Simulating battery electric vehicle on powertrain testbed

AVL Simulation Meets Testing Conference 2019

Dejan Ciglar

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- Background
- Overall Setup
- Simulation integration workflow
- Office co-simulation with Model.CONNECT™
- Setting up an testbed simulator
  - HV Battery simulator
  - Powertrain testbed simulator
- Testbed measurements
  - Quick charge
  - High speed
  - Race track
- Outlook

Background

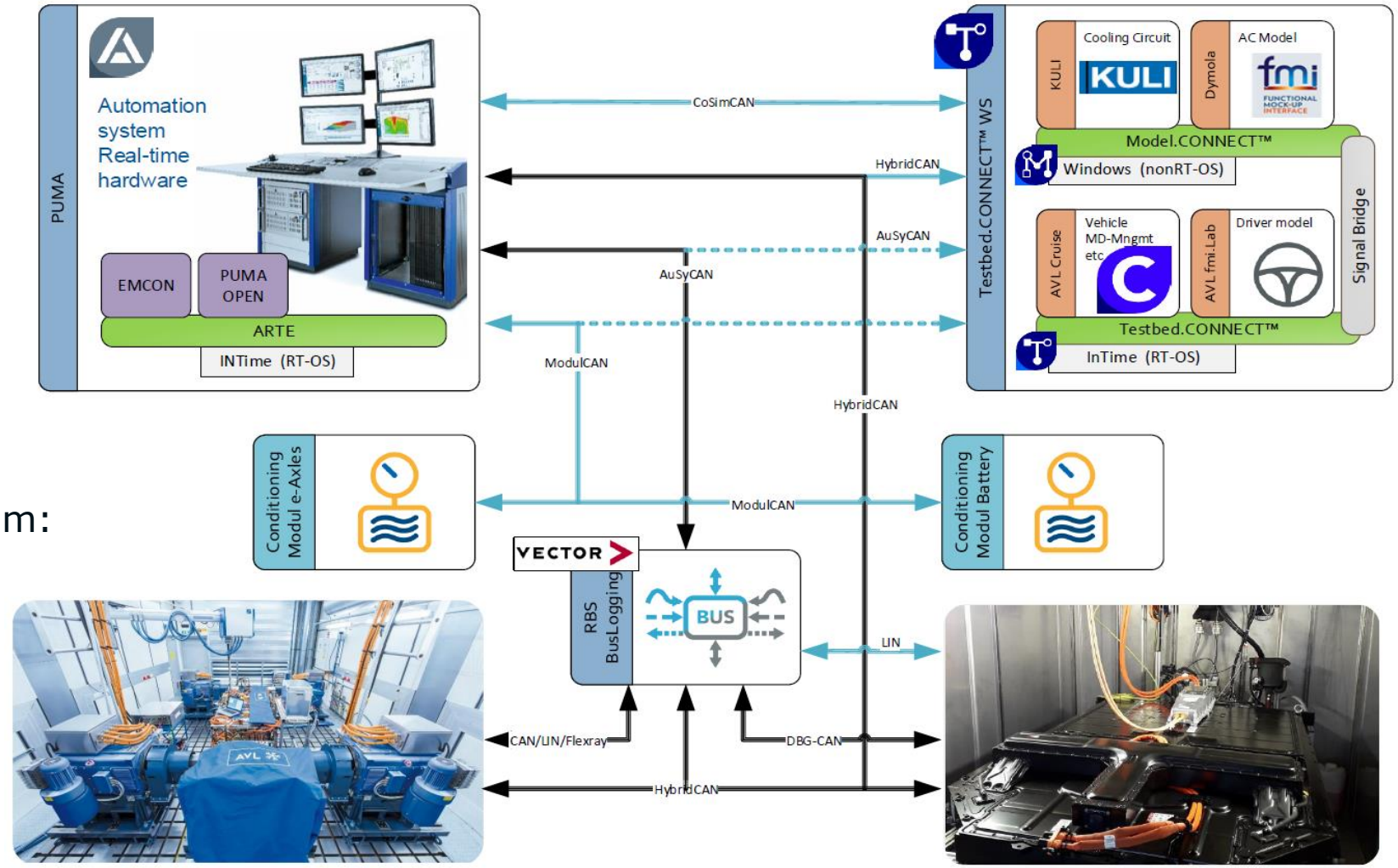
- Thermal management is a very important discipline for Battery Electric Vehicle (BEV)
  - Optimal operating temperature is rather low
  - Heat energy is not inherently available
  - It interacts to their performance behavior due to derating
  - Can be relevant for driving comfort or even safety

- This presentation describes a method to frontload thermal management development and testing from prototype vehicles to a hybrid testing lab consisting of simulation models and real hardware UUTs
  - An integrated approach to describe the behavior of the thermal system in a testing environment was developed
  - The thermal interface between simulation and real components was realized
  - A functional vehicle prototype was developed which consists of real and simulated components

Overall Setup

E-Integration Powertrain Testbed (PTTB)

PUMA Open automation system



Simulation models:

- Thermal-system,
- AC-cycle,
- chassis,
- Wheels
- Control-Unit (xCU) functions

Real HW system:

- E-motors
- Gearbox
- Inverters
- xCU

HV-battery was located in a separate climate chamber

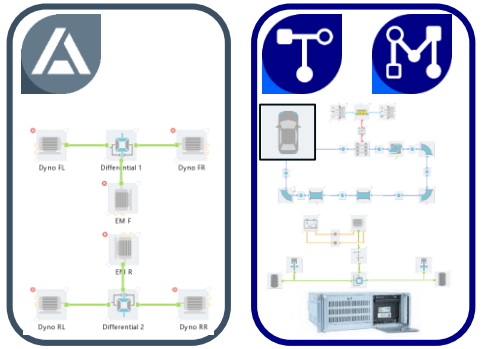
Simulation Integration Workflow

Since testbed time is expensive, a step-by-step integration methodology was developed

Prepare Simulation Models

- Define required I/O
- Ensure standalone real-time capability
- Ensure co-simulation stability

Prepare Testbed Simulator



- Setup overall system
- Integrate simulation on a testbed simulator
- Test the test runs

