



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

A Prototype Transition provided by INTEC and ETAS

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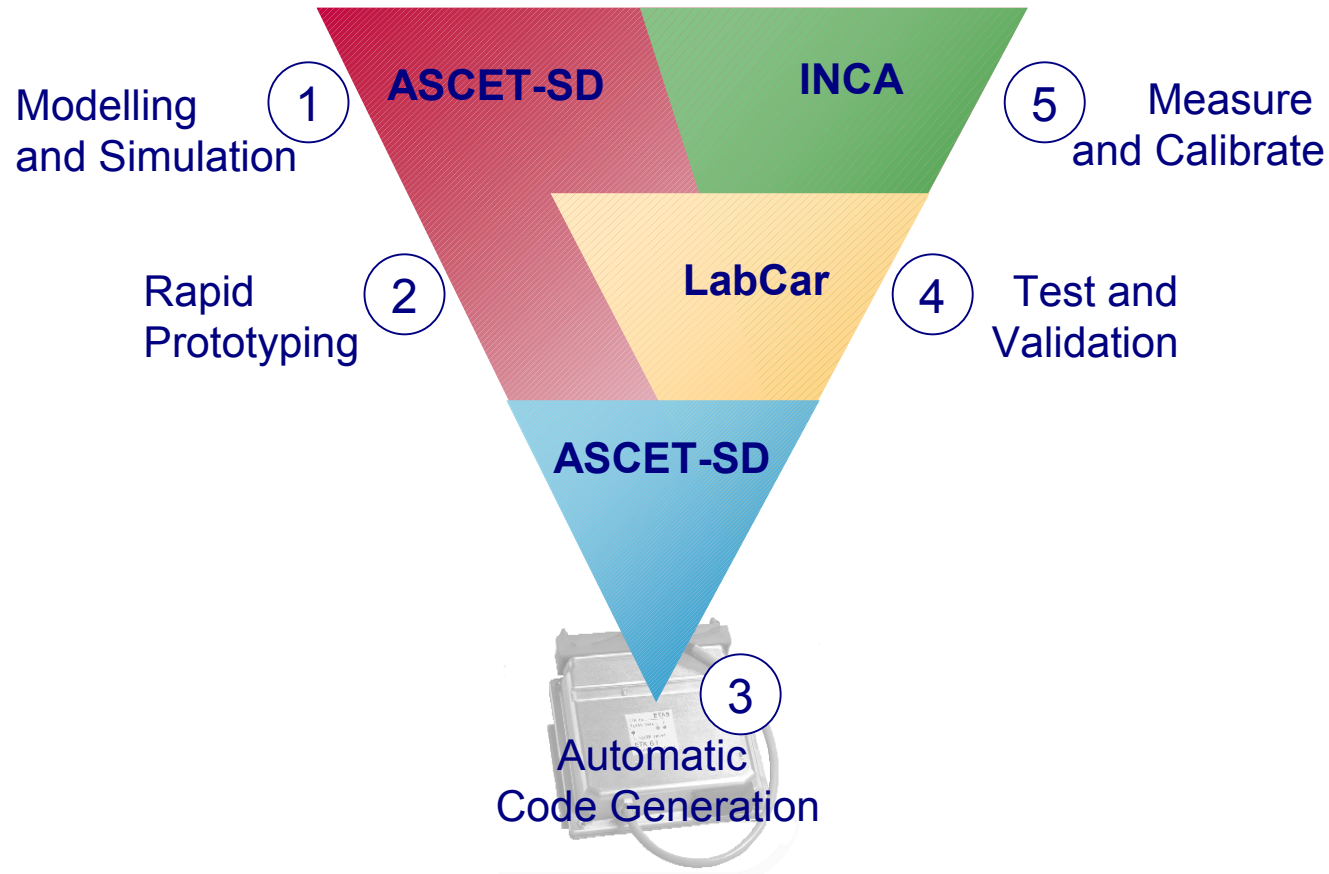
SIMPACK User Meeting 2003



- Development Process of Electronic Control Units
- The Vision
- A Prototype Transition from Ride to HiL
- Summary

