Vehicle-in-the-Loop Testbed and Motion Laboratory

Testing ADAS in a virtual environment with realistic pedestrian interactions

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Testing ADAS – Simulative or in reality?

MiL / SiL / HiL

+ High reproducibility
+ Easily scalable
+ Cheap in operation
+ High safety
- Challenge to validate models
- Limited accuracy of simulated vehicle behavior

On road test

+ Real vehicle behavior
+ Detects unknown scenarios
- Limited reproducibility
- High test effort
- No systematic testing possible
- Limited safety

Test bed – X-in-the-Loop concept

Steering-in-the-Loop

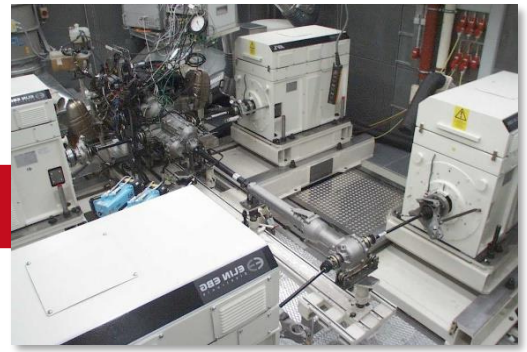
Vehicle-in-the-Loop testbed

Sensor-in-the-Loop

Camera | Radar | GNSS

SRS (IMU) | Lidar

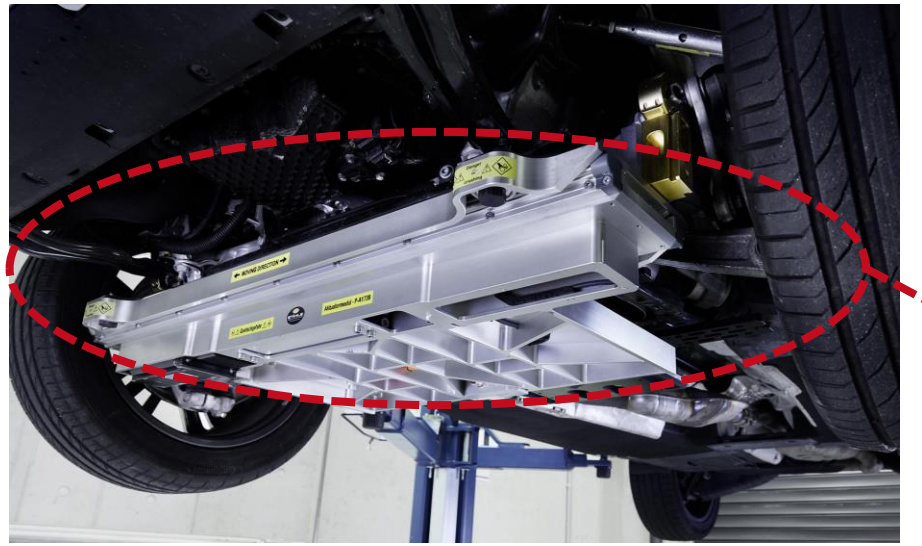
Brake-in-the-Loop



Powertrain-in-the-Loop

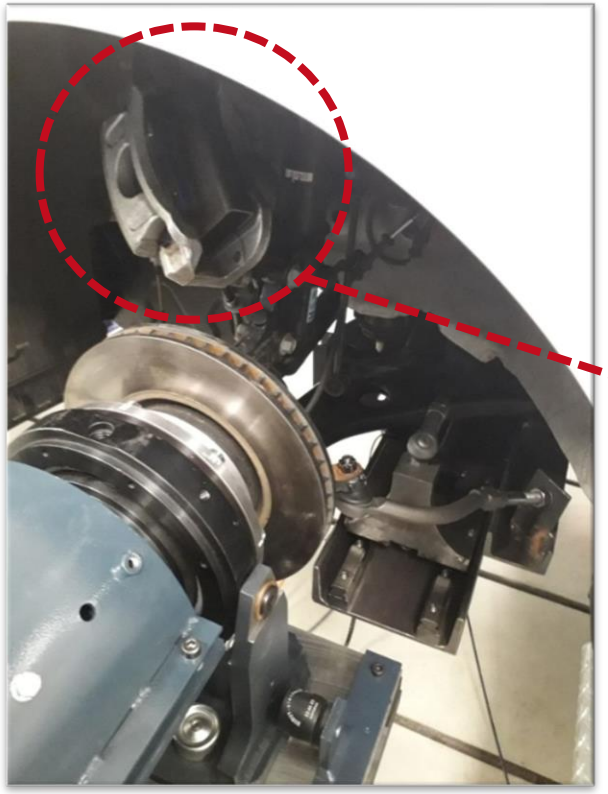
Test bed – X-in-the-Loop concept

Steering-in-the-Loop



Dynamic steering force emulator
ealistic steering force is applied to the steering rack
→ no steering motion on the wheel carrier, but on the rest of the steering system

