PROJECT of the PEGASUS FAMILY

VERIFICATION VALIDATION METHODS

Mid-Term Presentation 15 / 16 March 2022

Derivation of Requirements for Data Collection

Christian Gutenkunst, AVL Deutschland GmbH

Supported by:

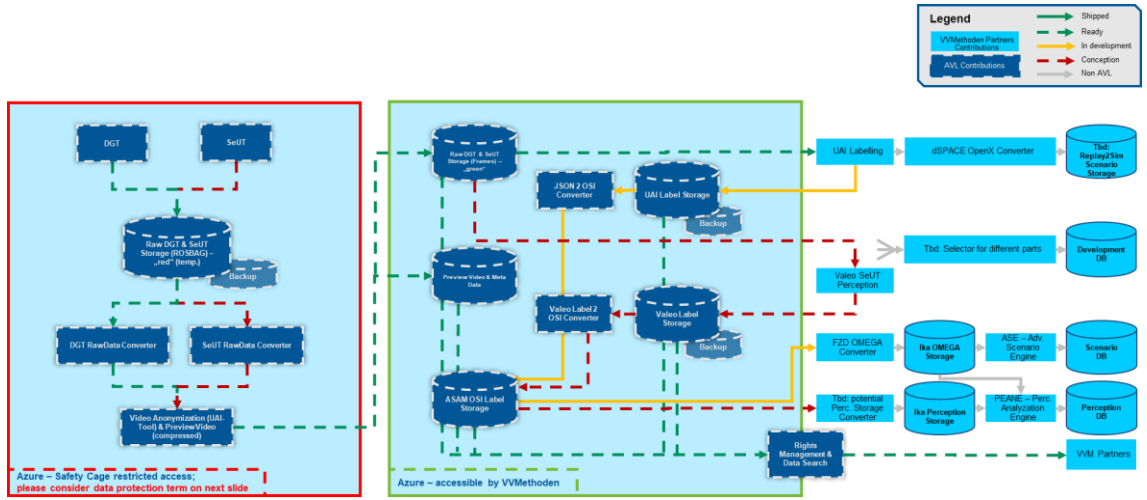
Federal Ministry for Economic Affairs and Climate Action

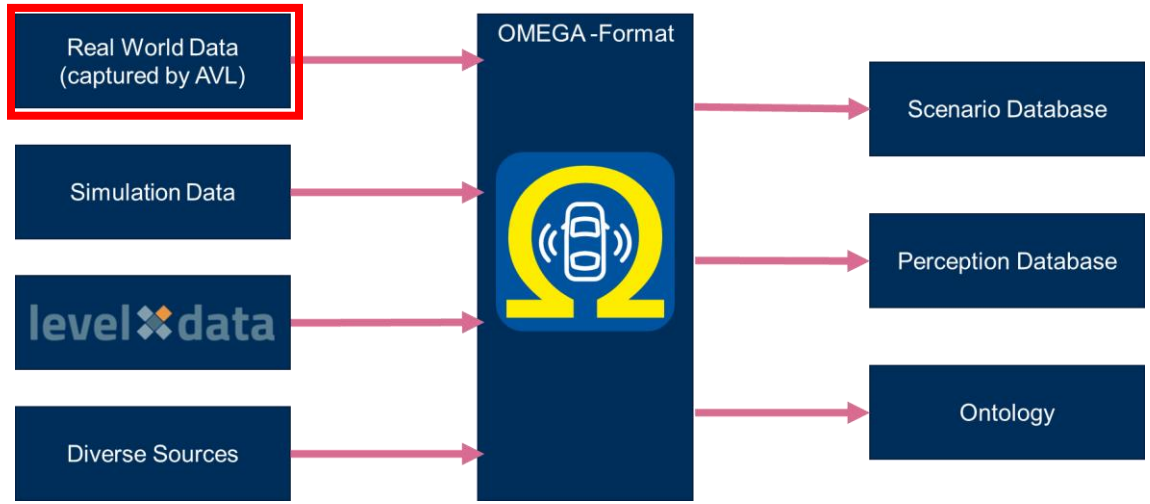
on the basis of a decision by the German Bundestag

Data Collection in the VVM Project

- *“Dataflow in the VVM Project”*
  - Showed the **dataflow/processing** in the project
- *“The OMEGA Format – A Comprehensive Open-Source Measurement Data Format”*
  - Showed the **advantages** compared to OpenDRIVE, OpenSCENARIO, OSI, Lanelet2, PEGASUS and L3Pilot-CDF
  - and the **required information** for data collection

- How have the **requirements** for the data collection be **derived**?