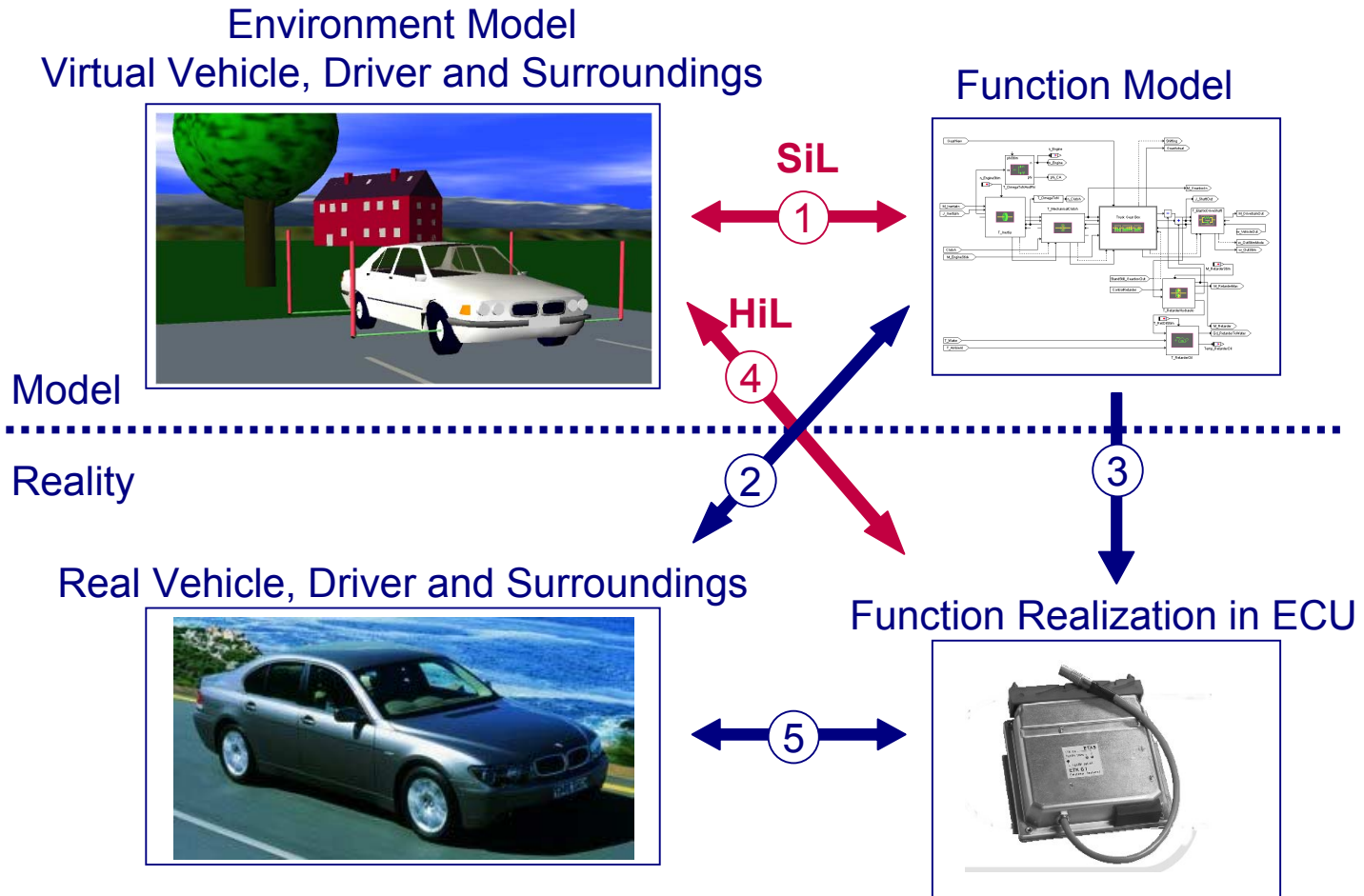
Development Process of ECUs

Model-based function development process according to V-cycle



Development Process of ECUs

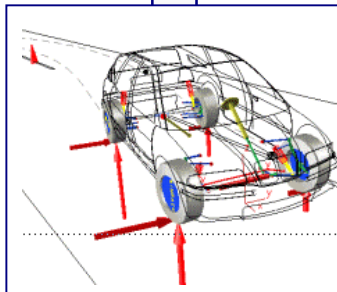
Use of Vehicle Models in the ECU development process



