Full-Vehicle Real-Time-Simulation with an advanced flexible Tire-Model on Fraunhofer's Driving-Simulator

Simpack User Meeting

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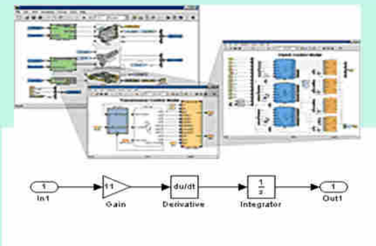
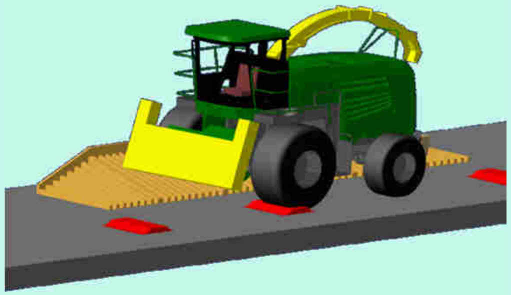
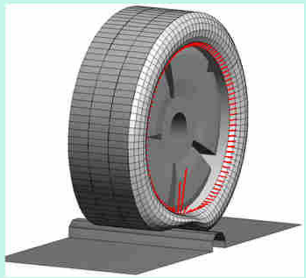
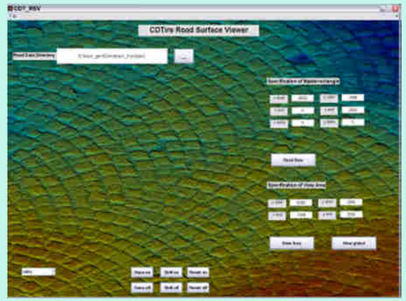
Simulation in vehicle engineering

- **Virtual product development (VPD):** simulate physical properties of the vehicle → analyze, evaluate and improve (optimize) design states









driver model | **vehicle model** | **tire model** | **ground / road model**

simulation input

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Full-Vehicle Real-Time-Simulation with an advanced flexible Tire-Model on Fraunhofer's Driving-Simulator

- Fraunhofer's interactive driving simuator RODOS
  - General setup
  - Objectives and Tasks
- CDTire/Realtime
- Coupling vehicle model – tire model - simulator
  - Realtime Co-Simulation
  - Realization
- Summary and Outlook

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Fraunhofer's Driving Simulator RODOS

RODOS – **Ro**bot based **D**riving and **O**peration **S**imulator

- The interactive driving simulator RODOS was developed and commissioned in Fraunhofer ITWM
- Motion system is based on KUKA KR1000 industrial robot
- Payload up to 1000 kg.
- Vehicle cabin is connected to the robot via modular flange
- Serial 6-axis kinematical scheme of the robot allows large translational and rotational motion
- 3kW shaker system for frequencies up to 200Hz

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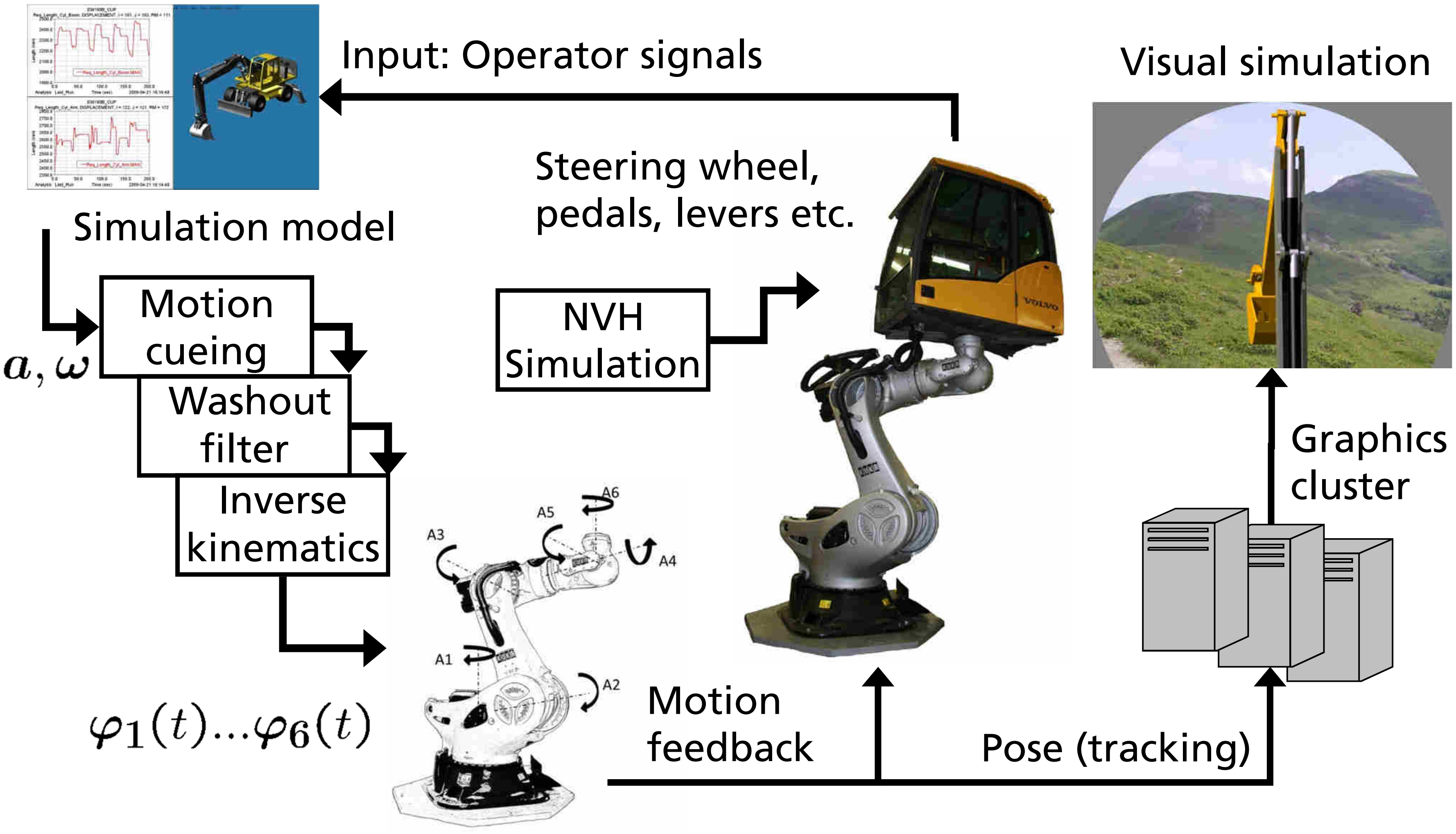
Simulator Setup



