ENABLING EFFICIENT TESTING OF HIGHER-LEVEL AUTOMATED DRIVING SYSTEMS
TESTING REQUIREMENTS

SAE Levels of Automation

- Level 0: Manual Driving
- Level 1: Partial Automation
- Level 2: Limited Automation
- Level 3: Conditional Automation
- Level 4: High Automation
- Level 5: Full Automation

More kilometers
More test cases
TEST METHODS / PLATFORMS

Software-in-the-Loop (SIL)
Closed-loop software testing of components in a virtual environment

Vehicle Testing
Test drives on test tracks and public roads.

Hardware-in-the-Loop (HIL)
Closed-loop, real-time testing of components in a virtual environment

Reprocessing
Open-loop injection of traces captured with a vehicle.

Cross-Validation
Virtualization
Common Components
VIRTUALIZATION

+ Modularization of simulation environments

+ Intelligent Re-use of simulation modules
SENSOR INTERFACE COMPLEXITY

SAE Levels of Automation

More sensors
Lower-level interfaces
 SENSOR INTERFACE COMPLEXITY: EFFECTS ON SIMULATION ENVIRONMENTS

### Increase in Data Rates
Vehicle environment represented in sensor detections instead of object lists.

Example: one single Lidar conveys information about several 100,000 detections, instead of a handful of objects & object states.

Overall more sensors employed.

→ More data needs to be generated and handled in simulation environments.

→ Consistency of simulated data must be ensured across different signal chains.

### Increase in Model Complexity
Mere object-based environment simulation inadequate to simulate sensor detections.

Expert know-how on sensor physics required … for each sensor technology employed!

Simulations of sensor physics (e.g. ray tracing) must be efficient.

Authors of high-fidelity sensor models want to protect their intellectual property (IP).
MULTIPLE SIMULATION ENVIRONMENTS

Generate and handle large amounts of data

Ensure data consistency

Modular, with interchangeable components

Ensure IP protection of modules
**STRATEGY & ACHIEVEMENTS**

**FOCUS:** HIL TEST BENCHES WITH DSPACE COMPONENTS

**Sensor Simulation Models**

Models provided by sensor ECU suppliers.

Black-box FMUs (FMI standard), integrated into Linux-based BMW framework.

Same models for SIL & HIL testing.

OSI as input interface, provided by dSPACE ASM on HIL test benches.
STRATEGY & ACHIEVEMENTS
FOCUS: HIL TEST BENCHES WITH DSPACE COMPONENTS

Bus/Ethernet Data Generation
- More than 700 Mbit/s, provided through dSPACE SCALEXIO PC.
- New, more efficient concepts for manipulation of selected signals.
- Provisions for synchronization between sensor models and with video streams.

BMW Linux Model Environment

- FMU
- FMU
- FMU
- FMU
- FMU
- FMU

dSPACE SCALEXIO (incl. ASM)

Manipulation and Synchronization

System Under Test
Video Stream Generation

More than 20 Gbit/s, generated with dSPACE SensorSim & ESI unit, including optical path simulation.

Provisions for synchronization with Bus/Ethernet Data.
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KEY ENABLERS

Tool Performance
Simulation tools tailored & tested for high volume / high rate of data

Interoperability
Pro-active support of interface standards (“Open-X”)

Sensor Simulation Model Integration
Support of Functional Mockup Interface standard and commonly used libraries

Sensor Simulation Know-How
Experts to set up simulation models for OEMs / suppliers / tool providers.

Scalability
Tools and licensing suitable for desktop as well as data center
THANK YOU FOR YOUR ATTENTION