The VIVID sensor simulation tool chain for scenario-based safety assurance

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TU Ilmenau (Project coordination)

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

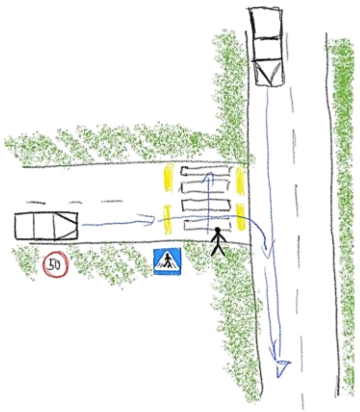
Federal Ministry of Education and Research

Cabinet Office

Thüringer Innovationszentrum MOBILITÄT
TECHNISCHE UNIVERSITÄT ILMENAU
TECHNISCHE UNIVERSITÄT DARMSTADT
KIT Karlsruhe Institute of Technology
Hochschule Kempten University of Applied Sciences
DLR
AVL
Blickfeld LiDAR / scan your world
Continental
IPG Automotive
Mercedes-Benz

Virtual verification and validation in consequence

- **Distance-based → scenario-based**



- **Real environment → virtual environment**

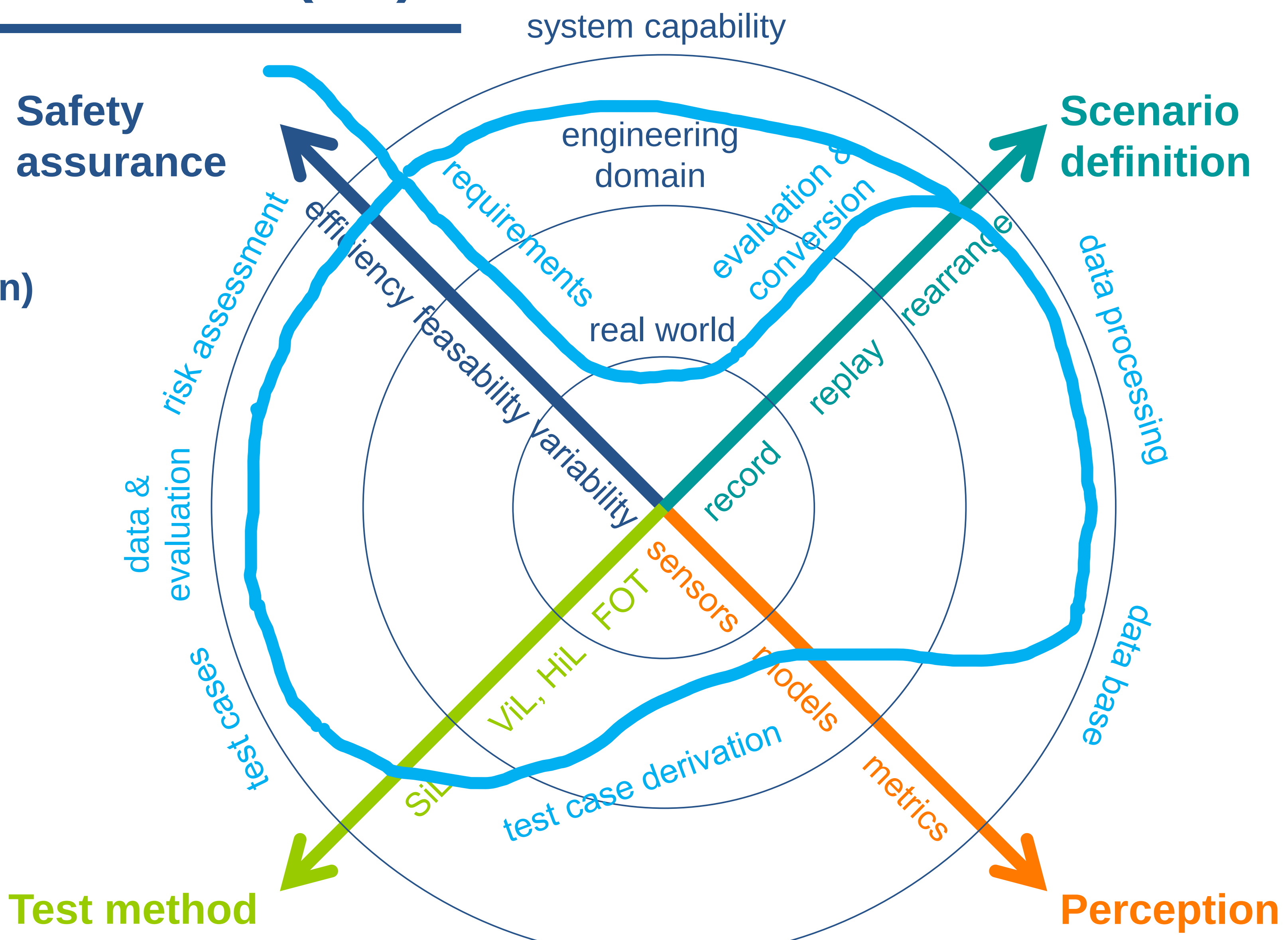
- **How X is X enough?**
- **X = Realistic, evident, consistent, justifiable, credible, safe**

