Over-the-air vehicle-in-the-loop testing for safety assurance of automotive radar

Matthias A. Hein, **E. Asghar, S. Buddappagari, F. Kreutz, A. Schwind, R. Stephan**

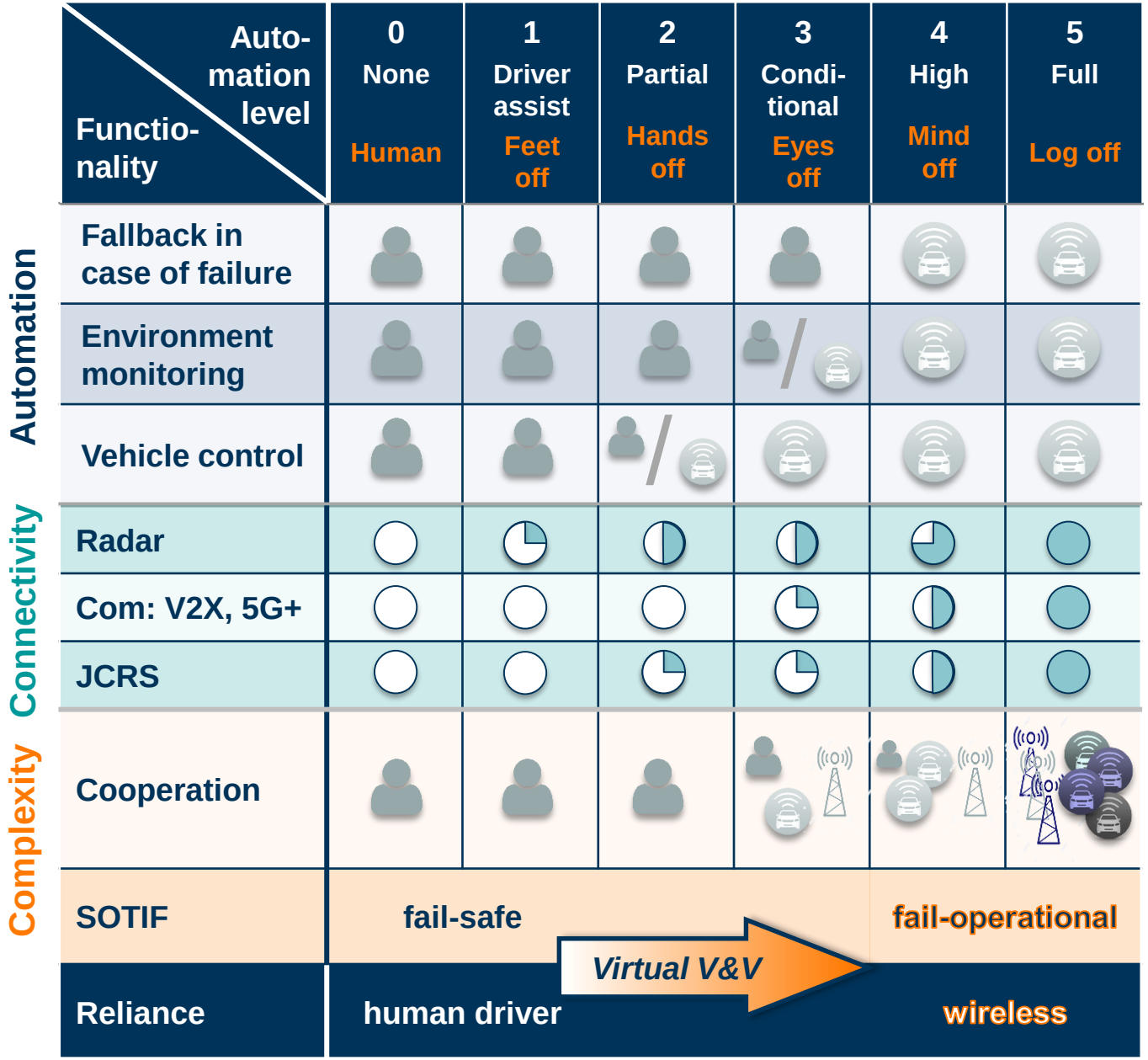
1. **Motivation**
2. **Method: OTA/ViL testing in virtual environment**
3. **Results: Virtual V&V of automotive radar**
4. **Conclusions and outlook**