Today: Separation of Vehicle and ECU Development

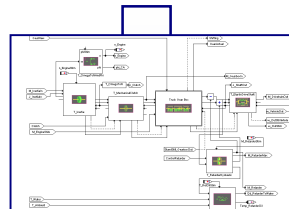
Vehicle Development

CAD FEM
CFD MBS



ECU Development

ABS, ASC, ESP,
EBA, VDC, EHB
EMB, EBD

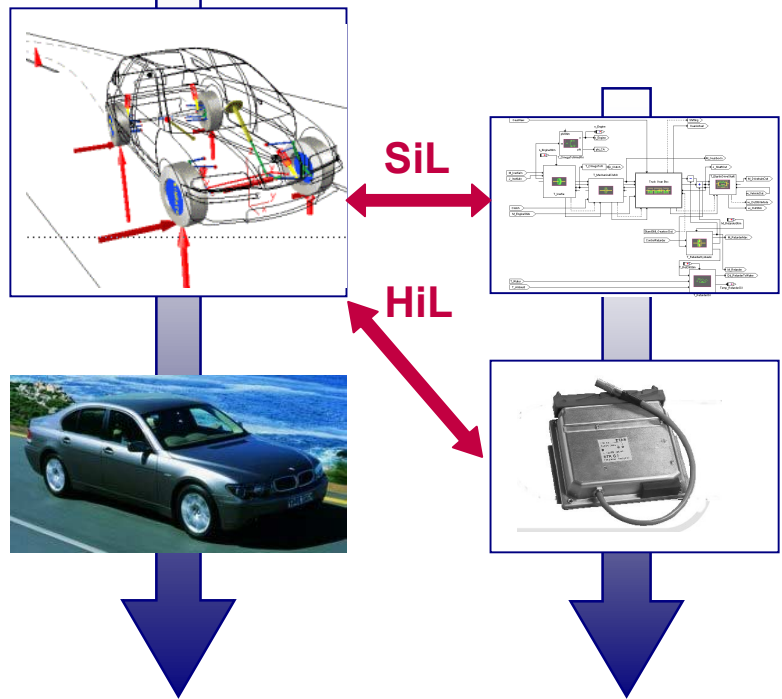


Problems Today

- 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.

Vehicle Development	ECU Development	Vision
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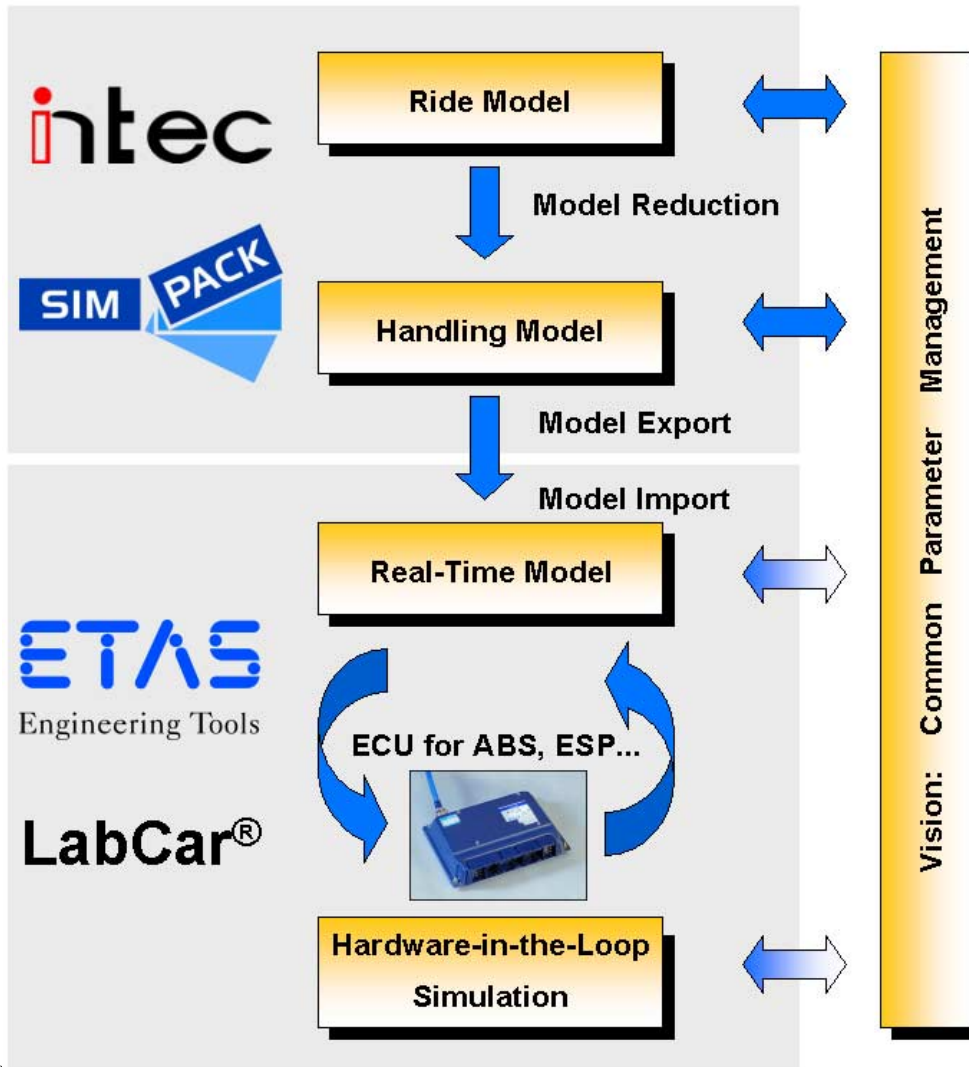


