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# Multi-Domain Vehicle Dynamics Simulation with Dymola

# Overview

- Introduction
- Dymola / Modelica
- Vehicle Dynamics Library
- The Model used
- Comparison with an according Adams-Model
- Ways to interface Dymola and VDL-Models with Matlab Simulink
- Simulation of an electric Power Steering System using Dymola / VDL and Simulink
- Summary

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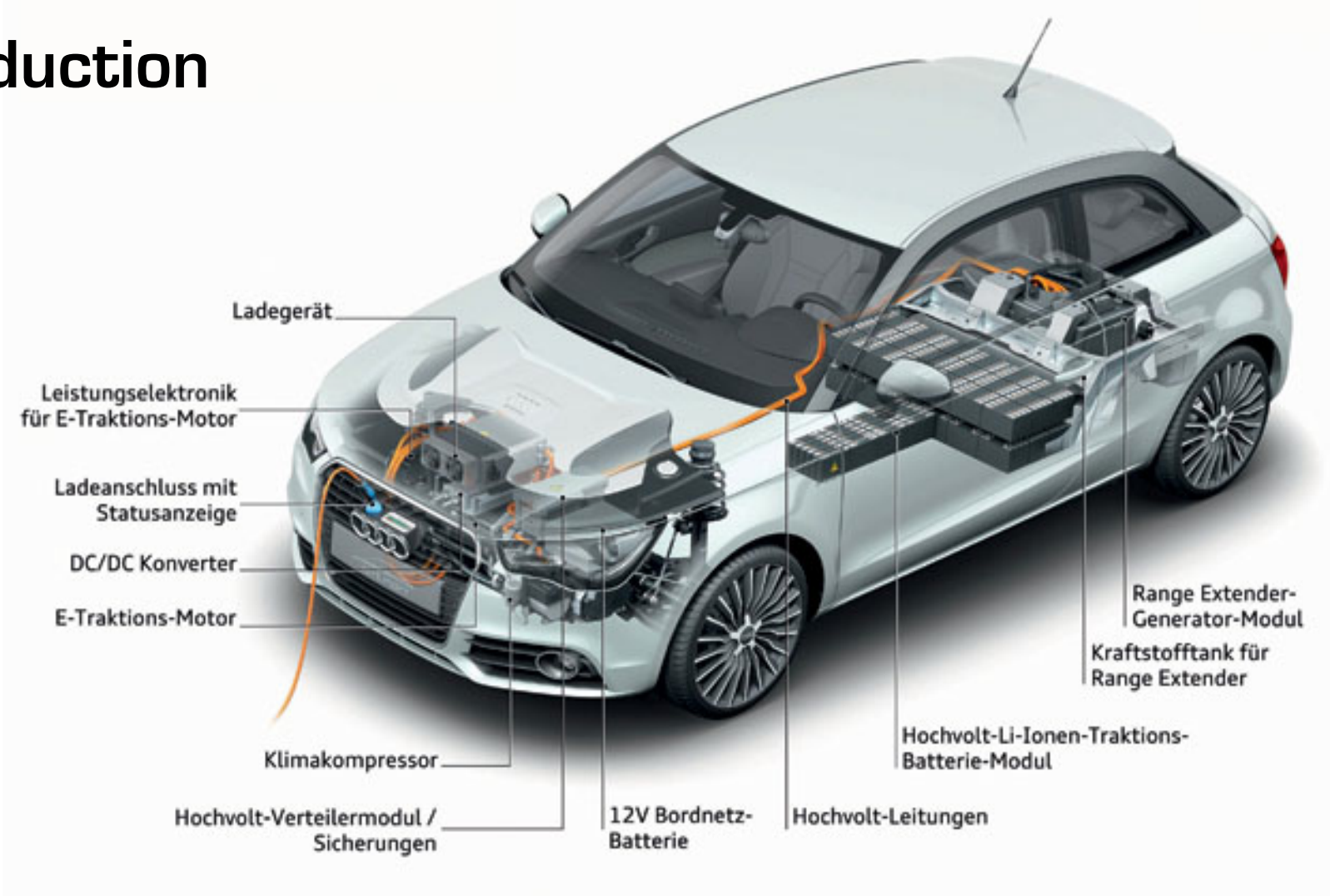
# Introduction




Focus of the project was to study automotive multidomain simulation (mechanic, electric, software, ...) with Dymola using a vehicle dynamics multibody model

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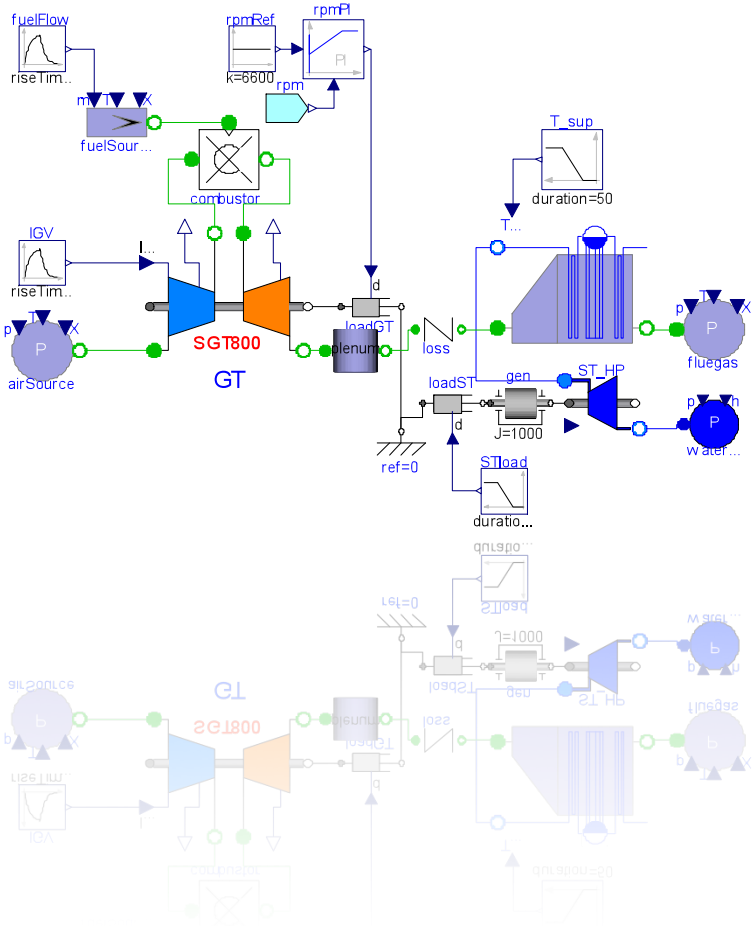
# Dymola / Modelica

