Embedded Success

dSPACE

DLR's ROboMObil HIL Simulator Using FMI 2.0 Technology on dSPACE SCALEXIO Real-time Hardware

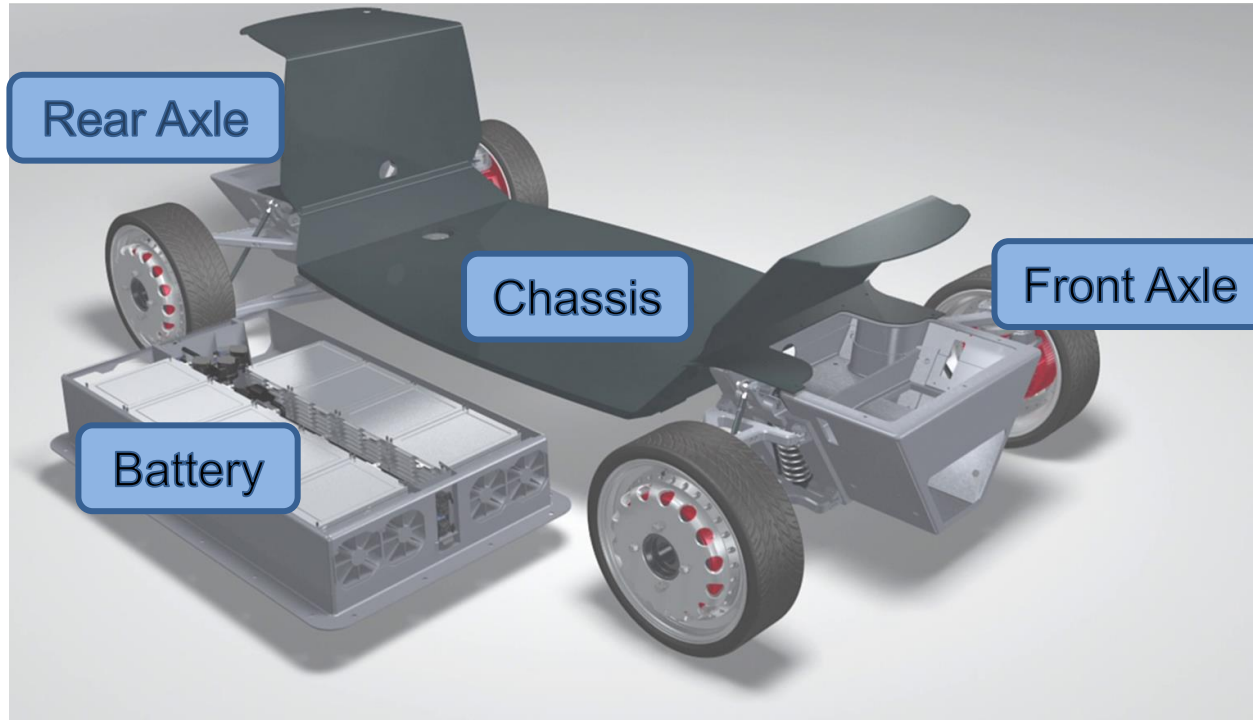## FMI User Meeting at the Modelica Conference 2017

