3/2005

dSPACE NEWS

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The Need for Speed: Our Boards Deliver

Customer Applications

DLR: Flying with the Iron Bird

Automotive Simulation Models: Completely Open

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dSPACE NEWS
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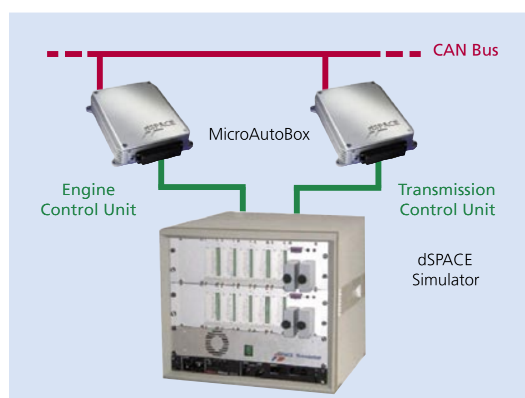
4 *The German Aerospace Center (DLR) is currently designing a test facility that uses dSPACE equipment and will provide enormous flexibility in developing future flight systems.*



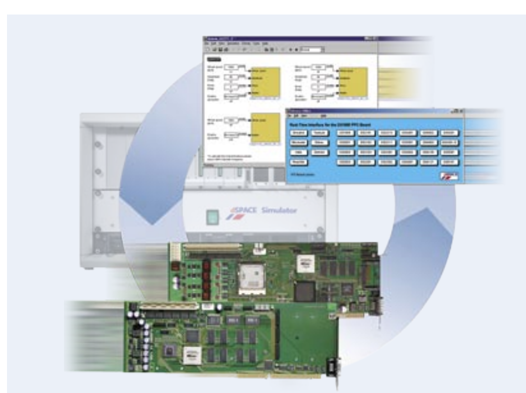
8 *An algorithm for estimating combustion engine torque, developed at the Università del Sannio, optimizes control strategies for engines and drivetrains.*

EDITORIAL

In April, I visited China for the first time. This was at the invitation of SAE, to give a lecture at the first conference on Automotive Electronics & Advanced Technology, organized by SAE China and SAE International in Shanghai.
I had heard and read a lot about the speed of development in China, but you don't really get a feel for the dynamics until you are actually in the country. There are enormous opportunities there, for both domestic and international companies. On the other hand: In the long term, Europe, USA, and Japan will all have to adjust to the competitive pressure that will come from China.
Every year, China produces around 350,000 engineers. By comparison, about 38,000 engineers graduate every year in Germany, 8,000 of them having studied electrical engineering (fewer than fine art graduates). Obviously, quantity alone will not boost productivity and innovation in development departments; a lot also depends on graduates' specialist subjects and overall course contents, and also on infrastructure. Even so, the figures give pause for thought.
On top of this, OEMs and suppliers at the technological forefront in the classic automotive countries feel virtually compelled to take their technology to China and open it up there – and in the final analysis, create competition for themselves. The message in Shanghai was loud and clear: potent Chinese OEMs are fast-forwarding towards greater independence.
A senior Chinese R&D manager put it like this: "The government has stipulated that we must meet the Euro 4 exhaust emission standard in 2008 in Beijing, and two years later in the whole of China. To do so, we cannot rely solely on integrating the technology of Western suppliers. We don't want to end up in a situation where we merely add the engine block. As an OEM, we work on selecting, evaluating, and adjusting various technologies (selective catalytic reduction, exhaust gas recirculation, variable geometry turbine turbocharger, etc.), and we want to use the results of this work ourselves. So we also need to do the engine management systems ourselves."
For tool manufacturers like dSPACE, the outlook is good. Suppliers will view the situation with mixed feelings. We look forward to interesting and challenging projects in the region.

Dr. Herbert Hanselmann
President

10 *Automotive Simulation Models (ASM) are a new product line from dSPACE, providing simulation models for developing and testing automotive electronic control units (ECUs).*



14 *Discussion of the tough requirements for complex real-time applications – solutions for an optimum mix of high computing performance, low I/O latencies, and perfect scalability.*

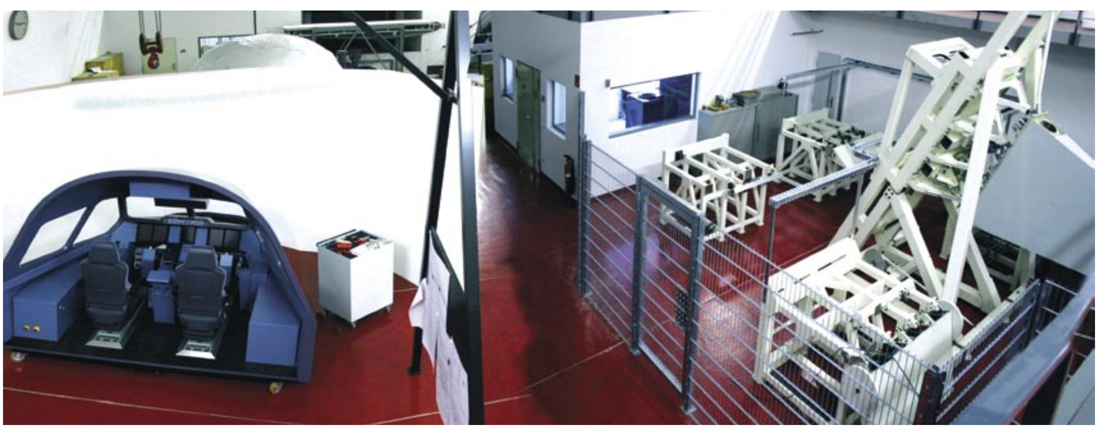
Flying with the Iron Bird

- Test bench for new actuator concepts at DLR
- Multiprocessor environment with DS1005 PPC Boards
- Realistic simulation of flight maneuvers

Statistically, you are far more likely to win the lottery jackpot than you are to experience a plane crash due to a system failure. This high level of safety is partly due to the comprehensive tests that flight systems have to pass while still on the ground – long before the prototype aircraft takes off for the first time. The German Aerospace Center (DLR) is currently designing a test facility that uses dSPACE equipment and will provide enormous flexibility in developing the flight systems of the future.

More Hydraulic Pressure – New Actuators

Standards require that the safety-relevant systems in commercial aircraft, such as the hydraulic systems for driving elevators, rudder, and ailerons, have double and triple redundancy.



▲ *The iron bird at the German Aerospace Center (DLR) allows a wide range of flight situations to be simulated. The control surfaces are on the right, the cockpit at bottom left.*

In hydraulics, for example, there are usually three independent systems. This redundant system architecture ensures maximum safety, as total failure of all systems is extremely improbable. However, minimizing weight is a major priority for aircraft designers, so the current trend is to increase the pressure in the hydraulic systems from the usual 3000 psi to 5000 psi or more, as greater hydraulic pressure allows the use of smaller and lighter actuators.

The "More Electrical Aircraft"

Another trend is towards replacing hydraulic actuators by electrical or electrohydrostatic actuators (EHAs), in other words, actuators with their own integrated hydraulic supply. The new Airbus A380 is an example. This latest generation of actuators, combined with a reduction of the central hydraulic system, cuts weight and therefore saves kerosene. The idea is called the "more electrical aircraft", and the aim is to reduce the diversity of power systems (hydraulics, pneumatics, electrics) to just one – the electrical system. The result would be a reduction in system complexity and weight.

To prepare for these new actuator concepts, we are designing a test facility with dSPACE equipment that will be able to cope with all foreseeable developments and allow us to test a broad range of actuators in widely varying configurations.

Our Most Important Tool: The Iron Bird

Commercial aircrafts typically fly at speeds of 800–900 km/h and at altitudes of 8–12 kilometers. Reproducing these conditions on the ground is extremely difficult, and to implement authentic system tests, we need a special test facility known as the "iron bird". Each iron bird is a framework of steel tubing roughly shaped like an aircraft, with practically all system-relevant components installed on it. Numerous situations that could conceivably occur in flight can be reproduced realistically on an iron bird. For example, aerodynamic loads can be simulated by means of load cylinders on the iron bird's control surfaces.

