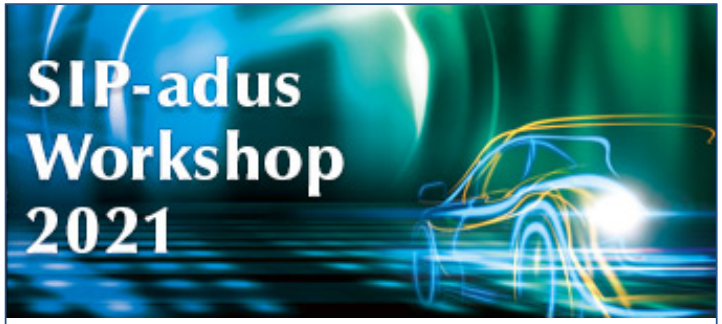
Simulation toolchain for safety assurance with focus on automotive radar

1. Virtual verification and validation (V&V)
2. Simulation toolchain
3. Reference data for RCS of traffic objects
4. Conclusions

See also SIP-adus contribution from Dr. Frank Gruson, Continental



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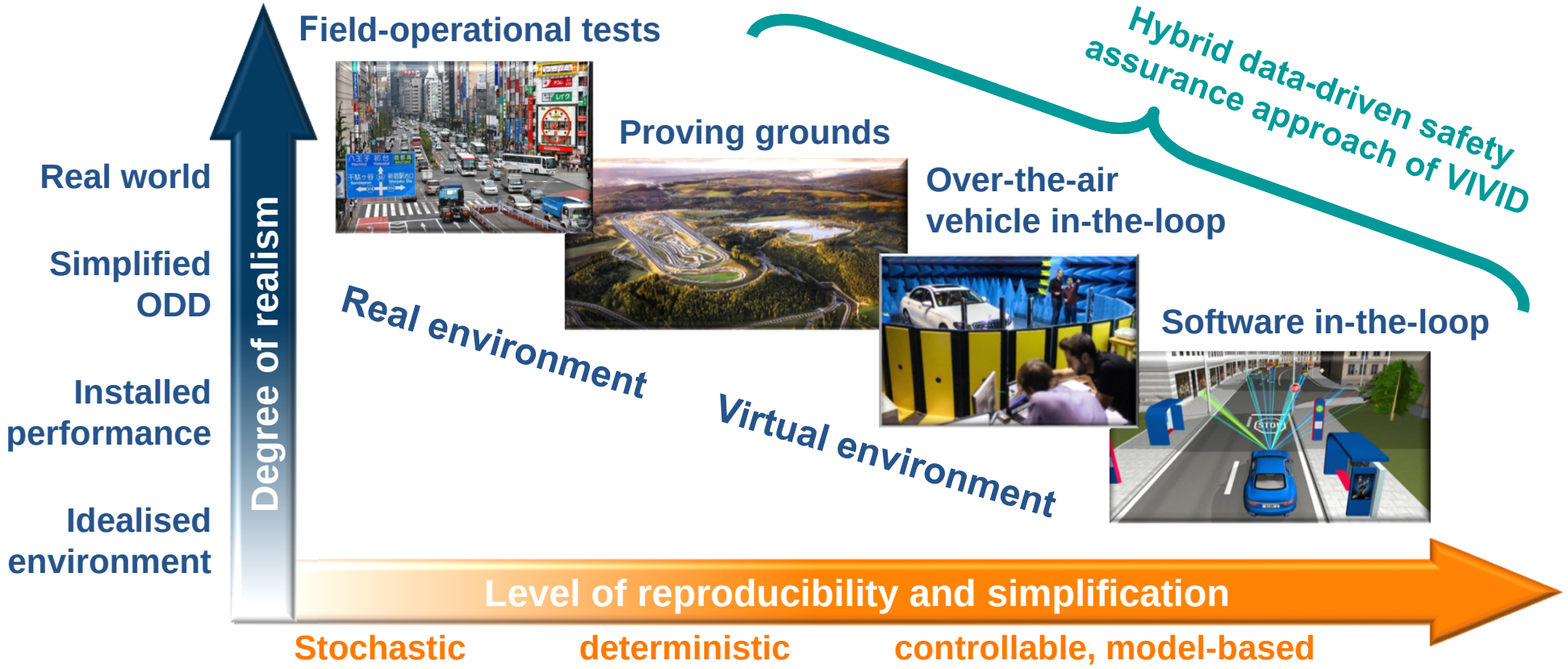
TU Ilmenau and AVL Deutschland GmbH

