Validation Of Automated Driving

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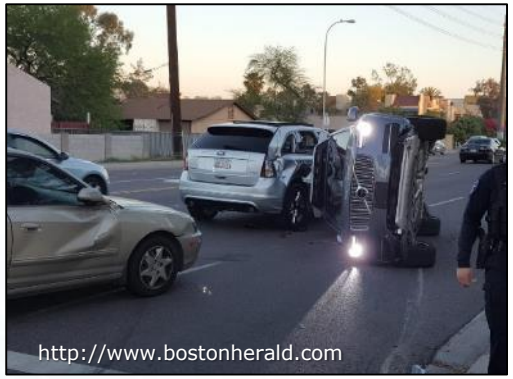
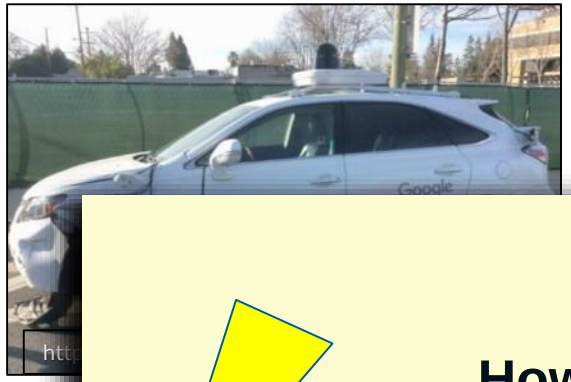
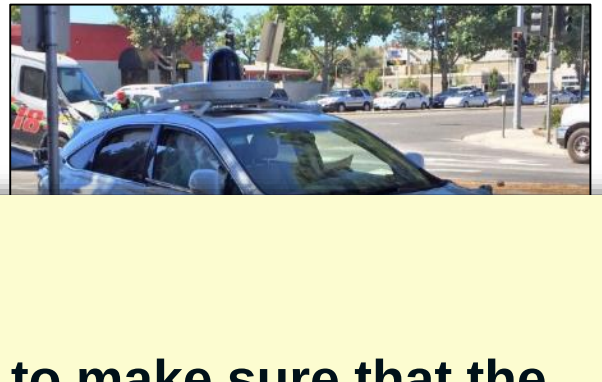
Eco-System in Automated Driving

Source: AutoSens Conference (www.auto-sens.com), Vision Systems Intelligence, LLC. (www.vsi-labs.com)

How to avoid this?
…. and achieve that?



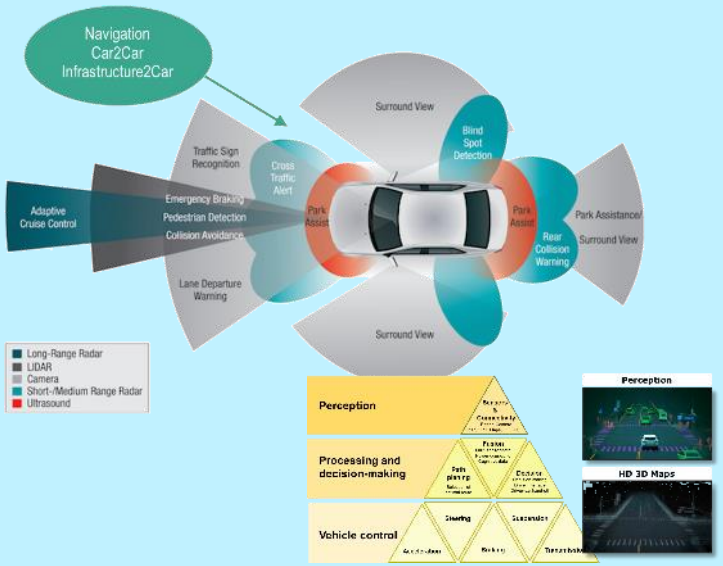




How to make sure that the automated vehicle behaves correct in EVERY situation?

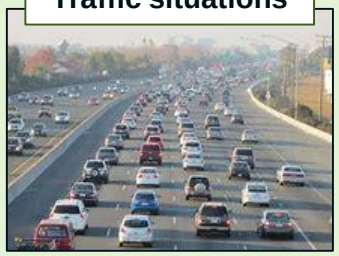
Automated vehicle and environment interact

