



Flexible Test Track

Testing new driving concepts under reproducible conditions with a hexapod 360° driving simulator

To find and validate concepts for chassis, vehicle dynamics controllers, and advanced driver assistance systems, Daimler AG relies on a driving simulator in addition to test drives on the road. The best thing about it: The test driver and the real vehicle are right in the middle of the action.

The Daimler 360° driving simulator in Sindelfingen, which is used for extensive vehicle dynamics tests, takes up an extremely large factory workshop. It has no less than six legs and can swallow up entire passenger cars. Its pivotable dome is attached to a hexapod (six-legged platform). The six legs that consist of electromechanical spindle actuators can move the dome into a great variety of positions by means of coordinated extension and retraction movements. By combining rail and hexapod movement, the simulator can represent all relevant driving situations as realistically as possible. The design of the motion system dynamics is essentially based on the requirements for vehicle dynamics investigations, extending to the vehicle's limits.

Realistic Driving Situations

While the motion system simulates the acceleration forces, an image generation system visualizes continuous motion. This creates a realistic driving situation for the driver. To do this, multiple projectors create a 360° view for the driver inside the dome. Instead of side mirrors, the vehicle inside the dome has digital displays for the virtual rear view. With the combination of image and traffic simulation software and a complex sound system, a holistic, realistic representation of the entire driving situation and maneuvers is created.

Central Control System

All driver actions, such as the actuation of the accelerator or brake pedal as well as the steering, are trans-

mitted to a computer system that computes the motion of the vehicle in real time and sends the relevant commands to the driving simulator's electronics. The motion system sends the computed vehicle movements to the dome, in which the virtual vehicle subsequently behaves as if it were driving on a real road: When braking, it pitches; when accelerating, the driver is pressed into the seat; and when cornering at high speeds, the driver feels the centrifugal force. The passenger cabins are usually production vehicles whose propulsion unit and wheel suspensions have been removed. The operation is the same as in a real vehicle. When the driver moves the steering wheel, an actuator sets a feedback force at the steering wheel, which is calculated by the vehicle model [1].

Requirements for the Vehicle Simulation

The vehicle model receives the driver input and simulates the vehicle movements in real time. Various simulation programs are implemented to fulfill the different requirements for chassis, vehicle dynamics controllers, and driver assistance systems. The driving simulator has a flexible interface, which makes connecting the vehicle model in different programs possible [1]. For the vehicle dynamics test, it is important to reproduce the vehicle behavior to the extremes. Therefore, the vehicle model must be able to simulate the chassis as accurately as necessary but also as simply as possible. Most of the applied vehicle models do not use structural parts and mountings. Instead, the models are described by look-up >>

An image generation system creates realistic visual impressions in the dome, and a motion system generates the related acceleration forces, for example, when braking and cornering.



tables. This way, the models can provide sufficient accuracy but also remain real-time-capable.

Setting up the Virtual Vehicle

Since 2013, Daimler AG has been using the dSPACE Automotive Simulation Models (ASM) tool suite as a real-time-capable model in the driving simulator to evaluate the handling characteristics of passenger cars during chassis predevelopment. With the driving simulator, it is possible to subjectively evaluate the driving behavior of a chassis design with regard to lateral dynamics. By continuously developing the operating system in the driving simulator and enhancing the ASM model, the test scope has been enhanced. The following tests have become possible during this time:

- *Adjusting the suspension with regard to lateral dynamics*

With the ASM model, it is possible to specify the characteristics of the spring, the stabilizer, and the damper for a chassis system. The characteristics are

tuned by varying the model parameters with respect to subjective criteria, such as agility, yaw behavior, and steering behavior. This allows for evaluating and optimizing the handling characteristics at an early stage when no development mule is available.

- *Subjectively comparing different chassis systems*

In addition to the influence of suspension and damping systems on vehicle dynamics and driving experience, the impact of kinematics, compliances, loading conditions, and the tires is also investigated. With the help of the driving simulator, sensitivity analyses can be performed, for example, to find the influence of bushing stiffness on the self-steering behavior. This analysis is not only useful when developing suspension concepts, but it is also a sensible addition to the real test drive. On the one hand, the adjustment of the chassis parameters, which can be changed only with great effort in a real vehicle,

can be changed quite easily by modifying or replacing the look-up tables and values in the ASM model. On the other hand, the test can be performed more efficiently by simply exchanging the model parameters, because the tester can compare and evaluate the different chassis types without interruption.