VIVID – German Japan Joint Virtual Validation Methodology for Intelligent Driving Systems (16ME0164K)

Federal Ministry of Education and Research

Cabinet Office

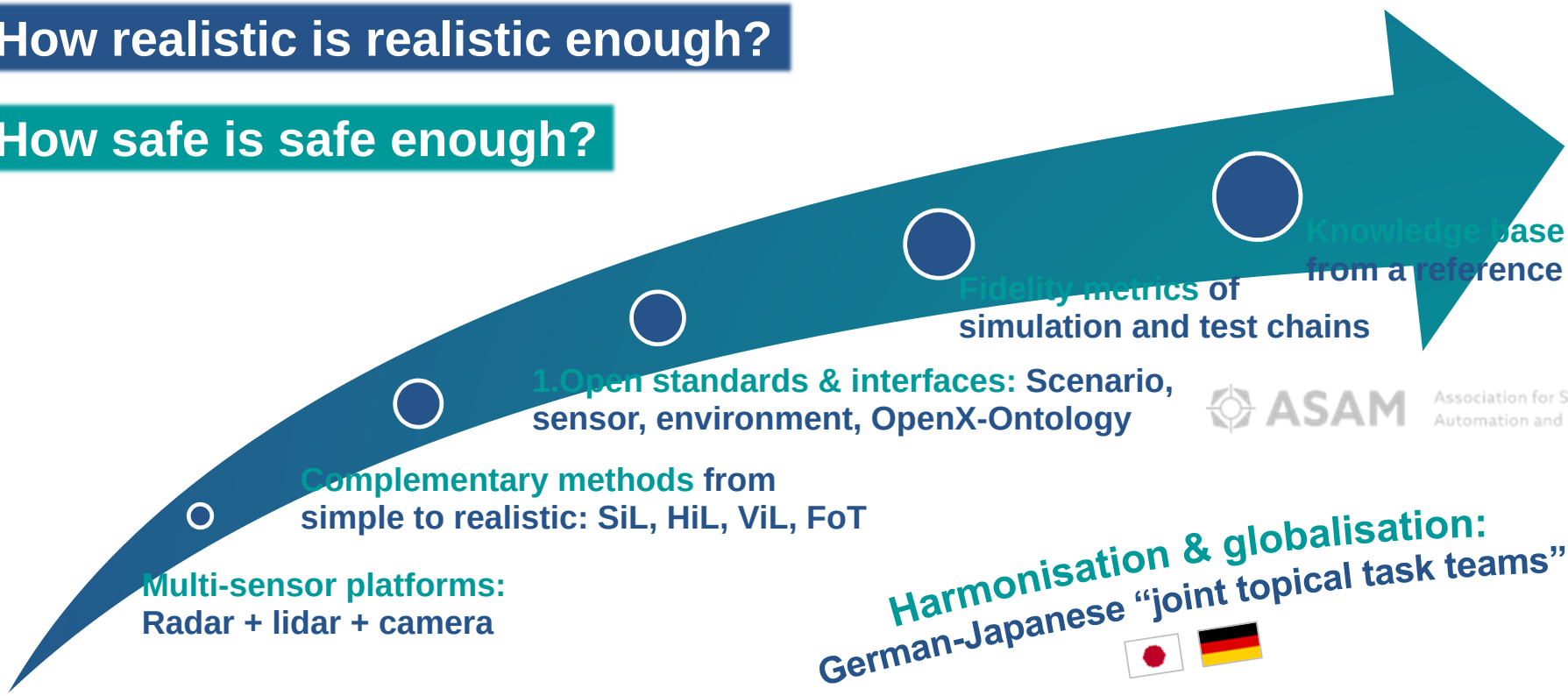
Methods and measurability of safety assurance



VIVID key objectives: Virtual V&V

How realistic is realistic enough?

How safe is safe enough?



