

# Digital Twin (DT) of Open Vehicle Powertrain Platform (OVPP) using Internet of Things (IoT)

EPOWERS Research Group  
MOBI Research Centre & ETEC Department  
Vrije Universiteit Brussel (VUB)



# What in an OVPP?

»A scalable, modular, customizable powertrain testbed

»An Enhanced Hardware in the Loop Simulator (HiLS)

- \* Like HiLS, OVPP is used to test individual powertrain components, subsystems or entire drivetrains
- \* OVPP is also used for calibration and parametric testing

»A Real-time and realistic scenario generator

- \* Real-time monitoring and control
- \* Realistic driving scenario using actual drivers

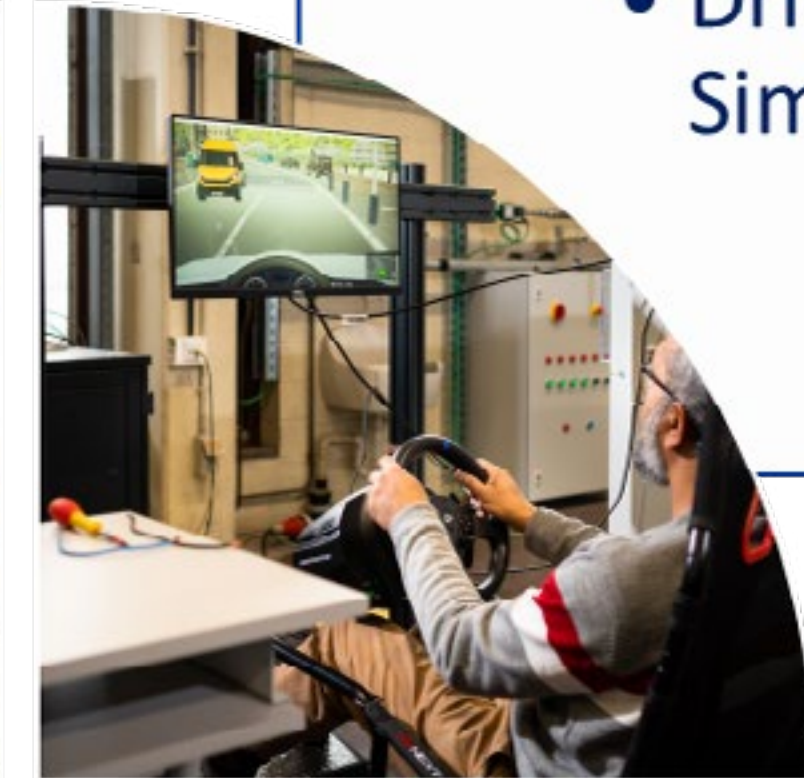
»An IoT connected DT model of hardware under test

- \* Accurately estimates lifetime of components based on scenario
- \* Predictive maintenance of components based on scenario
- \* Evaluate a variety of control algorithms on test hardware