- **Virtual verification and validation requires harmonized global R&D and standardization efforts**

Scenario-based safety assurance (SA)

- **X-model derived from Y-model (Gajski-Kuhn, 1983, VLSI HW design)**
- **Axes: 4 complementary domains forming the letter „X“**
- **Circles: Successive abstraction layers (top-down) for every domain**
- **PEGASUS assessment for HAD-F maps onto trajectory in X-diagram**

www.pegasusprojekt.de/



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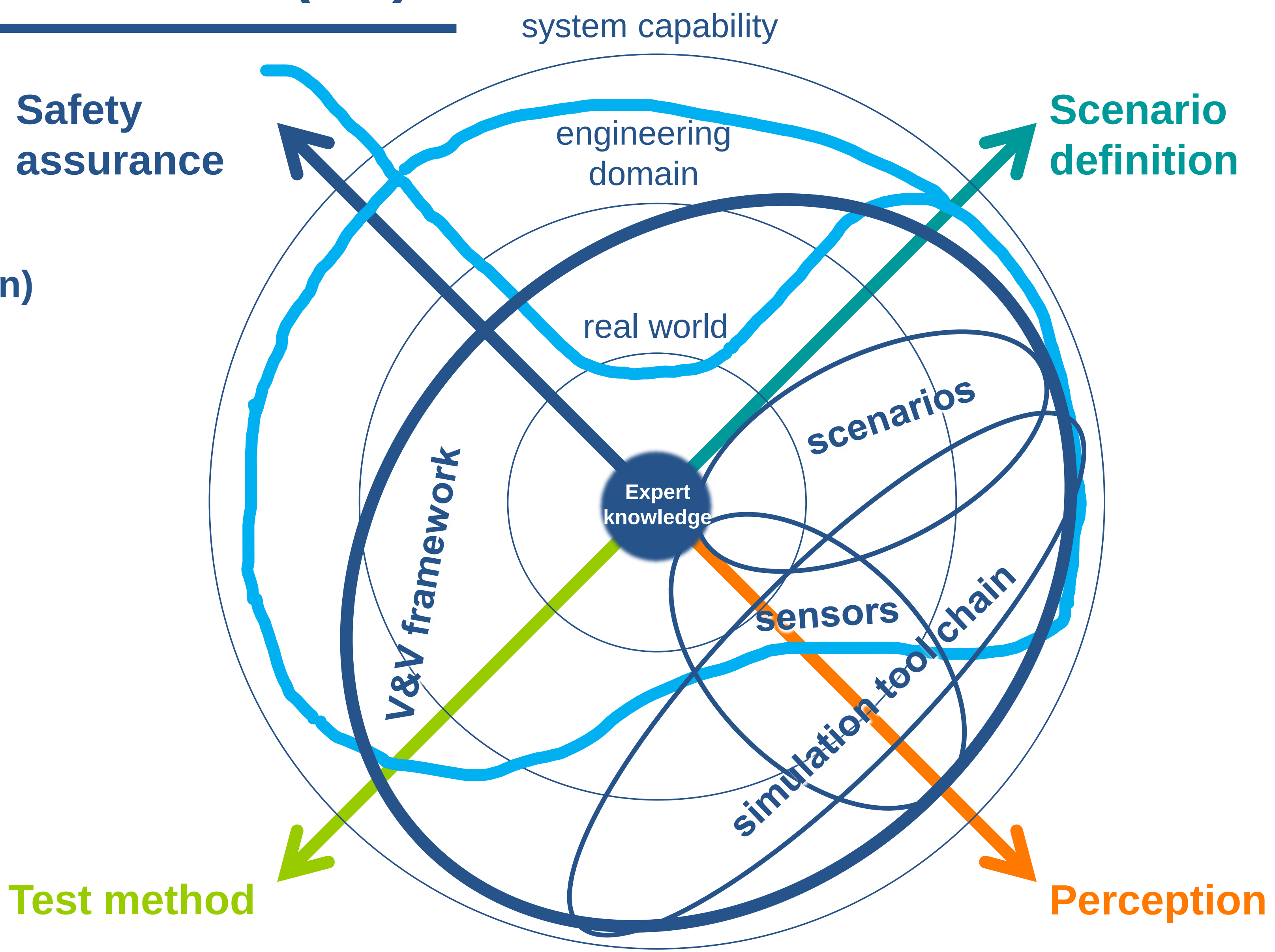
  www.pegasusprojekt.de/
- 4 VIVID DE/JP joint topical task teams: Complementary coverage