Testbed

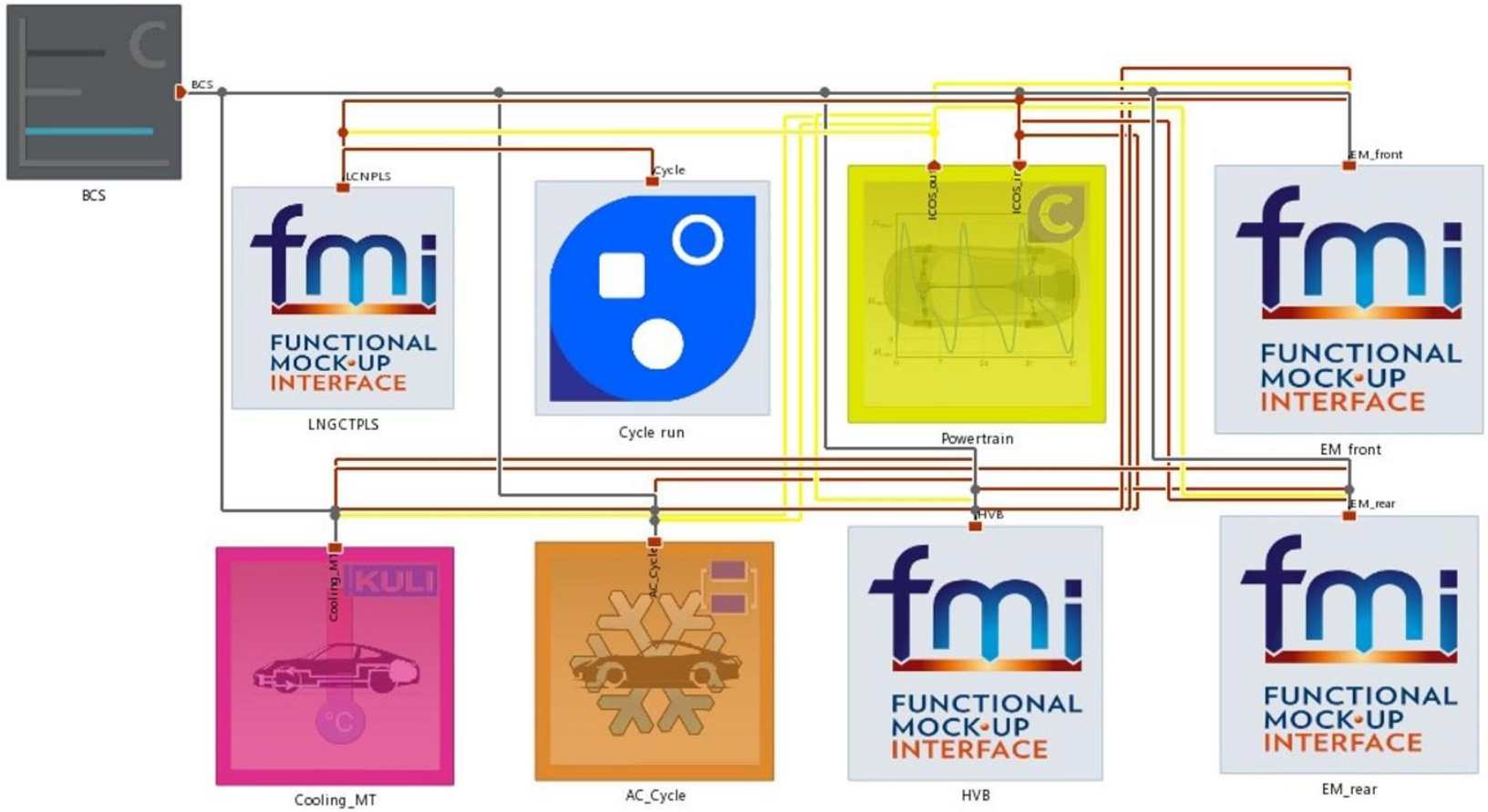
- Transfer Simulation on the real testbed
- Final adjustments
- Conduct the testruns

Office Co-Simulation with Model.CONNECT™

BEV co-simulation model in AVL Model.CONNECT™ co-simulation platform

- Full CRUISE vehicle model
- KULI thermal system
- Dymola AC model
- Front e-motor
- Rear e-motor
- HV Battery
- Driver model
- Boundary conditions
- Profiles

I/O definition, RT, stability



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- **Setting up an testbed simulator**
  - **HV Battery simulator**
  - **Powertrain testbed simulator**

- Testbed measurements
  - Quick charge
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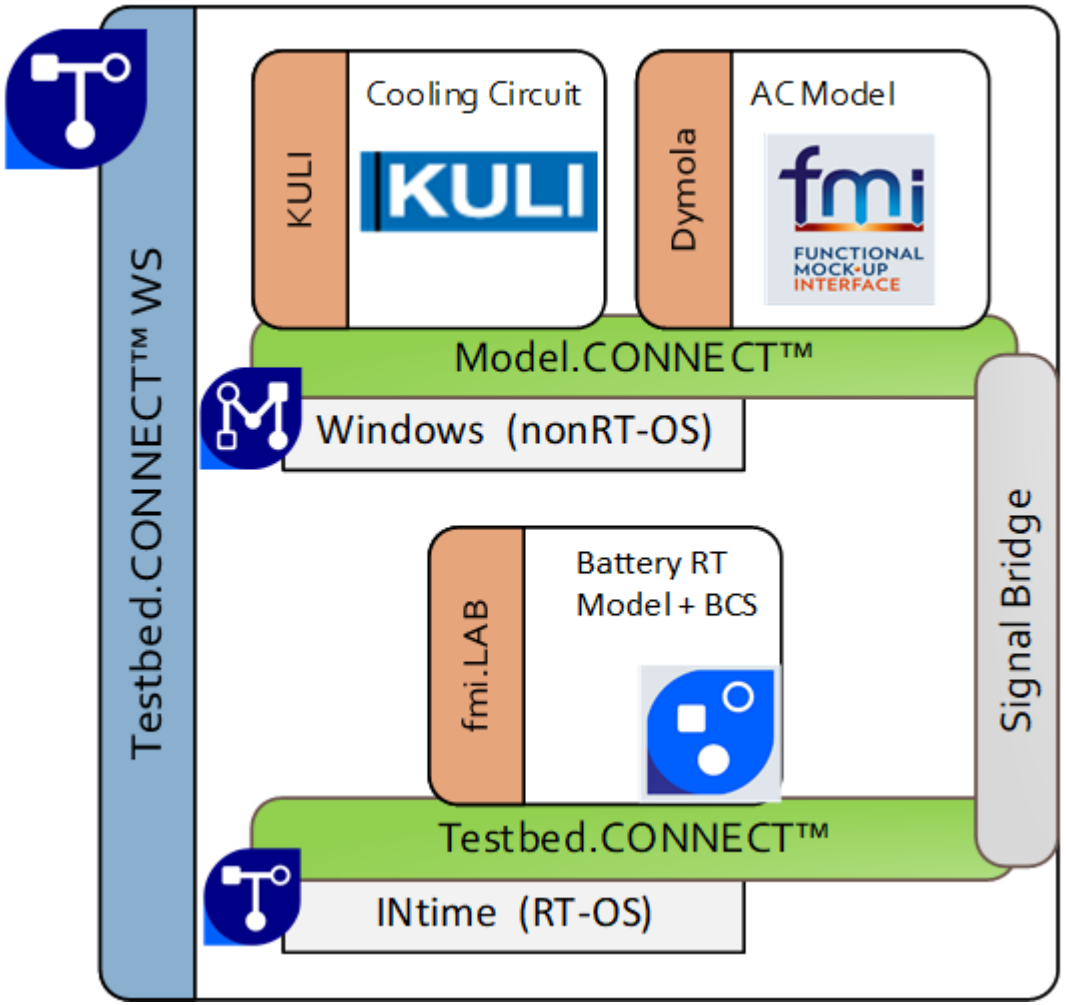
HV Battery simulator for quick charge



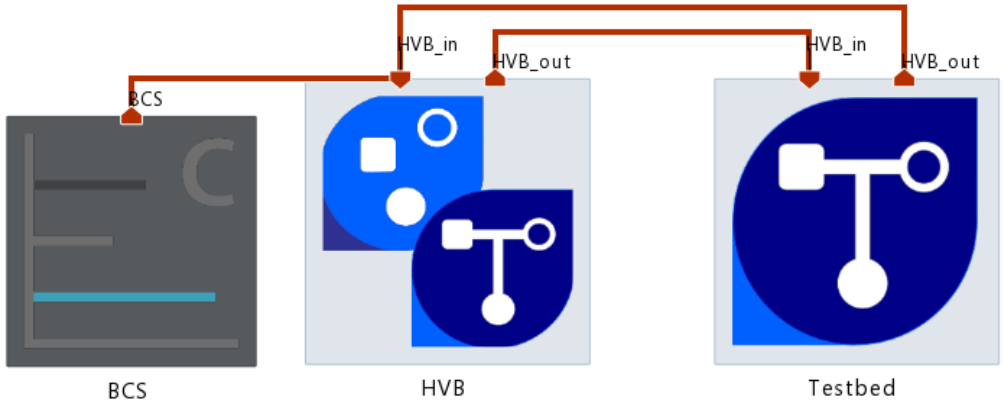
Checking and tuning the RT capability of KULI model

nRT, Model.CONNECT™

- KULI thermal system
- Dymola AC model

RT, Testbed.CONNECT™:

- Battery Model + BCS
  - fmi.LAB model + Model.CONNECT™ export



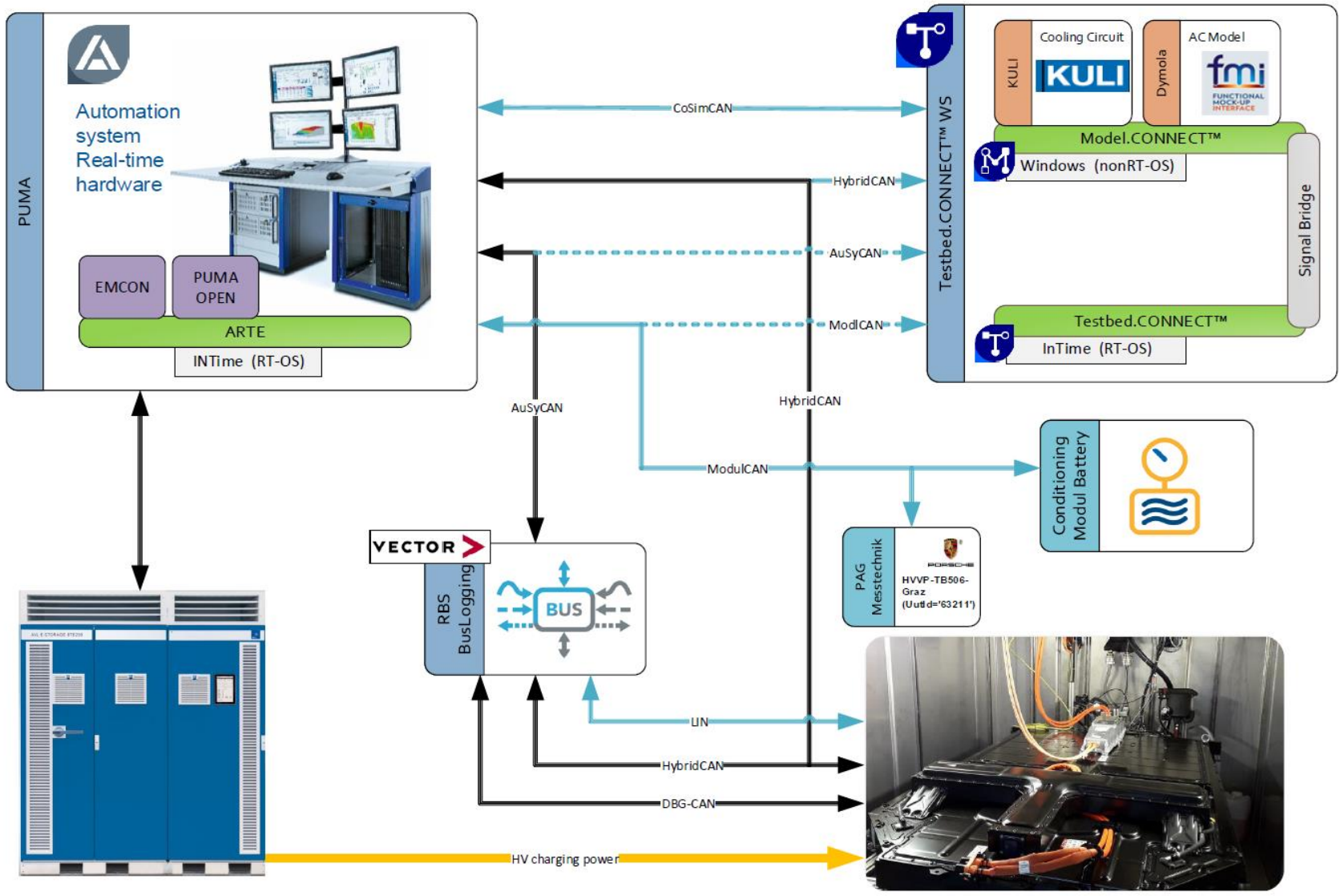
Testbed setup for quick charge

Analyze thermal managment of the HV battery

Used PUMA safety features

Emulated known current profiles, coolant temperature and flow

Comparison and verification of thermal beraviour to vehicle ptototype



Powertrain Testbed Simulator

PUMA Open 2 RT models:

- CRUISE™ powertrain (1ms)
- Front E-motor (100ms)
- Rear E-motor (100ms)
- Battery (200ms)

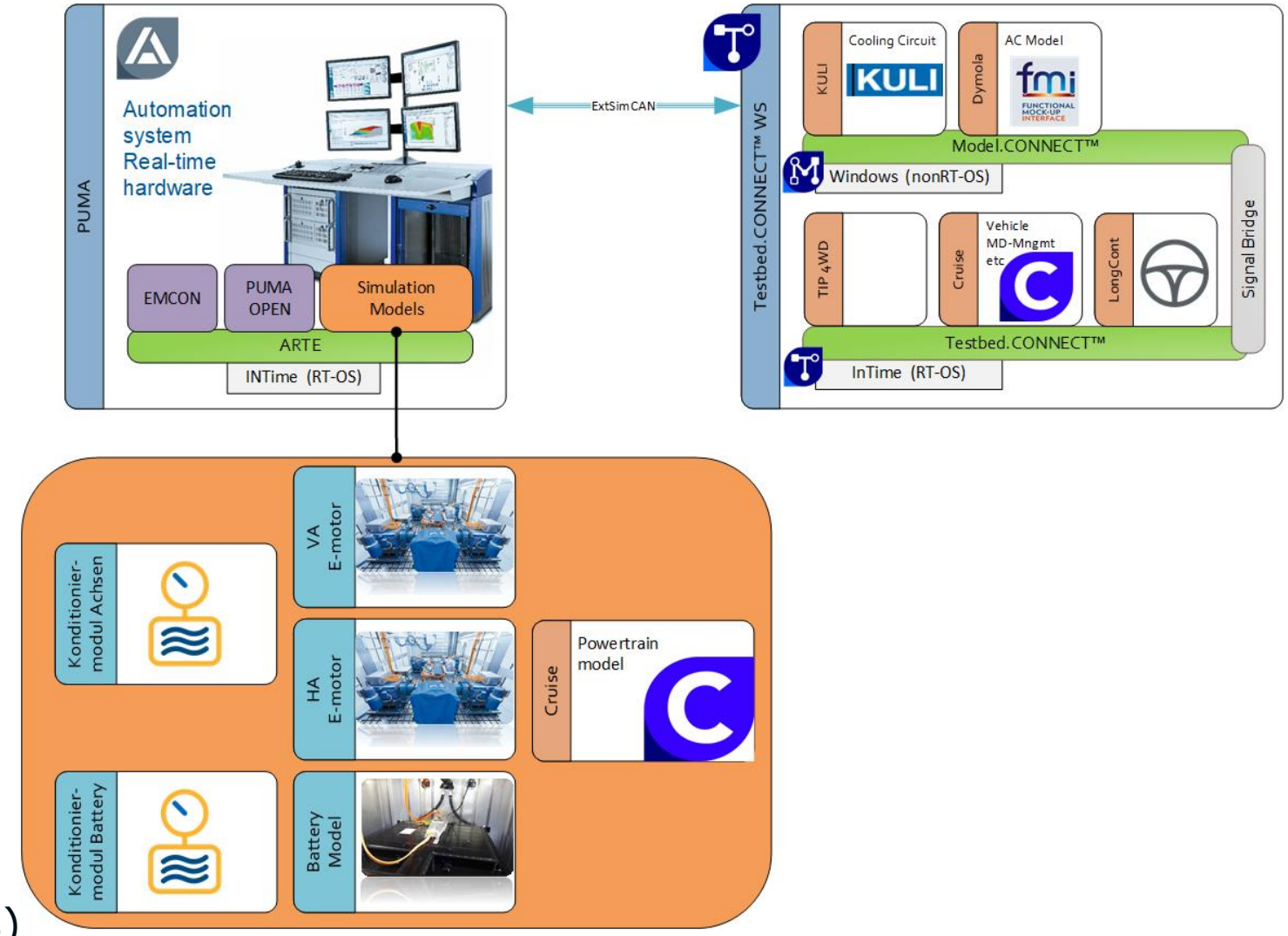
Testbed.CONNECT™ workstation

nRT:

- KULI thermal system (500ms)
- AC model (1000ms)

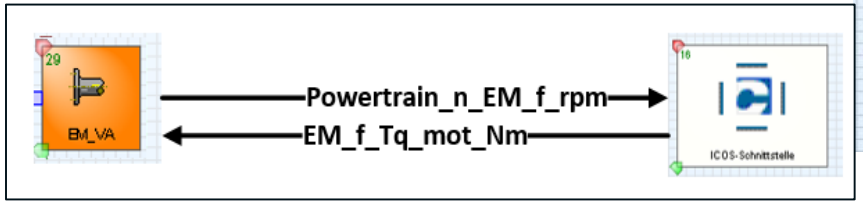
RT:

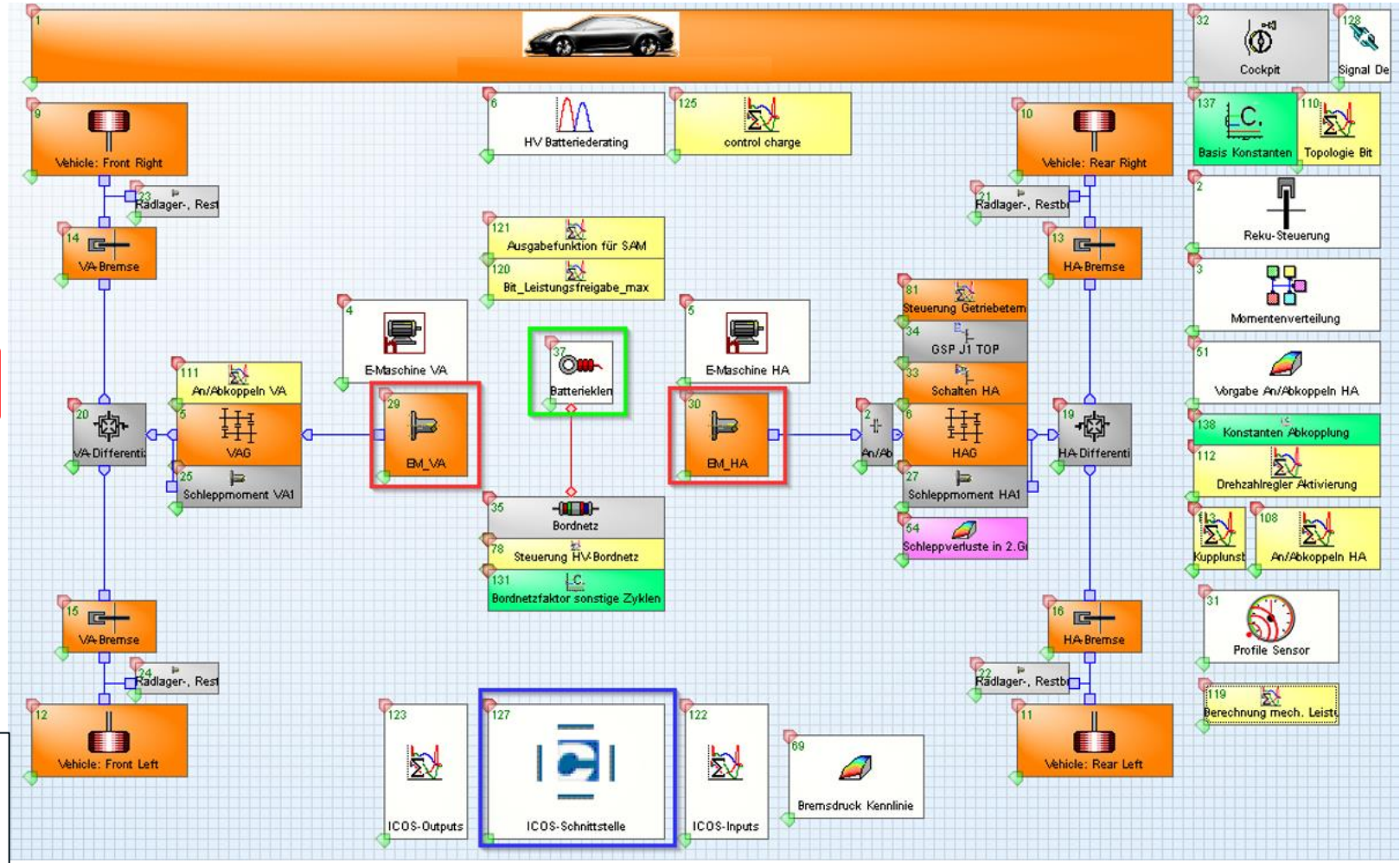
- CRUSIE™ vehicle model (1ms)
- Driver (1ms)
- Testbed integration package (1ms)



AVL CRUISE™ vehicle model in office co-simulation

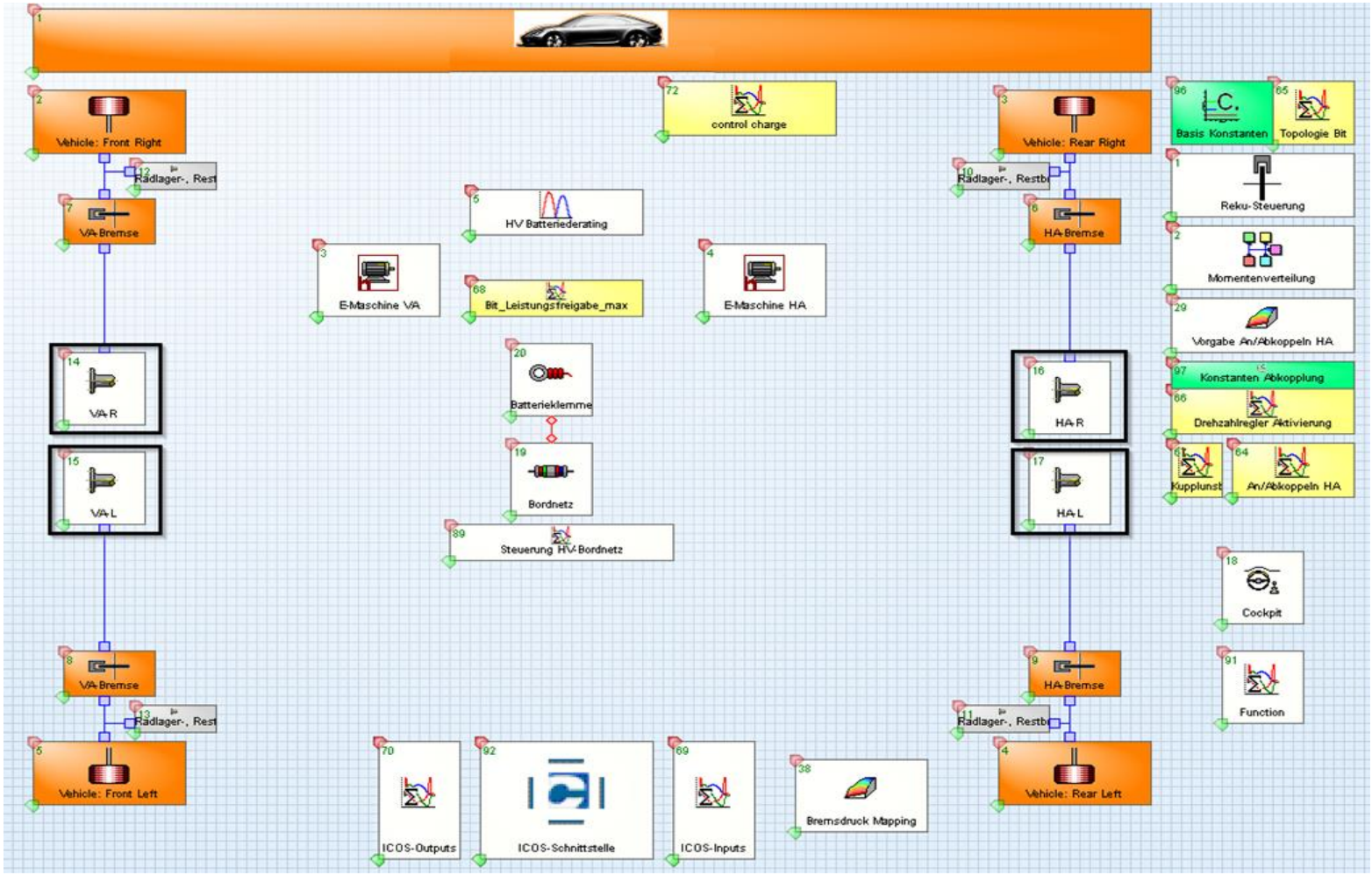
- Main vehicle components modeled in CRUISE™
- E-motors and Battery are not part of the model
  - Connected trough Flange components red and Terminal component green
- Main interface component blue