Fraunhofer's Driving Simulator RODOS

RODOS – **Ro**bot based **D**riving and **O**peration **S**imulator

Objectives and Tasks

Objectives

- Handling of usage variability: durability load data analysis and energy efficiency with the influence of the operator (load case catalog)
- Development of driver / operator models for detailed offline simulations
- Presentation / visualization of simulation results (motion, visual, sound, etc)
- Development of assistance systems

Application: construction and agricultural machines, as well as passenger cars and trucks

- ➢ The first group of vehicles is operating in rough and deformable terrain, thus, an adequate tire model is required.
- ➢ For comfort application the tire model should accurately represent a frequency range 0-150 Hz.

⇨ *Realtime tire model based on physical tire properties is required*

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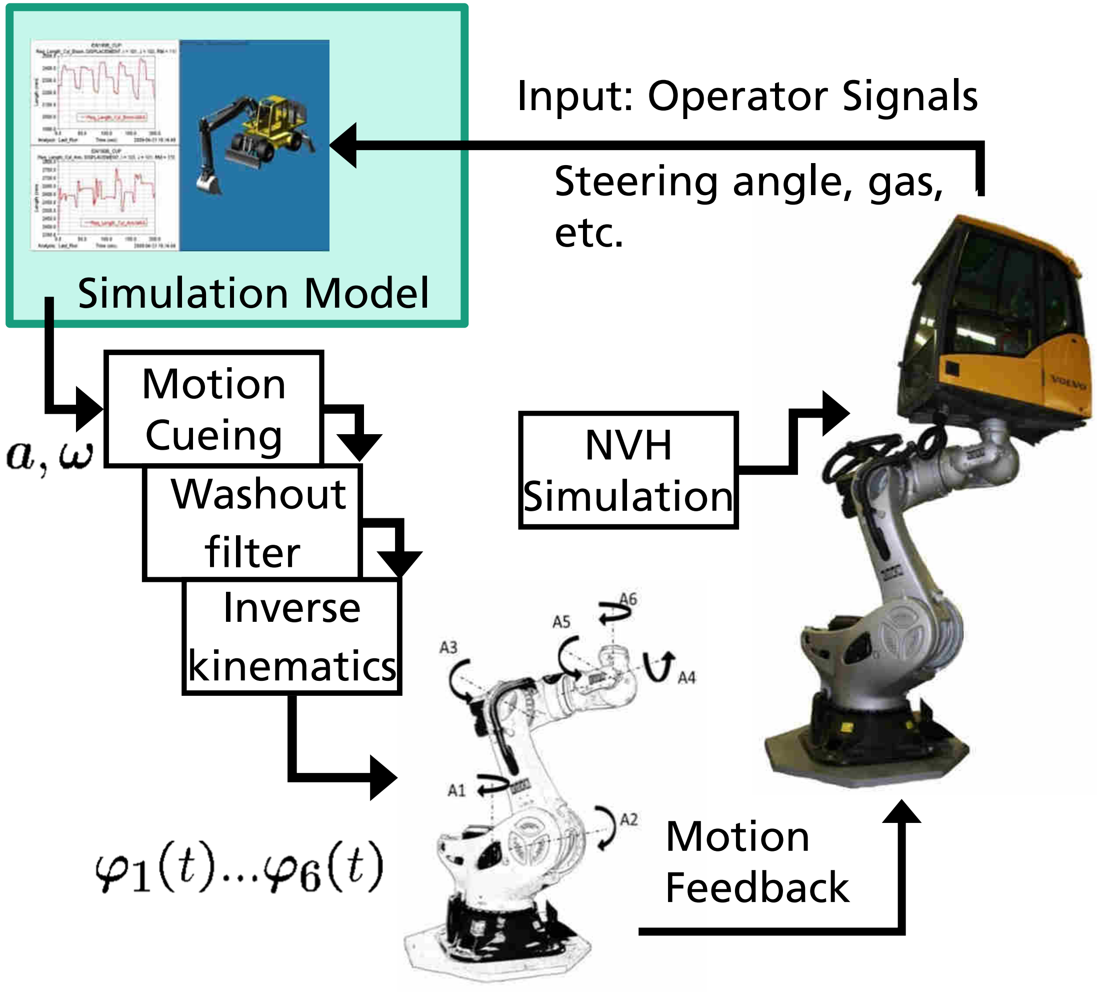
Integration of the Realtime Tire Model in RODOS