Jonathan Brembeck – DLR
Andreas Pillekeit - dSPACE

DLR

Knowledge for Tomorrow

ROMO Concept (I) – Modular Design

Rear Axle

Chassis

Front Axle

Battery

Facts:
Steering range: -25° to 95°
Power 4x16 kW, max. speed 100 km/h,
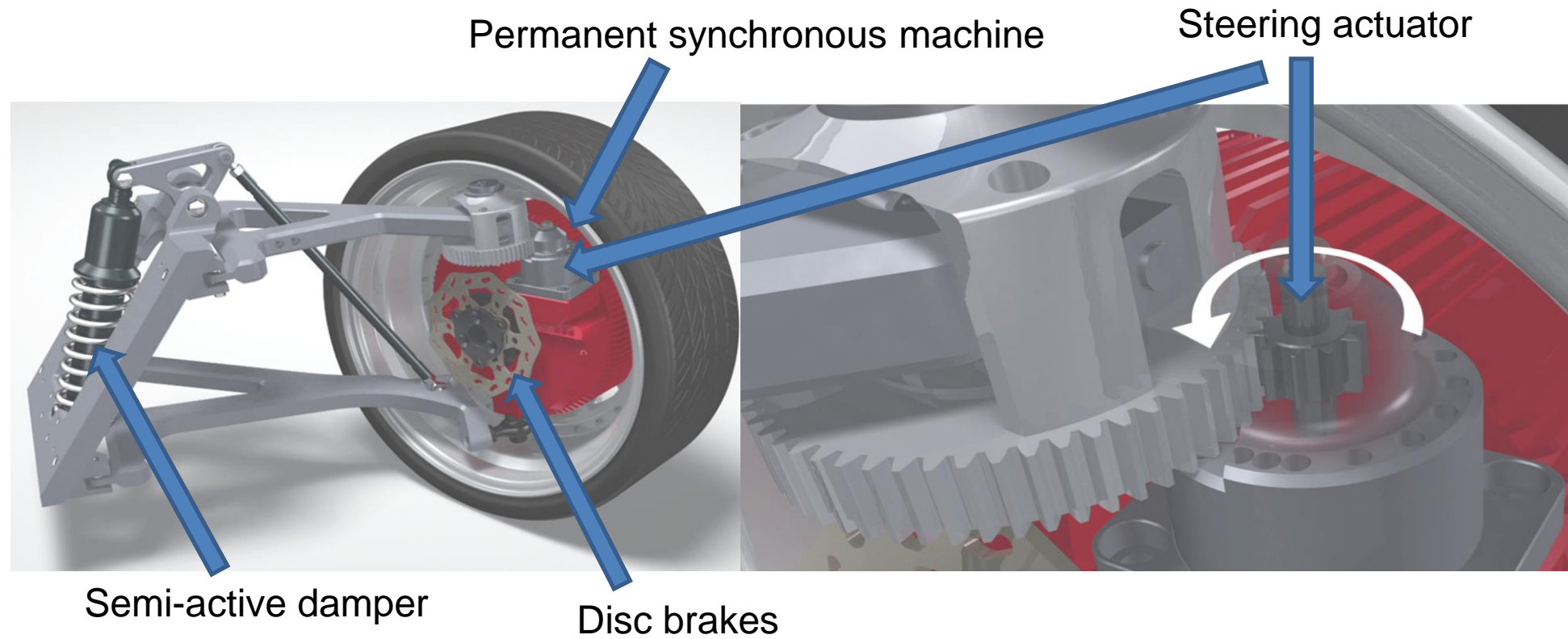max. range 100 km, weight ~1000 kg

14 actuators:
4 In-Wheel motors
4 Steering actuators
4 Semi-active dampers
2 Brake actuators

ROMO Concept (II) – The Wheel Robot

Permanent synchronous machine

Steering actuator

Semi-active damper

Disc brakes

# Video – The ROboMObil and its Possibilities

ROMO - IT-Architektur

- dSPACE rapid prototyping system in synchronized execution

- PC based vision system (RM Sensonet) with two FPGA modules for autonomous driving (not shown)

