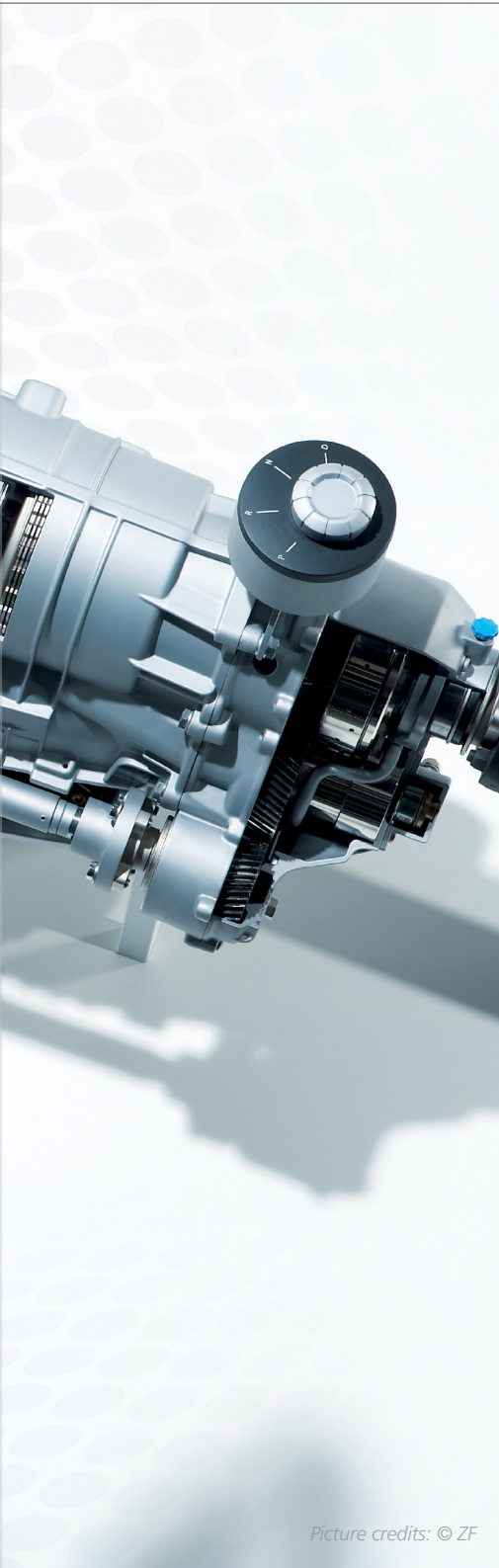




Simulated test drives
and real loads put ZF
drivetrains to the test

Virtual Torque

The ZF technology group is increasingly using virtual solutions to test and validate new real drivetrains in the early development phases. To this end, highly dynamic test benches realistically simulate the test track, the entire vehicle and even the driver. The ASM tool suite from dSPACE is used for this purpose.



Picture credits: © ZF

Drivetrains in modern vehicles are becoming increasingly modular in design, making it possible to accommodate a large number of drive types. In addition to automatic, dual clutch, manual, and automated manual transmissions, today's vehicles feature a broad range of hybrid configurations as well as purely electric drives. A further distinction can be made between central drives, drives near the axle, and in-wheel drives. Test benches must therefore be able to perform reproducible and reliable tests on all of these configurations. This requires the vehicle simulation model to be open and easy to modify.

Reasons for Drivetrain Test Benches

ZF uses highly dynamic test benches to test a drivetrain's functions and life cycle as early on as possible. Such test benches make it possible to test the entire real drivetrain in a simulated vehicle. The aim is to plausibly simulate various drivetrain and vehicle configurations. These simulations must be as realistic as possible so that all loads (load collective) that occur during a real test drive as well as the vehicle behavior in all of its possible features and configurations are covered. Only then can the drivetrain be realistically evaluated and optimized on the test bench. During the analysis, it is important to simulate the behavior of the active components in the vehicle, such as the interaction between the propulsion engine and the transmission. This ensures that the gears can be shifted either comfortably or dynamically, depending on the driver's preference. The behavior of different drivers is equally relevant, i.e., whether they drive the vehicle cautiously or sportily.