- Dymola is a state-of-the-art multi-physical system simulation tool by Dassault Systèmes
  www.dymola.com
- Based on modelling language Modelica (public domain)
  www.modelica.org
- Libraries for a wide range of applications (hydraulics, electrics, control, vehicle dynamics)
- Libs are commercial, public-domain or company specific



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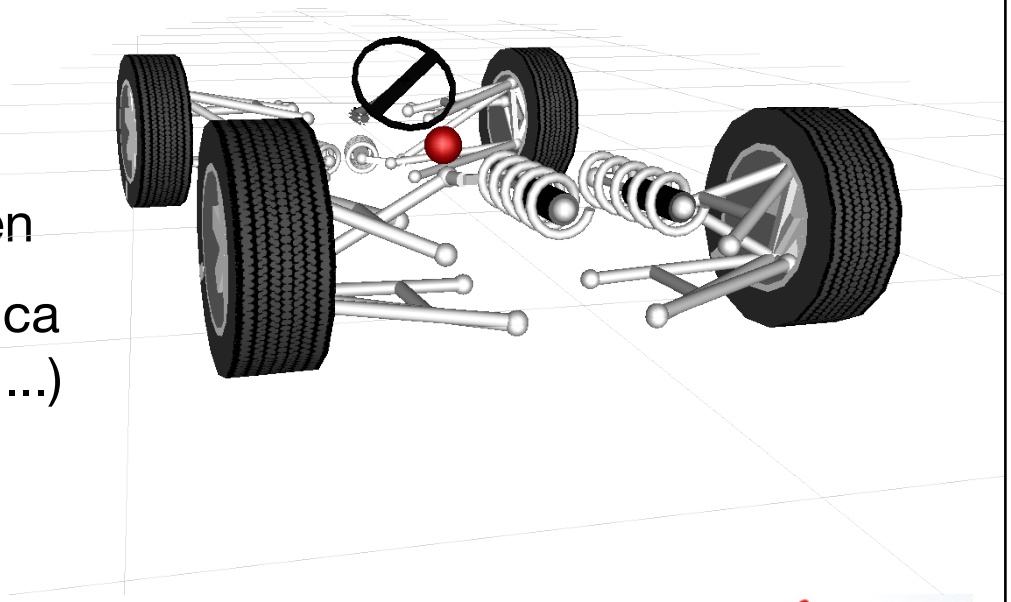
# Vehicle Dynamics Library

- Components and templates for complete car modeling (chassis, suspensions, body, wheel, driveline, brakes, etc.), compliant kinematic suspension models
- Test rigs and scenarios for simulation and analysis
- Drivers, grounds, test rigs, etc.
- Product of Modelon AB, Sweden
- Compatible to any other Modelica lib (electric, control, hydraulics, ...)
- To large extent open Modelica code (extendable by user)



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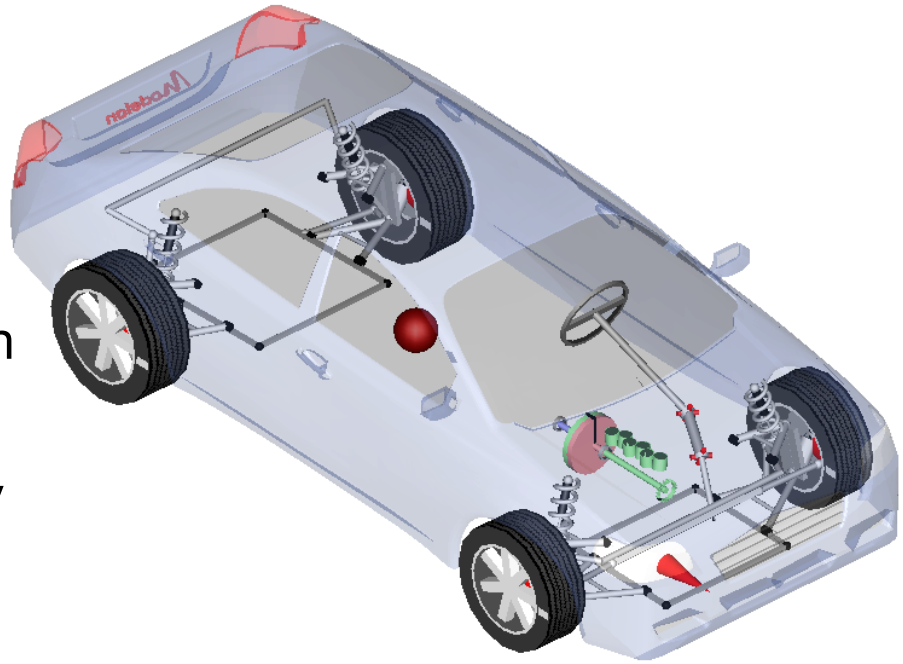
# The Model Used (Vehicle Dynamics)