Multi-sensor platforms:
Radar + lidar + camera

Complementary methods from
simple to realistic: SiL, HiL, ViL, FoT

1.Open standards & interfaces: Scenario, sensor, environment, OpenX-Ontology

ASAM Association for Standardization of Automation and Measuring Systems

Fidelity metrics of
simulation and test chains

Knowledge base created
from a reference architecture

Harmonisation & globalisation:
German-Japanese "joint topical task teams"

Scenario-based verification & validation

- **Relevant** for testing and standardisation
- **Challenging ODD:** Tunnels, brigdes
- **Complex traffic conditions:** Vehicles, VRU
- **Adverse sensing conditions:** Lighting and precipitation
- **Modular decomposition:** Comparability, scalability

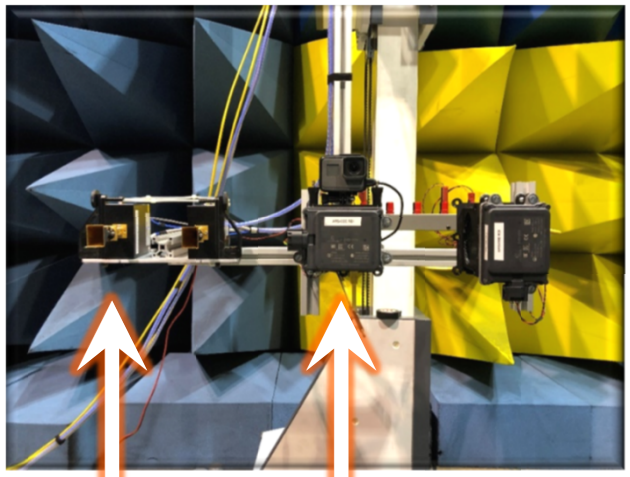
Scenarios	Radar	Camera	Lidar
WP2000 Basic scenarios B1. C2P longitudinal adult (CPLA) B2. C2P nearside child (CPNC) B3. C2P turning adult (CPTA) B4. C2C Front turn-across-path (CCFtap) B5. C2B nearside adult obstructed (CBNAO)	1 1 front	1	1
WP3000 Advanced scenarios A1. Obstacle on lane (e.g., lost cargo) A2. Varying appearance of traffic participants A3. Tunnel A4. Bridge A5. Obstacle in field-of-view	7 1 front 2 rear 4 side	5	1

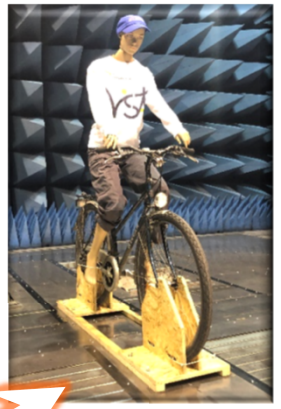
Parameter space of V&V environments

	Environment	Vehicle dynamics	Sensors	ADAS/AD function
	Integration platform (e.g. Model.CONNECT™)			
SiL	• Street & road network • Traffic infrastructure • Movable objects • Environmental conditions	• Multi-body simulation • Tire model • Steering model • Brake model	**Sensor models (SW)** • Camera • Lidar • Radar	**FMU** AD perception | AD function
HiL/OTA			**Real sensors (HW)** • Camera • Lidar • Radar	**ADAS/AD control unit** AD perception | AD function
ViL/OTA	**Sensor raw data** • Camera • Lidar • Radar		**Powertrain/mock-up with sensors and control units**	
Vehicle drive test	**Proving ground, FoT** **Real world testing**	**Full vehicle with sensors and control units**		

Scenario generation

Radar raw data for traffic participants and road objects



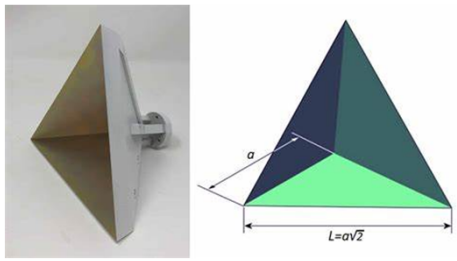


- Vector network analyzer with mm-wave horn antennas
- Commercial automotive radar (ARS430)
- Semi-anechoic chamber
- Polarized, calibrated, post-processed, camera-controlled
- Test objects relevant for selected scenarios

