Ride, Handling, Real-Time and Hardware-in-the-Loop

A Prototype Transition provided by INTEC and ETAS

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ETAS

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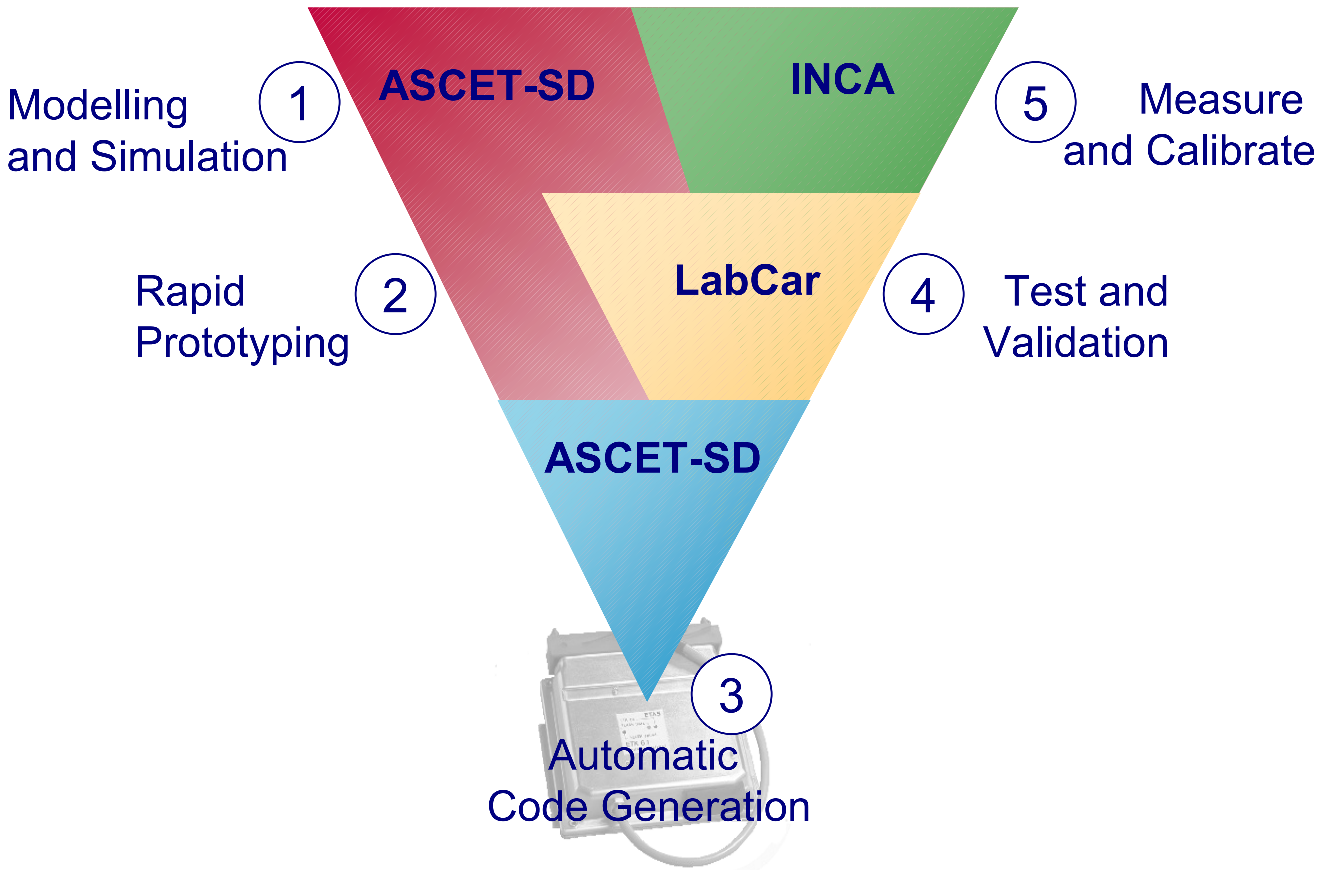
Development Process of ECUs