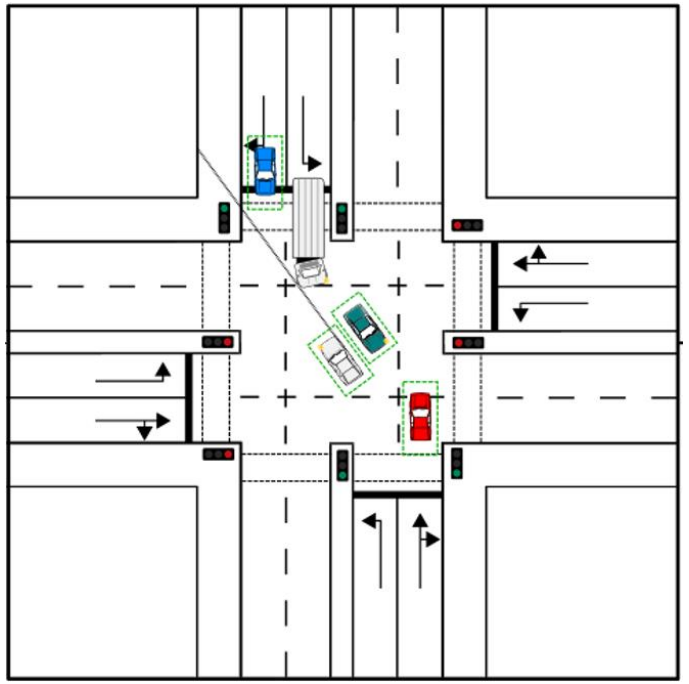




Requirements on Data Collection

- In order to **substantiate the safety argumentation** with evidences, various methods in the VVM project require the **collection of** suitable **data**

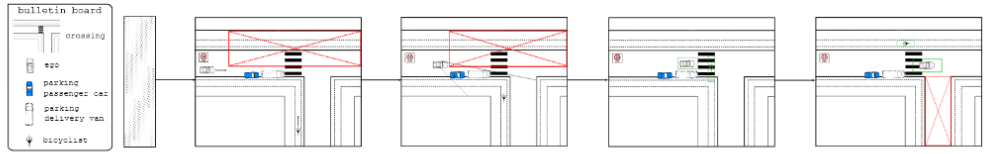
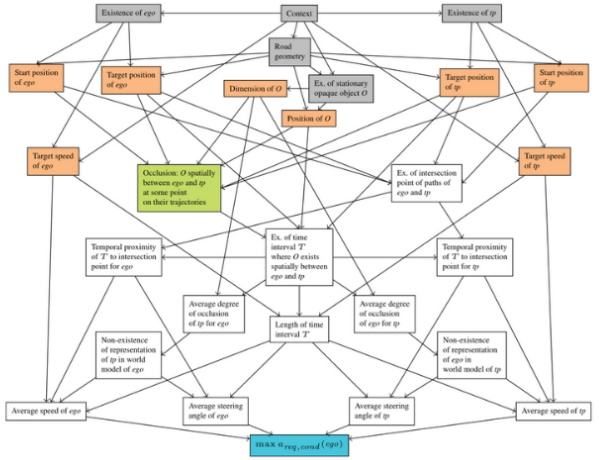
- requirements on data collection can be split in two main categories
  - **semantic requirements**, that
    - specify constraints on the content of the required data
    - can be provided by a methodical Criticality Analysis
  - **technical requirements**, that
    - specify constraint on the measurement system and ist sensors
    - can be obtained from analysis of the operational domain, e.g.
      - urban intersection



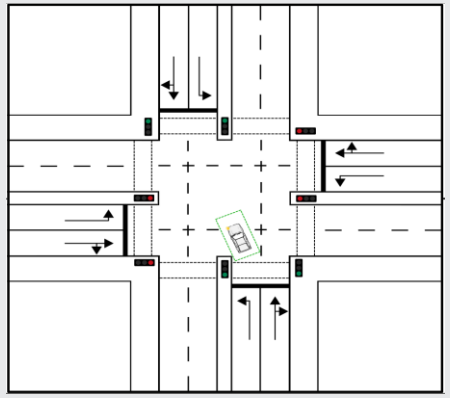
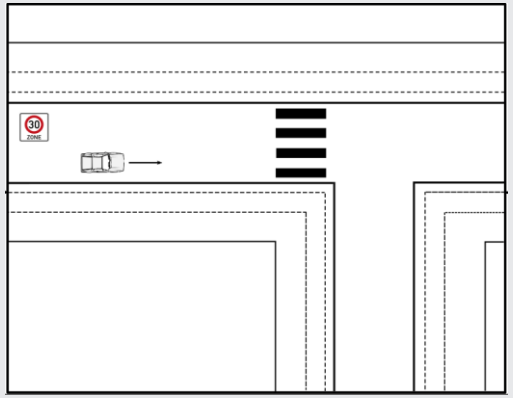
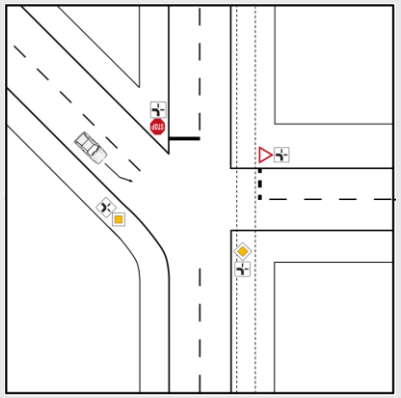
Semantic Requirements on Data Collection

- a Criticality Analysis provides artifacts such as
  - **criticality phenomena** and their underlying **causal relations**, that
  - can be used to formulate **semantic requirements** on data collection