RCS measurement results

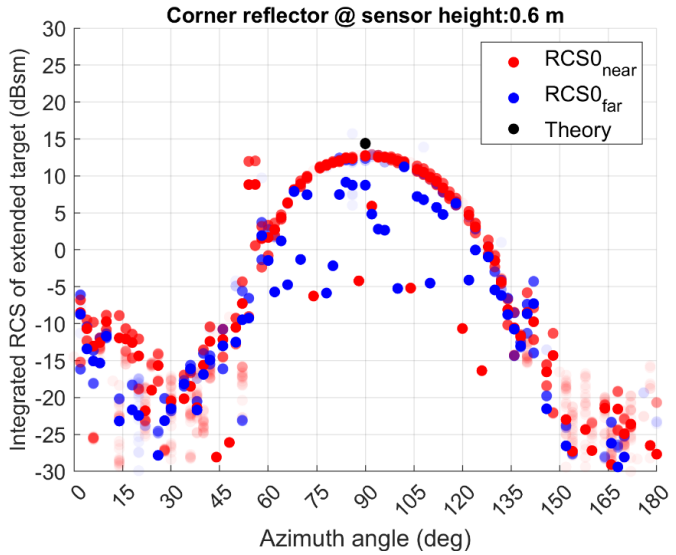
- Realistic measurement distance (radiative nearfield)
- Range-gating and direction-gating, RCS integration
- RCS calibration with corner reflector

- Mid-sized passenger cars (different brands)
- Contours and multiple-reflections
- 3D mapping of scattering centers



www.miwv.com/wp-content/uploads/2019/10/tri.jpg

$$\sigma = \frac{4}{3}\pi a^2 \cdot \left(\frac{a}{\lambda}\right)^2$$



RCS signatures of elementary traffic objects

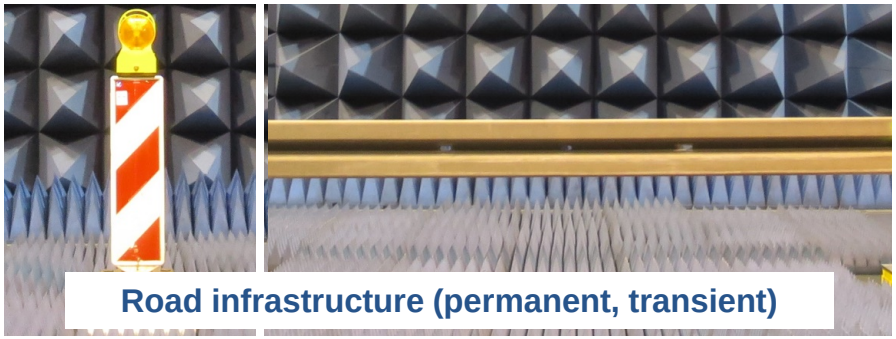
Measurement technique

- Frequency f = 67...115 GHz
- Polarization HH and VV
- Horizontal scans, φ = 0...180°
- Time domain gating
- Statistical analysis

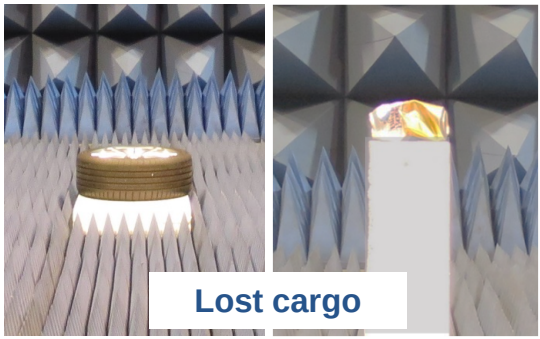
Measurement objects

- Traffic signs (different shapes and materials)
- Warning beacon
- Guardrail and posts
- Lost cargo: Wheels and cans (intact and crushed, different orientations)

