Mercedes-Benz

Simulation-based development of automotive control software with Modelica

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Contents

Software in the loop simulation at Daimler

Application area

- Testing and deployment of functional code
- Version update safequarding of functional code
- „Desktop“-application / -calibration
- Fault simulation
- Virtual endurance testing
  - ➔ safequarding of drivetrain components
  - ➔ calculation of load collectives for gearbox and drivetrain

Requirements

- Powerful, stable and fast simulation environment
- Easy to use by any engineer

Tool chain

SIL-tool

- Backbone (in house development)
- Silver (QTronic GmbH)

Plant model

- MSL 2.2 in Dymola 6.2 (Dassault Systèmes)
- In the future MSL > 3.1 with Dymola from v. 7.4 or SimulationX from v. 3.4 (ITI GmbH)

Test generator

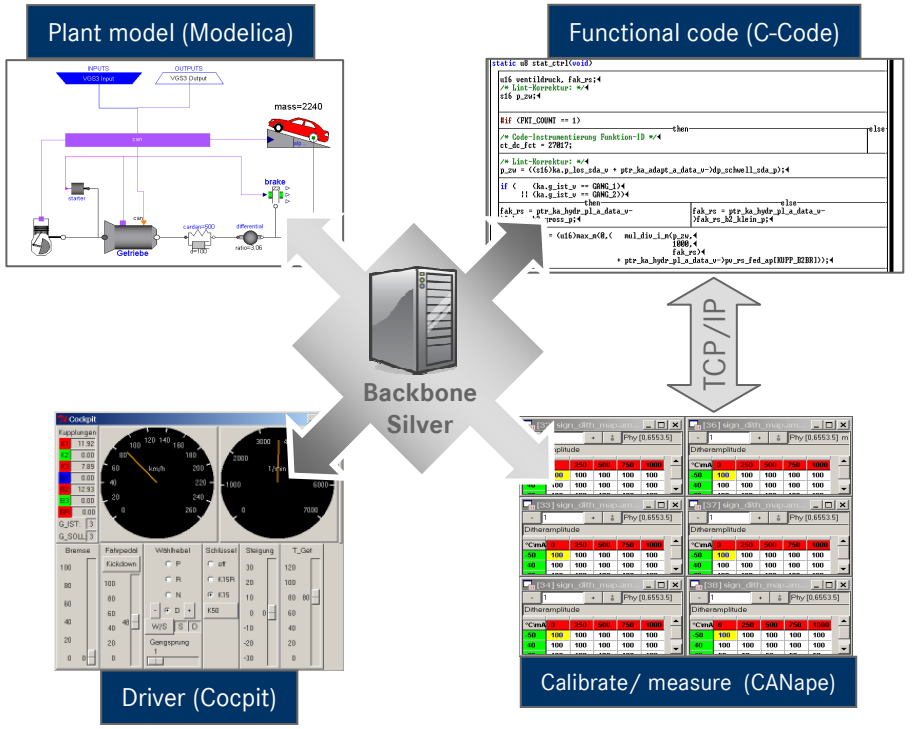
- TestWeaver (QTronic GmbH)

Software integration platform

- Microsoft Visual Studio 2005 or 2008

SIL-environment / functionality

- The simulation is controlled by a special program (e.g. Silver) which guards the single modules
- Every module (called „Client“) sends its Outputs to Backbone und reads its Inputs from him, i.e. no direct communication between the modules occurs (except for the CANape-coupling with the control software)
- The communication step time is fixed and represents the lowest task time step of the functional code (5, 10 or 20 ms)
- The plant model is wrapped with a nummerical solver which calculates with smaller time steps
- Backbone waits after each communication step until all clients are finished so that the next step will be initiated (slow model slows down the simulation)

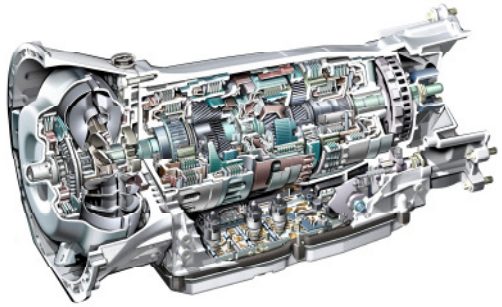


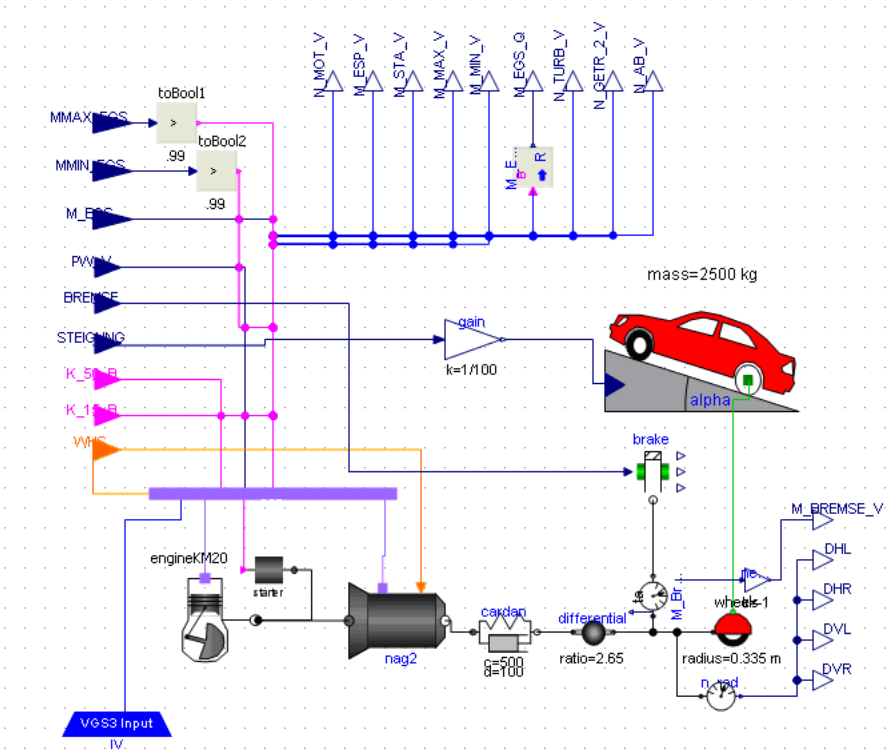
- Every „Client“ must be available in C-Code or be pre-compiled (obj-file)
- The integration in the SIL environment takes place by “wrapping” the C-code with the desired API (backbone or Silver)

