal bypassing or additional sensor signals are needed, developers can quickly switch to an external prototyping system without modifying the models. The same applies in the opposite direction, for example, when a function that was developed in external bypassing has to be validated directly on ECUs in a fleet test. Moreover, external and internal bypass parts can be combined in one function model in any possible way. Because ECUs with production software versions usually have very little free RAM and flash memory, one possibility would be to compute function parts in very fast rasters on the ECU and execute calculations in slower control loops on an external prototyping system.

After reading in the A2L and hex files via the relevant RTI bypass blocks, in the modeling environment the user can select the service calls that were previously integrated by means of the ECU Interface Manager and use them to read and write any ECU variables or to call the bypass function. The code for the function model is then generated, linked to the free area of the ECU's flash memory, and merged with the original ECU software – all with push-button ease. The result is an A2L file with added internal bypass function variables, and new hex code that can be flashed to the ECU with proven tools. During the modeling process, an info block indicates how much free RAM and flash memory is available. When the Simulink® Coder™ is used to generate 32-bit floating-point code for a function model with around 400 blocks and 30 input and output variables, for example, about 30 kByte flash memory and less than 4 kByte RAM memory are required on Infineon TriCore™ microcontrollers.

The ECU Interface Manager and the internal bypass option currently support Infineon TriCore™ microcontrollers. There are no dependencies on ECU platforms of specific suppliers. Other microcontroller families, such as MPC5xxx from Freescale, will follow in the second half of 2012. ■

The Benefits at a Glance:

- End users can quickly integrate function bypass hooks into the compiled ECU software
- Support of on-target prototyping and external bypassing
- No need for access to ECU's source code and build environment
- Easier bypass hook integration thanks to graphical representation of function calls, conditional branches and variable accesses in the ECU software
- Switching between internal and external bypassing without modifying the model

AUTOSAR 3.2 4.0

Production Code for the Toughest Demands

TargetLink 3.3

dSPACE TargetLink 3.3 is leading the way for new trends in production code generation, covering conventional, safety-critical and AUTOSAR 4.0 and 3.2-compliant development projects. The new version contains comprehensive enhancements in AUTOSAR-compliant development, data management in the Data Dictionary, and component-based work methods. TargetLink 3.3 is available as a 64-bit and a 32-bit variant.

Support for AUTOSAR 4.0 and AUTOSAR 3.2

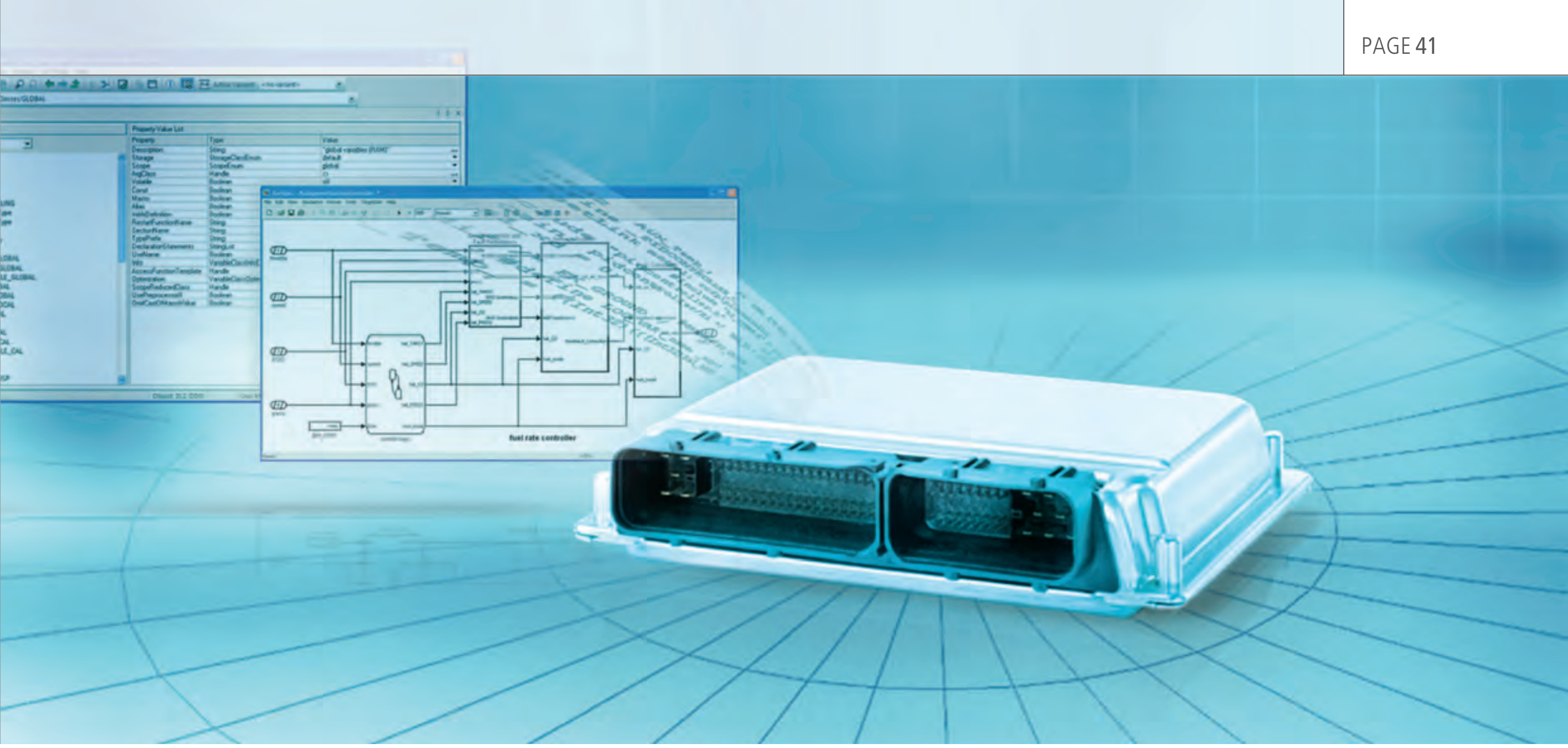
When designing TargetLink® 3.3, we particularly focused on expanding AUTOSAR support to cover the definitive AUTOSAR versions of the future, AUTOSAR 4.0 and AUTOSAR 3.2. This opens up new doors for TargetLink users and their future AUTOSAR projects, enabling them to use the single source principle to generate software components for different AUTOSAR versions from the same TargetLink model. In addition, dSPACE also extended the AUTOSAR language range supported by TargetLink, especially in the areas of mode management and structure handling. TargetLink's flexibility in data and package partitioning and its usability were enhanced, and the software container concept was optimized further to streamline using TargetLink and SystemDesk® in combination. Developers can perform AUTOSAR round trips between SystemDesk and TargetLink reliably and transparently, and with a minimum of user intervention.

