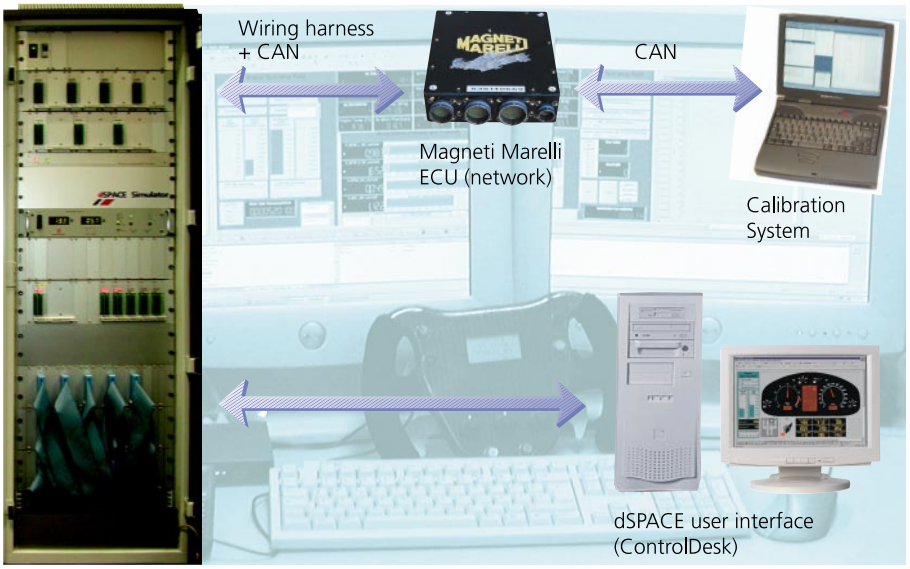
Toyota Motorsport Races with dSPACE

CUSTOMERS

- **Simulation replaces expensive tests**
- **dSPACE Simulator with 450 I/O channels**
- **New generation of Formula One control system**

To guarantee smooth, simultaneous development of ECU and vehicle, the electronic control units of Toyota's new Formula One racing car require testing at an early stage. At this time, tests on the road would be too dangerous, too expensive and not satisfactory as only a small portion of all possible failure conditions could be detected. Several tests are not possible as most measuring devices do not fit in the small racing car. The solution is hardware-in-the-loop simulation with dSPACE Simulator, which checks all specification requirements *"off-road"* in the lab.



Test stand with dSPACE Simulator Full-Size.

Our Formula One racing car is entirely designed and built in-house in Cologne, Germany, by a team of more than 550 talented engineers. We were looking for a modular concept for testing ECUs in the software design and integration phases of development, and for acceptance tests later. In order to meet these demands, we decided to use the turn-key dSPACE Simulator for the complete powertrain, covering the entire I/O of the ECU network, as well as the engine (V10 engine) and chassis signals. The test stand consists of dSPACE Simulator Full-Size, ECUs, and Magneti Marelli Vision32 calibration system.

The simulator was completely engineered at dSPACE. It was then quickly installed at our own facilities where our Toyota Motorsport engineers found it easy to start the simulation process.

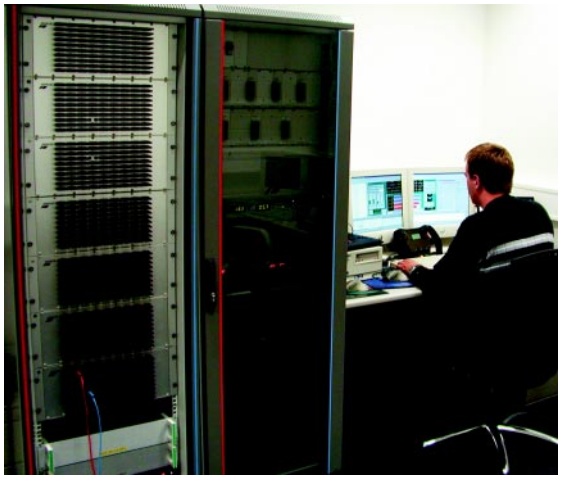
More than 20,000 RPM

The simulator is suitable for all engine (closed loop) and chassis (stimuli) signals, with a total of more than 300 I/O channels, which was recently increased to 450. This makes enormous demands on real-time hardware. To simulate the dynamic behavior of the engine and its components, the en-DYNA engine model from TESIS, Munich, is integrated into the simulation process. The Simulink-based engine model is ideally suited to dSPACE Simulator. Communication between dSPACE Simulator and the ECU is via three DS2210 HIL I/O Boards that simulate and measure all the signals for the 10-cylinder engine. The boards can even generate crankshaft and camshaft signals of up to more than 20,000 RPM (1 rev. = 3 ms). These features make the DS2210 unbeatable in racing applications.