AVL CRUISE™ vehicle model for powertrain testbed usage

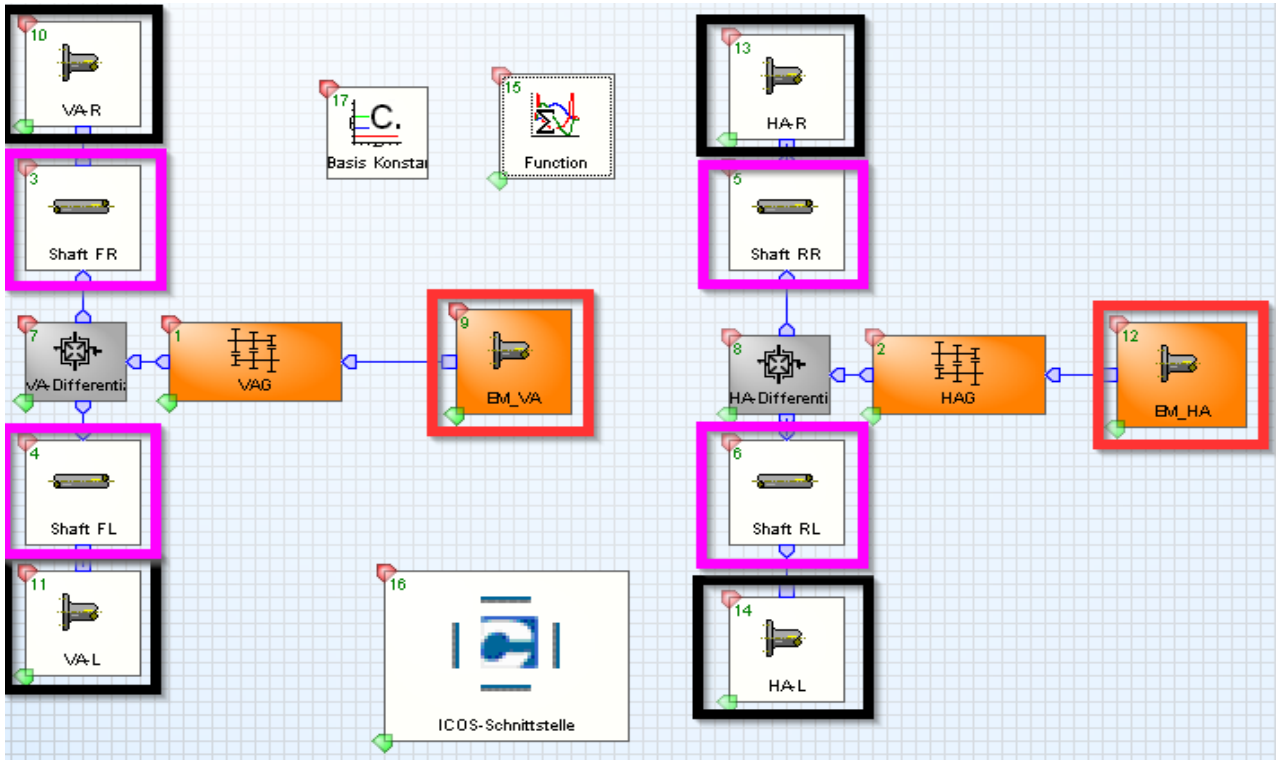
- Vehicle model
- Running on Testbed.CONNECT™
- First paired with a conventional powertrain simulation
- Wheel flanges

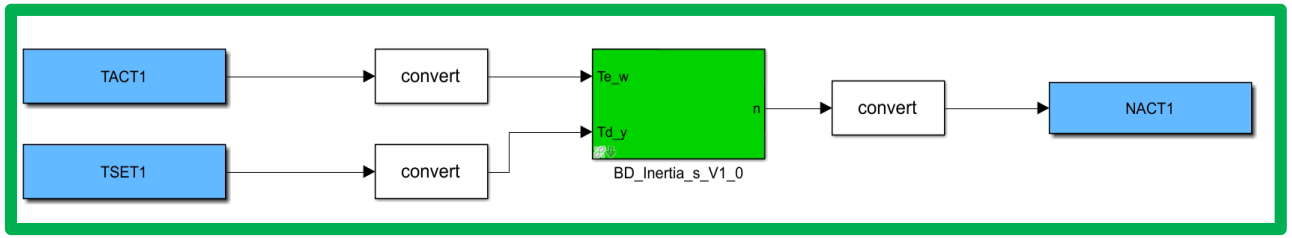


AVL CRUISE™ Powertrain Model

- PUMA Open 2 powertrain testbed simulator
- Identified and replaced internal simulation model

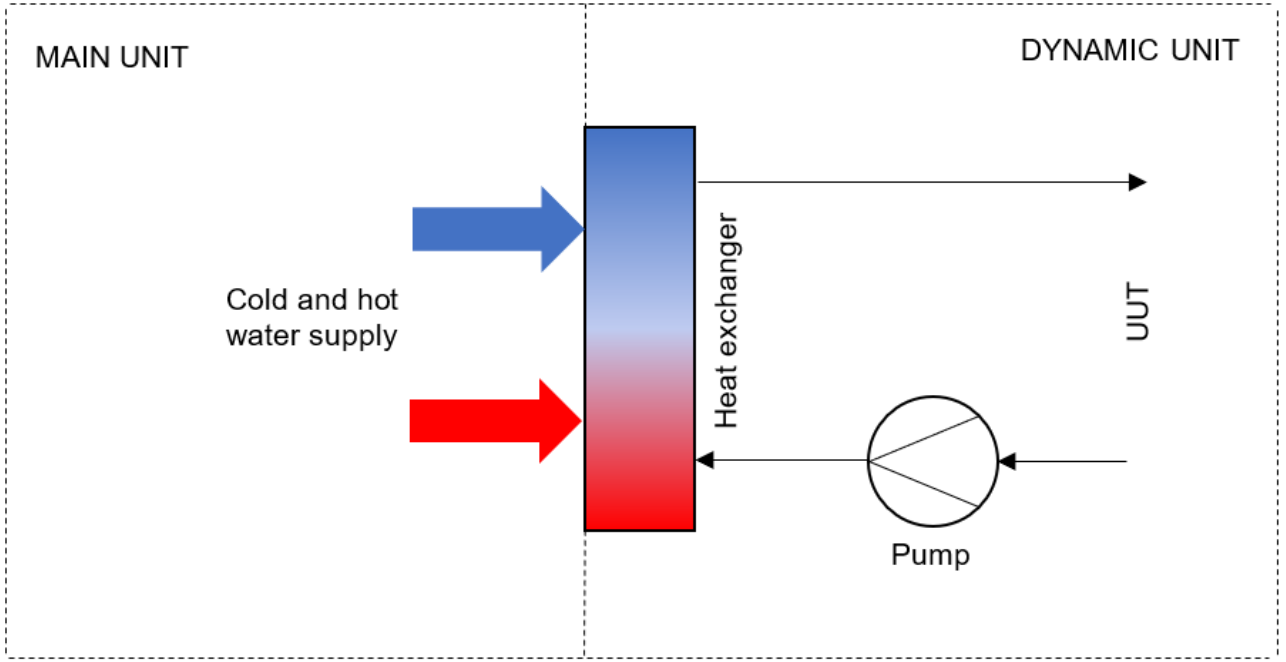
- Wheel/Dyno flanges in speed mode
- Elastic shafts
- Axle flanges
- Dyno model has been added