• Vehicle Powertrain



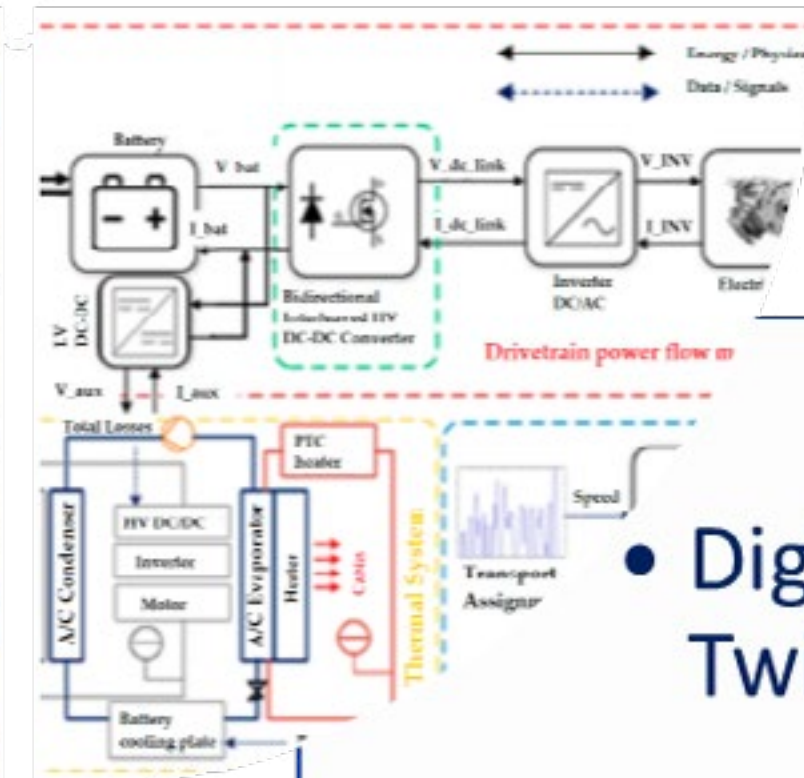
• Driving Simulator



• Control & Monitoring

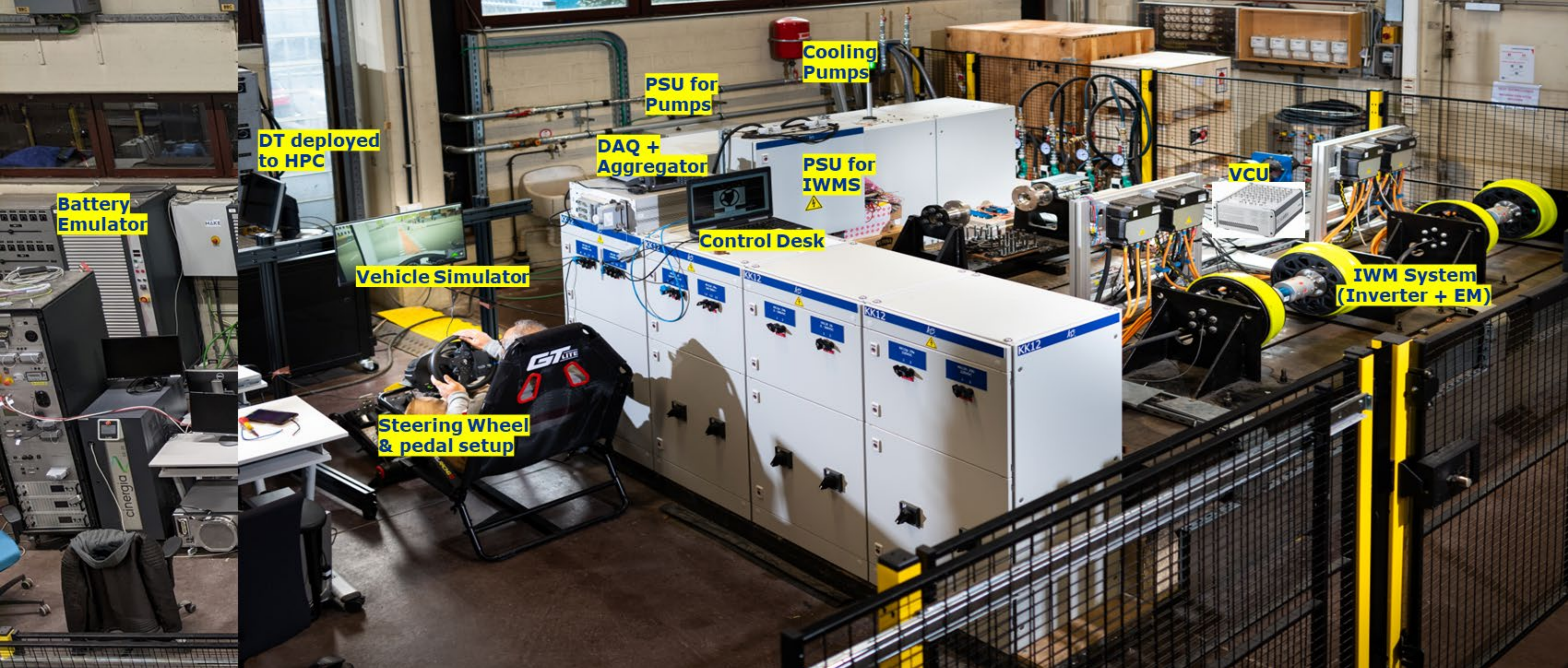


• Digital Twin



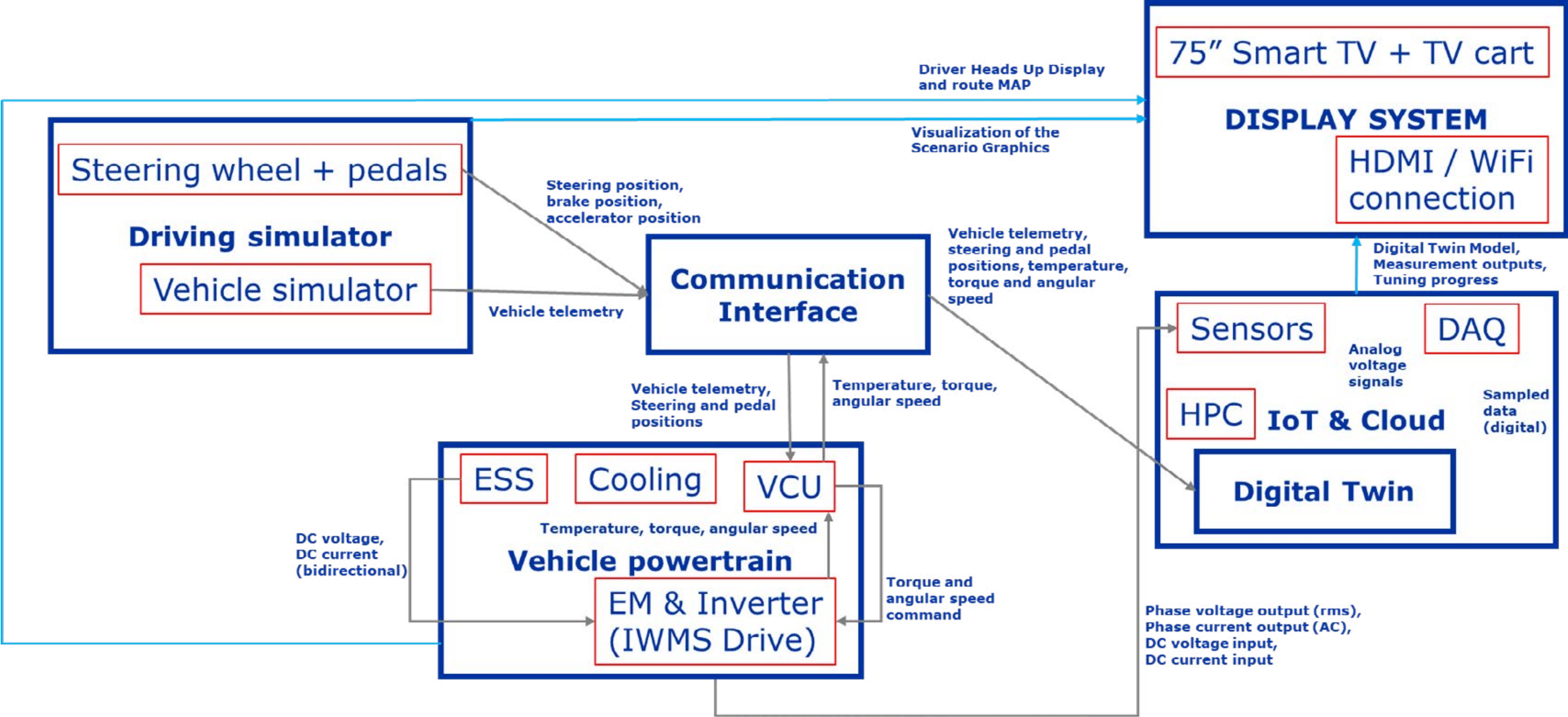


# OVPP System Overview





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# OVPP Subsystem Details

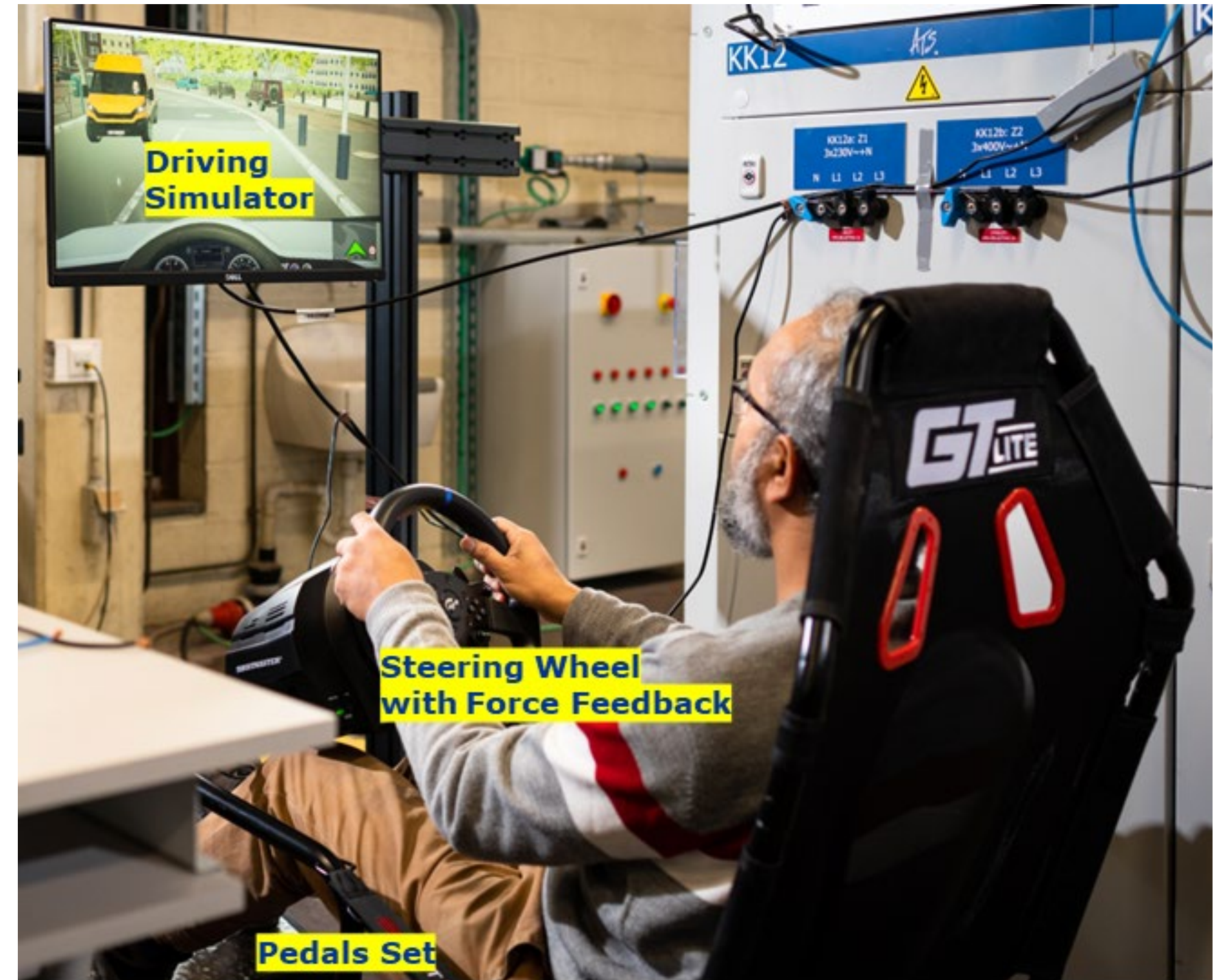