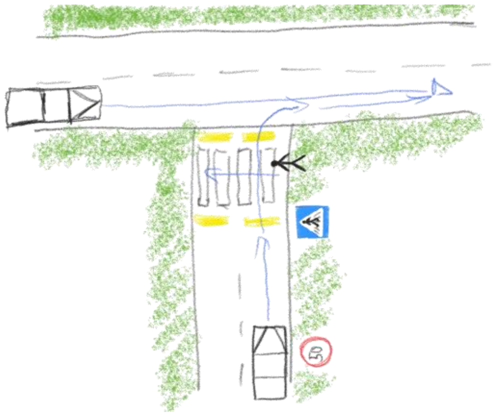


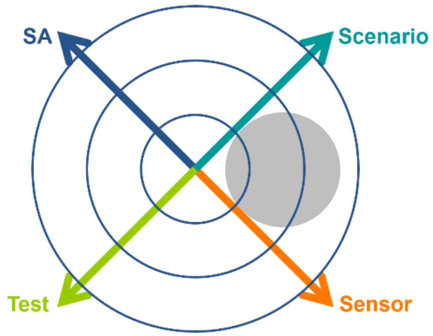
Sensor-oriented scenario description and reference data (IPG)

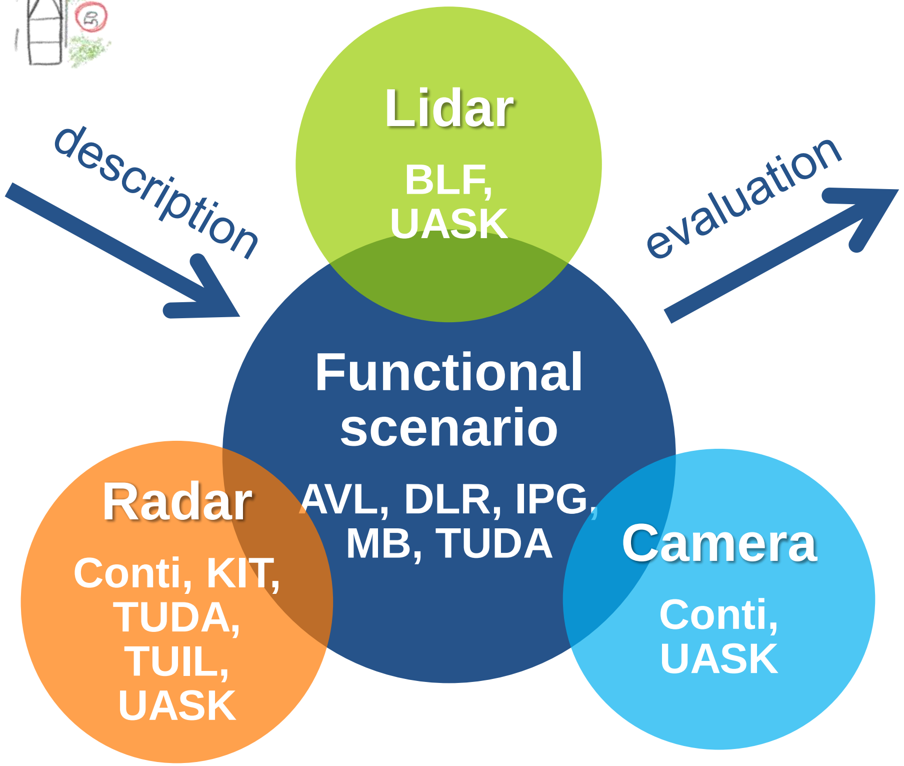
Functional
- Sensor effects
- Relevance ranking
- Scenario selection

Logical
- Parameter relevance
- Recomposition according to simulation

Concrete
- Parametrization
- Baseline values
- Critical cases
- Guidelines for measurements

