

dSPACE

2/2011

# MAGAZINE



KIT –  
Lights Get Smart  
Yamaha –  
Simulation Wins  
SKF –  
Intelligent Stopping





In the fall of 2009, the year of crisis, there were signs that the recession might have reached its lowest point. I was often asked how I viewed the future. Was it a V-shaped recession, or would there be a double dip, a W shape, a recession after the recession? When would we get back up to 2008 sales levels? My theory was that we were going through a kind of 'tilted L': after dropping dramatically, we would resume the old growth trend, but on a lower level. If this had been the case, it would have taken us until at least 2013 to get back up to 2008 levels. It's now clear that it really was a 'tilted L', but the rise was, and is, far steeper than expected. We will surpass our 2008 sales levels as early as 2011. Having been in a state of economic shock throughout 2009, many of our customers are now racing to catch up. We had a record order book in 2011.

It looks as if the old trend of continuous growth is returning, driven mainly by our customers' increasing

requirements as electronics and software continue to advance. They need to develop new systems in the face of constantly growing complexity. And as everybody knows, one way to stop complexity leading to chaos is to use methods and tools, particularly hardware-in-the-loop tests and model-based design. Both areas in which dSPACE is very successful.

But it's not enough to just master each stage in the development process and increase its quality and productivity. That alone will not tame complexity. What is needed is process support across all stages – with the aid of tools, of course. And with efficient, clearly organized management of all the innumerable, complex data and models. This needs to be possible across process steps, and between all the individuals and teams who are users and producers of the data. At dSPACE, we're putting our best efforts into tackling this issue.

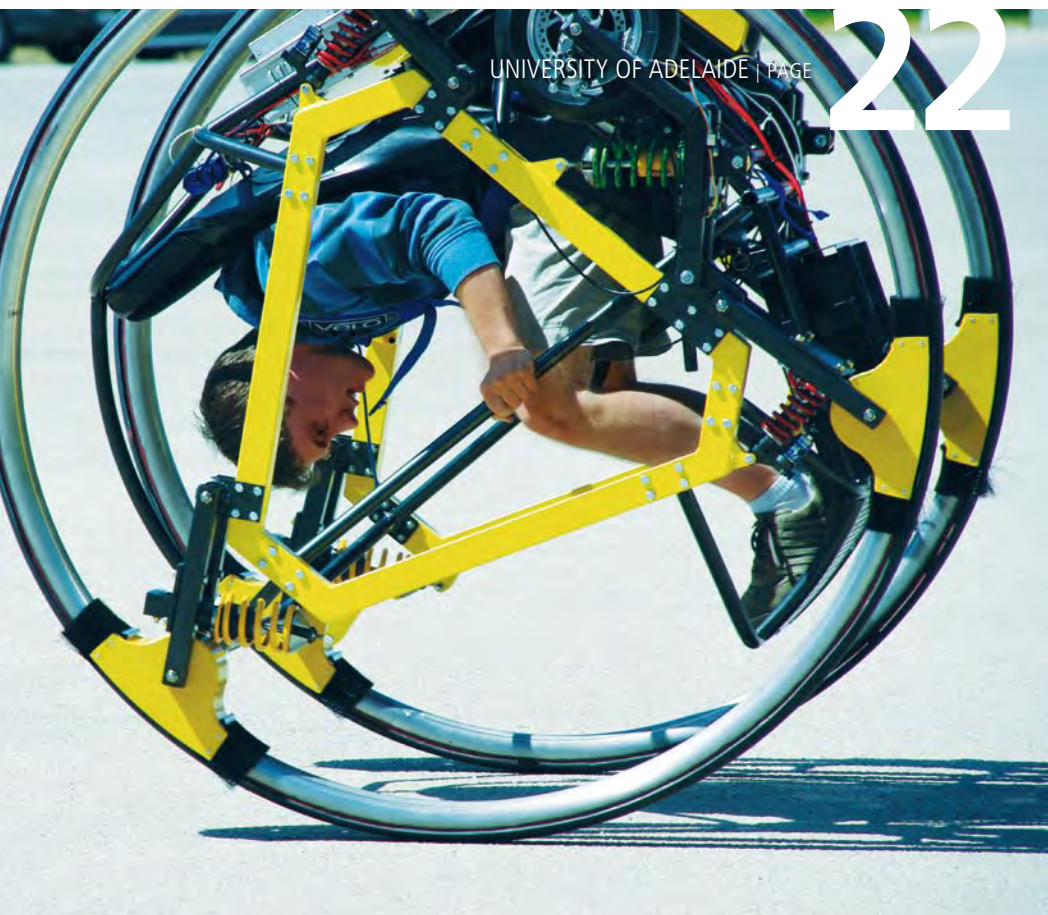
With our years of experience and know-how from numerous development projects, we will offer a multi-user-capable platform for central data management that supports the efficient handling of models, parameters, signals, tests, variants, etc. across the entire development cycle for ECU software. We already completed our first project for variant-oriented parameter management in model-based development. A test management solution will be available in mid-2012. And there's more to come. Stay tuned.

Hope you have a very happy festive season and a successful 2012!

Dr. Herbert Hanselmann  
President

Embedded Success

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**IMPRINT**

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Simulation Spurs Yamaha's MotoGP Success

# Simulating for Track Speed

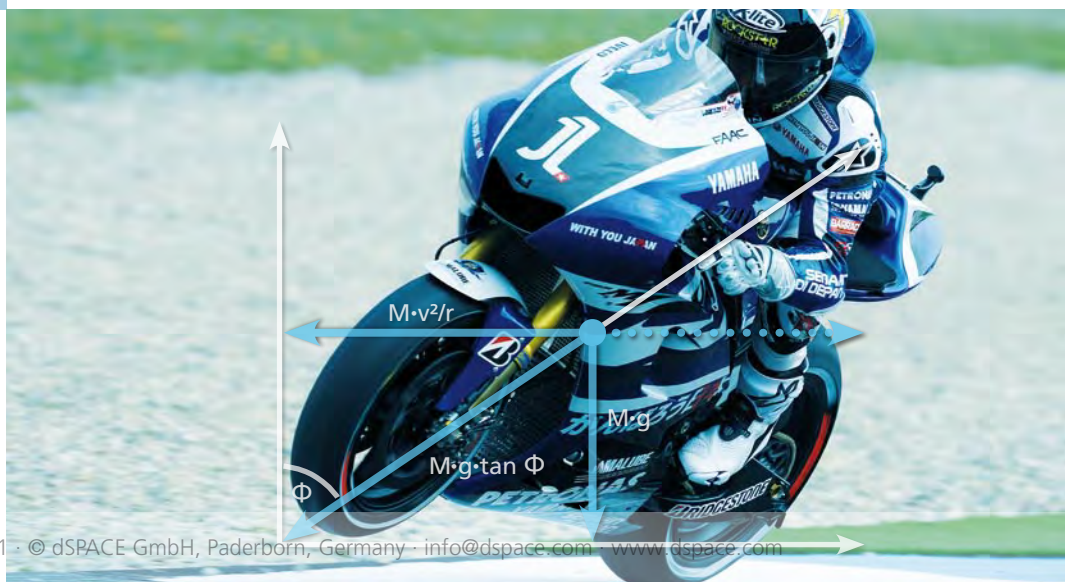


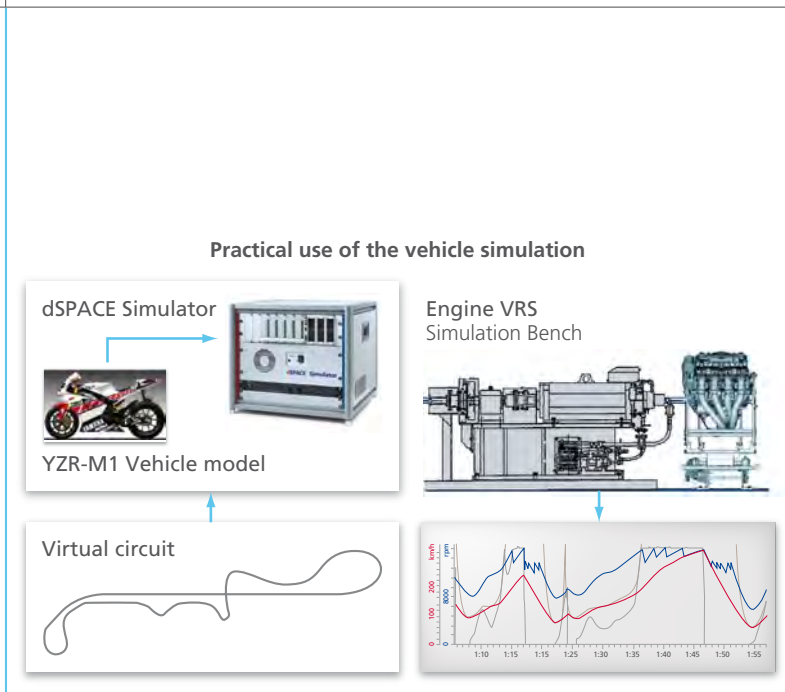
The MotoGP triple crown is a remarkable achievement in the world's top motorcycle sports class. Since 2008, the Rider, Constructor and Team titles have belonged to Yamaha. The company relies on simulation techniques to continue its success.

#### Yamaha MotoGP Activities

Yamaha entered the motorcycle manufacturing market as a late entrant in 1955, the year Japan's motorcycle history really began. In 1961 Yamaha began participating in World GP road racing, and 2011 marks the company's 50th year of GP racing. Over this half century of road racing, Yamaha has continued racing in different forms and has won many titles, despite several withdrawals from the racing world. Yamaha carved out a glorious history along with a string of champion

riders such as Phil Read (UK), Giacomo Agostini (Italy), Kenny Roberts (USA), and Wayne Rainey (USA). Behind this history are the unceasing efforts of Yamaha's technical staff and a spirit that refused to be daunted by failure. In particular, over these many years, Yamaha has needed to constantly adopt leading-edge technologies to swiftly adapt to numerous changes in regulations and maintain a high level of competitiveness, and has introduced various innovative development approaches.





*Schematic of the simulation environment based on dSPACE Simulator and a dynamometer with test vectors from real race tracks.*

### Approaches for Developing MotoGP Machines

When Yamaha motorcycles are being developed, developers try to share the values that emerge from the rider-machine unity where the machine responds to the rider's will and feeling for the bike, and from the man-machine sensibility that expresses the rider's joy arising from this sense of oneness. To embody this man-machine sensibility, two engineering ideas have been sys-

tematized. These are GENESIS in the mechanical field, and G.E.N.I.C.H. in the electronic control area. As a MotoGP machine, the YZR-M1 is designed to realize these ideas at the very highest technological level, to support the rider's will and feeling for the handling of the machine, and to achieve the very best performance. While upgrading each element of the chassis, engine, and control system, the

developers strive day by day to help the riders go faster by working with them, while the riders bring out all the performance the tires can deliver. MotoGP races are short-distance sprints that last about one hour. The MotoGP machine is designed and manufactured to allow its capabilities to be maximized over that short period. The durability that is a part of racing over long distances has never been necessary.

a range of areas, including friction loss. To achieve this, various new mechanical systems and control methods were tried. So that a machine can really be ridden safely, reliability and safety must be properly verified, as well as conformance, before the machine is ridden. And to shorten the development cycle, it is now important to carry out desktop checks with a virtual vehicle where possible. The success rate of systems that have been produced after adequate checks is rising and as a consequence make-over rates are falling. Even where early-stage checks have taken considerable time, even more time has been saved in the long run.

### Development Environment Outline

Yamaha's race division has begun using simulation technologies to make the maximum use of limited resources. Part of this involves durability testing on the simulation bench and the use of hardware-in-the-loop (HIL) systems for control systems development.

### Durability Testing using a Simulation Bench

Engine durability testing involves driving in a simulated pattern. The

**"By using dSPACE Simulators in the development of engines and control systems, we have noticed a significant improvement in development precision and efficiency."**

*Noboru Yabe, YAMAHA MOTOR CO, LTD*

tematized. These are GENESIS in the mechanical field, and G.E.N.I.C.H. in the electronic control area. As a MotoGP machine, the YZR-M1 is designed to realize these ideas at the very highest technological level, to support the rider's will and feeling for the handling of the machine, and to achieve the very best performance. While upgrading each element of the chassis, engine, and control system, the

### Coping with Regulations and Durability Requirements

Over the last few years, however, regulations have restricted the number of race machines in an effort to cut operating costs, and durability and reliability are now more important than before. When limits were imposed on the total amount of fuel per bike in each race in an effort to address environmental problems, it became necessary to reduce loss in

bike's movements are replicated using a physical model of the bike, and a dSPACE simulator is used to run a dynamometer control system. The simulation bench can be a kind of HIL system where an actual engine is used for closed-loop hardware testing. Thanks to this system, durability testing on a test course or chassis dynamo can be eliminated, and engine durability testing can be conducted just on the simulation





## Yamaha's MotoGP Success: Winning the Triple Crown Three Times in a Row

In 2002, with the emergence of the new-look MotoGP, Yamaha introduced its four-stroke YZR-M1. That year, Max Biaggi (Italy) notched up two wins on this machine but stopped short of taking the title. And in 2004, the third year of the new MotoGP, Valentino Rossi (Italy) chose Yamaha as his race mount. By now, the YZR-M1 had evolved to feature the crossplane-type crankshaft engine. In his first year of racing for Yamaha, Rossi took the championship title with a total of nine wins in the series. He took the World Championship

GP title in 2005, 2008, and 2009 with Yamaha. The rider tipped to take over Rossi's mantle as the new ace was Jorge Lorenzo (Spain), who signed on with Yamaha from 2008. In 2008 he recorded a win at the start of his MotoGP career and achieved a ranking of 2nd in 2009. Then in 2010, Lorenzo recorded podium finishes in 12 races in a row, starting from the season's curtain-raiser, a reliable performance that earned him his first championship title. In 2010, Yamaha achieved a triple crown for the third year in a row, taking the Rider, Constructor,



and Team titles and capping a winning streak that began in 2008. Now, in 2011, the 50th anniversary of Yamaha's entry into world GP racing, all eyes are again on Yamaha and its powerful team once more poised to dominate the world of MotoGP racing.

bench. As a result, the development cycle is considerably shortened and costs associated with running actual bikes are reduced. Because development precision improves and fewer prototypes need to be produced, the reduction in total costs is considerable.

### Control System Development

With engine control systems becoming more complex every year, dSPACE

HIL systems are used to verify the functions of programs and hardware. For example, it is virtually impossible to conduct test drives under what are normally inconceivable conditions such as sensor failure. This is why HIL systems, which can simulate these conditions and run tests under them, are essential for the development of MotoGP machines. On the race circuit, problems such as

conformance incompatibilities can occur from time to time. dSPACE HIL systems can also be used to address such problems. When implementing a measure to deal with a problem, it is necessary to run tests that replicate the driving conditions under which the problem occurred to ensure the measure is tested thoroughly. dSPACE simulators have proved effective tools in this situation too.

*Left: Controlling vehicle features by software is a common technique for advanced race machines.*

*Right: For the highest efficiency in controller development, race engineers rely on simulated test runs directly at their desks.*



## Race Machine YZR-M1: Technical Data

Engine:	Liquid-cooled crossplane crankshaft inline four-cylinder, four-stroke
Top speed:	In excess of 320 km/h
Power:	Over 200 horsepower (147 kW)
Transmission:	Six-speed cassette-type gearbox, with alternative gear ratios available
Chassis:	Aluminum twin tube delta box, multi-adjustable steering geometry/wheelbase/ride height. Aluminum swing arm.
Suspension:	Ohlins upside-down front forks and Ohlins rear shock, all adjustable for pre-load, high- and low-speed compression, and rebound damping. Alternative rear suspension links available.
Wheels:	MFR Forged Magnesium 16.5 front, 16.5 in rear
Tyres:	Bridgestone, 16.5 front, 16.5 in rear, available as slick, intermediate, wet and hand-cut tyres
Brakes:	Brembo, two 320-mm carbon front discs, two four-piston calipers. Single 220-mm stainless-steel rear disc, twin-piston caliper.
Weight:	150 kg (in accordance with FIM regulations)

### Perform under Ultimate Conditions

Customer demands relating to Yamaha products – not just race products – are becoming more difficult to satisfy every year. As well as cheaper bikes, customers want machines that are more comfortable and enjoyable to ride as well as fuel-

efficient. It has become very clear that simulation-technology-based testing methods can be a highly efficient way of satisfying multiple demands like these in one fell swoop. Because race machines, in particular, perform under ultimate conditions, conducting test drives

under the extreme parameters required can present difficulties. Within the world of simulation, safe testing is possible. And product safety levels can be improved as large numbers of tests can be conducted. In this sense, the value of dSPACE's simulation products is

### Outlook: 2012 1000cc YZR-M1

© Yamaha Factory Racing



Yamaha Factory Racing riders Jorge Lorenzo and Ben Spies comment on the 2012 1000cc YZR-M1 after testing it at the Misano circuit in San Marino.

