Driver-centric development leveraging on remotized Hardware-in-the-Loop and Dynamic simulators

VI-Grade ZPS – Udine, May 2025

Speakers:
Andrea Spicuglia – Stellantis
Claudio Annicchiarico – Meccanica42

Contributors:
Giuseppe Raimondi – Stellantis
Alessio Anticaglia – Meccanica42

Stellantis - Chassis & Dynamics

Dynamic Simulators availability

- Same SWs in all the regions
- Global standardized methods
- Sharable models, scenarios, tracks
- Unique vision for a global team

+ 5 between static and compact simulators, all equipped with HiL systems

Stellantis - Virtual Approach

Continuos Integration & Validation Process

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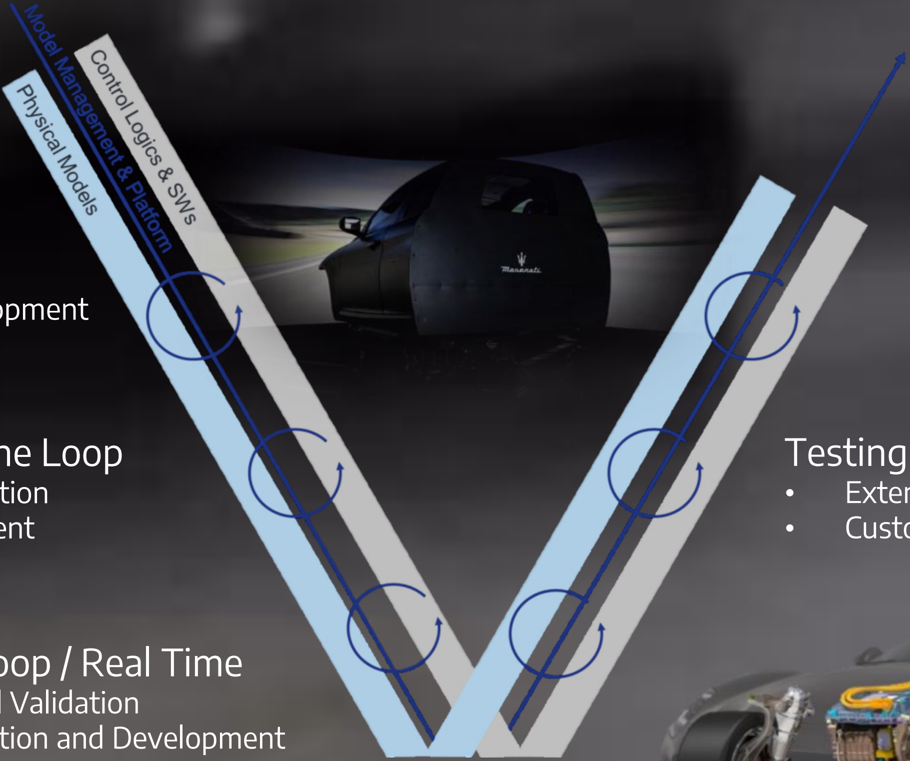


Models in the Loop

- Vehicle and Propulsion models development
- Control & SW Requirements

Hardware in the Loop

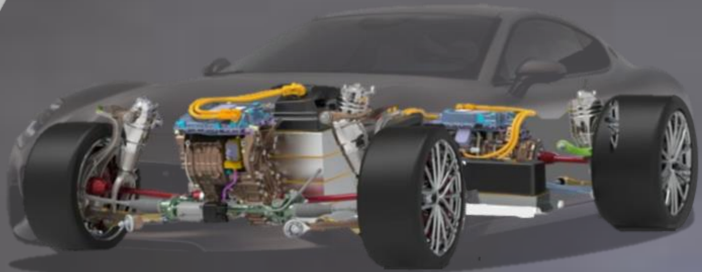
- ECU's integration
- Real component integration

Driver in the Loop / Real Time

- System virtual Validation
- Virtual Calibration and Development

Testing Data

- Extended Validation
- Customer Data



HiL Benches

Why? What?