Realistic Flight Simulations on the Ground

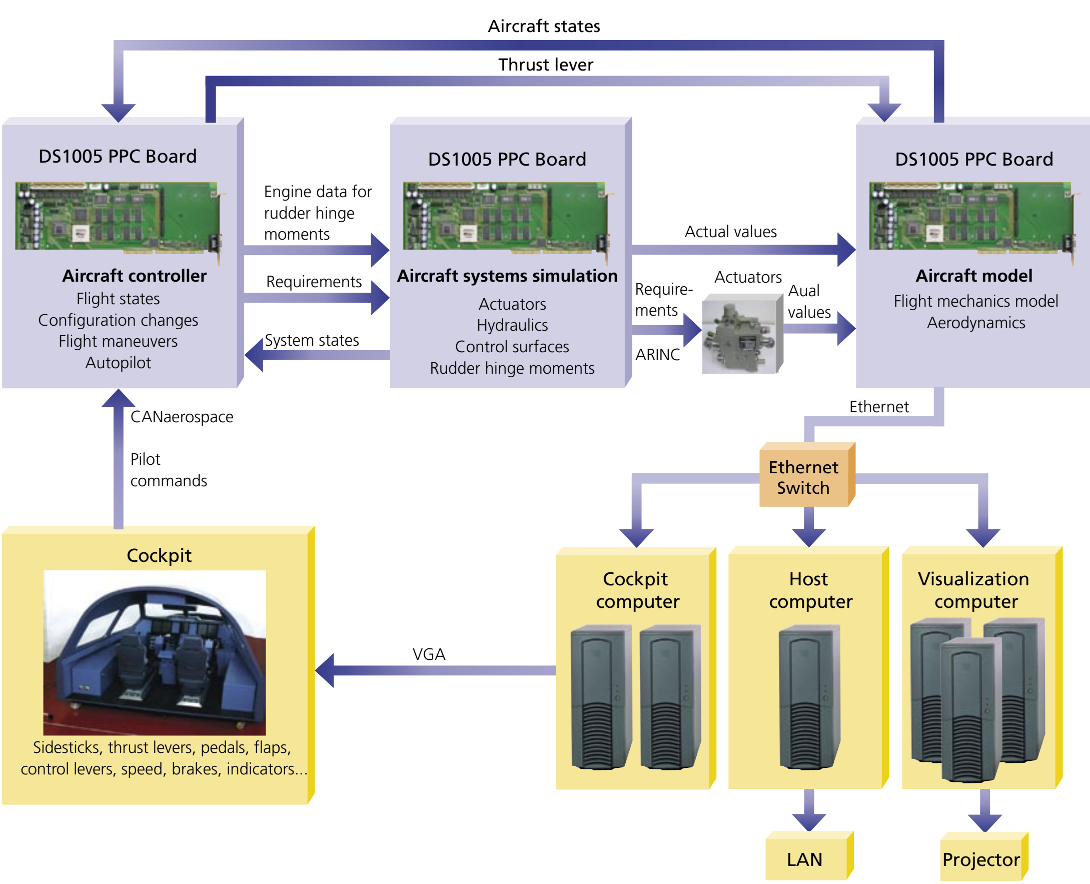
The iron bird will be used to develop and test new flight control concepts and systems. It is designed to let us run through the majority of all conceivable flight situations and simulate a large number of faults in the hydraulics, electrics, flight control system, and actuators. The faults that are simulated include pressure changes in the hydraulics and component failures. The iron bird will support the following testing activities for flight control systems:

- Reproducing aircraft hydraulic systems with pressures of up to 5000 psi
- Testing the latest generations of actuator systems, in varying configurations
- Integrating load cylinders for realistic simulation of real flight conditions
- Developing and testing new kinds of actuator systems
- Integrated cockpit simulation for implementing closed-loop tests

Simulation Environment with dSPACE Hardware

The simulation environment includes three DS1005 PPC Boards and various I/O boards from dSPACE. Each of the DS1005 boards has its own task to perform, such as calculations for the real-time simulation of flight maneuvers, the hydraulic system, horizontal stabilizers, or autopilot functions such as automatic landings. The boards are easy to configure for their tasks using MATLAB®/Simulink®, and the control can also be changed quickly by modifying the Simulink model. Because the simulation environment is modular in design, additional DS1005 boards and I/O boards can be added, or the existing ones replaced, with little effort. This allows us to produce a multiprocessor environment that is tailor-made for a new range of tasks. The dSPACE components give us the flexibility we need to adapt the test facility to new actuator concepts and aircraft types, with a minimum of effort.

Holger Spangenberg
Deutsches Zentrum für Luft- und Raumfahrt
Deutschland



◀ *The multiprocessor environment consists of three DS1005 PPC Boards and performs calculations for the real-time simulation of flight maneuvers, hydraulic system, horizontal stabilizers, autopilot functions, automatic landing, and so on.*

Process for By-Wire-Brakes

- Process to identify the optimal combination of processor, sensors, code and resources
- TargetLink's code profiling techniques aid in processor selection
- Quick turn around

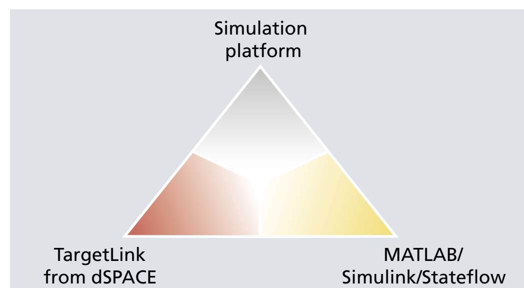
Fast-tracking electronics development usually creates prototypes that are not representative of the final product. PBR and the Research Centre for Advanced By-Wire Technologies (RABiT) decided to transform this design approach. They integrated TargetLink into a product development cycle to accelerate development of PBR's new electric park brakes. They achieved the triple crown of enhancing features, functions and performance, added automatic production code generation to the process – while controlling product costs.

New Park Brakes

Developing automotive products that enhance the driver-vehicle relationship, increasing product performance and reduce costs would seem to be incompatible requirements. At PBR, we took on this challenge when we developed our range of ePark™ electric park brake solutions. The criteria to be met by the product include:

- End users' need for reliability, ease of use, convenience and advanced safety features
- The vehicle manufacturers' focus on reliability, reduced weight, cost, manufacturing flexibility, improved design freedom, performance, and packaging space

While developing our ePark product range including a cable puller and an innovative park brake mounted directly on the disc brake caliper, we bridged the development divide between software, sensor system and electronics using modern development techniques and processes primarily supported by the close integration of TargetLink from dSPACE and MATLAB®/Simulink® from The MathWorks.



▲ *Development triangle*

Development Bottleneck

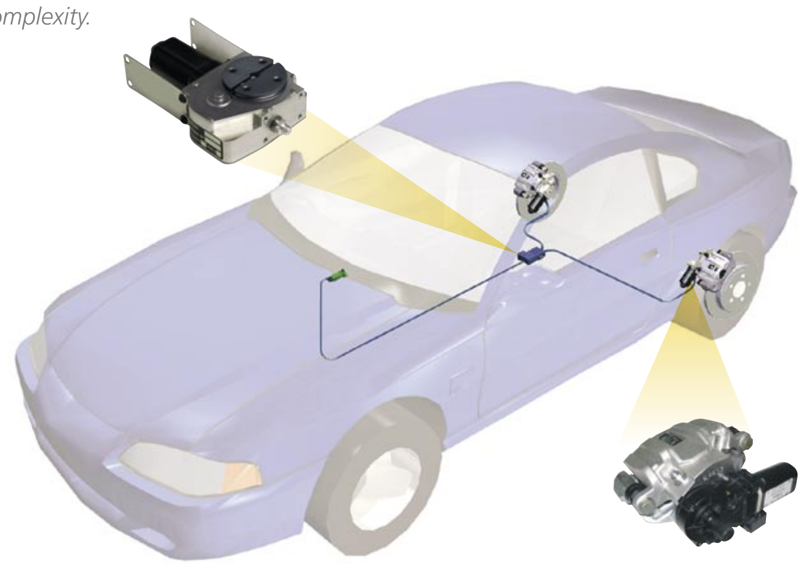
Electronics is a significant part of the modern automobile. The software that supports electronic devices is intangible; for some period designers may not fully comprehend the optimum configuration of sensors, processors, electronics and software that achieves the lowest cost. This often initially sends prototype development in a direction that is not representative of the final product intent.

In the development of mechanical components, methods like stereo lithography are used to produce quick-turnaround prototype parts that we can evaluate for a number of criteria including fitment, clearance and appearance. However, there is no such family of techniques for electronics.

Changing of the Guard

Working closely with RABiT, we challenged ourselves to find a workable solution and opted to use Simulink to deploy a zero-distance, virtual development

▼ *PBR's innovative electric park brake reduces vehicle weight and park brake complexity.*



environment that simulates the park brake control structures. TargetLink was used to generate code and perform processor-in-the-loop (PIL) simulations. To evaluate the functional prototypes, we developed a simulation platform to execute the code on each selected processor and to connect the sensors. This proved to be an efficient development triangle, where at any stage activities can be monitored, evaluated, compared and tested for attributes such as performance and functionality using TargetLink's PIL simulation and code profiling features.
This process enabled us to determine the viability of a concept or optimization strategy. The result of this method was an integrated solution that mirrors the final product.

Stage 1 – Control Design

Development of the control structures included modelling the system sensitivity and response times against target hardware requirements. This step enhances early stages of product development as the requirements are assessed by other divisions e.g. product test for:

- Clarity
- Completeness
- Consistency
- Functionality
- Performance
- Testability

Stage 2 – Model Simulation

Simulation of the models was conducted and the results used to evaluate performance and establish if the product goals were attainable, providing a benchmark for each solution. This step ensured that any changes made did not have a negative impact.

Stage 3 – Development of Test Harnesses

Simulation test harnesses that enabled over 20 test cases to be performed were created. This allowed collection of maximum and minimum values and studies of sensors' cost, performance and resolution to be conducted. The results of this were fed back into the control design. This step allowed us to quickly evaluate the impact of sensitivity and refine the requirements of supporting sections to suit the selected sensor.

Stage 4 – Fixed-Point Implementation

The target code was converted into fixed-point, and integration simulation was performed again to establish the scaling errors. Any scaling errors identified were fed back into the control design.

Stage 5 – Simulating the Target

Using PIL simulation, TargetLink code was executed on the simulation platform, effectively creating functional prototypes. The recorded signals from stage 3 were used to excite the simulation.

Stage 6 – Performance Feedback

The results of the tests, including sensor results, processor performance, code size and RAM size were analyzed with the aim of optimizing the control design for the selected processor and electronics platform and the desired functionality.