- Fully detailed multi-body suspen–sions (double wishbone front & rear)
- Suspension parts mostly connected with non-linear bushings
- Rigid car body and subframes
- Based on VDL-standard models
- Based on Audi sports car
- Based on ADAMS/Car model with comparable complexity
- ADAMS model not realised in any detail, as not focus of the project (missing elasticity)



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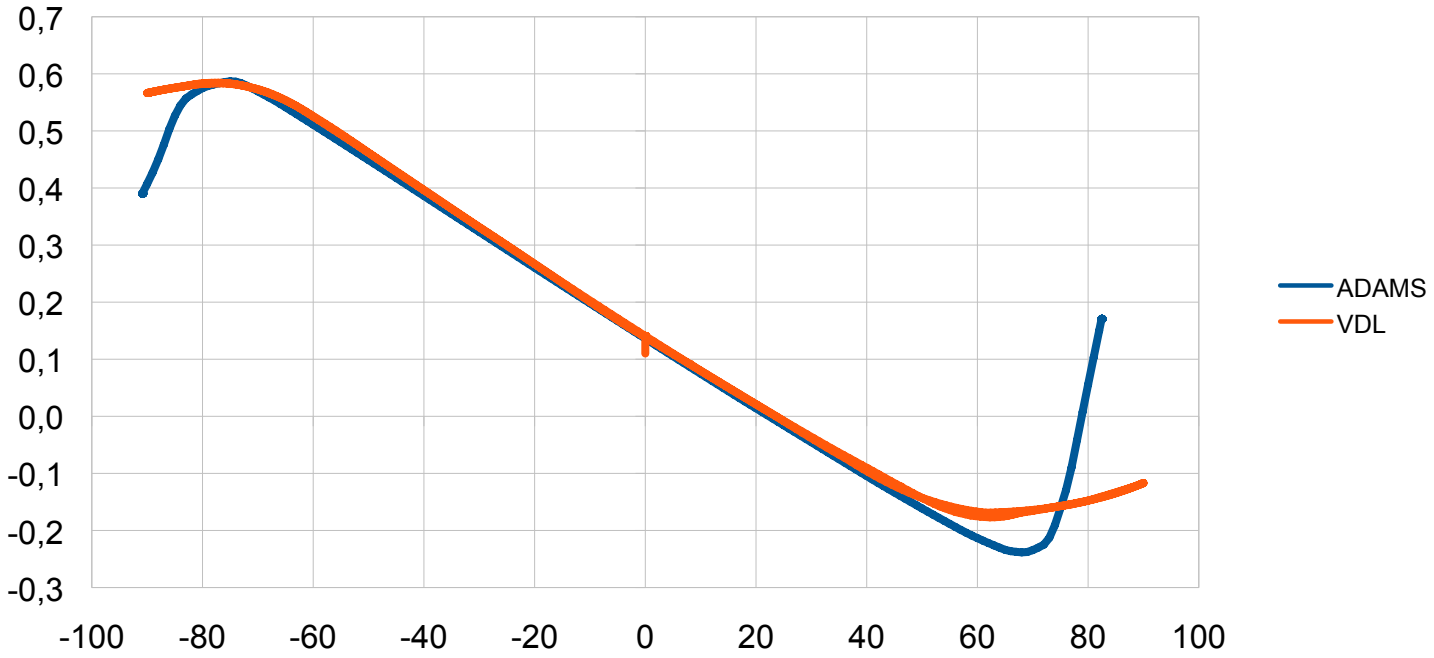
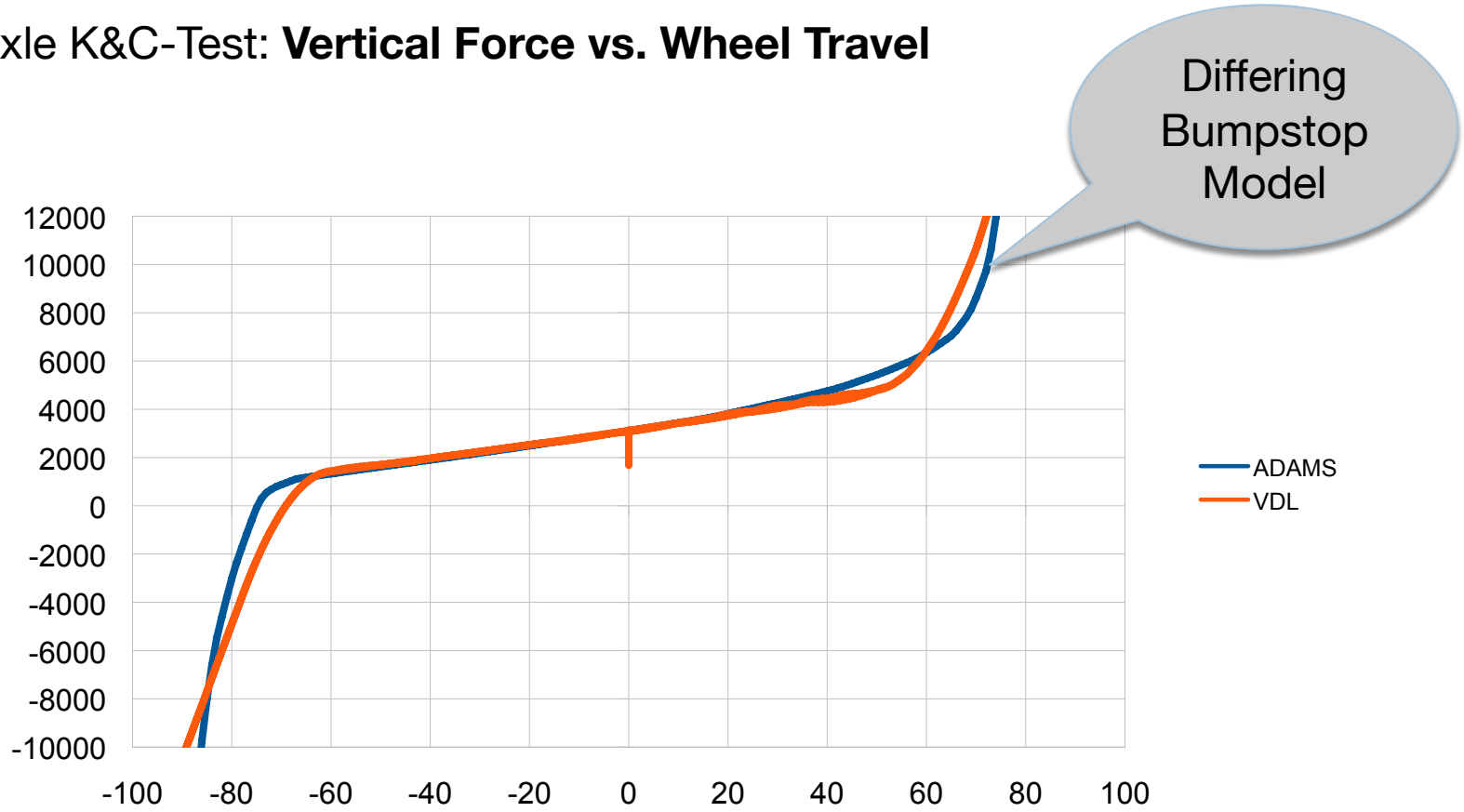
# Comparison VDL with ADAMS