OTA – over the air
ViL – Vehicle in the loop
V&V – Verification and validation

The vision of CAD

Reliable test chains for safety assurance

- **Complementary sensor technologies must outperform human cognitive abilities**
- **Sensing and wireless connectivity require fail-operational performance anywhere anytime**
- **Safety assurance and homologation require efficient testing**



CAD – Connected and automated driving
JCRS – Joint communication and radar sensing
SOTIF – Safety of the intended function

Safety assurance of CAD

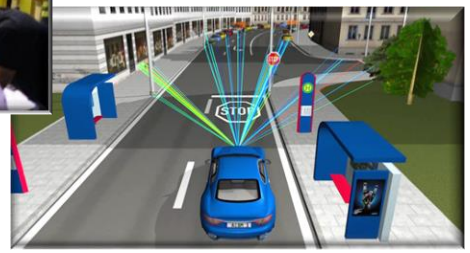
Phase space for verification and validation

Field-operational tests

Proving grounds

Over-the-air
vehicle in-the-loop

Software in-the-loop



Real world

Simplified ODD

Installed performance

Idealised environment

Degree of realism

Real environment

Virtual environment

Level of reproducibility and simplification

Stochastic

deterministic

controllable, model-based

ODD – Operational Design Domain

Closed-loop OTA virtual-drive testing of wireless functionalities

Relevant real-world scenarios

Measure & model

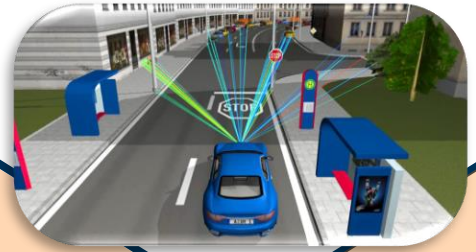
- Real drive testing
- Real world or simplified ODD

Validate & predict

Virtual environment

Emulate & verify

- Adaptive, technology agnostic
- Installed system performance, XiL



Projection

Simulate & implement

- Road domain: Traffic, environment
- Radio domain: Signal, channel

Sreehari Buddappagari, M.E. Asghar, F. Baumgärtner, S. Graf, F. Kreutz, A. Löffler, J. Nagel, T. Reichmann, R. Stephan, and Matthias A. Hein, „Over-the-Air Vehicle-in-the-Loop Test System for Installed-Performance Evaluation of Automotive Radar Systems in a Virtual Environment“, EuRAD 2020

*To **emulate** something means to imitate or to reproduce a function of something*

FoT – Field-operational test

XiL – Anything-in-the-loop

Scenario-based OTA/ViL testing (SafeMove)