Simulations must also realistically reflect the pedal actuation and the steering wheel's movement.

Simulation as a Solid Basis

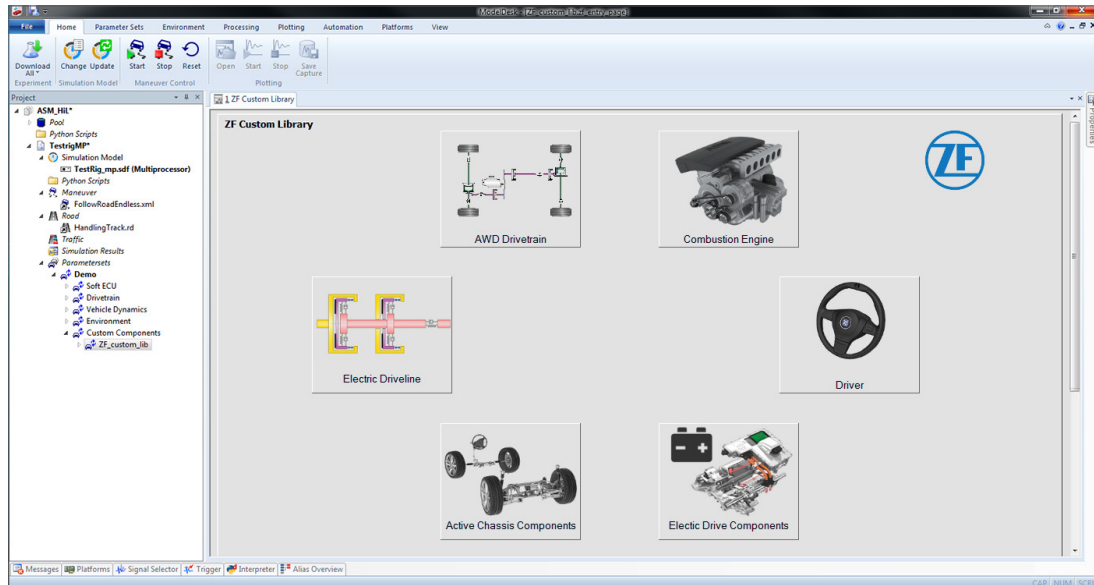
When designing the highly dynamic test benches, ZF first had to find a suitable solution for vehicle simulation. This meant the engineers had to build a virtual vehicle whose dynamic behavior is suitable for controlling the test bench. This is typically done using a real-time simulation model that can be flexibly configured and parameterized for all required vehicle types. After the evaluation of technical, economic, and process-related factors, the Automotive Simulation Models (ASM) tool suite proved to be the most suitable choice. The main benefit of ASM, aside from the open model structure, is that it can be used without an additional simulation environment, which eliminates extra license fees.

Setting up the Virtual Vehicle

The virtual vehicle that was built in ASM covers front-wheel, rear-wheel and four-wheel drives as well as all hybrid and electric drive Model. The ASM Vehicle Dynamics model is equipped with the desired vehicle dynamics features. To simulate drive units with gasoline or diesel engines, ZF uses a proprietary model that is seamlessly integrated into the model environment. An environment model based on the ASM Environment model enhances the simulation with roads and their various attributes, such as surface conditions, inclines, and gradients. The ASM Traffic model is also part of the simulation so that surrounding traffic can be taken into account. Other models from the ZF library were integrated into the overall vehicle model, for example, a steerable rear >>

“To optimally use active drivetrains, we perform realistic test drives using the ASM tool suite.”

Oliver Maschmann, ZF



An overview page in ModelDesk provides convenient access to the customer-specific model libraries.

axle or active shock absorbers. ASM's open structure made it particularly easy to integrate the ZF models. For instance, the developers were able to access exactly those signals that were required for the components they had developed.