“We’ve been working on the electronics to help in the braking area but mainly I’ve been getting used to the riding style of the bike and also adapting the bike to my riding.”  
*Jorge Lorenzo*

“We’ve got a lot of data now for the engineers to go away and work on the next step for our next test.”  
*Ben Spies*



■ “We expect dSPACE to lead innovation in the HIL area.”

*Noboru Yabe, YAMAHA MOTOR CO, LTD*

increasing all the time. On the other hand, the costs associated with testing and test equipment are also rising. The more complex the testing, the higher the cost of training the user to use the equipment properly. It will be necessary to improve the functions of test equipment, but it is possible that the associated costs will fall.

#### **Feedback on dSPACE products**

At Yamaha we have come to use HIL simulators in the development of engines and control systems, and have noticed a marked improvement in development precision and efficiency. In the past, we needed a racing circuit to see how we were doing, and at times, couldn't see how we were doing anyway. But once we used a simulator we could see what was happening. As a result, the riders have been able

to concentrate on their riding and have achieved good race results. Although our developers use dSPACE products for long periods at a time, there are few malfunctions or problems, and the products are very reliable and useful.

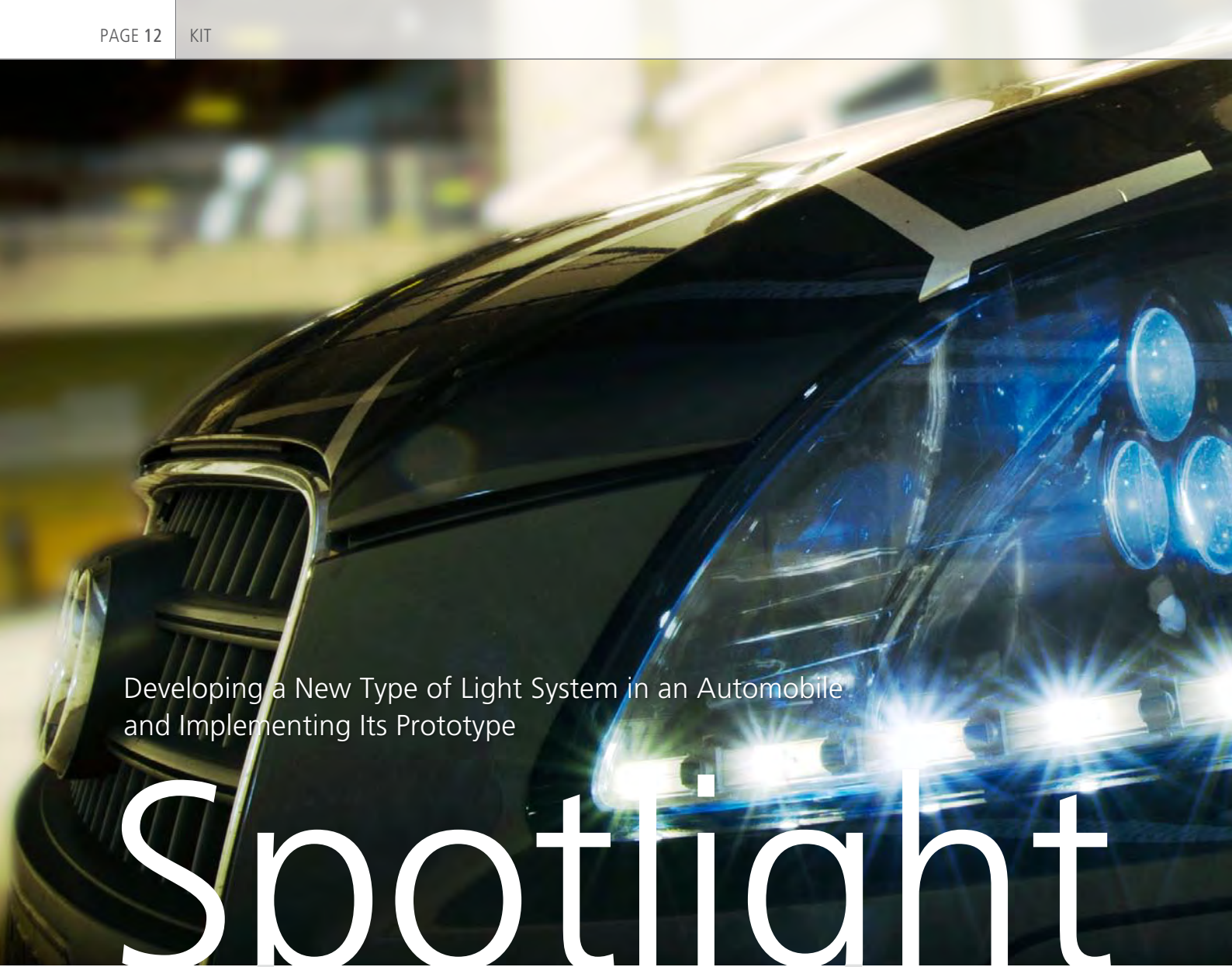
It is obvious that introducing new technologies into the development process causes new complexities and ties up resources. But the benefits of a HIL system definitely balance these.

Simulation technology is unlikely to stop advancing in the future, and the value of using HIL systems as test equipment seems to be growing. In the future, we expect dSPACE to continue to lead technological innovation in this area.

*Noboru Yabe  
MotoGP Group  
YAMAHA MOTOR CO, LTD.*

*Noboru Yabe  
Mr. Yabe is senior engineer in the  
MotoGP group at Yamaha Motor Co.,  
Ltd, in Shizuoka,  
Japan*





Developing a New Type of Light System in an Automobile  
and Implementing Its Prototype

# Spotlight on Hazards

An innovative new light function offers motorists more safety and comfort during night-time driving, using image sensors that detect potentially dangerous objects on the road and specially designed headlights that spotlight these objects. In field tests, this marking light presents a whole new picture of the roads at night.



Photo: Breig/KIT

### Motivation: High Accident Rate in Night-Time Traffic

The latest figures from the database of the German Federal Statistical Office speak for themselves. The year 2010 was the most accident-prone of the past eleven years. Around 2.4 million traffic accidents were reported in Germany, which is 4.2 % more than the year before. On the positive side, though, the number of traffic fatalities dropped to its lowest level of the past 60 years despite the increase in accidents. Although 3,648 people lost their lives on German roads last year, this is still 12 % less than in the year before. On closer inspection of the detailed records and reconstructions of how, when and where the accidents occurred, it is readily apparent

*A potential collision object – a pedestrian – on the road is spotlighted (marked) by the intelligent light system.*



Photo: Hörter/KIT



*Candidates for spotlighting are detected in several image processing steps.*

that the probability of being involved in a traffic accident is significantly higher at night. It is also clear that in contrast to the popular belief that highways are the most dangerous place for motorists, the country roads actually have the higher potential risk. Here, the speed traveled on roads outside of city limits combined with often inadequate road lighting and the high probability of hitting pedestrians, cyclists and wildlife can often lead to tragic accidents.

#### **Live Objects on a Collision Course**

All the facts mentioned above are no reason to just accept these night-time phenomena as a given. Instead, they motivate science and industry to strive towards finding innovative technical solutions that make driving on night roads safer bit by bit – until the ultimate goal of “accident-free driving” has become a reality. One piece in this puzzle could be “marking lights”, also called “danger lights”. This new light system explicitly shows its special strengths on the “hotspots”, namely on country

roads at dusk, night and dawn. Live objects that are calculated to be on a collision course with the vehicle are spotlighted or “marked” with a specially designed light source to help the driver recognize and react to the object earlier. The chosen marking strategy regularly alternates the marking phase with a phase of constant illumination of the object, guaranteeing a maximum recognition distance and the resulting collision avoidance.

#### **Essential Technical Components**

When it came to implementing this new idea, it soon became clear that the desire for creating a “hands-on” test vehicle would lead to a mechatronic project par excellence. The productive interaction between engineers from fields of mechanics, electronics and computer science and the technical equipment they selected ultimately lead to the complex mechatronic test setup that was integrated into the Audi Q7. dSPACE MicroAutoBox, the selected prototyping platform, with its diverse ana-

log and digital inputs and outputs, CAN and FlexRay interfaces, and its excellent computing performance, formed an unbeatable team together with the specifically configured RapidPro unit, which was installed in the harsh environment of the engine compartment. This team made it possible to flash the different controller models onto the MicroAutoBox very quickly and intuitively. The RapidPro unit then converted the input signals (which were mostly on the TTL level) into output signals with more power, and passed them to the light actuators.

#### **Real-Time Database as the Central Synchronizer**

First, it was necessary to master the flood of data that the integrated sensors provided (from an infrared camera, CMOS camera, inertial measurement platform, CAN connection, etc.). To handle this task, a real-time database was developed that not only synchronizes the varying arrival times of the sensor signals to a common time base, but also records the signals so that the test drives can be reconstructed in the laboratory whenever desired. For standardization reasons, this real-time database was implemented on an external, Linux-based high-performance computer that also communicates with the MicroAutoBox via a CAN network.

#### **Image Processing Combined with Artificial Intelligence**

In the causal chain of image preprocessing, detection, classification, object tracking and the subsequently derived warning strategy, image processing was a complex challenge because the input data (the appearance and pose of the objects to be marked) can come in very different shapes.

The goal of image preprocessing is to provide the most homogeneous base possible for the downstream



Photo: Breig/KIT

“Right from the beginning, dSPACE stood by my side with help and advice, so I was promptly able to find the right combination of dSPACE products and have them available for us quickly.”

*Marko H. Hörter, KIT*

processing steps. The existing gray-scale image (10-bit resolution) is converted into a binary image (1-bit resolution) by using a dual-adaptive threshold filter. This produces an image divided into two classes: foreground and background. At this stage, objects that are candidates for further consideration should be in the foreground.

The detector plays an important role: It discovers the image segments (blobs) in the preprocessed image scenery that have the same shape as one of the figures in the previously parameterized geometric shape pool. Simple, and thus real-time-capable, filter operations (such as length x width, number of pixels, position in the image, etc.) are used to minimize the number of potential image segments that are passed to the classifying mechanism. However, before the classifier can decide whether a potential live object (such as a pedestrian, cyclist, deer, etc.) is present in the discovered image segment, this image segment needs a technical representation so

that a numeric operation can compare the object with a previously trained data set. By converting the original image segment into a gradient image and dividing this into small square segments it is possible to depict the image information reliably enough for interpretation by a machine.

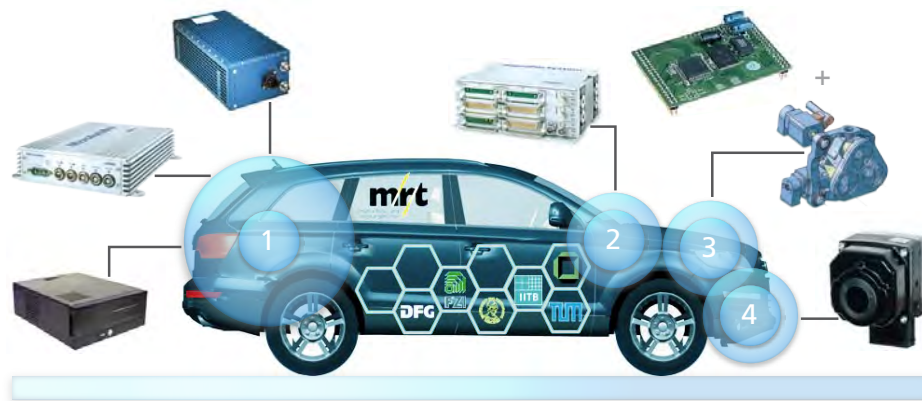
#### **Performance Reserves for Separate Object Tracking**

Thanks to the generous hardware resources of the MicroAutoBox, it was a natural decision to run the CPU-intensive operations, such as object tracking over time using Bayesian minimum-variance estimators, on the MicroAutoBox. By optimizing the process, it was even possible to execute several filter instances in parallel in order to estimate the initially unknown object size (such as the size of a human body) and thus more accurately infer the distance between the object and the vehicle. In addition, using the sheer unlimited modeling capabilities of MATLAB®/ Simulink®, it was possible to easily

and clearly implement the coordinate system transformations between the camera (2-D), the vehicle (3-D), and the light actuators (polar), and thus ultimately represent the entire function chain from the sensors to the final light-based object marking.

#### **Interaction Thanks to a Common Language**

To have not only the existing vehicle network but also all the decentralized components communicate with each other via CAN bus, all of the MicroAutoBox's available CAN channels were used. Whether from the light actuators (each with a dedicated microcontroller that also communicates via CAN), from the current speed, position or rotation rate of the inertial measuring platform, or even from the cyclically updated item list of the Linux-based high performance computer – all of the messages went to the MicroAutoBox communications node. Here they were reliably processed and, where appropriate, passed to a communi-



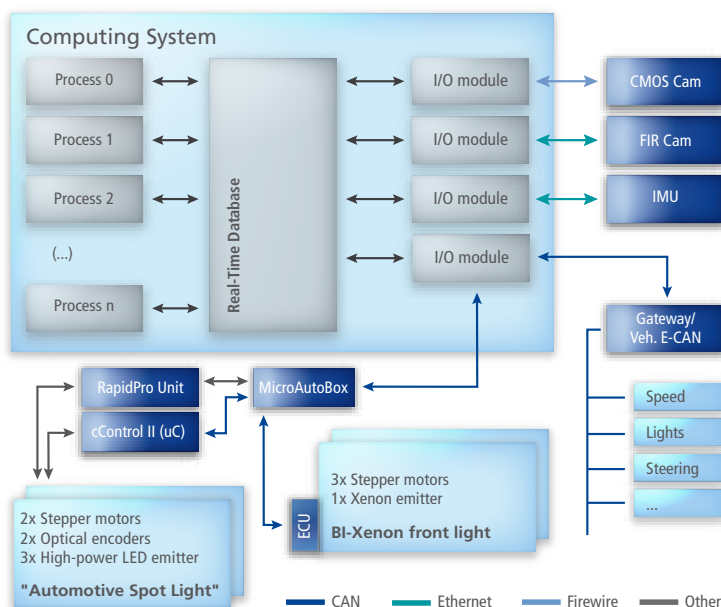
The technical components installed in the Audi Q7 test vehicle: 1) image processing, MicroAutoBox, inertial measurement platform, 2) signal conditioning (RapidPro), 3) light actuators, 4) FIR camera systems.

cation partner. This very valuable technical feature and the very intuitive modeling of the communication blocks in MATLAB/Simulink guaranteed a modular design and that the overall system could be adjusted flexibly to new technological conditions in the project.

### System Tests in the Lab

To use valuable work hours efficiently during the development of the overall system, the system tests in the laboratory played a very important role. These tests included identifying which light actuator parts needed to be controlled, then finding and param-

eterizing a suitable controller for them offline. In addition, thanks to the recording capabilities of the real-time database, complete test drives with all of the relevant accompanying information were reproduced in the lab, which greatly simplified the coordination of component interfaces.