- Goal: Vehicle model with 4 tire models in the simulation loop
- Stepsize: 0.5-1ms



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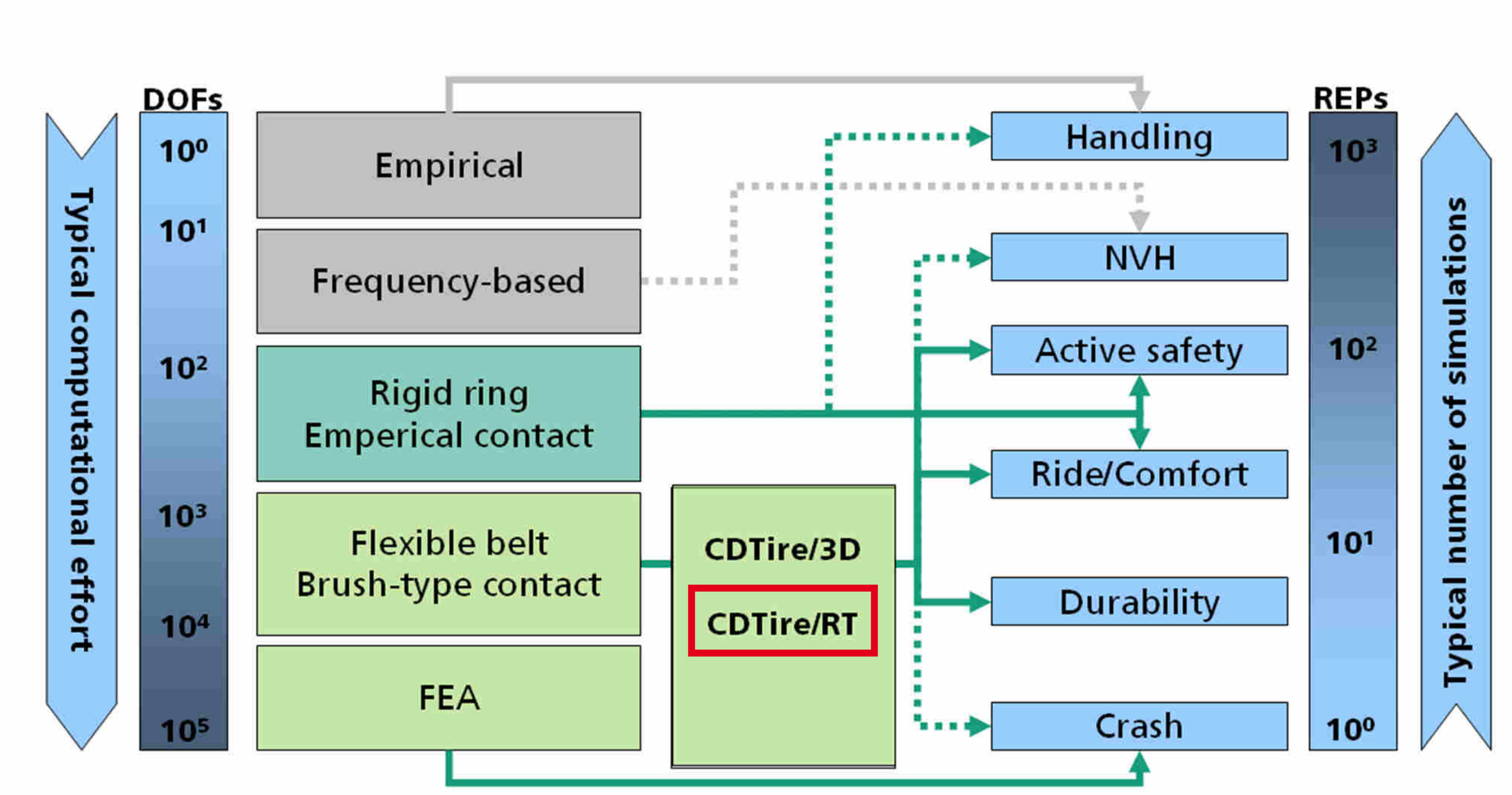
Structural MBD Tire Models



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CDTire/Realtime: Model Structure

- Model properties
  - Flexible belt
  - Brush-based contact formulation
  - Analytical formulation for sidewall deformation

- Road models
  - Arbitrary wave length

- Typical application scenarios
  - Ride & Comfort
  - Durability

- Realtime factor
  - 0.5 at 2GHz Processor

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CDTire/Realtime: Properties

- Software Architecture: C-Code
  - Thread-safe
  - Inlining
  - Reduced application of trigonometric functions
  - Sequential maximal looping
  - Local data management
- Numerical: Deterministic
  - Implicit time integration of Newmark type
  - Fixed step size and number of iterations
  - Efficient Newton iterations

- Model
  - Applicable for ride and comfort simulations
  - Applicable for durability simulations
  - No loss of accuracy
  - Flexible belt
  - Model elements are identical to off-line previous generations (no linearization was used)