Test bed – X-in-the-Loop concept



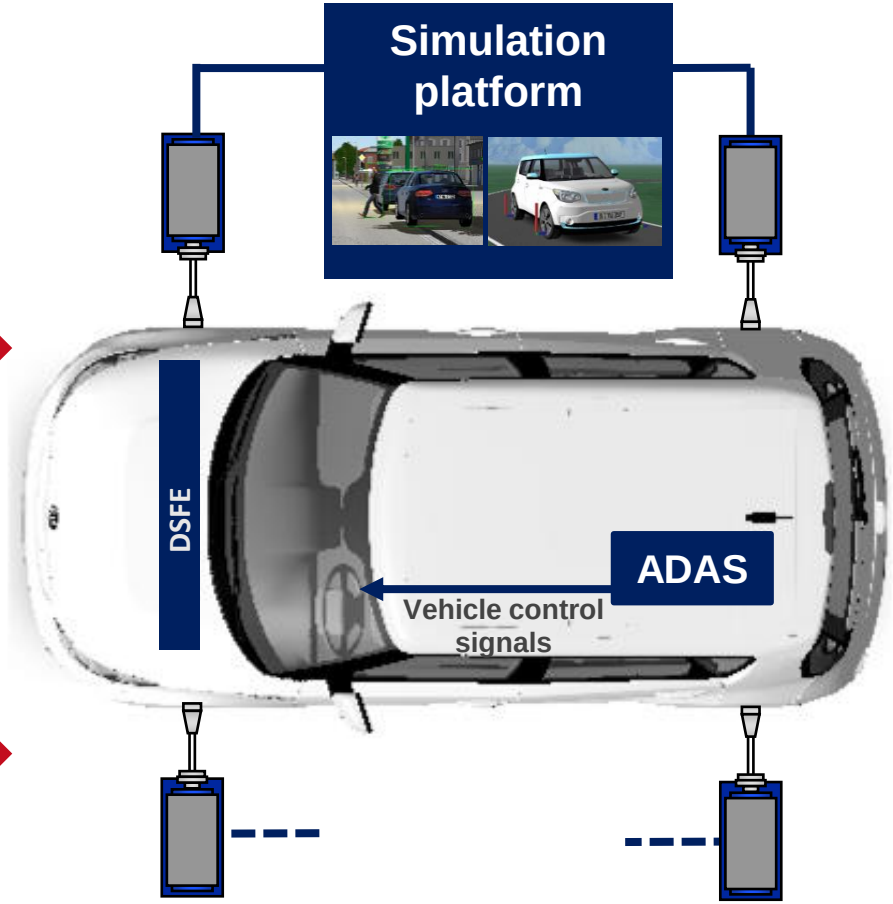
Brake-in-the-Loop

Individual wheel brake pressure measurement
Calculation of the braking torque and application via load machines
→ No brake dust, no heating, no conditioning