- High precision measurement units for validation and control purposes

- Central control of the vehicle actuators without horizontal interconnection

- Note: The components represented virtually by the real-time vehicle dynamics simulation, i.e., simulated on **SCALEXIO**, **are shaded in light blue**
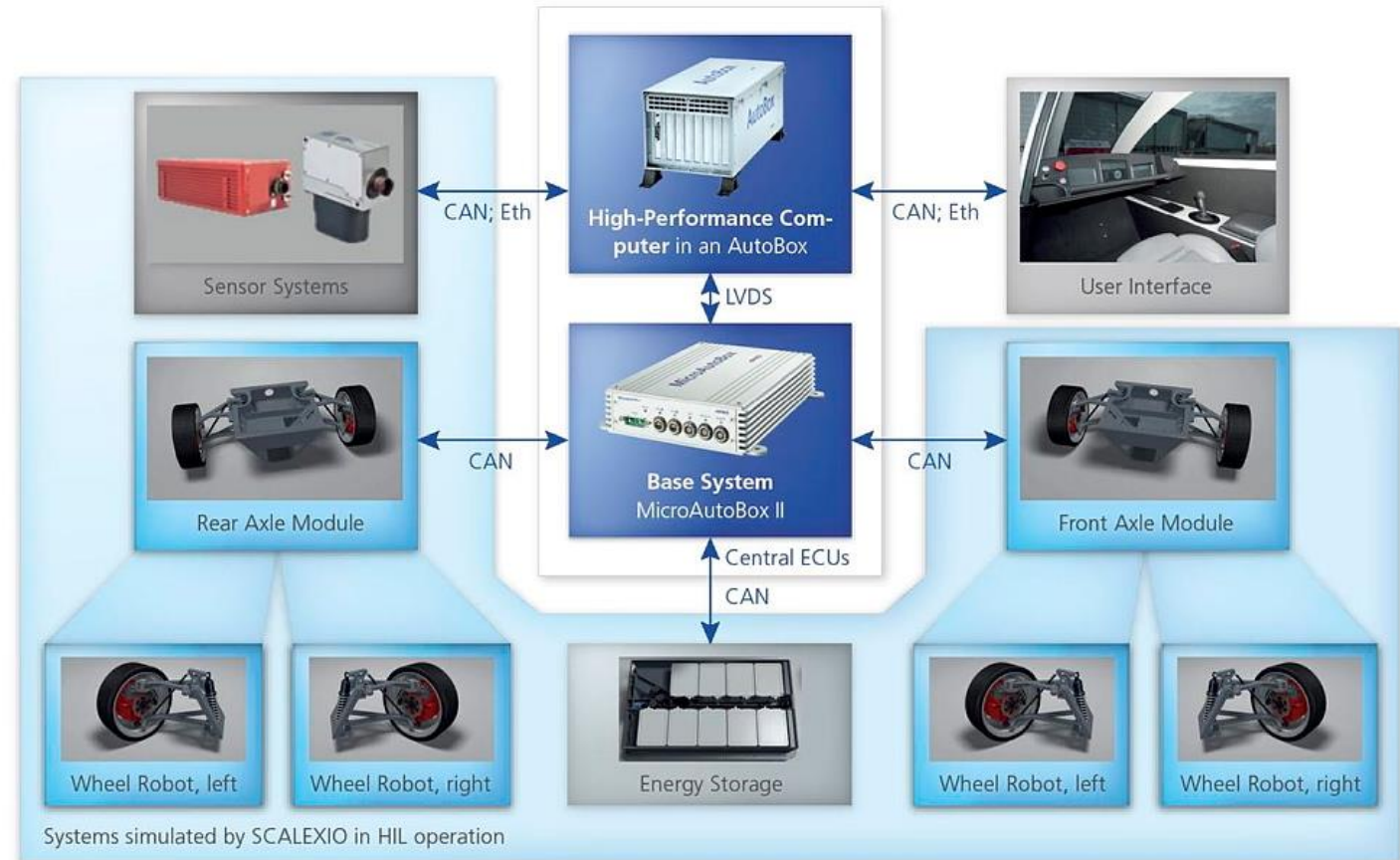
ROMO – Static HIL Architecture

- ROboMObil in motionless HIL operation to <u>test</u> the <u>operating software</u> and <u>controls safely</u>.

- ROMO's actuator (Wheel Robots) and sensor systems are emulated via models (partly as FMUs) on the SCALEXIO system.