A Complex System …



… in a Complex Environment

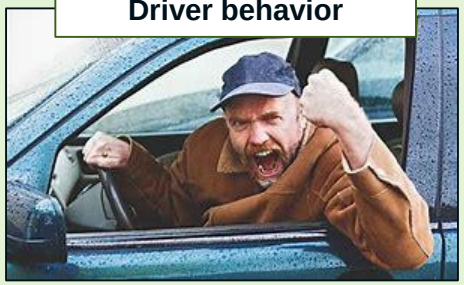
Traffic situations



Road conditions

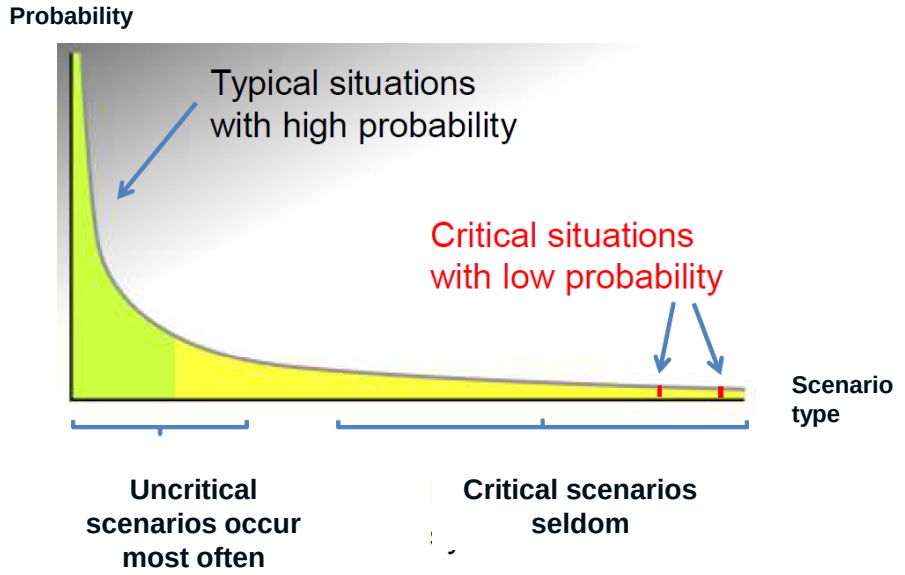
Weather conditions

Driver behavior



ADAS/AD System Validation Challenges

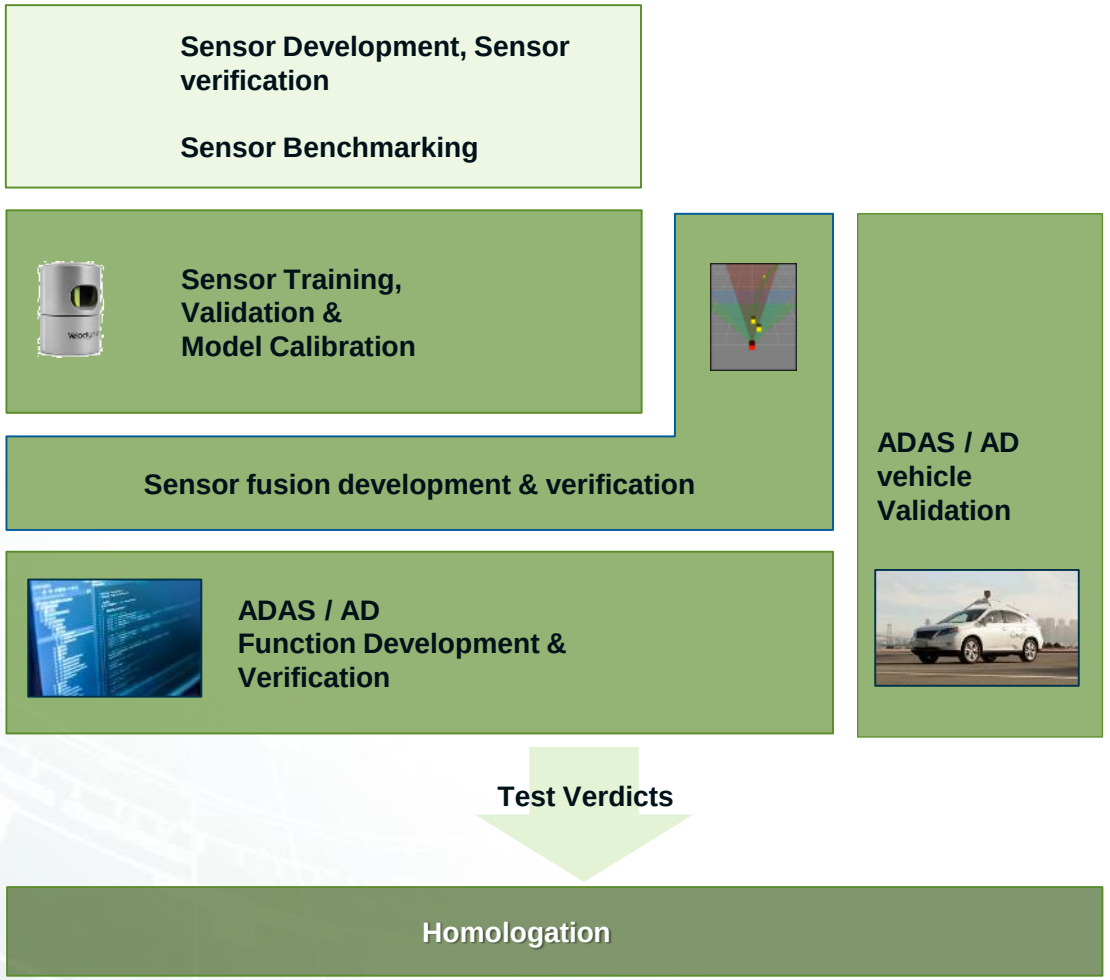
- Automated vehicles are most complex cyber physical systems
- Environment interacts with automated vehicle
- Uncountable number of scenarios
- Critical scenarios occur only rarely
- AD sensors imperfect in rough weather conditions