Easier Handling for Large Models

With TargetLink 3.3, developers can decide whether they want to work with the 64-bit or the 32-bit software variant. The 64-bit variant of TargetLink 3.3 has decisive advantages wherever there are large models that would lead to storage problems on 32-bit systems. The more powerful incremental code generation for subsystems and referenced models with TargetLink 3.3 also makes it much easier to handle large models and use a modular component-based work method. And last but not least, TargetLink's own mechanism for reusing generated code has been extended substantially.

Data Management for Process-Reliable Engineering Round Trips

TargetLink 3.3 contains considerable improvements in the Data Dictionary's data management. In the new version, multiple Data Dictionary workspaces can be handled and attached to various project files. This makes applications much easier, especially the scenarios for engineering round trips in which project-global data is exchanged between the dSPACE Data Dictionary and other tools in the development process. The data can be in AUTOSAR files, XML files or SWC containers.



TargetLink 3.3 is certified for use in ISO 26262- and IEC 61508-compliant projects.

For change management, TargetLink users just have to load the current data into an additional workspace and then carry out a Diff&Merge operation with the old data to transfer the changes and/or updates into the Data Dictionary reliably and inspect their effects on the TargetLink model (figure 1). In addition, the Data Dictionary now provides easier loading of partial Data Dictionary files, so that their contents can be inspected and so that they can be inserted into an existing Data Dictionary project.

Continuous Further Development of Modeling, Usability and Code Efficiency

TargetLink 3.3 includes many new modeling features and usability enhancements such as:

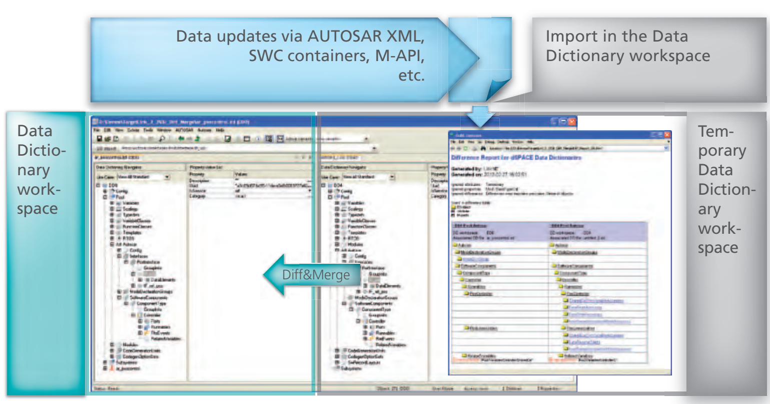
- Multi-rate modeling styles for conventional or AUTOSAR-compliant models
- API functions for visualization of and access to simulation data
- Convenient dialogs for editing Stateflow® chart function properties
- Easier connections between Data Dictionary variable objects and models

The efficiency of the generated code was also further improved by introducing lifetime analyses of variables.

Simple Migration, High Flexibility

Thanks to the new installation methods, migrating from TargetLink 3.1 and 3.2 to TargetLink 3.3 is especially easy because TargetLink 3.3 can be installed and operated in parallel to older TargetLink versions. The 64-bit and the 32-bit variants of TargetLink 3.3 are both used with a MATLAB® version that has the same bit width. With its support of six different MATLAB versions from R2009a to R2011b, TargetLink 3.3 gives users the highest flexibility possible. ■

Figure 1: Multiple Data Dictionary workspaces, with Diff&Merge, improve the support of engineering round trips.



FPGA-based simulation models for highly dynamic controlled systems

Things Are Speeding Up

In demanding and highly dynamic electromobility applications, FPGAs provide an enormous performance boost for real-time simulation. dSPACE is moving one step closer to the future by providing completely FPGA-based simulation models.

