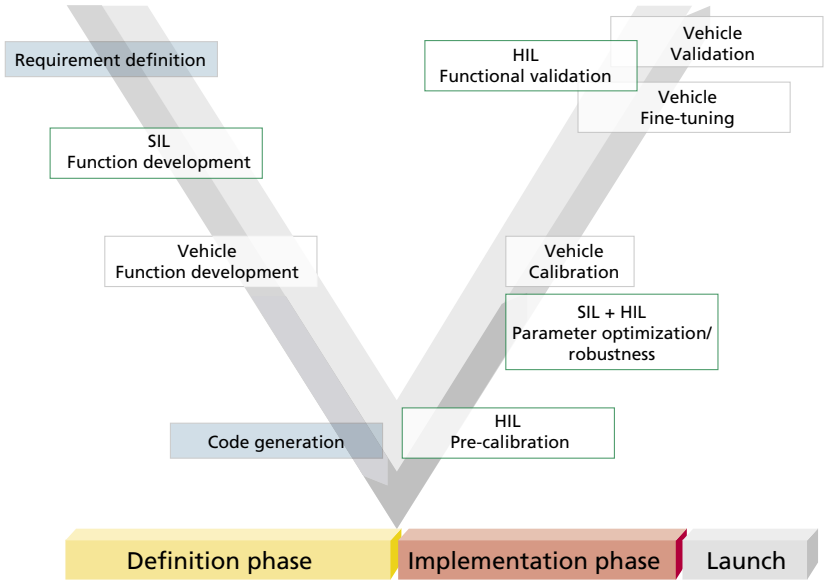
Strategic Use of HIL and SIL

- **dSPACE Simulator integrated in the development process at Audi**
- **Controller calibration and parameterization in the simulation**
- **Optimum mix of simulation and test drives**

Hardware-in-the-loop (HIL) and software-in-the-loop (SIL) simulations have long been used to test electronic control units (ECUs) and software. Now they have a new application field: calibration and parameterization of a vehicle stability controller, using simulation. A virtual calibration procedure like this requires far more precise models and new approaches to optimizing vehicle dynamics, and also raises a lot of development process issues.

AUDI AG has developed a process for vehicle dynamics development in which HIL and SIL simulation is an integrated part of every project. The company set up a team of HIL/SIL specialists to function as service providers within the department, processing development tasks by means of virtual procedures.



▲ *Optimum mix of simulation and test drives: Using HIL and SIL simulation at an early stage reduces the number of test drives.*

AUDI AG is using dSPACE Simulator for this. The tasks of the HIL/SIL team comprise vehicle-specific parameterization of various functions in vehicle dynamics control, and the development of new brake systems and stability functions in ECU networks.

Aims of the Development Process

Our development process aims to fulfill as many different customer and process objectives as possible, and to add maximum value.

- Optimum controller functionality, for example, for a short braking distance
- Good function validation, ensured by great test depth
- Fast response to technical modifications by means of model-based function development and parameterization
- Expertise in ECU networks, which are growing in importance as the number of functions and ECUs in vehicles increases
- Maximum added value by systematically automating time-consuming development tasks

A good understanding of the underlying system is vital to achieving these aims. Using HIL and SIL simulations at an early stage supports this. They enable us to use make much more systematic and goal-specific use of the test vehicles. Methods, model quality, and process are all equal factors in simulation potential and must be worked on continuously.

Methods

To improve the methods, we are working on objectivizing the vehicle dynamics properties. A quality evaluation process was introduced for this. We have defined objective properties for assessing vehicle dynamics. These enable us to compare different controller configurations from a purley phenomenological point of view. The quality criteria for vehicle dynamics are combined to form task-specific quality vectors. The quality vectors can then be used to implement auto-

matic optimization of controller parameters in the simulation. This optimization process can be used on the HIL and SIL systems from dSPACE.