Test bed – X-in-the-Loop Concept

Steering-in-the-Loop

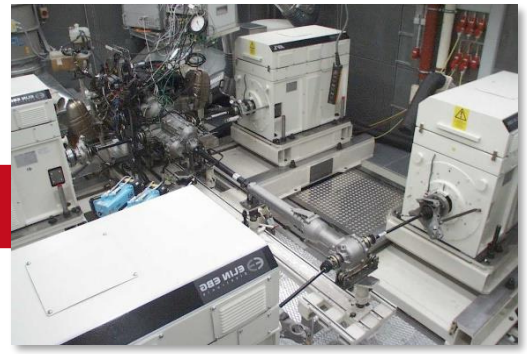
Brake-in-the-Loop



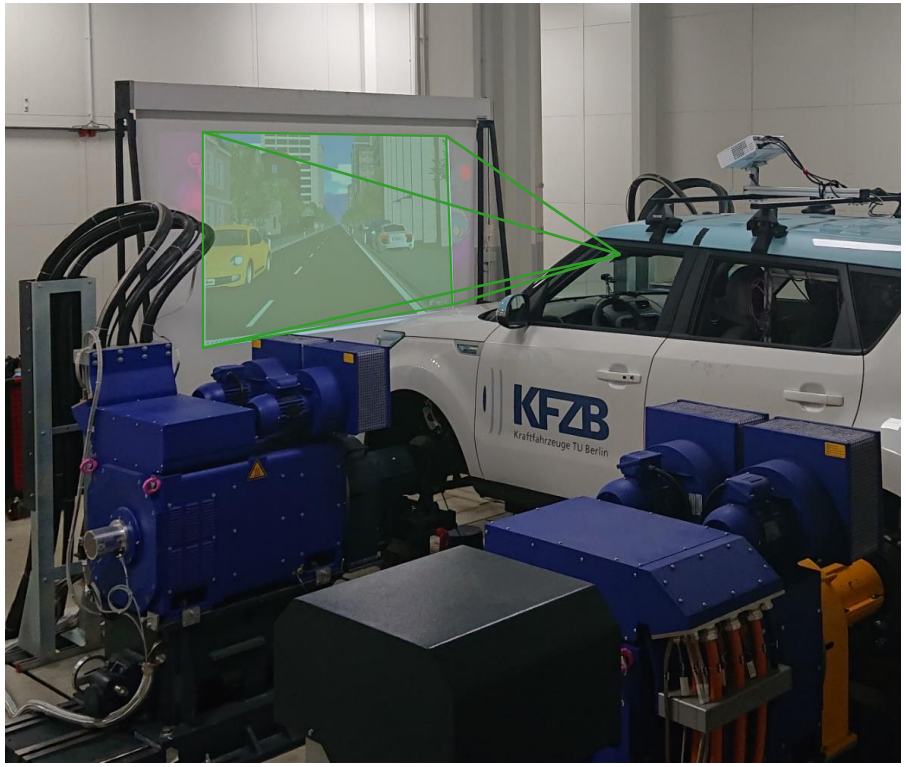
Vehicle-in-the-Loop Testbed

Sensor-in-the-Loop

Powertrain-in-the-Loop



Test bed – X-in-the-Loop Concept



Sensor-in-the-Loop

MobilEye6

Camera

ARS408

Radar

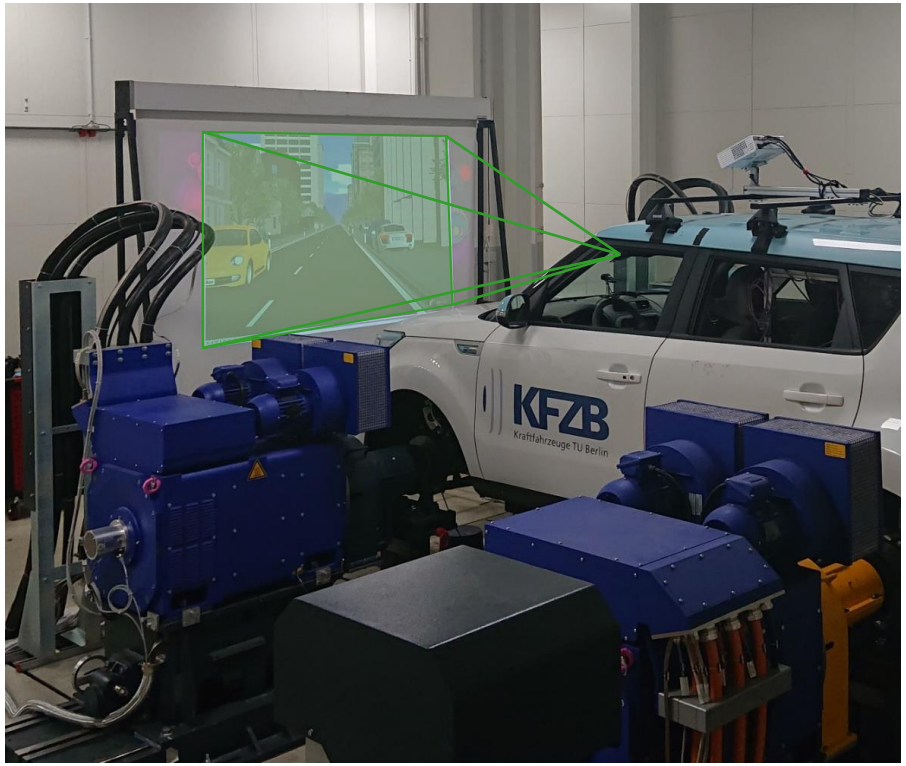
GNSS

SRS (IMU)

Lidar

Velodyne VLP 32c

Test bed – Sensors(t)imulation



Digital Twin

Real World