Plant model

Requirement: accurate calculation of gear shifting

- Filling and draininig of clutch pistons
- detailed representation of piston mechanics
- calculation of the gearbox kinematics including the impact of it to the internal inertia

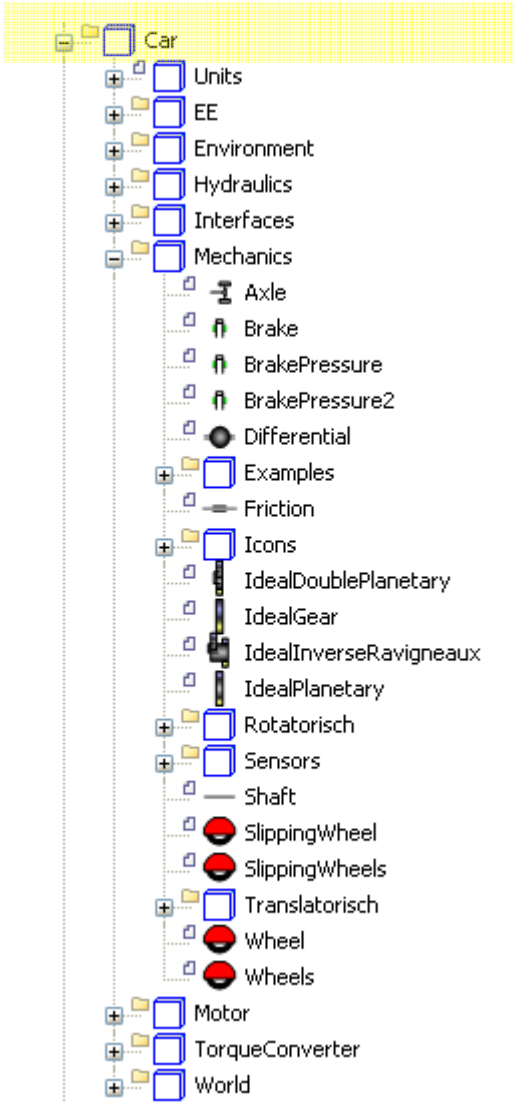




Description

- The plant model describes the torsional (1-D) and translational (1-D) dynamics of an entire vehicle
- The modeling focus lies on the detailled description of the gearbox (piston mechanism, coefficient of friction, filling and draining of pistons, etc.). It is about the 7-gear planetary automatic transmission of Mercedes-Benz (7G-Tronic)
- The engine model is descriptive (look-up table characteristics) and includes an idle speed controller as well as the functionality to manipulate the engine torque during the gear shifting
- The drag forces are calculated in the vehicle model
- The model is cut out for the SIL environment and in this form, it is designated for the SIL-export

Plant model: Modelica Libraries

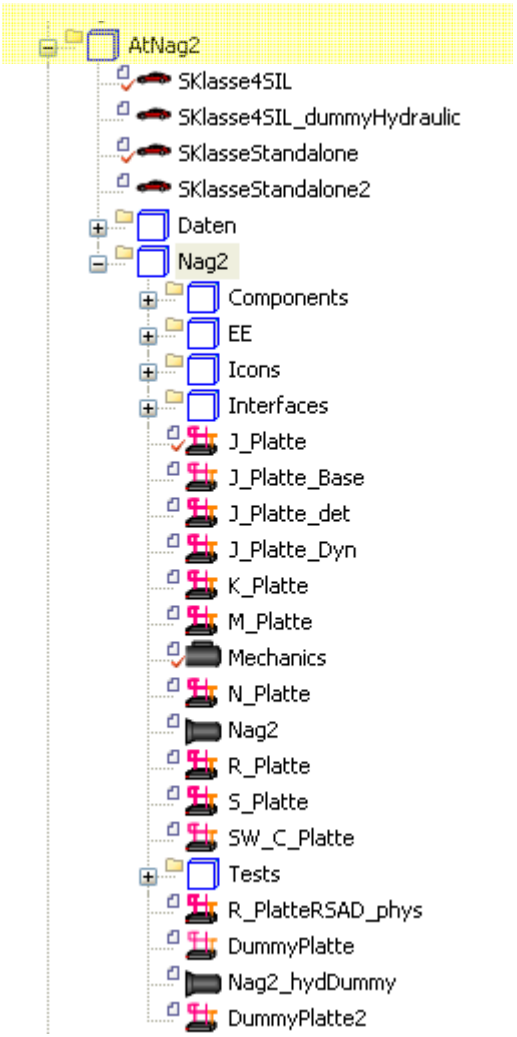


For the creation of the plant model, own devised libraries and standard Modelica components have been used

Car-Library
includes basic models for building hydraulic and mechanical structures (e.g. orifice, valve edge, planetary gear, parking lock, etc.)

AtNag2-Library
includes and describes transmission specific models such as hydraulic control unit, mechanical model, clutches and brakes, etc.