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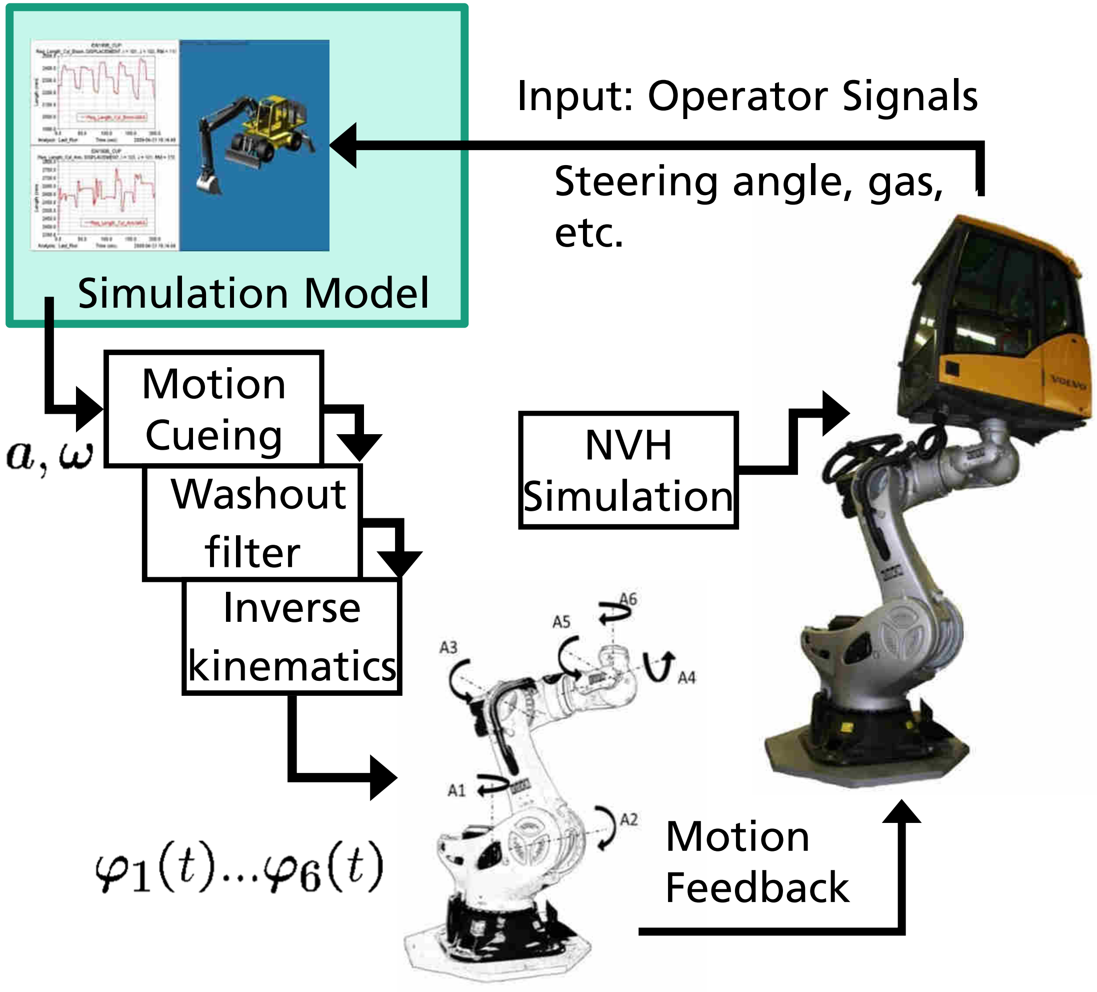
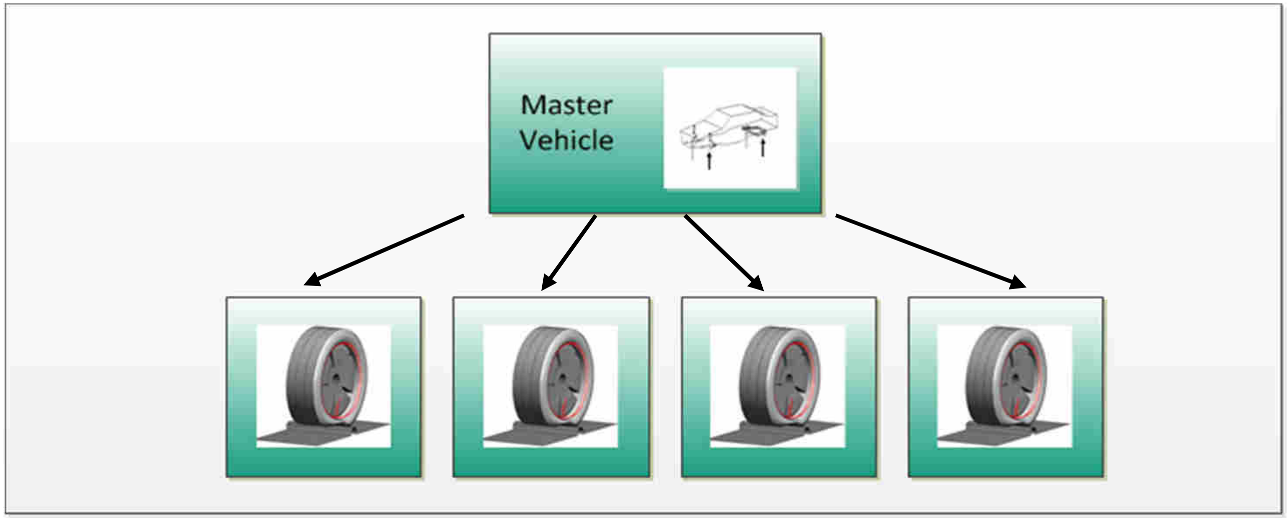