- a description for a **data collection drive** can be build upon
  - an **abstract scenario**
    - specified by constraints
  - a **criticality phenomenon** of interest
  - a hypothesized **causal relation**
  - various **additional information**

Name	Occlusion of Bicyclist through Parking Cars
ID	DCD#002
Tags / Keywords	Occlusion, T-junction, Camera, Lidar
Source / Correspondence	AP2.2 Identifikation von Kritikalitätsphänomenen & Wirkzusammenhängen
Functional Use Case	FUC2-3 – Occlusion of Bicyclist through Parking Cars 
Constraints	• T-junction where right has right of way • Parking vehicles potentially cause an occlusion • Pedestrian crossing • Potential bicyclists/pedestrian crossing the Ego lane are occluded for camera and lidar sensors by parking vehicles
Criticality Phenomenon	Occlusion (Camera/Lidar)
Causal Relation	
Criticality Metrics	• Conditional Required Acceleration a_{req,cond}, Scaled Predictive Encroachment Time (SPrET)
Safety Principles	• Recognize potential occlusion and already slow down • Slowly creep towards pedestrian crossing (conflict area) as to increase the visibility of crossing vulnerable road users
Additional Information	• Priority of data collection: high • Probability of occurrence: quite regularly in everyday traffic • Estimated criticality: medium • Indication: record data in proving grounds; recording in live-traffic is potentially hazardous

Overview Functional Use Cases (FUCs)

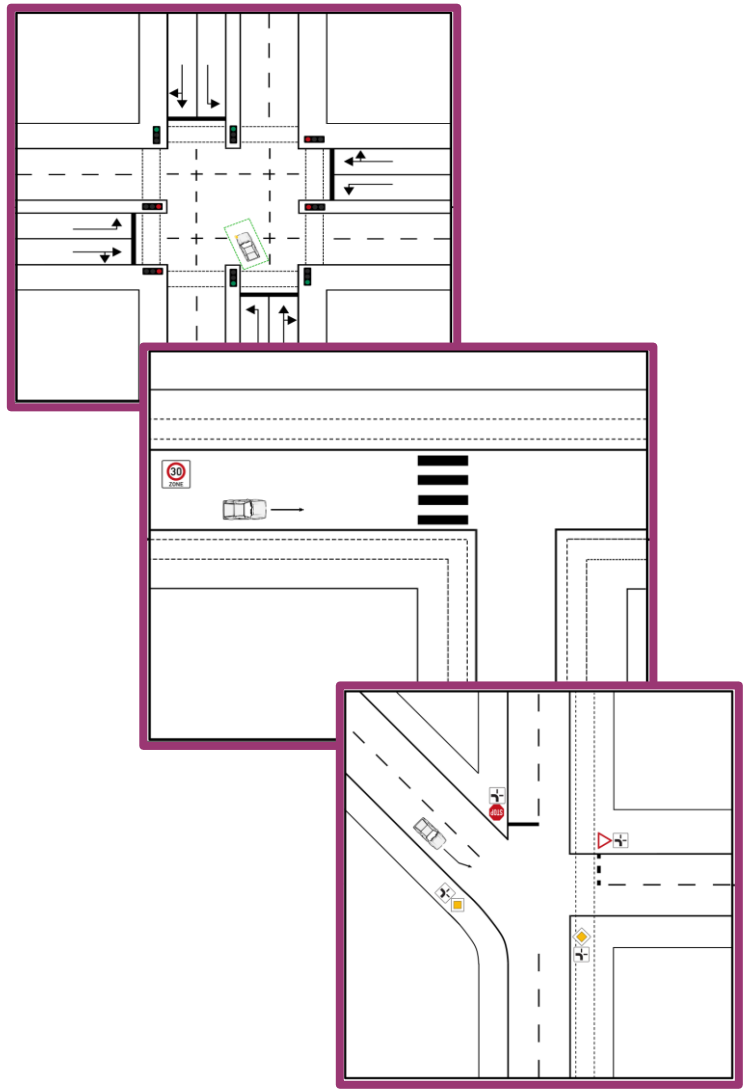
	Functional Use Case 1 (FUC1)	Functional Use Case 2 (FUC2)	Functional Use Case 3 (FUC3)
Core Concept	left turn on an X-crossing with traffic lights	straight passing of a T-crossing with pedestrian crossing	left turn on a bending right of way X-crossing with an angled arm
Sketch			
Variation 1	+ oncoming traffic with right of way	+ traffic from the right with right of way	+ traffic from the right with right of way
Variation 2	+ oncoming traffic + occlusion through oncoming crossing traffic	+ pedestrian using crosswalk + bicyclist crossing in same direction + oncoming traffic wants to cross left	+ traffic, needs to give right of way + pedestrian with right of way
Variation 3	+ non-functional traffic lights + rush hour traffic	+ parking cars + bicyclist using crosswalk + occlusion of bicyclist by parking cars	+ ambulance with right of way + following car, needs to give right of way