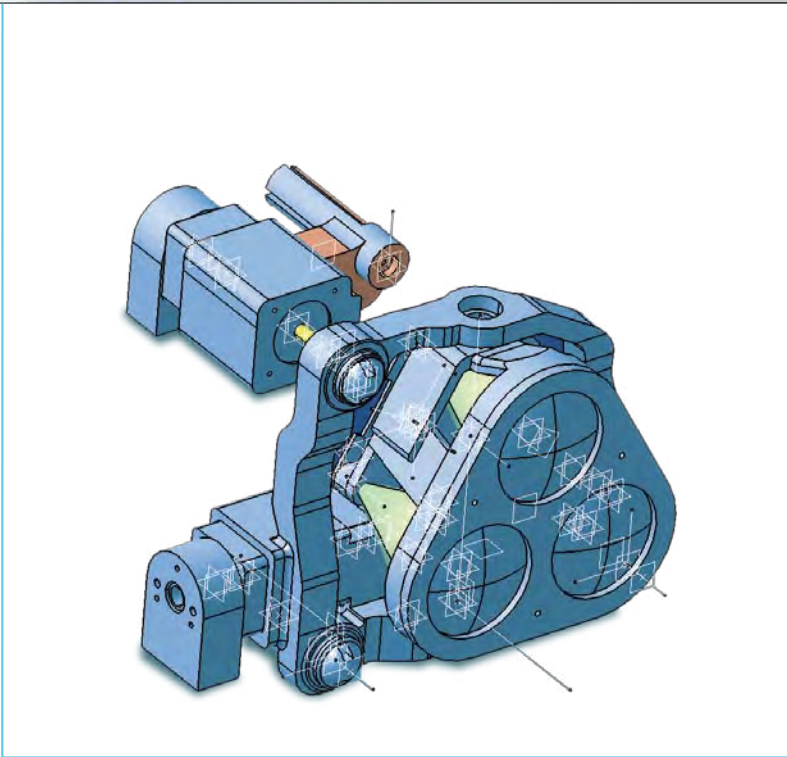


### System Tests with Real Test Persons

As is common in research on lighting technology, only the final field study can determine the usefulness and benefits of a new light application. Such studies rely on the most critical and most sensitive of all measurement instruments: people themselves. For this project, 35 volunteers enjoyed the opportunity to drive the test vehicle, filled to the roof with the new technology, on a closed-to-the-public highway through the Palatinate Forest. Measurement technology was used to determine the recog-

Prototype setup of the systems for object recognition, analysis and actuators.





*Mechanical setup of the actuator integrated in the front light for the marking light.*

nitition distance as well as the optimal marking strategy. The first variable, recognition distance, describes the distance between the detection point at which the test person notices the test object and the position of the test object in the traffic area. The second variable, related to the marking strategy, reflects the ratio between the periodic marking phases and the static phases where the objects in front of the vehicle are spotlighted.

#### Empirical Findings

A statistical analysis of all the data that was input in the system when the test drivers activated the steering wheel levers indicated an increase in the mid-range recognition distance of up to 35 meters for all test objects. At a cruising speed of 70 km/h, this meant an average of a nearly 2-second gain in driver reaction time for all test objects.

#### Marking Lights

The field study was completed without any significant technical complications, and all the subcomponents performed their services stably. Most of the voluntary test drivers were enthusiastic and look forward to this new lighting system someday going into production. Thus, the testbed implemented by the Karlsruhe Institute of Technology (KIT) is one of the first of its kind on an academic level that can clearly perform sensor activity and light-based object marking in traffic scenes. The original idea has finally become experienceable reality. ■

*Marko H. Hörter  
Karlsruher Institute of Technology (KIT)  
Germany*

“dSPACE MicroAutoBox offers an enormous flexibility and computing performance to process the many different signals reliably.”

*Marko H. Hörter, KIT*

## Conclusion

- Technical realization of an experienceable entire system
- Easy system integration thanks to compatible interfaces
- Real-time requirements met by means of decentralization

#### *MBE Marko H. Hörter*

*As a research assistant, Marko H. Hoerter (MBE) developed an experienceable overall system in the field of light-based driver assistance systems at the Karlsruhe Institute of Technology (KIT), Institute of Measurement and Control Technology (MRT, Prof. C. Stiller) in Karlsruhe, Germany.*





# Intelligent Stopping

Tough requirements are no problem for SKF's Electronic Parking Brake system for heavy agricultural machines

SKF's Electronic Parking Brake system is an extremely convenient solution for parking brakes and emergency brakes in tractors. Its intelligent functions support drivers in all situations and on completely different types of ground. SKF chose dSPACE solutions for the decisive phases of its software development.

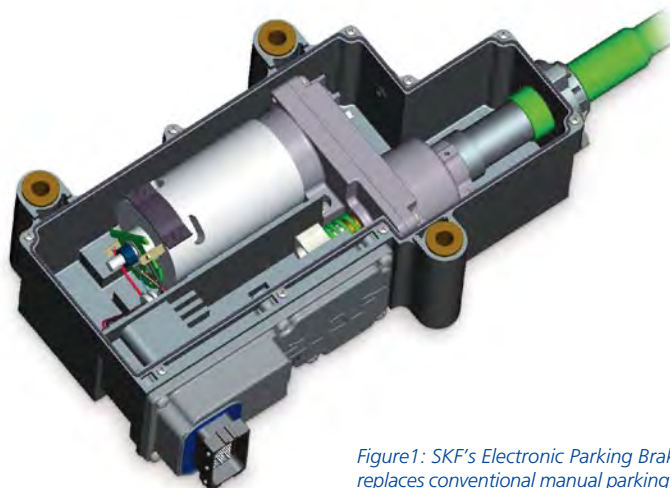


Figure 1: SKF's Electronic Parking Brake replaces conventional manual parking brakes.

### Electronic Parking Brakes in Agriculture

The Electronic Parking Brake (EPB) is based on a geared electric motor in a watertight enclosure with an integrated control unit. As an actuator, it tightens and releases the Bowden cable connected to the brake system. The system is designed to replace conventional manual parking brakes (Figure 1).

### Intelligent Functions for Maximum Convenience

The EPB's intelligent functions make the driver's work much easier.

- Automatic Apply switches the parking brake on when the driver removes the key and leaves the vehicle.
- Hill Holder and Drive Away make driving more convenient, even on hilly terrain.

- Automatic wear compensation eliminates the necessity of regular maintenance checks.

The new technology is suitable for numerous vehicle platforms with intelligent transmissions (CVT/IVT, full powershift). The software is adaptable, so the unit can be used in numerous vehicle types and under different operating conditions. Using intelligent solutions has a direct positive impact on the productivity, operating costs and safety of utility vehicles like tractors.

### Software Development and Architecture

Software development follows the phases of the V-cycle with support by dSPACE solutions for software design, implementation and software tests (Figure 2).

“After successfully completing the electronic parking brake development project with the dSPACE tools, we are now using the same approach in all our mechatronics development projects.”

*Fortunato Pepe, Product Development Manager at SKF*

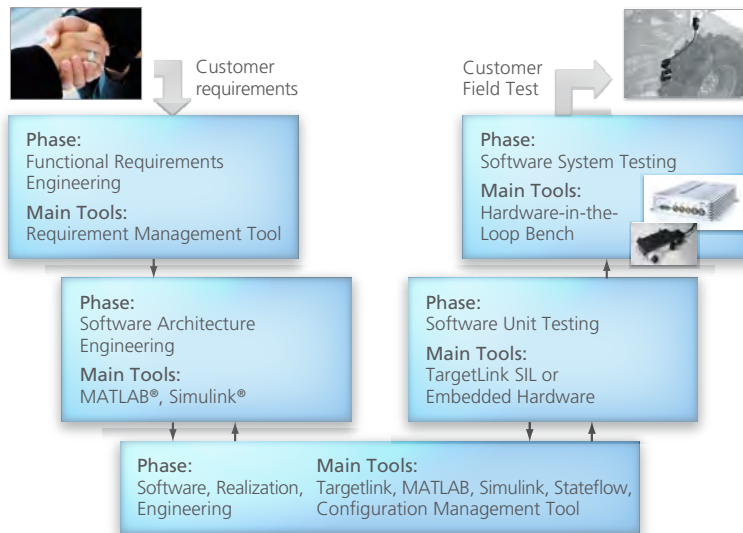


Figure 2: The main phases of software development and associated tools.

The software is divided into three main abstraction levels with clear interfaces. This reduces complexity and avoids having to handle implementation details on every level. It also makes the data and functions more robust against software errors, and lowers the cost of integration into different vehicle architectures.

The low-level software controls the brake's hardware functions such as electric motor control, low-level I/O and low-level CAN bus management, and is independent of the vehicle in which the parking brake is integrated.

The vehicle interface software collects the data from the low-level

software and passes the input signals to the application software with the correct scaling and format. It is highly dependent on the vehicle network architecture.

The application software consists of controls for the parking brake. Its great advantage is that it can be adapted to implement any intelligent functions that customers require, like Auto Apply on removal of the ignition key. The parking brake can therefore be used in different vehicles without any hardware changes (mechanics and electronics).

### Better Development with TargetLink®

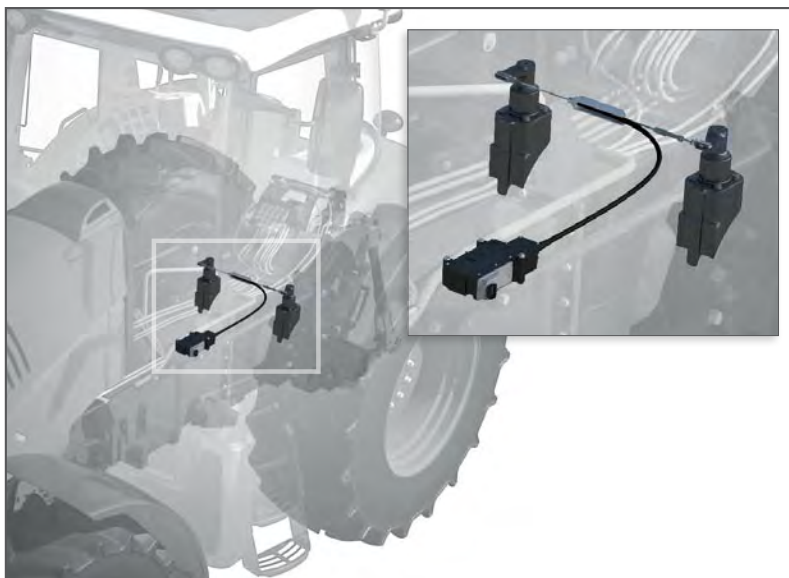
When developing the application level, SKF benefited from using dSPACE TargetLink.

- The application software was modeled in Simulink® and Stateflow®, and TargetLink generated production code straight from the diagrams and charts.
- SKF designed clear interfaces between the model-based software and the lower software levels, so the application software integrated seamlessly into the parking brake's software architecture.
- TargetLink ensured that the software modules were extremely reusable.
- SKF used variable scaling options to achieve the highest possible resolution for precise control and improved diagnostics with fixed-point variables.
- TargetLink automatically generated the ASAP2 database, enabling SKF to perform measurement and calibration tasks on the actual vehicle.
- The resulting data flow facilitated detailed software analysis, such as software fault tree analysis.

### Testing Approach

For the system software test phase, SKF needed a programmable test bench with reproducible test

The EPB with bowden cable installed in a tractor.



sequences. They had to record test results (pass/fail, inputs, outputs) and measure the system's response times, and extremely long test sequences had to be executed. SKF designed a hardware-in-the-loop (HIL) test bench (Figure 3) in which the parking brake is connected to a mechanical load consisting of springs that simulate the properties of the vehicle's braking system. A MicroAutoBox acts as the main test bench control. It simulates all the vehicle's hard-wired and CAN-based interfaces to the parking brake. The MicroAutoBox has a break-out box to support tests that use fault generation. The external sensors can be used separately to measure the force and position effected by the parking brake. A signal conditioning unit conditions the signals and passes them to the main test bench control for the test sequences.

### Model-Based Testing

Modular test software was created to ensure that the HIL test bench was flexible and adaptable to all customer requirements. The test sequences were modeled in Simu-

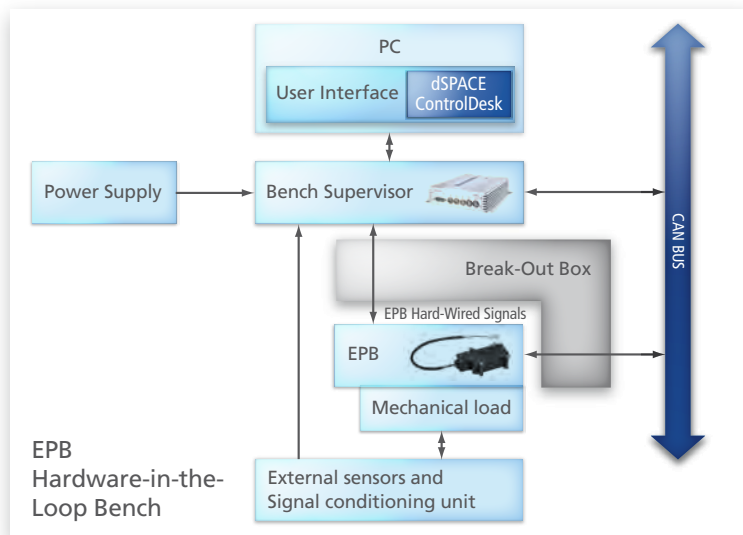


Figure 3: Block diagram of the HIL test bench for the parking brake.

link and Stateflow with the aid of dSPACE RTI libraries. With model-based design, complex and intensive test sequences can be created. The pass/fail criteria are also integrated into the test sequences. The test engineer runs each test sequence from ControlDesk®, which also displays the pass/fail results.

This considerably boosts the productivity of the test execution phase. ControlDesk also saves the test sequence results and manages test data configurations, so the test report phase is much simpler. ■

Fortunato Pepe  
Giuseppe Nuzzo  
SKF

### Fortunato Pepe

Fortunato Pepe is Product Development Manager at SKF in Airasca, Italy.



### Giuseppe Nuzzo

Giuseppe Nuzzo is Project Leader and Software-Engineer at SKF in Airasca, Italy.



## Conclusion

The EPB supports intelligent features such as Auto Apply, Hill Holder and Drive Away for various tractor types. It is easy and flexible to install and enhances the driver's safety and comfort. With TargetLink, MicroAutoBox and ControlDesk, SKF was able to implement and validate the EPB according to the highest quality standards.





Students and researchers in the School of Mechanical Engineering at the University of Adelaide have developed a so-called diwheel that allows a driver to travel in a conventional upright position and, for the more adventurous, in an upside down position. A dSPACE MicroAutoBox was used as the development and control platform.

Down Under:  
Diwheel Defies  
Gravity

Australian students developed an upside down vehicle.



Figure 1: The Electric Diwheel With Active Rotation Damping (EDWARD) developed at the University of Adelaide.

### Free Rotation Fun

Commencing in March 2009, honors students in the School of Mechanical Engineering at the University of Adelaide designed, built and tested an electric diwheel called EDWARD (Electric Diwheel With Active Rotation Damping).

Diwheels, like their more popular cousins the monowheel, have been around for almost one and a half

centuries. A diwheel is a vehicle that consists of two large coaxial wheels that completely encompass an inner frame containing a driver (Figure 1). The inner frame, suspended between the wheels, can rotate freely. The physical arrangement of a diwheel shares many similarities with two-wheeled inverted pendulum systems such as the Segway. In fact the dynamics of the two

systems are almost identical, the only difference being that the frame (pendulum arm) of a diwheel is smaller than the radius of the wheels, enabling the frame to completely rotate without striking the ground.

### Overhead Locomotion

The outer wheels are driven from the inner frame and forward motion



“EDWARD not only rocks (literally) but it’s green too. It’s fully electric, and employs regenerative braking, so energy is recovered when slowing down. The MicroAutoBox has saved us so much time compared to programming an embedded micro controller. Connection of all the I/O was simple and it has allowed us to rapidly try alternative control strategies. And using ControlDesk to develop the HMI was a breeze.”