Model-based function development process according to V-cycle



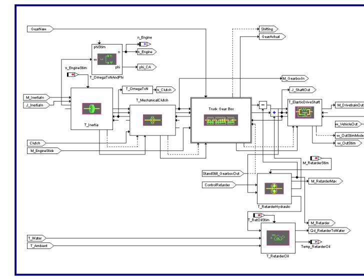
Development Process of ECUs

ETAS Engineering Tools

Use of Vehicle Models in the ECU development process

Environment Model
Virtual Vehicle, Driver and Surroundings

Function Model



SiL ← 1 →

HiL 4

Model

Reality

2

3

Real Vehicle, Driver and Surroundings

← 5 →

Function Realization in ECU

Today:
Separation of Vehicle and ECU Development

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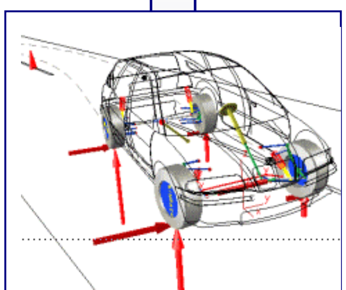
Vehicle Development	ECU Development	Problems Today

CAD FEM

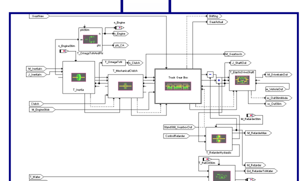
CFD MBS



ABS, ASC, ESP,

EBA, VDC, EHB

EMB, EBD



- Main efforts and costs in controller development are caused by real car testing
- Real car testing is mostly the main ECU test environment because of reliability
- Vehicle specific controller development starts often very late
- Different tools and models used in vehicle and ECU development -> no synergy effects
- Additional effort setting up real-time models for SiL and HiL
- Compliance between detailed MBS model and real-time model unknown
- Calibration-in-advance of controller is limited

Vision:
Collaboration between Vehicle and ECU Dev.