Requirements for Measurement System

VERIFICATION VALIDATION METHODS

Use Case Analysis

- Differentiation between scenario **Stop & Go** and **Passing**
- Relevant targets **motorcyclist**, **bicyclist** (recumbent) and **pedestrians** (child 1m tall)
- Calculation of required perception range, certain assumptions were made for **deacceleration**, **acceleration**, **friction coefficient**, **minimum number of pixels** (horizontal and vertical), **width** and **height of relevant target**, **etc.**
- Different **intersection scenarios** were evaluated



Offline Perception

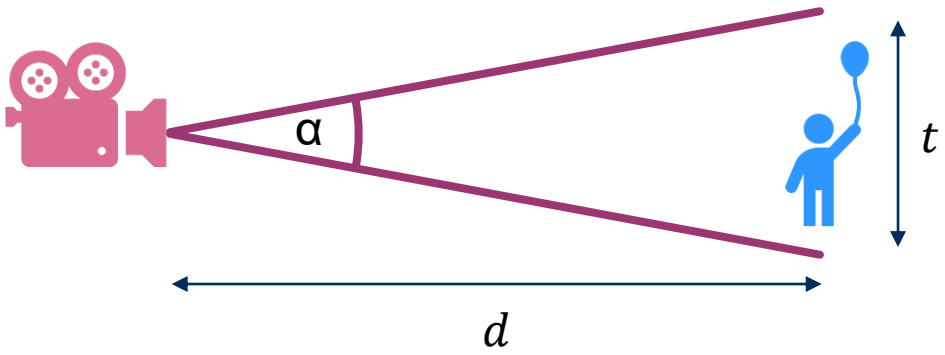
- To identify an object the following requirements, need to be fulfilled:
  - R_h x R_v pixels in camera image
  - N points in LiDAR point cloud
  - Min. recording frequency

Example for Camera Sensor Selection

VERIFICATION VALIDATION METHODS

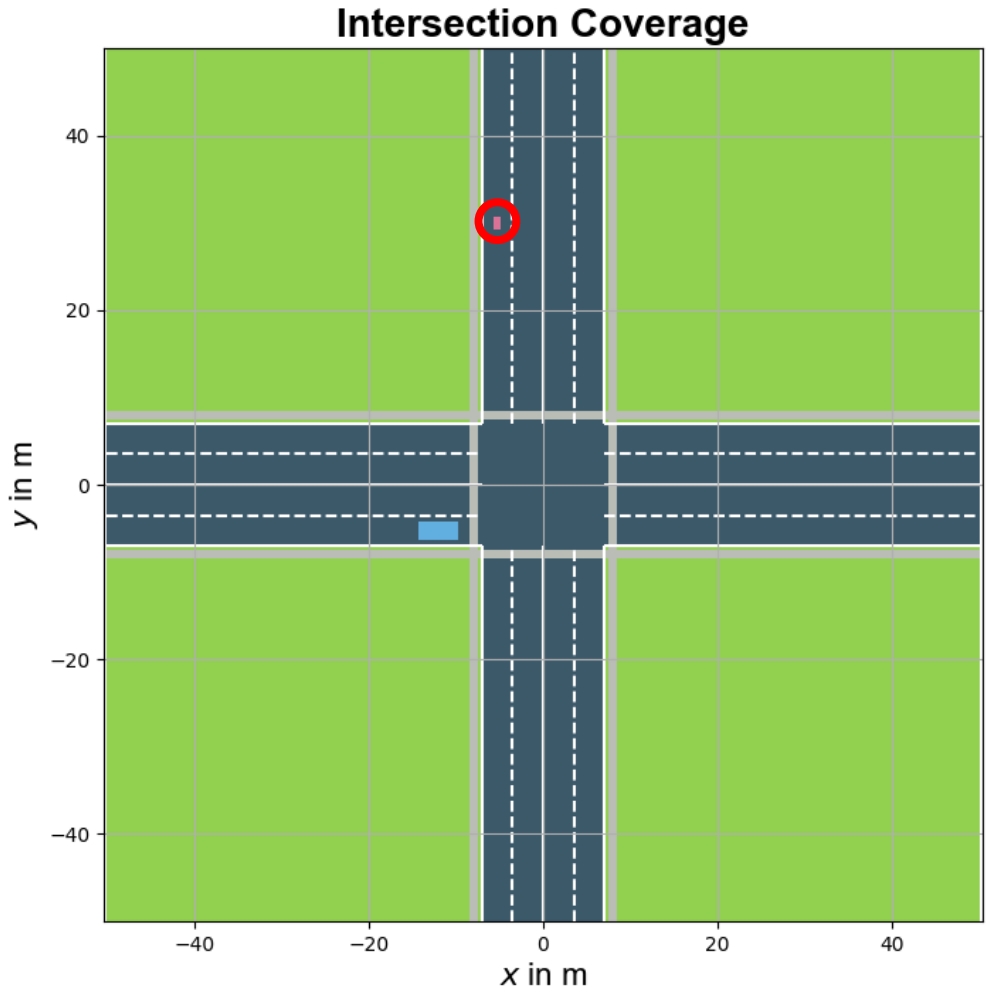
8 MP camera sensor

Sensor resolution:	$res_h = 4000\text{px}$	$res_v = 2000\text{px}$
Field of View:	$\alpha_h = 100°$	$\alpha_v = 60°$
Angular resolution:	${}^{\alpha_h}/_{res_h} = 0{,}025°/\text{px}$	${}^{\alpha_v}/_{res_v} = 0{,}03°/\text{px}$
Perception requirements:	$R_h = 10\text{px}$	$R_v = 10\text{px}$
Target geometry:	$t_h = 0{,}4\text{m}$	$t_v = 1{,}0\text{m}$
Perception distance:	$d_h = 91{,}7\text{m}$	$d_v = 191{,}0\text{m}$