*Jack Parsons, Student of The University of Adelaide*

is achieved through a reaction torque generated by the eccentricity of the centre of gravity of the inner frame. During operation, diwheels experience slosh (when the inner frame oscillates) and tumbling (also known as gerbiling, when the inner frame completes a revolution). This can make driving the vehicle extremely difficult and

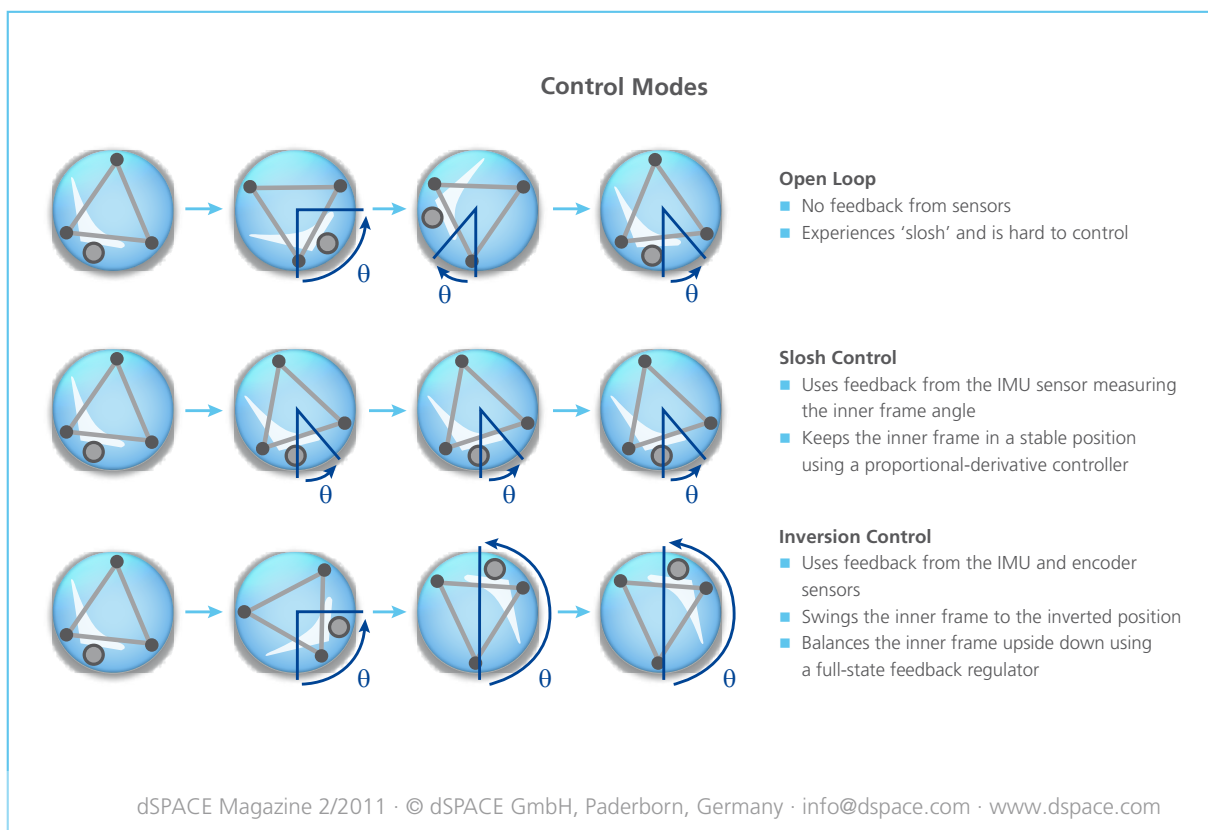
has impeded the development and commercial success of diwheels in the past.

#### The Inner Frame and the Outer Rolling Wheels

The outer wheels are rolled and welded stainless steel tubes with a rubber strip bonded to the outer rolling surface. The driver, who is held in place by a

five-point harness, is supported by the inner frame which runs on the outer wheels. The outer wheels have three nylon idler wheels each and are coupled to the inner frame by suspension arms, which act to provide some suspension and also maintain a constant contact force between the idlers and the wheel.

Figure 2: Schematic illustrating different control modes: Open Loop, Slosh Control and Swing-up/Inversion Control.



“We often get asked why build it? Why build a roller coaster? ‘Cause it’s fun! Apart from the incredible exhilaration of driving EDWARD, there are some serious pedagogical reasons to build such a device. It teaches engineering students about modern system design and control techniques – the very methods they will use when working as graduate engineers.”

*Dr. Ben Cazzolato, Associate Professor of The University of Adelaide*

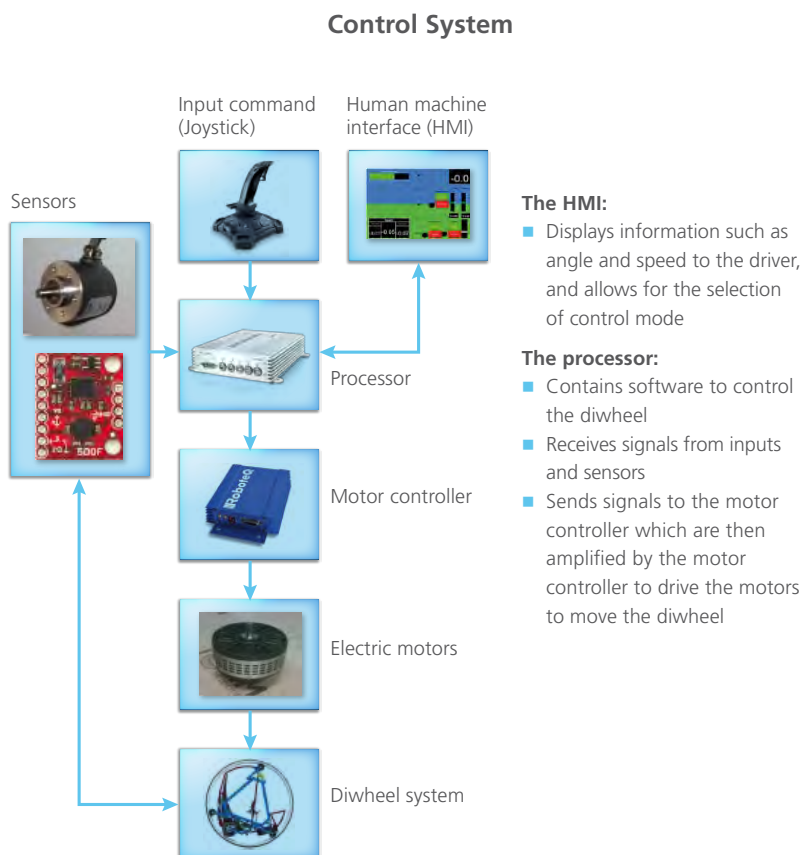
### MicroAutoBox-Developed Control Platform

Via sprockets and chain, two 4kW brushed DC motors each drive a small motorcycle drive-wheel which contacts the inner radius of the outer wheel. Thus the vehicle can be driven forwards and backwards using a collective voltage applied to the motors, and yaw is achieved when the motors are differentially

driven. The vehicle is drive-by-wire, with the driver controlling the vehicle via a joystick. A mechanical hand brake operates callipers on the drive-wheels for safety in case of electrical failure. There are three sensing systems onboard; an Inertial Measurement Unit (IMU) comprised of a solid state gyroscope for measuring pitch rate, a solid-state DC coupled accelerometer for state

estimation of pitch angle and two incremental encoders on each of the two drive-wheels that measure the difference in angular rate between the inner frame and the wheels. A dSPACE MicroAutoBox provides the development and control platform.

A touch screen mounted in front of the driver provides feedback on the states of the vehicle (such as pitch angle, forward speed, battery charge) as well as allowing the driver to change the control modes.



### From Simulation to Real-Time Control System

The fully-coupled differential equations of a generic diwheel were derived in order to allow the dynamics of the plant and control system to be simulated in MathWorks' Simulink®. Once the control laws were developed and performed well in simulations, the controller was ported to a dSPACE MicroAutoBox via MathWorks' Real-Time Workshop® for real-time control of the physical system.

Figure 3 illustrates the signal flow for the functional operation of the EDWARD platform, which employs

*Figure 3: Schematic illustrating the electronic control system and HMI.*

drive-by-wire technology and control theory to aid the driver in piloting the vehicle. Such technology prevents the inner frame from rotating (sloshing back and forth) during operation (Figure 2), an inherent property that has limited the drivability of previous diwheels. And for the thrill seeker, the unique dynamics of the vehicle can be exploited to invert the inner frame, so it is possible for the diwheel to be driven while the driver is upside down (Figure 4).

#### What About The Future?

The driver can be orientated in any direction, and held in by a racing seat and harness, allowing for

intense accelerations of several G's. For the first time a complete mathematical model of a diwheel has been derived, which will enable extreme maneuvers and tricks to be performed at the press of a button. These tricks are to be coded in software by future honors students in 2011. ■

*Dr. Ben Cazzolato*  
The University of Adelaide



Scan here to see  
the Diwheel in action.

#### *Dr. Ben Cazzolato*

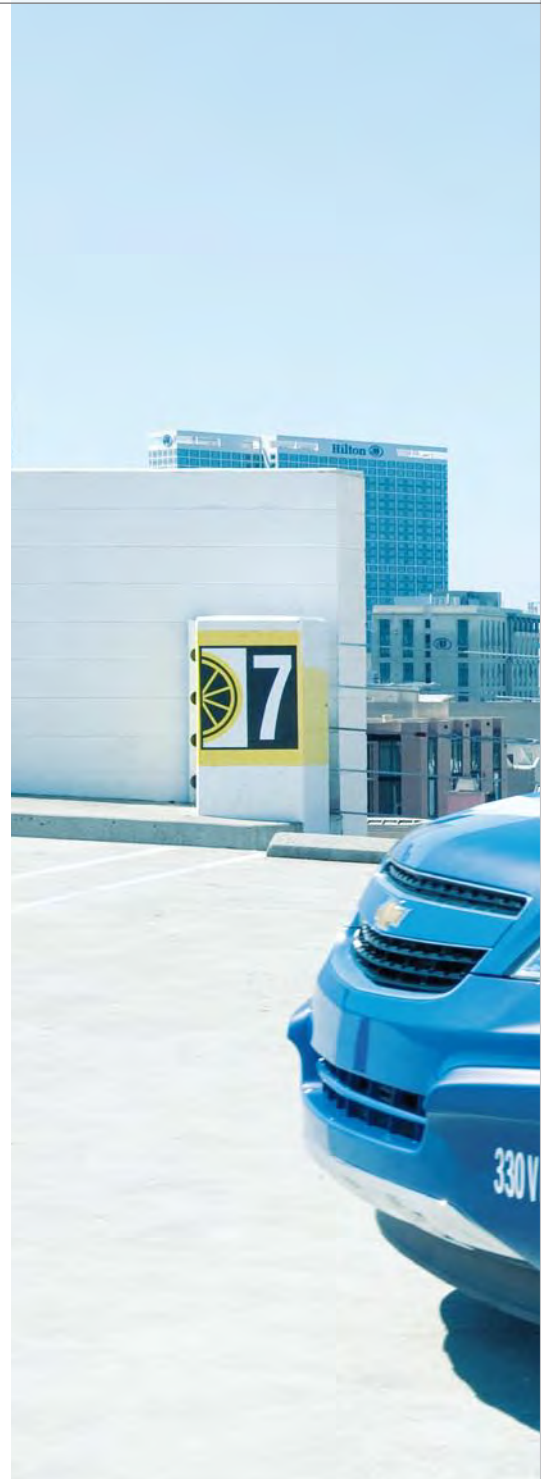
*Ben Cazzolato is Associate Professor at The University of Adelaide, teaching and researching in the fields of dynamics and control.*

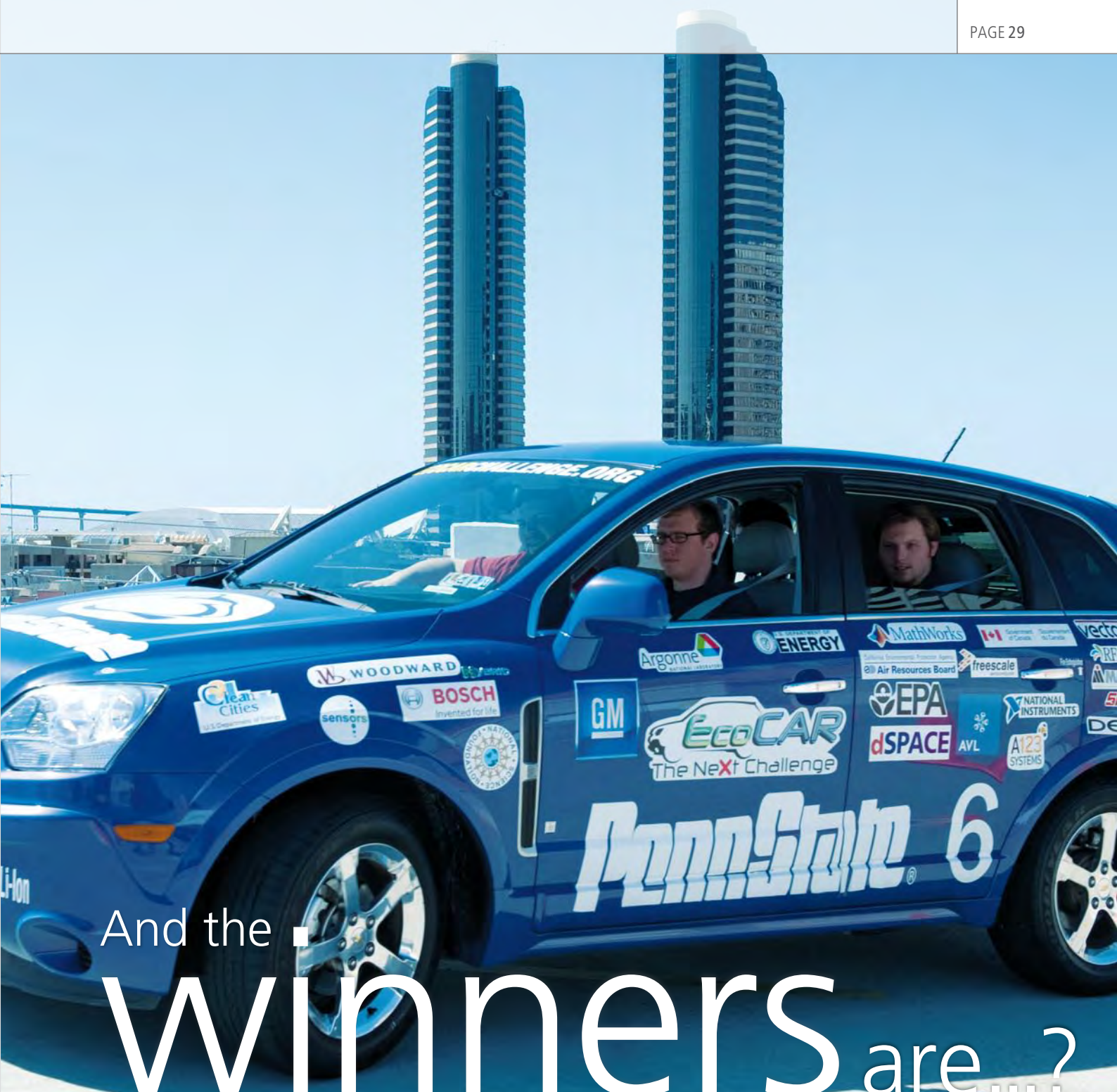


*Figure 4: Feedback control allows honors student Jack Parsons to drive around upside down.*



The final year of the EcoCar Challenge ended with an impressive show of the young engineers' green vehicle technologies, which included extended-range, hybrid, plug-in and fuel-cell electric vehicles. 16 North American universities were challenged to design and construct a near-production prototype vehicle with the goal of improving fuel economy and lowering greenhouse gas emissions, while retaining consumer acceptability in the areas of performance, utility and safety.





And the winners are ?

Final round of the three-year competition EcoCAR:  
The NeXt Challenge



### The Winners

After three years of intensive work and a steep learning curve, three teams beat tough competition to become the winners of EcoCAR: The NeXt Challenge 2011. The top finisher was Virginia Tech University, followed by the Ohio State University and the University of Waterloo. The teams received their awards at a ceremony held in Washington D.C., USA on June 16, 2011.

### Today's Tools for Tomorrow's Engineers

The university students used a real-world engineering process to design and integrate their advanced technology solutions into a General Motors (GM) vehicle. During year one, each team set goals for their vehicle and used design and simulation tools to develop an advanced powertrain architecture that would accomplish those goals. During year two, teams procured components and constructed mule vehicles of their chosen designs. Finally, during year three, teams tested and refined their vehicles to optimize the system. This process employed a wide variety of software and hardware tools and products to bring the advanced powertrain designs to life. In addition to developing and building an advanced vehicle architecture, teams were also required to demonstrate smooth, reliable vehicle operation.

### dSPACE's Contribution

dSPACE Inc. is a platinum sponsor of the EcoCAR Challenge and supplies tools for the teams to develop and test their vehicle architectures and control strategies, including MicroAutoBox prototyping units, hardware-in-the-loop (HIL) simulators, as well as top-notch training, technical support and mentoring. Here, three of the teams – the Ohio State University, the University of Victoria and the University of Water-

“We relied on dSPACE hardware and software through all the phases of the three-year challenge. They really made a difference to our progress, from modeling and simulation to prototype development.”

*Eric Schacht, Ohio State University*

loo – report on how they used dSPACE products to solve the tough issues that they faced.

#### **Advanced Learning Effect for Ohio State**

For the Ohio State University (OSU), dSPACE hardware and software were integral to their automotive development through all three years of the EcoCAR Challenge.