Virtual Test Field

Test bed – Sensors(t)imulation

Stimulation

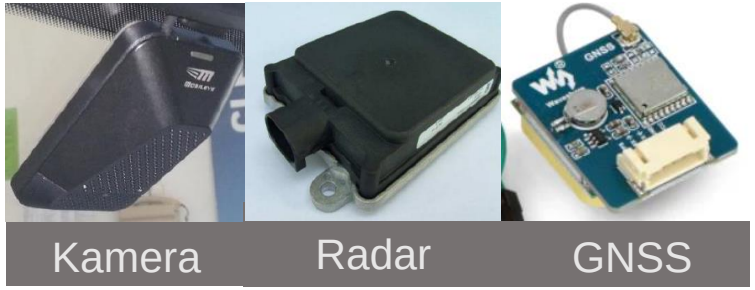
Radar target stimulator
- can create **complex artificial objects** with **variable distance, radial velocity, size** and **angle** without physically moving antennas or devices
- up to 8 targets, distance: 2-300m

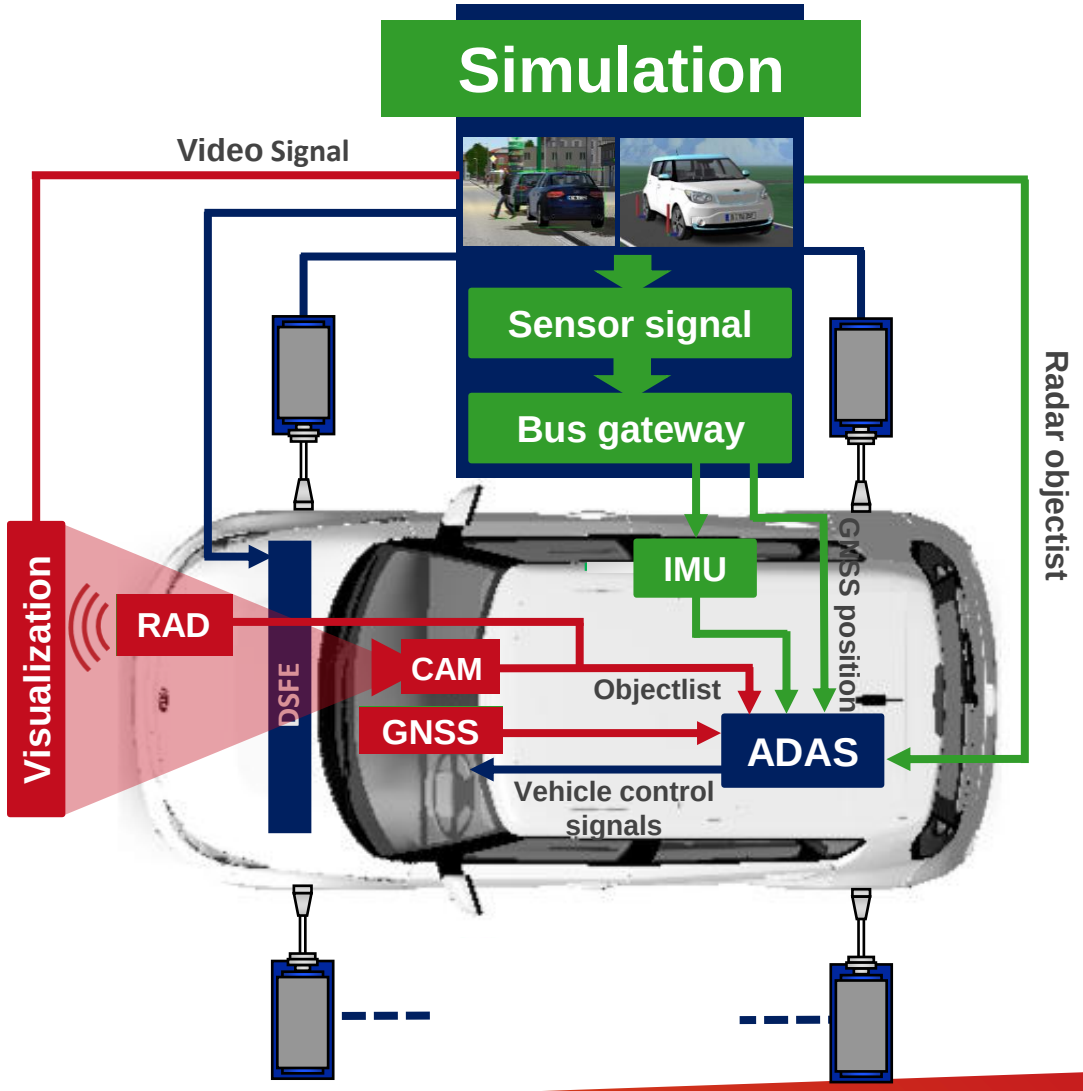
Radar GNSS

GNSS stimulator
- stimulate the vehicle's built-in GNSS system with **real GNSS RF signals**