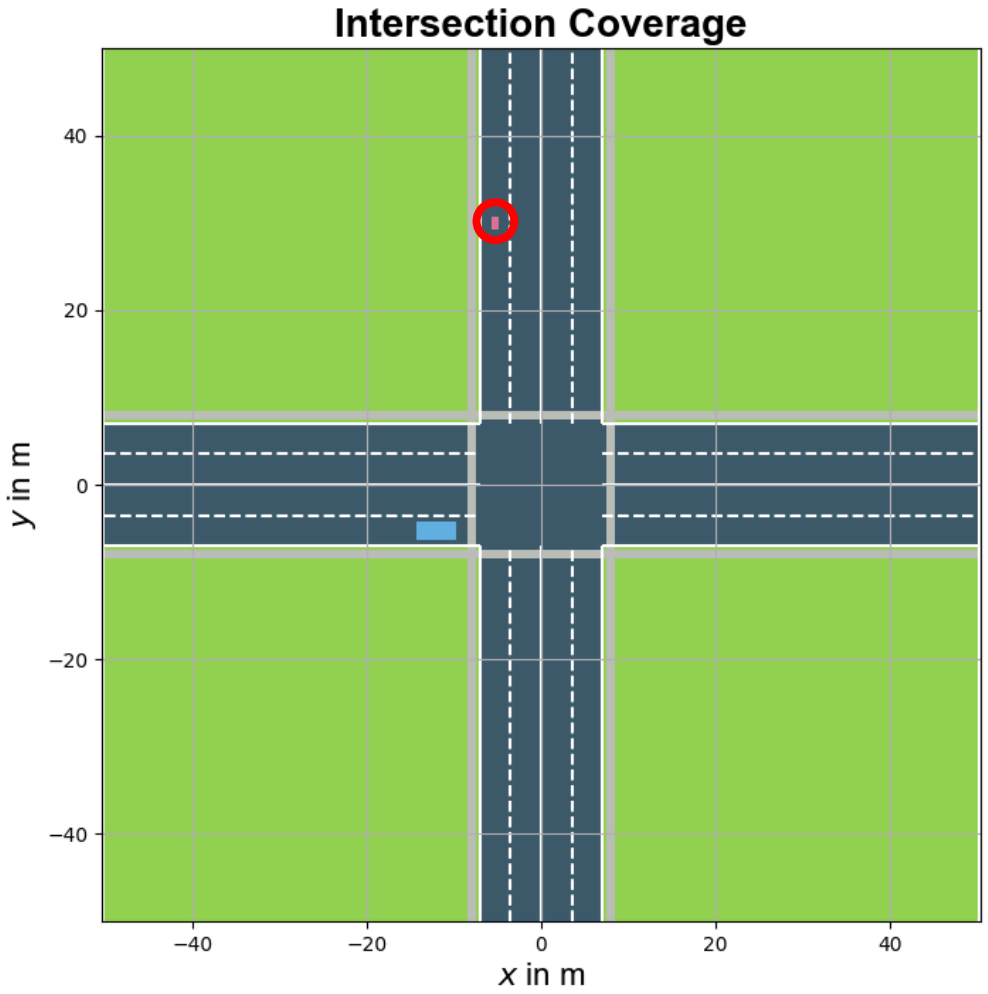
Results from Requirements

Motorcycle

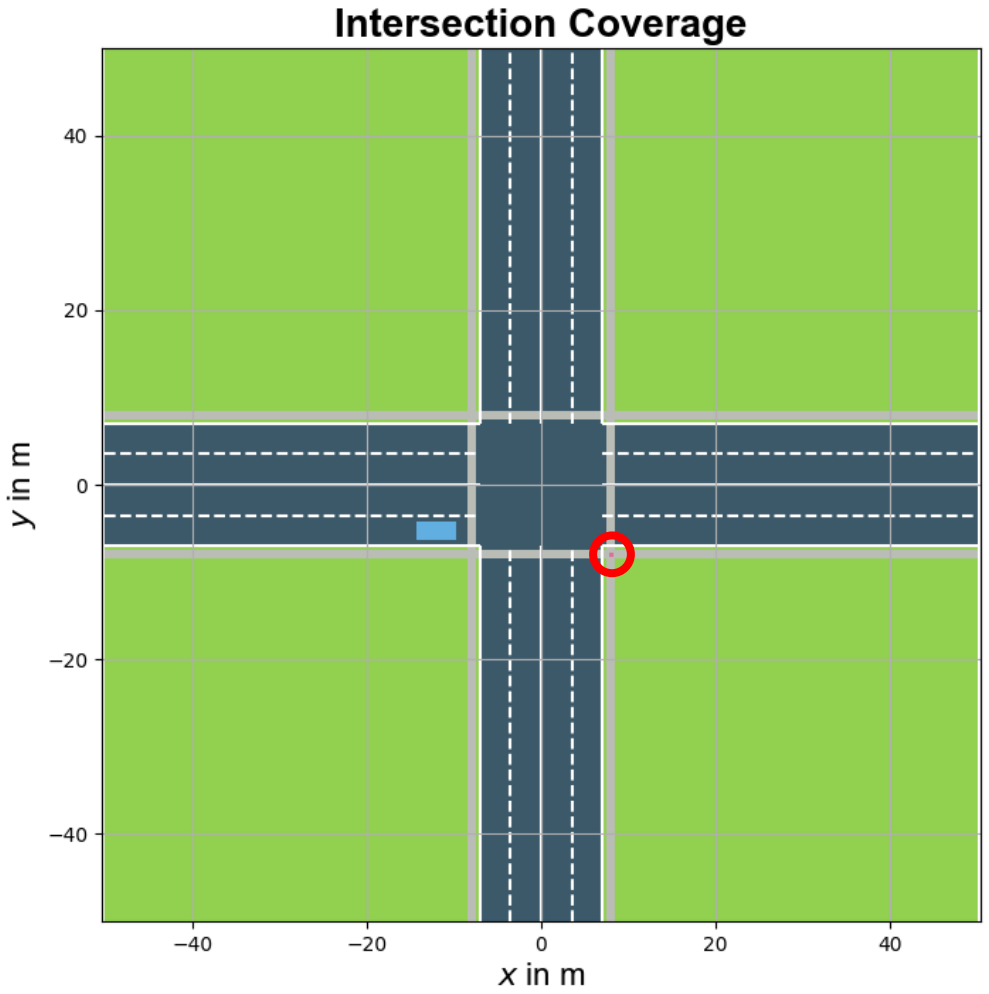