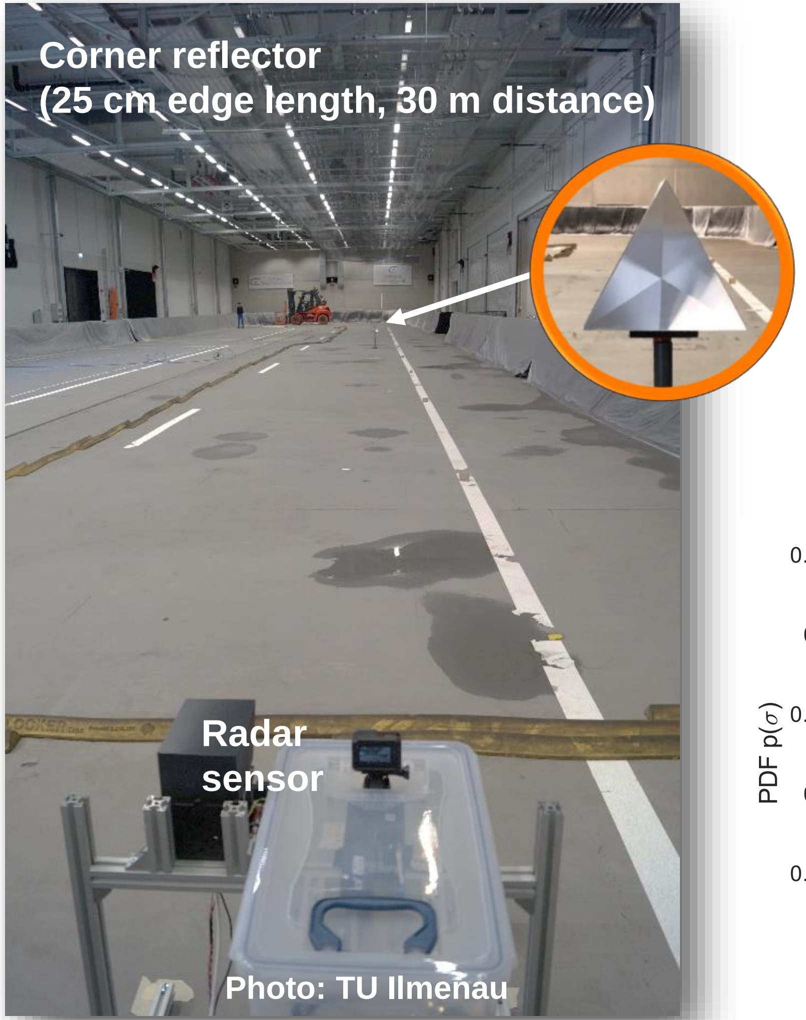


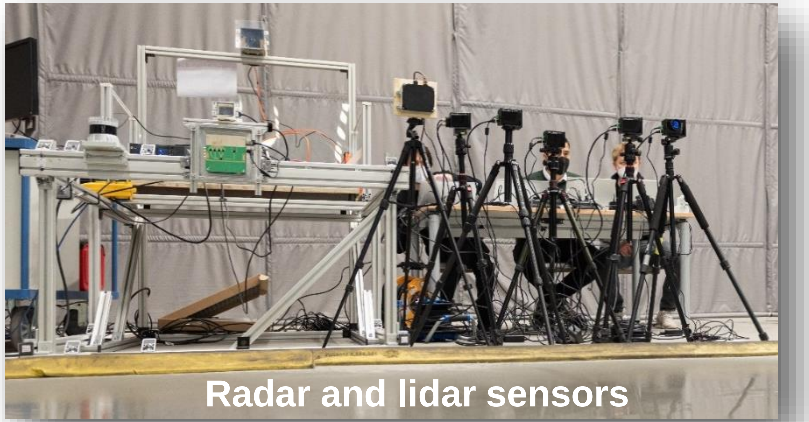




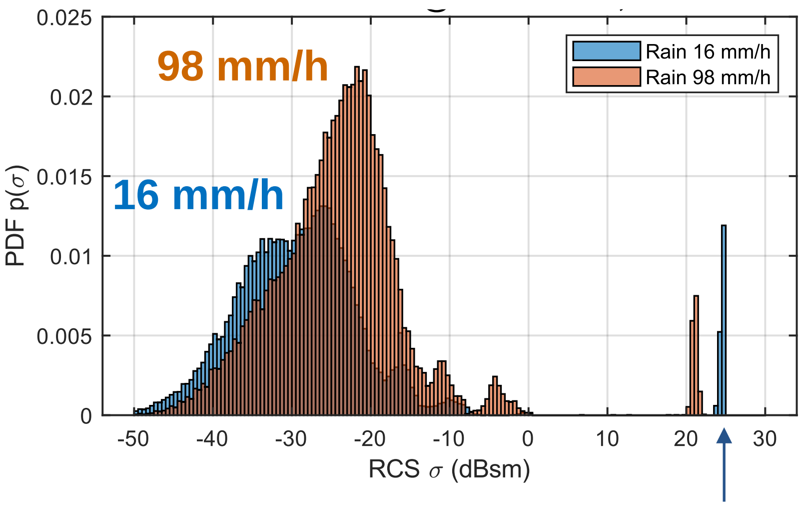
Sensor environmental effects: Rainfall and fog