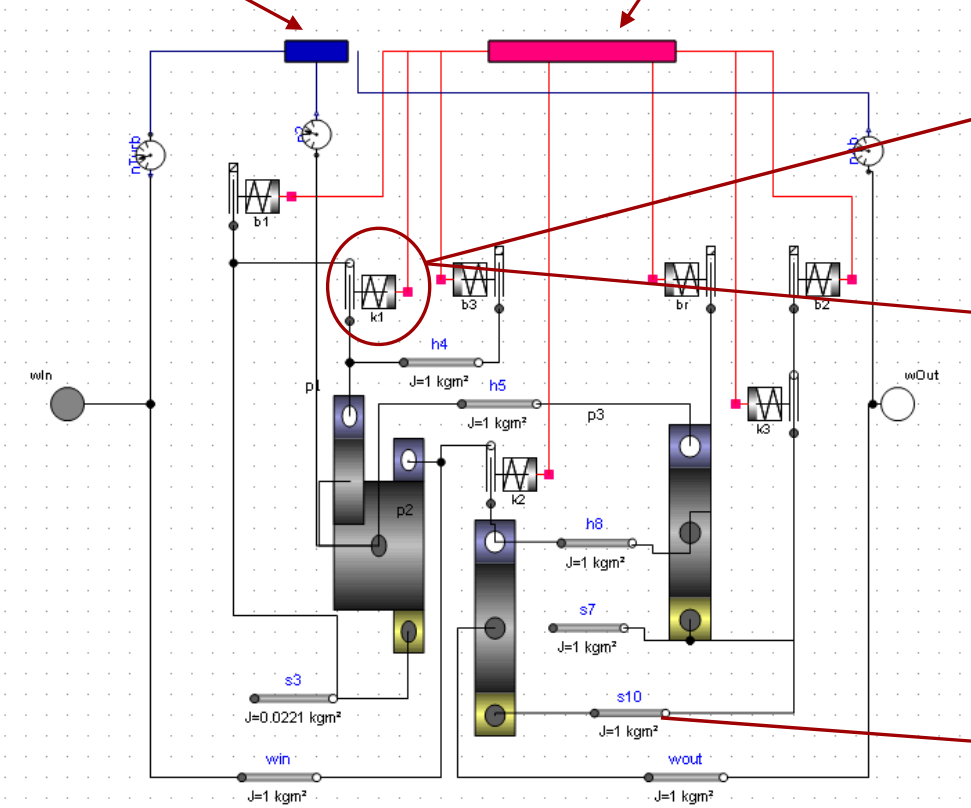
The libraries **Car** and **AtNag2** were originally created in Dymola 6 with Modelica 2.2



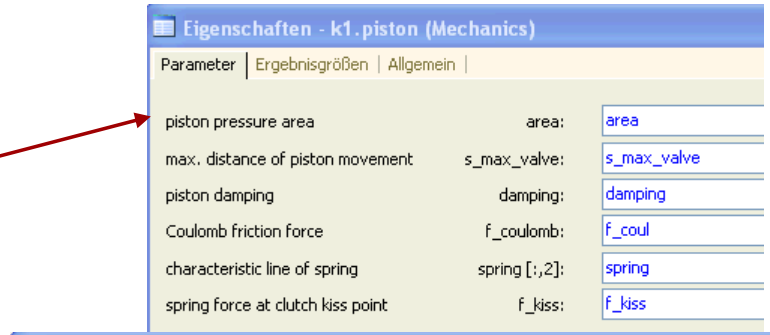
Plant model: mechanics

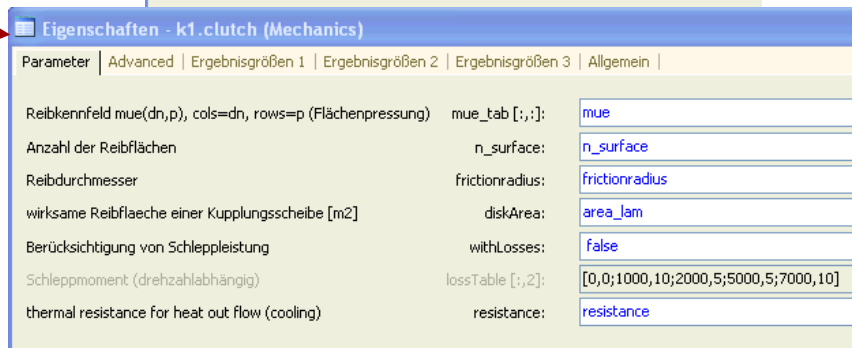
Hydraulic interface (from the hydraulic control unit)

Sensor interface (rot. speeds)