Results from Requirements

Motorcycle

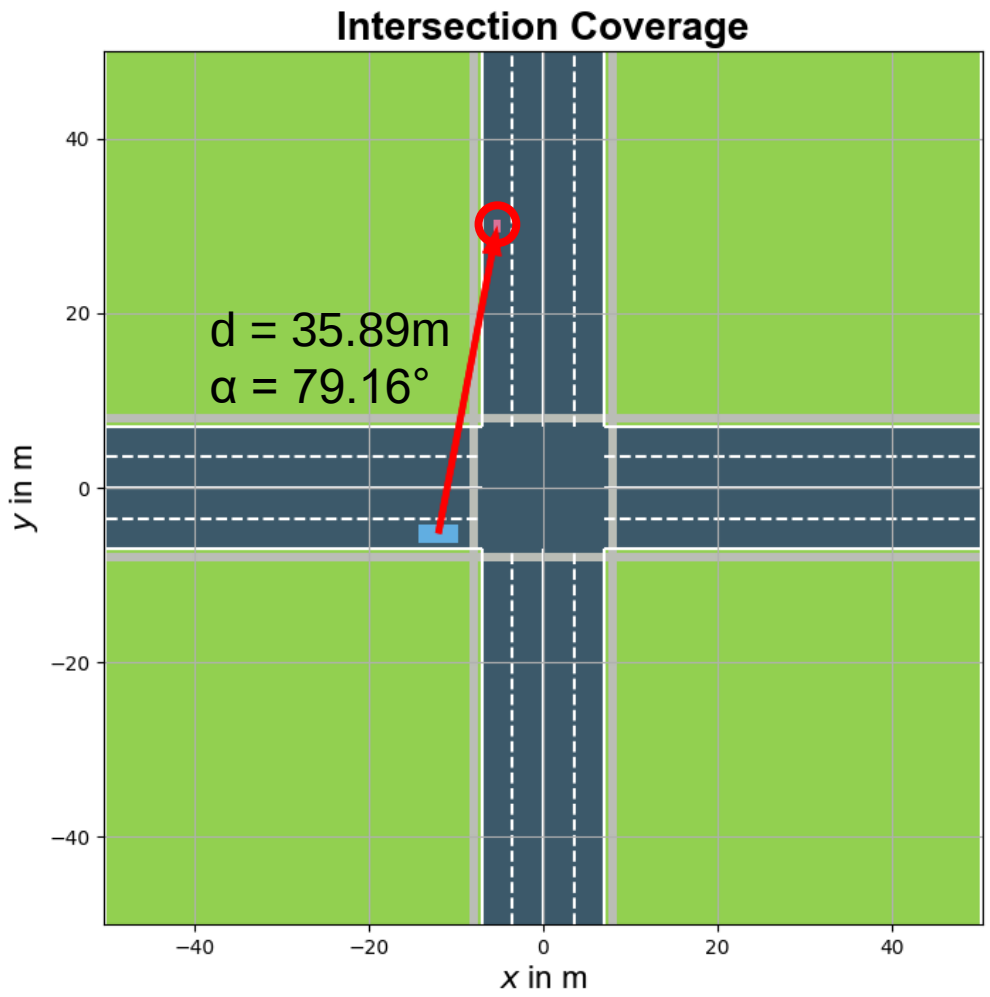


Pedestrian