Dynamic Conditioning Module

- Used to provide similar conditions to inlet temperatures and volume flows of coolant
- Main unit (left):
  - heating and cooling cycle
  - control unit
  - electric installation
- Dynamic unit (right):
  - heat exchangers
  - valves
  - pump
- Created CRUISE M Flow model for office simulation and Testbed simulation



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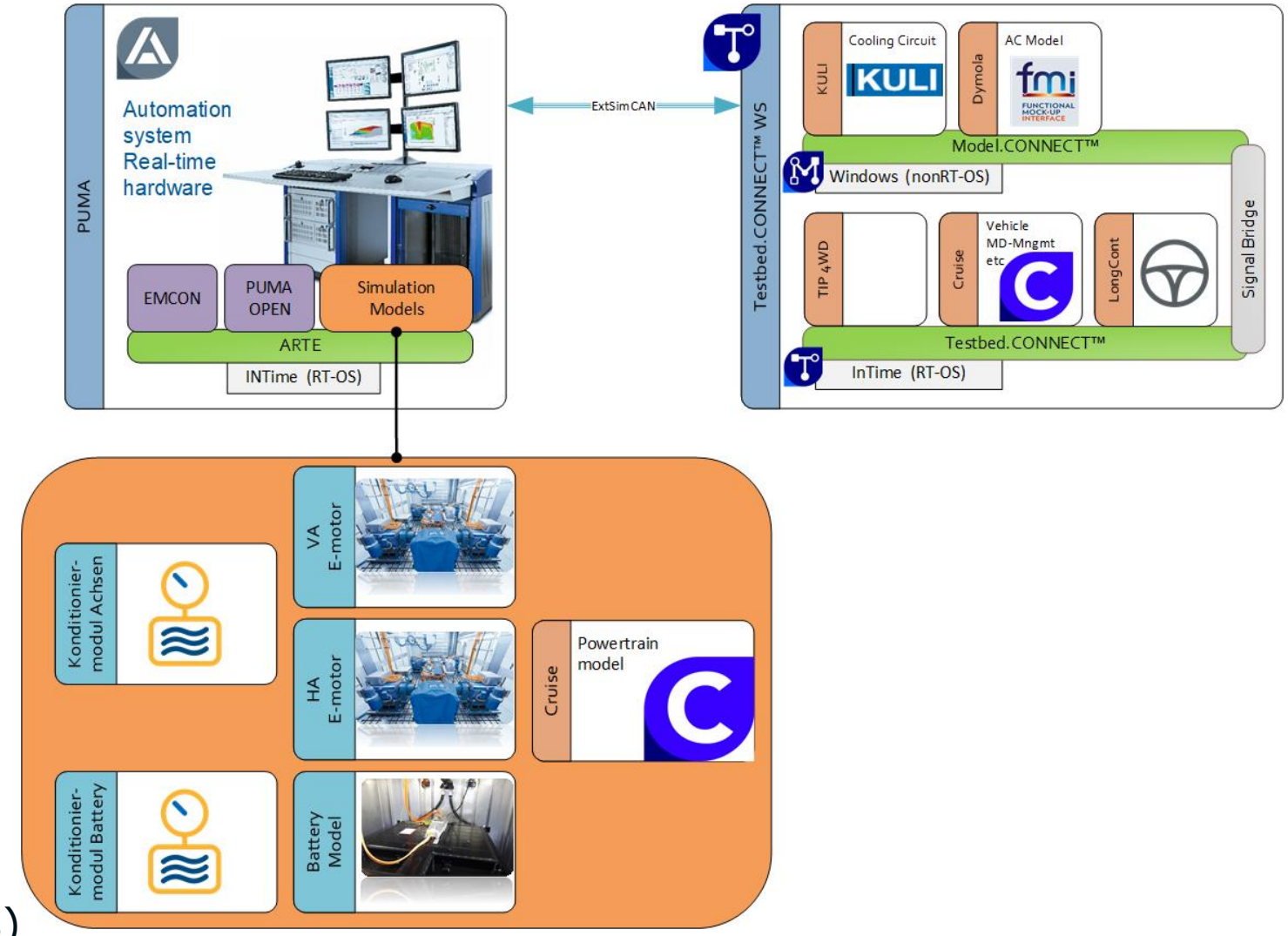

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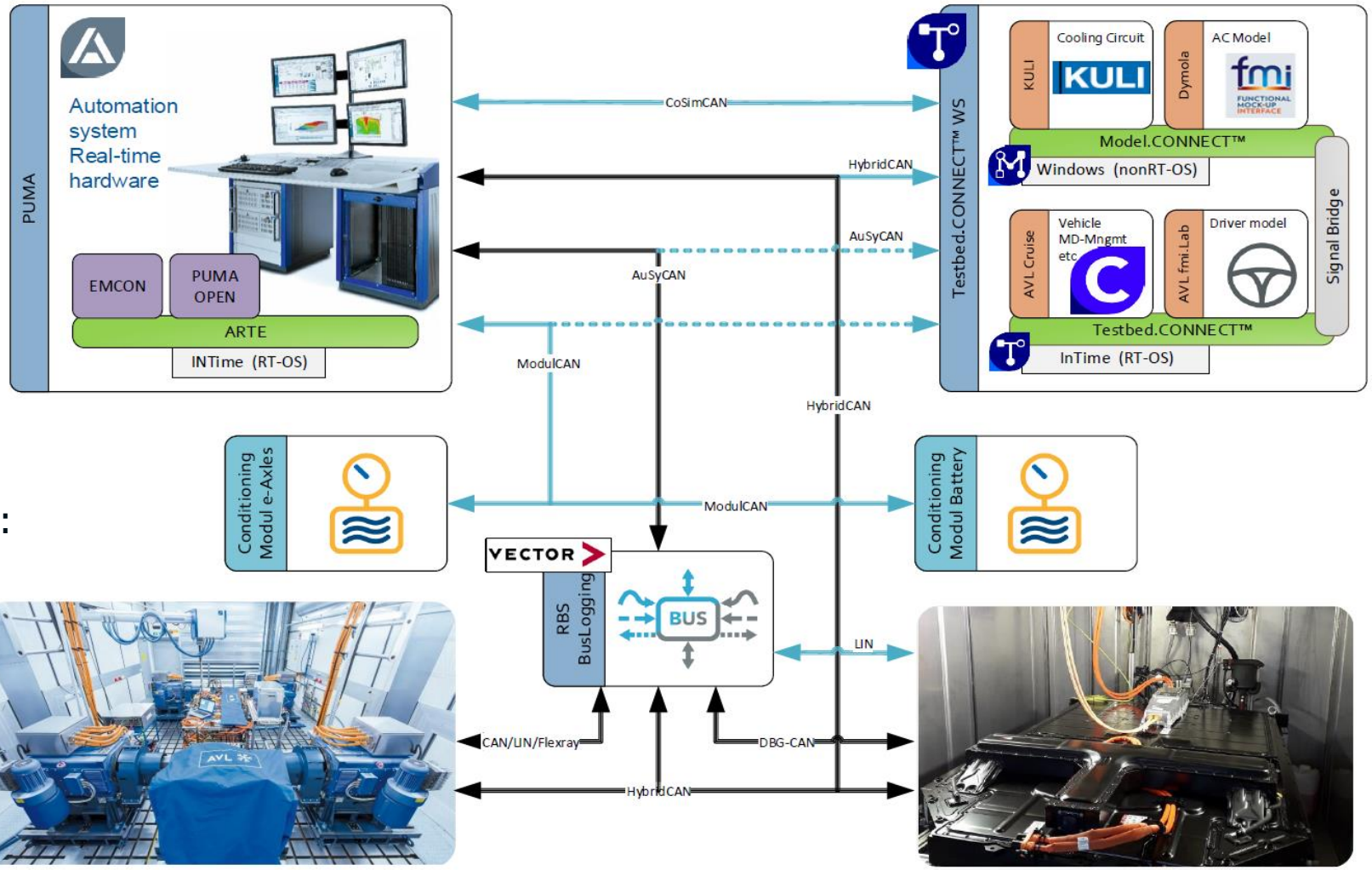