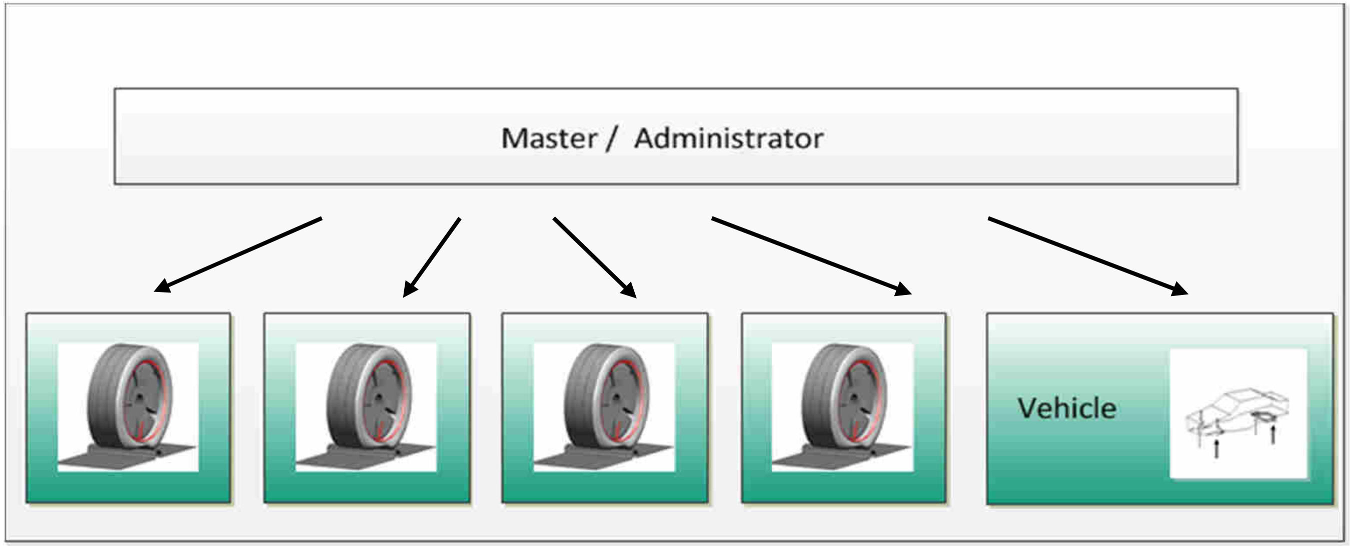
Classical Offline Interface Vehicle-Tire
Embedded Co-Simulation

- The MBS solver ‚*calls*‘ the tire model and *waits* for a force response
  - Vehicle and tire cannot be run in parallel
  - Realtime Application: Vehicle and tire model must be realtime capable