Emulation of automotive radar

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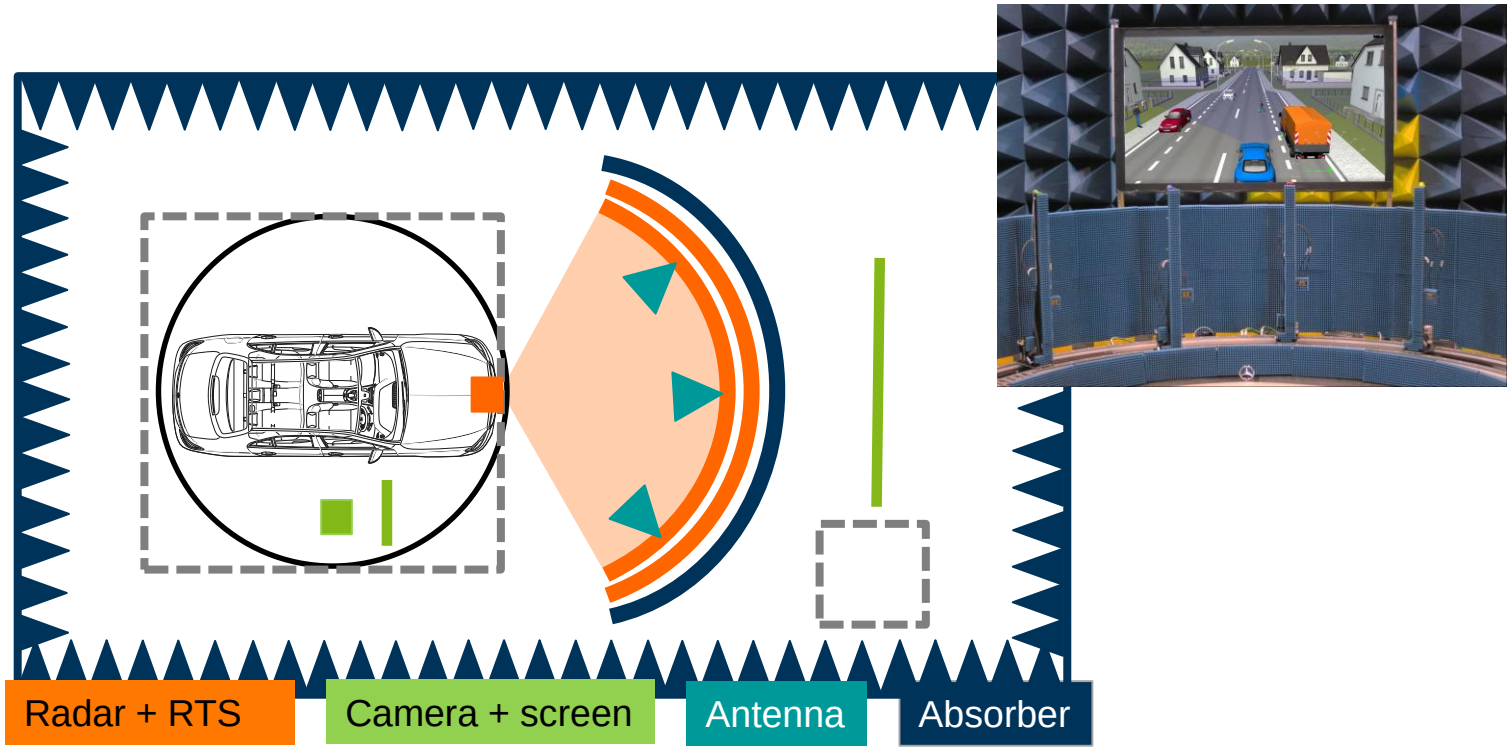
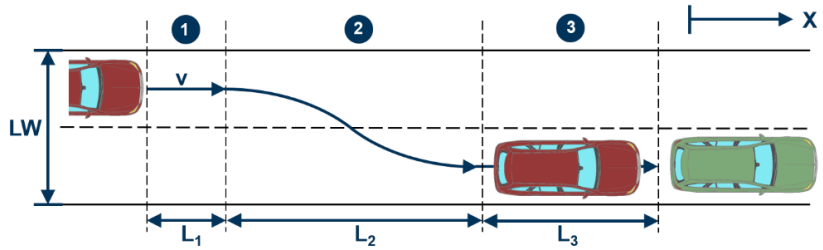
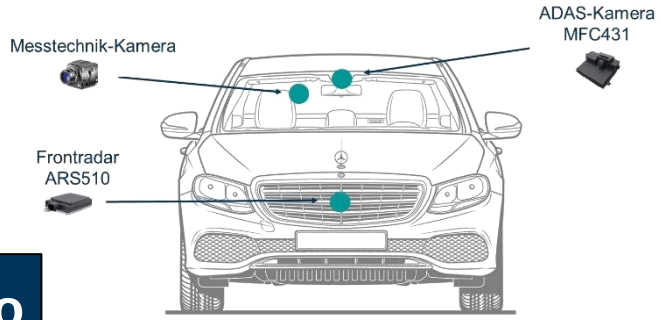


RTS – Radar target simulator

- Highway and crossing scenarios



- Radar signal propagation modeled by ray tracing
- Ground truth data acquired with research vehicle