##### ■ *Vehicle performance and fuel economy prediction:*

Various simulation and development tools from dSPACE helped

the OSU team predict performance capabilities. Specifically, the fuel efficiency measured by driving the final vehicle was quite similar to the estimated fuel efficiency found from simulation.

##### ■ *System integration:*

dSPACE-sponsored hardware and software and HIL simulation contributed immeasurably to testing and validating the vehicle's performance and control strategy.

##### ■ *Real-world engineering experience:*

Engineering students gained invaluable

experience of the cutting-edge control development technologies used in industry. The OSU team won the dSPACE Embedded Success Award twice. The students had the unique opportunity to gain real-world, hands-on experience while working on a fun and engaging project.

#### **University of Victoria Stays in the Loop**

The University of Victoria team (UVic) developed an electric vehicle with independent four-wheel-drive propulsion that couples a GM

*So that the students can gain real-world experience, they are given tools to use for everything from the simplest work steps to HIL testing.*



“Going through the entire modeling process and encountering real-world challenges is what makes EcoCAR such a great experience for engineering students. None of this would be possible, though, without the support and resources provided by dSPACE and our other tremendous competition sponsors.”

*Jeff Waldner, UVic EcoCAR's Team Leader*

2-mode transmission and a 2.4-liter LE9 EcoTEC engine to the front wheels, and a UQM PowerPhase 145-kW electric motor to the rear wheels. Electric power is supplied by a 21-kWh lithium-ion battery pack from A123 Systems that provides a range of up to 60 km.

Two of the major focuses of the EcoCAR Challenge were model-based design and HIL simulation.

These techniques help teams to test everything from failures to fuel economy using a virtual vehicle model. They also help to ensure that a robust, reliable and safe control system makes its way into the car.

#### **From Zero to 100 in 7.5 Seconds**

Throughout one semester, several members of the UVic EcoCAR Controls Team worked diligently to improve their system, taking advan-

tage of dSPACE Automotive Simulation Models (ASM). The mature model accurately represents the real vehicle, from the ignition and body roll right down to the frictional forces between the tires and the road. This work quickly paid dividends, allowing the team to accurately test their real-time optimization strategy before making any updates to the vehicle. The new model and preliminary on-road testing also confirmed

*Everyone's a winner in the EcoCAR Challenge. All the teams had a lot of fun and gained plenty of experience.*







that UVic's EcoCAR is capable of 0-100 km in about 7.5 seconds, as predicted back in year one.

#### **dSPACE Tools for Rapid Development**

The University of Waterloo Alternative Fuels Team (UWAFT) was faced with the question every designer asks: How do you speed up the development process without compromising safety and reliability? The team chose a complex powertrain and used the possibility to explore new methods and technology that significantly changed their vehicle development process. For example, they removed the vehicle's stock powertrain and replaced it with a hydrogen fuel cell plug-in hybrid electric powertrain. dSPACE provided its MicroAutoBox controller and its HIL simulator, which gave the students the ability to simulate various powertrain failures without

damaging real-world components. dSPACE also provided fault insertion and interface software. With dSPACE's support, UWAFT was able to develop and implement its control system strategy with relative ease. After UWAFT's vehicle control strategy passed all the required tests in the simulator environment, the dSPACE MicroAutoBox controller was ready to be installed and tested in the actual vehicle.

#### **Outlook: EcoCAR2**

The 16 teams competing in EcoCAR2 will all be using HIL systems and simulation models (ASM) from dSPACE. Working closely with General Motors and A123 Systems, dSPACE has parameterized the ASM modeling suite so that the teams can perform highly precise testing and verification of their controller developments for powertrain and battery components from the very beginning. ■

## In Brief

16 teams from North American universities each spent three years building their own production-close prototype of an ecological vehicle.

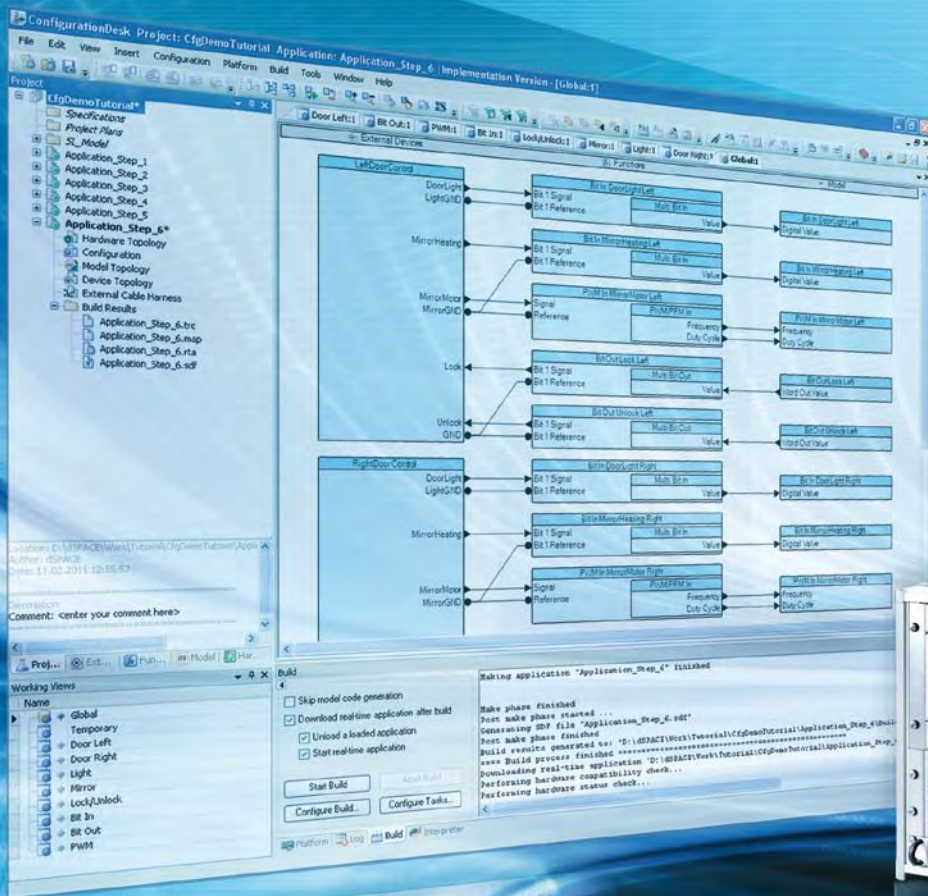
It was all part of the EcoCAR Challenge, in which the teams learned methods such as model-based design and hardware-in-the-loop (HIL) simulation, so they were able to test their systems with a virtual vehicle model. The methods also helped the teams make sure that their control systems were robust, safe and reliable when installed in a real vehicle. With all the experience gained, the students are ideally prepared for starting their careers.

## Awards for the Best

dSPACE Inc. supported the following university teams:

- Georgia Tech
- Mississippi State University
- North Carolina State University
- Ohio State University
- Pennsylvania State University
- Texas Tech University
- University of Victoria
- University of Waterloo
- West Virginia University

Finally, dSPACE presented three teams with an additional award, the dSPACE Embedded Success Award 2011, in recognition of the most effective use of control engineering with dSPACE equipment. The first-place winner of the dSPACE Embedded Success Award was the University of Victoria. Second and third-place honors were presented to Ohio State University and Texas Tech University. dSPACE gave \$750, \$500, and \$250 for first, second, and third place, respectively.



# Configuration Desk

New Workflow Flexibility

ConfigurationDesk is the configuration software for the new SCALEXIO simulator. Together, ConfigurationDesk and SCALEXIO are setting new standards in flexibility and reusability for hardware-in-the-loop simulation.

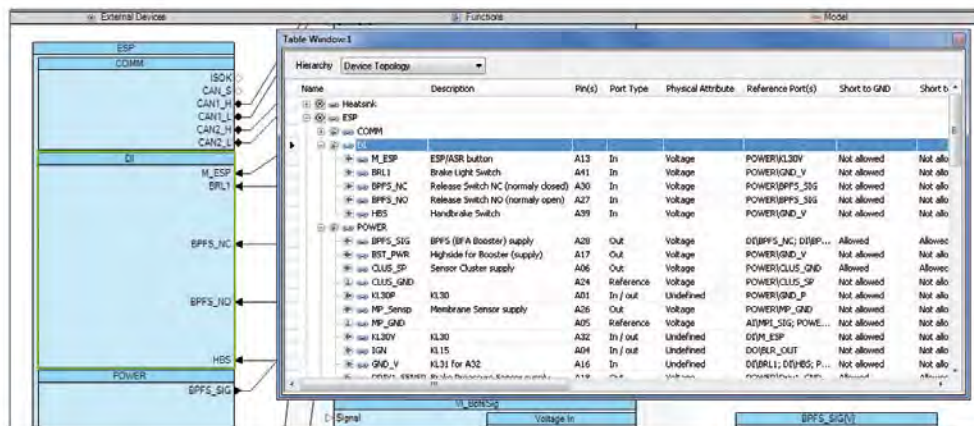


Figure 1: Interface description for the connected devices.

### Changed Requirements

In the field of hardware-in-the-loop (HIL) simulation, almost all companies now have specialized departments that develop and maintain different parts of projects (models, I/O configuration, etc.). These subprojects have to be combined flexibly to form a complete project, and the resulting HIL system has to be fully documented. The documentation must cover the connected devices i.e., electronic control units (ECUs) and real loads, the cable harness between the HIL system and the ECUs, the HIL hardware components with their configurations, and the environment model used for testing.

### Project Management with ConfigurationDesk

dSPACE designed ConfigurationDesk® with an intuitive, graphical user interface that supports the above requirements. The new Implementation Version is the successor to the well-known Real-Time Interface (RTI) for configuring hardware and implementing real-time applications on

SCALEXIO®, dSPACE's new HIL technology. The SCALEXIO hardware is completely configured with ConfigurationDesk, in other words, no settings have to be made by jumpers or any other hardware. In addition, ConfigurationDesk documents the entire HIL system, consisting of external devices, the cable harness, the dSPACE hardware with its configurations, and the environment model with all the interfaces to the I/O.

### Interface Description of the Connected Devices

Any HIL project begins with defining the electrical interface of the ECU under test. This requires information on the number of connectors and pins, and also more abstract data such as logical signal names with descriptions, the signal direction (the ECU's input or output), physical signal properties (voltage or current signal), and information on whether a specific electrical failure can be switched to an ECU pin and which loads the ECU expects on that pin. This data can be entered in the tool

manually (Figure 1) or imported via a Microsoft®Excel® list.

### Preparing the Environment Models

The environment models are usually available as MATLAB®/Simulink® models. To connect the I/O to a model, dSPACE provides a Simulink library containing what are called model port blocks for input, output and trigger signals (Figure 2). These blocks can be inserted on any level in the model. If all the signals for I/O connection are on the top model level, standard Simulink In blocks and Out blocks can be used as an alternative. Initially, the signal chain ends at these interface blocks, meaning that no hardware-specific information is placed in the Simulink model. This makes it very easy to reuse the same model in different HIL projects.

### From the ECU to the Model

All the components are brought together in ConfigurationDesk to form an overall HIL project. In an easy-to-read three-column view, the inter-

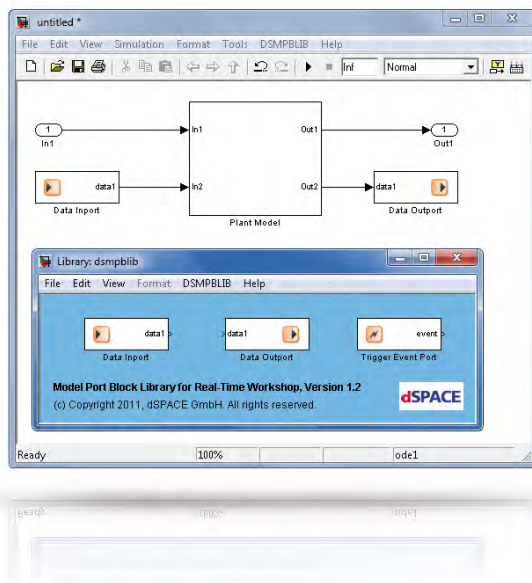


Figure 2: Simulink model interface.

faces of the connected devices (left column) are linked to the HIL system's I/O functionality (center column), which in turn is linked to the model's interfaces (right column).

ConfigurationDesk can make suggestions on suitable I/O functionalities for the connected devices.

For example, when an ECU pin provides a voltage signal, the tool suggests an HIL I/O function for voltage measurement. You can also select I/O functions from a library. The tool also warns you if there are any wrong connections such as ECU outputs that are accidentally connected to HIL outputs instead of to HIL inputs.

The I/O functions are connected to the model interfaces (right column) in the next work step. There are two different ways to do this: Either ConfigurationDesk generates a model interface description that fits the I/O functions and exports it to a Simulink model, or you yourself prepare the model in Simulink by inserting model port blocks. A model analysis is then performed to transfer the

interface description to ConfigurationDesk. Initially, the I/O functions that the simulator has to execute (for example, PWM signal generation), and not the SCALEXIO hardware that will provide that functionality. In most cases, the same functionality can be provided on different hardware channels or channel types.

The necessary hardware channels are therefore assigned to the I/O functions in a separate configuration step called hardware resource assignment. This can be done manually, or automatically by ConfigurationDesk. If signal properties such as the maximum power consumption cannot be handled by a single hardware channel, ConfigurationDesk determines the number of channels required for the channel type and assigns them to the I/O function.

### Calculating the Cable Harness

ConfigurationDesk not only computes the data for connecting the HIL system and the ECU, but can

also calculate data for connecting the HIL system to other external devices such as real loads. All the pins to be connected are listed on an Excel spreadsheet, together with the connections between the simulator pins or direct connections between the ECUs and the real loads, making it very easy to assemble the actual cable harness.

### Controlling the Build Process

All the phases of the build process are controlled from ConfigurationDesk. The model C code is generated by MATLAB/Simulink. For the I/O functionality, ConfigurationDesk generates extra code parts. It is also possible to switch off individual phases. For example, if only the I/O functionality has been modified, generation time can be saved by deactivating model code generation and reusing "old" model code. When all the C code parts have been generated, they are compiled and linked, and a real-time application is generated from them. The application can then be loaded to a SCALEXIO system for execution.

### Flexible Work Steps

The sequence of work steps described above is only one of many possible workflows. Moreover, not all the elements of the signal chain are required in every case. Some examples: Information on the connected devices is not necessary for HIL simulation itself. A build process can be carried out even if only the I/O functions and the behavior model are available. The left column is primarily necessary for computing the external cable harness, and for documentation.

### Project Clarity

Any HIL project rapidly accumulates large quantities of signal chains, so the ability to concentrate on individual aspects is a great help. Con-

figurationDesk therefore gives you options for creating different views. For example, with just a few clicks you can display only signal chains that contain a voltage measurement, or create a view of the signal chains that are connected to one specific ECU connector. A global view containing all the elements of a project is also always available.