Step 7 – Target Deployment/ Testing

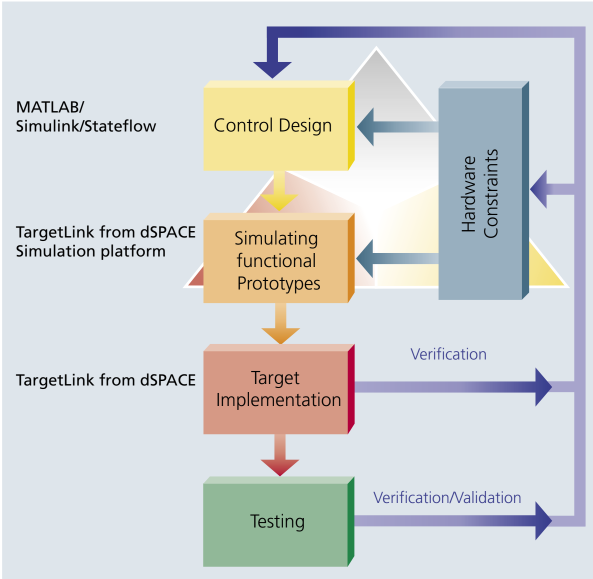
The resultant code was deployed on the target and tested in both an HIL- and a vehicle-based environment.

Answers in No Time

Simulation did more than just simulate, linking in the development variables, it also enabled us to evaluate different variants of processors, electronics and sensors. This was not done against standard test routines, but rather each solution was individually optimized for the specific target elements. Any assumption of cost conflicting with performance, features or functionality was quickly swept away, enabling the right design decision to be made.

Dennis Plunkett,
System Engineer
PBR Australia

▼ *Performance and resource measurements were conducted to select the best-suited combination of processor and sensors for the control design.*



PBR is a subsidiary of Pacifica Group Ltd. and Australia's leading supplier of brake system technology. SAE Australasia's Gold Award for Automotive Engineering Excellence was awarded in 2004 for the design and development of the ePark electric park brake.
www.pbr.com.au
RABiT is a cooperative facility for by-wire technology development and vehicle dynamics research.
www.rabit.com.au

New Strategy for Torque Estimators

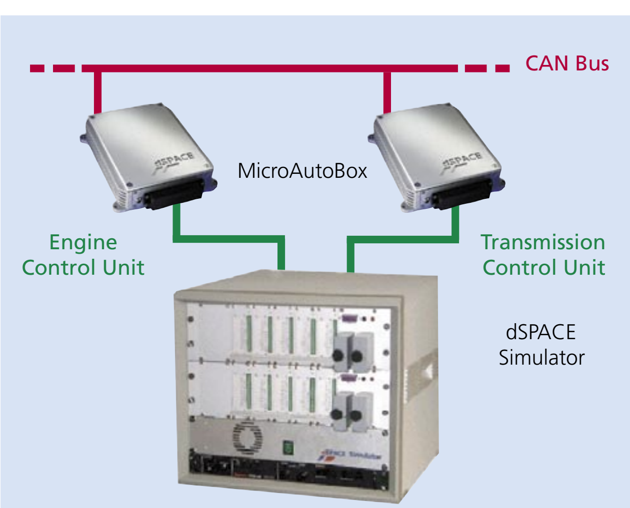
- **Università del Sannio uses dSPACE Simulator Mid-Size**
- **Torque estimator for internal combustion engines**
- **Testing of integrated control strategies**

In automotive powertrain control strategies, engine torque estimators are preferred to expensive sensors for obvious economic reasons. At the "Group for Research on Automatic Control Engineering" (GRACE) laboratory at the Università del Sannio in Benevento, Italy, engineers developed a completely new strategy, called "nicely nonlinear torque estimator". This is an algorithm that can be efficiently used for engine-transmission or engine-vehicle integrated control strategies. The tests confirming the performance of the proposed algorithm were run with dSPACE prototyping and hardware-in-the-loop systems.

Torque-Based Control Strategies

In automotive control strategies, particularly vehicle dynamics applications, an amount of torque generated by the internal combustion engine is required at the crankshaft in order to achieve specific goals. For example, traction control applications require net torque regulation during wheel slip or in response to the driver's request. Similarly, for emissions reduction and fuel consumption strategies, a suitable torque profile is actuated without degrading the performance requested by the driver. In this scenario, a controller able to accurately regulate the engine torque is vital to reach high performance. Since cheap and noninvasive on-line engine torque sensors are not yet available, an observer is necessary to design a closed-loop control scheme. In this project a torque estimator, suitable for different applications, was developed and tested in real time. We set up a control architecture using dSPACE rapid control prototyping (RCP) and hardware-in-the-loop (HIL) hardware. The dSPACE Simulator Mid-Size for HIL tests is equipped with a DS1005 PPC Board and two DS2211 HIL I/O Boards. The engine and transmission control strategies that we are developing are tested by means of two MicroAutoBoxes. The I/O capabilities of MicroAutoBox allow communication between the two electronic control units (ECUs) by means of a CAN bus based communication link. The engine model running on the dSPACE Simulator Mid-Size is an en-DYNA® SI 1.5 from TESIS.

▼ *The RCP and HIL station, at the automatic control laboratory of the Università del Sannio.*

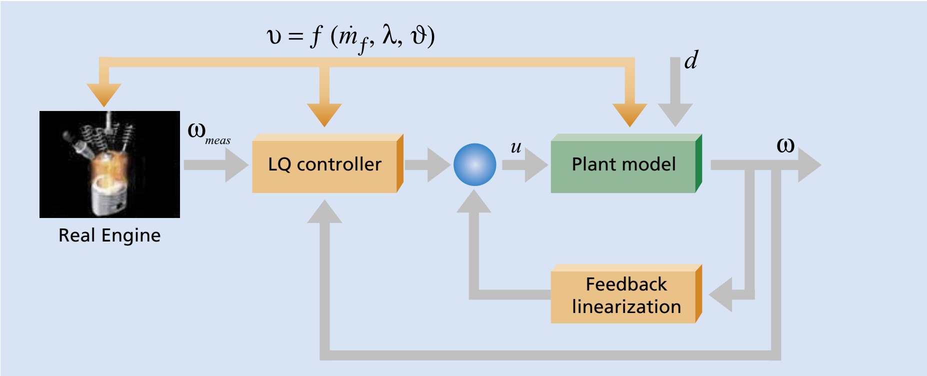


The Nicely Nonlinear Torque Estimator

The problem of estimating the mean value of the total torque acting on the crankshaft was treated as a tracking problem, solved by utilizing the information on injected fuel, air-fuel ratio, spark angle and the measured shaft speed (see tracking control scheme). The system to be controlled is a simplified nonlinear model of the combustion process. It reproduces the engine torque production and the shaft speed dynamics. In order to track the measured shaft speed ω_{meas}, a model-based control strategy is designed. In particular, the control input u represents the amount of extra torque that the system needs to reach the desired shaft speed, compensating both model uncertainties and all unknown external torques. It is computed by solving an optimal control problem to minimize the following function:

$$V = \frac{1}{2} \int_0^{\infty} \left[q(\omega - \omega_{meas})^2 + \rho u^2 \right] dt$$

The algorithm consists of three steps. First a nicely nonlinear model, i.e., a second-order Taylor approximation of the engine model including the combustion model and crankshaft dynamics, is computed. Then a linear model of the engine is obtained by means of feedback



◀ *Tracking control scheme: d is the unknown disturbance, which groups all external load torques, and υ is the known disturbance, a vector formed by fuel mass flow rate, air-fuel ratio, and spark advance.*

Variables	Description
ω	Shaft speed
u	Control input representing the amount of extra torque
d	Unknown disturbance
υ	Known disturbance
$\dot{m}_f$	Fuel mass flow rate
λ	Air-fuel ratio
ϑ	Spark advance

linearization of the nicely nonlinear system. Finally, an LQ tracking control over an infinite horizon is obtained for the linear system.

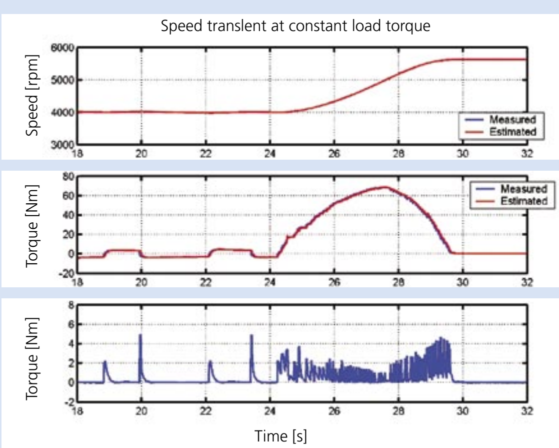
Testing Phase

The testing phase confirms the excellent performance of the proposed algorithm, with regard to both the precision of the estimation and the robustness of the strategy to uncertainties. These encouraging tests induce us to continue the development of control strategies for engine and transmission.

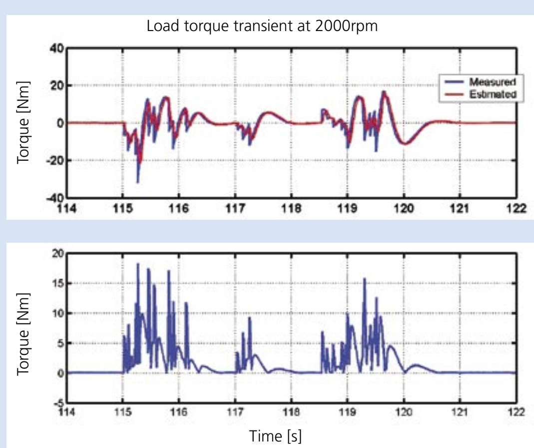
Moreover, since in a hierarchical control architecture, such as in automotive applications, high-level strategies are executed on dedicated ECUs and demand specific torque profiles for the torque controller running on a different control unit, and since communication between different ECUs usually relies on data busses such as the CAN bus, another research activity we aim to analyze in depth is the integration and the communication of such different strategies. With this aim, we set up a similar control architecture for integrated engine/transmission control strategies using dSPACE prototyping and hardware-in-the-loop hardware.