- Reuse validated MBS handling models for model-based ECU development

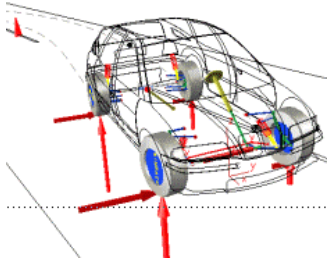
Benefits

- 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

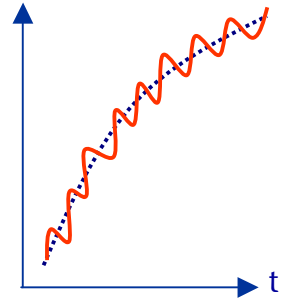
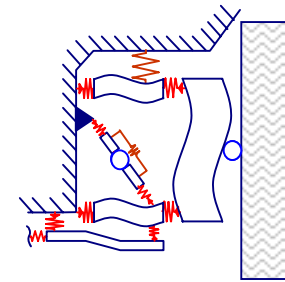
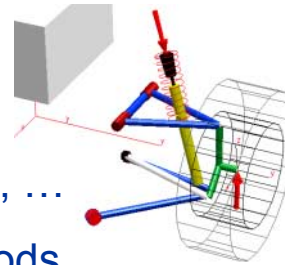
Vision: Seamless Transition from Ride to HiL



Typical Model for Loads or Ride Analysis

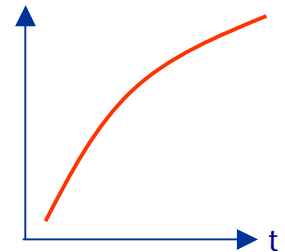


- up to 200 Hz dynamics
- detailed modeling
- equations of motion: DAE, ...
- solved efficiently by methods with variable step-size and order



