Dynamic Models

Vehicle dynamics are the showpiece of car manufacturing. Porsche uses an efficient, seamless vehicle development process to pass on excellent vehicle dynamics genes from the first development steps to the final product.


918 Spyder

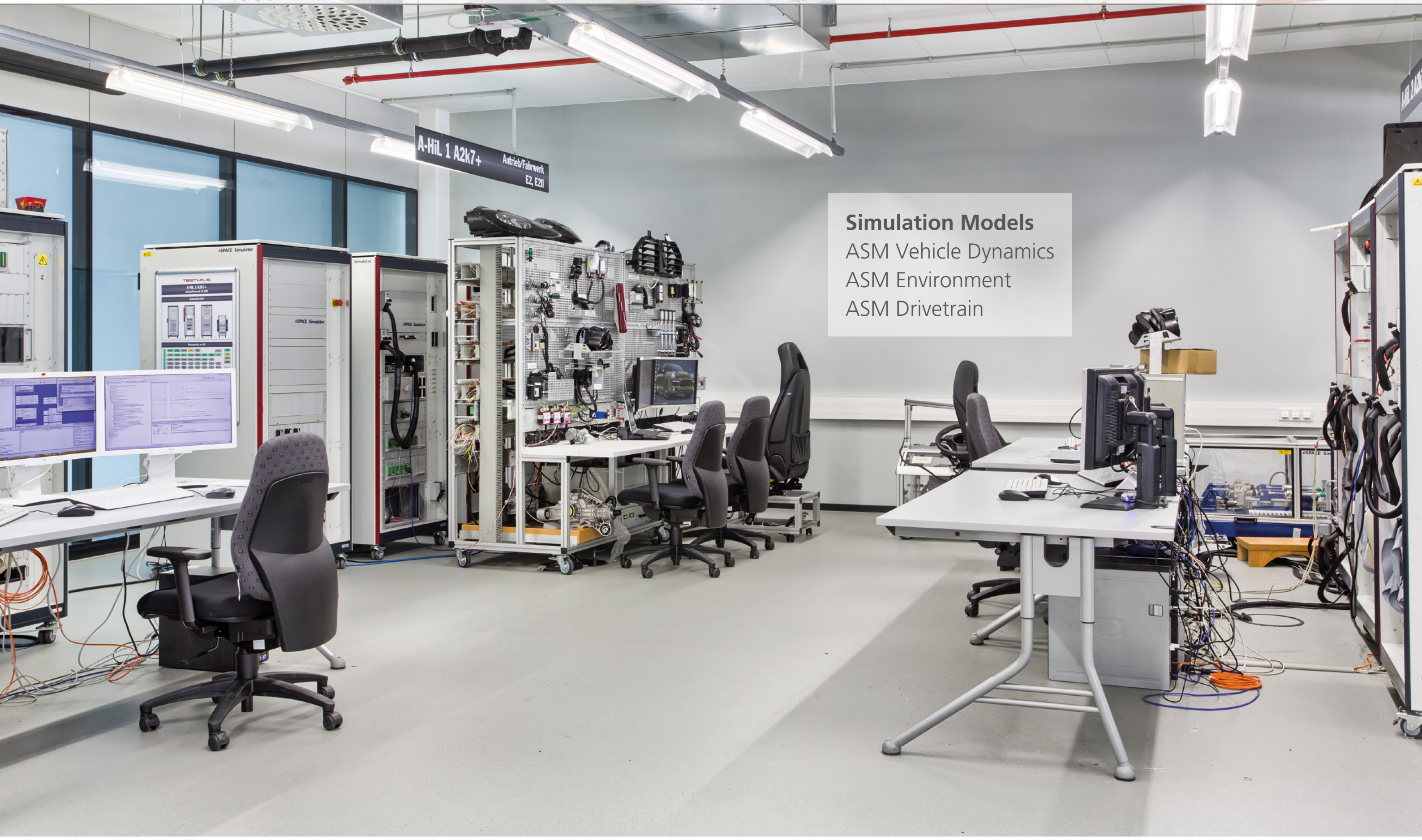


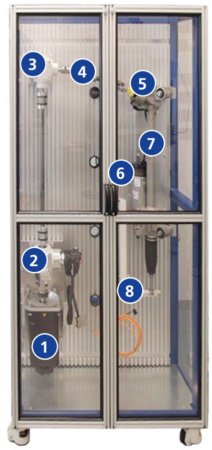
Figure 1: HIL test benches for validating the drive/chassis applications. A setup for installing ECUs and for integrating real components (throttle valves, injectors, transmission valves, actuators for the electronic parking brake, radiator shutters, etc.) is located at the center back.