Front Axle K&C-Test: **Toe Angle vs. Wheel Travel**



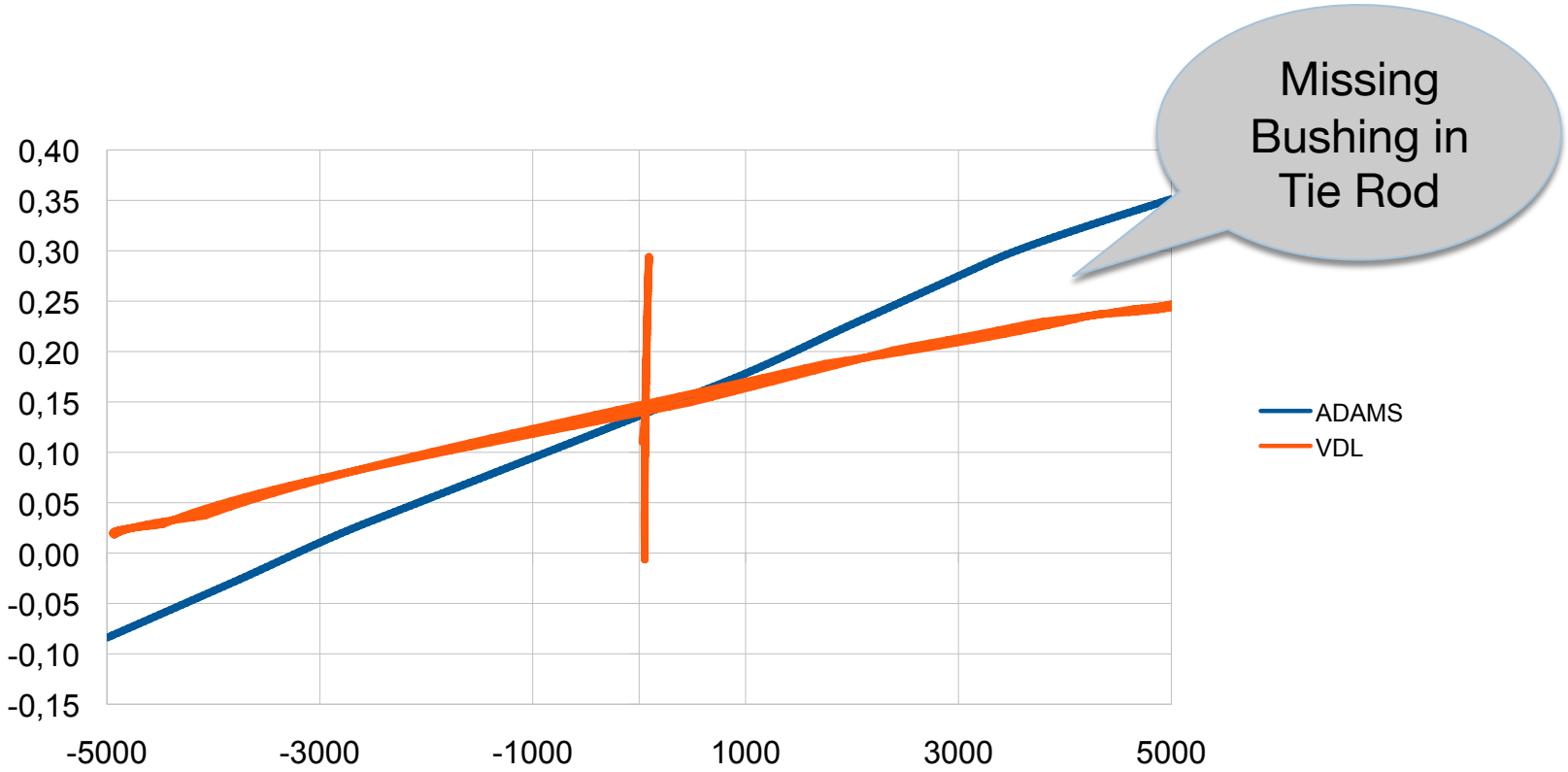
# Comparison VDL with ADAMS

Front Axle K&C-Test: **Vertical Force vs. Wheel Travel**



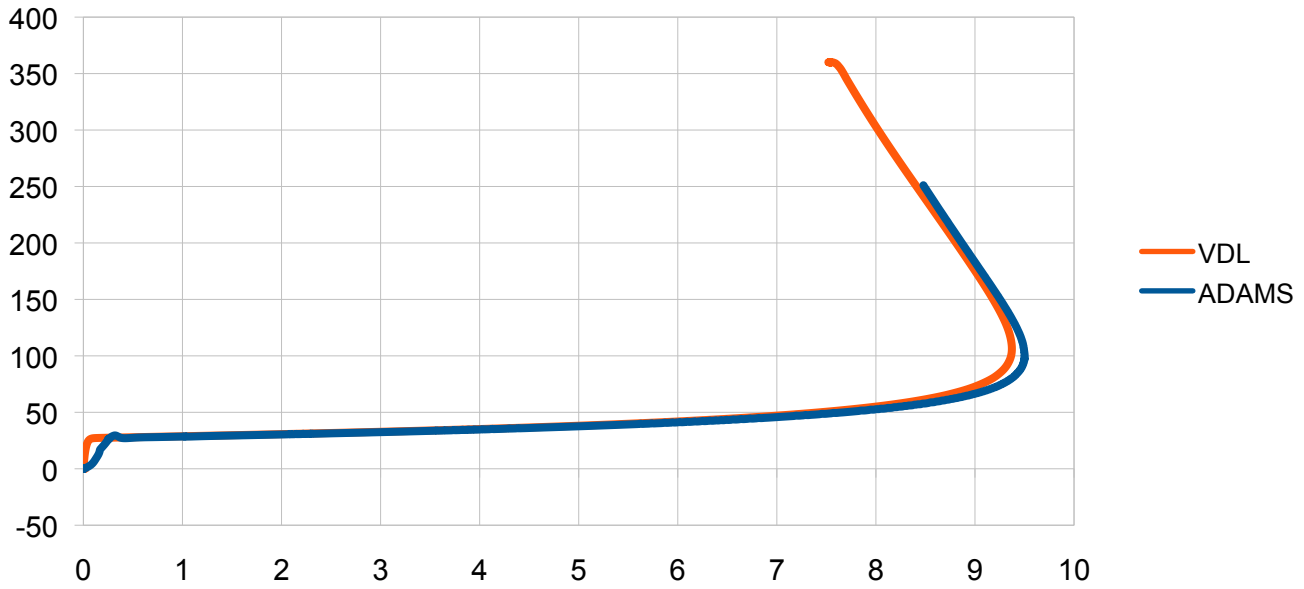
# Comparison VDL with ADAMS

Front Axle K&C-Test: **Toe Angle vs. Lateral Force**



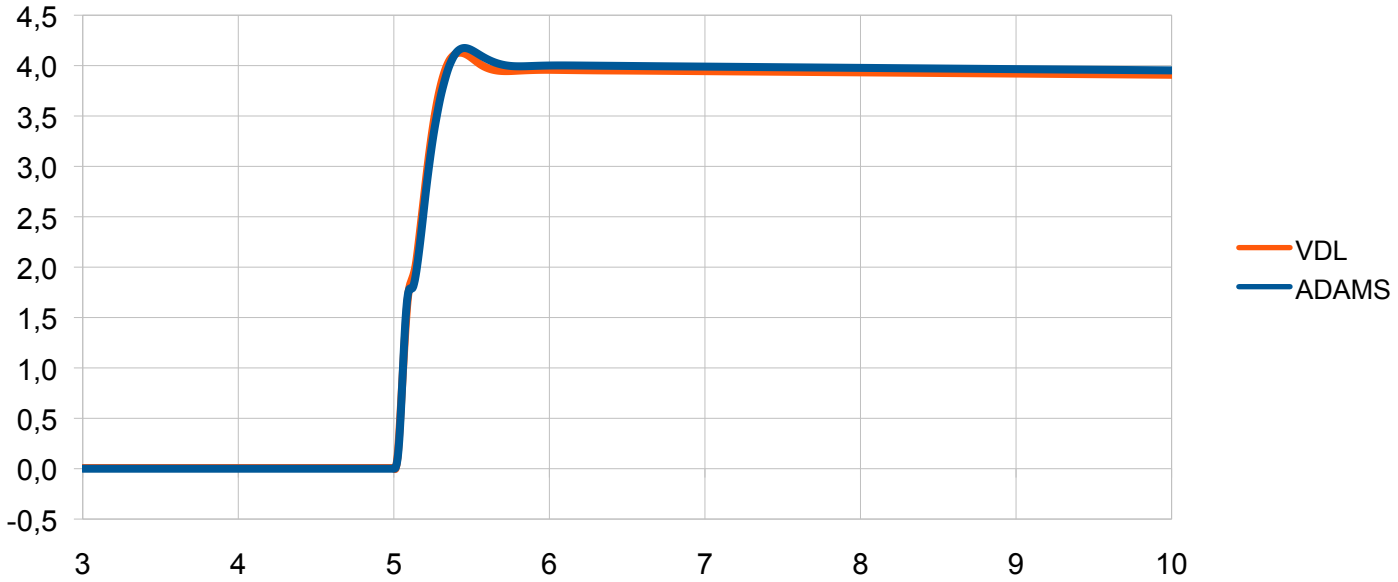
# Comparison VDL with ADAMS

Full Vehicle Stationary Cornering: **Steer Wheel Angle vs. Lat. Acceleration**



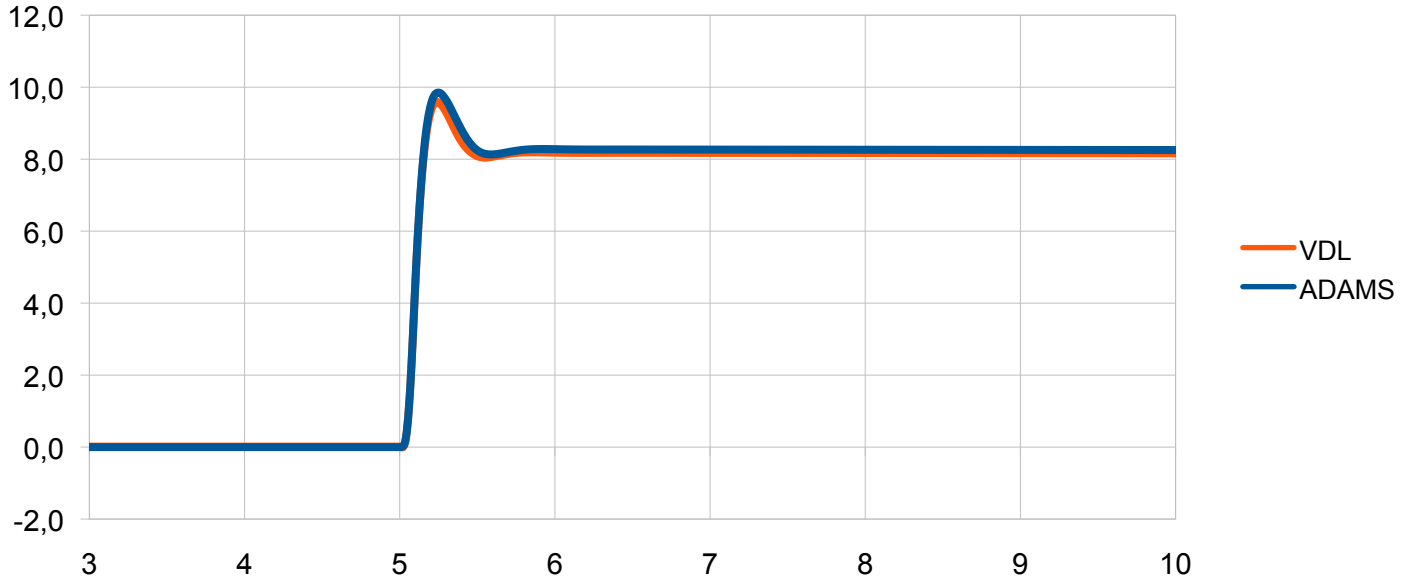
# Comparison VDL with ADAMS

Full Vehicle Step Steer: **Lat. Acceleration vs. Time**



# Comparison VDL with ADAMS

Full Vehicle Step Steer: **Yaw Rate vs. Time**



# Comparison VDL with ADAMS

- K&C results in good accordance or with explainable deviance due to differences in modelling
- Quality of K&C accordance was not further optimised as not being in the focus of the project
- Full vehicle simulations *Step Steer Manoeuvre* and *Stationary Cornering* in good accordance
- Higher accordance of results possible by usage of equivalent component models (e.g. bumpstop, missing bushing)