Facility: CARISSMA, Ingolstadt





Photos: UAS Kempten



RADAR

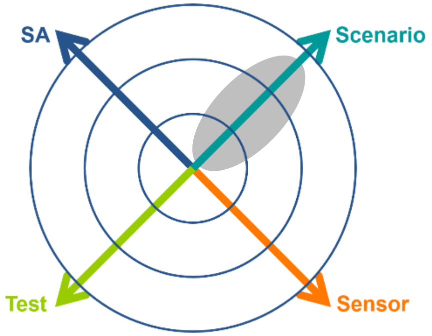
- Conti ARS430 RDI, NXP S32R274
- Backscatter -50 dBsm … 0 dBsm
- Attenuation ≈ 5 dB at 98 mm/h
- Accurate detection of artefacts

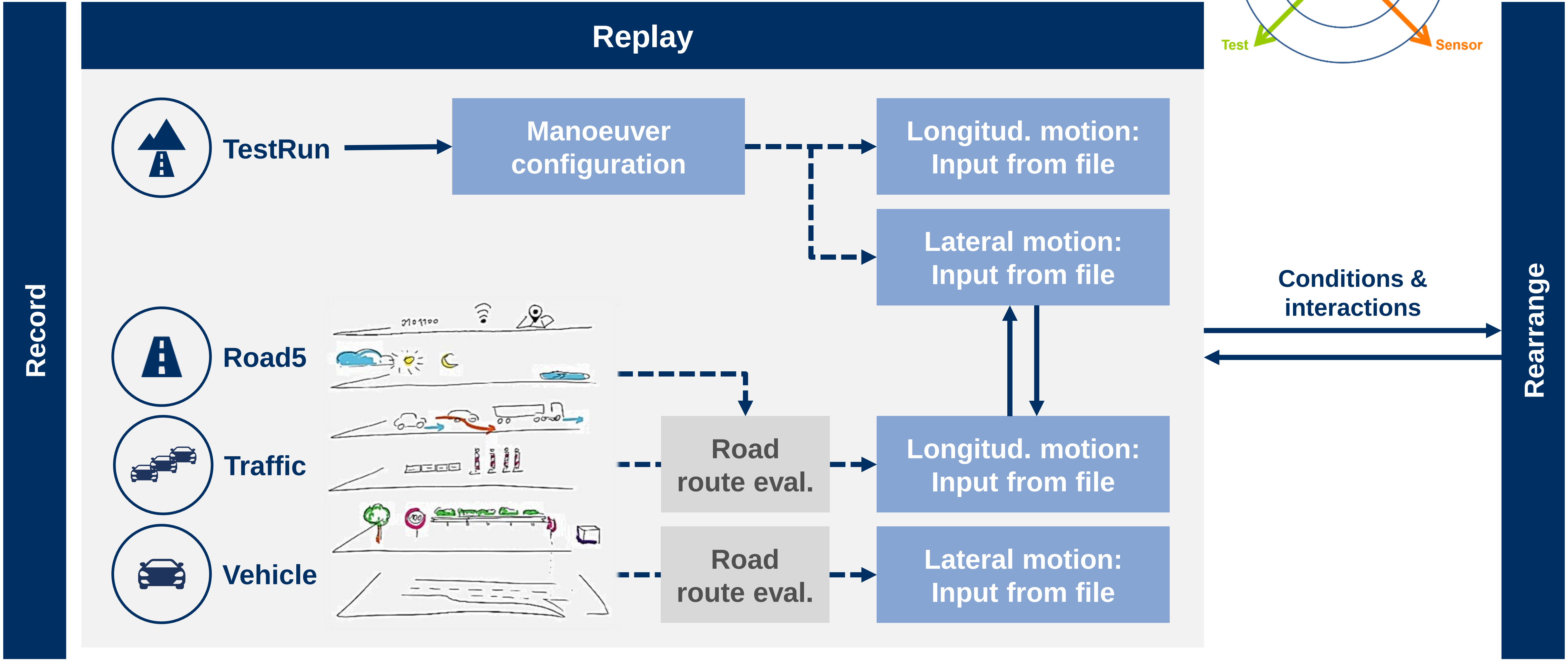
LIDAR

- Blickfeld CubeRange1, Cube1, Cube2
- SNR_{rain}: 40.2 dB (0 mm/h), 14.0 dB (16 mm/h), 6.6 dB (32 mm/h)
- SNR_{fog}: 32.5 dB (0), 2.0 dB (50 m), -2.3 dB (40 m)