- ROMO's central control does not know about the <u>change</u> and only the system <u>signal conditioning and mapping</u> module is reconfigured to HIL mode.
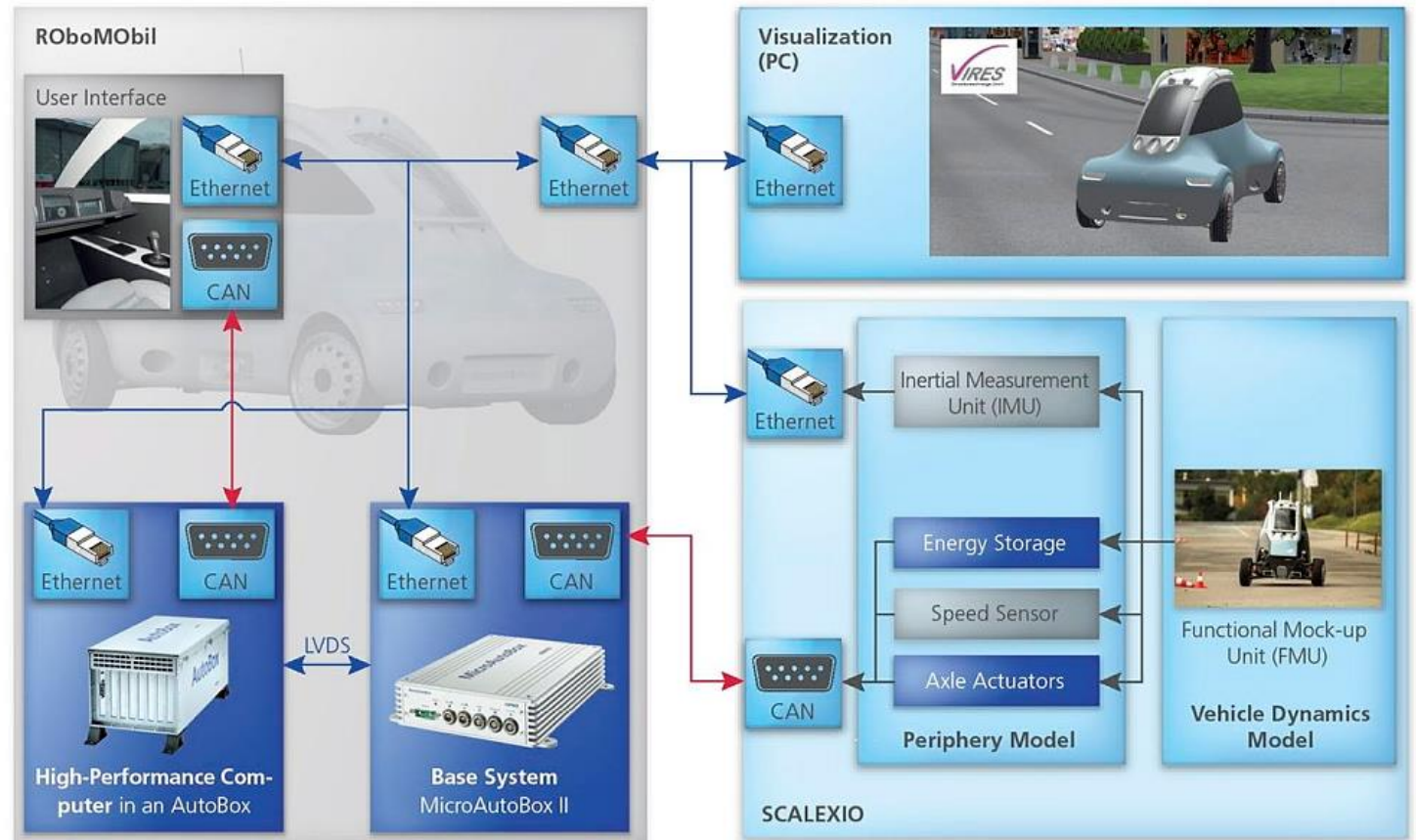
Virtuell function testing
RMS – ROMO HIL