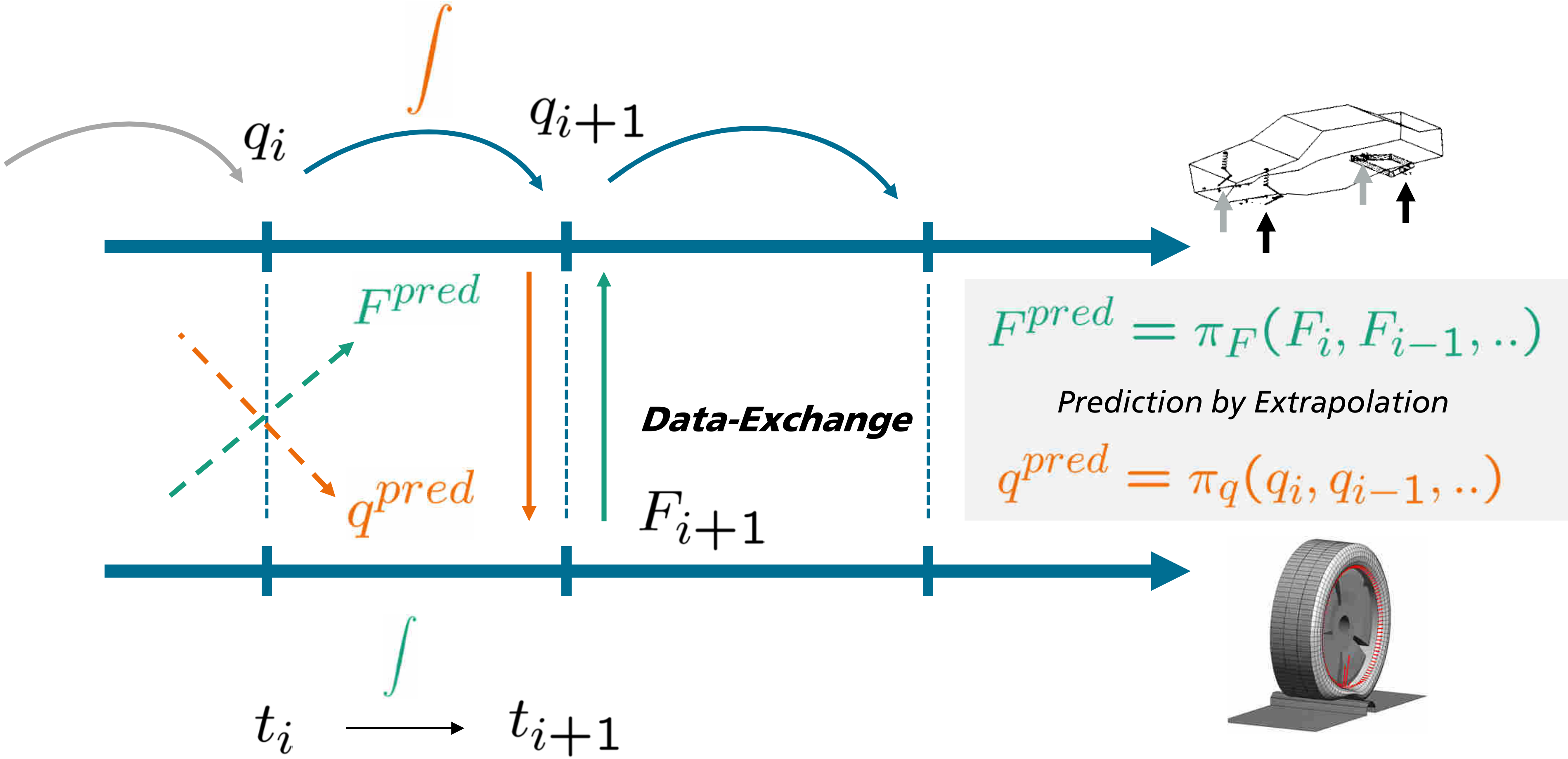


Interface Vehicle-Tire with Delay-Concept
Classical Co-Simulation

- Goal: Parallel simulation of vehicle and tire model
- Only vehicle model and tire model need to be realtime capable seperately
- Data exchange is organized and administrated by a *Fraunhofer Co-Simulation master algorithm*
- Time-Delay in the coupling quantites is inevitable



Interface Vehicle-Tire with Delay-Concept
Classical Co-Simulation



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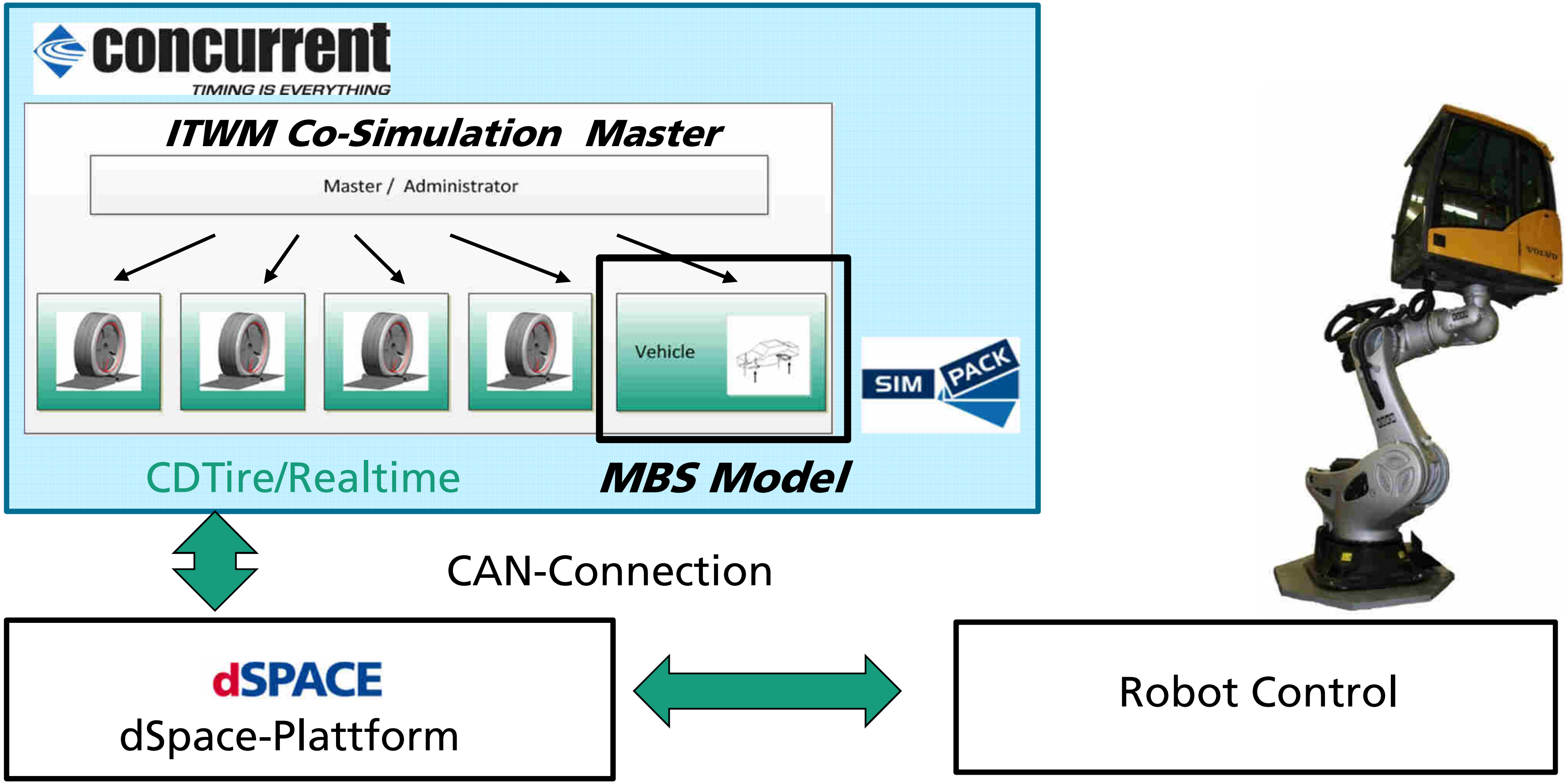
Realization at the Driving Simulator RODOS