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Engineering Tools

Vehicle Development	ECU Development	Vision

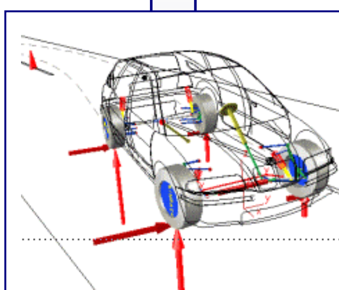
CAD FEM

CFD MBS

ABS, ASC, ESP,

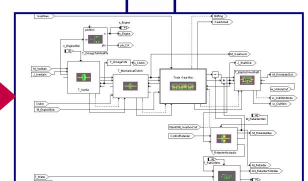
EBA, VDC, EHB

EMB, EBD



SiL

HiL

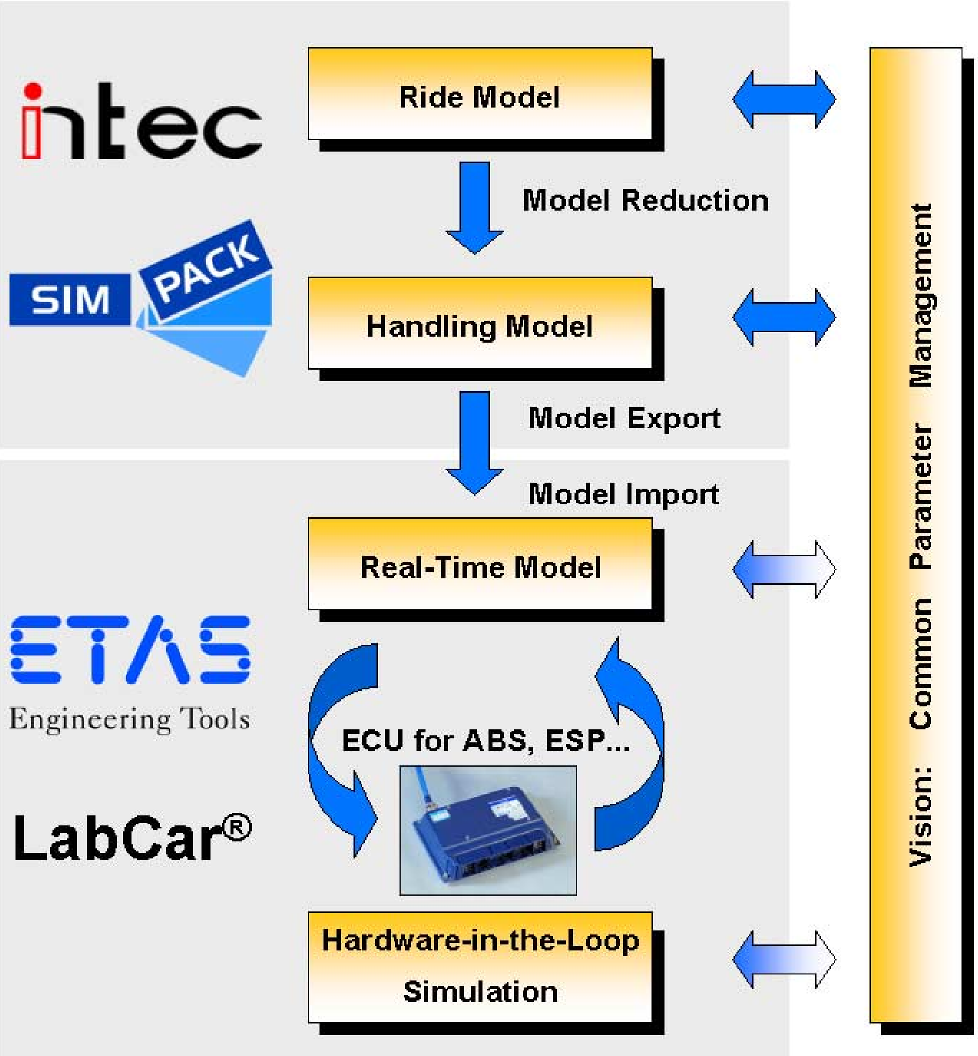


- Reuse validated MBS handling models for model-based ECU development

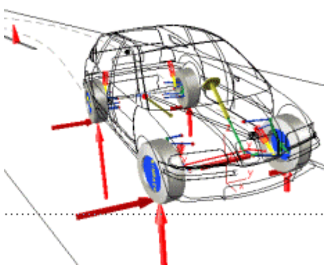
Benefits

- Avoid effort setting up additional real-time models for SiL and HiL
- Enable compliant behaviour between detailed MBS models and real-time models
- Enforce ECU development stages in the laboratory by calibration-in-advance
- Reduce efforts and costs caused by real car testing

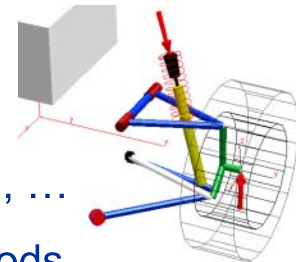
Vision:
Seamless Transition from Ride to HiL

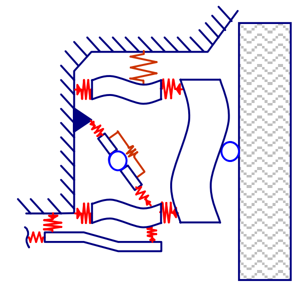


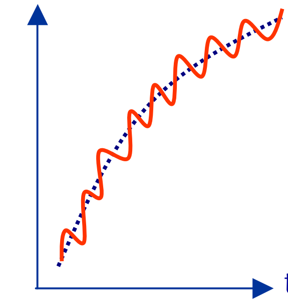
Typical Model for Loads or Ride Analysis



- up to 200 Hz dynamics
- detailed modeling
- equations of motion: DAE, …
- solved efficiently by methods with variable step-size and order

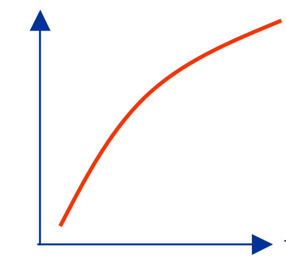






Handling

- <25 Hz dynamics
- only *quasi-static* parts of *previously high frequent modes*