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

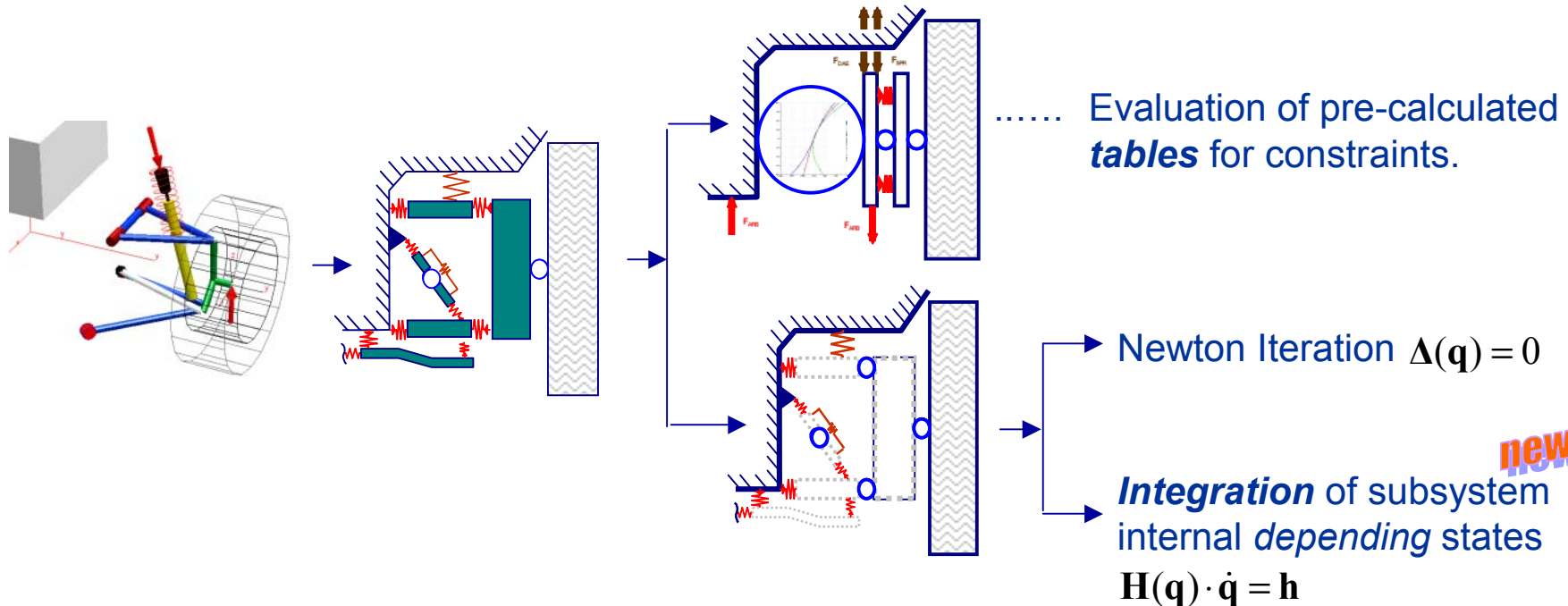
(same physical & simulation MBS-model but mathematical reduced to low frequent dynamics)

Assumption:

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

Reduction for Ensemble: Automotive Suspension

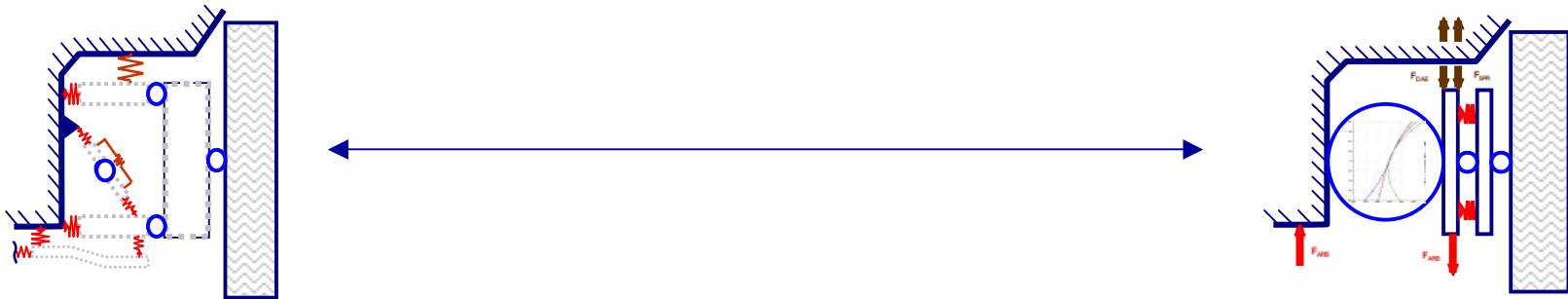
DAE eqn. of motion from subsystem “suspension” convert to *kinematical joint equations*^{*)} with subsystem *internal* constraint equations. These are solved on position level by:



new

*) ... MBS-algorithm in relative coordinates required

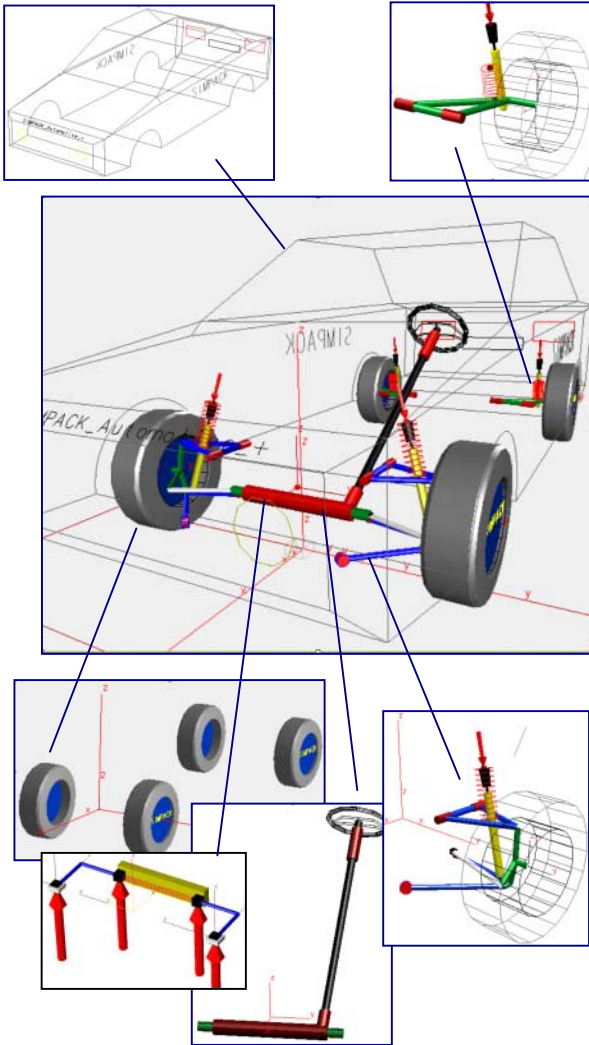
Advantages of Macro Joint Approach compared to Table Fields



- ✓ *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

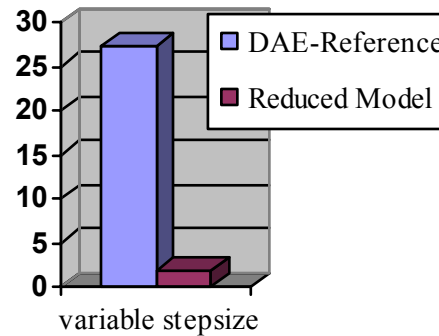
Maneuver : curve entry on plane road

Simulation Time: 10 sec

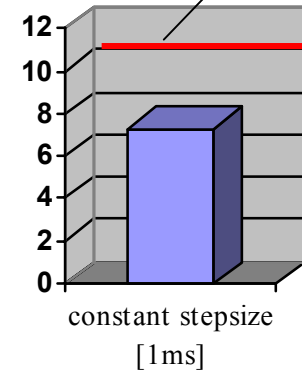
CPU : 450 MHz PC

Performance:

CPU-time [sec]



CPU-time [sec] real time limit for 1 [ms] sample time



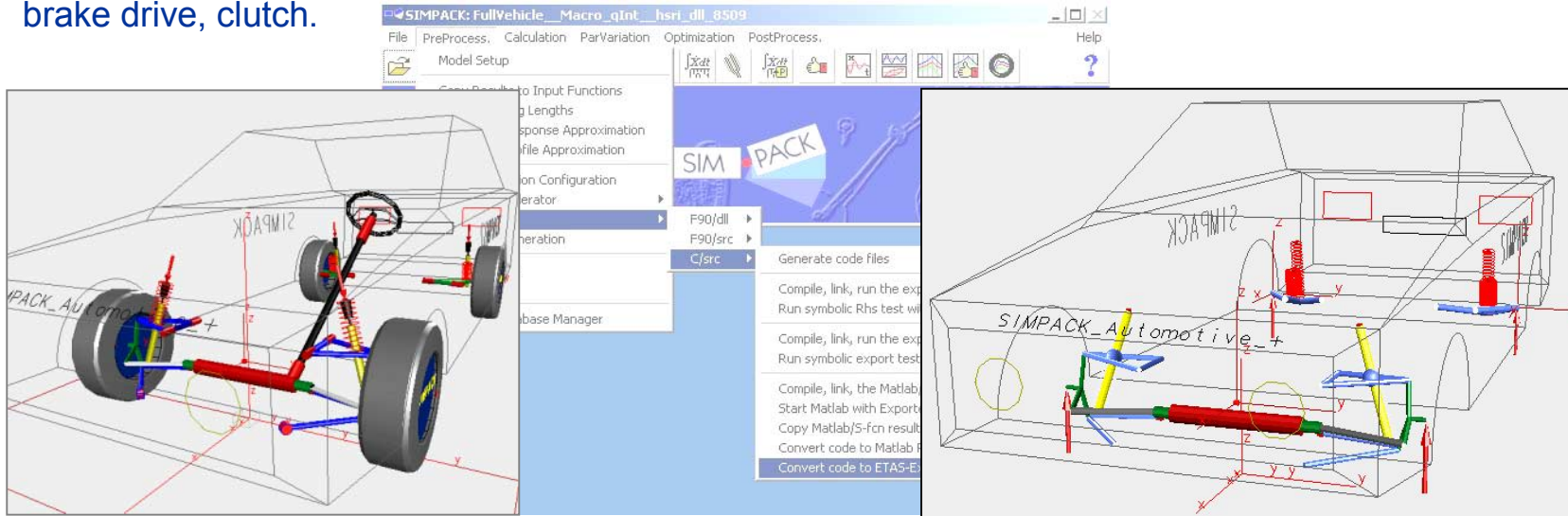
- **Real-time factor about 0.75 for 1ms sample interval**
- **Identical results in interested frequency range^{*)}**