In hardware-in-the-loop (HIL) simulation, field-programmable gate arrays (FPGAs) are typically used to take some of the load off the processor. Particularly time-critical I/O computations are performed on the FPGA so that the processor has more capacity to calculate the plant model. However, this procedure is useful only if the models are not too complex and the sampling rates are not too high. When controllers are developed for the dynamic, highly precise ECUs installed in electric vehicles, the procedure sometimes reaches its limits. The solution is to compute not only the I/O but also the entire plant model on the FPGA. dSPACE now provides a library of ready-to-use components for this (figure 1).

For Highest Dynamics Requirements

In conventional approaches, processors frequently have only enough computing power to simulate mean-value models, often updating the output signals only once per PWM cycle.
When the highest demands are made on dynamics and signal precision, FPGA-based model computation offers decisive advantages. FPGAs reach very high sampling rates that allow output signals to be updated considerably more often than once per PWM cycle. This ensures a far greater simulation quality (figure 3). For example, with high-frequency simulation it is possible to simulate the inductance current ripple caused by PWM control, simulate higher frequencies with greater precision, and ensure high control loop stability. In comparison with a processor-based model, cycle times are typically reduced from 50 µs to 100 ns.

Convenient Model Library

For maximum convenience in creating FPGA-based models, dSPACE offers a library of completely modeled electrical components: the XSG Electric Components Library. This library is available during work in Simulink®. The models were created with the Xilinx® System Generator (XSG) blockset. During code generation, they are directly converted to VHDL code that is executable on an FPGA such as the DS5203 FPGA Board. The generation of interfaces is partly automated so that in many projects, developers do not require detailed knowledge of FPGA programming, just experience in using Simulink.
The FPGA library contains ready-made models for the following components:

- Permanent magnet synchronous motor
- Brushless direct current motor
- Direct current motor
- Three-phase frequency converter
- Incremental encoder
  - Resolvers
  - Sine encoder
  - TLL encoder
  - Hall encoder
- Aids
  - Mean-value calculation
  - Tables: 1-D, 2-D
  - Scope function
  - Center-aligned PWM measurement

The Advantages of FPGA-Based Simulation

The FPGA-based models from dSPACE also have other advantages in addition to very fast computing speeds:

- *Project-specific adaptations:* The models are open and their implementation can be viewed right down to base block level. So users can either make project-specific adaptations themselves, or have them implemented by dSPACE Engineering Services. They can therefore react flexibly to sudden project or requirement changes.

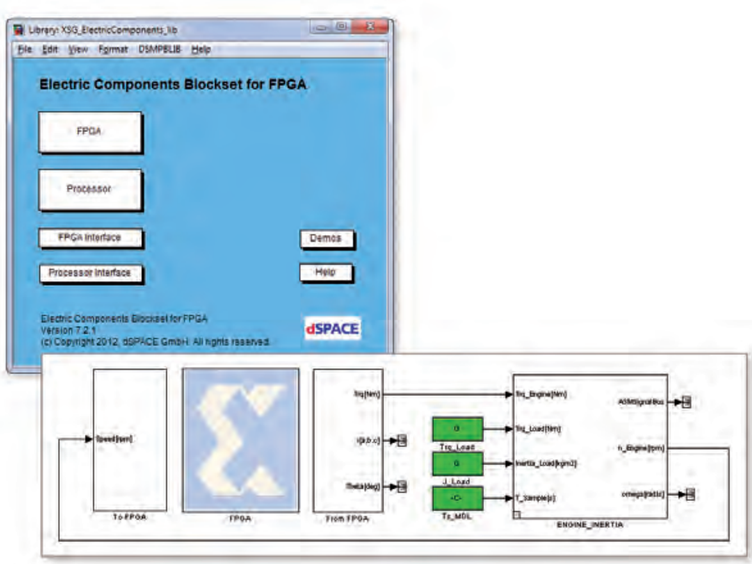


Figure 1: The XSG Electric Components Library contains ready-to-use model components.

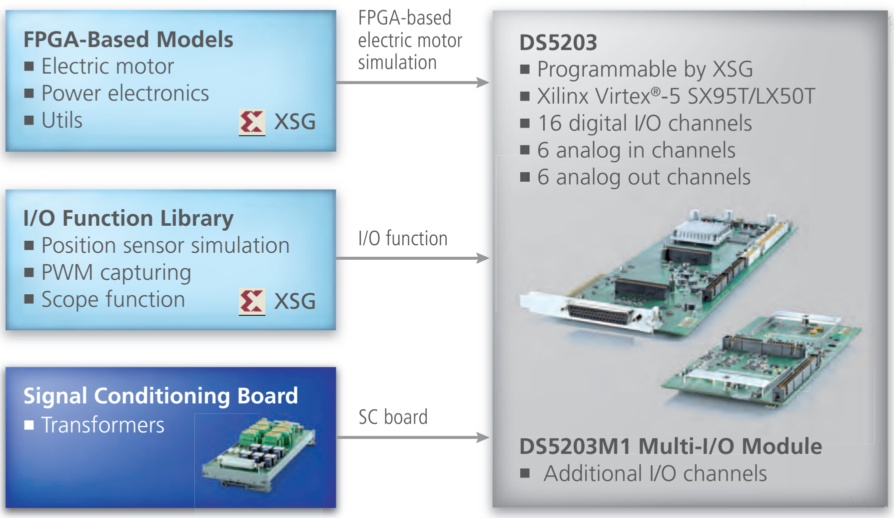


Figure 2: FPGA-based simulation uses the FPGA simulation models and the DS5203 FPGA Board, together with additional modules if required.