HiL/ECU - Requirements

- equations of motion: ODE, solved by fixed step-size methods
- environment externally in soft or hardware given
- arbitrary exchange of forces and sub-model components

Objective:

one model & ***one*** data source for ***all*** tasks

Model Reduction as Key to a seamless Process

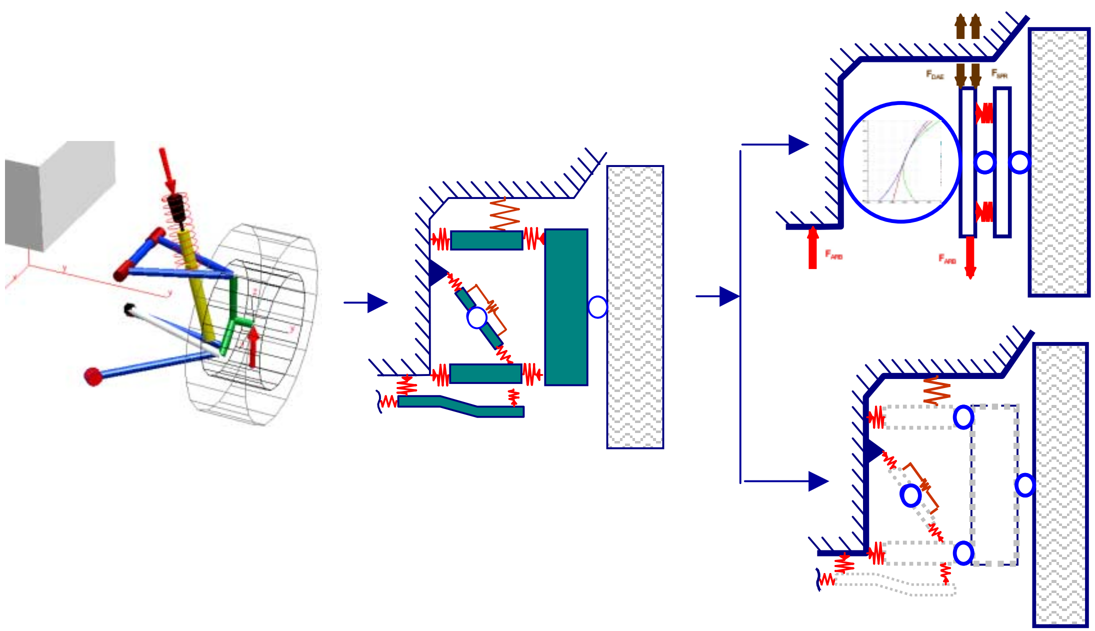
(same physical & simulation MBS-model but mathematical reduced to low frequent dynamics)

Assumption:

- Neglect high frequent relative dynamics of bodies with small masses -> $m \cdot \ddot{\mathbf{x}} = 0$

Reduction for Ensemble: Automotive Suspension

DAE eqn. of motion from subsystem “suspension” convert to *kinematical joint equations* *) with subsystem *internal* constraint equations. These are solved on position level by:



...... Evaluation of pre-calculated ***tables*** for constraints.