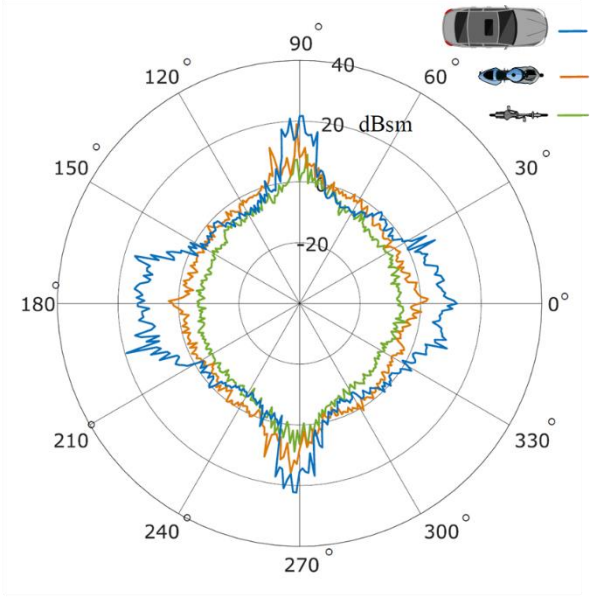


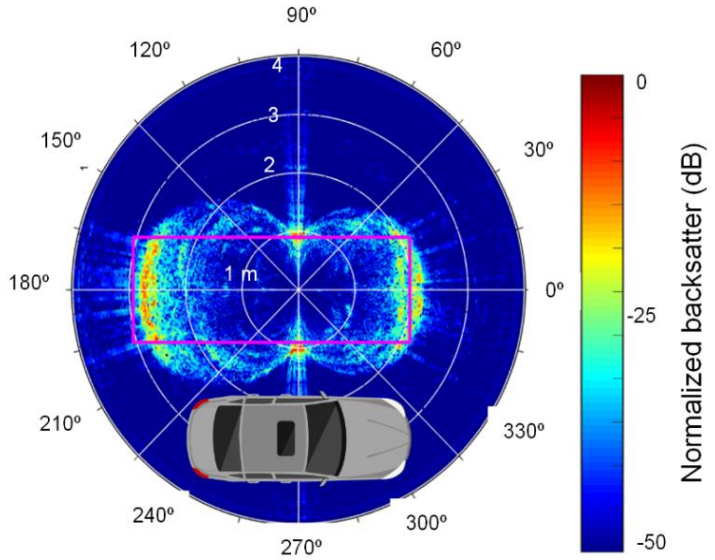
System = Radar sensor + car + wave propagation + traffic scenario

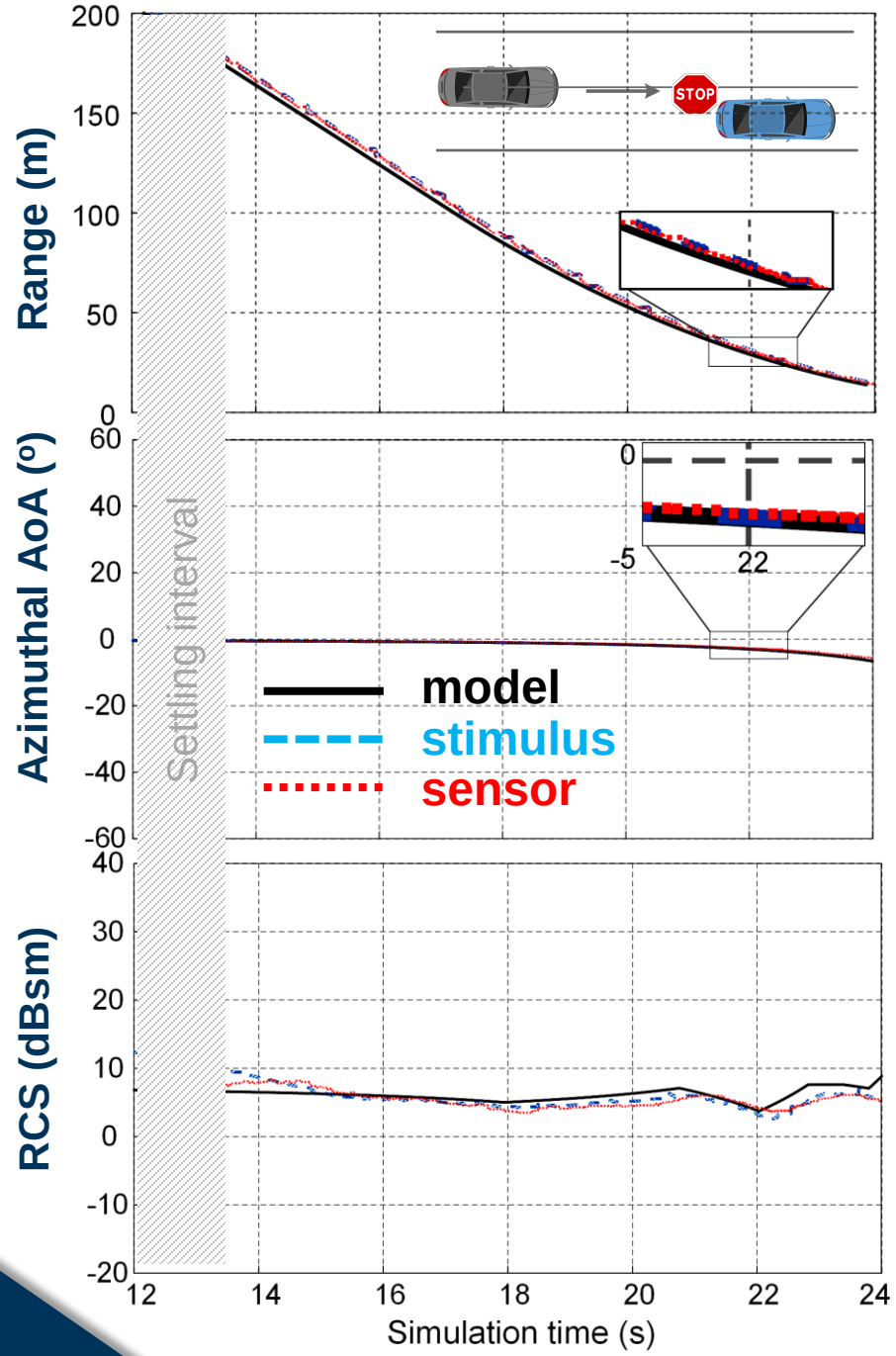
OTA/ViL testing (SafeMove)