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  - **High speed**
  - **Race track**
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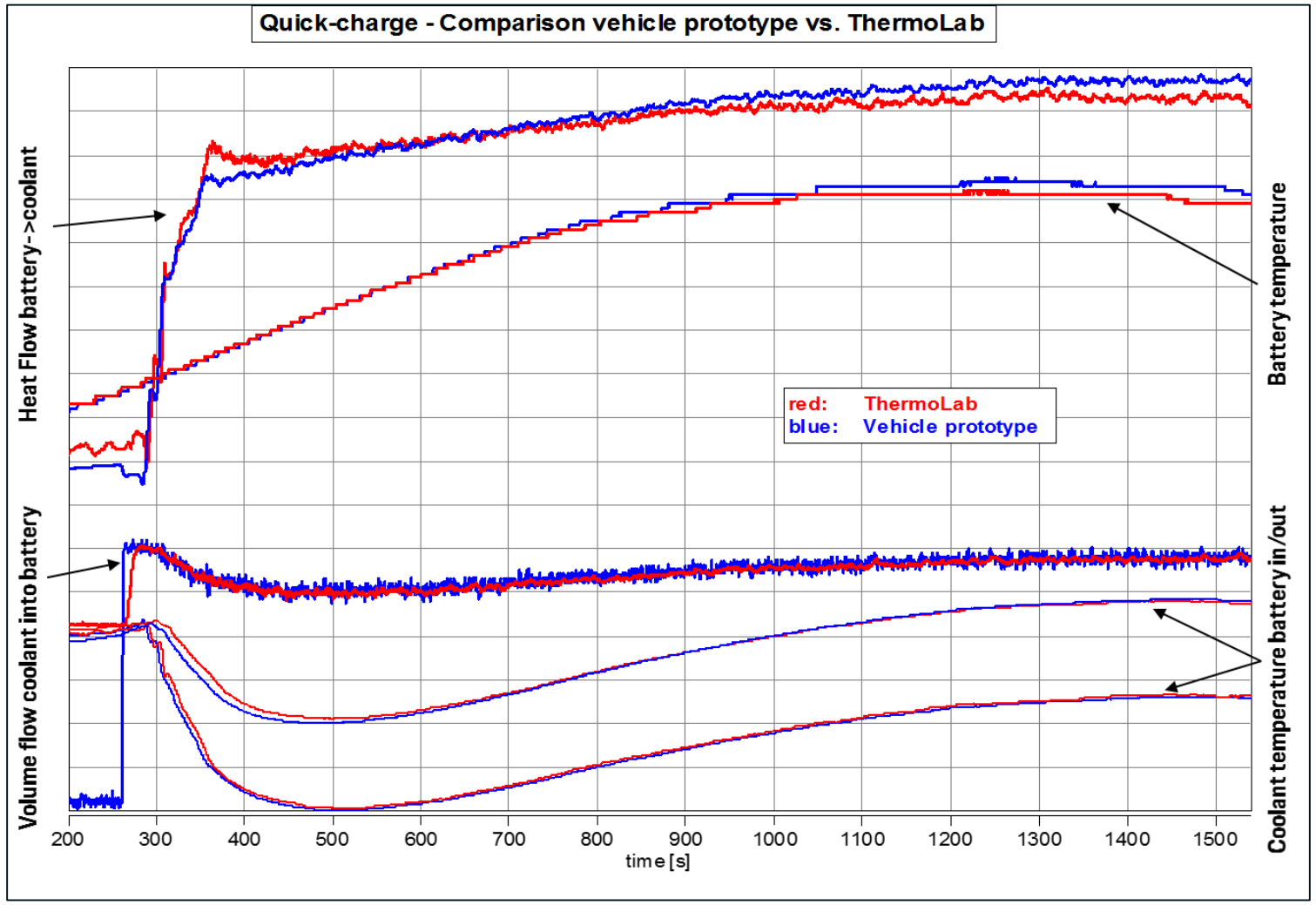
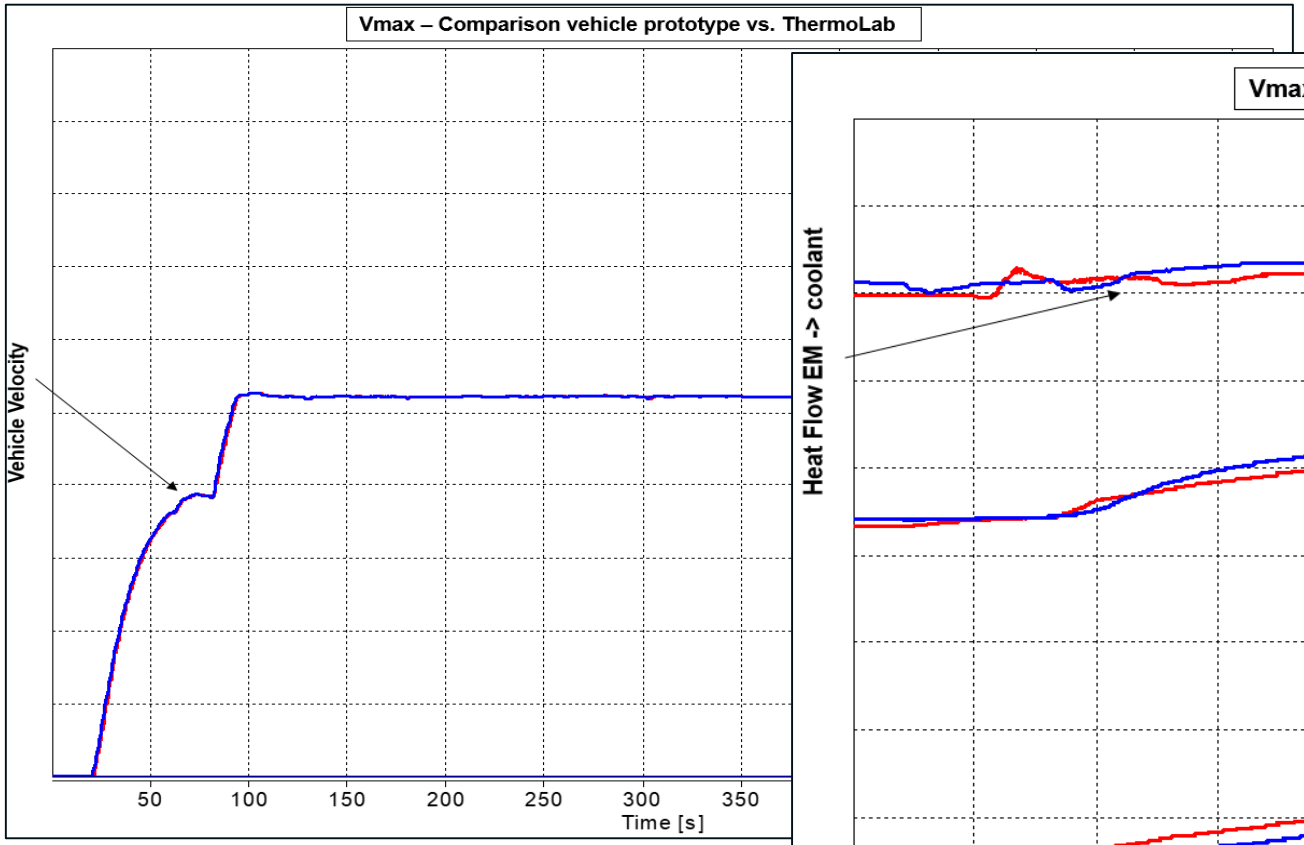
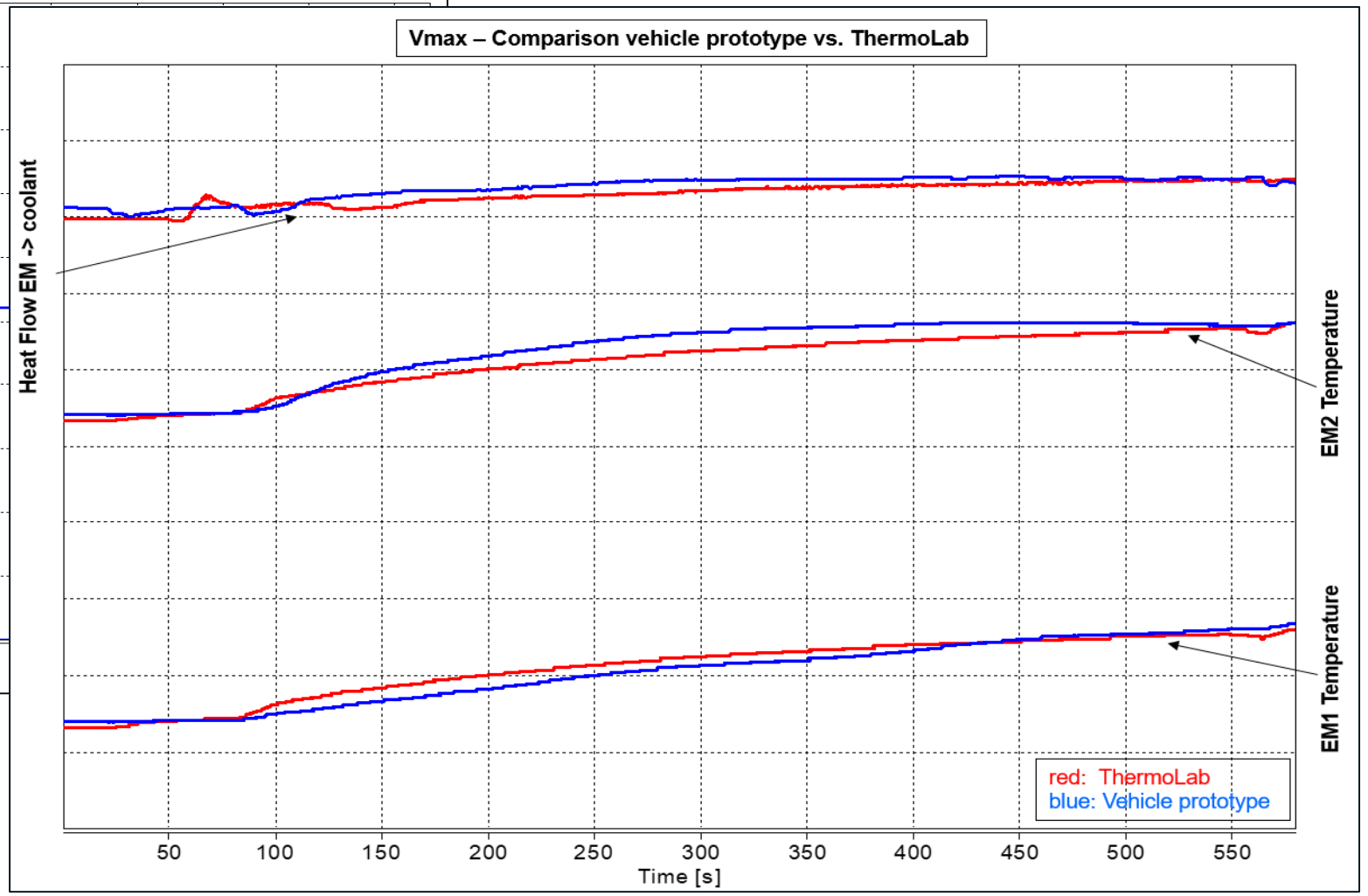
Quick Charge – Vehicle vs. Simulation