### Reusing Subcomponents

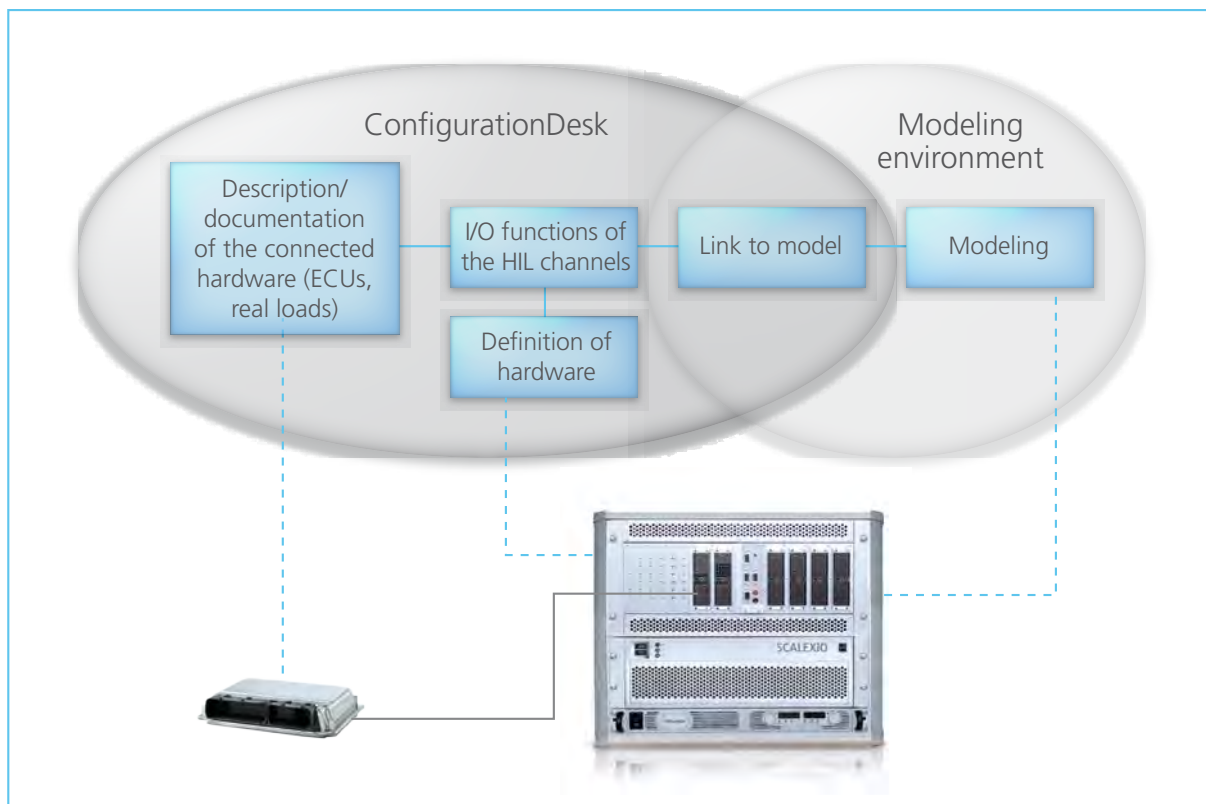
The subcomponents of a project are very easy to reuse (Figure 3). For example, an ECU description can be imported into a new project and adapted. The same Simulink model can easily be used for different projects. Because the model does not contain details of the I/O hardware, completely different I/O functionalities can be connected to the same

model interfaces. All subcomponents are saved to separate XML files so that they can be managed in a version control tool. ■

## The Benefits at a Glance

- ConfigurationDesk makes working in distributed teams very easy: For example, Simulink modeling can be performed separately from (and independently of) hardware configuration.
- The modular design of ConfigurationDesk makes it easy to reuse subcomponents.
- The flexible SCALEXIO hardware can be optimally utilized because the functionality and the hardware are configured separately.
- ConfigurationDesk provides comprehensive documentation on the entire HIL project.

Figure 3: Signal chain on the HIL system and assigned subcomponents in ConfigurationDesk.



FPGA/Processor Combination Makes  
MicroAutoBox Even More Flexible

# Flexible Logic





With their powerful processors, rapid control prototyping (RCP) systems like the dSPACE MicroAutoBox II are ideal platforms for the model-based design and testing of new controller concepts. If applications have special I/O requirements, FPGAs come into play, supplementing the processors to boost performance and flexibility.

RCP systems like dSPACE MicroAutoBox II have an established position in the fast, model-based design and testing of new controller concepts. Controller models are implemented on this real-time hardware with push-button ease. Model parameters can be modified during run time, and signals can be easily captured. To give developers maximum freedom, the powerful processors in these systems can execute even extensive, processing-intensive controller models and I/O computation within extremely short cycle times. Even so, the I/O of some applications is so processing-intensive that it considerably reduces the capacity available for model computation. These are often applications with

extensive, fast, or parallel data preprocessing or postprocessing. In such cases, it makes sense to offload the I/O to a suitable device. With a hardware architecture that allows fast, parallel processing, FPGAs are ideal for this task. Another advantage is their adaptability and programmability, allowing new I/O functions to be added and existing ones to be modified. Concrete problems and their solutions are described in detail below with practical examples.

#### **Fast, Complex Data Preprocessing with FPGA**

If an application demands frequent, very fast I/O accesses and complex data preprocessing or analysis, such



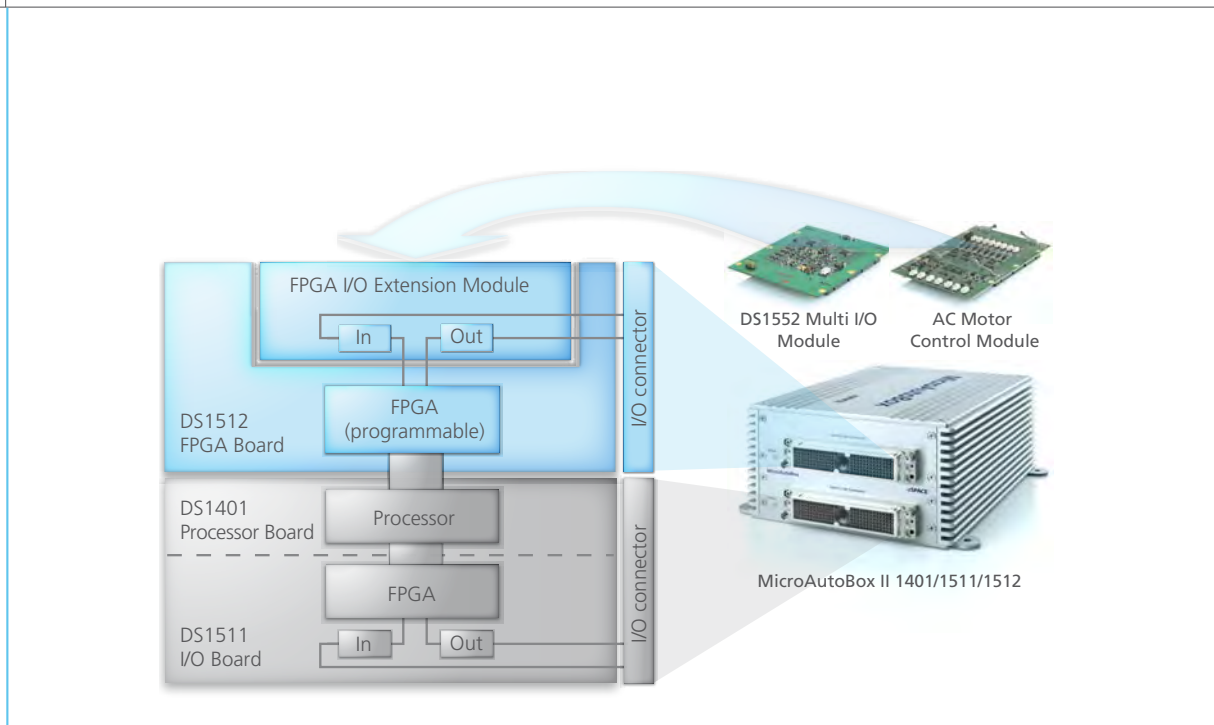


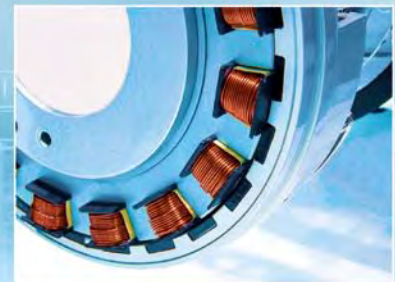
Figure 1: MicroAutoBox II variants 1401/1511/1512 with a user-programmable FPGA and slots for I/O modules.

as high-pass or low-pass filtering or fast Fourier transform of measurement values, it makes sense to run these tasks on upstream FPGAs. This reduces the load on the processor, freeing up valuable processing capacity for the actual controller computation. FPGAs can execute signal conditioning on different I/O channels and single functions in parallel and also completely independently of

one another. This speeds up computation and enables deterministic time behavior. The number of I/O channels can also be scaled without risking higher latencies. These same properties can be used to design fast, cascaded controllers with the inner control loop implemented on an FPGA, where cycle times of 10  $\mu$ s or sampling rates of 100 KHz and more are easily achieved.

#### Retrofitting I/O Functions Flexibly

Even though RCP systems support a large number of different I/O functions, it can still happen that a specific interface is not available for a particular application. There can be various reasons for this: The interface is a very special one, its specification is not publicly available, its necessity was not known at the time the RCP system was acquired, and so on. So the



■ The FPGA's ability to perform fast, low-latency analysis of large data volumes independently of the processor enables the development of innovative combustion

processes to reduce vehicle fuel consumption and exhaust emissions. And because the FPGA can address numerous parallel control and measurement channels syn-

chronously, it is frequently used to control e-motors and converters in the implementation of electric and hybrid drive concepts.



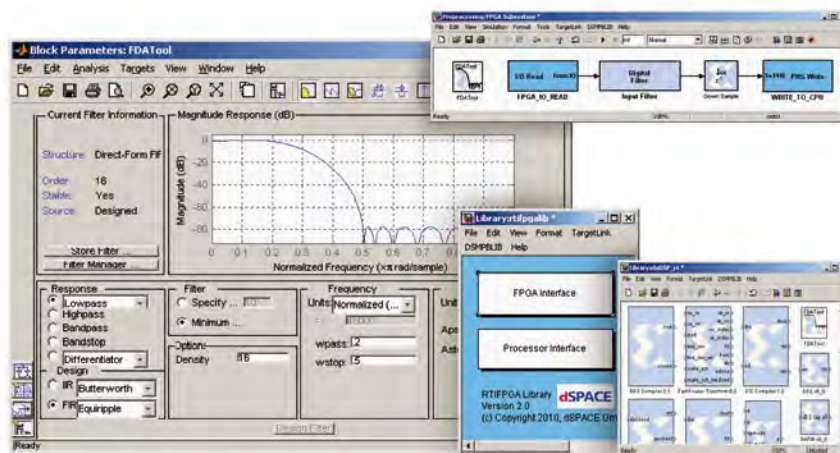


Figure 2: Model of a low-pass filter designed with the Xilinx® System Generator and implemented on the MicroAutoBox II by means of the dSPACE FPGA Programming Blockset – an example of model-based signal conditioning with FPGA support.

ability to add or modify I/O functions whenever necessary is extremely useful. FPGAs provide the required flexibility by allowing almost any digital circuit to be implemented, and unlike hard-wired interface components (such as ASICs), they can be changed at any time. For example, users have the freedom to implement different serial protocols to connect sensors from different vendors as required.

### Model-Based Development Simplifies FPGA Programming

FPGAs are traditionally programmed with text-based hardware description languages such as VHDL or Verilog. These provide access to all an FPGA's resources and allow functions to be optimized right down to the last detail. The down side is that users need specialist knowledge. If no one with sufficient VHDL skills and expe-

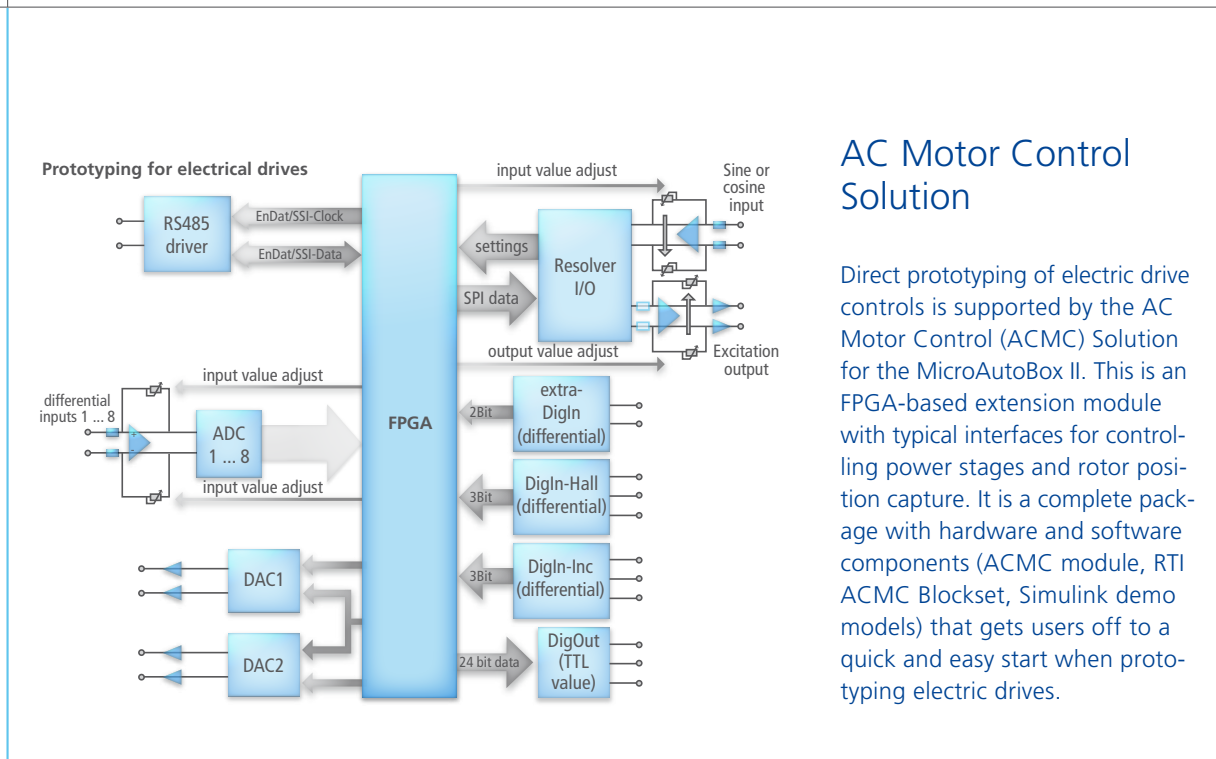
rience with FPGA technology and its specific properties is available, developers can nevertheless get off to a quick start with the aid of model-based development. The Xilinx® System Generator Blockset lets users model functions in MATLAB®/Simulink® and then implement them directly on the FPGA without any intermediate manual steps. Thus, they continue working in their familiar development



- The FPGA's architecture is perfect for fast, parallel data processing such as multi-channel filtering and frequency analysis.

For example, it is used in systems for high-quality active vibration damping or noise reduction, and for the health and usage monitor-

ing (HUMS) employed in mechanical engineering, railway technology, automobiles and aviation.



## AC Motor Control Solution

Direct prototyping of electric drive controls is supported by the AC Motor Control (ACMC) Solution for the MicroAutoBox II. This is an FPGA-based extension module with typical interfaces for controlling power stages and rotor position capture. It is a complete package with hardware and software components (ACMC module, RTI ACMC Blockset, Simulink demo models) that gets users off to a quick and easy start when prototyping electric drives.

environment and focus completely on function design. The blockset also gives developers convenient tools (such as one for designing digital filters) and enables them to integrate existing VHDL or Verilog source code into their models (Figure 2).

### MicroAutoBox II with FPGA

With all these advantages, it is clear

why dSPACE makes systematic use of FPGAs in our newest generation of MicroAutoBox II. The DS1401/-1511/1512 variant of dSPACE MicroAutoBox II gives developers the flexibility of user-programmable FPGAs (Figure 1). It has a Xilinx® Spartan-6-based FPGA board that can be freely programmed in VHDL or with the Xilinx® System Generator. To keep the latencies for I/O processing as

low as possible, the FPGA is connected to the processor via a fast parallel I/O bus and has direct interfaces to the I/O converters. For flexibility, the I/O converters themselves are on separate I/O modules that can be plugged onto the FPGA board and changed when the application changes. To support as many different applications as possible, dSPACE offers the DS1552 Multi-I/O Module,



- The FPGA is used to implement highly dynamic, cascaded controllers: for example, for very fast, very precise positioning tasks or for a control with particularly high

stiffness. There are applications in automation technology, medical engineering, robotics, and other fields. Because the FPGA can run the functions in parallel, even

very large-scale multi-axis systems can be controlled deterministically and with very low latencies.

## I/O Extension Modules for dSPACE MicroAutoBox II

	DS1552 Multi-I/O Module	AC Motor Control Solution	Customer- Specific Hard- ware Module
Model-based development for the CPU	✓	✓	🔧
Model based development for the FPGA	✓		🔧
VHDL-based development for the FPGA	✓		🔧

✓ = Available as a off-the-shelf product or solution  
 🔧 = Development on request by dSPACE Engineering Services, please inquire.

a universal I/O module with a large number of fast, powerful I/O converters and different serial interfaces. Users integrate the module into the Simulink model-based development environment with the dSPACE RTI

FPGA Programming Blockset (Figure 2). With all its versatility, the FPGA board can also provide the basis for application-specific I/O extensions. The DS1553 AC Motor Control Module (ACMC) is a tailor-made

solution for controlling electric motors. It has a large number of dedicated interfaces for the different types of rotor position capture (interfaces for Hall sensors, encoders, resolvers, EnDat, SSI and others) and for addressing the power stages. The module is supported by a predefined I/O blockset for Simulink with which users can implement the basic commutation methods (block and sinus) as well as PWM-synchronous measurement and control channels.