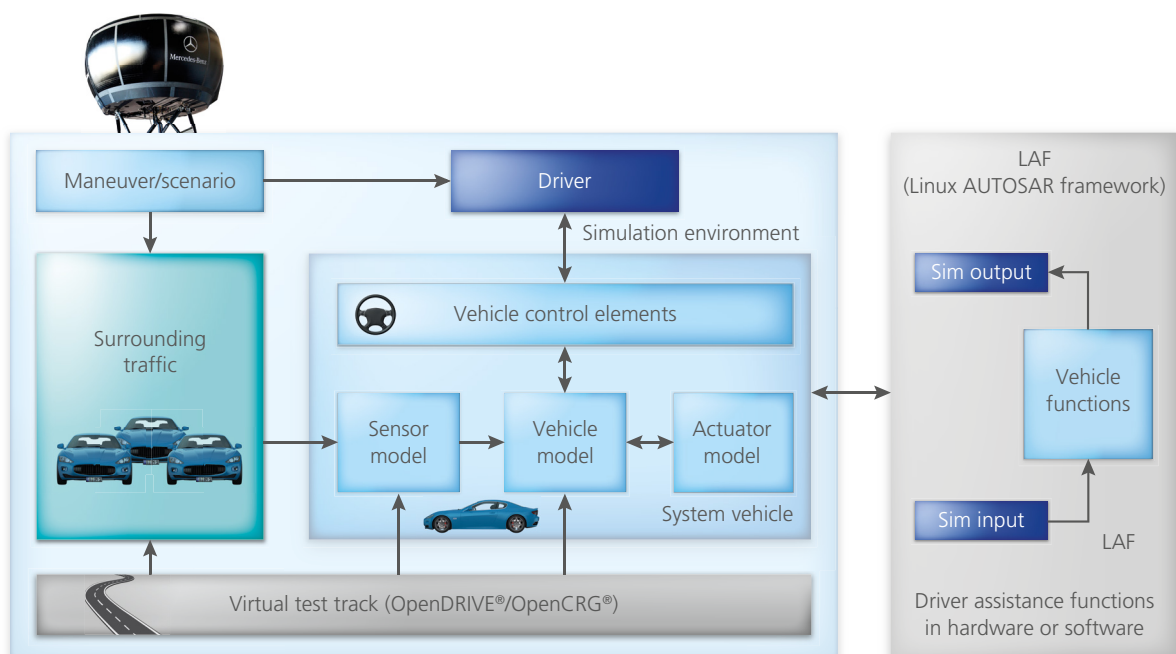
- *Recording the driver reaction during specific driving maneuvers*

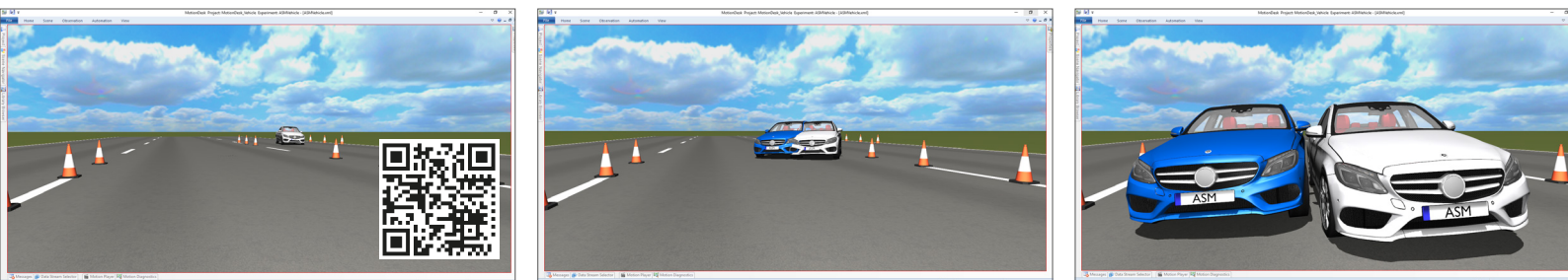
During an offline simulation of a closed-loop maneuver, it is a challenge to accurately model the driver. The driving simulator provides the option to record driver inputs, such as steering wheel angle as well as accelerator and brake pedal position, during the tests. Consequently, the driver model can be optimized on the basis of the recorded data.

- *Evaluating new chassis functions*

Innovative ideas and new concepts for chassis systems to improve driving comfort and vehicle dynamics can be tested and evaluated at the

Schematic setup of the simulation environment to control the hexapod. The vehicle dynamics were implemented with the ASM tool suite.





Superimposed representation of the vehicle behavior of two different chassis types in a step-steer maneuver simulated by the ASM tool suite. Watch the video of the driving maneuver: www.dspace.com/goldMag_20181_steer

“ASM is used as a real-time-capable model for evaluating the handling characteristics of passenger cars during chassis predevelopment.”

Dr. Hans-Peter Schöner, Daimler AG

early stages of the vehicle development without having to design components and set up mules. Both customer and expert evaluations for new ideas and concepts can thus be taken into account at an early development stage and for continued development.

Multistage Test Drives

A test drive in the driving simulator is performed in three steps. At first, the existing multibody simulation (MBS) modeling is transferred to a real-time-capable ASM model. This model is then tested in a fixed-base simulator, i.e., without a motion system, to verify that all variants are numerically stable in all maneuvers. Afterwards, the test is executed. During the test, the test participant successively drives a maneuver with two different chassis variants and then compares the two variants. The evaluations of all variants are documented. In the end, all test results are evaluated and summarized. The chassis variants with the best evaluations are simulated in the MBS model again to have an objective evaluation. The subjective evaluations and their sensitivities can be used as a reference for developing vehicle components and functions.

Summary

By using the driving simulator, it is possible for the automobile manufacturer to test and evaluate vehicles at different development stages. As a result, development times for future models can be significantly reduced. Regarding vehicle dynamics, the road handling, ride comfort, and intervention of control systems can be evaluated quickly and safely. ■

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See the driving simulator in action: www.dspace.com/goldMag_20181_FSIM

Literature:

[1] Dr.-Ing. Hans-Peter Schöner: “Erprobung und Absicherung im dynamischen Fahrsimulator”; Conference Paper: SimVec - Simulation und Erprobung in der Fahrzeugentwicklung: Berechnung, Prüfstands- und Straßenversuch, Baden-Baden, Volume: 17. Kongress (VDI), November 2014 www.dspace.com/goldMag_20181_SimVec

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