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

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

Simulink® Platform

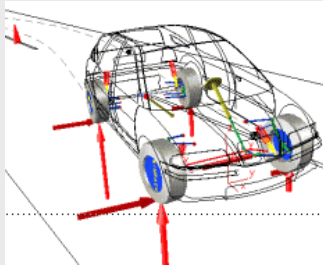


Real-Time Environment



SIMPACK Model

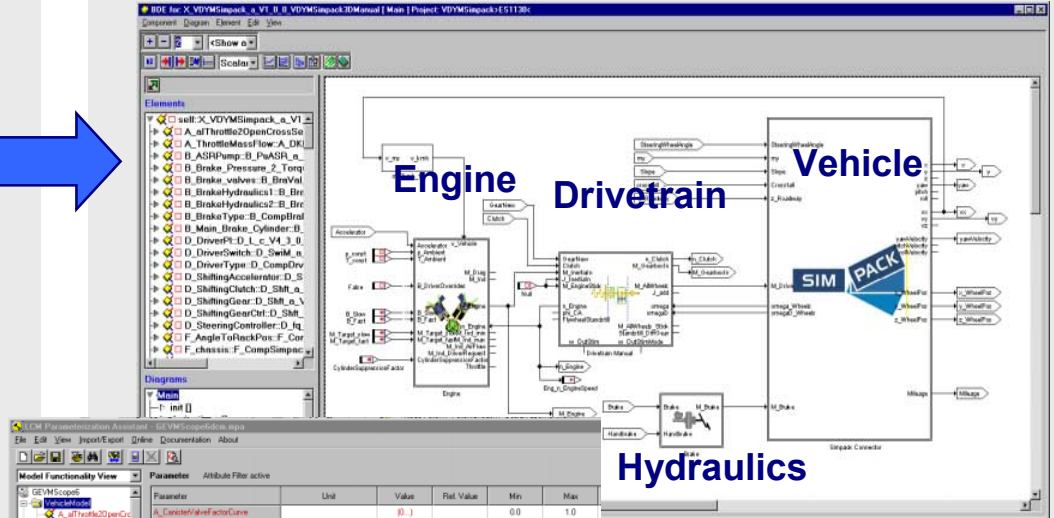
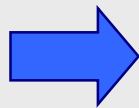
LabCar® Developer



SIMPACK Data

```

1 0_TestCycle_a_slower = 1.0; % (1/30) bezleze!
2 0_TestCycle_a_slower_Min = 0;
3 0_TestCycle_a_slower_Max = 0;
4 0_TestCycle_a_slower_ClassMax = 0;
5 0_TestCycle_a_slower_Stage = 'Normal';
6 0_TestCycle_a_slower_ModState = 'changed';
7 0_TestCycle_a_slower_FootState = 'init';
8 0_TestCycle_a_slower_Modge = 'operational';
9 0_TestCycle_a_slower_PosRecop = 'operational';
10
11
12
13 A_allTheoreticalConnections_A_TheorieMax = 0.0
14 A_allTheoreticalConnections_A_TheorieMin_Min
15 A_allTheoreticalConnections_A_TheorieMax_Max
16 A_allTheoreticalConnections_A_TheorieMax_Min
17 A_allTheoreticalConnections_A_TheorieMax_Min
18 A_allTheoreticalConnections_A_TheorieMax_Min
19 A_allTheoreticalConnections_A_TheorieMax_Min
20 A_allTheoreticalConnections_A_TheorieMax_Min
21 A_allTheoreticalConnections_A_TheorieMax_Min
22 A_allTheoreticalConnections_A_TheorieMax_Min
23
24 0_DriverSwitch_AcceleratorManual = 0.0; % [0...1]
    
```