Enhance simulator experience

Simulation higher fidelity

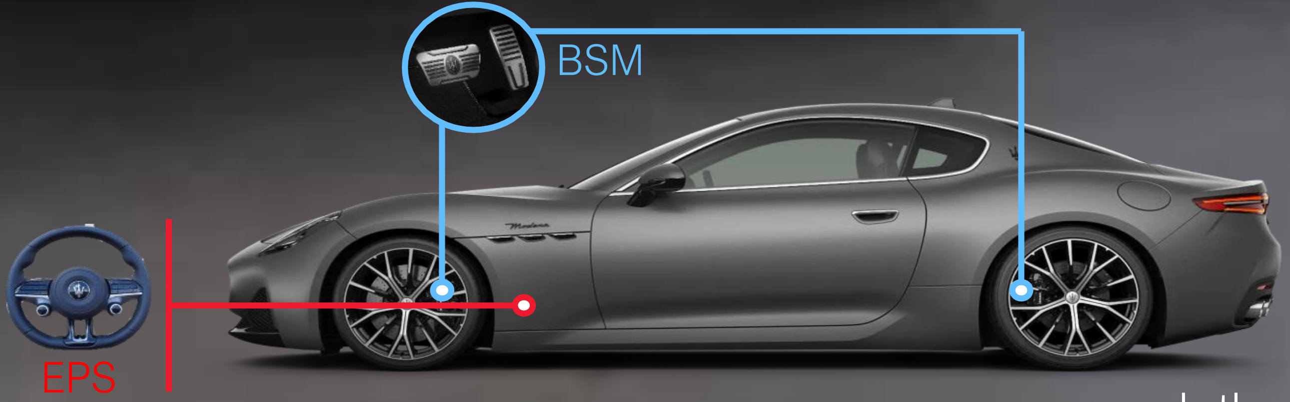
Functionalities development and debug

Virtual calibration

Virtual road release

FuSa assessment

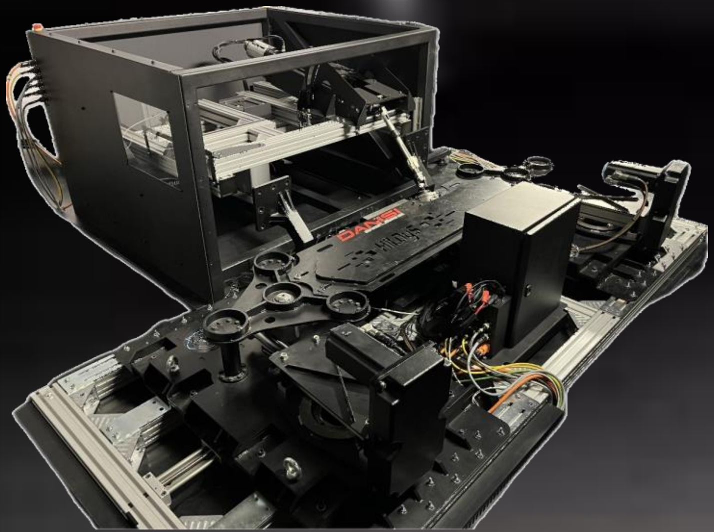
Fault injection



and others coming next...

EPSiL Bench

Description



New Steering Robot bench + legacy EPSiL bench

- **Full steering line hardware (rack + column + ECU)**
- **Actuators on tierods and upper column**
- **Adjustable steering column configuration**

The SWA from the Simulator cockpit is reproduced on the bench

The tierod forces from the simulation are reproduced on the rack

EPS ECU is fed with simulation signals, thus acting on the rack

SWT and rack displacement measured on the bench are fed back to the cockpit and to the simulation

Boost calibration | Damping features calibration | ADAS functions calibration

BRAKEiL Bench

Description

Entirely new bench

- **Brake pedal + ECU + 4 calipers**
- **Equivalent hydraulic braking circuit**
- **Linear actuator on brake pedal**

Brake pedal displacement from the cockpit is reproduced

BSM ECU is fed with simulation signals, thus acting on the hydraulic system

Brake pedal force and corner pressures are fed back to the cockpit and to the simulation

High/Low Mu ABS/ESC calibration

Brake blending calibration

ADAS functions calibration

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Our world at a glance

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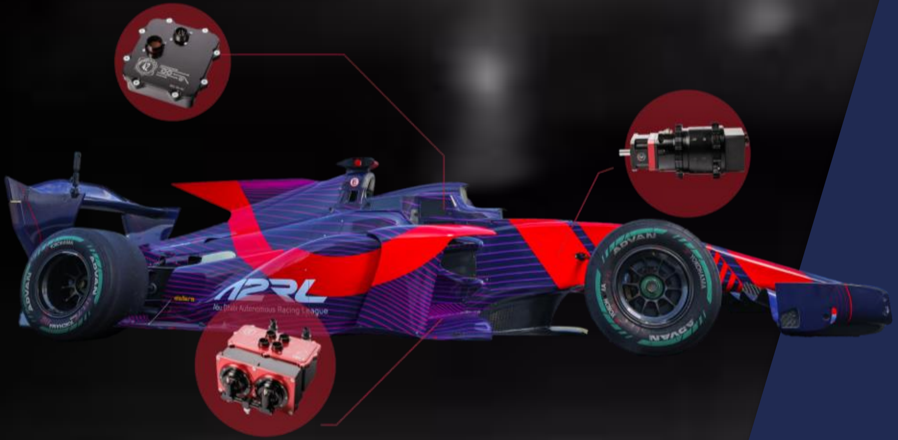


On-board devices for:
- Drive-by-Wire architectures for AD/ADAS
- Rapid control prototyping
- Vehicle functions definition
- Controllability
- ViL

Real-time rigs for:
- Performance assessment
- Validation
- Calibration
- Controllability
- HiL/DiL