Test bed – Sensors(t)imulation

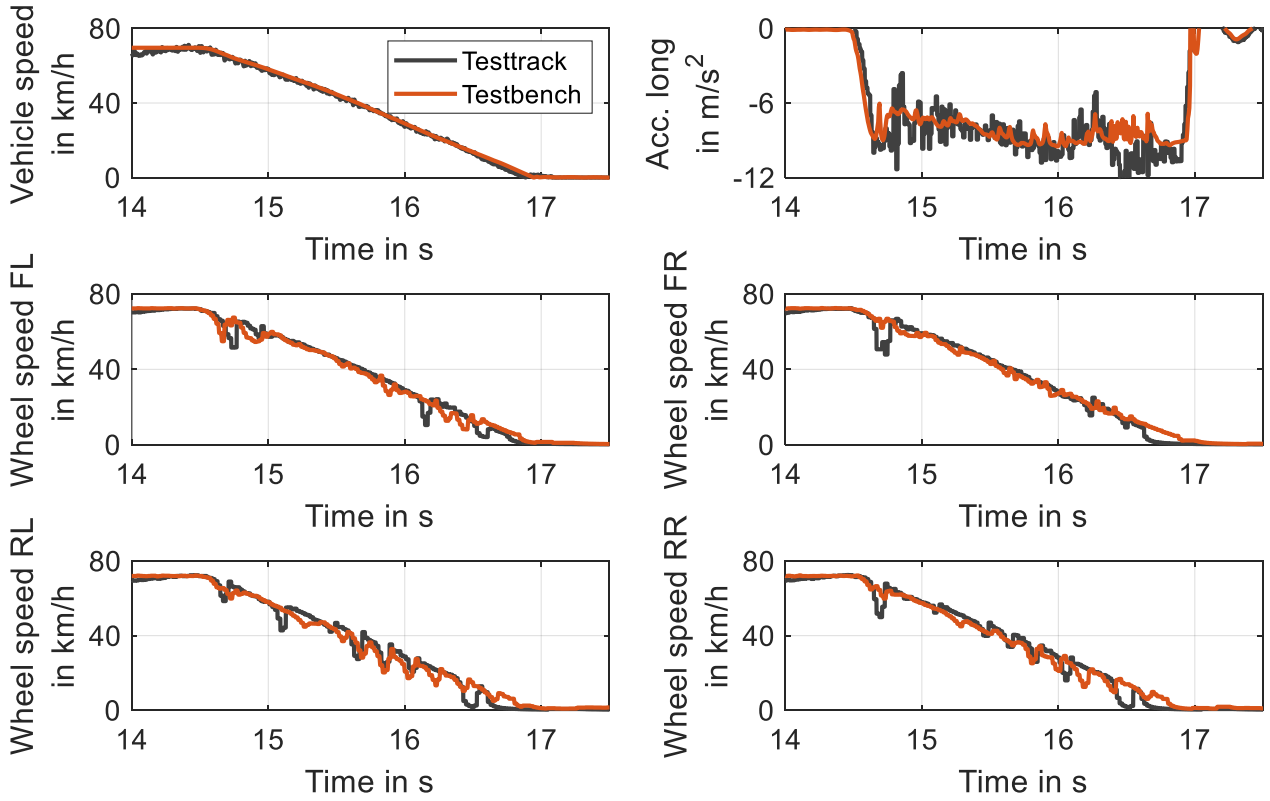
Stimulation





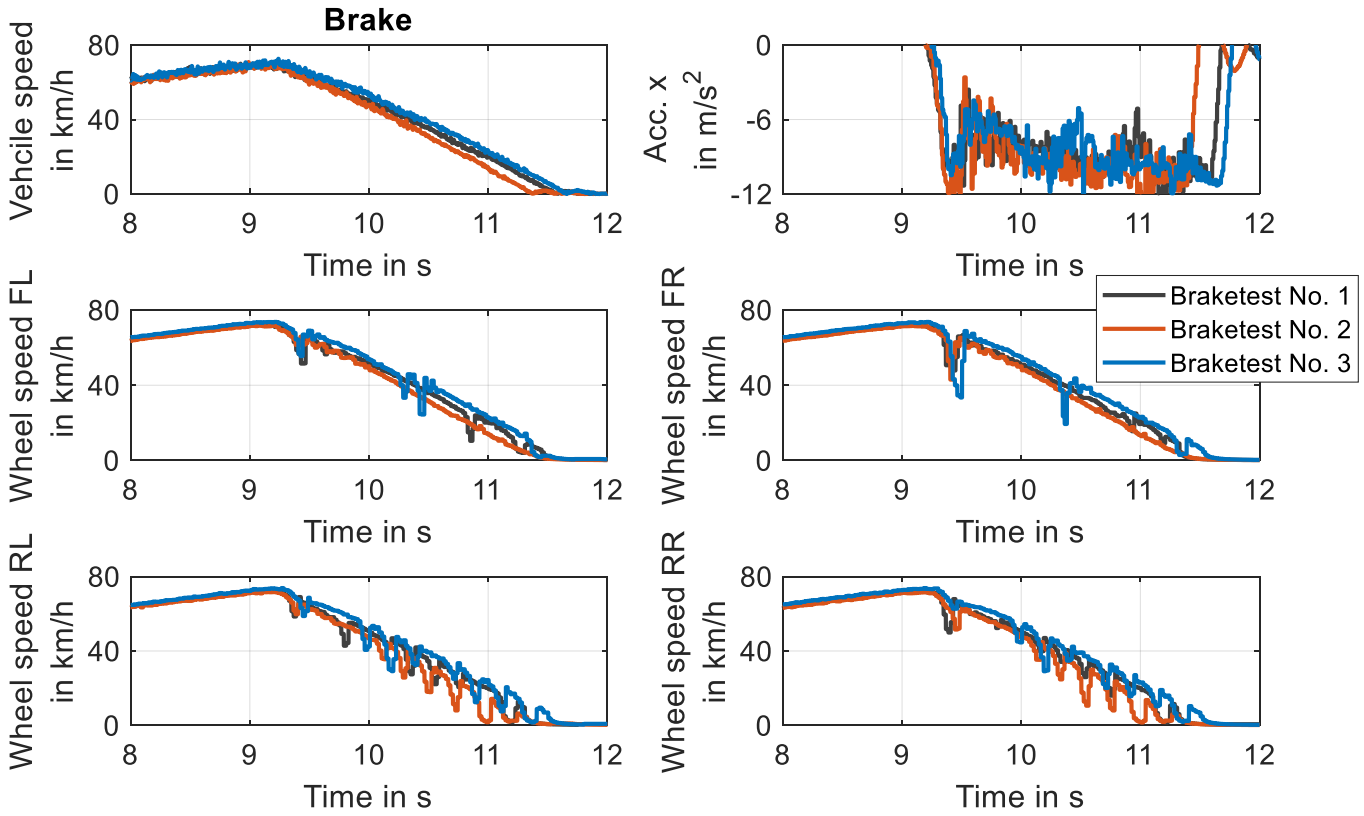
Reproducible tests of ABS and AEB

ABS – testtrack vs. ViL testbench



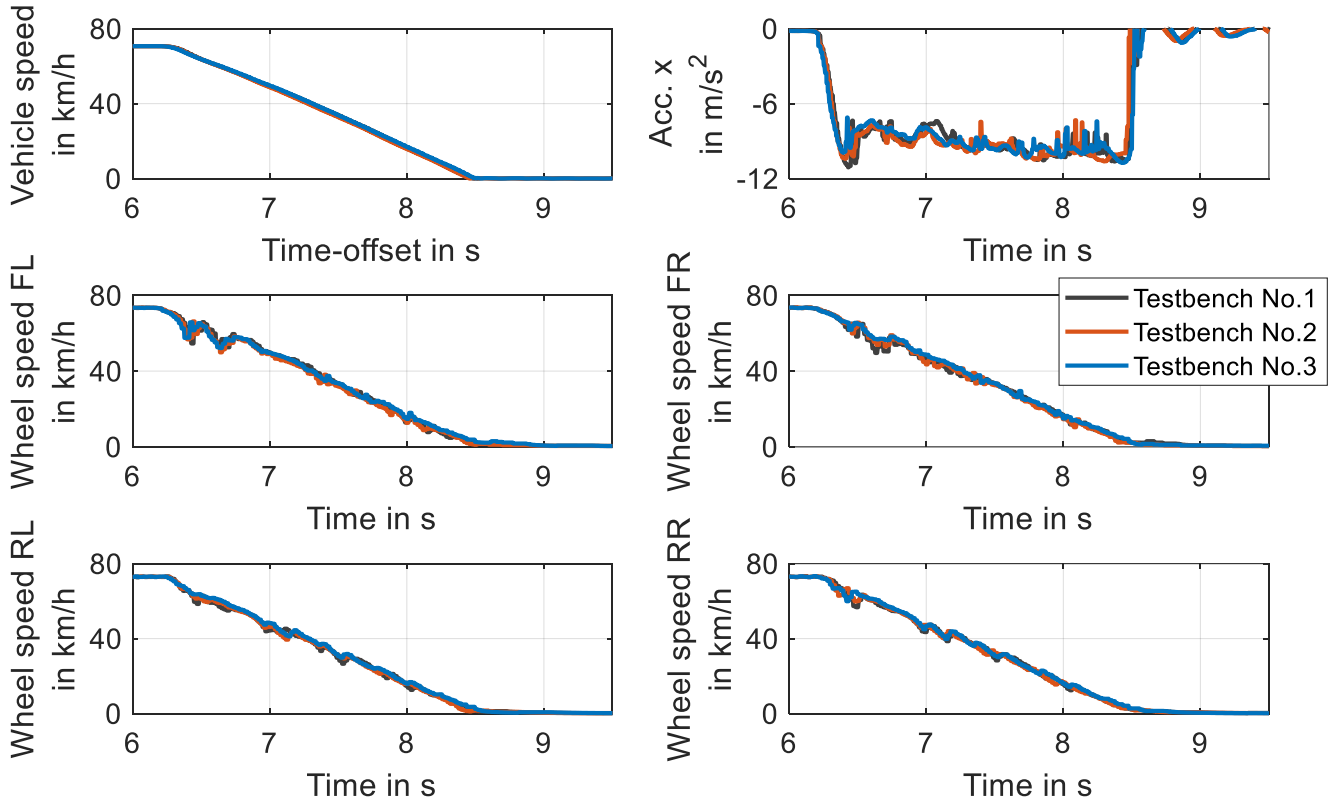
Reproducible tests of ABS and AEB

ABS – testtrack vs. testtrack



Reproducible tests of ABS and AEB

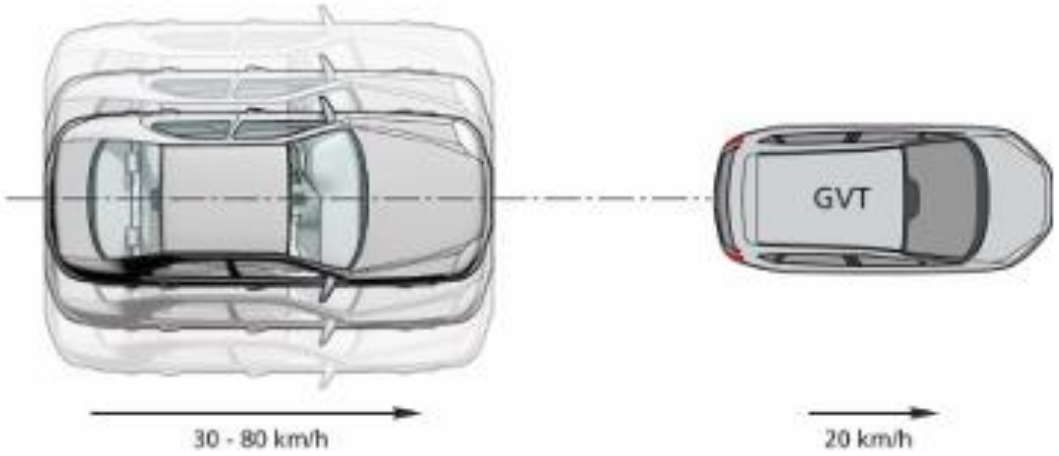