- *Extensions to model components:* Because the models are open, users can not only adapt them freely but also extend them by adding their own specific model components.
- *Offline and online simulation:* Function development on a PC is supported by offline simulation. The same model and the same parameterization can be used seamlessly throughout all the phases of devel-opment. It is easy to reuse tests and compare the simulation results from different phases.

Know-how from Practical Experience

To make sure the FPGA library is intuitive and easy to use, dSPACE incorporated their experience from numerous customer projects into it. The I/O functions were created along the same lines as the functions for the dSPACE EMH Solution, a special I/O board for the HIL simulation of electric motors. This was also based on dSPACE's experience from numerous customer projects.

The models are designed so that systems such as the highly dynamic electric motor model and the resolver model can run in parallel on the FPGA. Via an RTI interface, they communicate with a slower mechanical model running on the processor board.

Powerful Combination of Hardware and Software

The new FPGA library is ideal for use in conjunction with the freely programmable DS5203 FPGA Board. Users can implement complete model components from the library on the FPGA, for example, a permanent magnet synchronous motor model including a resolver model. The FPGA model is integrated into an overall model that runs on the processor board. The necessary interfaces are created automatically.

The connection between the dSPACE hardware and Simulink runs as usual via a Real-Time Interface (RTI) blockset. The DS5203 can be extended by plug-on I/O modules such as the DS5203M1, which doubles the number of channels. Other special modules support tasks such as the signal conditioning required for simulating electric motors, including transformers for resolver simulation.

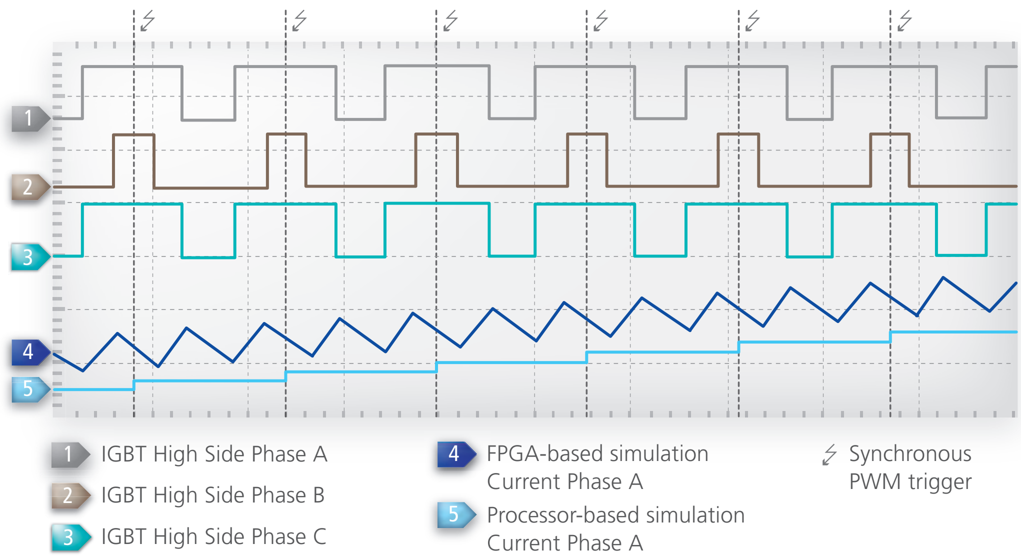


Figure 3: A comparison of the signal quality achieved with processor-based and with FPGA-based models.

Application Examples

The typical application areas for the XSG Electric Components Library are HIL simulations of highly dynamic controlled systems in the field of electric drives technology. Combining fast model computation and low I/O latencies provides benefits that enable these tough challenges to be met:

- Realistic representation of current behavior, as required for developing analog current controllers, with a sampling rate considerably higher than once per PWM period.
- Simulating electrical circuit frequencies higher than 1000 Hz takes processor-based simulations up against their limits. Using FPGA technology increases the range several times over. The computation is 500 times faster with an FPGA-based model.
- Highly dynamic applications such as DCDC converters require higher PWM frequencies. These frequencies are higher than 20 kHz, and the current and voltage can be represented realistically only by means of FPGA-based simulation.
- When an electric motor is simulated at power level, voltage and current values must be represented as realistically as possible. This is necessary if these reference values are to be used as input to the electronic load. Here too, fast computation is absolutely essential.

Conclusion

- Ready-made components for convenient creation of FPGA-based models
- Fast, project-specific model adaptation
- Online and offline simulation
- FPGA-based simulation provides much greater realism than processor-based simulation.