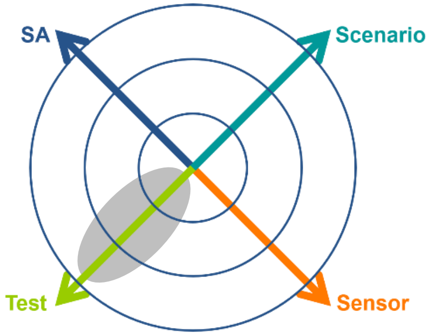
Parametrisation of the environmental model

Scenario generation with ScenarioRRR





Main challenges of validation of automated driving



What to test?

- Critical scenarios
- Specific traffic rules
- Regional specific environmental conditions
- “Understanding human behavior is the key problem in building a capable and safe self-driving car.” (Dmitri Dolgov, CTO Waymo)
- et cetera ...

How to test?

- Robustness validation
- Cover a high number of corner cases and critical scenarios
- Deal with vehicle variants and scenario variants
- Use virtual testing methods like X-in-the-loop approaches

Radar sensor simulation and verification (MB, TUIL)

Position refererence (R1)

$v_{ego}(t)$, $\mathbf{a}_{ego}(t)$, $v_{fellow}(t)$

Sensor reference (R2)

$[R,v,\sigma,\varphi,\Theta]_{sens,ref}(t)$

Compare object list

Abstration layers AL

OTA/ViL simulator

Model (AL1)

$[R,v,\sigma,\varphi,\Theta]_{mod}(t)$

Radar target simulator

Stimulus (AL2)

$[R,v,\sigma,\varphi,\Theta]_{stim}(t)$

Radar

Sensor (AL3)

$[R,v,\sigma,\varphi,\Theta]_{sens}(t)$

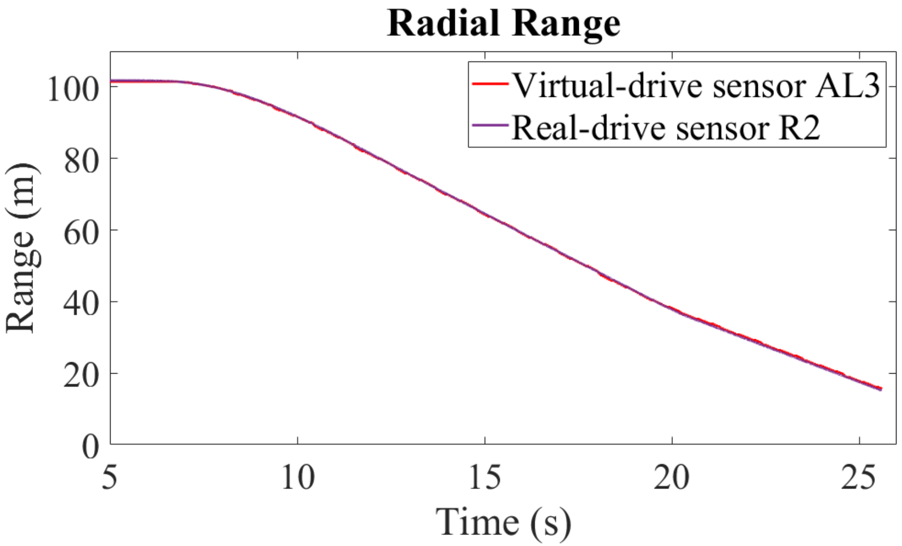
Real-drive
Data rate: 17 Hz (60 ms)

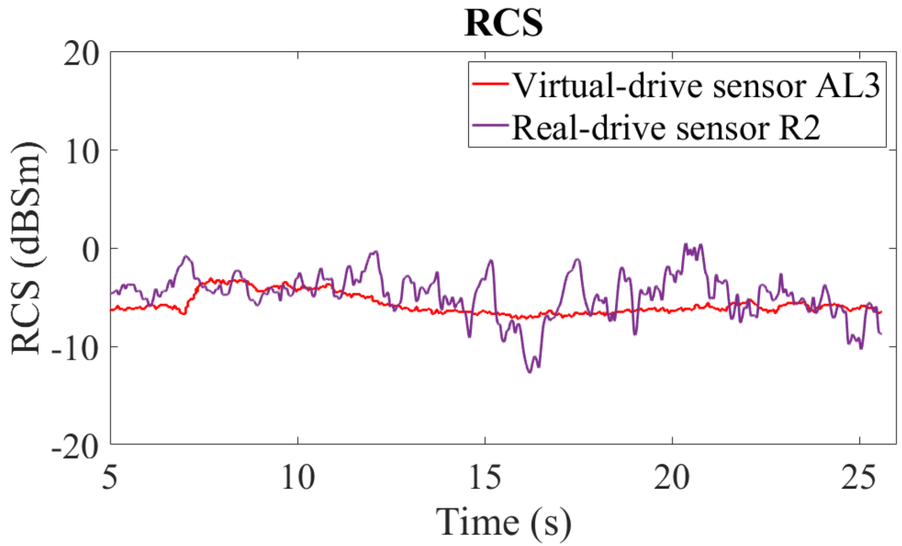
Virtual-drive
Data rate: 1 kHz (1 ms)