- Real-time motion simulation of DLR's ROboMObil by means of the DLR Robotic Motion Simulator (RMS)
- Simulator is based on a conventional industry robot
- Composed of a linear axis and a 6-DoF robot
- 500kg net load
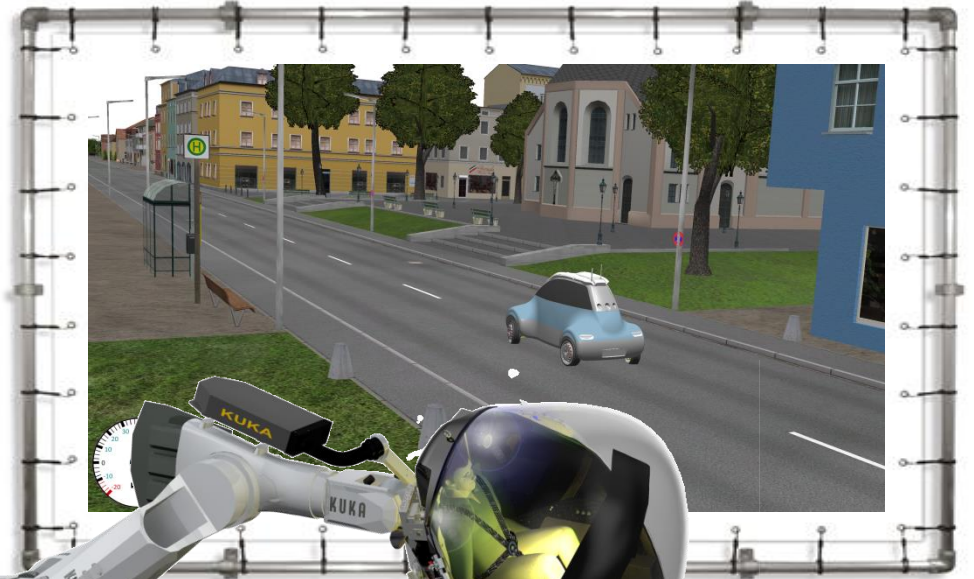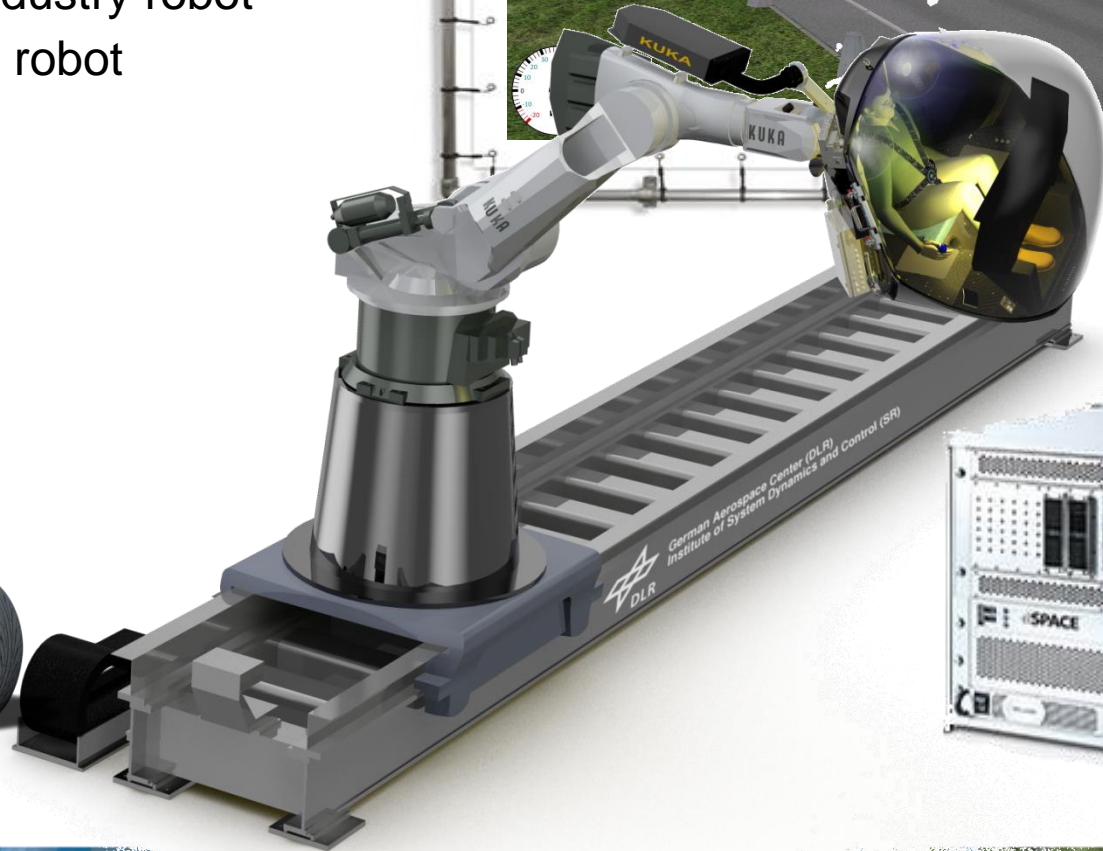
ROMO – RMS Interactive HIL Architecture