More ECUs, Less Weight

We are using the distributed control system "Step 10", supplied by Magneti Marelli, in the Formula One racing car. That means there are 10 ECUs in the racing car and some additional ECUs in the test car for additional controls and measurements. Step 10 is a flexible system and can handle a large number of I/Os, without increasing the complexity of the wiring harness. The system is used for engine management, transmission control and data acquisition. For example: Upright boxes measure wheel speed. This is important in terms of traction control as it reduces engine power to prevent wheel spin. The Master ECU reacts by enhancing traction and maintaining vehicle stability. After a gap of a few years traction control was approved for Formula One again and has been in use since this year's Spanish

Grand Prix in Barcelona – making electronics even more important in racing.



Simulator operation by steering wheel.

Gearshift in Less than 40 ms

In racing cars, gears are shifted by hydraulic actuators under ECU control. The driver just presses the "upshift" or "downshift" button on the steering wheel to initiate the gearshift sequence. Several closed-loop controlled systems must be regulated during the shifting sequence. For instance, during upshift the engine speed is reduced by closing the throttle and cutting the ignition, the clutch actuator then opens. The gear actuator engages the next gear, and the power is reinstated by opening the throttle and closing the clutch. This gearshift control sequence is done in less than 40 ms. With dSPACE Simulator, the strategies for gear-shifting, clutch control and engine control are tested thoroughly. Only with a real-time closed-loop model is it possible to test the time characteristics of the strategies.

Eliminating Expensive On-Road Tests

Hardware-in-the-loop tests with dSPACE Simulator Full-Size are easy to perform with test automation. This is important for testing the diagnosis functions of ECUs systematically within an extremely short time. Communication between ECUs (via CAN) as well as all ECU functions and channels are tested automatically in a closed control loop before the test drive and afterwards. This gives the engineers detailed information about ECU behavior in normal situations and in the event of an error.

Further Simulators Ordered

Simultaneous engineering is made possible with the turn-key dSPACE Simulator Full-Size, enabling us to develop and test electronics in parallel with engine and racing car development. Moreover, we don't need a resident engineer – the simulator makes it easy for us to add in our own know-how. With the aid of dSPACE Simulator Full-Size, we are cutting the duration and cost of tests, and getting detailed information about our ECUs that could not be obtained in any other way.

As proof of the successful cooperation with dSPACE we have already ordered further dSPACE Simulators.

Peter Urban
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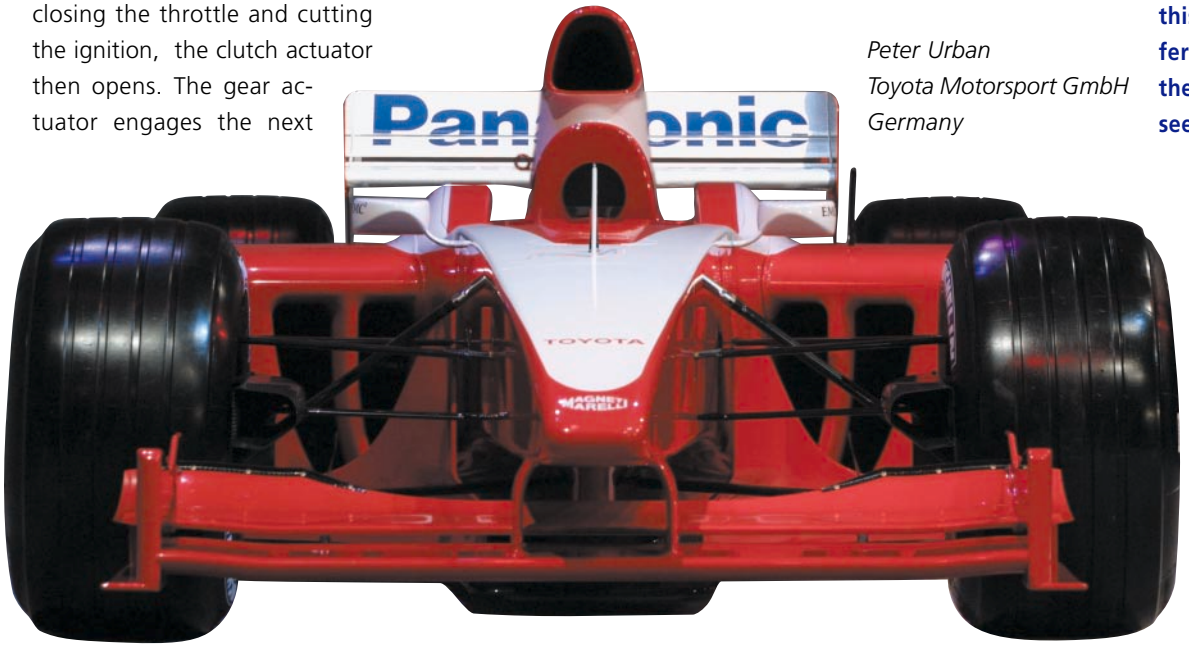

Peter Urban will discuss this topic at the "Conference on Hardware-in-the-Loop Simulation", see page 2.