OVPP consists of five main subsystems:

## 1. The driving simulator setup

- \* Racing wheels (steering wheel with force feedback)
- \* Pedal set (accelerator, resistance brake, clutch)
- \* Vehicle seat
- \* Driving Simulation software (Cars, buses, trucks)

## 2. The vehicle powertrain setup

- \* Vehicle Control Unit (VCU) deployed to a real-time Rapid Control Prototyping (RCP) module
- \* Battery and grid emulator to emulate the Energy Storage System (ESS) and DC/DC converter
- \* In-wheel Motor System (IWMS) Drive to emulate the Electric Motor (EM), Inverter, and vehicle load
- \* Water-based cooling system for the EMs and Inverters





# OVPP Subsystem Details

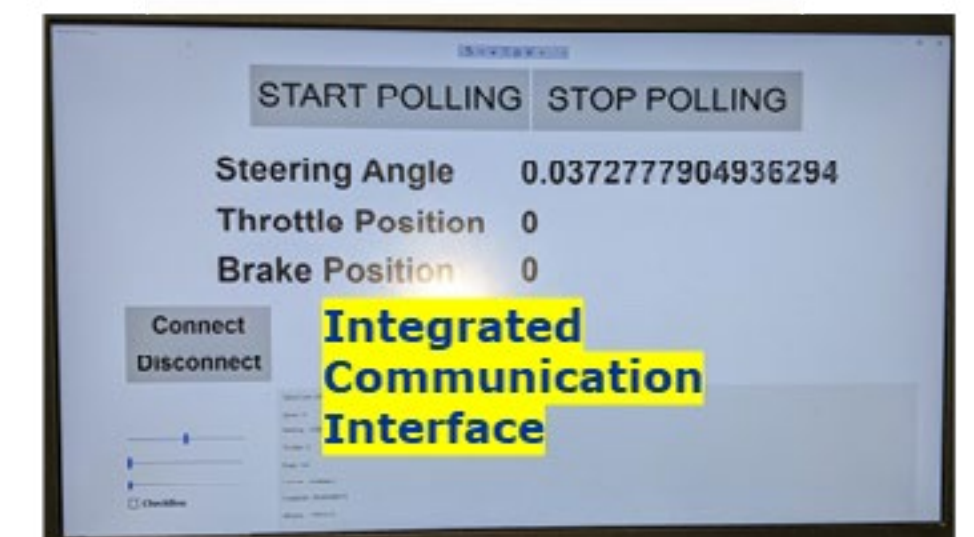
OVPP consists of five main subsystems:

## 3. The IoT setup

- \* Hall effect sensors to measure AC phase current output from inverter, DC current input to inverter
- \* Voltage transducers to measure AC phase voltage output from inverter, DC voltage input to inverter
- \* Thermocouples for temperature measurement
- \* High speed data acquisition (DAQ) and aggregation module
- \* High Performance Computing (HPC) system to provide the cloud interface to host the DT

## 4. The communications interface

- \* Communication between the simulation software and VCU > transfers telemetry data from vehicle
- \* Communication between the racing wheel and VCU > transfers driver inputs, i.e., steering, pedal, clutch, and gearbox data
- \* Communication between the DAQ and the DT > transfers sampled measurement data
- \* Communication between the VCU and DT > for tuning, validation and control
- \* Display plots of driving cycle, map, altitude profile, and battery SoC profile in real-time
- \* Communication interface developed in C#



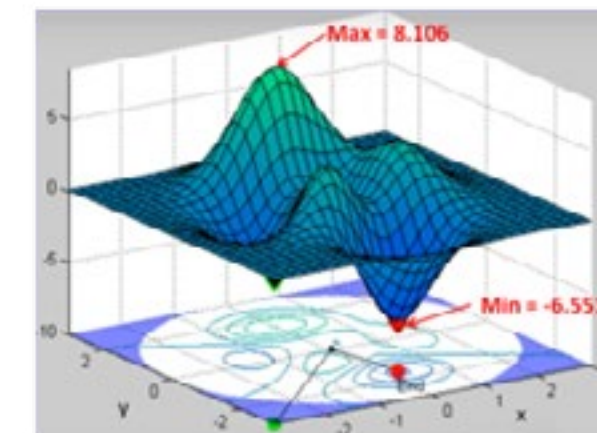
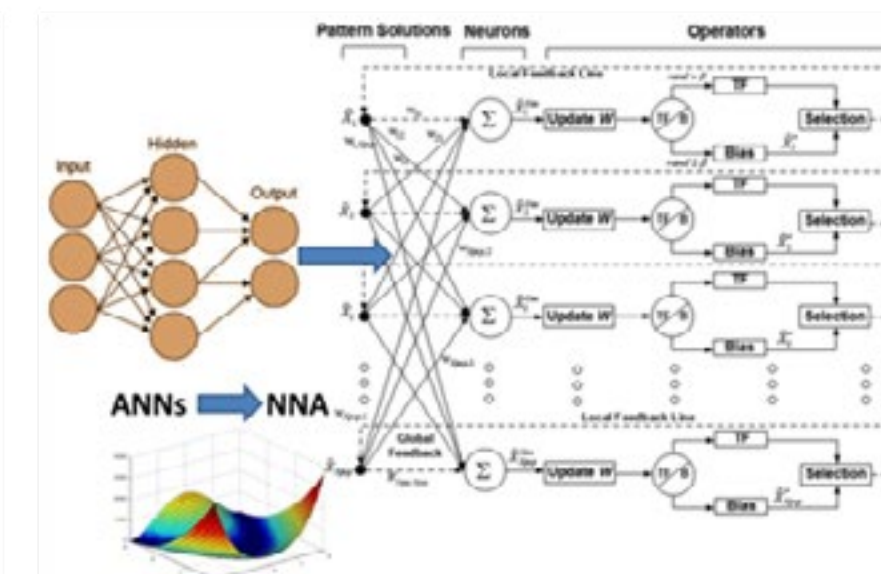
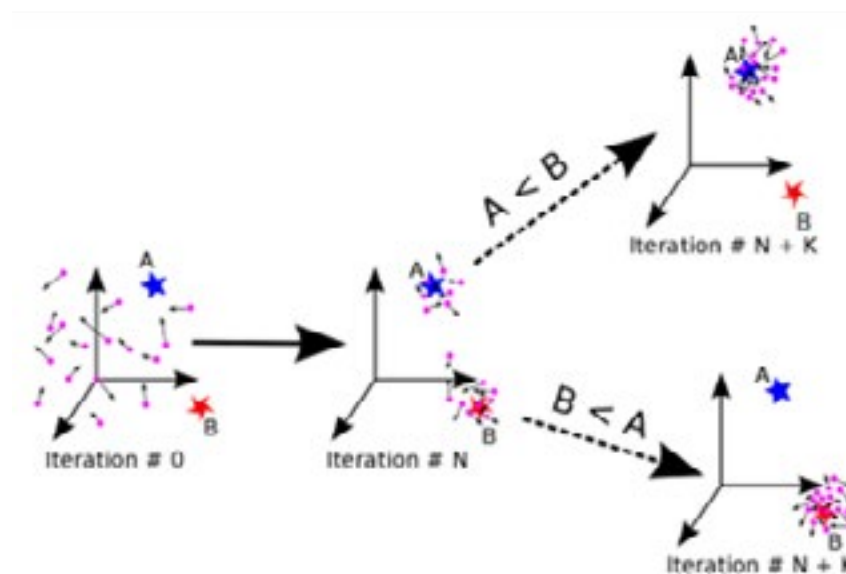
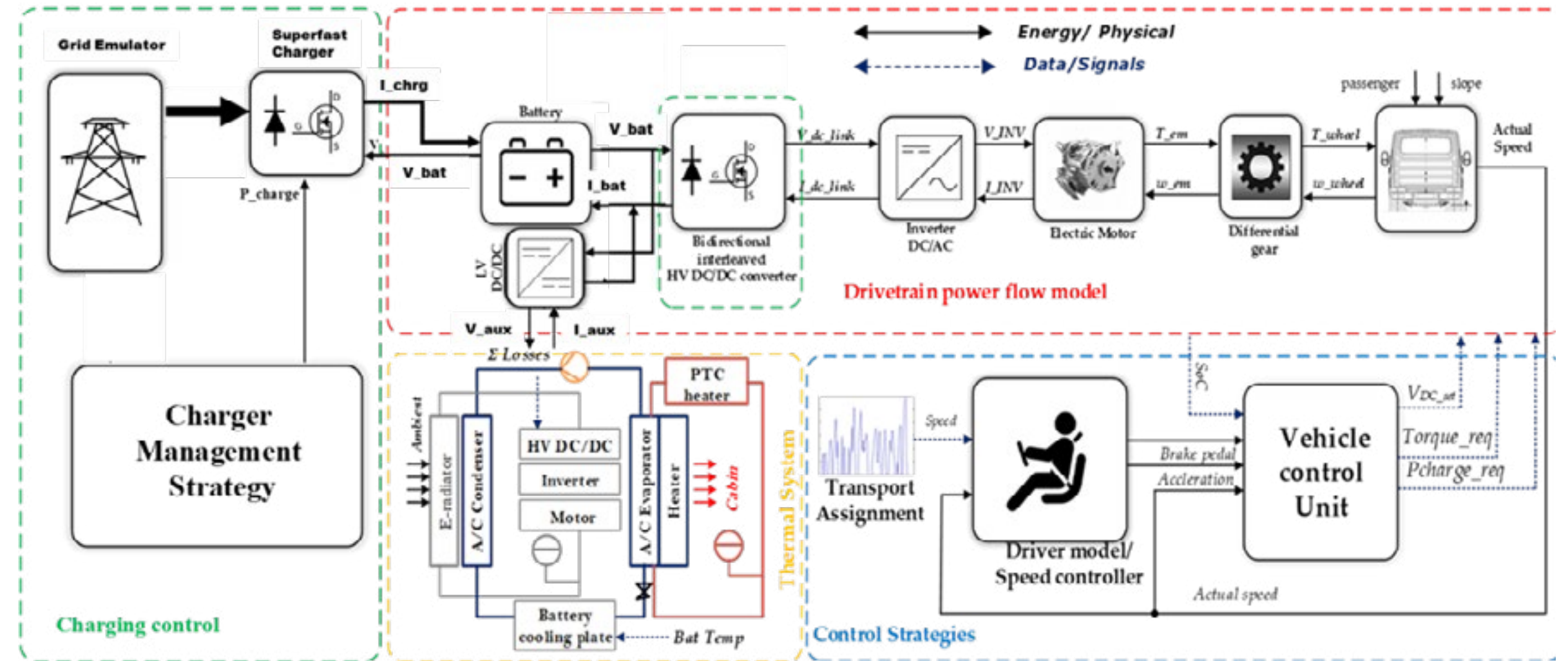