The request

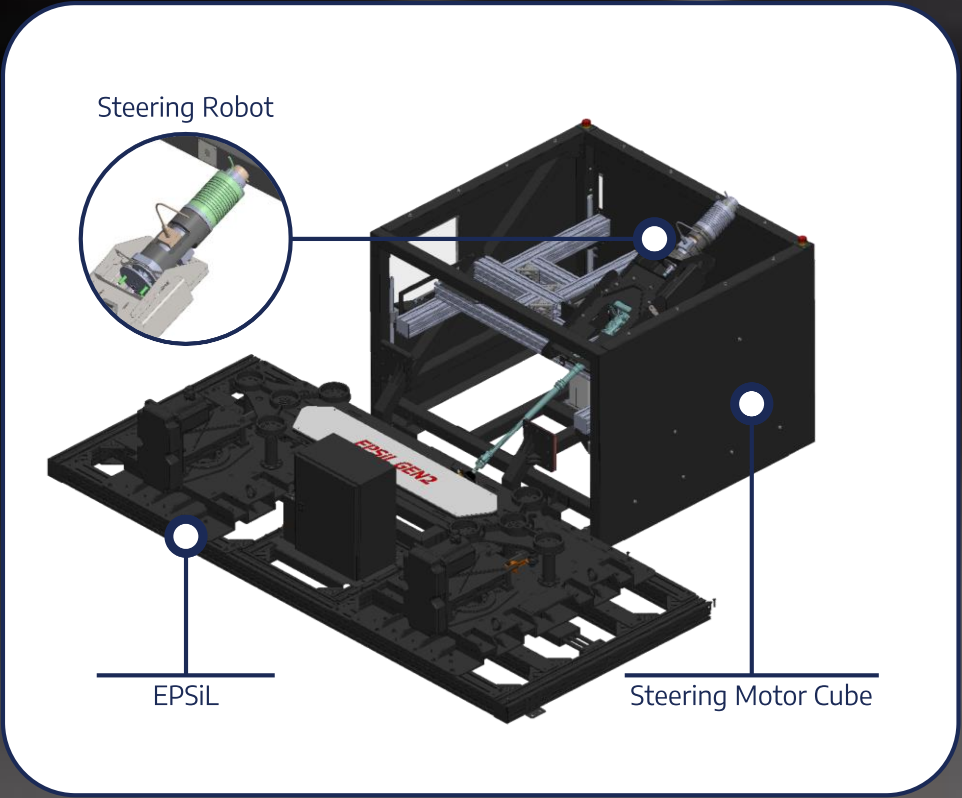
EPSiL Maserati - 2019

Connection with DiM (i.e. remote control)

+

- HiL for brake system
- Legacy steering feedback unit
- Legacy braking feedback unit

Steering HiL setup



EPSiL Gen2

Input
- Pinion torque
- Tie-rods forces
- Vehicle signals

Output
- Rack displacement

Steering Robot

Input
- Steering wheel angle

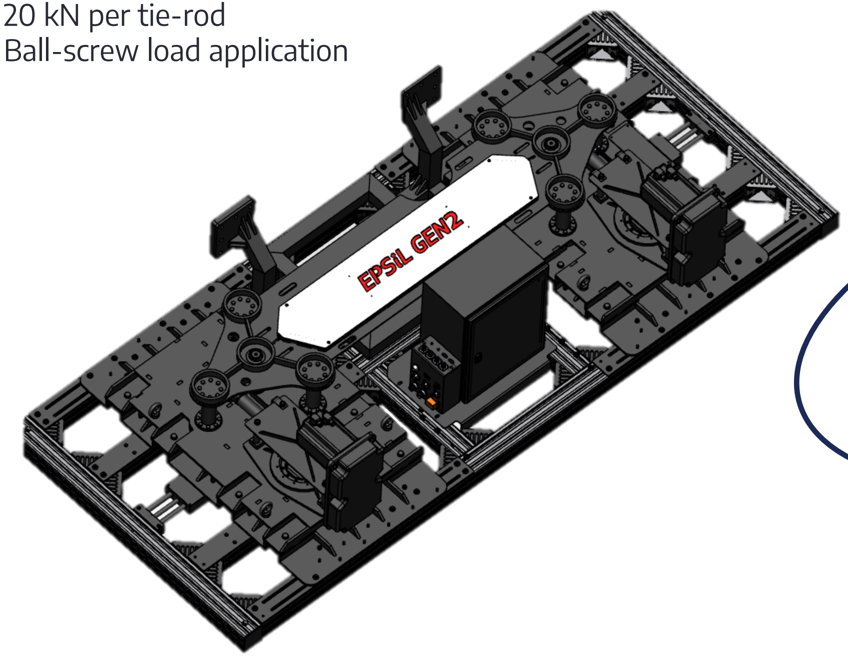
Output
- Steering wheel torque

Steering Motor Cube

For complete adjustability of the i-shaft position

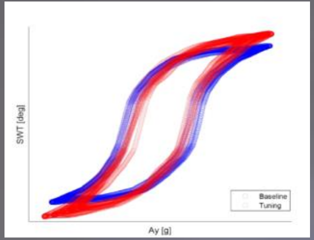
EPSiL Gen2

- Individual tie-rod force application
- 20 kN per tie-rod
- Ball-screw load application



- Rack position (actual)
- Left tie-rod force (actual)
- Right tie-rod force (actual)
- ...