Porsche vehicles are known for their outstanding vehicle dynamics. To achieve this high level of quality, all vehicle components must be very finely tuned to each other, especially the body, chassis and the wheels. Active chassis components are playing an increasingly important role in achieving Porsche's ambitious vehicle dynamics goals. These active components include the electronic stability program (ESP), active damping control and the Porsche Dynamic Chassis Control (PDCC), which reduces a vehicle's roll in curves to almost zero, improving agility and comfort. Because the number of vehicle variants increases steadily while development cycles are becoming shorter, the virtual simulation of the vehicle is gaining importance for the development process.

> "For the HIL validation of vehicle dynamics ECUs, we rely on dSPACE's ASM Vehicle Dynamics."
>
> *Dr. Günter Hetzel, Porsche AG*

Function and ECU Tests with HIL Test Benches

At Porsche, hardware-in-the-loop (HIL) simulation has earned its place for automated testing of the electronic control units (ECUs) during the development process. It has become a core component in the creation of new products. Networked HIL test benches are used for the integration and function validation of applications in drives and chassis as well as body and infotainment. These test benches include all ECUs of the relevant application (figure 1). While relatively simple simulation models are sufficient for body and infotainment applications, the modeling effort for drive and chassis applications is much higher, because they require more complex models, such as for combustion engines and transmissions. These models simulate all system variables (such as sensor signals or bus signals), which can then be used for ECU testing via the HIL simulator. However, systems whose ECUs cannot be separated from the actuators simply cannot be simulated in this way (e.g., electric steering systems).



1. Motor for superimposing the driver steering torque
2. Angle gear for steering angle sensor (only on the test rig)
3. Angle gear (only on the test rig)
4. Steering column
5. Steering box
6. Servomotor for steering support
7. Rack and pinion
8. Measuring device for analyzing the specified path

Figure 2: Setup for testing an electric steering system.

In these cases, the entire mechatronics system is integrated into the setup, including the ECU, the electric machine, and the steering column. A servomotor takes on the role of the driver and generates the steering torque (figure 2). The high complexity of the chassis ECU functions place high demands on the vehicle models used with the HIL test bench. Testing and validating the vehicle dynamics functions of the ECU network in particular requires validated models that emulate the real vehicle behavior as precisely as possible. The simulation models used for the drive/chassis test benches consist of a combination of Porsche's own models (e.g., for the transmission) and dSPACE's Automotive Simulation Models (ASM). The vehicle dynamics are simulated with ASM Vehicle Dynamics.

Simulating Vehicle Dynamics in the Development Process

Simulation models can support the objective evaluation of vehicle dynamics even in early project phases. They allow for a systematic, automated and therefore efficient and comprehensive validation of all relevant criteria. Depending on the task, different model classes are used for chassis/vehicle dynamics testing at Porsche AG's development center in Weissach:

- Reference models with a high-fidelity simulation of the chassis and vehicle components, but with increased computation times
- Function models with a simplified representation of the parts, which can be simulated in real time or faster
- Property models with a summarizing description of the components and a complexity comparable to that of a function model, but with very short calculation times
- Component models without a model of the overall vehicle to observe individual components, as in a test bench model

To use these model classes equally for the associated tasks and without any additional effort, Porsche introduced a process of seamless parameterization and uniform validation (figure 3). This approach makes it possible to create the models from the respective superordinate classes and validate them based on the same driving maneuvers. Because only open-loop driving maneuvers are possible, such as specifying steering and speed profiles, objectively capturing the vehicle properties becomes easy in both the real test drives and the simulation. At the same time, the stationary and the dynamic behavior of the vehicle are considered.

Combining Strengths on the HIL Test Bench

To benefit from the uniform model preparation process while being able to use the mature test automation >>

Type	Real-Time Capability	Parameterization Effort	Component Models
Reference model	No	High	Exact simulation
Function model	Yes	Partly automated parameterization from the reference model	Simplified
Property model	Yes	Partly automated parameterization from the reference model, function model or measurements	Simplified, component summary
Component model	Model-dependent	Model-dependent	Model-dependent

Table 1: Classes of the vehicle dynamics models.