- **Only road testing not enough**
- **Virtual testing required too**
- **Artificial intelligence requires new validation methods**

Source: Prof.Dr. Ing. Philipp Slusallek / DFKI: Artificial Intelligence & Digital Reality - Do we need a "CERN for AI"

ADAS/AD Validation Tasks



Six different ADAS/AD test tasks:

- Sensor validation
- Sensor model calibration
- ADAS/AD sensor fusion validation
- ADAS/AD function validation
- ADAS/AD vehicle validation
- Homologation

Accelerated ADAS/AD System Validation required

Potential **Acceleration** measures for ADAS/AD System Validation:

1. Virtual Validation: Perform tests in virtual environment using high performance parallel computing
2. Select relevant Scenarios: Test only relevant scenario from real world driving (which may case safety issues)

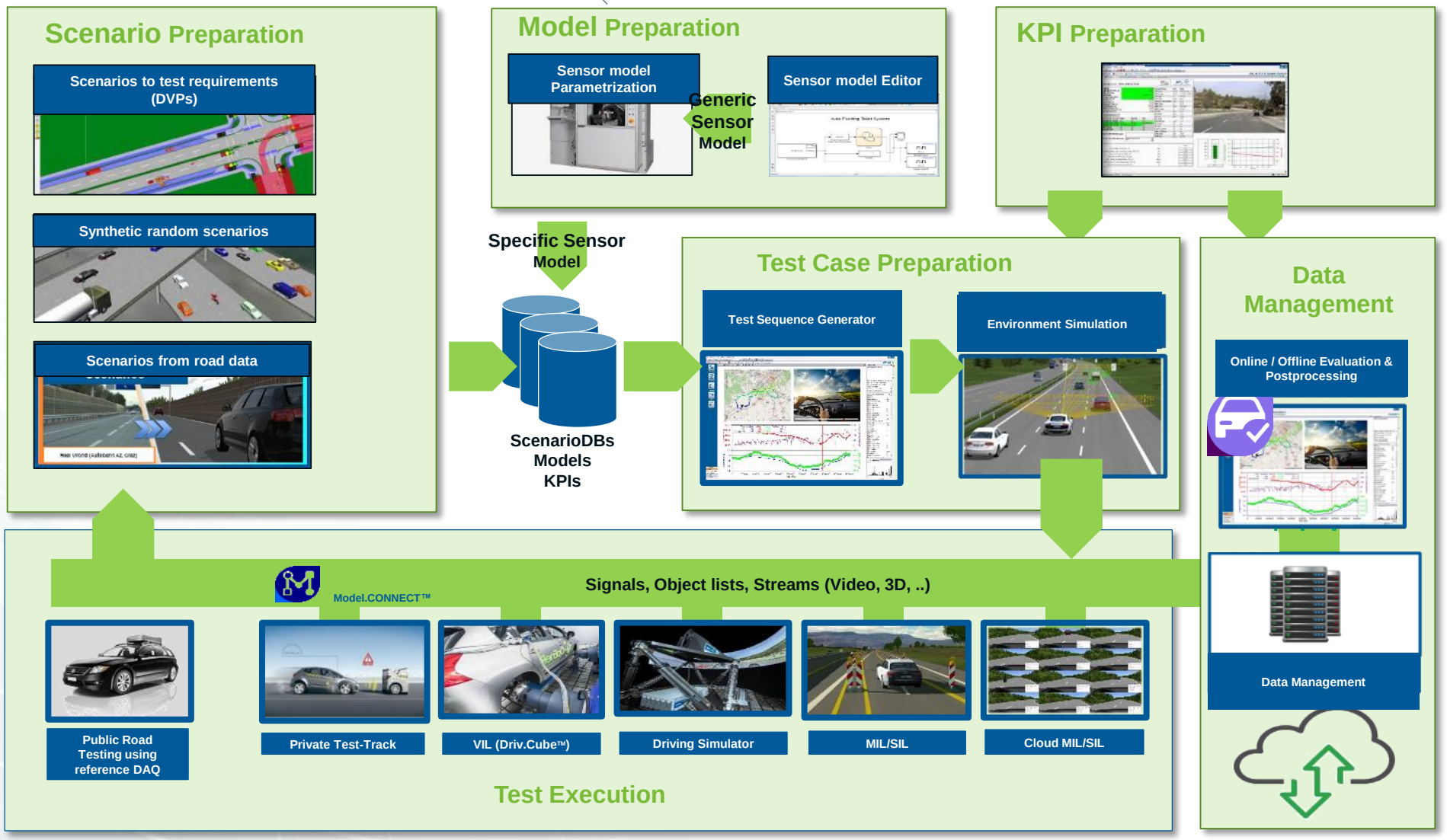
Problem:

- Excellent simulation models of vehicle, driver, sensors as well as replica of ADAS/AD SW strategy required
- Otherwise “another” vehicle is validated

Acceleration measures **:**

3. Identify edge-cases in virtual environment
4. Test edge-cases using real sensors
5. Use road testing to validate virtual tests (models, scenarios)

Scenario based ADAS/AD Verification and Validation Tool Chain



Sources for Validation Scenarios

Scenarios, parameters and statistics are extracted and stored

Scenario Data base

Engineered scenarios

Real world scenarios
Accident Database

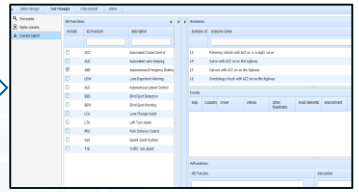
Relevant synthetic scenarios

Excerpt of criteria:
- Scenario parameter ranges
- Environment conditions (daylight, fog..)

Scenarios relevant for ADAS function

Scenario parameter ranges

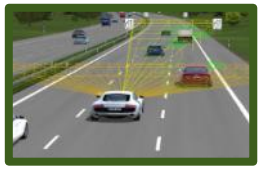
Environment conditions (daylight, fog, rain, traffic type, ..)



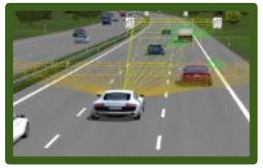
Experiment generator

List of scenarios with variations

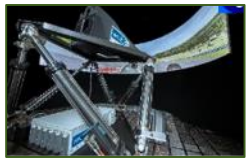
Cloud



MIL



HIL

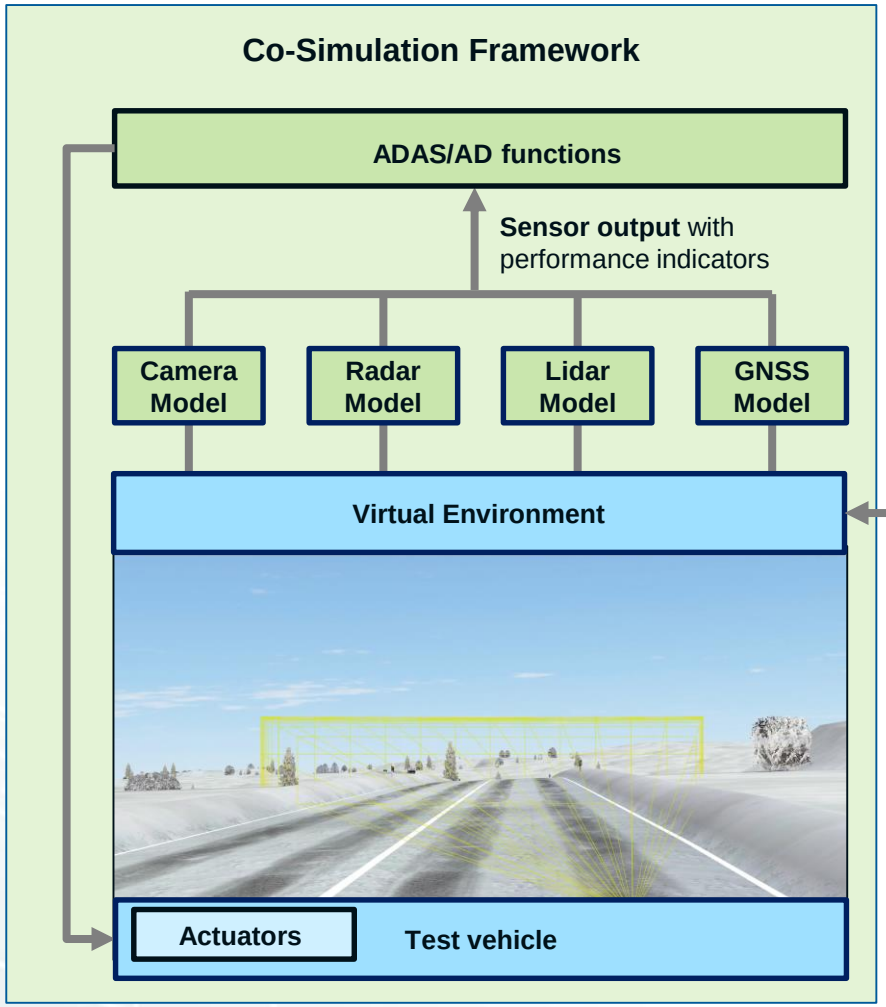


VIL

Road

Virtual Test Environment

Source: RobustSense research project funded by European Commission and National funding authorities