- Entire system setup. The goal of this special HIL application is to <u>evaluate innovative HMI concepts</u> under real and known laboratory conditions.
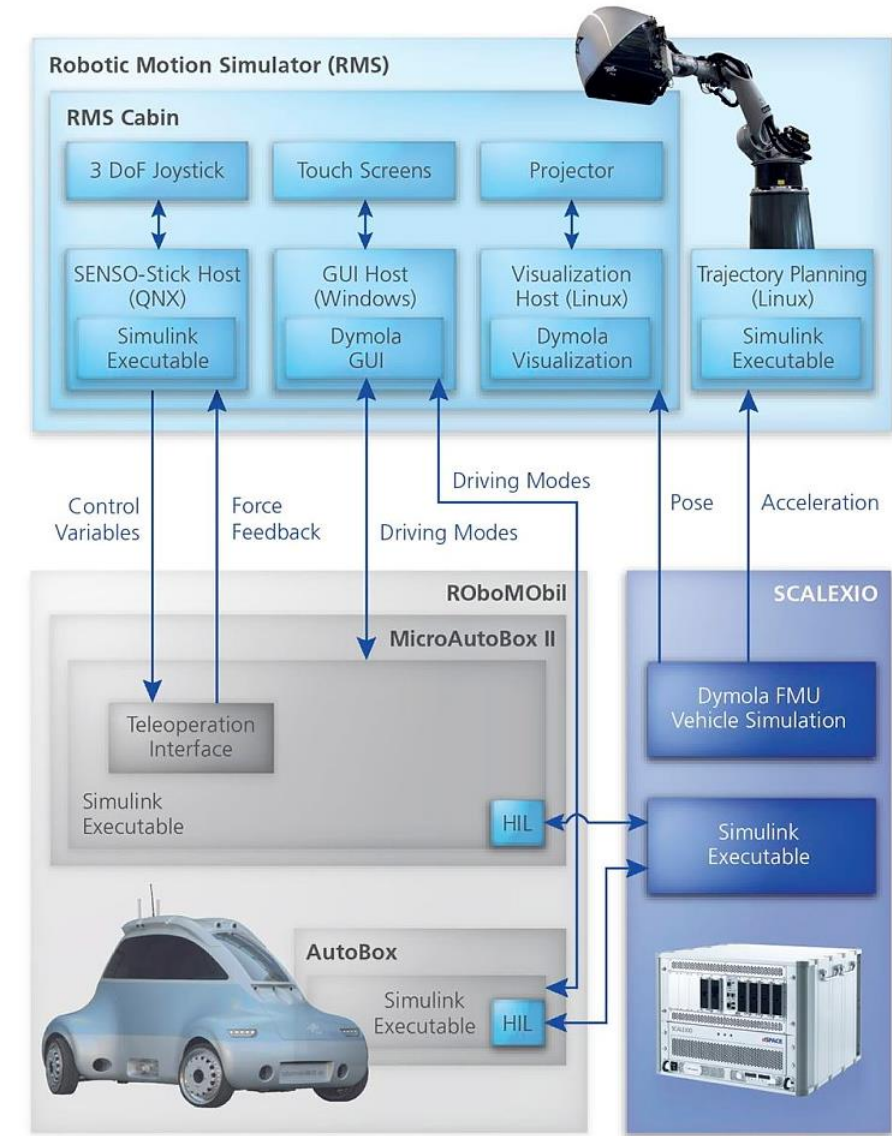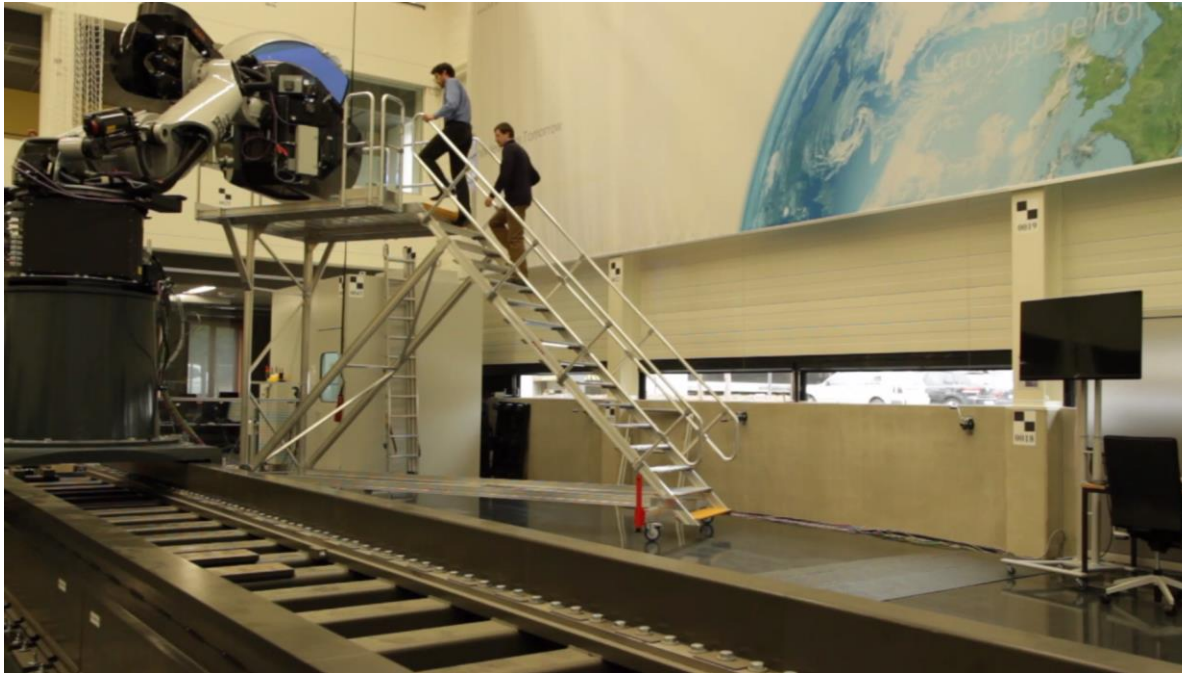
DLR's Experiences