In cases where an application requires additional support for particular converters or I/O functions, customer-specific solutions can be developed. Thanks to the modular design, these are easily integrated into MicroAutoBox II. ■

On land, at sea, and in the air – with an FPGA module, the application scenarios of MicroAutoBox II are practically unlimited.



■ The FPGA's ability to generate and measure high-definition signals synchronously means it can also be used on test benches and in industrial automation. The fact that

higher order digital filters with narrow transition band can be directly implemented on the FPGA facilitates their use in noisy environments.

### In Brief

Every application has different requirements for an RCP system. MicroAutoBox II is dSPACE's extremely flexible, universal solution. An FPGA can be used to add or extend application-specific functions. Graphical programming is a simple, convenient way for users to adapt a development system to particular requirements. Equipped with an FPGA extension module, MicroAutoBox II is the ideal prototyping solution for a very broad range of applications.

Limited availability of the RTI FPGA Programming Blockset outside of Europe and Asia, please ask dSPACE.



# A Direct Line

The versatile diagnostics module for direct ECU access



The diagnostic interface is a central access point to an electronic control unit (ECU), and often the only available one. For tests performed on a simulator, this interface is fundamentally important. With the ECU Diagnostics Module, ControlDesk Next Generation can be used flexibly for diagnosing ECUs.

#### Talk to Me, ECU!

When developing electronic control units (ECUs), it is often necessary to access the ECUs by using a diagnostic interface. One of the major application areas this occurs in is hardware-in-the-loop (HIL) tests, where not only individual ECUs but also ECU networks are put under test. On the one hand, the diagnostic functions themselves must run through HIL tests. On the other, the diagnostic interface of the ECU can be used for many other tasks: in general, handling the fault memory, and reading and setting variants and calibration/measurement val-

ues; more specifically, activating and deactivating functions, and flashing data sets. The diagnostic interface is also often the only available way to access the ECU, so there is no way to avoid using this specific interface during the tests. When accessing ECUs via diagnostic interfaces it is necessary to use corresponding standards, such as the description language ODX (Open Diagnostic Data Exchange, ASAM MCD-2 D) and ASAM MCD-3, which is the standard for object-oriented API interfaces in measurement, calibration and diagnostic applications.

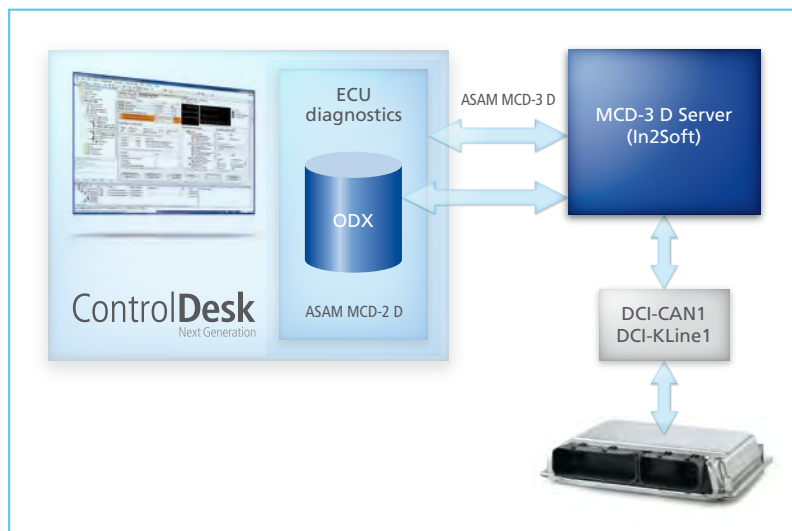


Figure 1: ControlDesk Next Generation, ECU Diagnostics Module, and the In2Soft MCD-3 D server working together

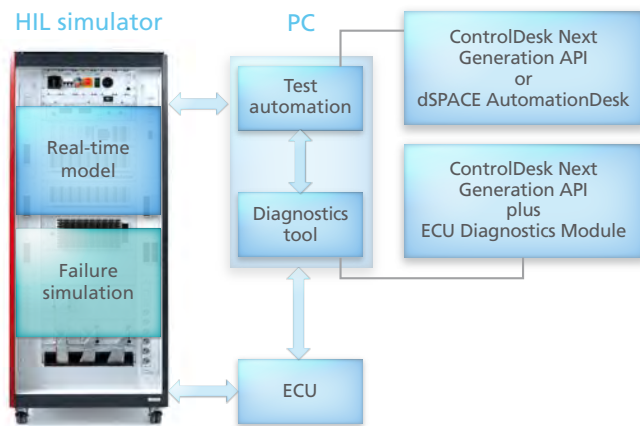


Figure 2: Structure of an HIL simulator with integrated diagnostics.

### Flexibility with the ECU Diagnostics Module

With the optional ECU Diagnostics Module, ControlDesk Next Generation becomes a very versatile tool for directly accessing ECUs. The module supports the ODX standard and integrates the MCD-3 D server from the company In2Soft (Figure 1). The server license is included in the purchase of the ECU Diagnostics Module. The module also supports various CAN hardware interfaces offered by dSPACE (such as DCI-CAN1) and by third parties, a K-line interface (DCI-KLine1), and certain diagnostic protocols. The ECU Diagnostics Module for ControlDesk Next Generation offers a wide selection of functionalities. This includes methods for reading and erasing the ECU fault memory, connecting to diagnostic services and jobs in ControlDesk Next Generation, displaying diagnostic errors, saving faults in a file, using faults as triggers, setting bookmarks during the data recording, and flash programming. The ECU Diagnostics Module supports the diagnostic protocols KWP2000 on K-Line, KWP2000 on CAN, UDS on CAN, TP2.0 on CAN, OBD on CAN, and GMLAN on CAN.

### Diagnostic Services and Jobs

One important component of the ECU Diagnostics Module is the Generic Diagnostics Instrument, with which the diagnostic services and jobs can effortlessly be parameterized and executed (once or cyclically). The function classes are displayed in a tree structure, which makes it easy to find the specific services and jobs. It is also possible to log the actions that are performed on

the instrument. One special feature is that the Request PDU (protocol data unit) can be manipulated directly for data entering the bus, in order to deliberately sidestep the constraints in an ODX definition. Among other things, this enables the user to send distinct service calls, even if it is not possible to find a suitable adaptation of the ODX file for a specific situation.

### Fault Memory Access and Data Display

To work with the ECU fault memory, there is the Fault Memory Instrument. No matter whether for reading the fault memory of one or several ECUs (once or cyclically), displaying the status information and environment conditions of diagnosed faults, erasing the fault memory partially or completely, or storing the fault memory information as an ASCII file or an XML file, the Fault Memory Instrument is always convenient to work with. With the aid of the ECU Diagnostics Module, ODX diagnostics data can also be displayed in a plotter together with signals from other sources. This makes it easy to display and analyze the temporal relation to other values (message signals on the CAN bus, model signals and parameters in the HIL simulator, memory addresses in the ECU, etc.).

### HIL Tests via the Diagnostics Interface

Diagnostic tests on the hardware-in-the-loop simulator are one of the typical application areas for the ECU

With the integrated, ODX-based diagnostics solution, ControlDesk Next Generation is ideal for use as an MCD tool in current and future ECU projects.

Diagnostics Module (Figure 2). For these tests, the user must set the operating points and events whose functions to be tested are active. The deliberate inclusion of faults plays a key role here. For example, faults can be created at signal level via failure simulation, after which the diagnostic interface is used to read the ECU fault memory and compare it with the expected fault

codes (diagnostic trouble codes, DTCs). It is even possible to validate diagnostics communication via HIL tests; namely, by using protocol tests in which, for example, the user tests all of the services that are defined in the respective ODX file. Communication faults can also be forced by sending invalid data (i.e., via a HexService or direct manipulation of the request PDU on a service). The test process can be automated (Figure 2) with dSPACE AutomationDesk (and ControlDesk's MCD3 Automation Module) or with ControlDesk Next Generation's API tool Automation Interface.

### Measurement and Calibration

With the ECU Diagnostics Module, measurement and calibration tasks can also be carried out effortlessly

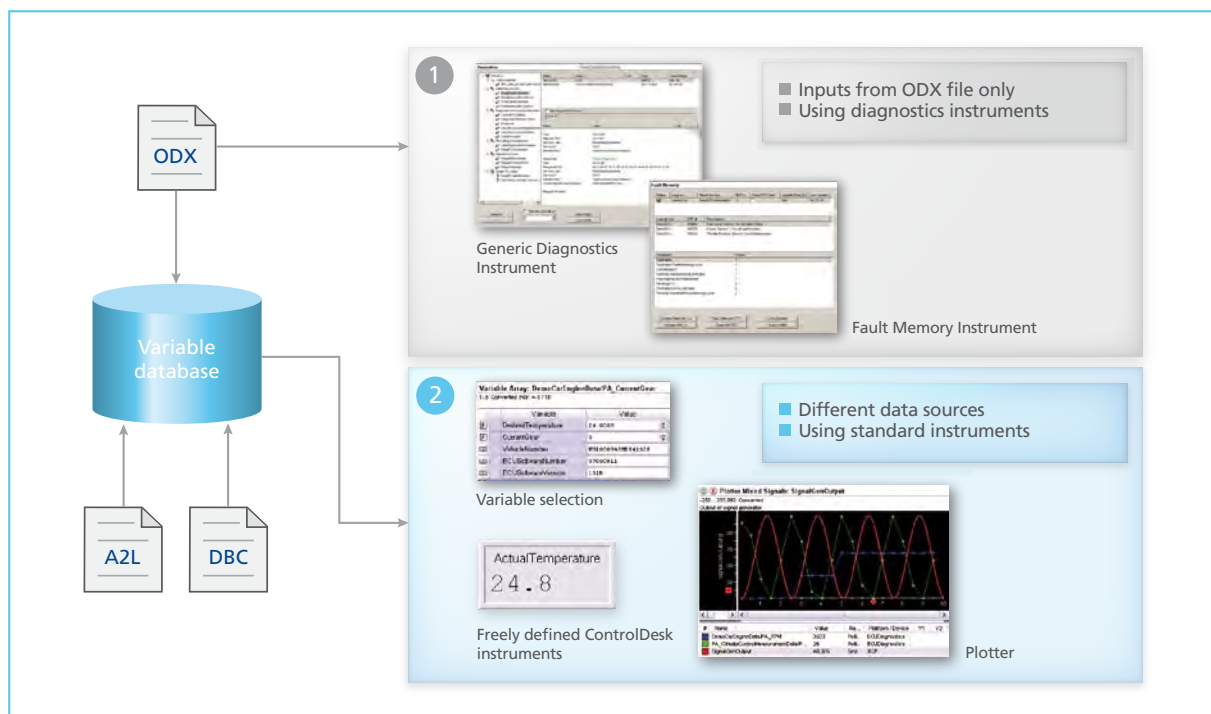
(Figure 3). For example, with the diagnostics interface the ECU data can be changed and the consequences can be documented in the form of measurement data. In this type of scenario, the access to the measurements, calibration and diagnostics can be combined in any desired configuration. On the one hand, the ODX data can be used together with the diagnostics instruments of the ECU Diagnostics Module. On the other, the measurement variables and parameters from the ODX description can be used in all of ControlDesk Next Generation's standard instruments. All of this makes the ECU Diagnostics Module the ideal supplement for any ControlDesk Next Generation user who wants to benefit from the maximum possible flexibility for ECU access. ■


## Profile

### ControlDesk Next Generation's ECU Diagnostics Module

- Integrated measurement, calibration and diagnostics tool (MCD tool)
- To read and erase the ECU fault memory
- Integration of diagnostic services and jobs (incl. measurement and instrumentation)
- Display diagnosed faults and store them in a file
- Use faults as a trigger and/or set bookmarks during data recording
- Support ECU flash programming

Figure 3: Example of a possible measurement and calibration workflow – diagnostic data can be used with diagnostic instruments (1) and also with standard instruments (2).





SystemDesk and TargetLink speed up AUTOSAR workflows  
by exchanging component containers

# Container Swapping





The current versions of SystemDesk and TargetLink make AUTOSAR-compliant software development much easier by using containers to exchange software components (SWCs). This brand-new concept ensures transparency, efficiency and reliability in the AUTOSAR development process.

#### AUTOSAR in Practice

The efforts of the AUTOSAR development partnership to establish a unified software architecture and standardized exchange formats have achieved results in automotive production projects in numerous different ways. AUTOSAR-compliant application software is usually developed with a combination of a software architecture tool and a behavior modeling tool. The two tools exchange data in the AUTOSAR ARXML format in an iterative process called an AUTOSAR round trip. This exchange of data has proven to be critical and practical experience shows that well-coordinated tools and efficient workflows are vital for efficient, AUTOSAR-compliant work. Two of the typical issues that often come up in practical work are:

- What is the most efficient way to handle the data and files in an AUTOSAR round trip for developing a software component (SWC)?
- How can components be tested efficiently during interaction with each other and with the AUTOSAR Runtime Environment (RTE)?

SystemDesk® 3.0 and TargetLink® 3.2 have the perfect answer to these and other issues: a completely new concept based on the exchange of SWC containers.

#### The Concept of SWC Containers

SWC containers let users perform AUTOSAR round trips with just a few clicks, and also make the interaction between SystemDesk and TargetLink completely transparent and reliable (figure 1). SWC container exchange is based on the following principles:

- All the files involved in developing a component (ARXML files, code files, A2L files and so on) are collected in a container and managed together by using a single container catalog file.
- All AUTOSAR-specific data is partitioned into different ARXML files such that either the architects or the component developers have complete ownership of each file. This simplifies merge scenarios in AUTOSAR round trips and ensures clearly defined responsibilities.
- Meta-information is placed in the

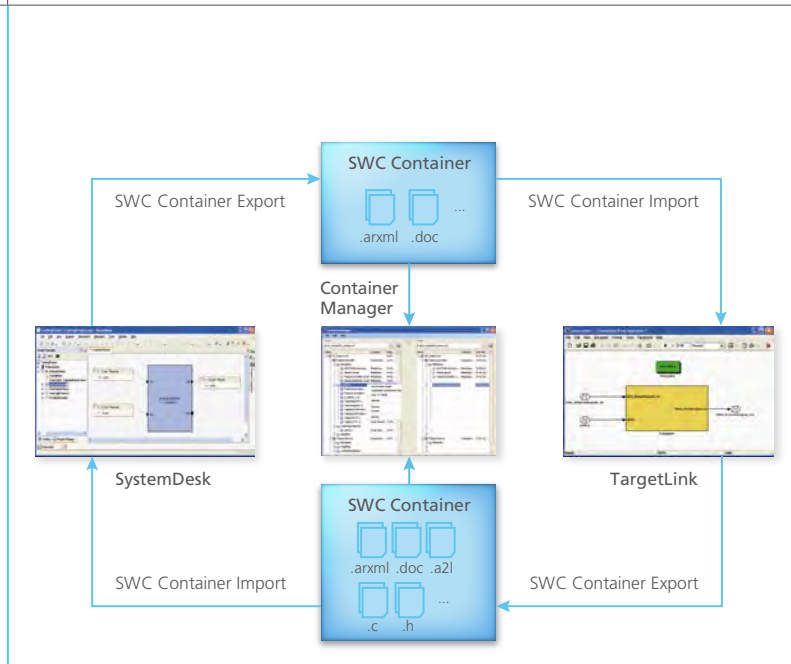


Figure 1: AUTOSAR round trips between SystemDesk and TargetLink by means of SWC containers.

the component developer, the architect exports an SWC container from SystemDesk. The container holds the necessary AUTOSAR data in ARXML files, and the architect can also add other specification documents (figure 1).

To perform component implementation, the TargetLink user imports the SWC container and uses the component's interface specifications to generate an AUTOSAR frame model. The design of the control function is then added to the frame model. Finally, the TargetLink user directly generates AUTOSAR-compliant code and executes it in the Simulink environment to test components in software-in-the-loop and processor-in-the-loop simulation.

When these activities have been completed, an updated SWC container is exported from TargetLink. The updated container holds not only the ARXML files with added implementation information, but also additional artifacts such as code files and A2L files (figure 1). The container meta-information and the stored workflow ensure that the interfaces involved in the AUTOSAR

container catalog file as file categories and responsibilities. In combination with a user-configurable workflow description in XML format, the meta-information ensures that the different statuses of an SWC container are synchronized in a controlled, secure manner.