ABS – testbench vs. testbench



Reproducible tests of ABS and AEB

AEB – NCAP tests on ViL testbench

Car-to-Car rear moving:

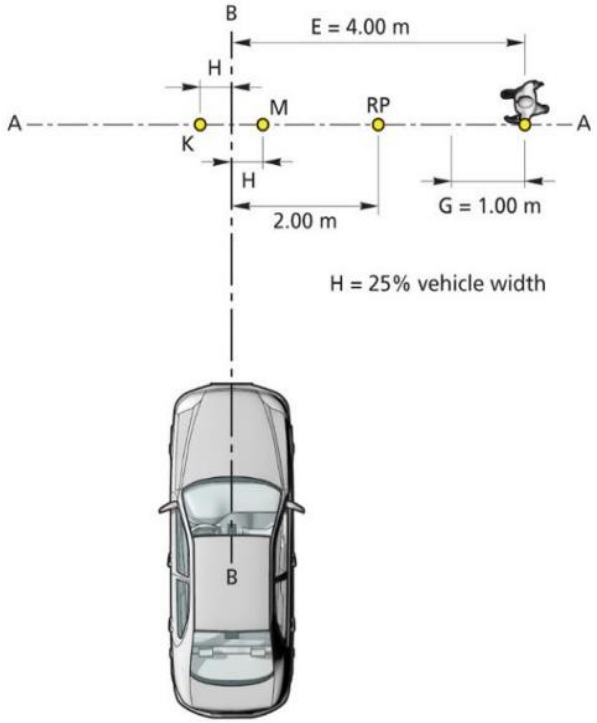


Euro NCAP AEB C2C Test protocol V 3.0.3 (2021)

Reproducible tests of ABS and AEB

AEB – NCAP tests on ViL testbench

Car-to-Pedestrian Nearside Adult:

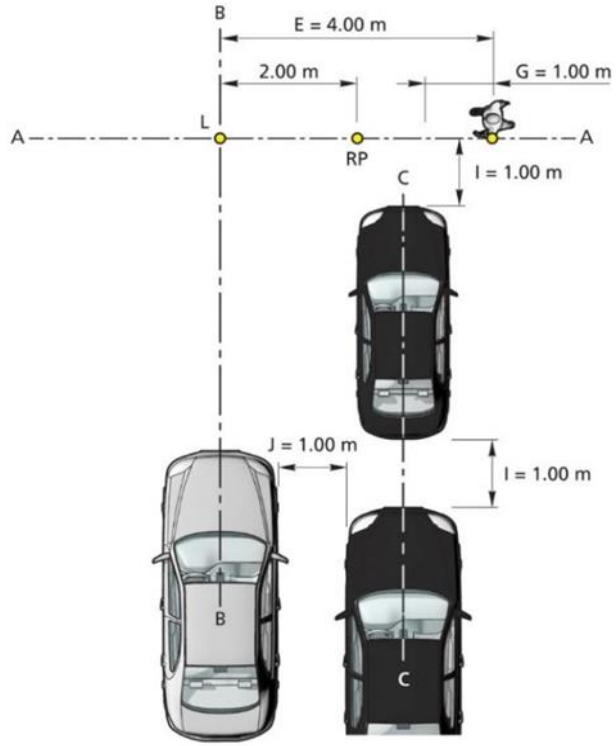


Euro NCAP AEB VRU Test protocol V 3.0.3 (2020)