- Successful integration of an FMI 2.0 for co-simulation in a heterogenic real-time environment

- No MATLAB / Simulink / RTW licenses have been necessary to bring the Modelica vehicle model to the HIL (only the QNX cross-compiler and dSPACE SCALEXIO Tool-Chain) – Note: sensor models have been modelled in Matlab / Simulink

- FMI is capable to make use of the QNX file system ("Resources-Folder" on dSPACE SCALEXIO) where the road definition is stored for the calculation of vehicle road contact in the virtual world

- Within the FMI the DLR Visualization Library has been used which communicates via Ethernet with the visualization PC without the need for the user to care about the actual communication protocol

DLR's Experiences 2

- The dSPACE SCALEXIO system design with the separation of I/O model and behavioral model (e.g. the FMU) made it easy to develop the vehicle model completely separate from the HIL

- The exchange of the model interface description from Configuration Desk to Modelica to FMU and vice versa was simplified:
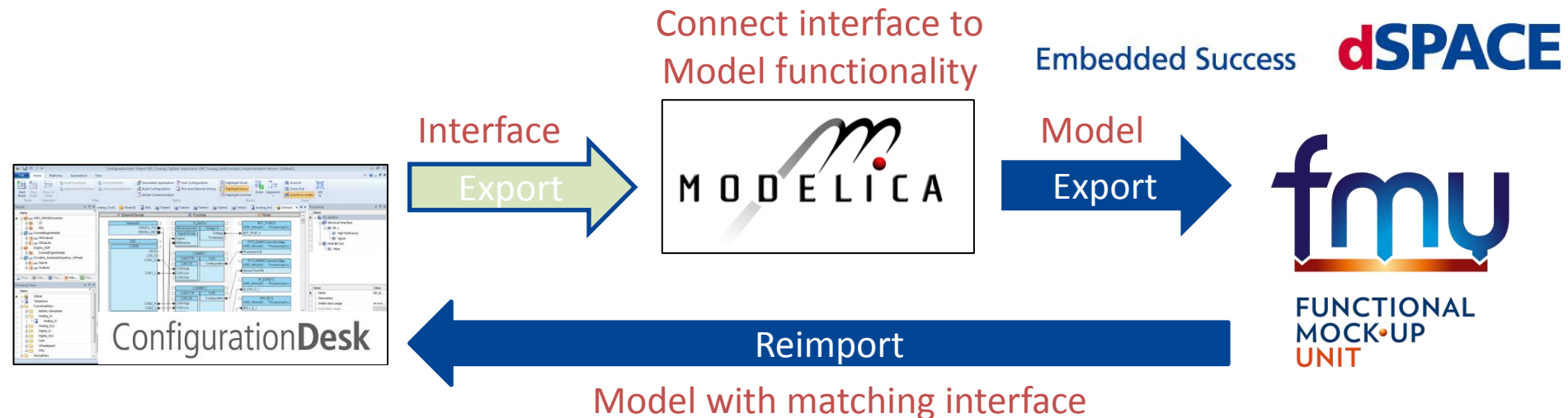
FMI Improvement Suggestions

- Potential improvements for FMI tool support for HIL applications:

  - support of tunable parameters (for online model tuning without model restart/re-init)

  - unlimited stop times option for FMI exports (most model should NOT stop after 100s…)

- FMI improvements (focus FMI for Co-Simulation):

  - Structured data types in interface (array, matrix, struct) – e.g. Motor moment M[4]

  - Multiple rates description in interface – e.g. brake/tire contact model T_s << chassis model T_s

  - Interrupt/Event dependent computation – ~~e.g. brake pad to disc contact point~~
                                             – e.g. I/O interrupt of triggered measurement of HIL