Implementing a Graphical User Interface

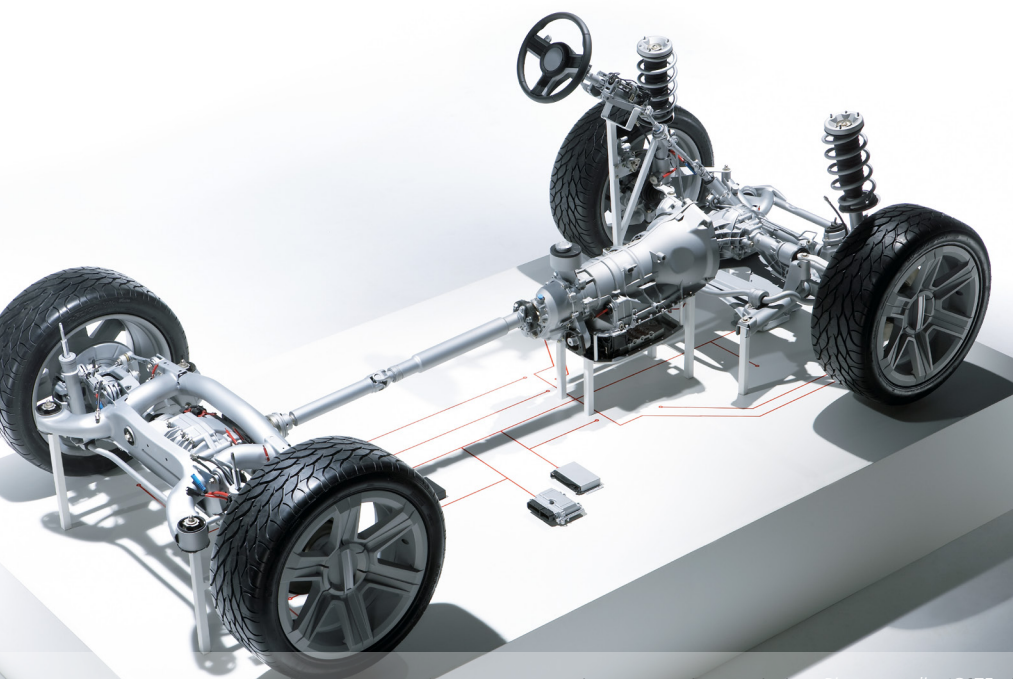
Since test benches along with their simulation environment are needed

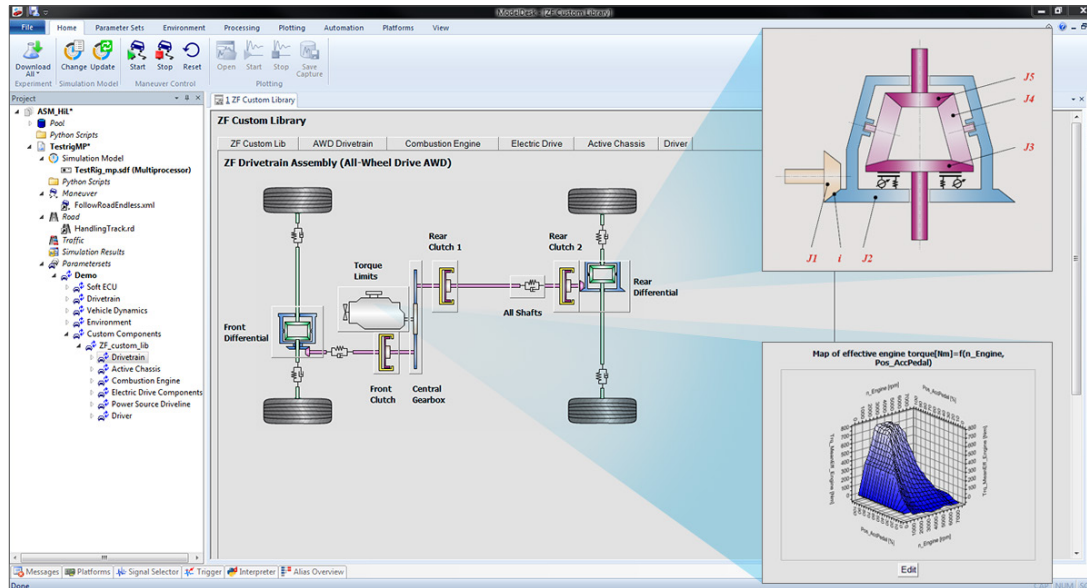
at several locations with identical setups, they must be easy and intuitive to use. To meet this requirement, ASM is equipped with dSPACE ModelDesk, which provides a graphical user interface for parameterizing and configuring the models. Moreover, the developers can execute prepared test programs and simulations using only one user interface. This process can be comfortably controlled by a script and thus easily automated.