System-under-Test

Augmented and validated sensor models

Static Scenario Content (Lanes, traffic signs, barriers, …)

Dynamic Scenario Content (other vehicles, pedestrians, dynamic traffic signs,, …)

Scenario parameters (e.g. weather conditions)

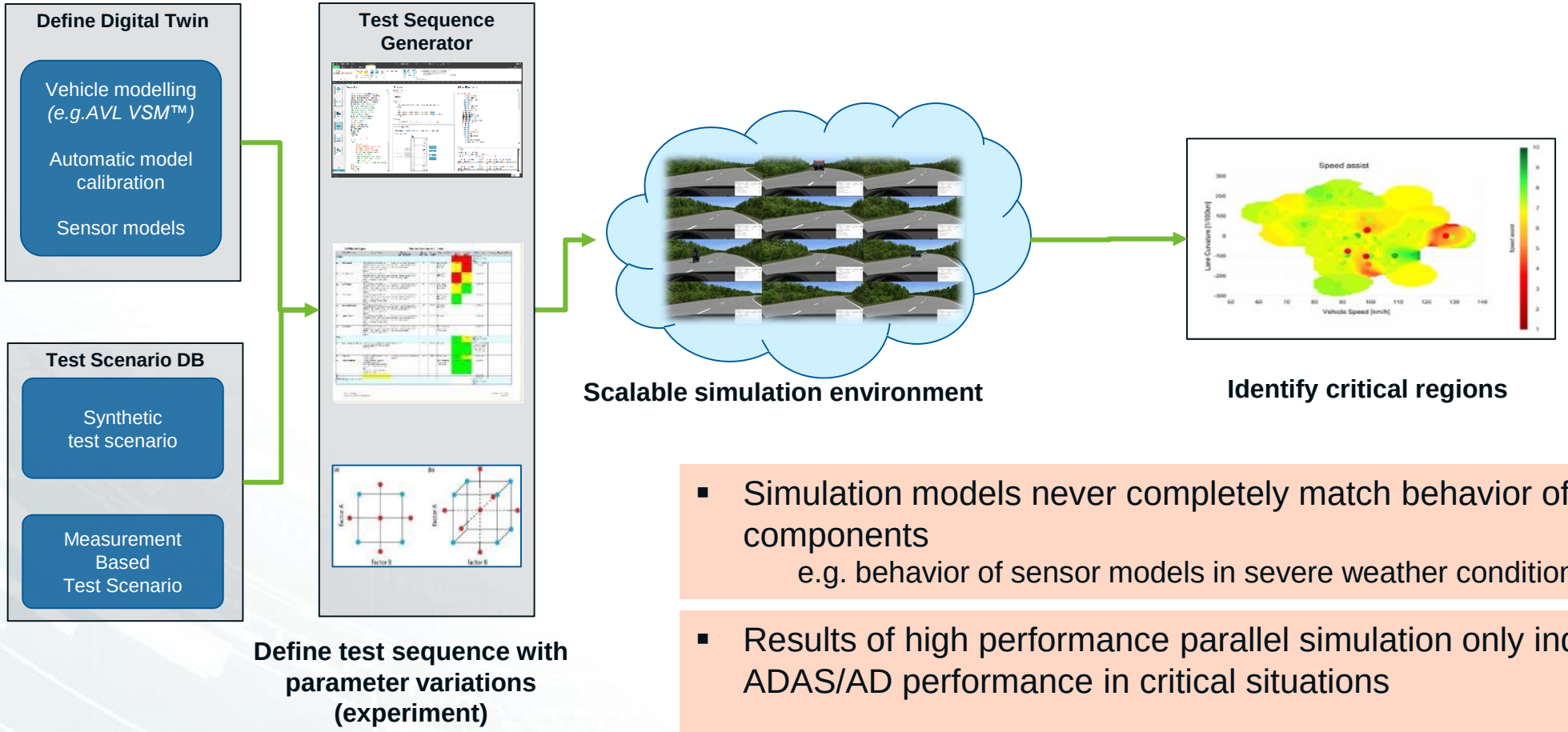
OSI

FMI

OpenDrive
OpenCRG
OpenFlight

OpenScenario

Cloud Simulation to Identify Critical Scenarios



- Simulation models never completely match behavior of real components
  - e.g. behavior of sensor models in severe weather conditions
- Results of high performance parallel simulation only indication of ADAS/AD performance in critical situations
- Additional tests with **real components** required (Verification of model performance)