Traffic signs with posts

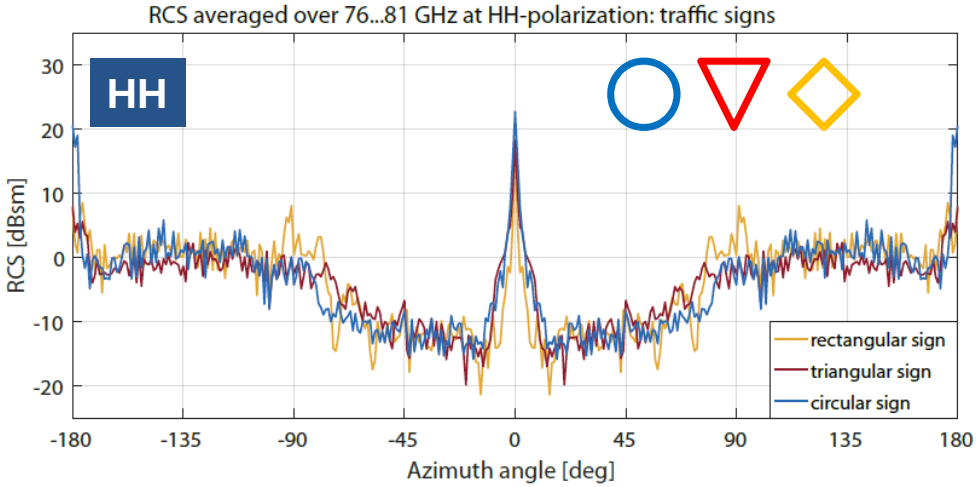


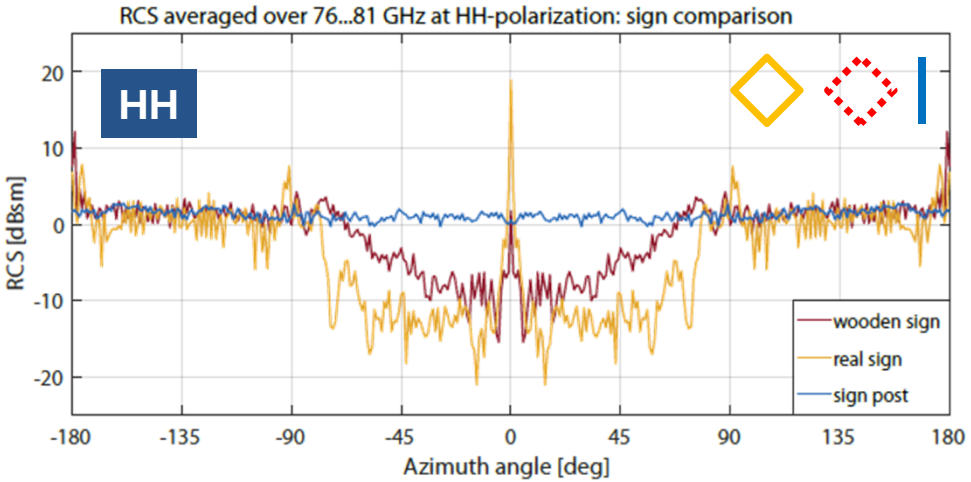
Road infrastructure (permanent, transient)