ModelDesk can be used for all ASM libraries. For the proprietary models in the ZF library, the developers can automatically generate suitable user interfaces. For this, ModelDesk contains a parser that analyzes a model and then automatically generates a functional framework that contains all parameters, maps and interfaces for tool automation. ModelDesk provides this framework as an HTML website. Cascading Style Sheets (CSS) help implement all created user interfaces uniformly and according to ZF's design requirements. The manual effort for this is very low, which means all pages can be created in one day, even if the libraries are more extensive.

Preparing for Deployment

After the simulation environment is set up, it must be validated. For this purpose, the developers used benchmark measurements from a real vehicle. The simulated vehicle must return the same results (yaw rate, longitudinal acceleration, lateral acceleration) under the same conditions (speed, steering angle, etc.). In addition, a driver model is used that has been extended and optimized according to ZF's requirements. The goal





The contents of customer-specific model libraries are displayed clearly and can easily be changed.

was to ensure a plausible, realistic actuation of the pedals and the steering system. The PC-based simulation platform dSPACE VEOS enables developers to start up the entire setup virtually at their desks before testing on the test bench. If required, all processes as well as the test case can be executed significantly faster than in real time. This is very useful if the developers have to simulate long test drives of hundreds of kilometers because they complete them within a few minutes. Combining ASM and VEOS also offers advantages regarding a consistent and efficient development process. Thanks to the open architecture, any number of Functional Mock-up Units (FMU) or ideas for functions can be used in Simulink, even if they are only rough drafts. Another advantage is that it is easy to integrate measurement data into the simulation. The processing function in ModelDesk is recommended for this because it can be used to prepare the data accordingly.

Evaluation and Next Steps

The installed ASM tool chain for simulating vehicle dynamics enables ZF to take an important step towards realistically testing drivetrains on the

test bench. The models meet the demanding requirements regarding cycle time and accuracy on highly dynamic four-wheel test benches, for example. Moreover, the simulation has proven to be suitable for testing drivetrains using customer software by means of automated, closed-loop driving of load collectives on the test bench. During these test drives, comfort criteria can also be analyzed, for example, during drive-off. The system is continuously enhanced to make larger road networks and traffic flows available during the automated test runs. The tool chain is available internationally: It can be purchased locally at the various ZF development locations worldwide. The proprietary libraries allow users to create an identical test bench configuration at all ZF locations, thus ensuring identical use. ■

Oliver Maschmann, ZF

Requirements for a Drivetrain Test Bench

Simulated components:

- Active chassis with steering
- Combustion engine with hybrid module
- Active rear axle kinematics
- Vehicle dynamics
- Longitudinal and lateral drivers
- Soft ECUs

Required flexibility:

- Using real and emulated drivetrains
- Active components in the drivetrain (active axle differential, switchable four-wheel drive, differential lock, etc.)
- Modular interfaces in the drivetrain for additional configurations

Oliver Maschmann

Oliver Maschmann is responsible for the highly dynamic test benches at ZF in Friedrichshafen, Germany.