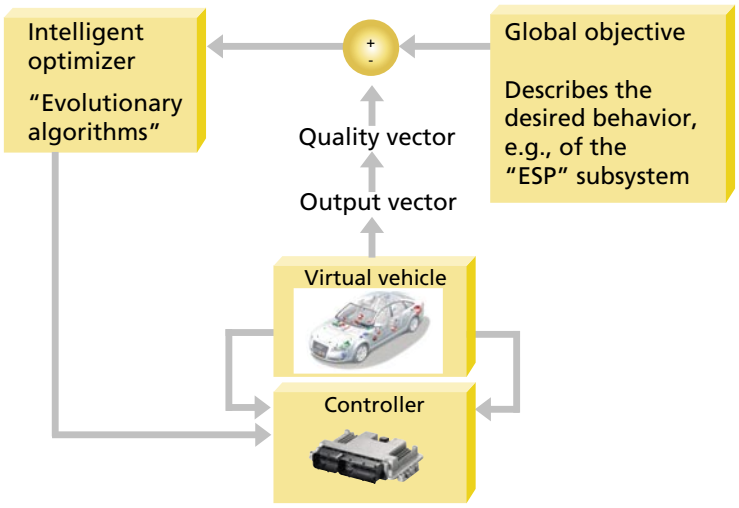
Model Quality

The level of model quality that is required depends on the task, for example, function development, pre-parameterization, optimization, or functional software tests. We introduced model classes to handle this and defined the steps needed to achieve class-specific model quality. Beginning with a predecessor model extended by target data, there are several steps that finally lead to a completely validated model for concrete test vehicles.

To achieve good model quality, we first divide the entire dynamics model of the vehicle into model modules. The parameters of the modules are derived from the test benches and from the simulation results of the responsible department, so that the modules can be validated and tested separately.

The modules are the building bricks for creating specific variants of the overall vehicle.

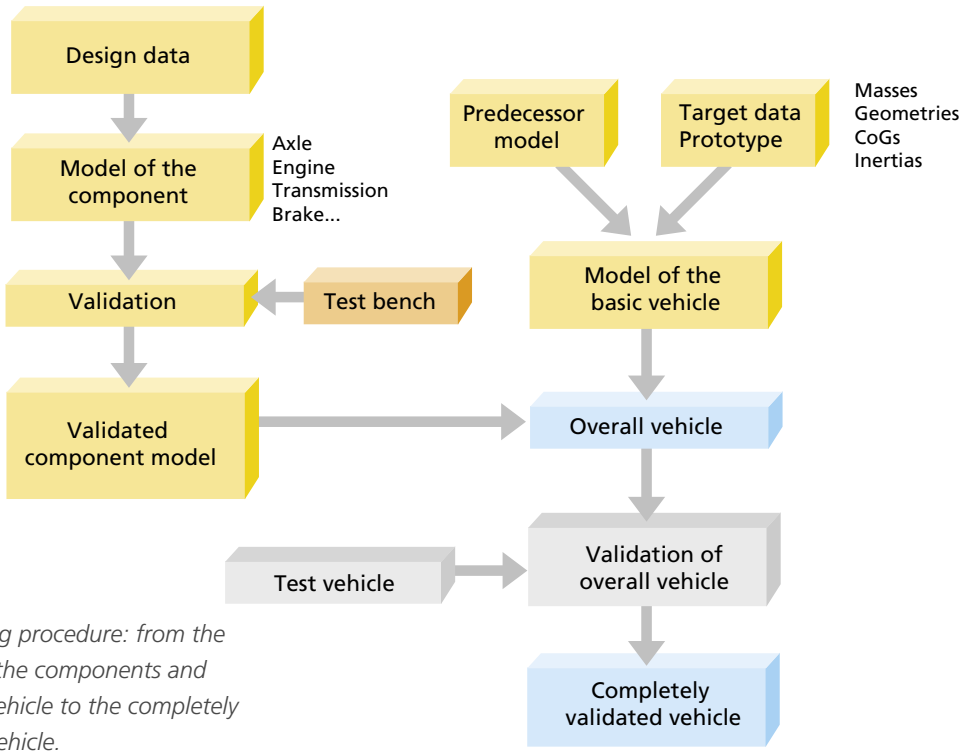
Measurement data obtained from driving maneuvers in the test vehicles are used to validate the overall model of a specific variant. This ensures the comparability of simulation and test drive.