- Left tie-rod force (target)
- Right tie-rod force (target)
- Vehicle speed
- ...



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Steering Robot

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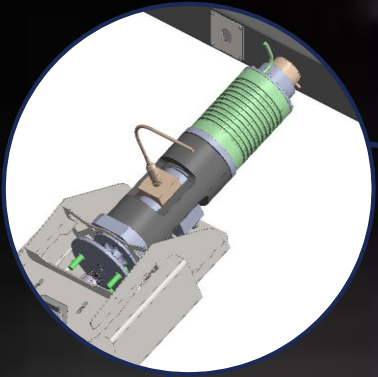
Steering wheel angle actuator with embedded steering wheel torque sensor

Steering Robot



- MEASURED steering torque
- MEASURED steering position

Vehicle Model

- TARGET steering wheel angle

Steering Robot specifications	
Peak torque	60 Nm
Maximum speed @ peak torque	2’100 deg/s
Torsiometer accuracy	0.5% FS
Communication latency	< 3 ms
Communication protocol	EtherCAT
Safety system	Multisensor-based STO

Brake rig

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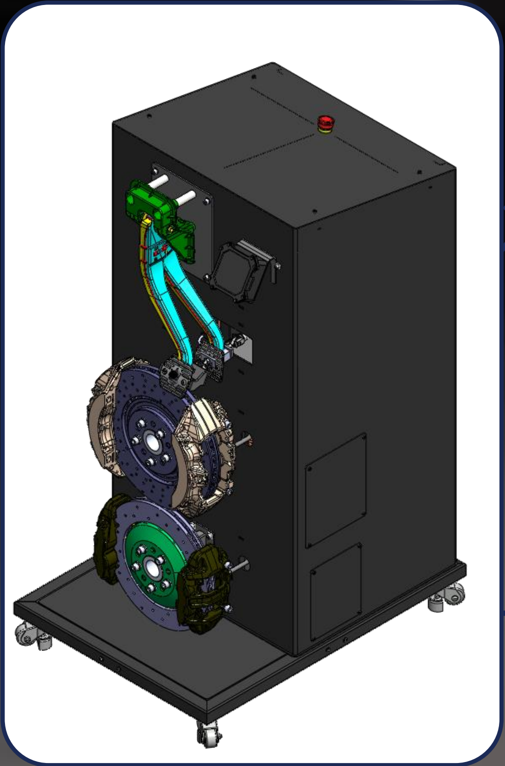

- 4 MEASURED caliper pressures
- MEASURED pedal force (load cell)

- TARGET pedal position
- 4 (individual) wheel speeds

BrakeiL specifications

Maximum force	2’000 N
Maximum speed	1.1 m/s
Load cell accuracy	0.5% FS
Communication latency	< 3 ms
Communication protocol	EtherCAT
Safety system	Multisensor-based STO

Brake rig

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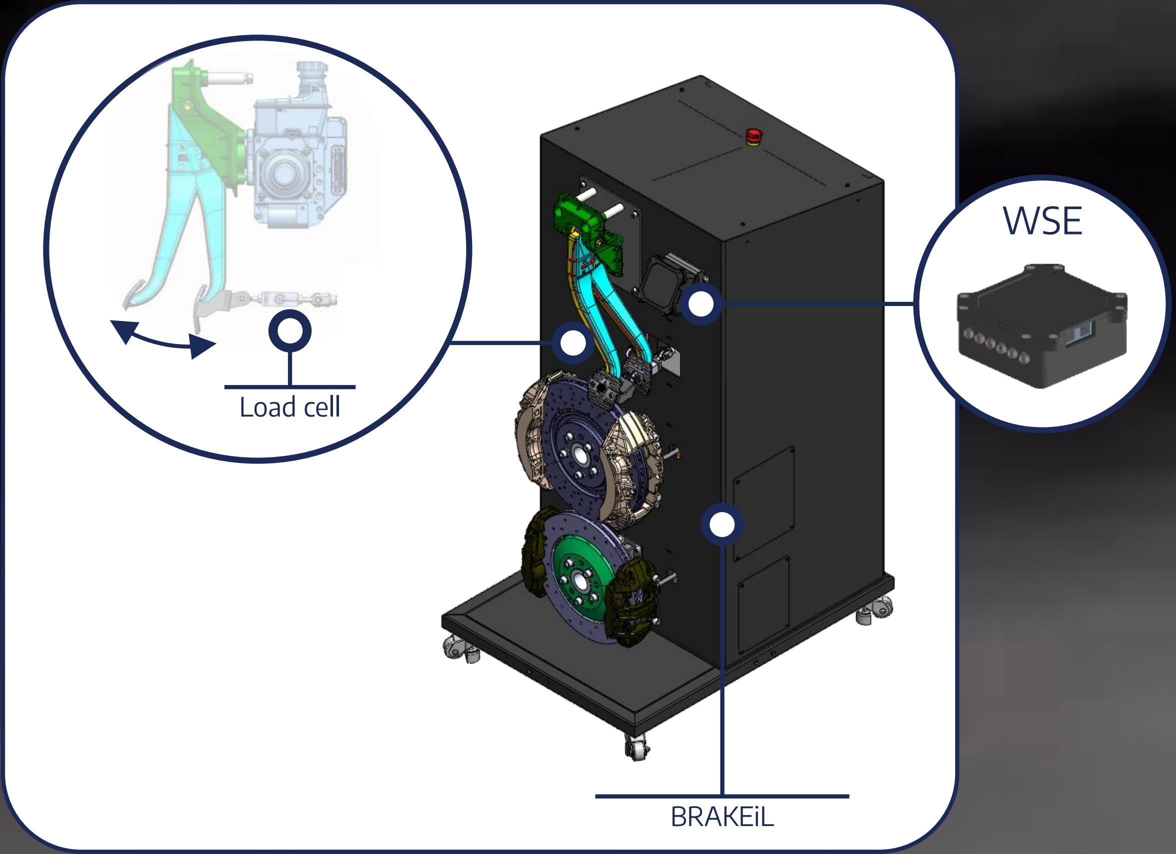