Paolo Falcone, Giovanni Fiengo, Luigi Glielmo
Dipartimento di Ingegneria
Università del Sannio
Benevento, Italy

The details of the algorithm can be found in P. Falcone, G. Fiengo and L. Glielmo, "Nicely Nonlinear Engine Torque Estimator", 16th IFAC World Congress, Prague



▲ *Speed transient at a constant load torque of 20 Nm.*



▲ *Load torque transient at a constant speed of 2000 rpm.*

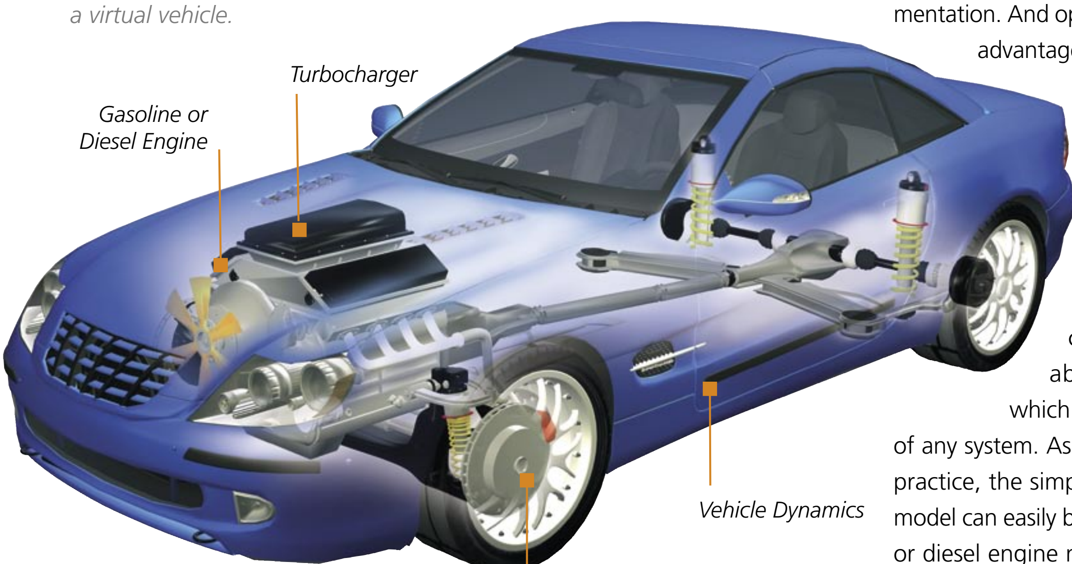
Open Simulation Models

- dSPACE Simulator and models from a single source
- Perfect HIL integration
- Graphical parameterization in ModelDesk

Automotive Simulation Models (ASMs) are a new product line from dSPACE, providing simulation models for developing and testing automotive electronic control units (ECUs). The models are designed for engine and vehicle dynamics simulation and have their own graphical user interface, ModelDesk. They are ideal for both online and offline simulation. We focus on hardware-in-the-loop (HIL) simulation here.

dSPACE is the world's most successful provider of HIL solutions and was recently recognized as the "Leading Manufacturing Test Company of the Year" by Frost & Sullivan for its pioneering achievements. These lay mainly in developing simulator hardware and the necessary operating and control software (ControlDesk, Real-Time Interface, etc.). The models of the controlled systems that were used in simulation came from other manufacturers or were developed by customers themselves. However, a simulator and the model running on it need to be regarded as a single unit, and an increasing number of customers were asking their system supplier, in other words dSPACE, to meet special requirements. To respond to customers' requests faster and better, we decided to develop our own models.

▼ *Use ASMs to build a virtual vehicle.*



Integrating HIL Models

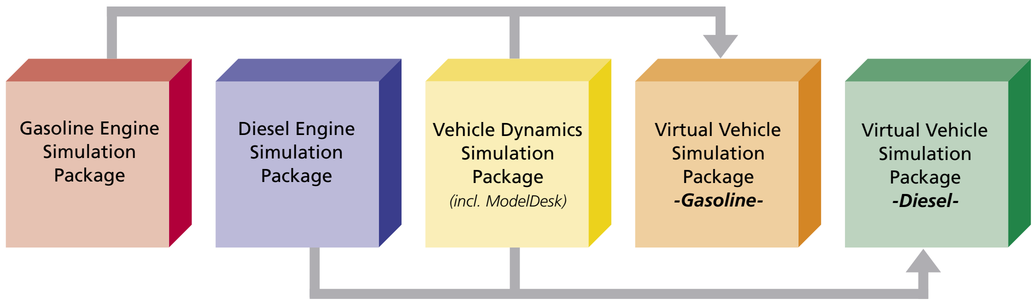
In the real world, even the best simulator cannot reach its full potential if it cannot be adapted properly to project requirements. So flexibility in commissioning and modification is a vital requirement for any HIL system. We have therefore given our new Automotive Simulation Models the features they need for better integration into customer projects and for faster modification processes.

Open Simulink Models

The ASMs are implemented completely in Simulink®, and a major feature is that they are visible to users right down to the level of standard Simulink blocks. This means that users can view the models and modify them, with the assistance of comprehensive documentation. And open models have another invaluable advantage: they provide direct access to vital parameters during simulation.

Seamless Interfaces for Interoperability

The engine, drivetrain, and vehicle dynamics systems all share the same interface concept. This is based on two variables, engine speed and torque, which form the input and output signals of any system. As an example of what this means in practice, the simple engine in the vehicle dynamics model can easily be replaced by the complex gasoline or diesel engine model, as all the systems have the same interfaces. The models can be put together like building blocks to construct more complex systems, right up to a virtual vehicle.



◀ *Overview of simulation packages.*

User-Friendly

Combinations of simulators and models from different manufacturers typically require a certain amount of adaptation work. The ASMmodels and dSPACE Simulator are ideally adapted to one another. This is immediately apparent when the I/O models and the controlled system models in a simulator are initialized: their start-up procedures interact perfectly.

The model signals are available in a hierarchical bus, the ASMSignalBus, implemented with the Simulink Bus Selector. As an example: to find the pressure in the common rail system of a diesel engine, the path through the bus is Engine – Fuel System – Rail – p_Rail. With the ASMSignalBus it is easy to connect the Simulator's I/O hardware to the associated signals.

ModelDesk

ModelDesk is a graphical user interface for parameterizing and managing parameter sets. It contains graphical tools for creating roads and planning maneuvers. ModelDesk finds the automotive components of a model and displays them in graphical form. If brake hydraulics are added to the vehicle model, ModelDesk displays the appropriate graphical parameter pages. The intuitive user guidance is also graphical: clicking a differential in the drivetrain displays the parameterization page for that differential, for example.

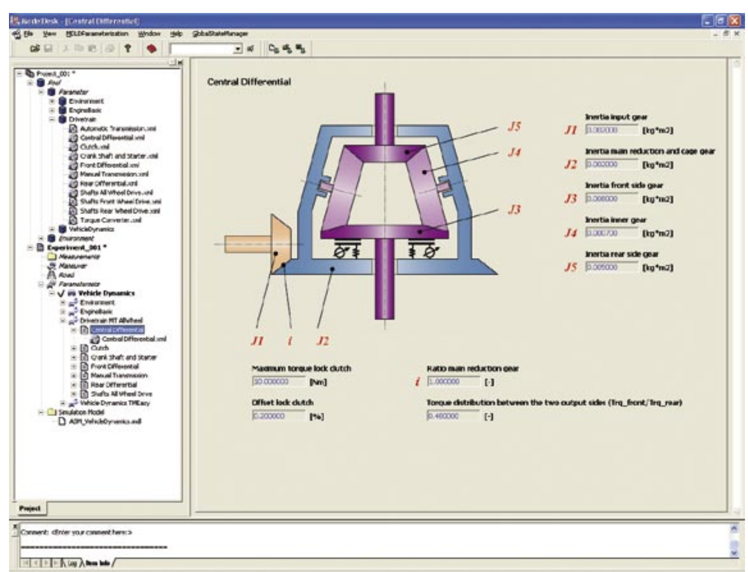
ModelDesk currently supports the vehicle dynamics and brake hydraulics models, and can provide parameter sets for offline and online simulation.

ASM Packaging

The following simulation packages will be available at launch:

- Gasoline Engine Simulation Package
- Diesel Engine Simulation Package
- Vehicle Dynamics Simulation Package

▼ *Parameterizing a differential in ModelDesk.*



Engine Models in Brief

The engine properties are represented by a mean-value model with crankshaft-angle-based torque generation, dynamic simulation of the air path, and several injection models. To simulate the engine in a vehicle system in a closed control loop, the engine model has a drivetrain with longitudinal dynamics and either manual or automatic transmission, and models for the driver and the soft ECUs.

Vehicle Dynamics Model in Brief

The physical vehicle properties are modeled as a multibody system with 32 degrees of freedom. The model contains a drivetrain with elastic shafts, a table-based engine, two semiempirical tire models, a nonlinear vehicle multibody system with table-based axle kinematics/elastokinematics and aerodynamics, and a steering system model. It also includes an environment model consisting of a road, driving maneuvers, and a driver.

ASM flyer

RapidPro: Stand-Alone Prototyping ECU

- Flexible prototyping platform
- Based on the new MPC5554
- RapidPro concept of sensor/actuator adaptation

RapidPro will soon be available as a stand-alone electronic control unit (ECU) for prototyping. The RapidPro Control Unit will form the basis of a modular hardware platform, using the new microcontroller MPC5554 (Copperhead). This will mean you can develop and test new concepts for control functions on production-close hardware and software. Open software interfaces will enable you to integrate C code from different sources and to integrate a calibration tool.