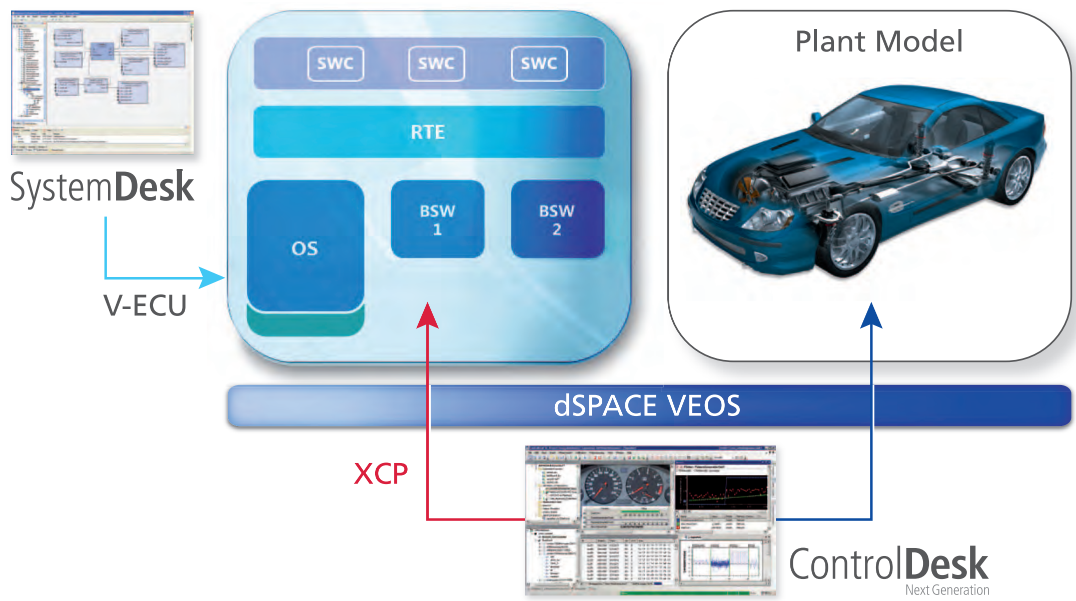
Real Tests for virtual ECUs

The trend is clear: Use the ECU models from the development process for simulation, and save a lot of time, money and work by early testing and validation. dSPACE is helping developers do this by introducing the simulation of virtual ECUs.

Dr. Krügel, what are virtual ECUs?
Nowadays, the application software and basic software for an ECU are available in an early phase of its development. If you integrate these two levels, bring them together, you get a virtual electronic control unit or V-ECU. A V-ECU is a realistic ECU model that can be executed on a simulation platform such as a PC. Thanks to the AUTOSAR standard, integration like this is much easier today than it would be without standardization. More and more customers were asking us for this form of integration and other potential uses.

How do customers benefit from using virtual ECUs?
Today, ECU architects can easily lose track of things in a complex system. But by generating a V-ECU, they can obtain a realistic representation of the future ECU as early as the development phase, and simulate it offline on a PC. They can perform consistency tests, check the plausibility of interfaces, and verify task scheduling very early on. And because ECU functionality can be tried out at an early stage, it can be verified even before the first ECU prototypes are available.

HIL system users benefit in other ways: They can use existing V-ECUs to test the actual HIL tests in advance and to optimize HIL simulator utilization – for example, by running



Use case for VET: Integration and virtual testing of ECUs. SystemDesk is used to model an ECU architecture and to integrate the SWCs and BSWCs that were implemented. Together with the controlled system model, the behavior of the ECU software can be simulated with the offline simulator dSPACE VEOS. The offline simulation is visualized and controlled in ControlDesk Next Generation.

> "Bring your ECU functions to life and test them early – it's the way of the future!"

Dr. Karsten Krügel, dSPACE GmbH

numerous variant tests beforehand. When virtual electronic control units are used for validation in these application cases and others, we call this "virtual ECU testing", or VET for short.

What dSPACE products are used for VET?

We believe that V-ECUs will play an important role from beginning to end of the development process, so we are integrating almost our entire tool chain. In the first phase, TargetLink® is the production code generator, and our SystemDesk® AUTOSAR architecture tool is used to generate V-ECUs. The controlled system models required for closed-loop scenarios are provided by dSPACE ASMs. ControlDesk® Next Generation enables visualization and experimentation. Our offline simulator dSPACE VEOS is used for PC-based simulation. And because all of our solutions are open, third-party products can be integrated at numerous points in the development process. We are already supporting numerous use scenarios for virtual ECUs, and more will be added, drawing on our wealth of experience in the HIL and rapid control prototyping fields. The initial response from our customers shows that we are on the right road.