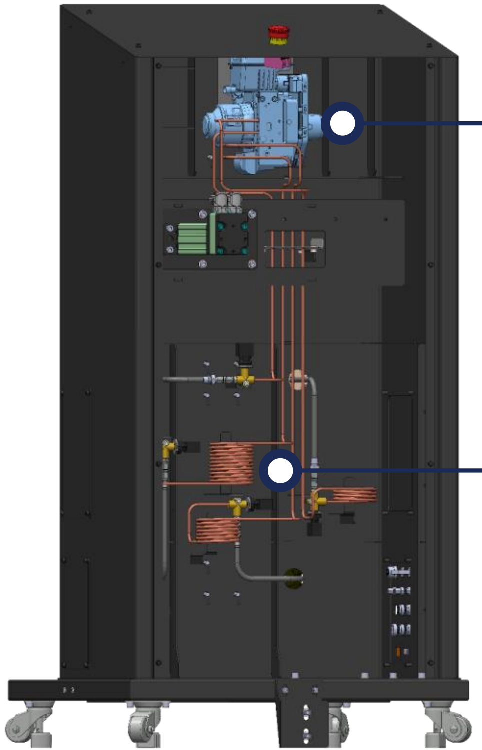
BRAKEiL:

- Real-time actuation of the brake pedal displacement
- Measurement of brake pressure at four corners

WSE:

- Emulation of multiple wheel speed sensors required for the brake unit
- Based on EtherCAT connection, allows for the emulation of any raw wheel speed signals

Brake rig



Device Under Test (BSM):

- Replication of the properties of the brake line from the unit up to the brake foundations

System architecture

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HiL control unit

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Component-level testing
System-level testing

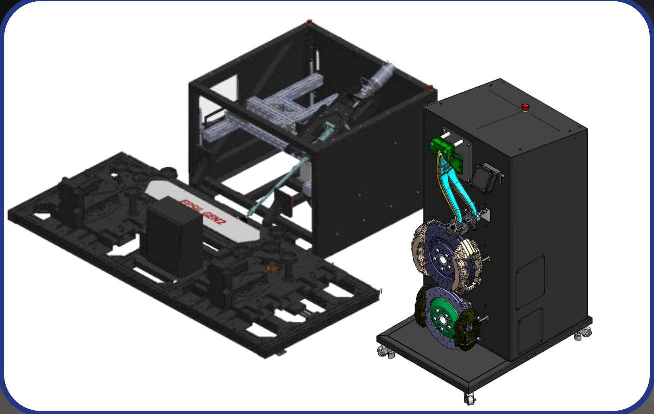
System-level testing
Vehicle-level testing