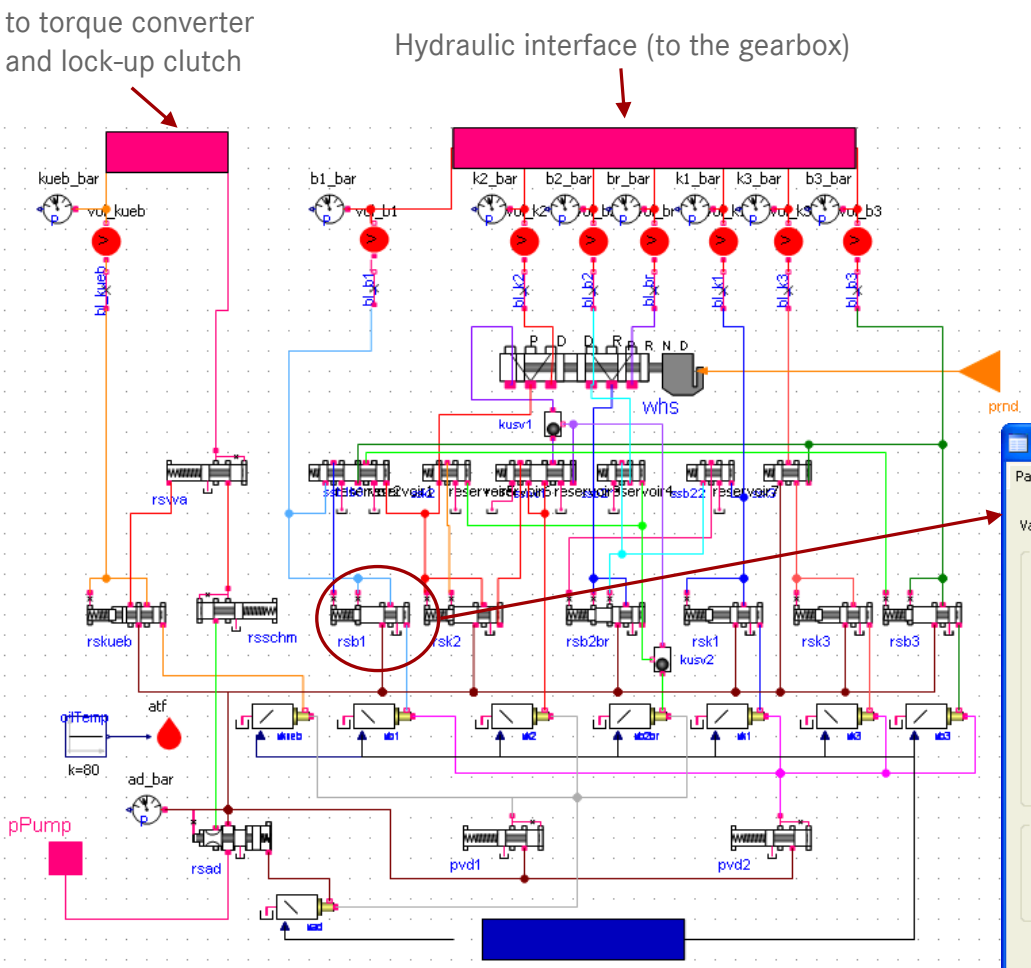
parameter masks of a clutch model





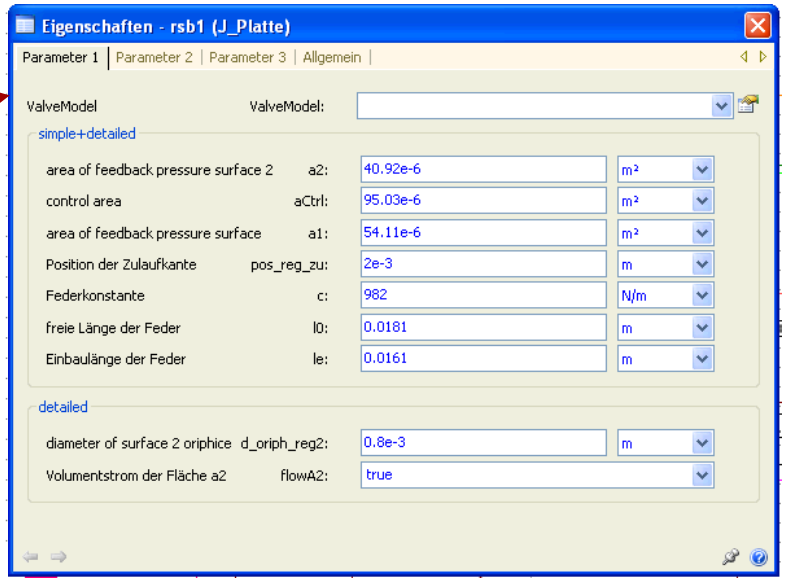
All independent inertias of the gearbox are explicitly modeled

Plant model: hydraulics (control unit)