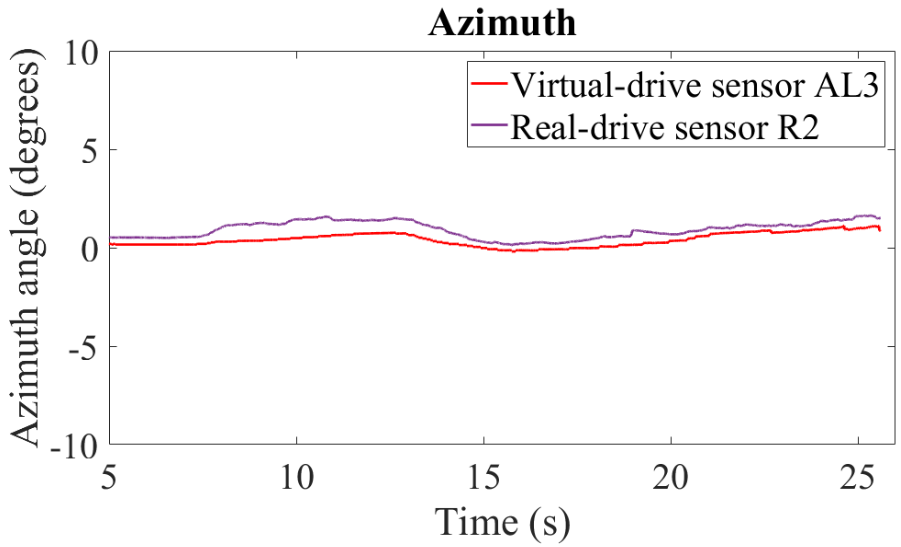
OTA – Over the air
ViL – Vehicle in the loop

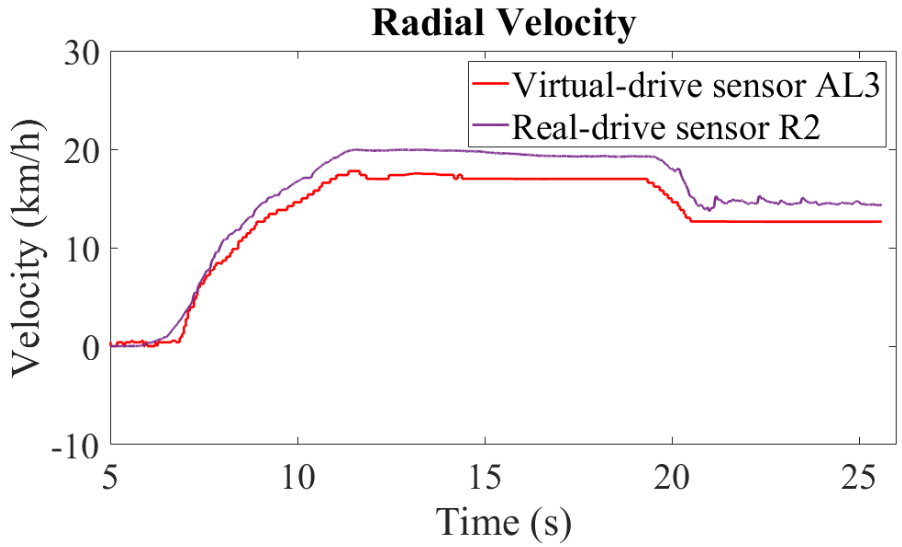
Radar sensor simulation and verification: CPLA-scenario

- **Convincing agreement between real-world reference and OTA/ViL test**
- **Discrepancies understood and manageable**