Vehicle Model

VI-CarRealTime

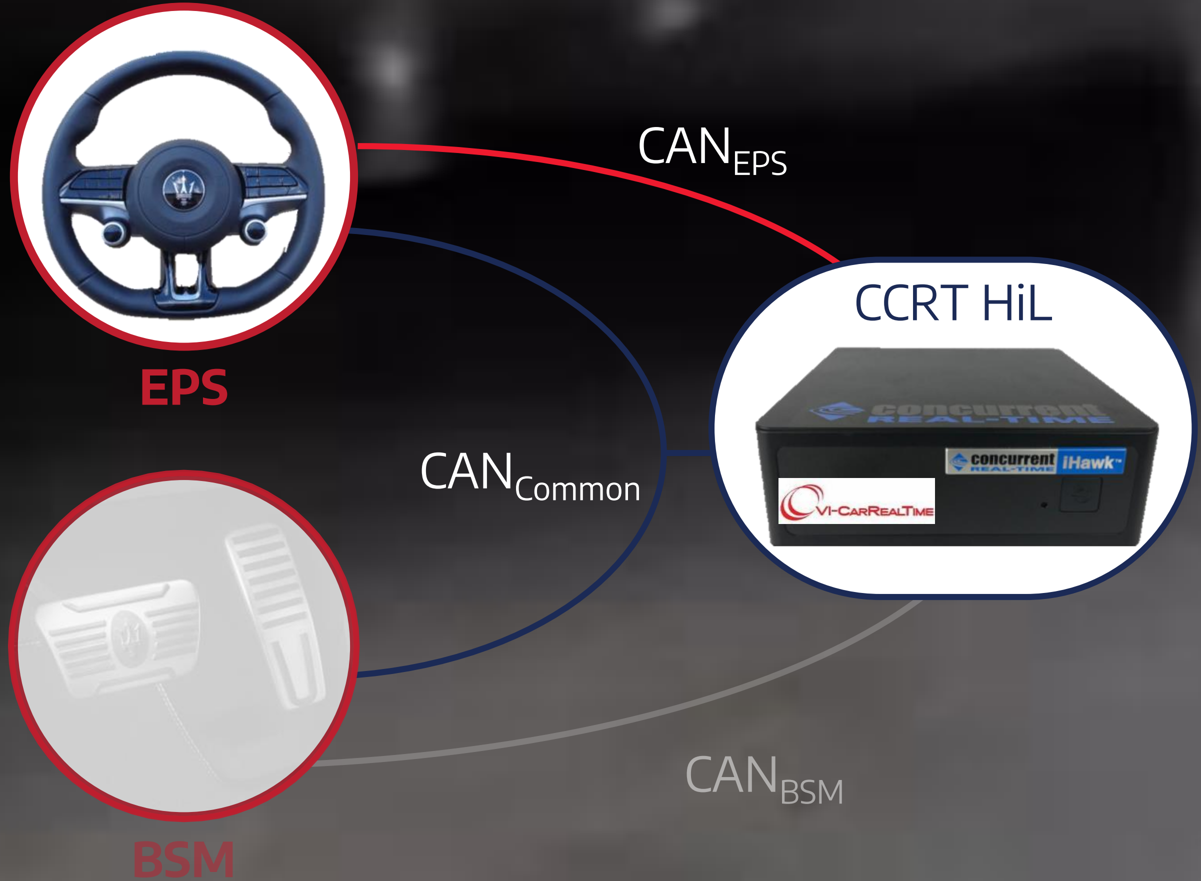
Multi-Sim

DiL testing



Restbus simulation on Simulation Workbench

Steering rig configuration:



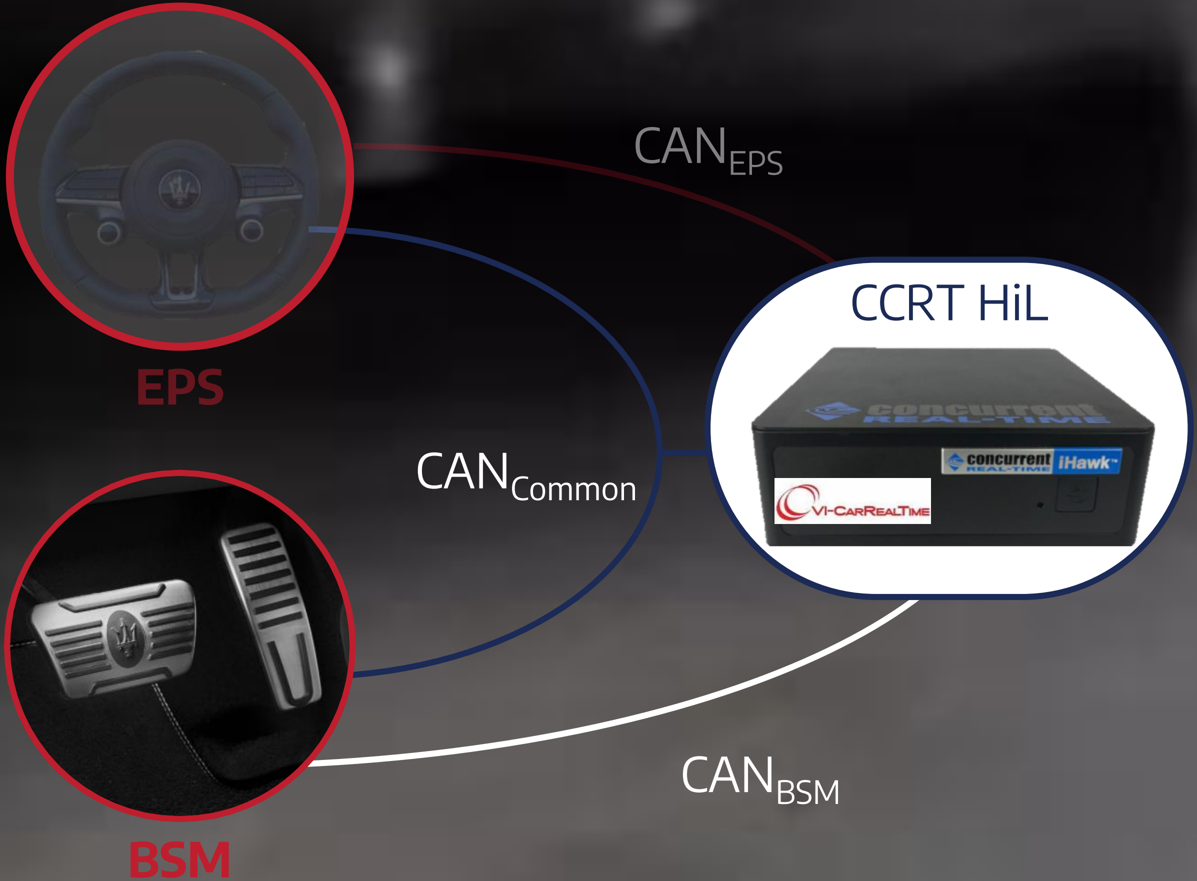
CAN bus networks:
CAN_{EPS}
CAN_{BSM}
CAN_{Common}