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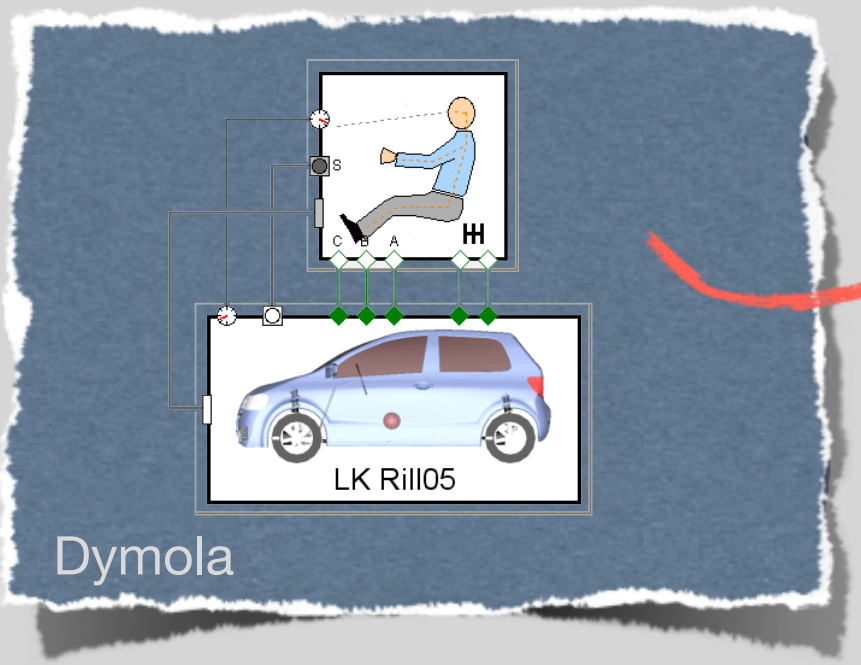
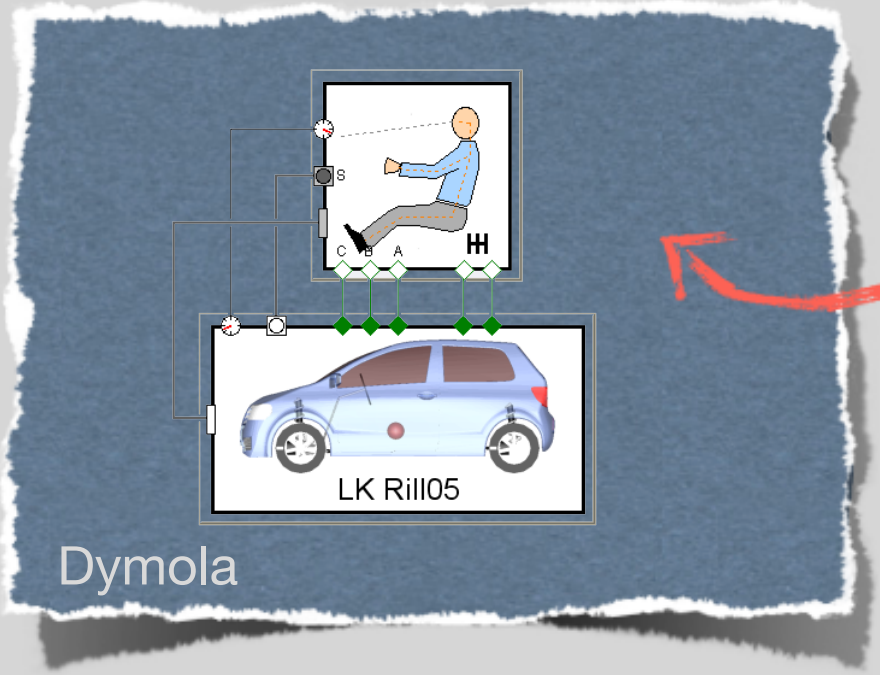
# Ways To Interface Dymola & Simulink




- C-Code
- Code Export
  (no license required at runtime in Simulink)
- Simulink-Interface
  (license required at runtime in Simulink, HIL)
- Binary Model Export
  (license for reduced price required at runtime in Simulink)

Matlab Simulink

# Ways To Interface Dymola & Simulink




- Functional Mock-up Interface
- No license required at runtime in the other tool
- Result of Modelisar research project
  http://functional-mockup-interface.org

Matlab Simulink

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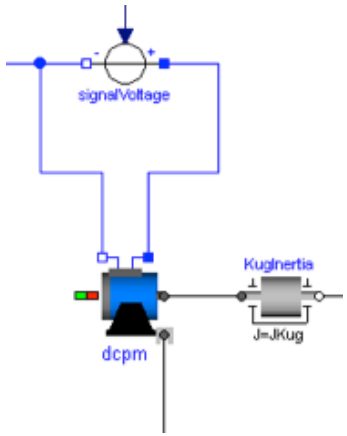
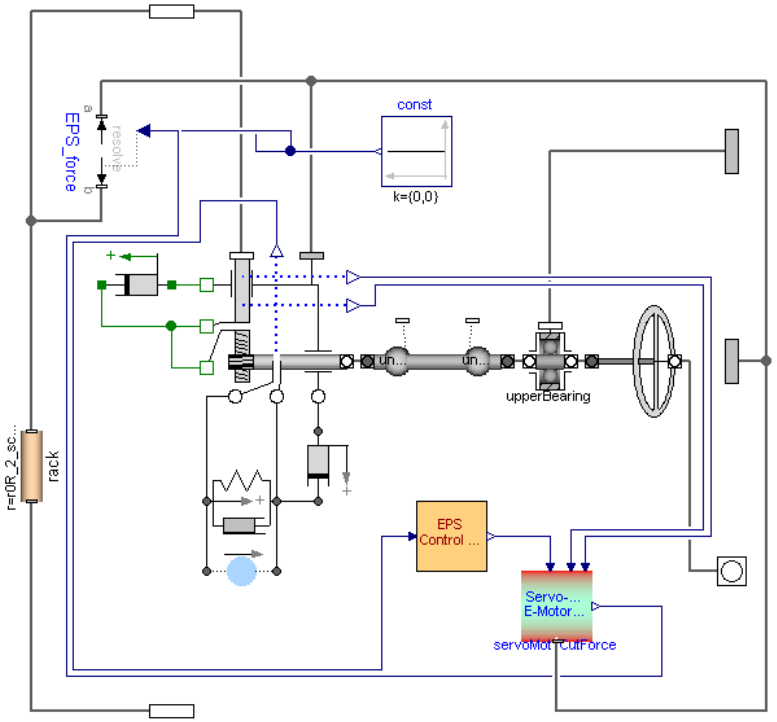
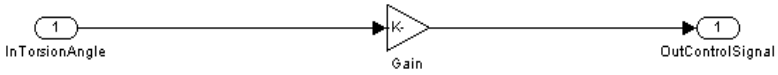
# EPS and Controller Model

- Electric Power Steering modelled in Dymola / Electric Lib
- DC-Motor Model, ideal Voltage Supply