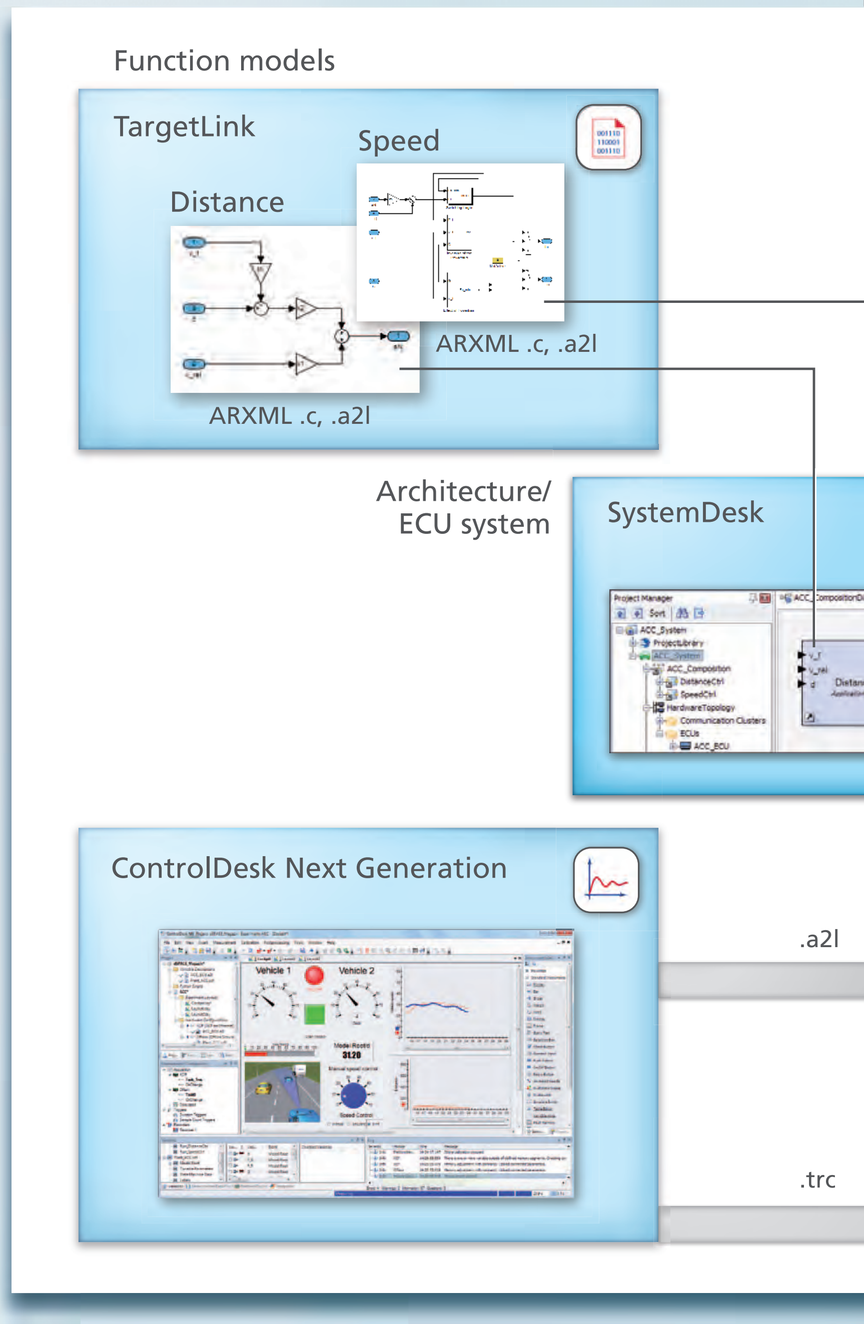
What other developments are planned?

We see enormous potential in automating the testing of virtual ECUs. Like HIL tests, these should run autonomously overnight or on weekends. Seamless use and reuse of these tests are also key issues. The same tests that were executed on a PC must be reused later on the HIL simulator. This also applies to models, data sets and layouts. And we will continue to extend the individual tools and optimize how they interact in VET application scenarios.

Dr. Krügel, thank you for talking to us.

Dr. Karsten Krügel
Dr. rer. nat. Karsten Krügel is a product manager at dSPACE GmbH and responsible for topics such as offline simulation and virtual validation.

Creating and Simulating Virtual ECUs



Introduction
With the dSPACE tool chain, architectures and function models are created according to the AUTOSAR standard, and then brought together and integrated to form a virtual ECU (V-ECU). The resulting V-ECU is connected to a model of the controlled system to form a simulation system that is executed in offline simulation on a PC, and visualized and tested with experiment tools.
The following example of an adaptive cruise control (ACC) system shows the workflow with the dSPACE products TargetLink®, SystemDesk®, the dSPACE offline simulator VEOS and ControlDesk® Next Generation.

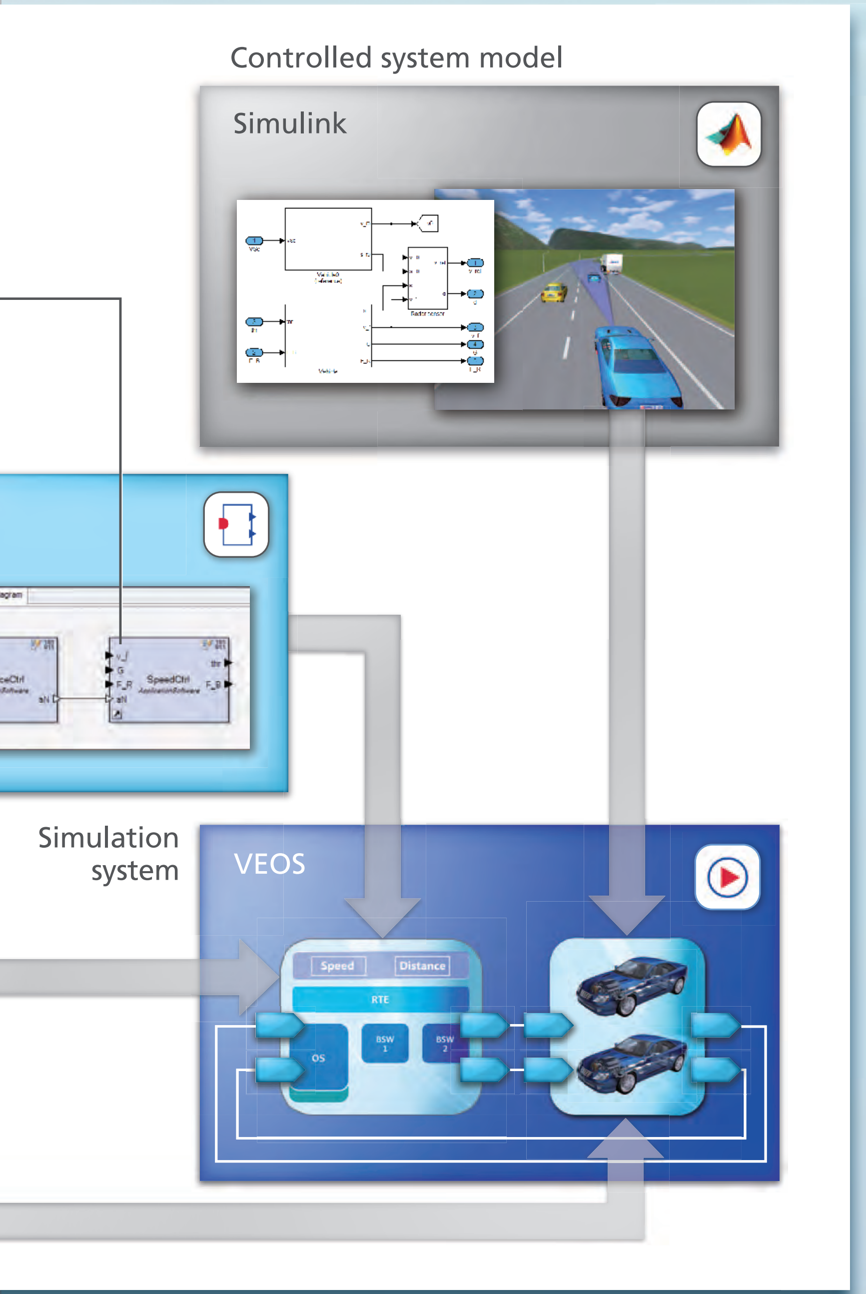
ACC System
The ACC system used as a reference example here consists of the function models for distance and speed control, which will be integrated on the ACC ECU later, and also of the controlled system model. This represents the vehicle environment for the ACC ECU, so it contains elements such as models for transmission control, look-up tables representing the engine, and a radar sensor for distance measurement. An additional part of the controlled system model is a preceding reference vehicle that drives at different speeds in different driving scenarios.