Prototyping Building Blocks

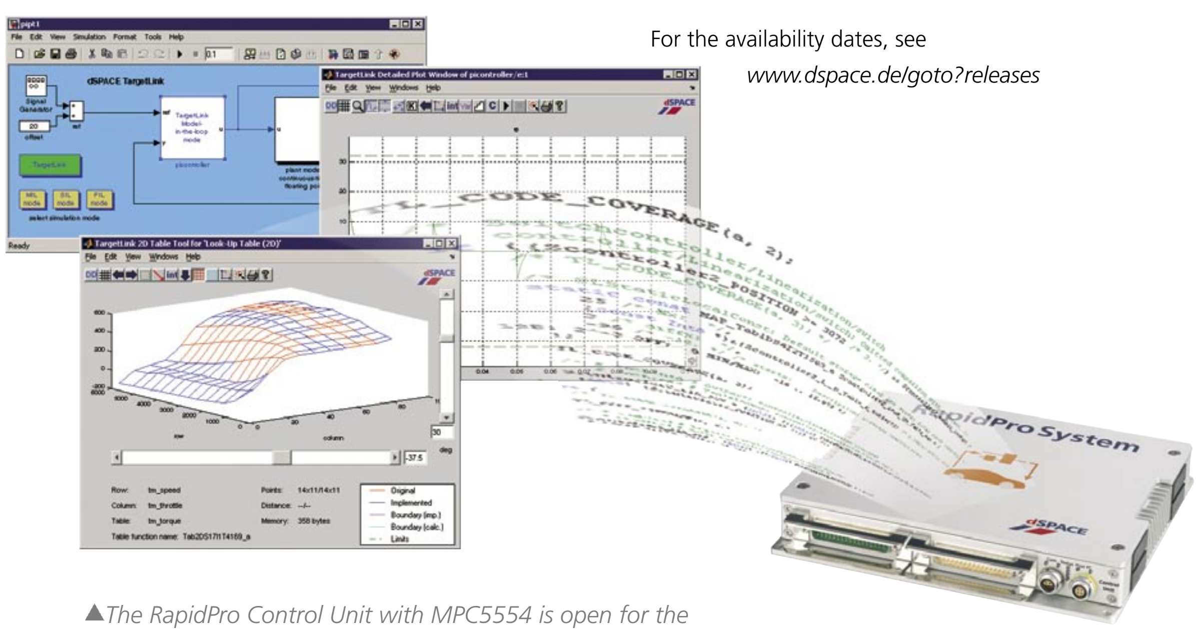
The RapidPro Control Unit is the central component of the highly adaptable prototyping ECU. It has a new microcontroller module with the powerful MPC5554 especially for this purpose, plus a new USB communication module for fast connection to CalDesk, dSPACE's experiment and calibration software.

For flexible sensor adaptation, there are slots for several signal conditioning modules on the Control Unit. If you need power stages for actuators or additional signal conditioning, you can add further RapidPro units (Power and SC Units) to build a stack. RapidPro's modularity and scalability enable you to build individualized systems quickly and cost-efficiently. As with all RapidPro units, the hardware is put into operation and configured by means of ConfigurationDesk, the software that was tailor-made for RapidPro.

C Code from Different Sources

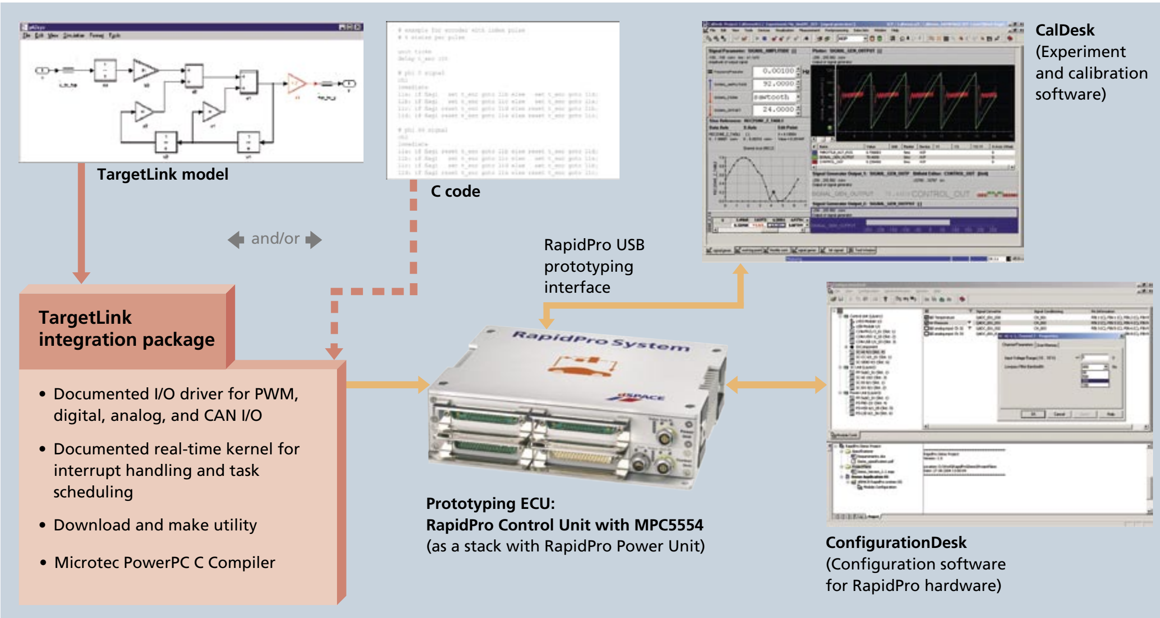
If you already have existing C code, you can integrate it on the RapidPro Control Unit manually. To support you, there are I/O drivers for PWM, digital, analog, and CAN I/O, plus a real-time kernel for interrupt handling and task scheduling. For model-based code generation from TargetLink, dSPACE offers an additional integration package that simplifies the integration of I/O, provides a TargetLink example model, and performs the build and download process at a click. The system is currently running in the customer pilot phase.

For the availability dates, see *www.dspace.de/goto?releases*



▲*The RapidPro Control Unit with MPC5554 is open for the implementation of C code and TargetLink models.*

RapidPro Hardware



◀ RapidPro Control Unit with MPC5554: an independent prototyping ECU, expandable flexibly for sensor and actuator adaptation.

MTest 1.3 Goes Solo

Good news for everyone who wants to run systematic and automated tests during function design with TargetLink: The MTest test management software is now available as a stand-alone solution. From Version 1.3, MTest is no longer an add-on to AutomationDesk, but can be ordered separately.

- **Tests during function design**
- **Stand-alone test tool**
- **Extended product features**

MTest vs. AutomationDesk

Design engineers showed such interest in MTest when it was integrated into AutomationDesk that dSPACE decided to make it a separate product.

Not everyone needs AutomationDesk 1.2's full functionality, which is optimized for hardware-in-the-loop testing. If your task is to run automated tests during function design with Simulink® and TargetLink, for example, you can now concentrate fully on MTest 1.3. The stand-alone version of MTest is also based on the proven AutomationDesk technology.

Features of MTest 1.3

Useful new features have been incorporated into the new version. Signal display has been improved, for example, and report generation has also been reworked and enhanced. MTest 1.3 is compatible with all MATLAB versions supported by TargetLink 2.0.6 and 2.1. Further innovations:

- Subsystems in TargetLink models can be tested.
- Masked subsystems can be selected as test objects.
- Fixed-point data types are supported.
- Subreports of a result tree can be generated, for example, for individual sequences of an extensive test.
- Test execution times can be optimized by TargetLink code generation for model changes only.
- Test frames and dSPACE Data Dictionary can be updated from a modified source model.

MTest 1.3

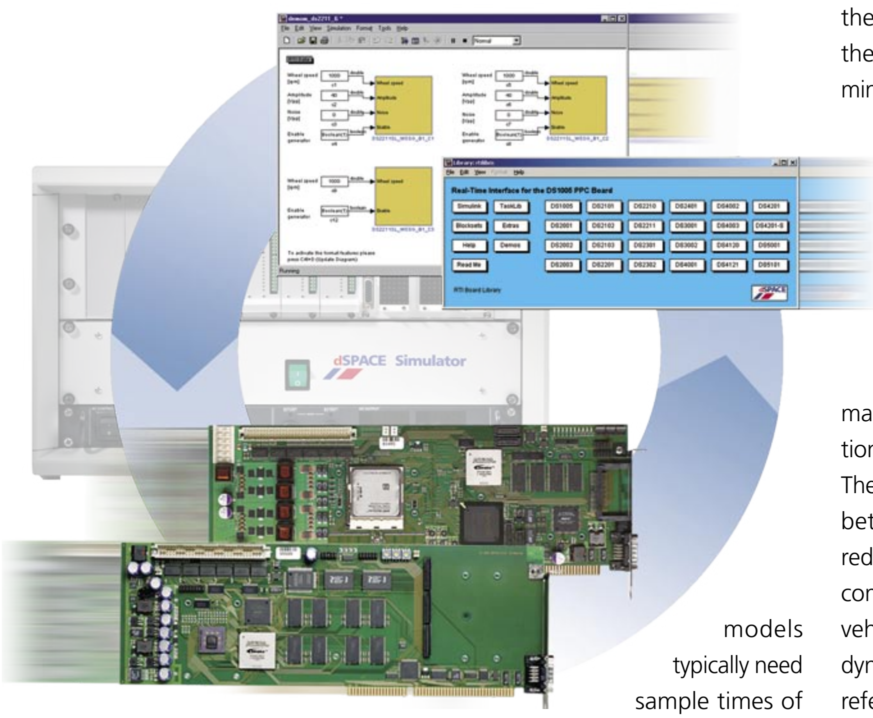
Real-Time Without Pitfalls

- High processing power
- Fast I/O performance
- Perfect scalability

Your real-time applications need more than just processing power. That is only one of the preconditions for meeting future challenges. The others are high-speed I/O-to-processor communication, system scalability, and a comprehensive software environment. Real-time systems from dSPACE provide all this, giving you optimum conditions for real-time applications.