- Realtime Hardware: Concurrent iHawk 12-Core-System



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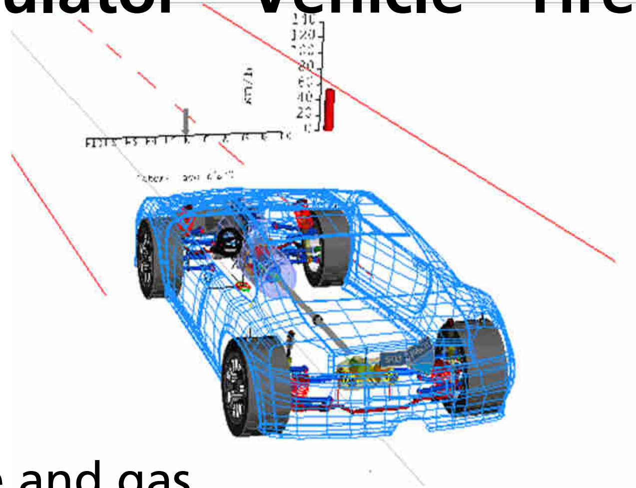
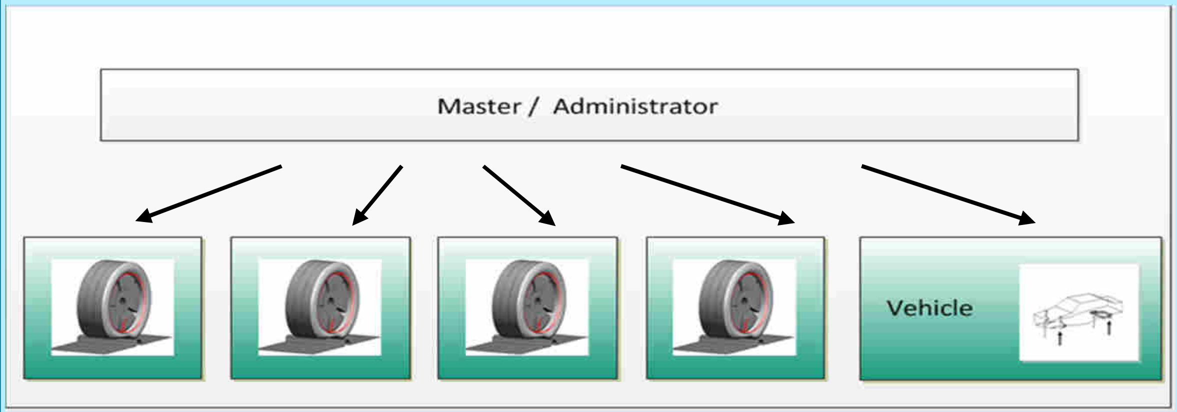
Realtime Co-Simulation Driver/Simulator – Vehicle - Tire

- Simulation with Simpack Vehicle Model

(~189 DOFs)

  - 3 cores
- 4x CDTire/Realtime
  - each of a single core
- Input Vehicle Model: Steering angle, brake and gas
- Output: Chassis Kinematics





CDTire/Realtime

concurrent
TIMING IS EVERYTHING

Simulation Workbench

SIM PACK

Simpack-Concurrent-Interface

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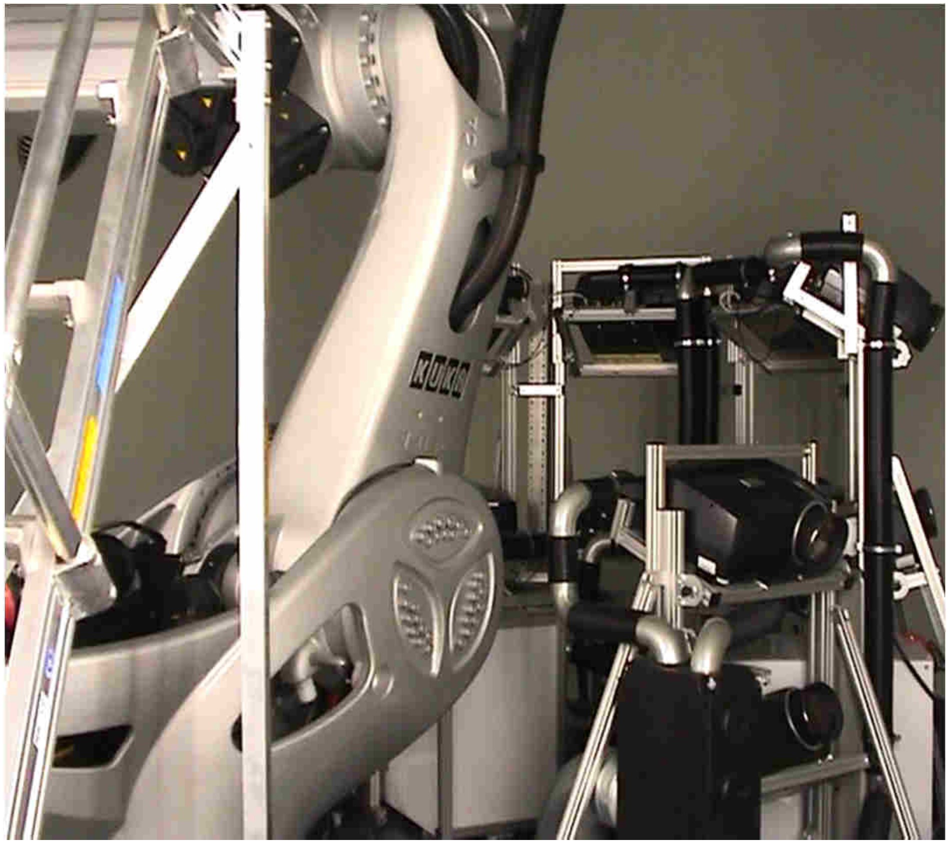
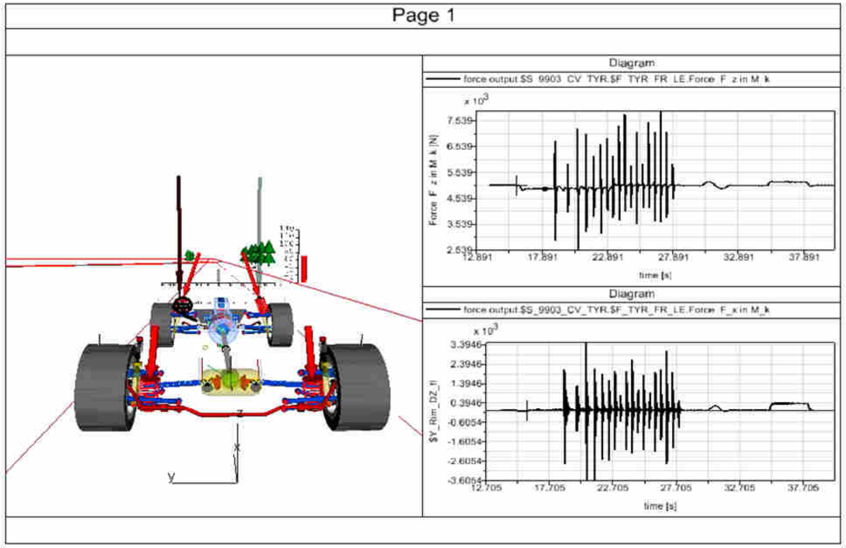
Realtime Co-Simulation Driver/Simulator – Vehicle - Tire