Parameterization Assistant

Parameter	Unit	Value	Ref. Value	Min	Max
A_ConverterValFactorCurve		0.1		0.0	1.0
A_ConverterValFactorCurve2		0.1		0.0	1.0
A_ConverterValFactorCurve3		0.1		0.0	1.0
A_ConverterValFactorCurve4		0.1		0.0	1.0
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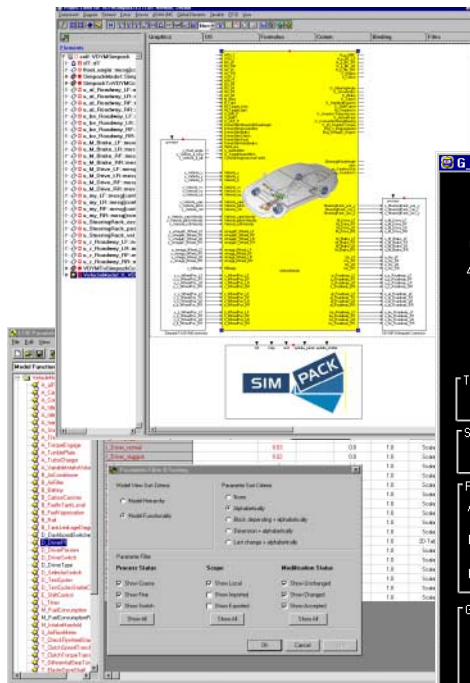


Real-Time Operation

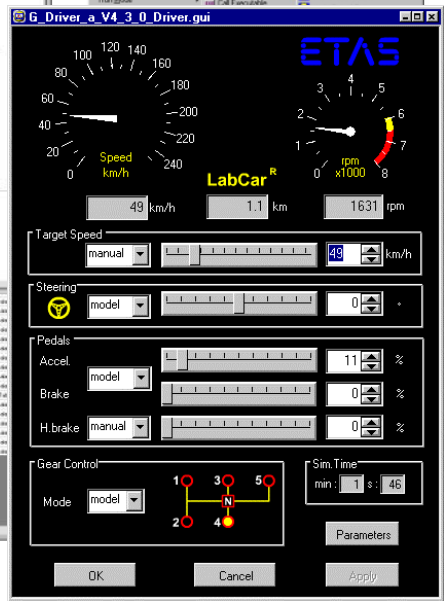
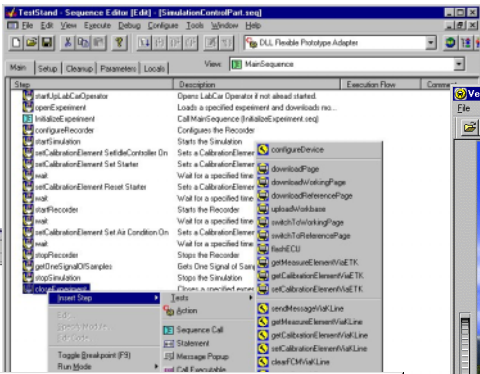
LabCar[®] Automation

LabCar[®] Animation

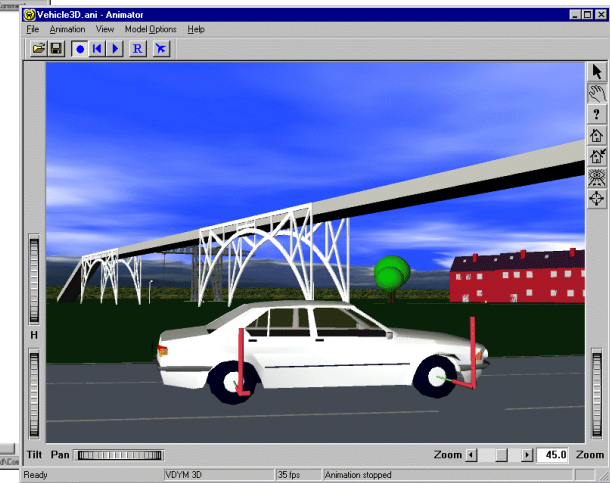
LabCar[®] Operator



Parameterization
Assistant



User Interfaces

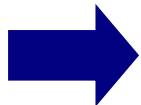


- Software-in-the-Loop
- Man-in-the-Loop
- Hardware-in-the-Loop
- Suspension Variants by Parameterization
- Signal Stimuli
- Test Automation

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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