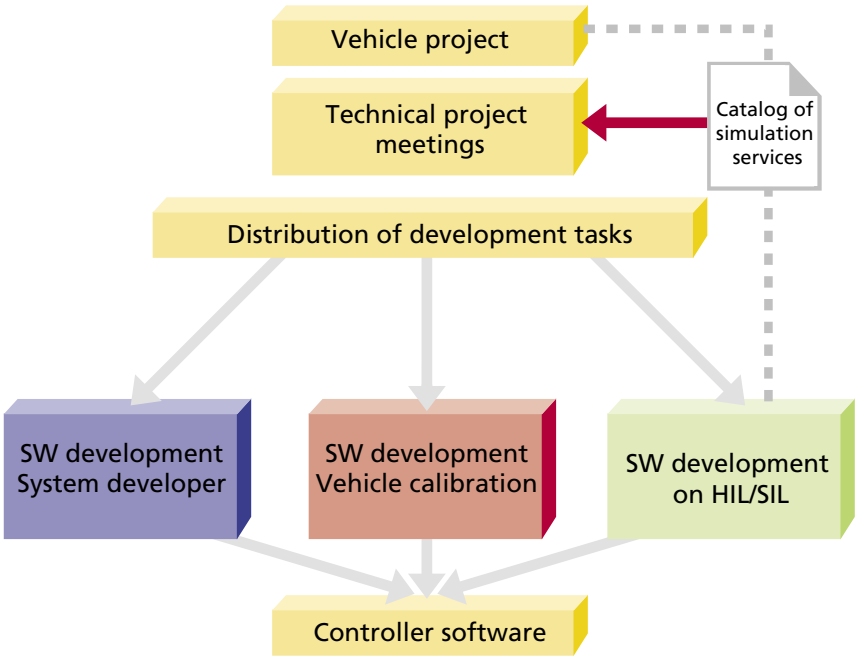
▲ *Vehicle dynamics objectivized to improve methods.*

Process Integration

Our catalog of simulation services is the key to integrating simulation tasks into the vehicle development process. The developers responsible for specific functions can commission defined simulation tasks at technical project meetings, using the catalog of services as a basis. The catalog of services precisely describes the scope of the tasks to be performed, the simulation quality that is achievable, and the model class that is required.



▲ *Modeling procedure: from the models of the components and the basic vehicle to the completely validated vehicle.*



▲ *Process flow: integration of HIL and SIL simulation.*

There were two main motives for introducing the catalog:

- It gives the responsible function developers a stable planning basis in the vehicle project.
- Method development and modeling tasks can be performed much more in tune with requirements than was previously the case.

Conclusion

HIL and SIL show considerable potential for calibrating, optimizing, and validating vehicle dynamics controls. Automated parameterization is already possible with real-time-capable models. The requirements for this are that the vehicle dynamics are objectivized, the process is seamlessly integrated, and the model has a module structure. With the service catalog as a basis, we can set up HIL and SIL simulation in vehicle projects. This is our contribution toward achieving an optimum development mix of simulation and test drives, in which full use is made of the specific strengths of the simulator and the vehicle as tools. Through systematic further development of the success factors methods, model quality, and process, we are working on continuously shifting the mix in the direction of simulation.

"Many development tasks can be performed considerably faster in HIL and SIL simulation than in the vehicle. This saves us a lot of time."
Jörg Pfau

Jörg Pfau
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Glossary

Objectivization – Describing subjective vehicle behavior by means of objectively measurable, physical variables.

Quality vector – Vectorial collection of quality criteria.

Phenomenologically – here: Investigation of the vehicle behavior that is finally relevant for the driver/vehicle interaction.