Newton Iteration $\boldsymbol{\Delta}(\mathbf{q}) = 0$

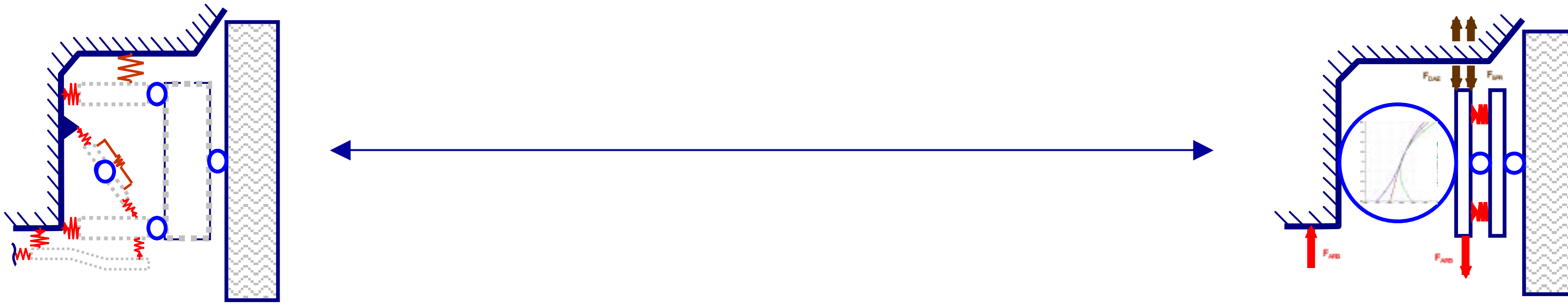
new

Integration of subsystem internal *depending* states

$$\mathbf{H}(\mathbf{q}) \cdot \dot{\mathbf{q}} = \mathbf{h}$$

*) … MBS-algorithm in relative coordinates required

Advantages of Macro Joint Approach compared to Table Fields

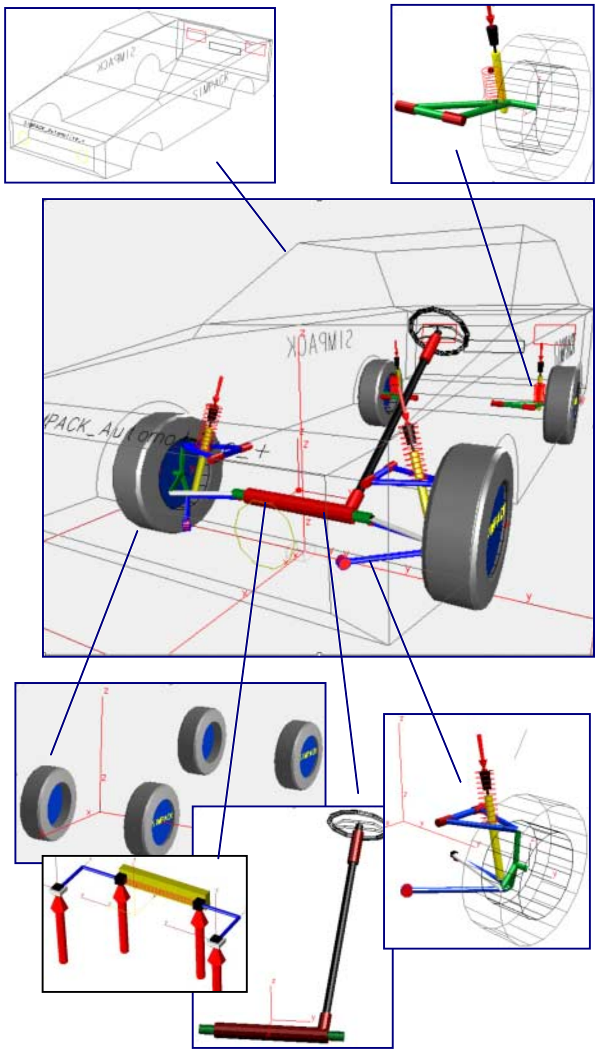


- ✓ *structure* and *topology* of the original (ride) model keep the same,
- ✓ *parameterization* of the original (ride) model keep the same,
- ✓ *no table refresh* necessary if geometry or force parameter change,
- ✓ *no model adaptation* necessary for mount points changes of dampers, struts and anti-roll bars
- ✓ *exchange suspension types* on the real time platform by simple exchanging *parameters* for *structure and kinematics without* invoking table refresh processes,

- ✓ both approaches result in an *ODE* for the subsystem equations, that is still an requirement for real time simulations and *reduce the simulation time* significantly.