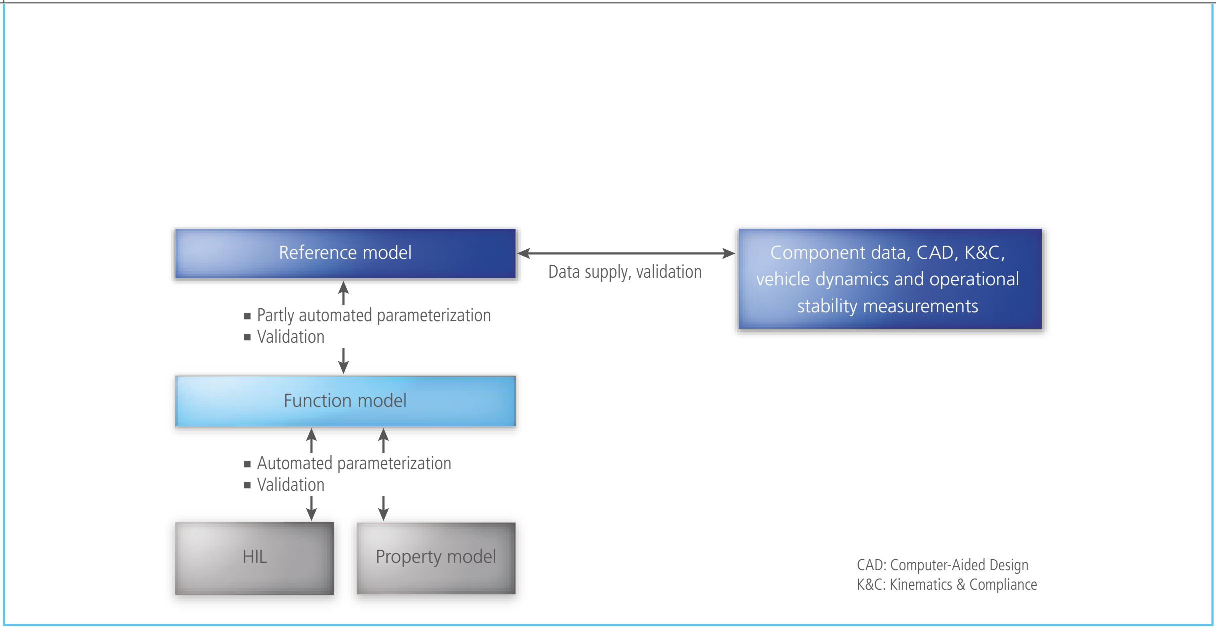


Figure 3: Seamless model parameterization.

and robust dSPACE ASM environment, Porsche created a function for translating the function model's parameters. This function can now be used to create fully automated model data sets for the HIL test bench that have practically the same vehicle dynamics properties as the reference model. Valid vehicle dynamics models let developers perform comprehensive tests of the ECU code's functional aspects with the desired accuracy.

A Double Win

Due to the process described here, the completely parameterized chassis models that are needed for the HIL test bench are already available during the established model preparation process. ECU development and validation therefore benefits from validated chassis models in early development stages. The simulations carried out in the ECU network can also be used for validating a software-in-the-loop (SIL) environment in which software models of the ECUs can be tested with the same vehicle data sets. Porsche therefore has a powerful and robust tool chain for all phases of vehicle development.

Outlook

Our goal is a seamless range of models for all future vehicle projects. In the next step, we will aim at automating parameter preparation and the validation and comparison of the HIL and SIL simulation results. This will make the work processes for virtual validation even more efficient. ■

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Seeing is knowing: The animation software MotionDesk is the perfect tool for visualizing simulated driving maneuvers.

ASM Vehicle Dynamics

ASM Vehicle Dynamics is a simulation model for simulating the vehicle dynamics behavior of a vehicle realistically in real time. The physical vehicle characteristics are represented by a multibody system with 26 degrees of freedom. ASM Vehicle Dynamics includes a configurable drivetrain with elastic shafts, a brake circuit and motor model, different wheel models, non-linear kinematics and elastokinematics properties of the chassis, a three-dimensional description of aerodynamics and a complex steering model with several degrees of freedom. An environment with a road, maneuvers, and an open- and closed-loop driver is included as well. All parameters can be altered during run time. The modular components of the additional ASM can be connected to form a virtual vehicle, for example, for testing ECU networks in a HIL environment.