Present Trends in Real-Time Hardware

Hardware-in-the-loop (HIL) simulation with complex, precisely detailed simulation models requires enormous real-time computing power. Common automotive HIL



models typically need sample times of 1 ms or less to meet real-time requirements. In Formula One applications, engine and vehicle dynamics simulations are usually performed with sample times of 0.5 or 0.25 ms. The size of HIL models continues to increase rapidly, and with it the need for more processing power. dSPACE regularly upgrades dSPACE Simulator and boosts the speed of its real-time hardware to meet future challenges.

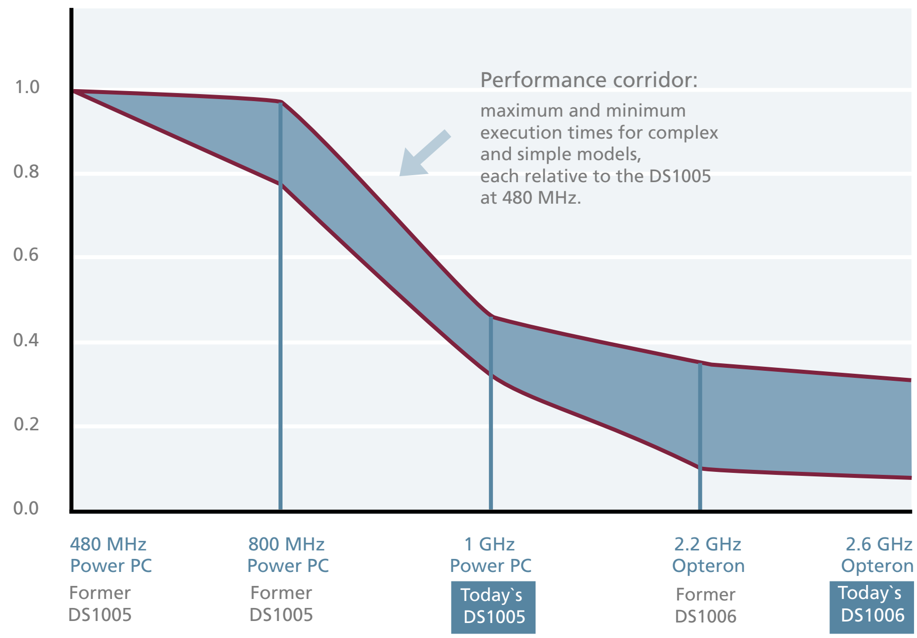
Upgraded Processor Boards

dSPACE Simulator's current flagships are the DS1006 Processor Board, now running at 2.6 GHz, and the DS1005 PPC Board with 1 GHz processing power. Designed for use in laboratories, the DS1006 has the greater computing power, while the DS1005 is the board of choice wherever I/O latencies must be minimized, and for in-vehicle applications such as rapid control prototyping (RCP). For example, the turn-around time for an F14 Simulink® demo model (without I/O) running on the DS1005 is less than 1.2 µs. Combining the DS1005 with the new DS2004 High-Speed A/D Board (see also article on page 18) produces sampling rates of up to 275 kHz for a PID control loop, including I/O.

The diagram on page 15 illustrates the performance increase of dSPACE processor boards in relation to the former DS1005 PPC Board with 480 MHz. The corridor shown in the diagram indicates the range between the maximum and minimum achievable reduction in processing time, which depends on the computed model and the I/O communication. Large vehicle models without I/O, and engine and vehicle dynamics models with comprehensive I/O, are used as references. The larger the computational load of the model (not counting I/O), the greater the advantage of the powerful AMD Opteron™-based DS1006. You can calculate large and complex HIL models on the DS1006 in a single task, without having to split them.

Low I/O Latencies

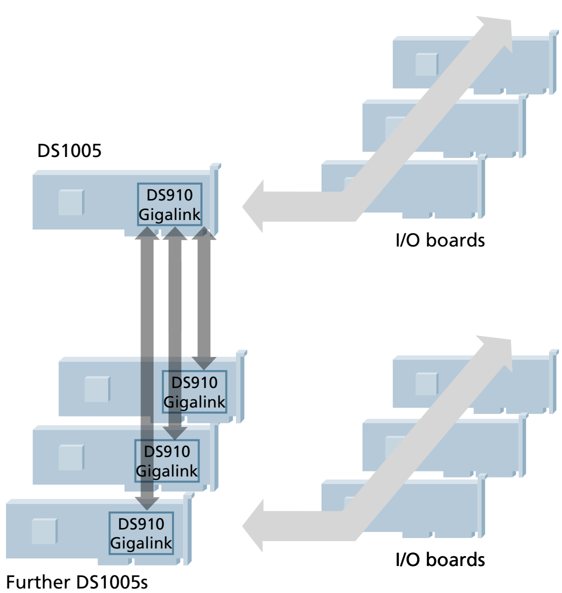
When designing the DS1006, dSPACE chose the AMD Opteron™ instead of an Intel® CPU because of its Hyper-Transport™ capabilities. The HyperTransport bus allows fast access to the Opteron processor itself. The I/O-to-processor communication of the DS1006 is performed via HyperTransport and the peripheral high-speed I/O bus (PHS). As the PHS bus is especially designed for real-time applications, this guarantees fast I/O access times. There is no software overhead caused by extensive transfer protocols. In contrast a solution with PCI I/O would be significantly slower than the HyperTransport connection. HyperTransport is 12 times faster than PCI-X, for example. Excellent processing power plus fast and deterministic access to I/O hardware with minimum latencies make dSPACE processor boards considerably faster than solutions based on commonly available PCs.



▲ *Performance increase: reduced processing time per processor board relative to the DC1005 at 480 MHz.*

System Scalability

Our customers often start running HIL simulation in one application, typically testing engine controllers, vehicle dynamic controllers, or body electronics separately. Then as control functions are increasingly distributed across several ECUs, HIL component testers have to be networked to test the interaction between ECUs that were previously tested separately. This requires flexible multiprocessor systems and comprehensive software which handles complex task synchronization automatically. dSPACE processor boards give you the ability to build scalable multiprocessor systems.



▲ *Building multiprocessor systems with dSPACE boards.*

We offer you scalability in terms of increasing performance and/or spatial distribution. Our multiprocessor systems achieve a net transfer rate of more than 600 Mbit/s (after deducting the protocol overhead) with the help of 1.25 Gbit/s optical fiber technology. You can connect up to 20 processor boards in one system and over distances exceeding 100 meters. Our customers never have to worry about losing earlier investments, as their systems are always expandable. It is even possible to couple an older DS1005 running at 480 MHz with the current DS1005 running at 1 GHz.

The dSPACE Real-Time Interface (RTI) software makes it easy to configure each dSPACE board in Simulink and to generate the code for your real-time hardware automatically. You can use RTI-MP to define the multiprocessor structure in Simulink, including the communication channels between the processors.

Conclusion

Processing power on its own does not guarantee a successful real-time application. When you plan your real-time system, you should also look for low I/O latencies, scalability, and a comprehensive software environment. All four factors need to be just right to produce a powerful and efficient real-time system.

Optimized: TargetLink 2.1

- **Extended target processor support: new TSM and new TOMs**
- **Comprehensive support of signal busses**
- **Many functions optimized**

Across industries, automatic production code generation is fast becoming a firm fixture in the model-based development process. TargetLink is the leading production code generator based on MATLAB®/Simulink®/Stateflow®. The new version, TargetLink 2.1, has been produced in response to users' requests for extended features and functions, and also has broader target processor support.

Support of Target Processors

TargetLink's unique simulation concept allows the generated code to be tested both on a host PC (software-in-the-loop) and on the actual target processor (processor-in-the-loop). The Target Simulation Module (TSM) performs the simulation on the target processor. Another of TargetLink's great strengths is generating processor-optimized code by means of the Target Optimization Modules (TOMs). The TSM and TOMs have both been extended, with the new processors and compilers that developers need.

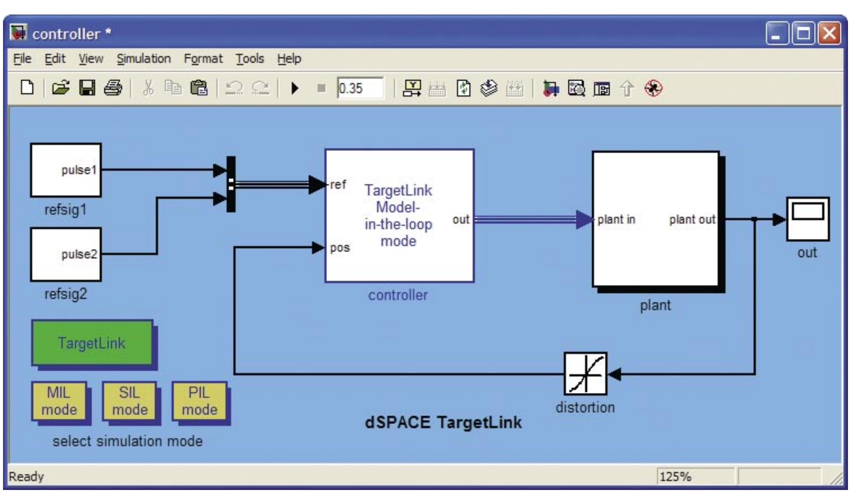
TSMs and TOMs

- HCS12/Metrowerks CodeWarrior Compiler
- TriCore TC1796/Tasking Compiler 2.2

TSM

- Freescale MPC 5554/Green Hills and Wind River Diab Compiler
- Freescale S12X/Metrowerks CodeWarrior Compiler
- NEC V850/Green Hills Compiler
- Renesas SH7058/Renesas Compiler
- STMicroelectronics ST10/Altium Tasking Compiler

TargetLink 2.1



New Features

For a complete list, please see the product brochure for TargetLink 2.1.