Cloud Simulation to Identify Critical Scenarios

Define Digital Twin

Vehicle modelling *(e.g.AVL VSM™)*

Automatic model calibration

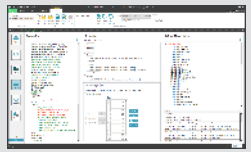
Sensor models

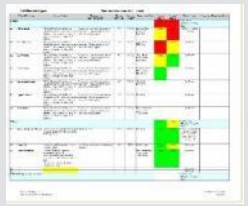
Test Scenario DB

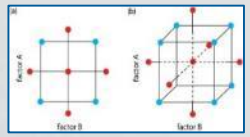
Synthetic test scenario

Measurement Based Test Scenario

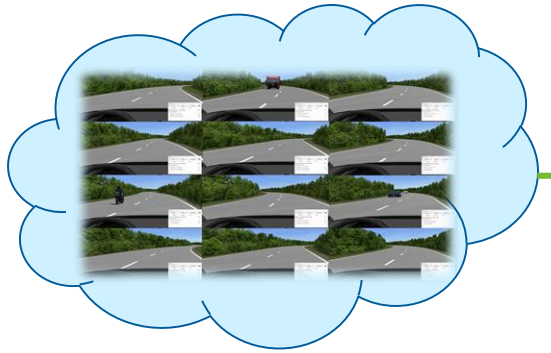
Test Sequence Generator



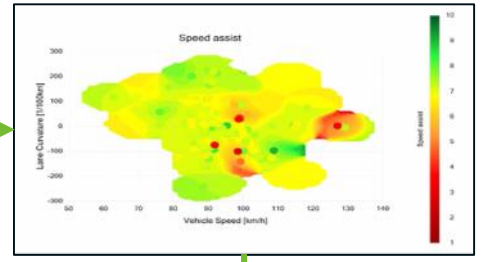




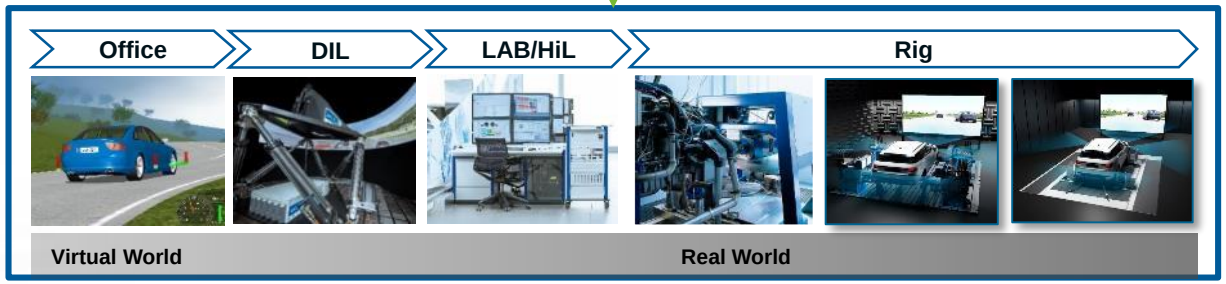
Define test sequence with parameter variations (experiment)