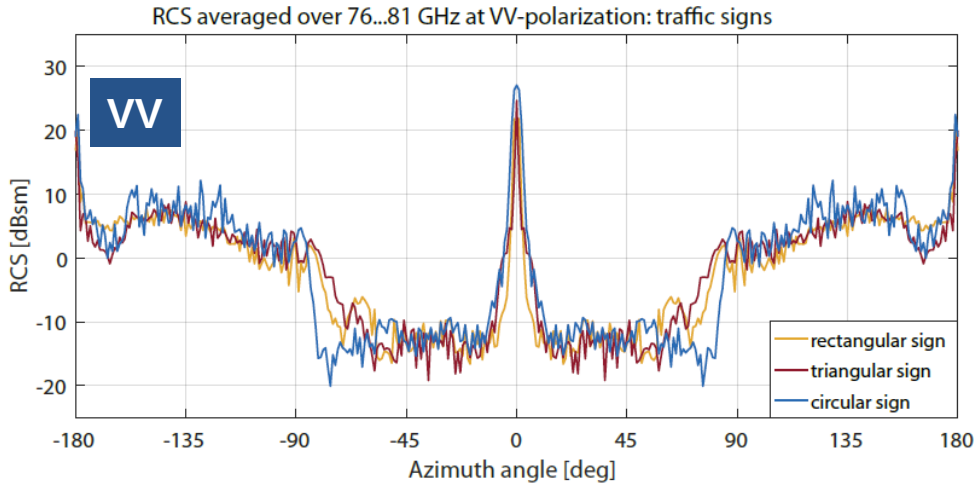


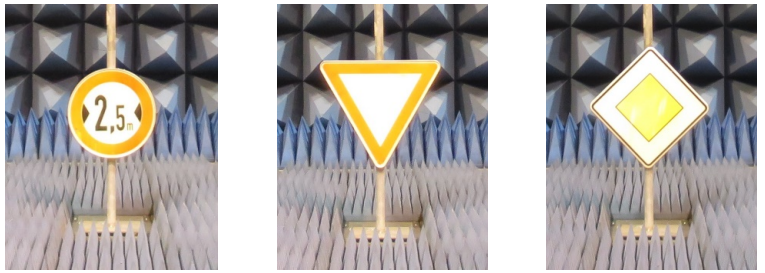
Lost cargo

RCS signatures of traffic signs



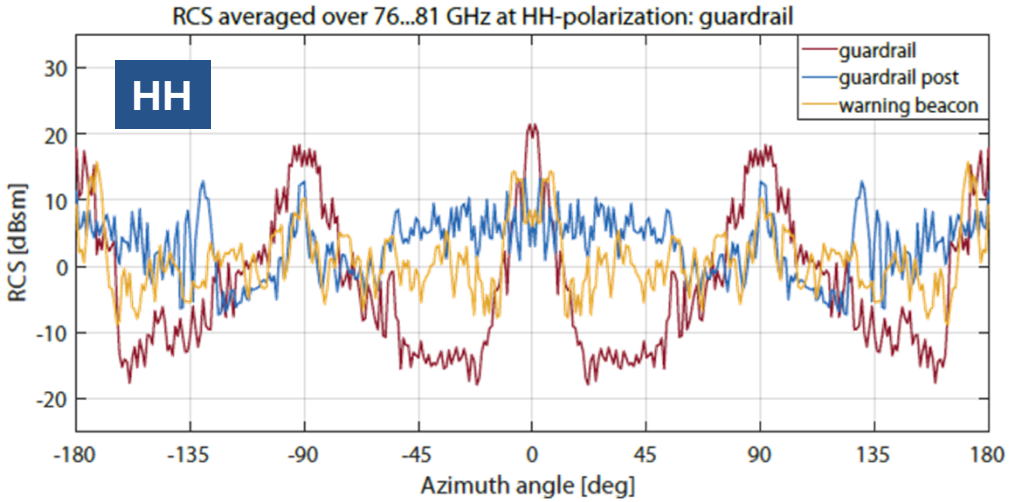


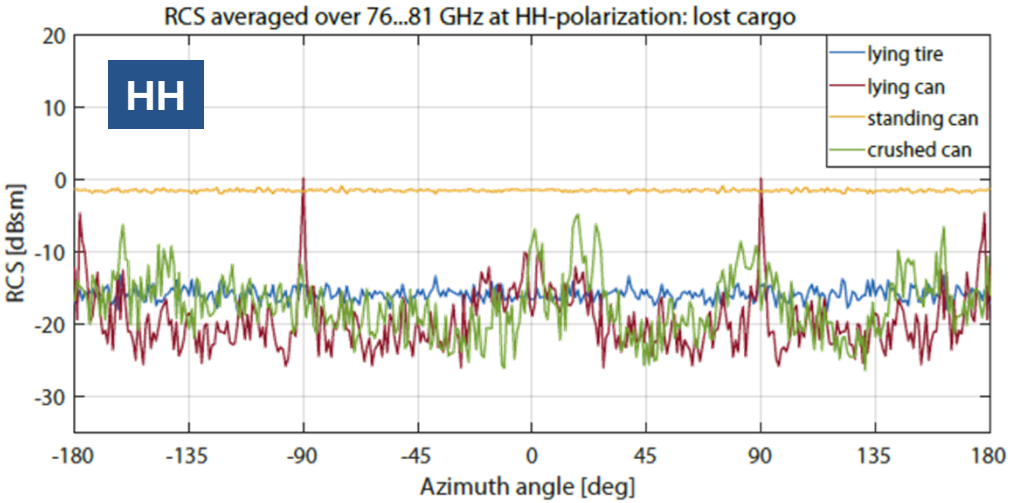


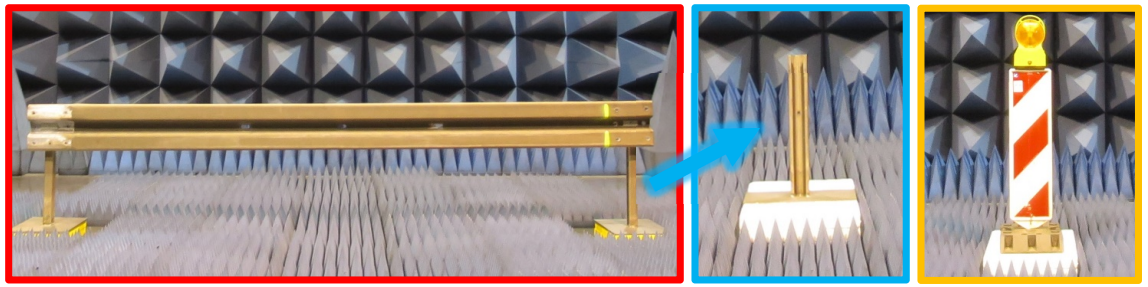


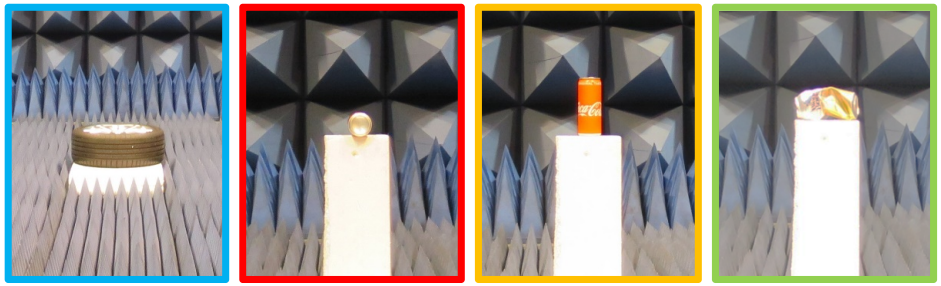
- **Angle-dependent RCS values**
- **Geometrical structure and aspect ratios**
- **Material composition**

RCS signatures of beacons, guardrails, lost cargo









- **Angle-dependent structural details**
- **Reference data input for sensor and sensor signal models**