Modeling Functions

- Simulink signal busses freely usable at the transitions to TargetLink subsystems and subsystems with TargetLink function blocks
- Stateflow `bind´ actions supported
- Events at state machine level supported
- Zero-based indexing supported

Code Generation

- Variant selection via preprocessor macros (#if, #ifdef) and variable class, also usable with Stateflow diagrams
- Division/multiplication
- Bit shift options

Process Integration

- Tracking of model and associated code via checksum
- MATLAB workspace variables and TargetLink block variables integrated into dSPACE Data Dictionary
- Build-all function simplifies incremental code generation

◀ *TargetLink subsystem with connected Simulink signal busses.*

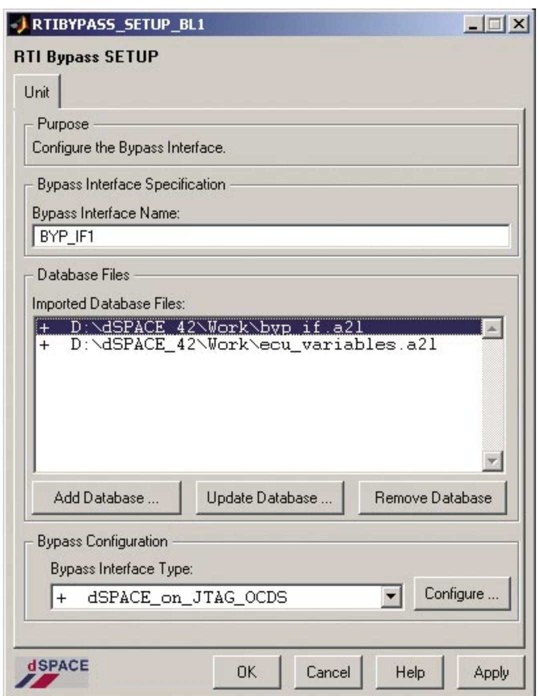
Complete Bypassing Portfolio

More and more microcontrollers in vehicle electronic control units (ECUs) provide an on-chip debug interface such as Nexus, JTAG/OCDS, JTAG/SDI, AUD, and NBD. These can also be used for bypassing purposes in function design. dSPACE Release 5.0 will include an extension to the RTI Bypass Blockset based on the generic serial interface DCI-GSI1. DCI-GSI1 can be used for simultaneously bypassing, measuring, and calibrating, so it is simple to reuse in different development phases. The RTI Bypass Blockset supports dialog-based configuration of bypass interfaces and bypass hooks in MATLAB®/Simulink®.

- **Simultaneous bypassing, measurement, and calibration**
- **Powerful real-time hardware**
- **Bypassing for today's generation of microcontrollers**

Large Selection of Bypass Interfaces

dSPACE is an experienced provider of tools for developing and optimizing control algorithms (rapid control prototyping) based on external bypassing. This involves the calculation of selected ECU functions on the



▲ *Configuring bypass interfaces with the RTI Bypass Blockset for MATLAB/Simulink.*

prototyping hardware, while the remainder of the code continues to run, unmodified, on the existing ECU in the vehicle. With powerful prototyping hardware and comprehensive software support, there are suitable tools for any application case, using either dual-port memory (DPMEM), XCP on CAN, or on-chip debug interfaces. There are two basic bypassing methods: address-based bypassing via code patches and service-based bypassing via service calls in the ECU code. The dSPACE prototyping hardware guarantees minimum latencies in data communications with the ECU, the greatest possible flexibility in development, and real-time behavior even with large function models.

Current Microcontrollers Supported

The support given to service-based bypassing for on-chip debug interfaces via the generic serial interface DCI-GSI1 is tailored to current and future processors used in ECUs. Whether you use a Freescale MPC5500, Infineon TriCore, or Renesas SH2 / M32R, the easy-to-use RTI Bypass Blockset software lets you configure bypass interfaces and perform tasks such as assigning variable names for service-based bypassing to ECU addresses. A browser with search options and hierarchical display helps you to select input and output variables for the bypass functions from the associated ASAP2 files (ASAM-MCD 2MC). As with all dSPACE bypassing solutions, powerful, vehicle-capable prototyping hardware is available, with extensive I/O interfaces to compute the bypassing algorithms.

▼ *Even more features with dSPACE Release 5.0: Support of current microcontrollers (selection)*

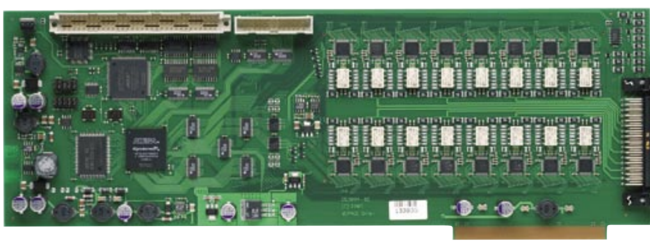
On-Chip Debug Interface	Microcontroller
Nexus	Freescale MPC55xx, Freescale MPC56x
JTAG/OCDS	Infineon TriCore
JTAG/SDI	Renesas M32R
AUD	Renesas SH2
NBD	NEC V85x, Renesas M32R

For release dates see *www.dspace.de/goto?releases*

A/D: Fast and Precise

The DS2004 High-Speed A/D Board is a new I/O board for our modular hardware. It provides fast, high-precision A/D channels plus 4 external trigger inputs and extensive trigger functions. It can convert both single measurement values and whole sample bursts.

▼ The DS2004 will be available from November 2005 and will be an important component in many dSPACE systems.



Each of the 16 channels on the DS2004 has an independent A/D converter with a resolution of 16 bits and differential inputs. The conversion time is 800 ns per channel. The board buffers up to 16,384 values per channel and then transfers them to the processor board as a burst. This cuts the volume of communication and improves overall system performance. Sample bursts are started by either software or trigger events.

The DS2004's burst mode gives you two ways of converting measurement values:

- Continuous sample mode:
  When one burst ends, the next burst starts automatically. The conversion of individual measurement values within a burst is triggered by software, an internal timer, or an external trigger.
- Triggered sample mode:
  A burst of measurement values is started by software or a trigger event.

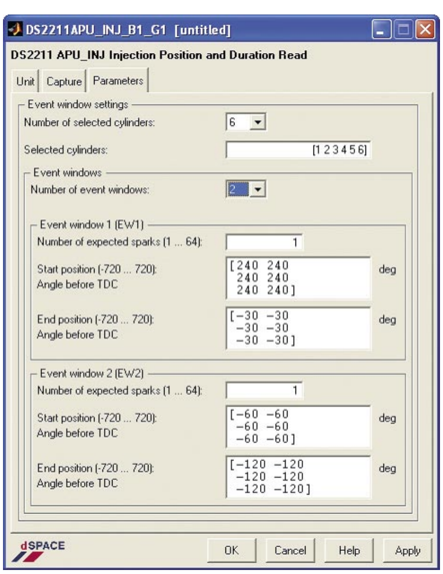
You can use the triggered sample mode to record measurement data within a defined window, for example, angle-synchronous measurements for a combustion engine. Possible applications include cylinder pressure-based control and the measurement of knock signals in an angle window.

DS2004 High-Speed A/D Board

Extended RTI Software Support for DS2211

DS2211 I/O Board

The proven Real-Time Interface Blockset for the DS2211 HIL I/O Board has been extended in dSPACE Release 4.2. The maximum frequency of the PWM channels has been raised from 20 kHz to 100 kHz. The blockset for measuring injection and ignition signals has been extended to meet the modeling requirements that will be posed by further development, for example, piezoelectric and multiinjection systems.



64 injection or ignition pulses can now be captured per channel and event capture window, instead of the previous 16. There are now two event capture windows for torque- and exhaust-relevant injection pulses, so that the model can use the torque-relevant pulses earlier. Additional blocks improve the support given to the common modeling of engines with different numbers of cylinders. Partially continuous output of captured measurement values has been implemented to make the values available for torque calculation earlier.

In addition, there is a tool for converting models and libraries from the earlier DS2210 HIL I/O Board to the current DS2211 HIL I/O Board and back again.

dSPACE Release 5.0 will include two additional capture modes for measuring the start time, end time, and duration of injection with a precision of 250 ns.

Model Initiative

dSPACE has developed its own simulation models for designing and testing automotive electronic control units (ECUs) for powertrain and vehicle dynamics. They will be available under the name Automotive Simulation Models (ASM) starting in the third quarter of 2005. dSPACE President Dr. Herbert Hanselmann and Head of Engineering Dr. Herbert Schütte give details of the new product line and the strategy behind it.

- New simulation models
- Strategy and positioning
- Frequently answered questions

There are already several model libraries on the market, so why does dSPACE need its own?
Hanselmann: Models from different suppliers, and frequently customers' own models, all run on our simulators. However, we often encounter gaps in these solutions – in modeling depth, in handling, in the quality of integration with our hardware and software, in synchronization with our project management, or in parameterization and commissioning. It is these gaps that we want to fill.

"However, we often encounter gaps in these solutions. It is these gaps that we want to fill."