choose the modeling due to available data and not due to tool restrictions

Benchmark Example



Model Statistic

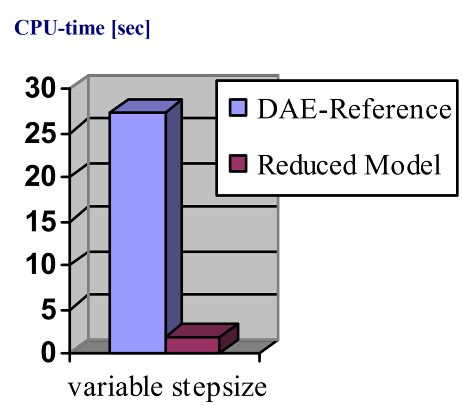
value	DAE reference	reduced (macro joint)
1st order states	130	44

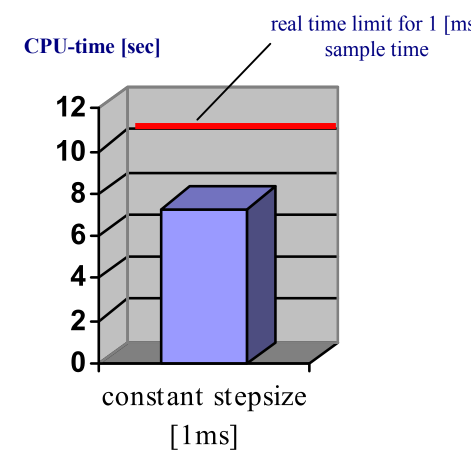
Maneuver : curve entry on plane road

Simulation Time: 10 sec

CPU : 450 MHz PC

Performance:





- ***Real-time factor about 0.75 for 1ms sample interval***
- ***Identical results in interested frequency range**** *)

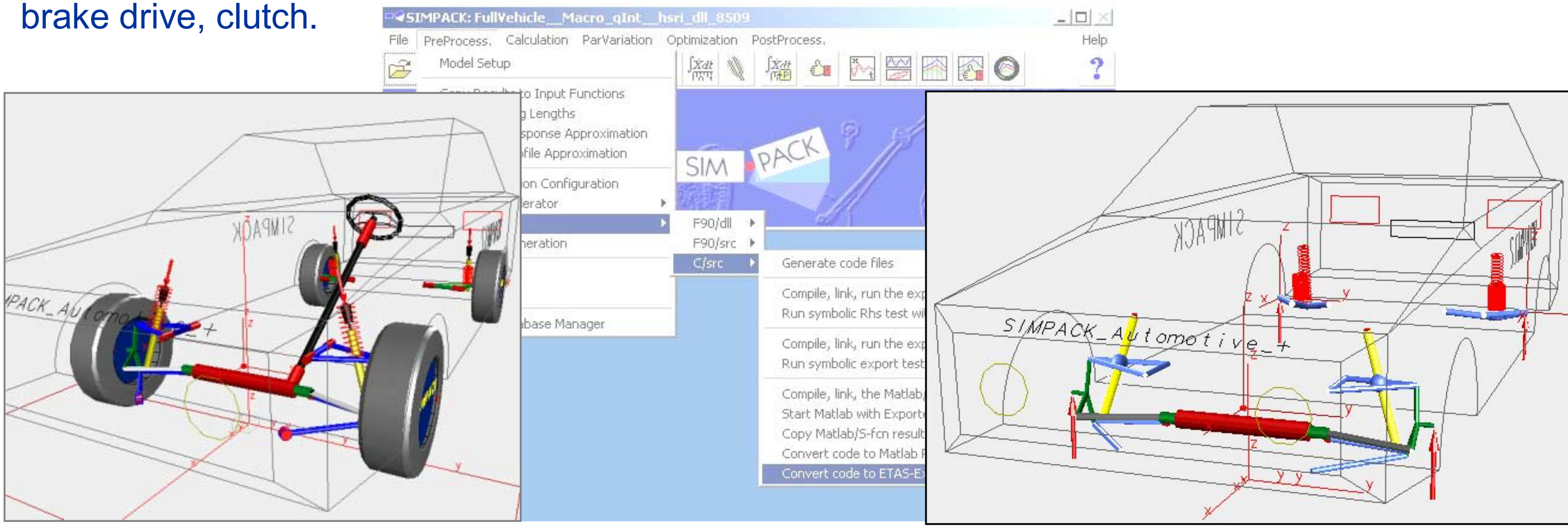
*) No additional model simplifications applied, like neglecting second order derivatives in tables, etc.