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## 5. The DT model (virtual subsystem)

- \* Different tuning algorithms, including neural networks, to synchronize simulated outputs of the DT with the actual system measurements
- \* Individual component models of EM, Inverter derived from FEM analysis of measurement test data using ANSYS Workbench
- \* A Low fidelity (Lo-Fi) model for highspeed and real-time simulation designed in MATLAB/Simulink
- \* Forward facing powertrain model of electric bus (e-Bus)



# OVPP System Demonstration

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- The driver responds according to the traffic scenario presented by the driving simulator
- Input from the driver (steering and pedal position) and the driving cycle from the bus simulator is used to control the EM drives
- The measurements from the drives are used to tune and validate the DT model of the vehicle powertrain

Please [click](#) to view the video demonstration.



# OVPP Services Offered

## » Hardware in the Loop Tests of Powertrain Components

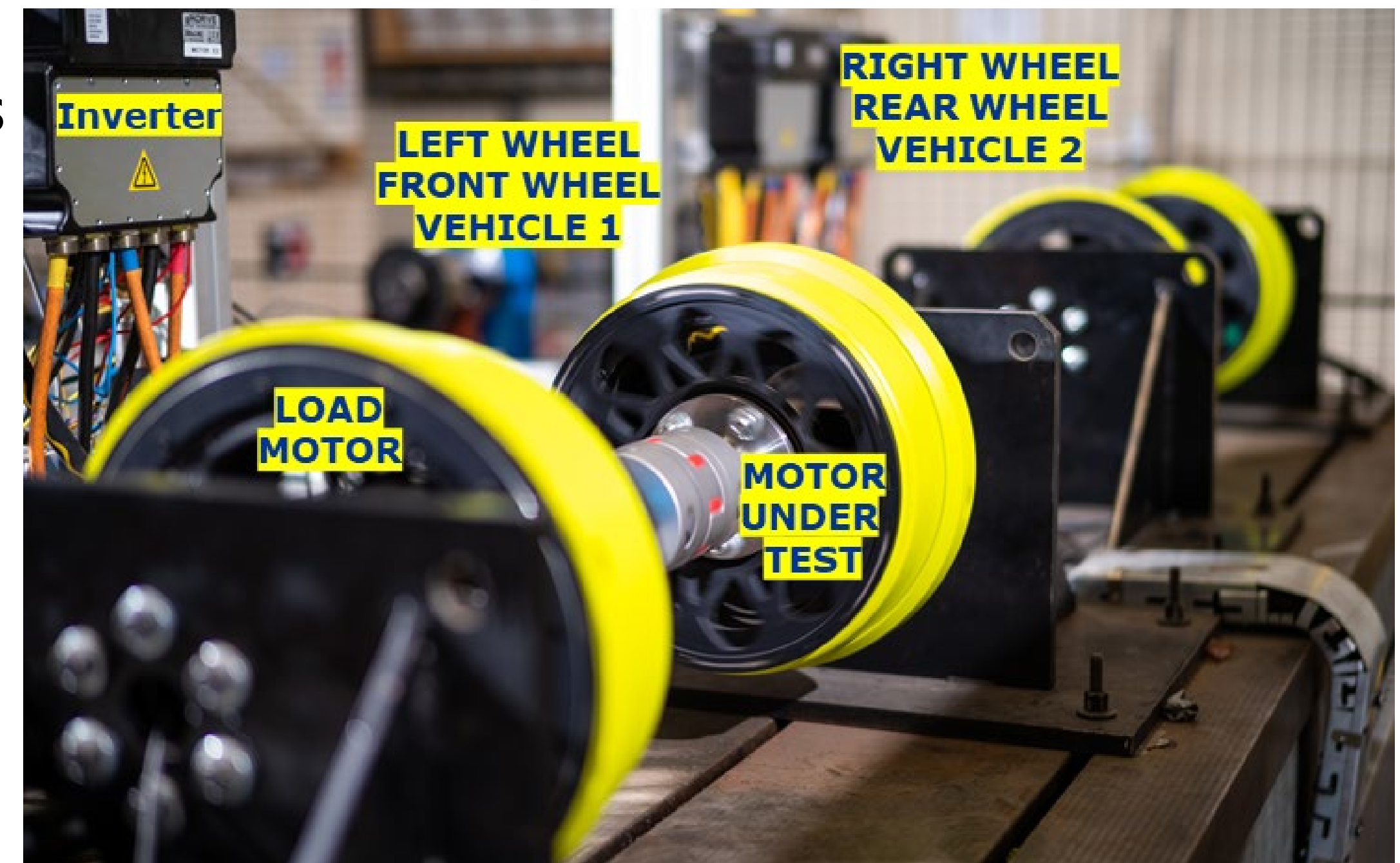
- \* Testing of ESS (Battery + BMS), Electric Motors and Inverters (drive), DC/DC converter, charger (on and off board), gearbox and transmission, cooling system
- \* Realistic test scenarios with actual driving behavior according to actual traffic scenarios
- \* Back-to-back testing capability. Can simulate a single actuator, or two wheels in a vehicle

## » Calibration & Parametric Tests of Powertrain Components

- \* Using test protocols supplied by OEMs
- \* Stress tests to determine limits of components

