Developing innovative features for vehicle dynamics at the extremes requires the right tools that do not manipulate vehicle behavior. BMW Motorrad has found the perfect solution.

Reality Is Key

BMW Motorrad relies on model-based development and rapid control prototyping (RCP) at the vehicle itself to develop new functions. The development team uses MATLAB®/Simulink® to develop new controllers, such as anti-lock braking systems (ABS), automatic stability control (ASC), dynamic traction control (DTC), or dynamic damping control (DDC). Basic functional aspects can be analyzed in offline simulation.

But there are complex influencing factors, such as the driver's behavior, the tires, and the fact that vehicle dynamics are often taken to the extremes. A controller's quality can therefore only be evaluated on the real vehicle. The development department for brake and control systems at BMW Motorrad, Function Development, uses both dedicated RCP systems and production ECUs with certain development software versions for in-

Maximum Tilt

Developing and testing vehicle dynamics controllers on motorcycles

vehicle testing. Both of these approaches have their advantages and drawbacks.

Finding the Right Balance

High processing power, a flexible I/O and comprehensive, intuitive configuration options make it possible to develop RCP systems fast and easily, minimizing the iteration cycles. But there are other aspects hampering the use of RCP systems. For example, if an RCP system is installed on a motorcycle, it changes the vehicle's center of gravity, affecting its driving behavior during test drives and causing a crucial problem for vehicle dynamics development. Having to install and uninstall an RCP system also makes it more difficult to change test vehicles. Last but not least, RCP systems are used under extremely adverse conditions. One major challenge even for production ECUs is the vibrations an engine causes when it is mounted directly on the chassis and reaches a rotational speed up to 14,000 rpm.

This is why function development for testing and prototyping often uses the motorcycle's own production ECU.

Production Before Predevelopment

Since design engineers cannot directly access the development environment and source code of the ECU software, they cooperate with the software department responsible for production development. The software department uses the C code of new Simulink

Top athlete BMW S 1000 RR uses a dynamic traction control system (DTC) to render maximum power under any road condition.
The DTC monitors the wheel speed of the rear wheel and the information given by the sensor box (such as tilt information).
It also limits the engine torque depending on rear tire slip to prevent the motorcycle from swerving or sliding.
This improves driver safety during sporty maneuvers even when road conditions are difficult.

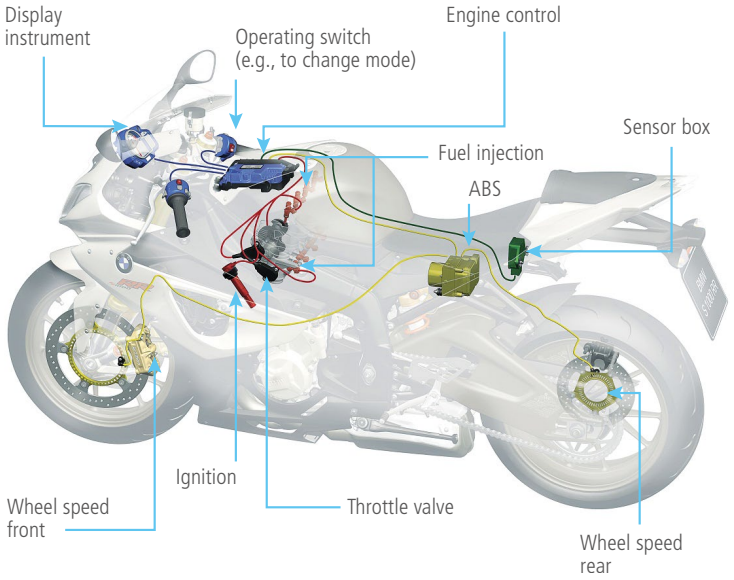

Figure 1: System design of the dynamic traction control system.

functions to develop a software version tailored to the needs of function development. The great advantage is that these software versions can easily be flashed onto different ECU types, allowing for a quick change of test vehicles. Relatively long lead times and iteration cycles are a drawback of this approach. And production usually has priority over predevelopment. Furthermore, the memory available for development purposes limits the number of controller variants that can be integrated simultaneously. Comparing several controller variants therefore becomes more difficult. The ideal solution would be to develop directly on an ECU designed for use on motorcycles, while benefiting from established RCP tool chains.