Export from SIMPACK to ETAS - LabCar®

Code Export as

Complete vehicle with external defined environment: driver, road, road/tire-friction, brake drive, clutch.

MBS-vehicle only, all force components by LabCar



Support of every solution, matching your requirement

Full parameterization on element level: *tire*, *spring-damper*, *mass* properties, mount point *positions*, *orientations*, *macro joint kinematics* and *structure* description.

Parameterization is based on user's SIMPACK *original* MBS description, including sub-structuring, mirroring, identity settings and 0-DOF body merges.

SIMPACK Model Import

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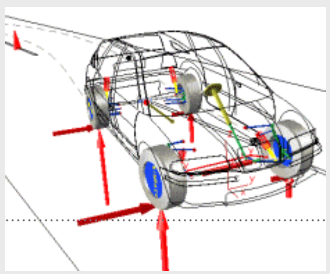
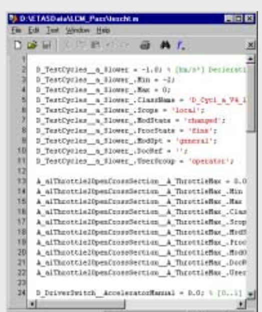
Simulink® Platform

SIMPACK Model

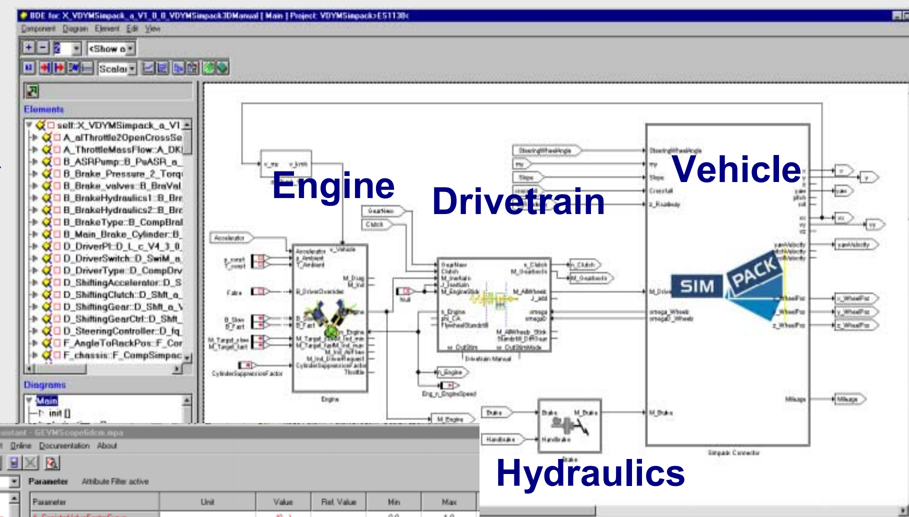