Reproducible tests of ABS and AEB

AEB – NCAP test on ViL testbench

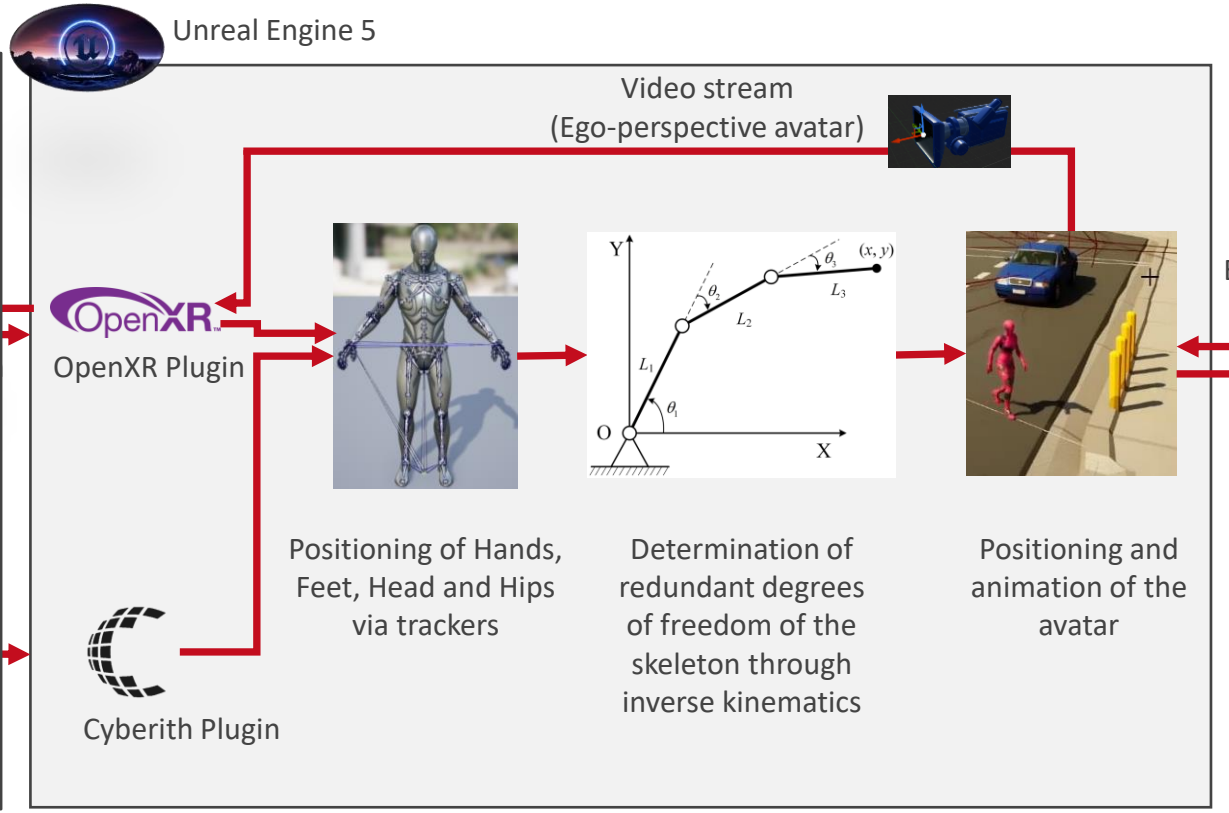
Car-to-Pedestrian Nearside Child:



Euro NCAP AEB VRU Test protocol V 3.0.3 (2020)

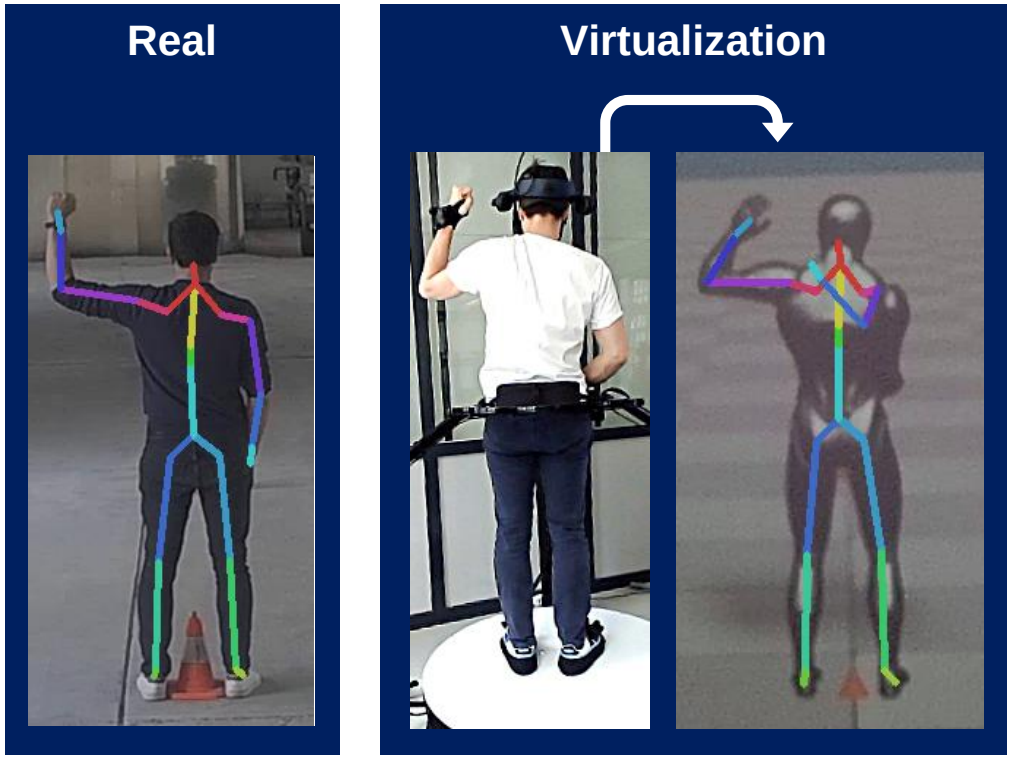
Motion laboratory and realistic pedestrian interaction