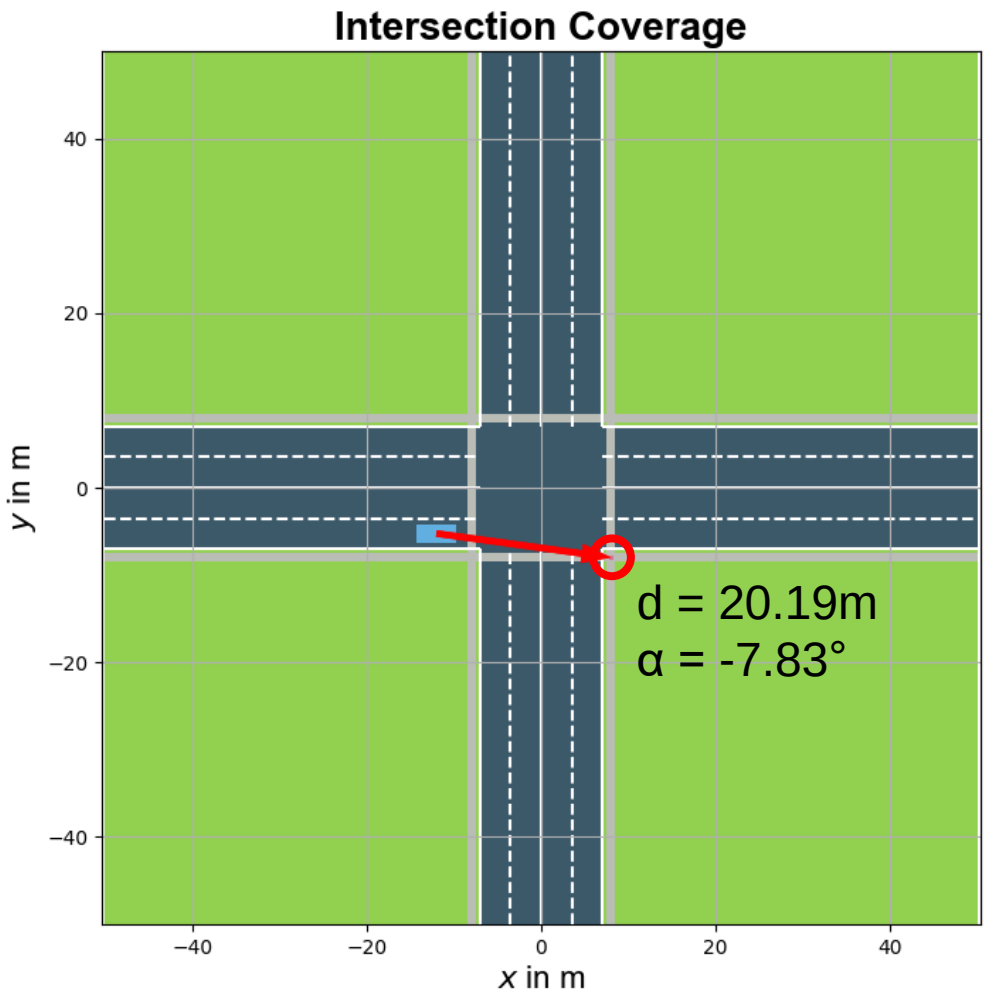


Results from Requirements

Motorcycle

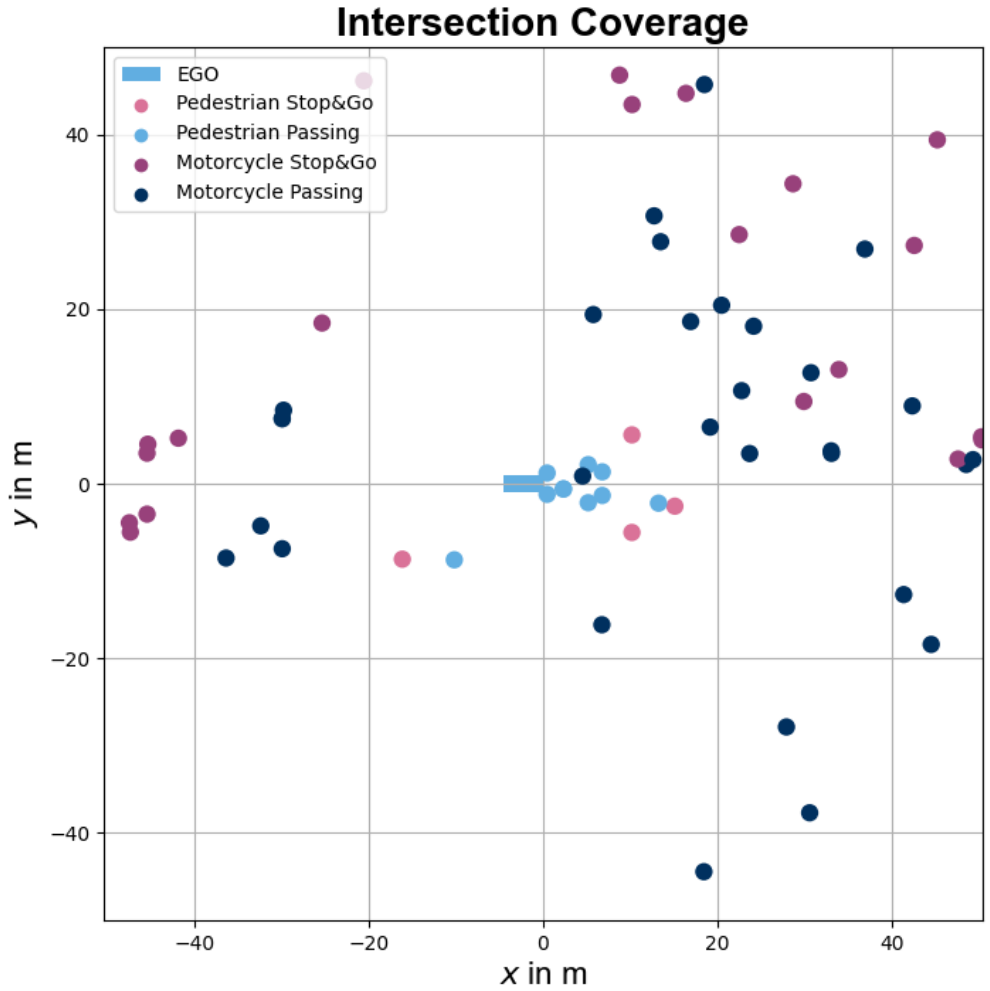