Creating AUTOSAR-Compliant Model Code
In this example of a development process, the ACC system's two controller models, Distance and Speed, are developed with TargetLink. The function developers model the interfaces and runnables for them according to AUTOSAR. AUTOSAR-compliant model code and a corresponding variable description (ASAP2) are generated for each TargetLink model. To bring the model parts together in a software architecture in SystemDesk, they are exported as AUTOSAR software components (SWCs) in a container that contains the generated code and ASAP2 files plus the associated AUTOSAR description files (ARXML).

Modeling AUTOSAR Software Architectures
After export from TargetLink, the containers for the Distance and Speed controller models can be directly imported into SystemDesk. With this bottom-up procedure, the SWCs and all the describing AUTOSAR elements such as ports, interfaces and data types and their internal behaviors are now available in SystemDesk. The compatible interfaces of the Distance and Speed components are then connected in a software architecture.

Generating Virtual ECUs
The software architecture and the SWCs it contains are mapped to a system with one ECU that was modeled in SystemDesk. OS tasks are created during ECU configuration, and the runnables modeled in TargetLink are assigned to the tasks. The ECU system can be created and configured manually, or alternatively, the process can be automated via SystemDesk. Once the ECU has been created, the AUTOSAR run-time environment (RTE) is generated to implement the connections between the application's components to the basic software.

To prepare the ECU for closed-loop simulation with a controlled system model, the open interfaces of the SWCs are defined as the ECU's inputs and outputs, and then the V-ECU is generated.



Controlled System Model and Creation of the Simulation System
A controlled system model mirroring the physical behavior of the two vehicles and the radar sensor is used to simulate the overall system. Thus, the ACC control in the V-ECU can be tested in advance virtually, and its behavior in the overall system can be visualized with ControlDesk Next Generation. The controlled system model is created with MATLAB®/Simulink®/Stateflow® and can be reused later in other verification steps such as HIL simulation.

Users can connect the V-ECU and the controlled system model via their defined inputs and outputs to create the simulation system. Because the interfaces have the same names, the connections can be defined quickly with one click.

dSPACE VEOS
Ideally, the PC computation uses simulation technology that can handle the same tools, models, transmission protocols and variable descriptions that have been firm fixtures in the real-time world for many years. dSPACE VEOS is precisely the product that is needed here, providing seamless transitions between PC offline simulations and real-time simulations on a HIL simulator. The same variable descriptions are used for online and offline application cases, i.e., ASAP2 for ECUs and TRC for controlled system models. With VEOS, a complex overall system can be simulated on a developer PC for early validation in the development process.

Experimenting and Testing
ControlDesk Next Generation lets users work interactively with the virtual overall system, providing completely transparent access to variables in the controlled system model and the V-ECU. The V-ECU's measurement and calibration variables (such as internal ACC control parameters) and the controlled system model's variables (such as the distance between the two vehicles and their current speeds) can be visualized and adjusted via numerous instrument types: switches, displays, sliders, etc. Users can create photorealistic layouts with these in order to assess intuitively during offline simulation whether the simulated software components are working correctly. The resulting project data, e.g., layouts, measurement data and data sets, can easily be reused later on a HIL simulator.

What Next?
As of the end of 2012, it will be possible to access VEOS directly from AutomationDesk®, so that automated tests of virtual ECUs can be created and executed efficiently. It will also be possible to simulate virtual ECUs with dSPACE SCALEXIO®. This will enable users to test and validate virtual ECUs in combination with real ECUs. In addition, Real-Time Testing and the Signal Editor in ControlDesk Next Generation will support offline simulation.

SCALEXIO: New I/O Functions and New Licensing Concept for Failure Simulation

With Release 7.2, dSPACE is expanding the range of SCALEXIO® I/O functions to include a SENT protocol and an Ethernet protocol, and also introducing a highly flexible licensing concept for failure simulation.