- Current Controller as Gain Factor in Dymola Control Lib and Simulink



# Simulation of a Vehicle with EPS-System

**(Electric Power Steering)**

| | Vehicle Dynamics Model | EPS Actuator Model | Steering Controller Model | Simulation Tool, Solver |
|---|---|---|---|---|
| **Variant 1** | Dymola VDL | Dymola Electric Lib | Dymola Control Lib | **Dymola** |
| **Variant 2** | Dymola VDL | Dymola Electric Lib | Simulink | **Dymola** |
| **Variant 3** | Dymola VDL | Dymola Electric Lib | Simulink | **Simulink** |

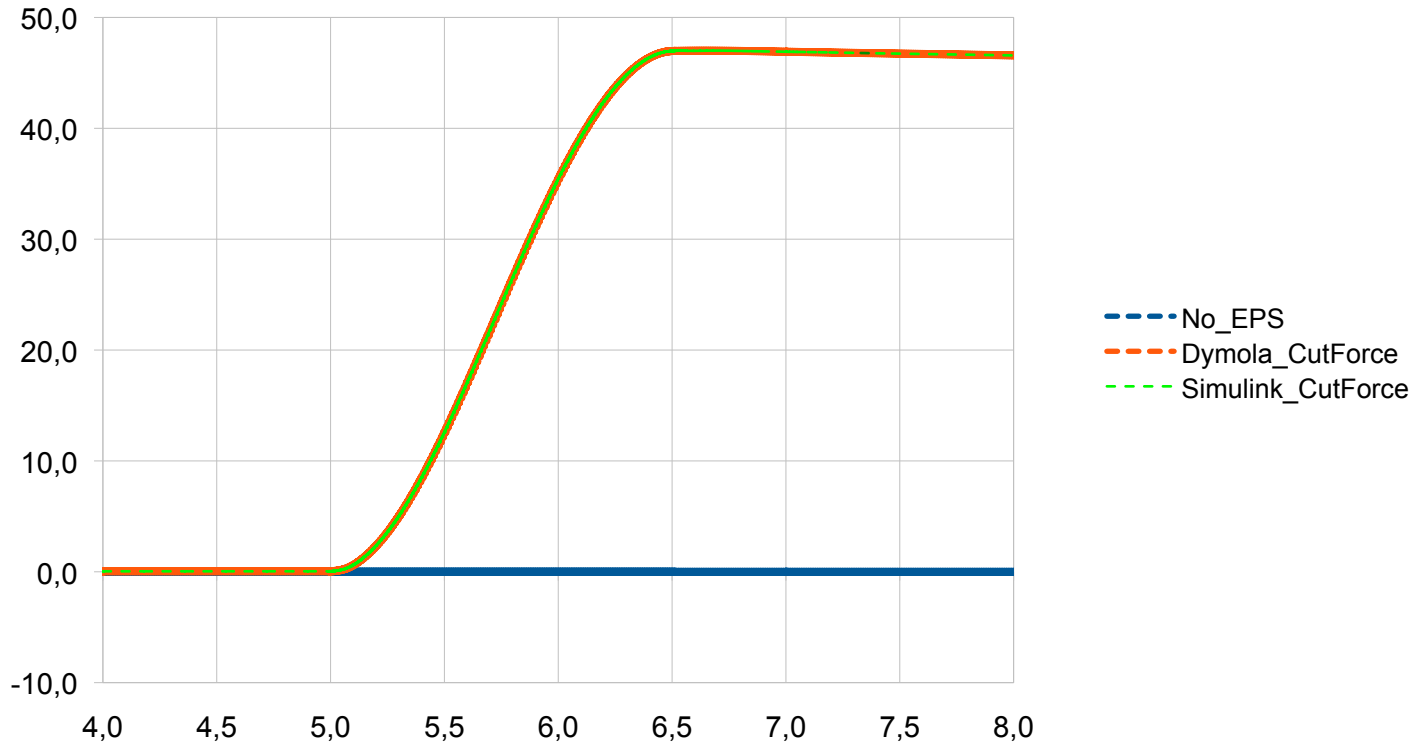
# Simulation of a Vehicle with EPS-System

**(Electric Power Steering)**

- Export of according Simulink Controller Model to Dymola (Variant 2)
- Export of Dymola Vehicle- and EPS-Model to Simulink (Variant 3)
  > Typical automotive Industry Solution
- Re-calculation of a **Step Steer Manoeuvre** (SSM) and **Stationary Cornering** (SC)
- Practically identical Results
- Different Calculation Times

# Multiphysical Simulation Results

Full Vehicle Step Steer: **Steering Motor Current vs. Time**



# Simulation of a Vehicle with EPS (Electric Power Steering)

| | Simulation Tool, Solver | Simulation Time, SSM | Simulation Time, SC |
|---|---|---|---|
| Variant 1 | Dymola | 25,2 sec. | 14,8 sec. |
| Variant 2 | Dymola | 25,2 sec. | 14,8 sec. |
| Variant 3 | Simulink | 25,3 sec. | 65,4 sec. |

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- Resolved Multibody Model comparable to original ADAMS-Model using Modelon‘s Vehicle Dynamics Lib
- Reasonable Effort invested to achieve comparable Results to ADAMS base
- Extensive Validation of Multibody Model
- Entire Mechatronic System Simulation in one Tool: Dymola
- Manifold Ways to interface Dymola and Simulink support flexible Approaches and Tool Strategies to simulate mechatronic Systems
- Multiphysical Simulation demonstrated
- Way forward for Simulations of hybrid and electric Drive Trains, Vehicle Dynamics Control Systems, ...