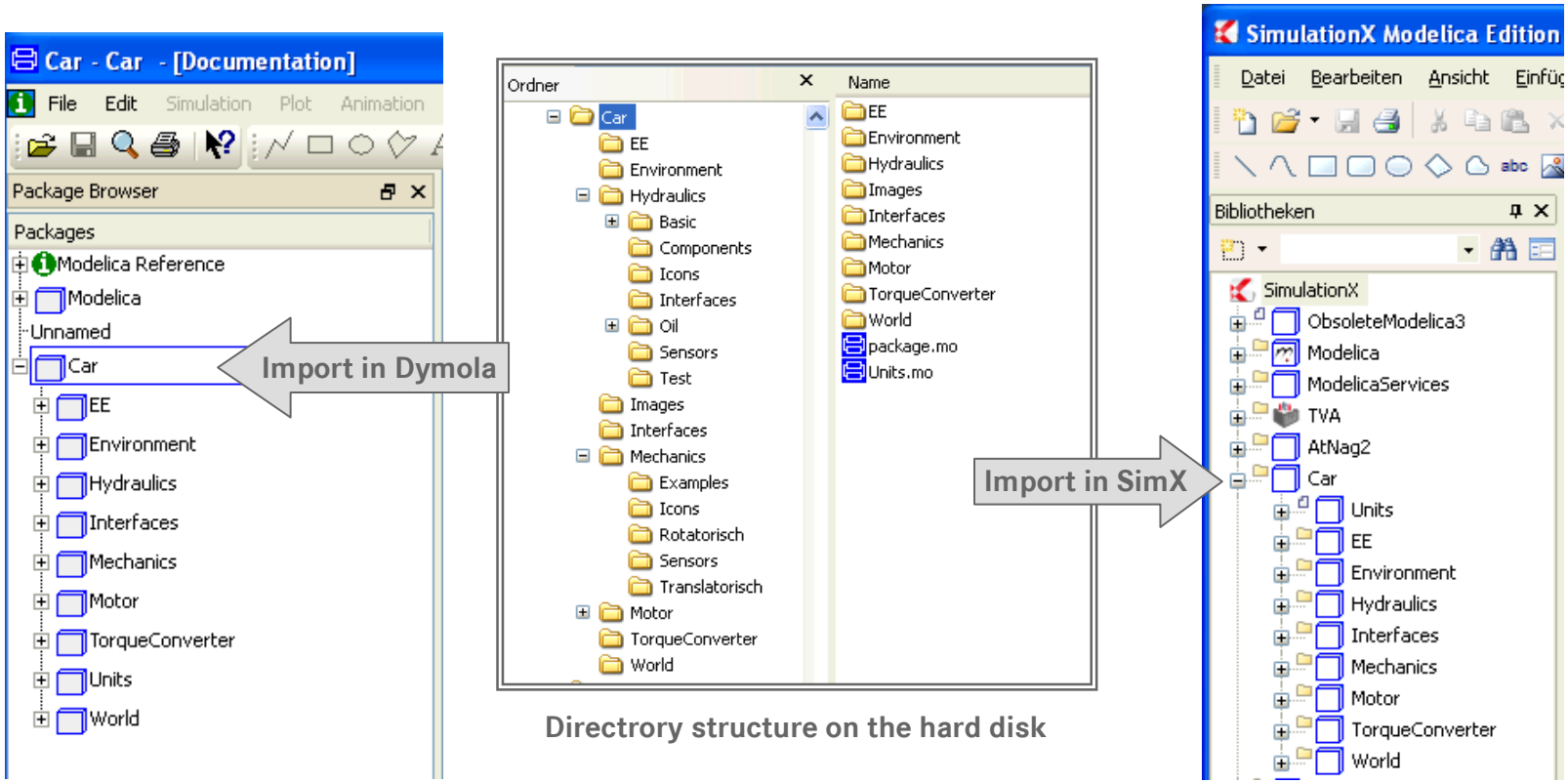
The electro-hydraulic control model has been modeled phenomenologically (control logic, no dynamics) for the sake of simulation performance. However, many components such as orifices, shifting valves, fluid volumes etc. have a physical model description in order to accurately describe important effects in the simulation (filling, draining, pressure switch, stucking valves etc.)

Parameter mask of a control valve



Model compatibility

- The model is compatible to both Dymola 7.4 as well as SimulationX 3.4 as long as MSL 3.1 is used
- Existing models based on older MSL versions have to be “upgraded”
- Once this job is done, no further adjustment is necessery and the models can be easily loaded in both software tools (Dymola and SimulationX)



Integration of a SIL-Project

SiL environment

- Simulation: Silver (QTronic)
- Measurement: CANape (Vector)
- Debugging: Visual Studio (Microsoft)
- Automated Test: TestWeaver (QTronic)
- Code Coverage: CTC++ (Verifysoft)

Silver

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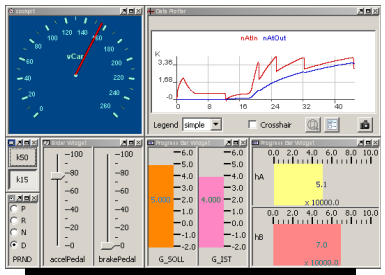
graphical user-interface:

- interaction of driver/user with simulated car
- accel pedal, steering, etc. can be controlled
- plotter, breakpoints, scripting, file in/out, ...



Configurable GUI

Silver

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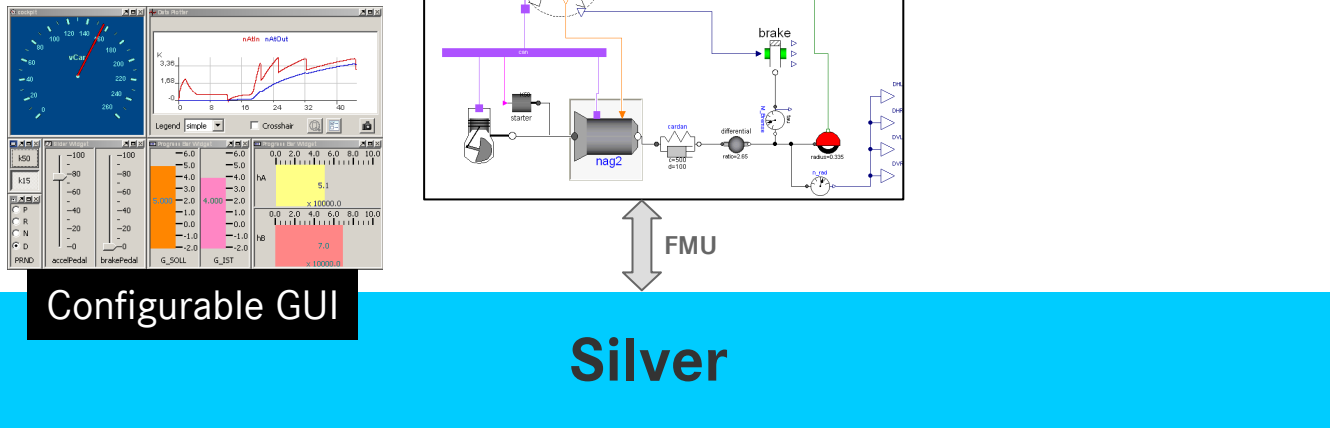
hardware DLL:

- simulated vehicle, engine and transmisssion
- Dymola/SimulationX



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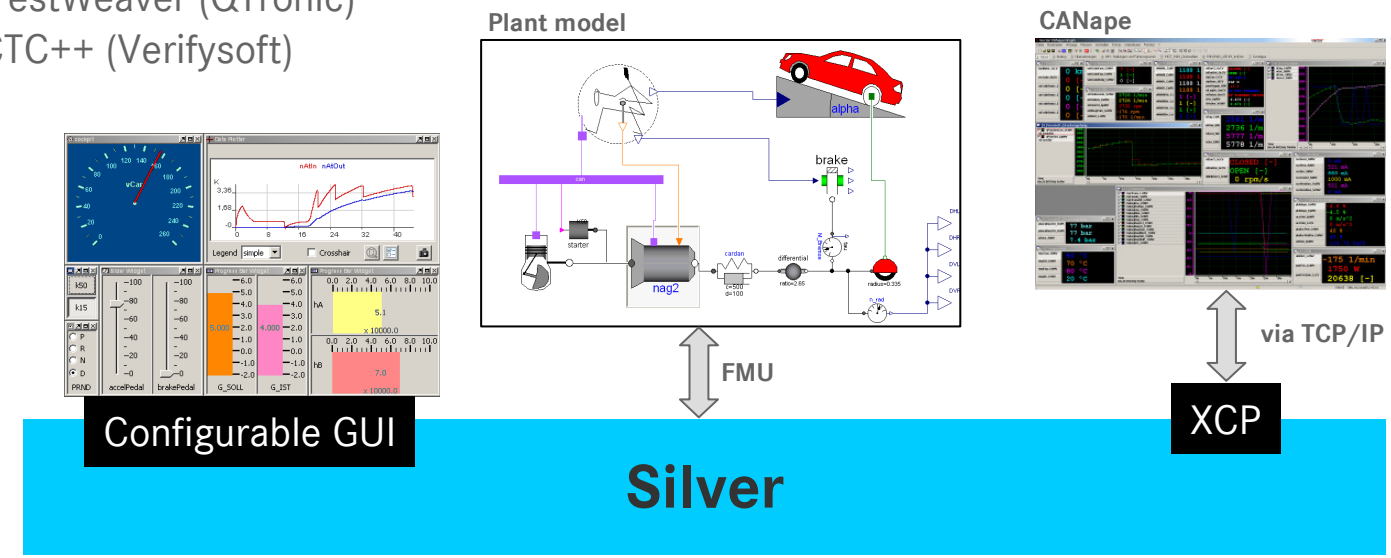
XCP with Canape/INCA:

- XCP measurements via TCP/IP
- no limitation of bandwith as with CAN
- online calibration of parameters



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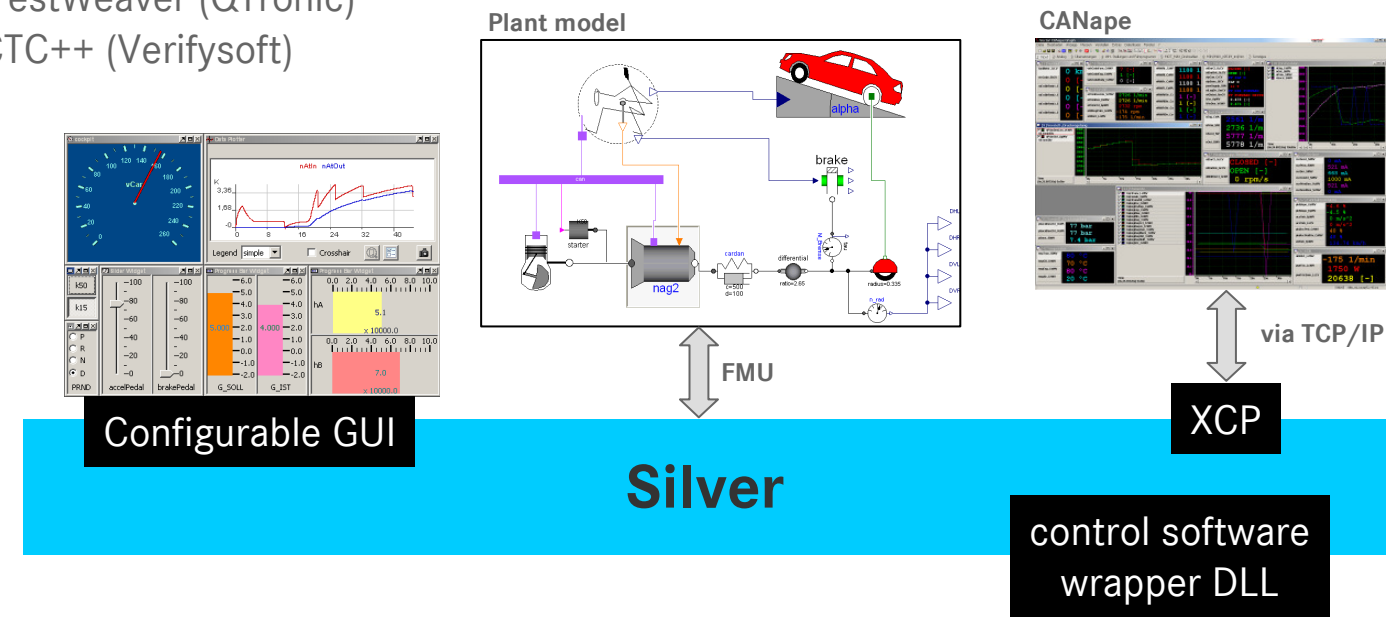
ECU control software as DLL:

- entire ECU control software
- frame software emulated by wrapper



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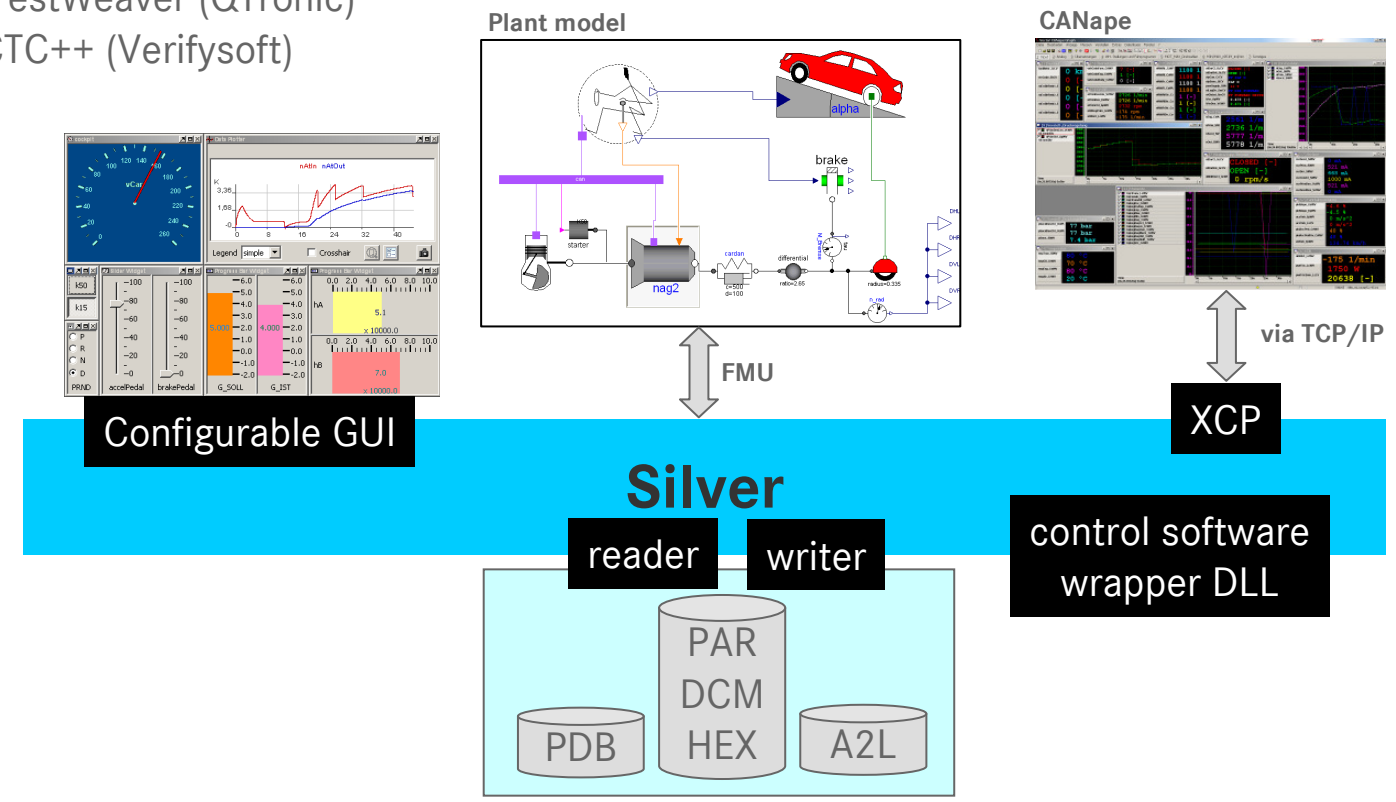
A2L and parameter:

- A2L with address infromation adapted to the DLL
- parameter values loaded at simulation start



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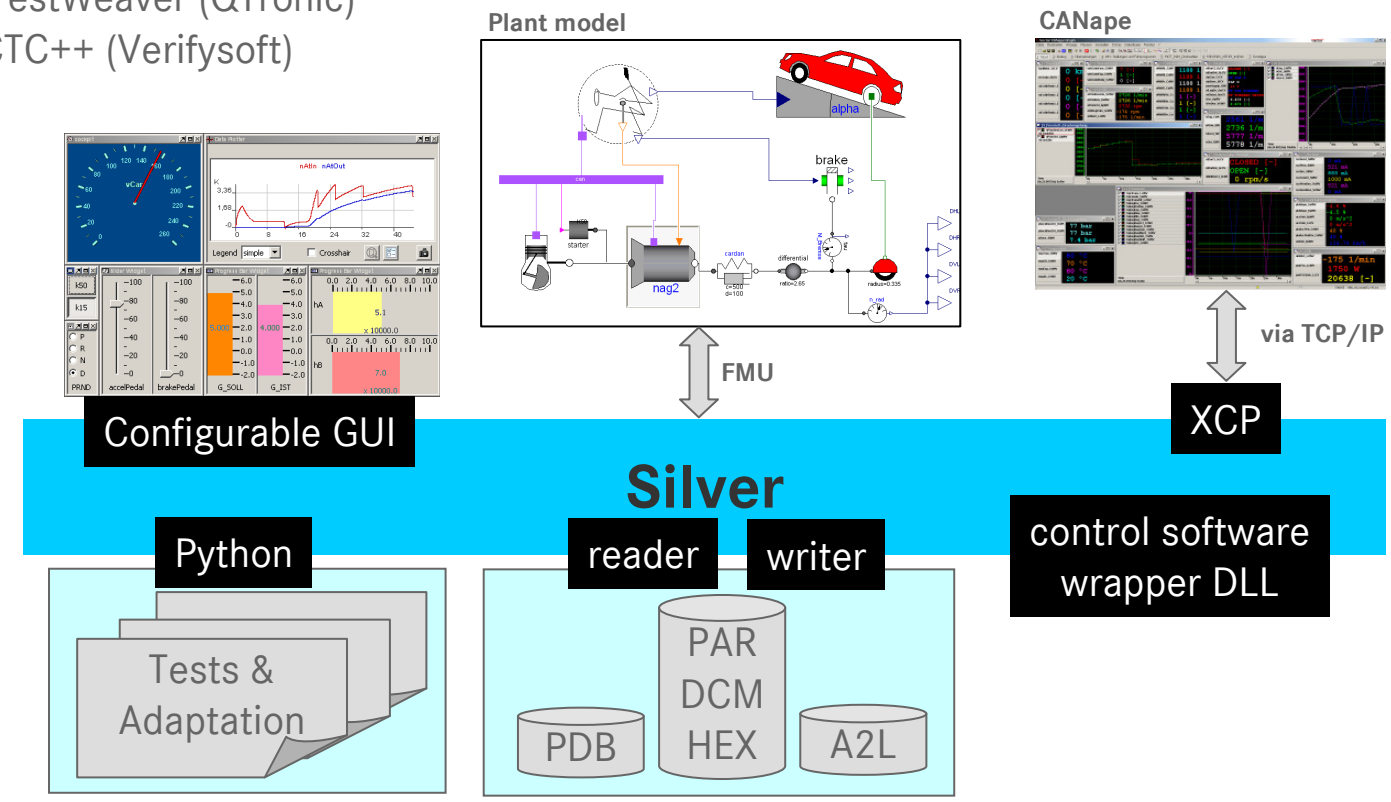
Scripting with Python:

- automate frequently used procedures (e. g. engine start, adaptation procedure etc.)
- implement control tasks (e.g. driver behaviour)



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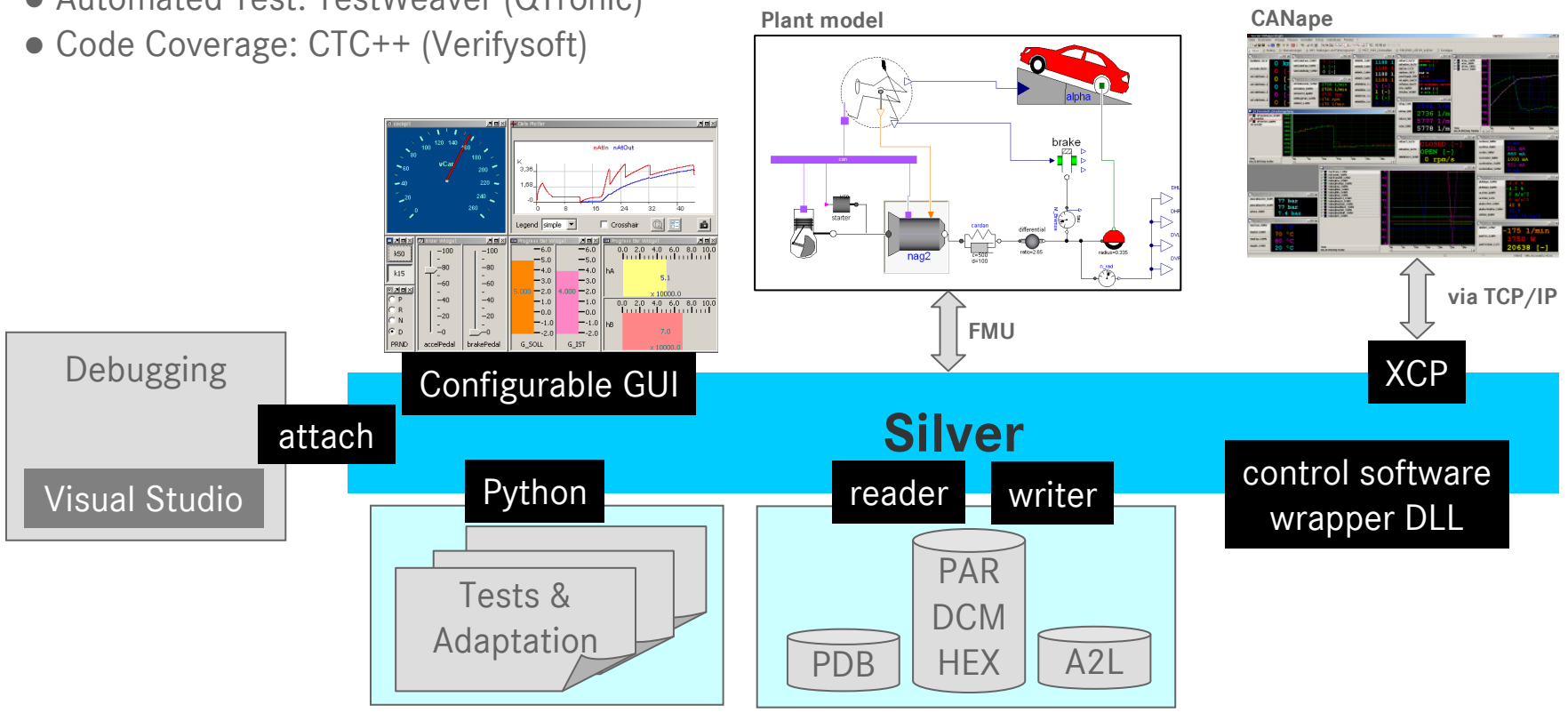
Debugging with Visual Studio:

- suspend simulation at any time
- attach Visual Studio Debugger to Silver



Summary

- SIL is an essential tool in the gearbox development at Daimler
- For the creation of the SIL plant model, Dymola (MSL 2.x) has been used
- Upgrade of the model to MSL 3.1 enables full compatibility to SimulationX v. 3.4
- For the plant model export to SIL the new Modelisar-FMI can be applied
- SIL integration of the functional code (TCU) is done by wrapping the original code with the Silver-API and emulating the frame software
- Silver offers the possibility to measure and calibrate TCU-internal signals either directly in the Silver GUI or by coupling to commercial calibration tools such as CANape or INCA
- The functional code can be easily debugged by using the features of MS-Visual-Studio
- The utilisation of SIL during the development process leads to accurate code coming along with essential development cost reduction