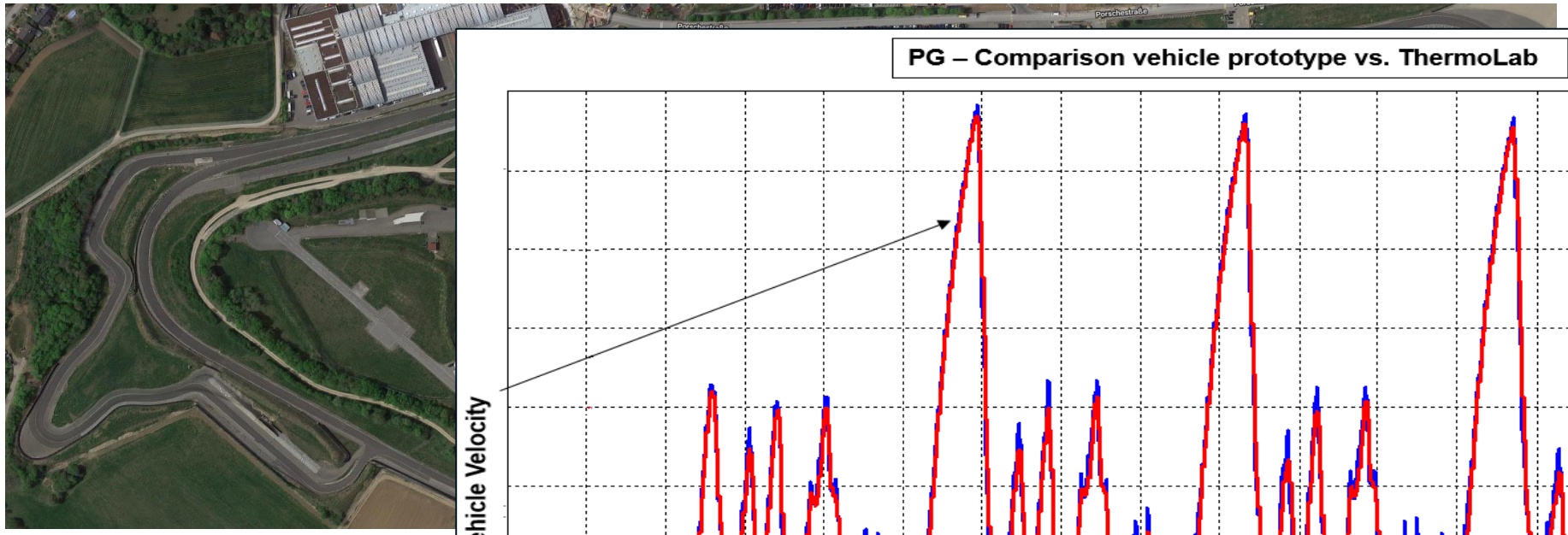


High speed – Vehicle vs. Simulation





Race track – Vehicle vs. Simulation



Outlook

Software/hardware-coupling is an effective way to close the gap between simulation or co-simulation and the full vehicle prototype testing

The further development and improvement of the high-dynamic conditioning units

Consequent implementation of this approach in different projects (i.e. PHEV)

Learn more about the possibilities and the limits of this method in substituting full-vehicle prototype tests

References:

ThermoLab for Battery Electric Vehicle – Thermal Development on Testbeds
A. Koller, Dr. H. Raiser – Dr. Ing. h.c. F. Porsche AG; C. Mayr, M. Walcher – AVL List GmbH; D. Ciglar – AVL-AST d.o.o.