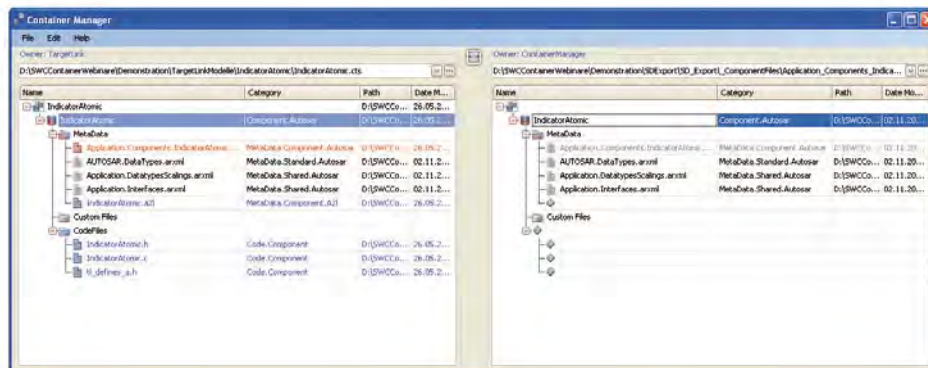
The SWC container concept implicitly uses ARXML files, so it is one hundred per cent AUTOSAR-compliant. It is also a useful extension to the AUTOSAR standard, since users

have to handle just one single container catalog file, which then implicitly manages all the other files.

### AUTOSAR Round Trips Based on Component Containers

In a top-down workflow, the development of a software component as an element in a software architecture is begun by the software architect, who specifies the component, including its ports and interfaces, in SystemDesk. To make the specifications for a component available to

Figure 2: Comparing and synchronizing different project statuses with the Container Manager.



## More transparency, efficiency and reliability in the AUTOSAR development process.

round trip cannot be modified unintentionally.

In addition, there is a specialized container handling tool, the Container Manager, which enables synchronization between containers and also provides a synchronized tree view for comparing them visually (figure 2). Thus, the user can control how to synchronize and merge the different project statuses that a container inevitably runs through during a round trip. For example, software architects can use the Container Manager to compare their version of the container with the version supplied by the TargetLink users, before reimporting the container in SystemDesk to complete the round trip shown in figure 1.

### Simple Integration into Different Simulation Scenarios

Because the SWC containers are designed to hold not only AUTOSAR

ARXML files but also code files and A2L variable description files, container exchange gives TargetLink users an extremely convenient, direct connection to SystemDesk's simulation functionality (figure 3). The implementation files generated by TargetLink and placed in the SWC container are used directly in the simulation build process performed in SystemDesk. The process compiles and links all the components against an RTE that is generated in SystemDesk. All this adds up to a system that covers numerous different simulation scenarios and tests.

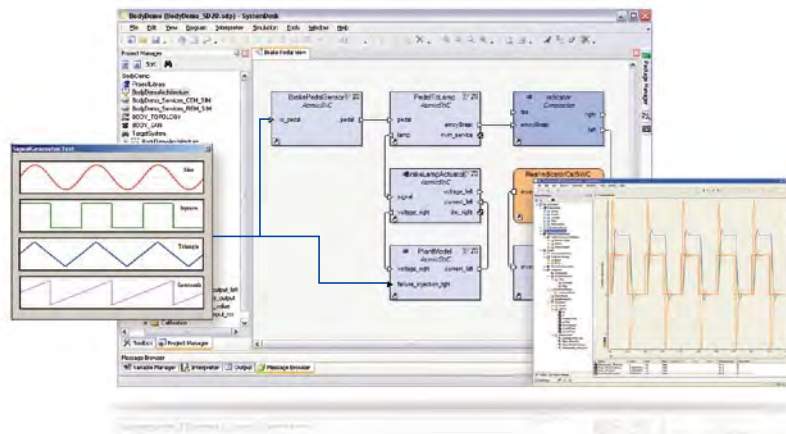
- Users get immediate feedback on whether TargetLink components can be integrated into the software and whether a compile-and-link operation for the components and the RTE is possible.
- The interactions between an extremely large number of compo-

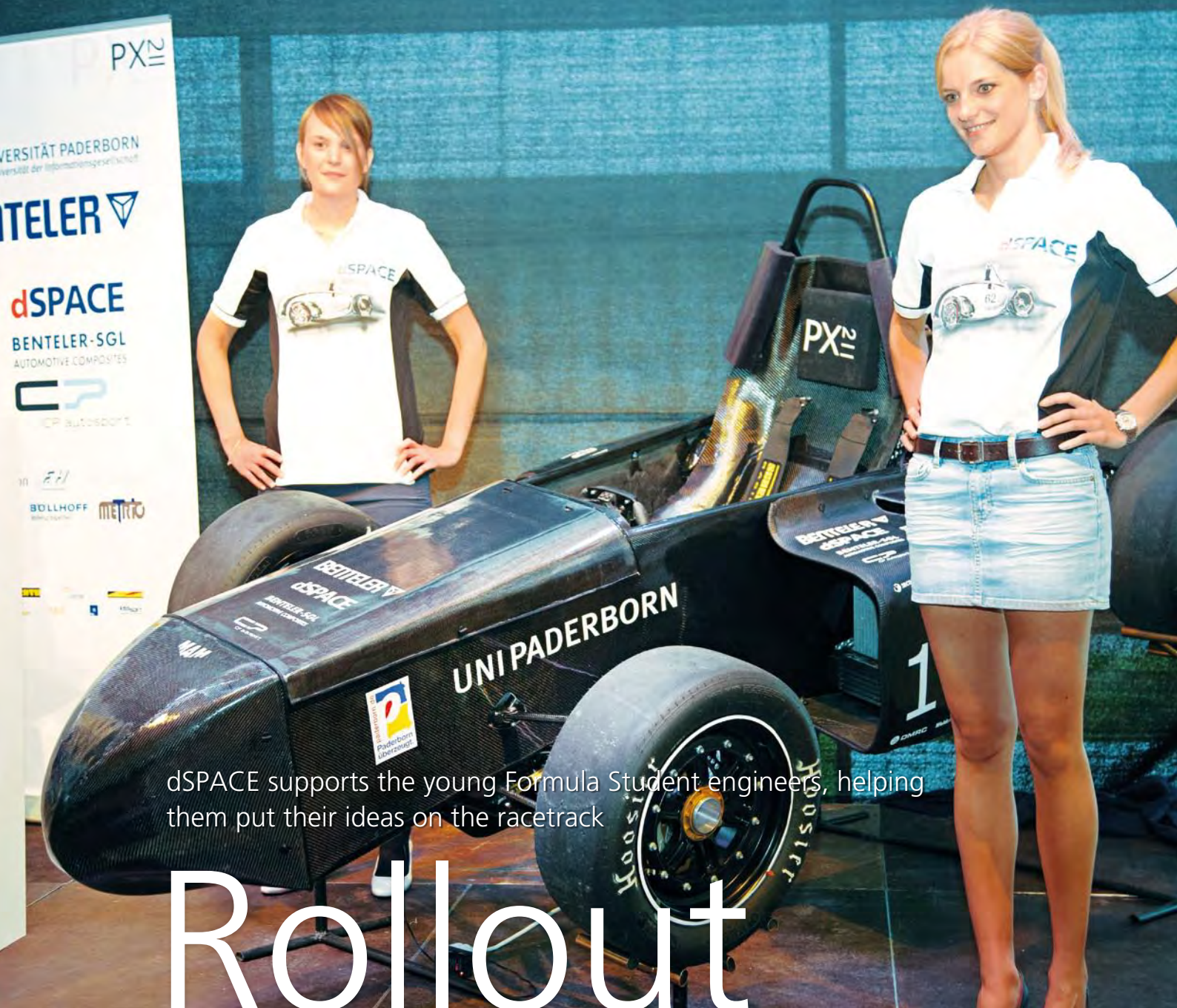
nents can be simulated and tested at "virtual function bus" level with push-button ease in SystemDesk.

- The A2L files in the containers also give simulation users direct access to internal component variables so that they can close current gaps in the AUTOSAR standard.
- In addition, the RTE can be precisely configured for more detailed simulation scenarios, including the scheduling and configuration of individual tasks, and simulated access to modules in the basic software.

SWC container exchange addresses all these scenarios directly and conveniently to simplify testing activities in the AUTOSAR development process. ■

Figure 3: Simulating the interactions between software components in SystemDesk.





dSPACE supports the young Formula Student engineers, helping them put their ideas on the racetrack

# Rollout at dSPACE



## Unveiling the PX211

Light, fast, agile – this is the UPB-racing team's winning formula in their race to beat the competition from all over the world. This group of approximately 60 students from the University of Paderborn, Germany,

works hard to put an innovative Formula Student race car on the starting line every year. What the vehicle looks like, and what technology it hides beneath its carbon fiber body, are top secret until rollout. June 1 was the big

“We believe that Formula Student is the ideal way to round off a university education. For one thing, the students learn to use real technical tools to implement their projects. And for another, practical work teaches them to plan and act independently, which makes them very attractive to future employers.”

Jürgen Plato, Chancellor, University of Paderborn



day. The team's new PX211 was ceremonially unveiled at dSPACE's headquarters in Paderborn. About 200 invited guests came to meet the young team. With optimized components, a self-developed engine control unit and dSPACE RapidPro on board, UPBracing is determined to take the lead in Formula Student. The PX211 can be seen in action on international race tracks like Silverstone and the Hockenheimring.

### Gaining Key Qualifications

The Formula Student teams are doing now what they will do later in their professions: planning, designing, purchasing, building, testing and marketing. By participating in the project, they acquire key qualifications. Because project work is so important for professional engineers, dSPACE regularly supports ten Formula Student teams, providing not only high-quality product packages, but also advice on technical issues.

### Tomorrow's Engineers

dSPACE's commitment to tomorrow's engineers begins before they even go to a university. Our ProMINT initiative aims to inspire enthusiasm for the MINT professions (MINT = Mathematics, Informatics, Natural Science, Technology), by giving children in Paderborn schools and kindergartens a taste of real-world engineering. Since 2007, the initiative has reached more than 2,700 pupils. ■

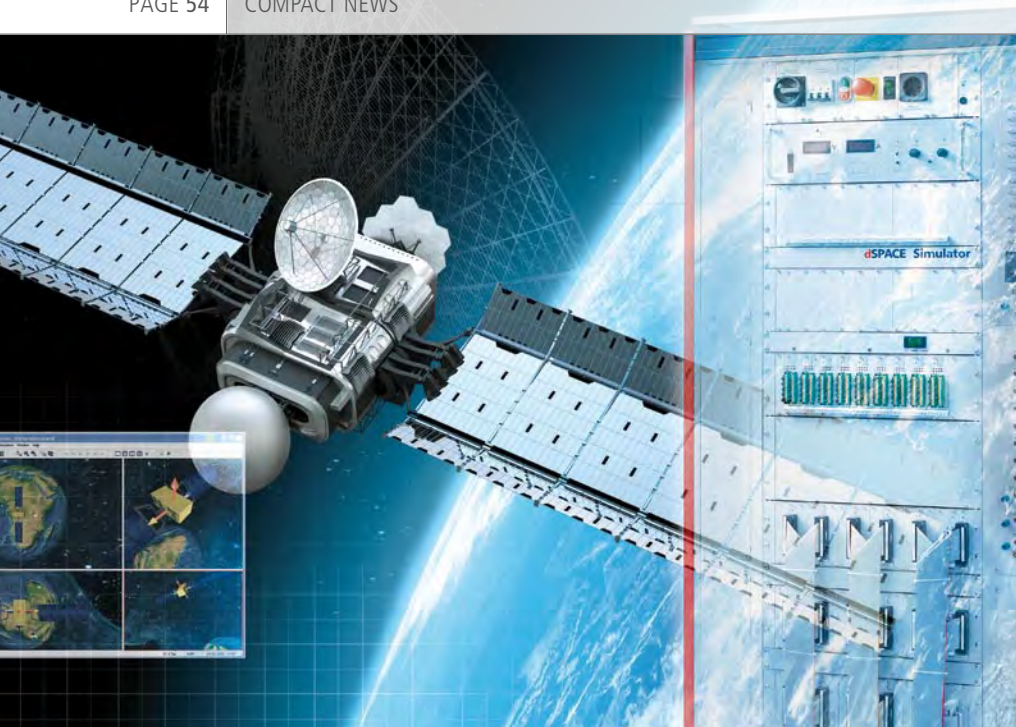


Sebastian Mailänder, Thomas Reiter, Heiko Bubenick and Alexander Diere present their new UPBracing race car.



Admiration!





## German Aerospace Center Uses dSPACE Satellite Models

dSPACE GmbH and the German Aerospace Center (DLR) have signed a cooperation agreement on satel-

lite modeling. Under the agreement, dSPACE will provide real-time-capable satellite models to the DLR's Institute

for Space Systems in Bremen. The institute is validating the models for its AsteroidFinder project and will use them to develop and test an attitude and orbit control system (AOCS). AsteroidFinder is a compact satellite mission planned by the DLR to detect asteroids that pose a high risk of collision with the Earth. The validation process will qualify the dSPACE satellite models for use in other missions by the DLR and the European Space Agency (ESA). With this latest addition to its product portfolio, dSPACE can provide the space industry with turnkey HIL simulators based on its internationally proven HIL technology to test AOCS systems. ■

## Listening to Customers

Satisfied customers are our top priority. And to guarantee the very best

quality, we're constantly looking for ways to improve. So in June, we

asked our customers to voice their opinions in a broad-based survey on our products, sales team, support staff and engineering service.

Customers filled out a questionnaire to assess dSPACE's performance.

We're happy to report that we scored well on all points, maintaining the good results from the last survey in 2008.

More than 90% of the responses rated dSPACE's overall performance as good or very good. Which areas scored highest?

Everything to do with customer relations – support, sales, and engineering service. This is completely in line with our corporate philosophy, and confirms that we are on the right track with our close customer contact.

Our thanks to everyone who responded. We promise we'll go on listening. And improving. ■



## Universal Prototyping Power Stages for Piezo Injectors



In cooperation with VEMAC GmbH, a specialist in the field of piezo technology, dSPACE is now offering vehicle-capable power stages for the model-based function development of piezo injection systems. The PZamp power stage box developed by VEMAC is connected to dSPACE's prototyping systems MicroAutoBox and RapidPro to enable the flexible

control of up to six piezo injectors. Common piezo injector systems from the manufacturers Bosch, Continental, Delphi and Denso are supported. PZamp can be conveniently configured straight from the Simulink model by using the dSPACE RTI blockset. Ready-made cable harnesses make it especially easy to connect to the dSPACE prototyping systems. Other

special features of the new power stages are that users can measure current and voltage behaviors with MicroAutoBox II at a high resolution, and also influence valve opening times in real time. All this provides much greater freedom for investigating new injection behaviors when developing combustion processes. ■

## Fit for AUTOSAR 4.0



dSPACE's production code generator TargetLink will support AUTOSAR versions 4.0 and 3.2. Seamless extensions to TargetLink's proven AUTOSAR support will serve the new

AUTOSAR versions, covering different development phases from component design to implementation to component testing. Support for AUTOSAR 3.2 will be an integral part

of TargetLink Version 3.3, to be released at the beginning of 2012, and AUTOSAR 4.0 support will be available as a patch at about the same time. ■

## New Simulation Environment for Testing Lane Assistants

The latest addition to the dSPACE Automotive Simulation Models (ASMs) is ASM Lane-Solution, designed to test lane keeping and lane change assistants. The standard road model has been extended specifically to simulate multilane roads. With the convenient user interface, roads can be defined quickly and

intuitively. The definitions comprise lane properties such as start, end, transition and surface, plus visual aspects such as the type and thickness of the line.

ASM Lane-Solution supports function development by offline-simulation and ECU testing on a dSPACE Simulator. ■



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System Architecture

Rapid Control Prototyping

ECU Autocoding

HIL Testing

## Driver Assistance Systems That Think – Tested with dSPACE Simulators



Before innovative driver assistance and active safety systems are put on the road, they need to be validated through and through. dSPACE covers the entire range, from virtual test drives based on real road maps to solutions that test camera-based systems to open simulation models for vehicles, sensors, roads and the environment.

dSPACE hardware-in-the-loop (HIL) simulators put you in front.

Think ahead. Stay ahead.

Embedded Success

**dSPACE**