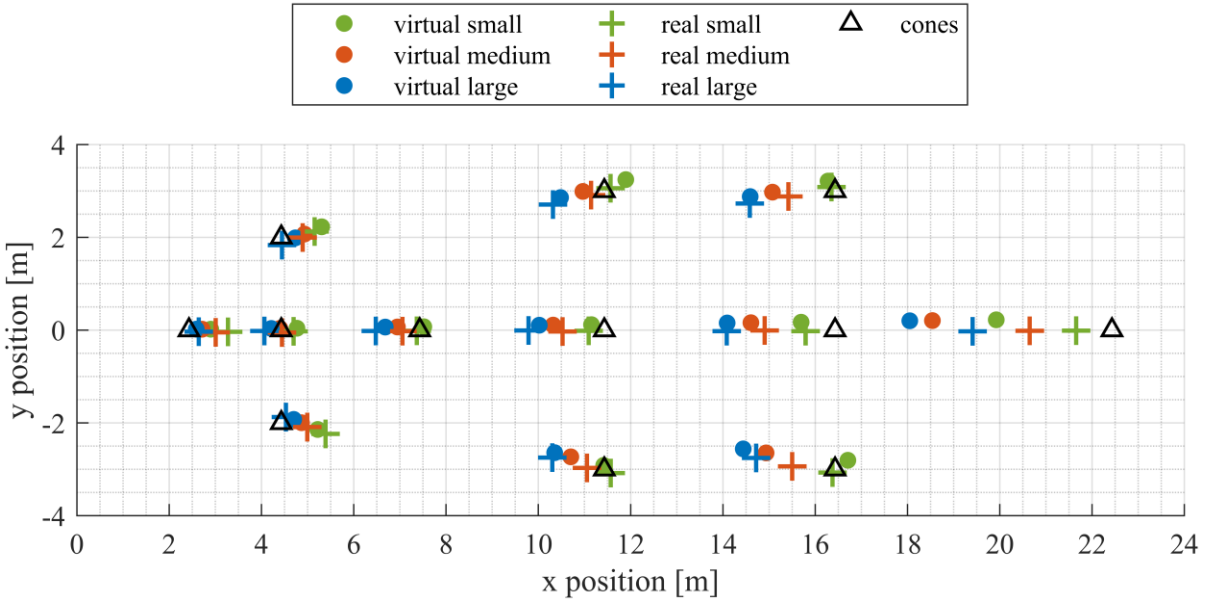
Software components and information flow



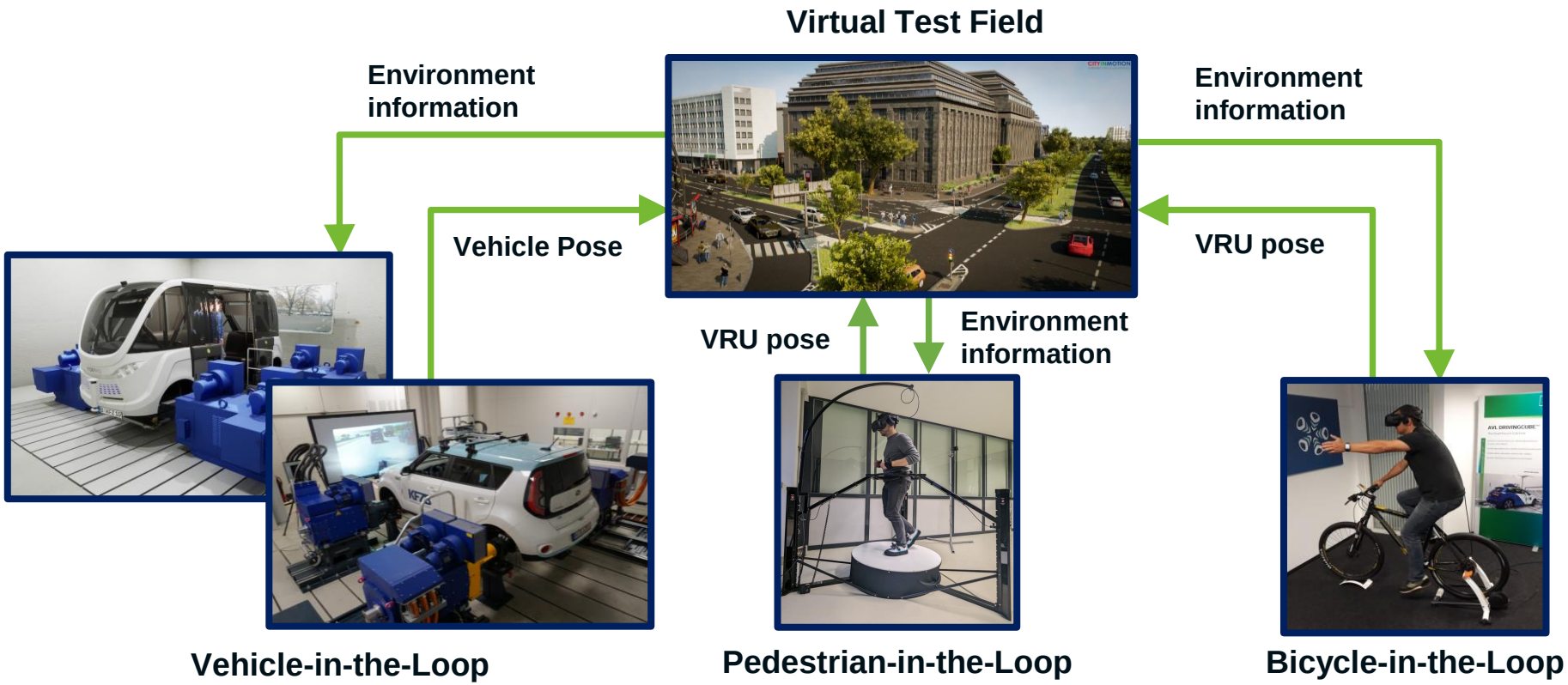
Motion laboratory and realistic pedestrian interaction

Equivalent detection of a virtualized pedestrian





Combination of ViL and Motion Lab for interactive ADAS testing



Outlook – Real interactions with VRUs in urban scenarios

Conclusion

MiL / SiL / HiL	Human-and-Vehicle-in-the-Loop	On road test
+ High reproducibility	+ Uses “Ready-to-drive” vehicle	+ Real vehicle behavior
+ Easily scalable	+ Allows complex scenarios	+ Detects unknown scenarios
+ Cheap in operation	+ Very close to real operation	- Limited reproducibility
+ High safety	+ High reproducibility	- High test effort
- Challenge to validate models	+ High safety	- No systematic testing possible
- Limited accuracy of simulated vehicle behavior	+ Real interactions with VRUs	- Limited safety
	- Limited resource	
	- Requires careful preparation