- **Implementation into OTA/ViL simulation toolchain**

Simulation toolchain for safety assurance with focus on automotive radar

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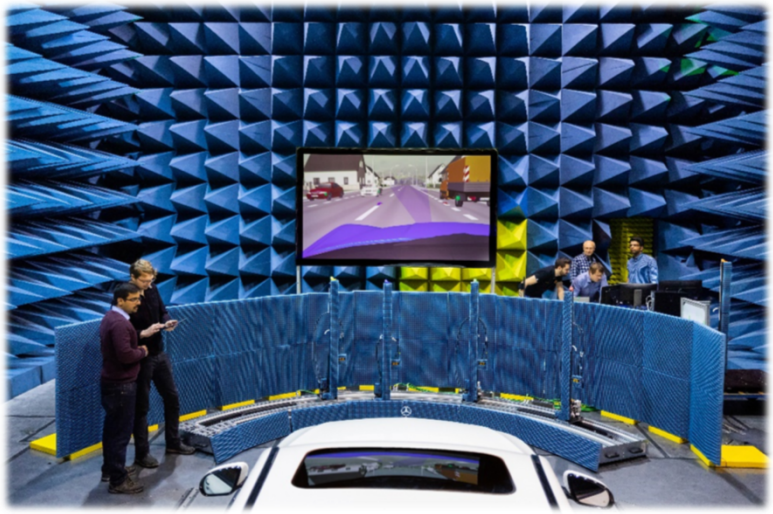
- Scalable approach towards scenario-based virtual V&V of ACD functions
- Open-source standards, models, and interfaces
- Body of measured reference data for sensor modelling
- Derivation of test fidelity metrics ongoing



Thank you for your kind attention!

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