## » Tests of Control Algorithms

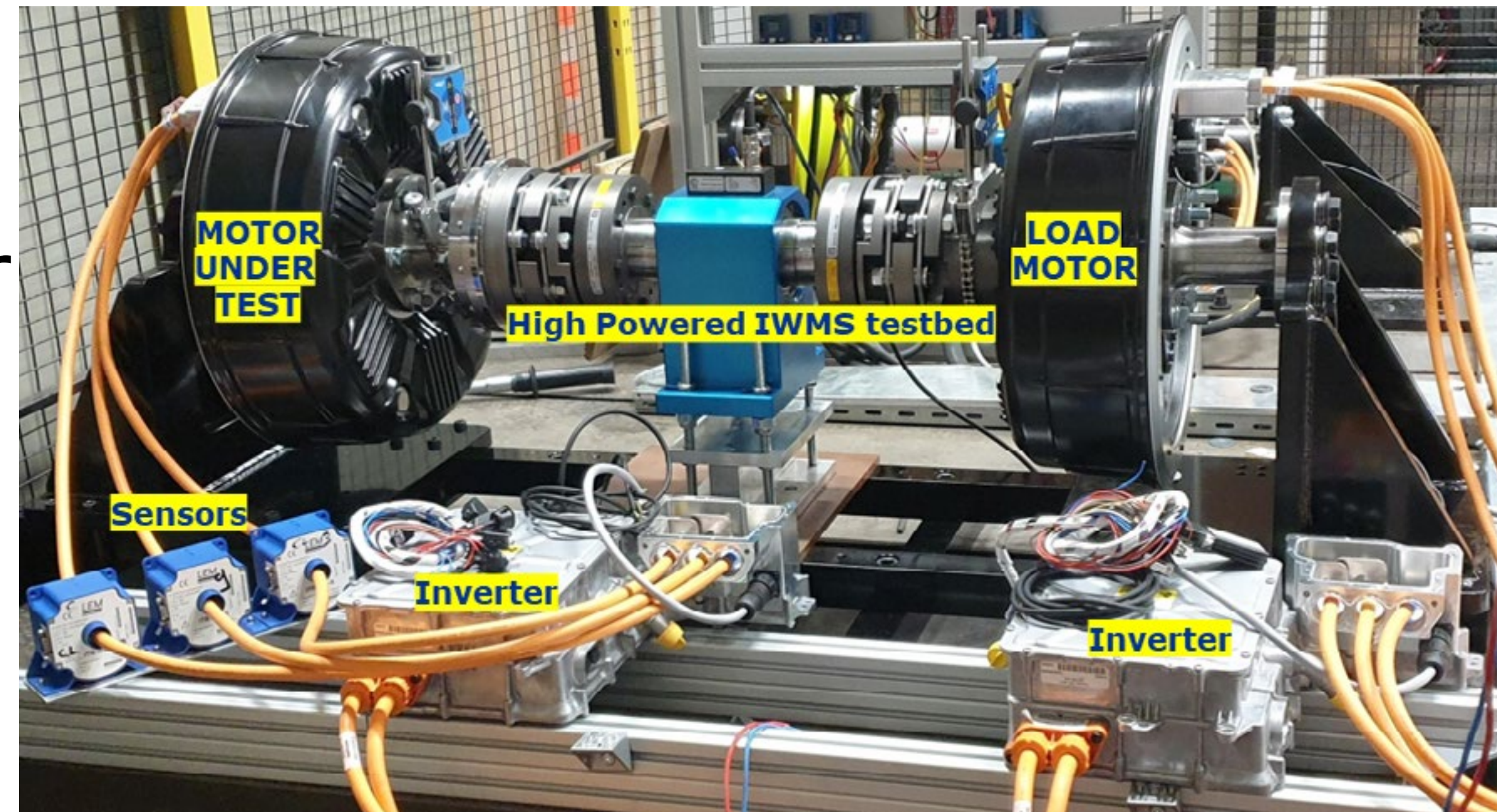
- \* Energy, thermal, charging management
- \* Vehicle control and performance





# OVPP Services Offered

- » Digital Twin of Powertrain Components
  - \* High speed and parallel tests of replicas of virtual models
  - \* Reliability and predictive maintenance calculations
  - \* Numerous flexible test scenarios
  - \* Accelerated lifetime modeling
- » Scalable, customizable and modular
  - \* Test entire vehicle, subsystem, or component
  - \* Customization according to OEM requirement
  - \* Different vehicle types (light and heavy duty)
  - \* Range of rated power





## Contact Details:

Prof. Dr. Ir. Omar Hegazy  
Head of EPOWERS Research Group

Email: [omar.hegazy@vub.be](mailto:omar.hegazy@vub.be)

Telephone: +32 2 629 2992

Mobile: +32 488 819 954

Skype ID: [omar.hegazy@vub.be](https://www.skype.com/people/omar.hegazy@vub.be) (Skype Business)