Received messages on CAN_{Common}:
7 messages and 189 signals

Received messages on CAN_{EPS}:
18 messages and 157 signals

Restbus simulation on Simulation Workbench

Brake rig configuration:



CAN bus networks:
CAN_{EPS}
CAN_{BSM}
CAN_{Common}

Received messages on CAN_{Common}:
13 messages and 193 signals

Received messages on CAN_{BSM}:
45 messages and 880 signals

Restbus simulation on SIMulation Workbench

Complete HiL rig configuration:

EPS

CAN$_{EPS}$

CAN$_{Common}$

CCRT HiL

BSM

CAN$_{BSM}$

CAN bus networks:
CAN$_{EPS}$
CAN$_{BSM}$
CAN$_{Common}$

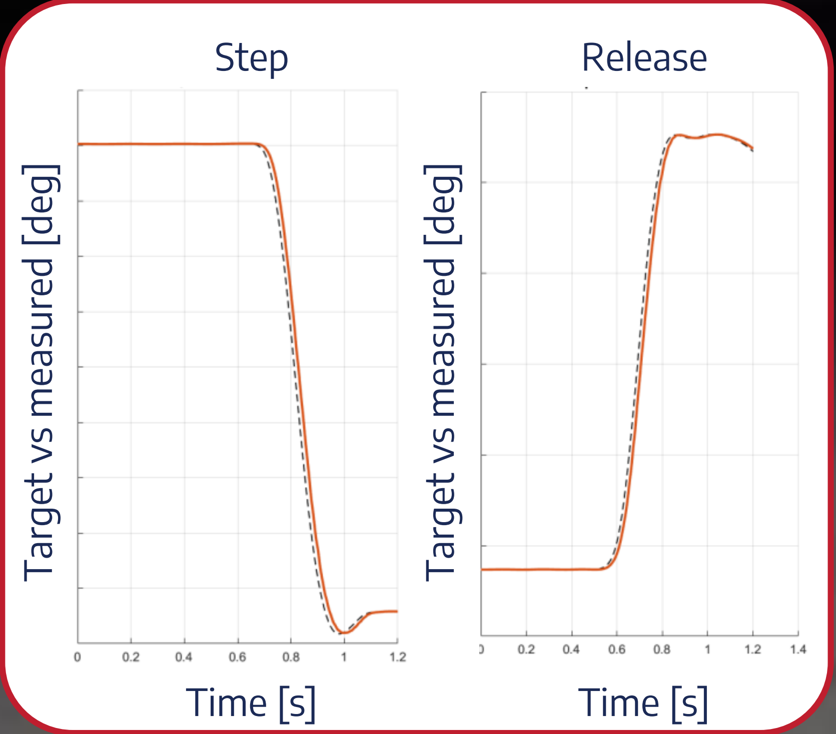
Received messages on CAN$_{Common}$:
1 messages and 14 signals

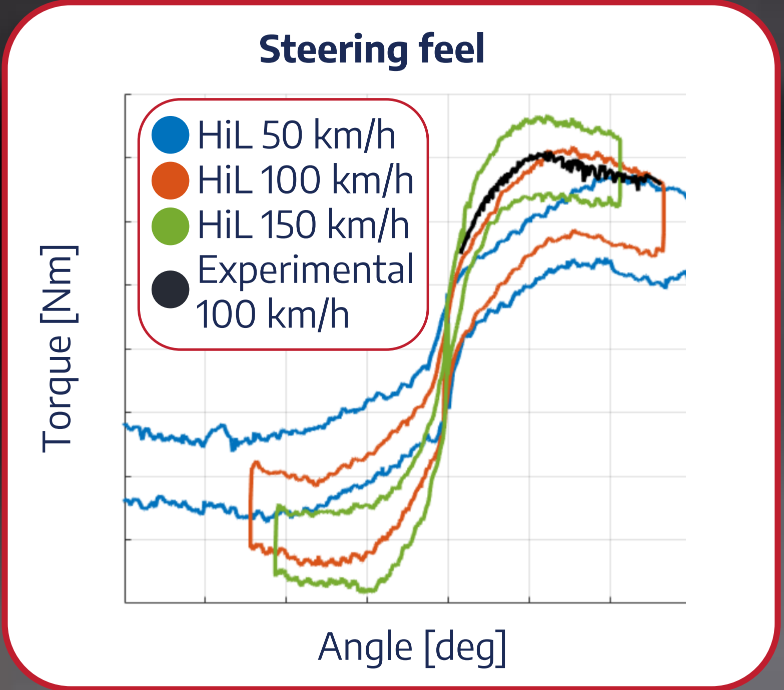
Received messages on CAN$_{EPS}$:
18 messages and 157 signals