System demonstrator and RCS measurements

- **Measured RCS patterns enhance degree-of-realism**
- **Excellent agreement: Model, stimulus, and sensor response**







Sreehari Buddappagari Jayapal Gowdu, A. Schwind, R. Stephan, Matthias A. Hein, „Monostatic RCS Measurements of Representative Road Traffic Objects in the 76 … 81 GHz Frequency Band “, IEEE Radar Conference 2020

SafeMove – Video

Virtual lab tour at: http://www.mobilitaet-thueringen.de/fileadmin/ThIMo/Tour/index.html

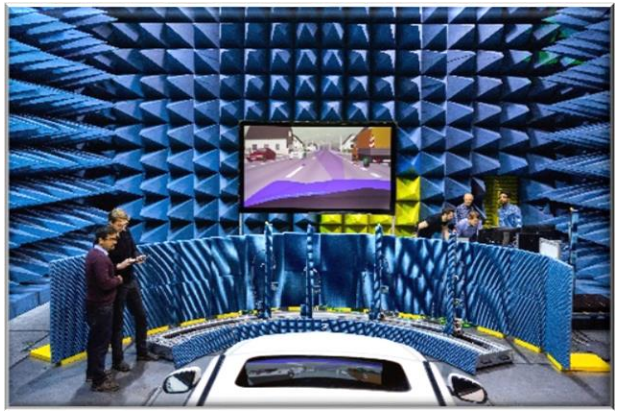
http://www.mobilitaet-thueringen.de/en/competence-field/wireless-and-information-technologies.html

Safety assurance through OTA/ViL testing

Conclusions and next steps

1. Virtual verification and validation

- Applicable to virtually any wireless functionality
- Indispensible for future drive automation
- Configurable and adaptive
- Installed performance testing includes real-world imperfections



2. Next steps

- *VIVID* – "German-Japan joint virtual validation methodology for intelligent driving systems" (Project start October 1, 2020)

Federal Ministry of Education and Research

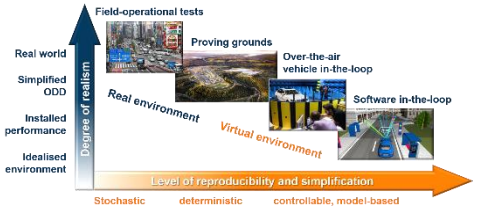
Cabinet Office

Virtual validation tool chain for CAD

VIVID Key objectives

How safe is safe enough?

UNECE



- Simulation and test chains: Fidelity metrics and KPI
- Complementary methods from simple to realistic: SiL, HiL, ViL, FoT
- Multi-sensor platforms: Radar, lidar, camera
- Open interfaces: Scenario generation, sensor and environmental models, co-simulation
- Building a reference architecture => creating a knowledge base

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VIVID

Scenario-based V&V tool chain

Test scenarios and test strategies

- Environments: Highways, toll gates, bridges, parking
- Lighting and weather conditions (bright sun, twilight, rain, fog, snow)
- Traffic participants (Vehicles, VRU, RSU, …)
- Digital twins of environments and sensors

	Radar	Camera	Lidar
Easy to test, yet relevant	1 (front)	1	0
Realistically complex	7 = 1 + 2 + 4 (front, rear, side)	5	1

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Thank you very much for your attention!

あなたの注意をどうもありがとうございました

Contact

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