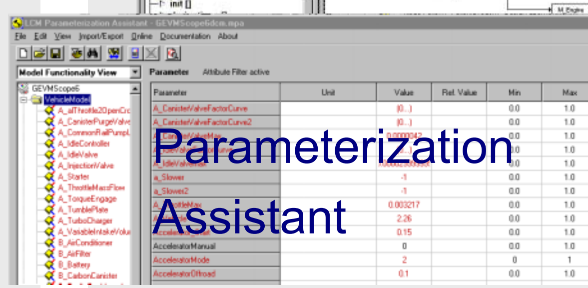
SIMPACK Data



Real-Time Environment

LabCar® Developer





Real-Time Operation

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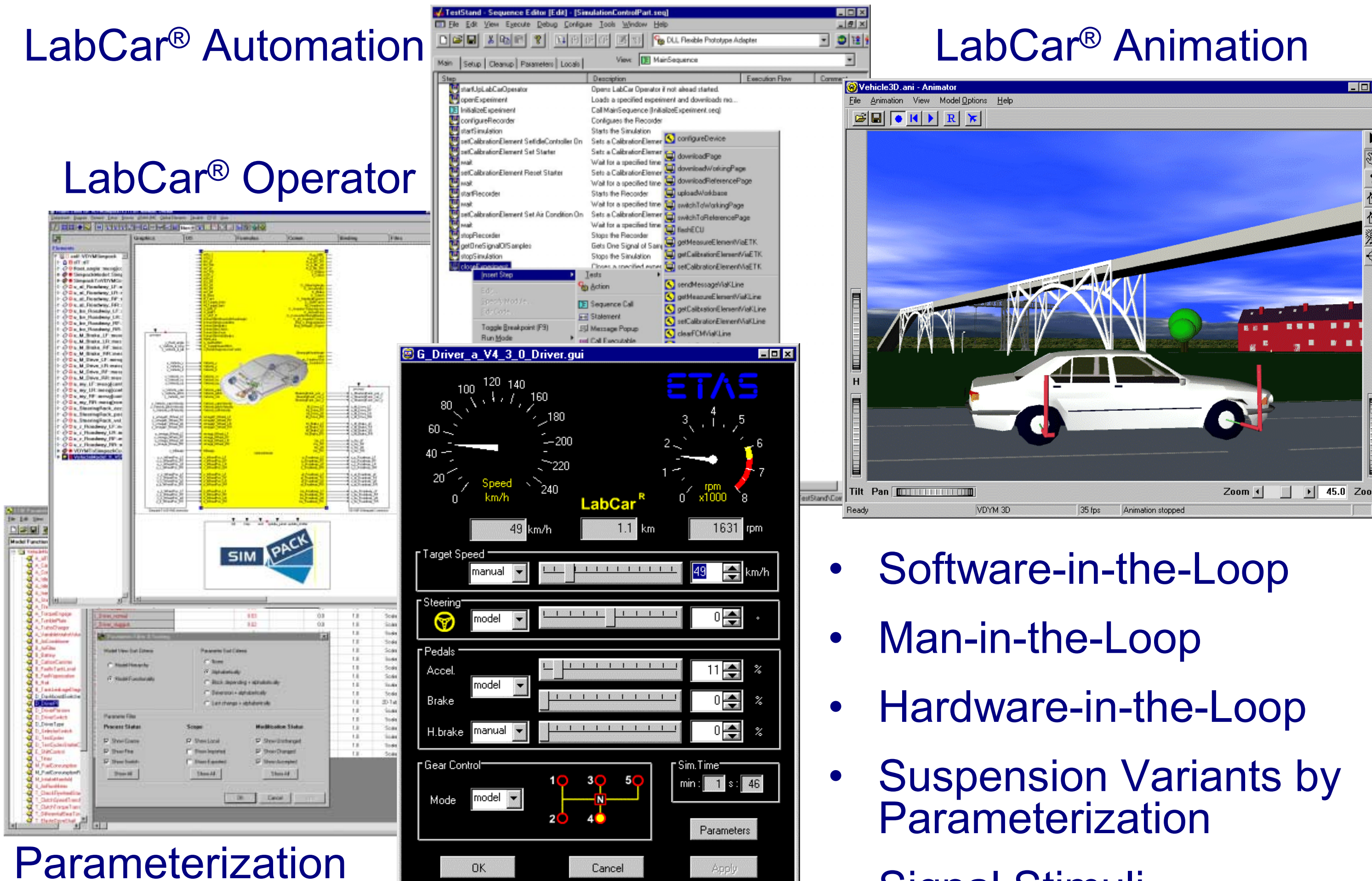
LabCar® Automation

LabCar® Operator

LabCar® Animation



Parameterization Assistant

User Interfaces

- Software-in-the-Loop
- Man-in-the-Loop
- Hardware-in-the-Loop
- Suspension Variants by Parameterization
- Signal Stimuli
- Test Automation

Summary

- Vision of Collaboration between Vehicle and ECU Development
- Cooperation between INTEC and ETAS
- First Prototype Transition from Ride to HiL available
- Next steps to be discussed with pilot customers

➡ Come and have a look on our first prototype (INTEC booth)

THANK YOU!

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