- Test-Scenario: Drive over 18 cleats (15-25mm height) and steering manoeuver
- Stepsize: 1ms, Realtime factor tire model 0.5





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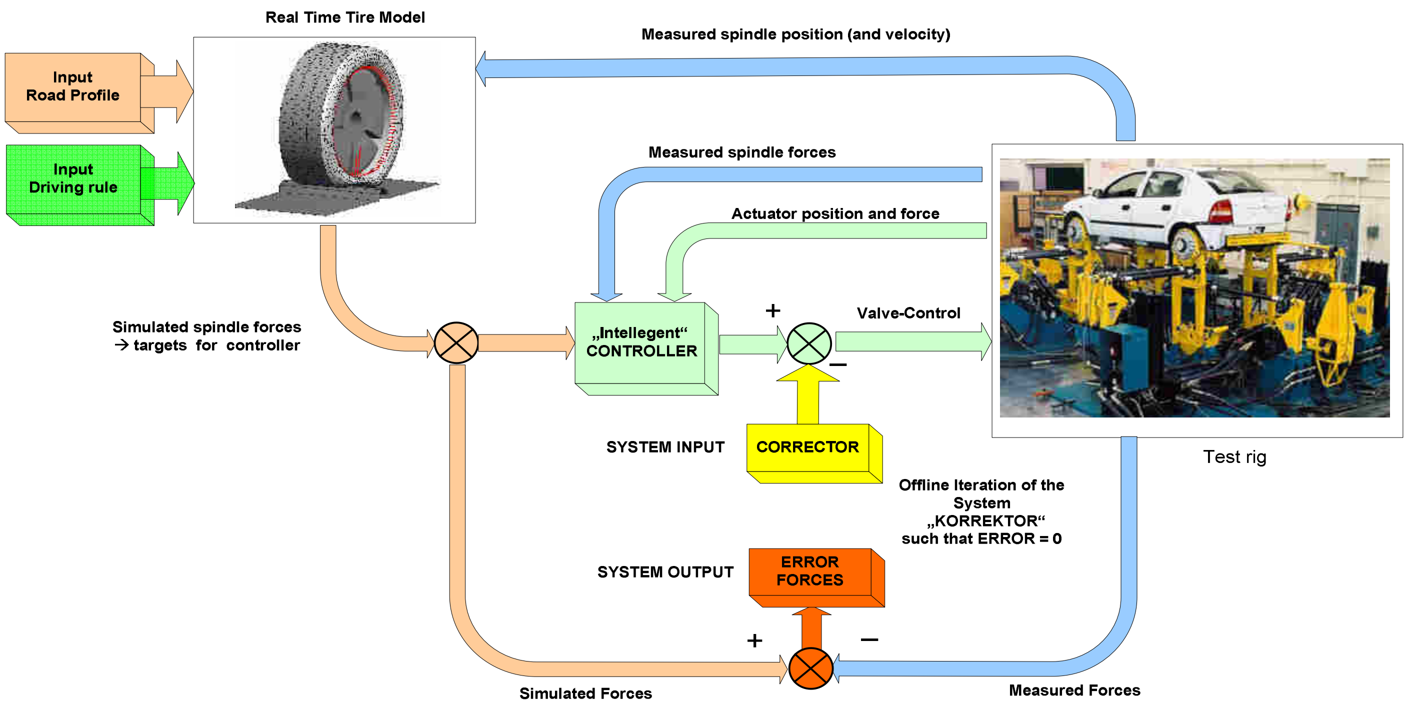
CDTire/Realtime: Full-Vehicle Test-Rig Application

- Scenario MIL / SIL / HIL: Tire model as part of a real test-rig
- Road profile and driver requirements as input for the real test-.rig
- No test-track measurements necessary



Summary & Outlook

- Successful Integration of CDTire/Realtime and a Simpack vehicle model at RODOS
  - → Realtime Co-Simulation scheme (ITWM Co-Simulation Master)
- Case-Study of a Simpack full-vehicle model and 4 tire models with a multicore hardware.

Outlook

- Application on different hardware and/or simulators.
- ‚Tire-in-the-Loop' at a full-vehicle test-rig