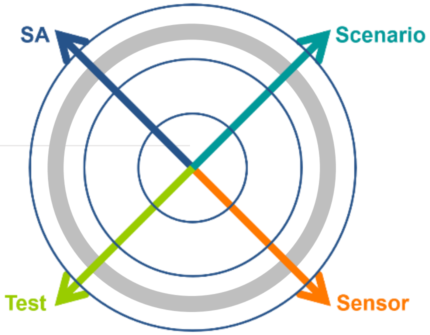


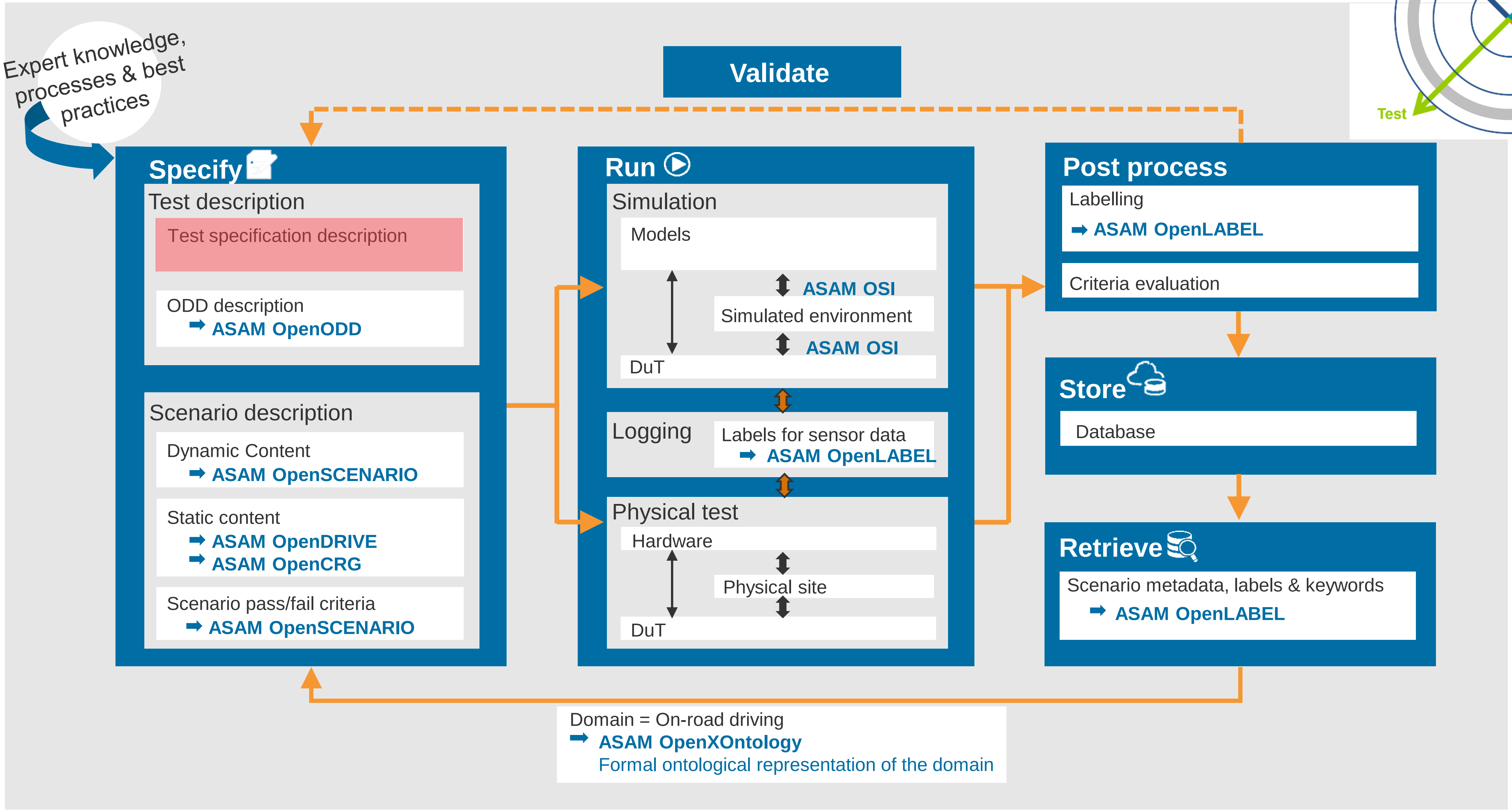




CPLA – C2P longitudinal adult

Scenario-based testing with OpenX





Conclusions

- **Domain model with abstraction layers for scenario-based safety assurance**
- **Sensor-oriented scenario description**
  - → **Example results radar and lidar (camera)**
  - → **Seamless integration into simulation tool chain**
  - → **Significant coverage of domain space at lower abstraction layers**
  - → **Basis for global harmonization and standardization**
- **German-Japan joint task teams: Exploit commonalities and complementarities**
  - → **競争 competition, contest**
  - → **共創 co-creation**