The New Approach: On-Target Prototyping

The ECU Interface Manager and RTI Bypass Blockset from dSPACE form the tool chain that makes rapid control prototyping on production ECUs possible. BMW Motorrad decided to test this tool chain in a new project to further develop the dynamic traction control system (DTC) of the BMW S 1000 RR (figure 1).

On-Target Prototyping in Practice

Largely independently from production development, design engineers took new functions developed in MATLAB/Simulink and integrated them directly into the HEX code of a production software used in a project (figure 2).
It was not necessary to access the source code or the build environment of the development software. The only configuration information needed from the software department was information that is available anyway during production software development. The modified software versions were then easily flashed onto the ECUs of various test vehicles to validate their functions during test drives. Developers used the test results to

> "On-target prototyping by dSPACE is an entirely new development method that makes us independent, saving both effort and time. We can continue to focus on innovation."
>
> *Martin Heidrich, BMW Motorrad*

improve the functions and test these on the vehicle using new software versions. This fast, iterative process allowed developers to test a greater number of controller variants, change test vehicles more quickly, and bring the new functions to greater maturity, while fully maintaining the ease of use of RCP systems. This approach's flexibility made it possible to quickly implement even short-term changes ordered by the management.

White-Box Testing on Target

But on-target prototyping benefits not only development itself. Soon, design engineers realized that this new tool chain can also be used for the final approval test for new functions. Design engineers are responsible not only for developing new functions but also for approving and releasing the production code implemented by the software department. Since input and output values of the new functions can be accessed on the ECU itself, design engineers were able to carry out white-box testing of the production implementation under real-time conditions. External stimulation of I/O and the use of real sensors and tedious restbus simulation became obsolete and a large part of approval tests were moved from the road to the lab.

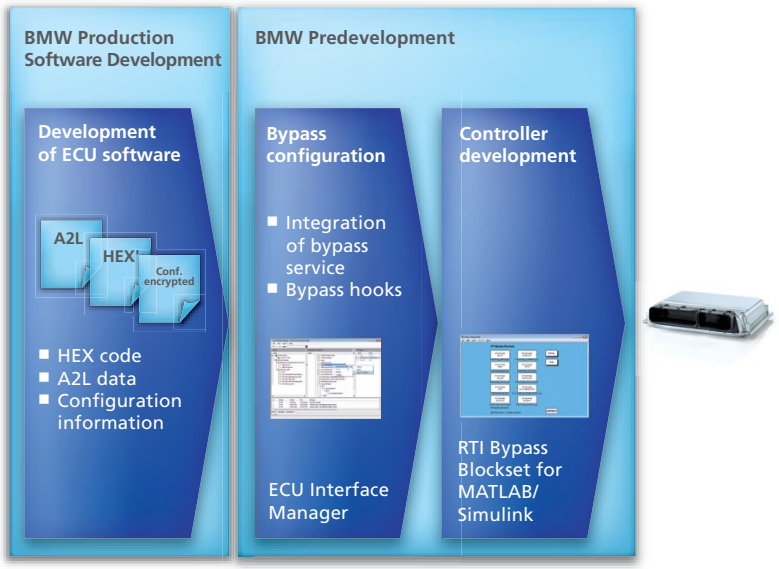

Figure 2: The workflow with the ECU Interface Manager. New functions can be integrated directly into the production ECU's software.

The result: reduced verification effort and a much shorter verification phase. ■

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Conclusion

BMW Motorrad extended their development process with a new development method: on-target prototyping. This method, based on the dSPACE ECU Interface Manager and RTI Bypass Blockset, was evaluated in the development project and passed the test with flying colors. It is more flexible, shortens development cycles and helps reach a higher product maturity. BMW developers were able to focus on the core of BMW Motorrad – innovation.

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