Scalable simulation environment

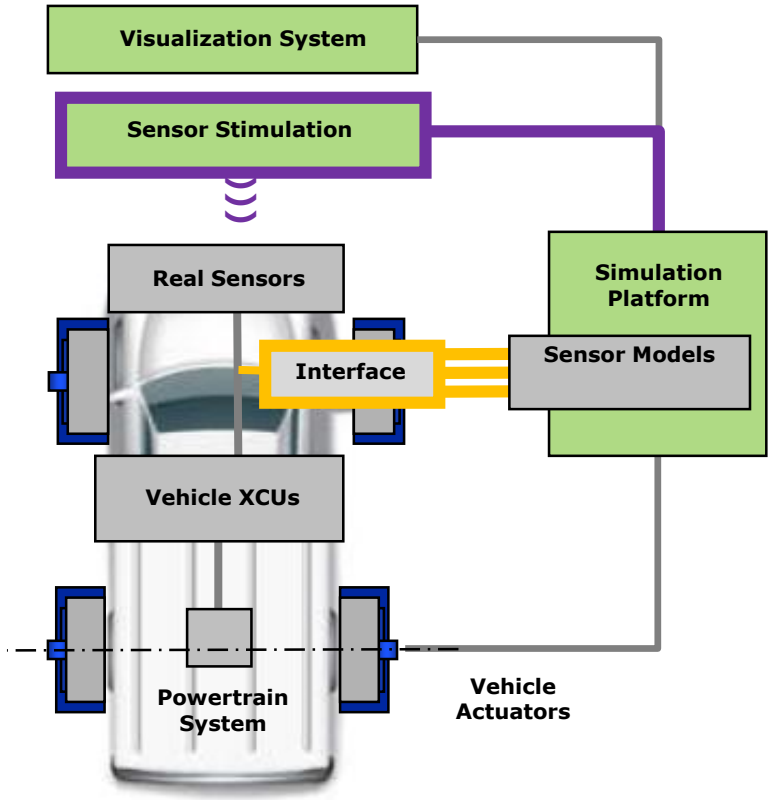


Identify critical regions

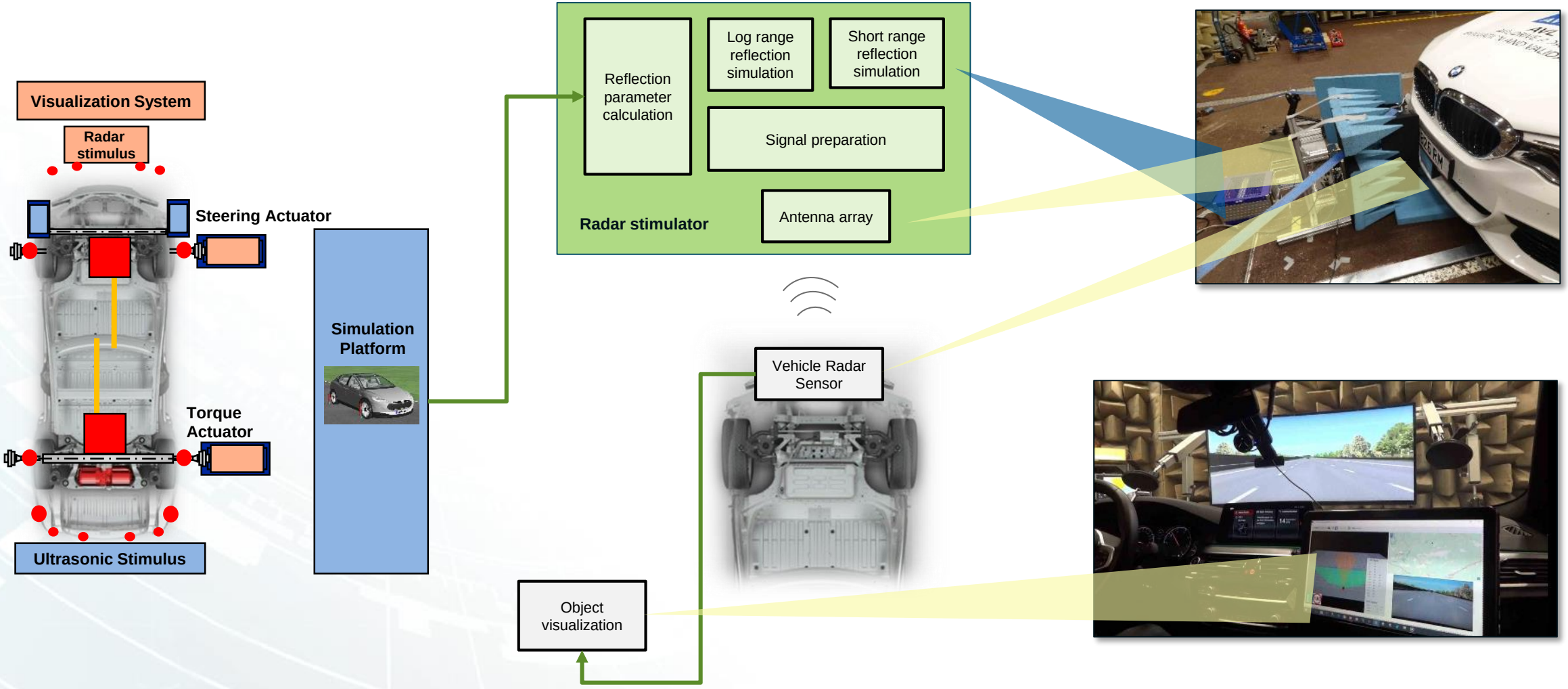


Validation of system performance in critical scenarios using more detailed models or real components