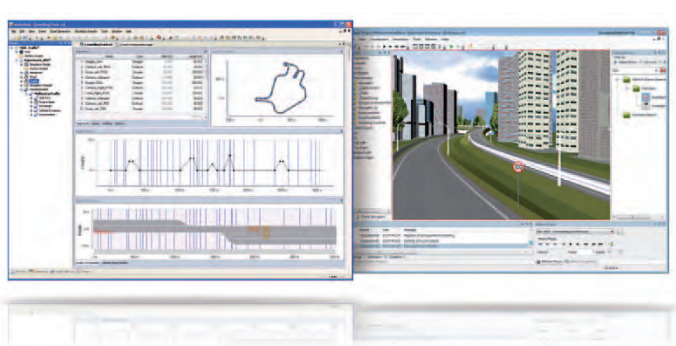
The new SENT In and SENT Out I/O functions support the SENT 2010 protocol. This SAE standard (J2716) provides users secure data transmission between the sensors and the electronic control unit.

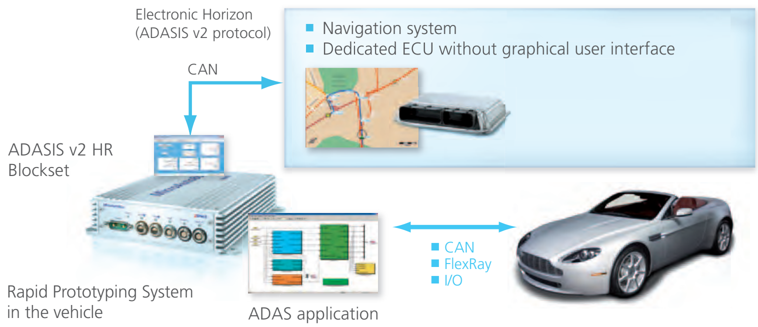
The other new I/O function makes it possible to use an Ethernet protocol. Connections with the Ethernet components can be established with the Ethernet interface of the SCALEXIO Processing Unit. And for configuration, dSPACE provides documented C code, which users can adapt to fit their individual needs. All of the I/O functions are configured graphically with dSPACE ConfigurationDesk®.
The new SCALEXIO licensing concept for failure simulation gives developers greater flexibility. At any time, the hardware license lets them activate the number of channels they need for failure simulation, and increase this number. All without any system modifications or system expansions. As a further benefit, the license can be used on different systems.

The next extended SCALEXIO version will support real-time processors with multicore architectures so that test systems with much more processing power can be set up.

Environment Simulation for Camera-Based Driver Assistance Systems

dSPACE **Automotive Simulation Models (ASM)** now offer optimized simulation of scenarios involving camera-based driver assistance systems. New functions for defining several lanes on virtual roads and an additional sensor model for lane recognition make developing lane departure warning systems and lane change assistants much easier. Together with the 3-D animation software dSPACE MotionDesk, it is also possible to set up systems that intuitively test camera-based traffic sign recognition.
For example, the signs can be placed directly in the virtual world of MotionDesk. The roads, maneuvers and virtual environment are created with ModelDesk's convenient graphical user interface, and the traffic signs can be evaluated in real time with MotionDesk's highly realistic graphical representation. In combination with MotionDesk, the ASMs provide a comprehensive solution for simulating complex traffic situations, including realistic simulation and animation of the traffic environment. The models are available as open Simulink® models for hardware-in-the-loop (HIL) simulation and as special Operator Versions for offline simulation.





Developing Predictive Driver Assistance Functions with the ADASIS v2 Standard

There's another new addition to dSPACE's range of products for developing driver assistance systems: the ADASIS v2 Horizon Reconstructor Blockset (ADASIS v2 HR Blockset). This is a Simulink® blockset that provides access to data on the road ahead. The data comes from a navigation system or a special ECU, for example, and is transmitted via the ADASIS v2 protocol. Used in combination with a dSPACE **MicroAutoBox** or **AutoBox** rapid prototyping system, the ADASIS v2 HR Blockset allows map-based driver assistance systems to be developed in an actual vehicle. This lets function developers implement and experience their ideas directly in the vehicle, and reduce development iteration cycles to a minimum. In addition to supporting the CAN bus, the ADASIS v2 HR Blockset also supports Ethernet as a transmission medium. Predictive road data such as curve radii, gradients and maximum speeds can be selected with just a few mouse clicks and connected to the actual driver assistance functions in the Simulink model on a PC. Then the real-time code is generated at the press of a button and subsequently loaded to the rapid prototyping system.

Function developers can now give their full attention to designing the actual application functions, and wave goodbye to spending time to implement the ADASIS v2 protocol themselves. ■

Eminent & Enigmatic: Alan Turing

He is one of the world's greatest computer pioneers. His work was instrumental in decrypting Enigma radio signals and had a major impact on the course of World War II. Yet outside the computer scene, his name is largely unknown: Alan Turing. "Eminent & Enigmatic – 10 Aspects of Alan Turing" is an exhibition at the world's biggest computer museum, Paderborn's Heinz Nixdorf MuseumsForum. Running from January 11 to December 16, 2012, the event presents the life and achievements of this British genius to a wider public. Born in London on June 23, 1912, Turing would have been 100 years old this year.

Entry to the exhibition is during the museum's usual opening hours: 9 am to 6 pm Tuesday to Friday, 10 am to 6 pm on weekends. ■

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