Is producing your own models the only way to do this, rather than closer cooperation with partners?
Hanselmann: A lot can be achieved by close cooperation. However, since we know our HIL systems intimately, we can clearly focus on meeting customer application priorities with a systems approach and avoid negotiating compromises with other parties. Also, there are many customers who appreciate a solution from a single source.

Will dSPACE's models now be first choice for use in its simulators?
Hanselmann: We're keeping all options open. Customers will decide which models they want to run on our simulators. We'll continue to support customers' models and models from third parties. This takes into account the fact that customers are "used to" specific models, and that no two models are identical. They can have different modeling depths, or different parameterizations. And the model vendor's specialist experience also plays a role. Our models are now an additional option.

Up to now, dSPACE has had a successful partnership with TESIS. What's going to happen to that?
Hanselmann: We will still offer TESIS models for use with our simulators and make dSPACE test and development systems available to TESIS for optimum technical maintenance and continued development.

What advantages will ASM have for customers?
Hanselmann: They will have better technical integration, plus particularly fast processes for setting up and modifying simulators. They will be able to modify the models simply and quickly themselves, for example, by replacing or adding components. Our ASM models are optimally designed for this, as they are open Simulink models, and completely accessible to and viewable by customers.


▲ Dr. Herbert Hanselmann, President

"They will have better technical integration, plus particularly fast processes for setting up and modifying simulators."

What does "open Simulink model" mean?

Schütte: To the greatest possible extent, the models are constructed from basic Simulink blocks. They are not implemented in S-functions, which would be visible to customers only as single, closed DLLs. So users can study the ASM implementation in detail. Though there are a few model parts that are awkward to describe in Simulink because of the block structure - for example, the modules for maneuver control, for the driver, or for computing the road. These parts are implemented as C-coded S-functions. However, customers can replace the modules any time they want, of course, and their functionality is explained in detail in the documentation.

> *"Users can study the ASM implementation in detail."*

What applications are the ASMs suited to?

Schütte: The ASMs are for simulating diesel and gasoline engines, and the dynamics behavior of vehicles. They represent the controlled systems for engine, transmission, and chassis ECUs, so they are ideal for real-time use in HIL test systems. The models are also easy to combine in Simulink, so they can be used to build a virtual vehicle, for example, for HIL testing of an entire ECU network in which both engine and vehicle dynamics ECUs have to be tested. But they are also suitable for offline simulation, so they can be used in function design.

▲ *Dr. Herbert Schütte, Head of Application/Engineering*

Are there model extensions?

Schütte: Yes, we currently offer a brake hydraulics model and a physical turbocharger model as extension libraries, for example. And we are more than willing to develop model extensions or special modules based on the present models, especially where this is necessary for the functionality of a dSPACE Simulator in a specific test task.

How well do dSPACE models perform?

Schütte: The ASMs are primarily designed for real-time use in HIL simulators and in terms of simulation precision, they are comparable to models that are already on the market. However, performance is more than just simulation precision. As Dr. Hanselmann already mentioned, features such as ease of parameterization, usability, variant handling, potential for specific further developments, and worldwide support are at least as important.

> *"The ASMs' execution time is far below the usual sampling rate of 1 ms, even including the necessary I/O."*

As regards real-time capability on current dSPACE hardware, the ASMs' execution time is far below the usual sampling rate of 1 ms, even including the necessary I/O, so users have plenty of scope for additional models.

Have the ASMs been real-world tested?

Schütte: Of course, we first tested the models on the HIL simulators we have available in-house for currently available ECUs, such as ESP8 for vehicle dynamics and EDC16c for common-rail diesel engines. We are running parallel projects to validate the vehicle dynamics model using measurement data from a vehicle currently in production. The initial results indicate very good consistency between measurement and simulation. An ASM engine model has been integrated into a universal HIL simulator for diesel engine ECUs and is performing well in practice.

"We will further develop the mathematical / physical core models as our international customers want."

What are the particular features and strengths of the dSPACE models?

Schütte: We're concentrating at the moment on implementing all the model parts that are needed for typical HIL applications. On the engine side, these include mean-value models with mass and energy flows, the associated component models such as turbocharger and injection systems, and the ECU functions needed for commissioning. There are also utilities for parameterizing the engines.

In vehicle dynamics, formulas are needed for the drivetrain, car body, axles, and wheels, plus additional model parts that HIL applications need. These include a driver model, a road model, and maneuver control.

A key tool in our view is ModelDesk, our user and parameterization interface, which has a typical dSPACE look and feel. It's a graphical user interface that makes it easy to enter parameters, and to manage and switch data sets. Frequently recurring structural variants can also be selected online. This is increasingly important for tasks such as adapting HIL systems to country and feature variants in automated testing. ModelDesk is also the front end for the fast and flexible definition of road profiles and test maneuvers.

"ModelDesk is also the front end for the fast and flexible definition of road profiles and test maneuvers."

Where did dSPACE gain the necessary know-how?

Schütte: That comes from a whole range of sources. First, we have years of experience in all the issues involved in real-time simulation, not least because we have run several hundred projects for turn-key HIL systems. For the actual modeling work, we put together a team of engineers who previously specialized in vehicle or engine technology at their university. Additional know-how comes to us via other routes, for example, through cooperation with universities. To produce ASM, we combined all this accumulated knowledge with state-of-the-art technology as reflected in the latest scientific literature.

How will the models develop from here?

Schütte: We will further develop the mathematical/physical core models as our international customers want, to meet the specific requirements of

HIL simulation. ModelDesk, the graphical interface for handling the models, will be given a whole series of functional extensions, for example, for engine model parameterization, user guidance, simulation control, and of course remote control for use in automated test sequences.

These requirements come from our own practical experience with applications and will be implemented as soon as possible after Version 1.0.

HIL Conference in Essen

“Hardware-in-the-Loop Simulation of Automotive Mechatronic Systems” will be the topic of a conference to be held at the Haus der Technik in Essen, Germany, on October 18-19, 2005 and hosted by two experts, Prof. Dr.-Ing. Ansgar Trächtler of the University of Paderborn and Dr.-Ing. Herbert Schütte of dSPACE GmbH. Leading automobile manufacturers and suppliers, including BMW, Bosch, DaimlerChrysler, IAV, Opel, and Siemens, will reveal details of their project work and talk about their particular challenges and solutions. There will also be talks by providers and an exhibition of the latest product developments and trends. The conference has been held regularly for a number of years, successfully stimulating discussion among engineers concerned with the development, integration, and automated testing of automotive electronics systems. For further details and how to register, see *www.hdt-essen.de*

dSPACE’s New Home on Schedule

Construction work on dSPACE’s new building complex has made rapid progress since the ground-breaking ceremony in January, as this view of the site shows. The first section of the complex will be ready for use in early 2006.

Symposium in Shanghai

At the 2005 Shanghai International Symposium on Automotive Electronics & Advanced Technology for Meeting Vehicle Emission Requirements arranged by SAE International and SAE China, attendees from the automotive and software sectors presented the available technologies. dSPACE also put forward solution approaches from its own tool chain.

Frost & Sullivan Award Ceremony in Florida

The Frost & Sullivan Award Ceremony was held in Naples, Florida, on May 25, 2005. Krishna Srinivasan,

President of Frost & Sullivan, presented the award for “2005 Leading Manufacturing Test Company of the Year” to dSPACE President Dr. Herbert Hanselmann. dSPACE was selected for the award for its pioneering role and market leadership in hardware-in-the-loop technology. Frost & Sullivan, a consulting company with worldwide activities, interviewed Dr. Herbert Hanselmann on the technology: *www.dspace.de/goto?Frost_Interview*

Papers

"Testing FlexRay ECUs with a Hardware-in-the-Loop Simulator" J. Stroop, S. Köhl, dSPACE; M. Peller, P. Riedesser, BMW

"Test Management and Test Automation at the BMW Group"
R. Rasche, dSPACE; P. Rissling, T. Konschak, BMW; T. Sußebach, argumentum

Paper download:
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- dSPACE Real-Time Systems
- ControlDesk
- RapidPro
- TargetLink
- HIL Simulation
- AutomationDesk
- MotionDesk
- CalDesk

Events

EUROPE

MeasComp
September 27-29, Wiesbaden, Germany
Rhein-Main-Hallen, Hall 1, Booth #34/35
www.meascomp.com

Aachener Kolloquium 2005
October 4-6, Aachen, Germany
Eurogress, Stand O 81
www.rwth-aachen.de/ac-kolloquium

VDI – Elektronik im Kraftfahrzeug
October 6-7, Baden-Baden, Germany
www.vdi.de

D&E Entwicklerforum SW-Entwicklung
October 13, Munich, Germany
www.elektroniknet.de/termine/kfz2005/index.htm

OMER3 Workshop
October 13-14, Paderborn, Germany
Heinz Nixdorf MuseumsForum
omer3.uni-paderborn.de

Hardware-in-the-Loop Simulation für Mechatronik-Systeme im Kfz
October 18-19, Essen, Germany
www.hdt-essen.de

MicroConsult – PraxisForum 2005 Embedded Software- Entwicklung
November 15., Maritim Hotel Munich, Germany
www.microconsult.de

SPS/IPC/DRIVES
November 22-24, Nuremberg, Germany
Messezentrum Nürnberg, Hall 7A, Booth #203

USA

Global Powertrain Conference
September 27-29, Ann Arbor, MI
Sheraton Inn

SAE 2005 AeroTech Congress & Exhibition
October 3-6, Grapevine, TX
Gaylord Texan Resort and Covention Center

Testing Expo North America
October 26-28, Novi MI
Novi Expo Center, Booth #5000

SAE Commericial Vehicle Engineering Congress & Exhibition
November 1-3, Metro Chicago (Rosemont), IL
Donald E. Stephens Convention Center

For more events, please visit *www.dspace.com*

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