Dangerous vehicle scenarios tested in save environment: AVL Driving Cube



Video Sensor and Radar Sensor Stimuli



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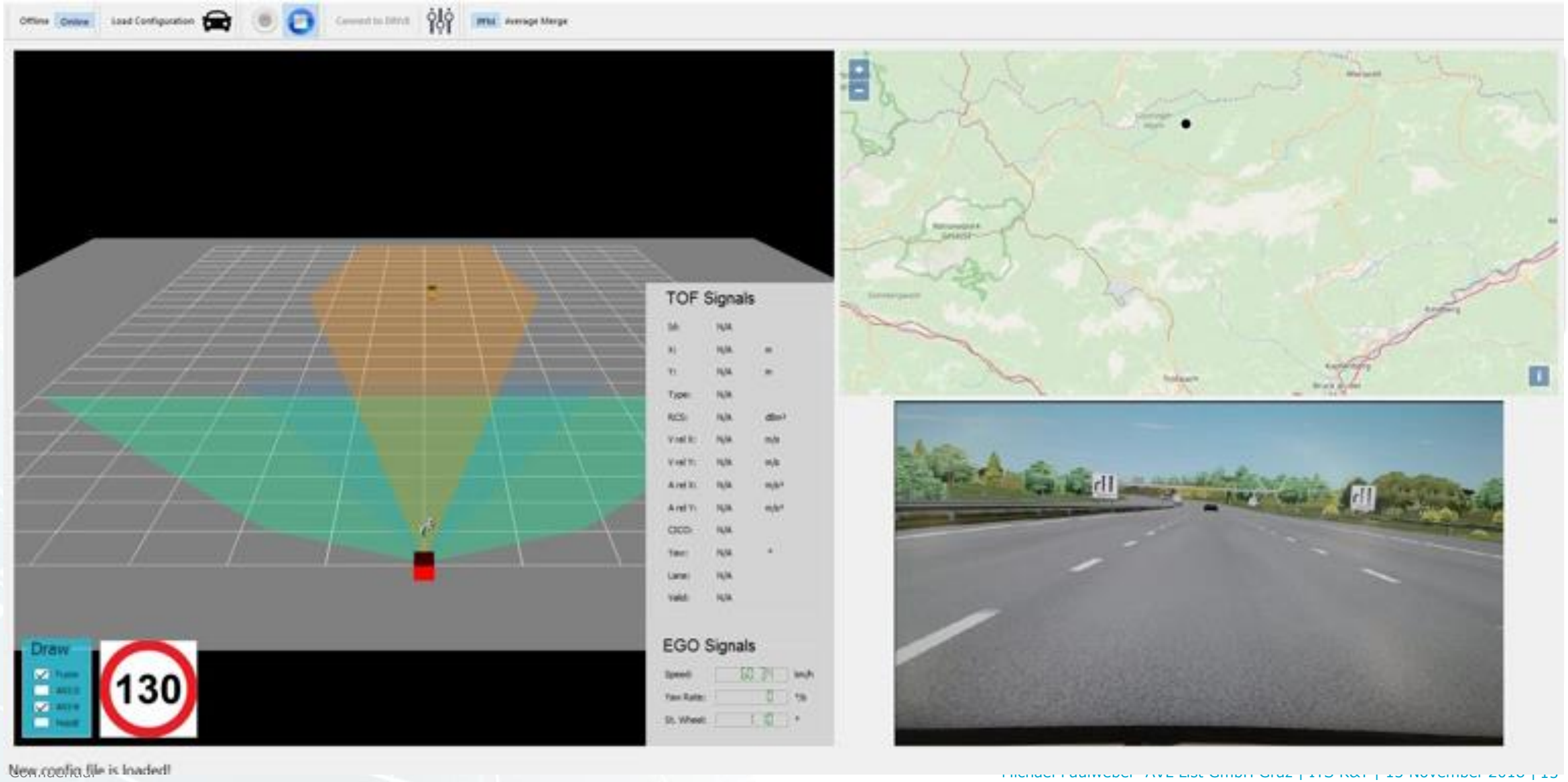
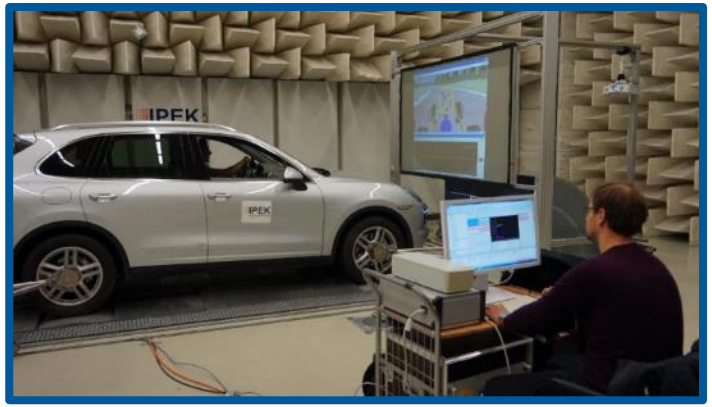


Steering Force Stimulus



Summary

- Virtual validation is key to cope with complexity of ADAS/AD validation
- Real world testing also required due to differences of digital twin and real twin
- Scenarios are base
- They come from requirements/analysis, real world data, synthetic data
- Models critical
- Model parametrization to adapt generic models to specific models essential
- Model validation significant effort
- Sensor stimulation enables near real-world tests in safe environment