Received messages on CAN$_{BSM}$:
45 messages and 880 signals

Steering system control loop

Good steering wheel angle following during steering step and release maneuvers
Almost constant delay of actuation

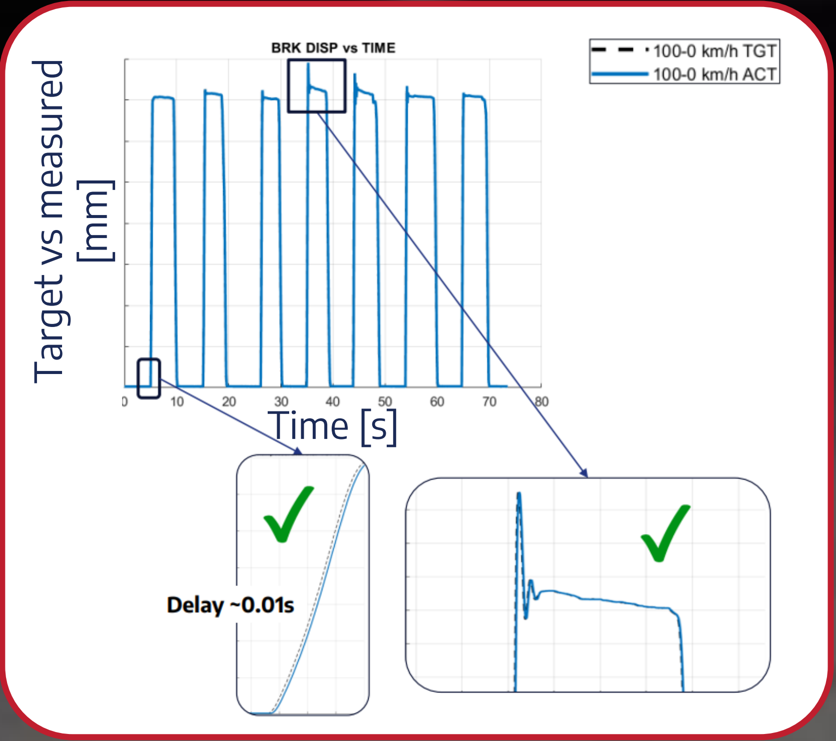


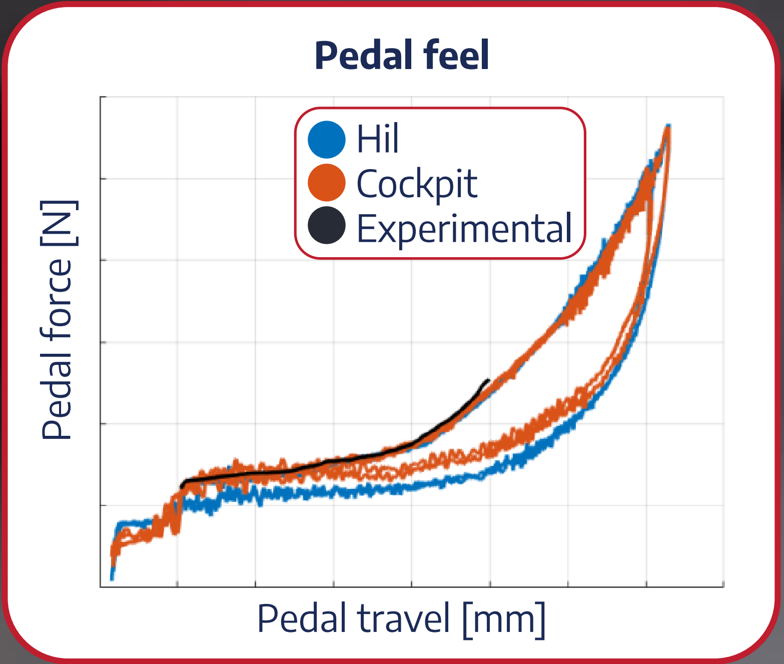


Possibility to evaluate steering feel behaviour of the real EPS and tune the assistance map in real time

Brake system control loop

Very good tracking of pedal displacement in brake steps and constant delay of actuation of just 10 ms





Reproduction of the real pedal feel sensed at the HiL rig in the driving cockpit

Conclusion & Next steps

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Mechanical integration achieved with compact solution ✓

Latency and signal transfer in target ✓

Subjective and objective assessment approved ✓

Extend the integration to different components »

Make the mechanical integration much more modular »

Evaluate upgrade to EPSil GEN3 and extend the application to the other regions »