Pedestrian



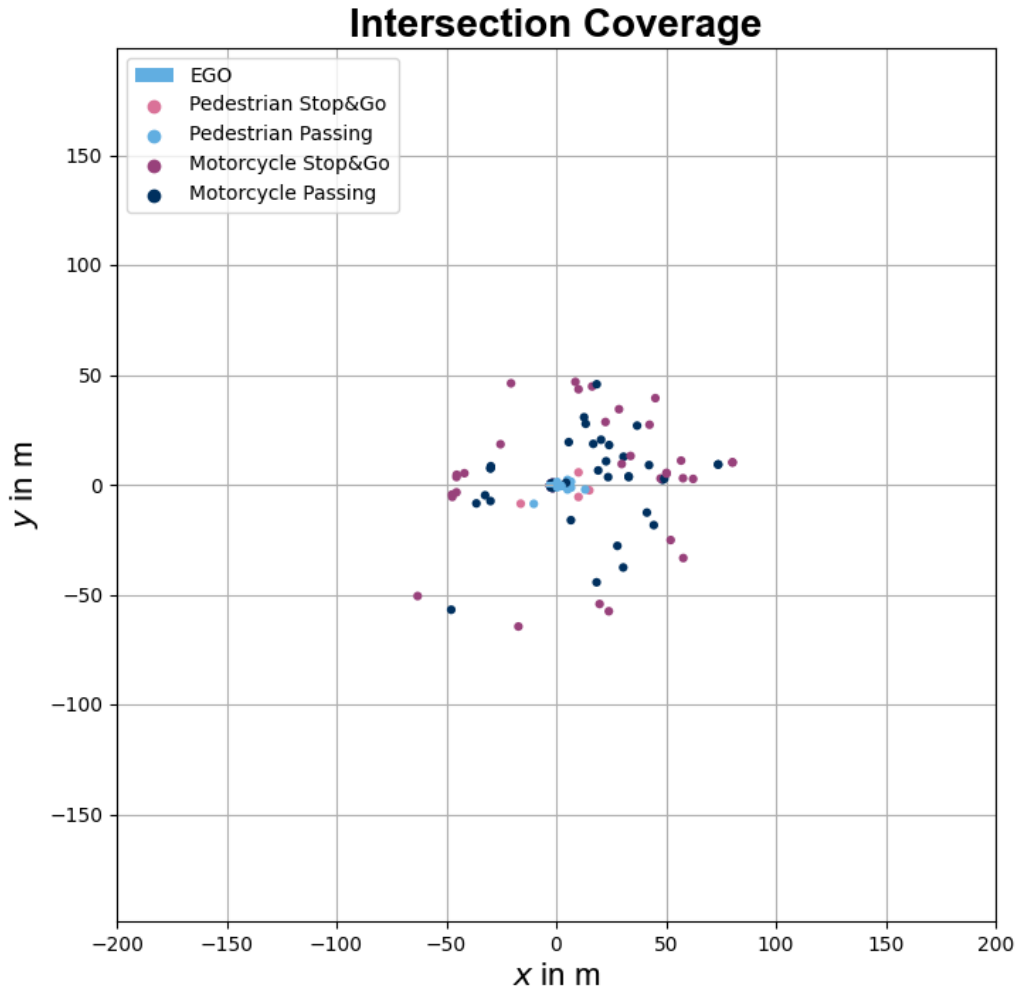
Results from Requirements

Area 100x100m

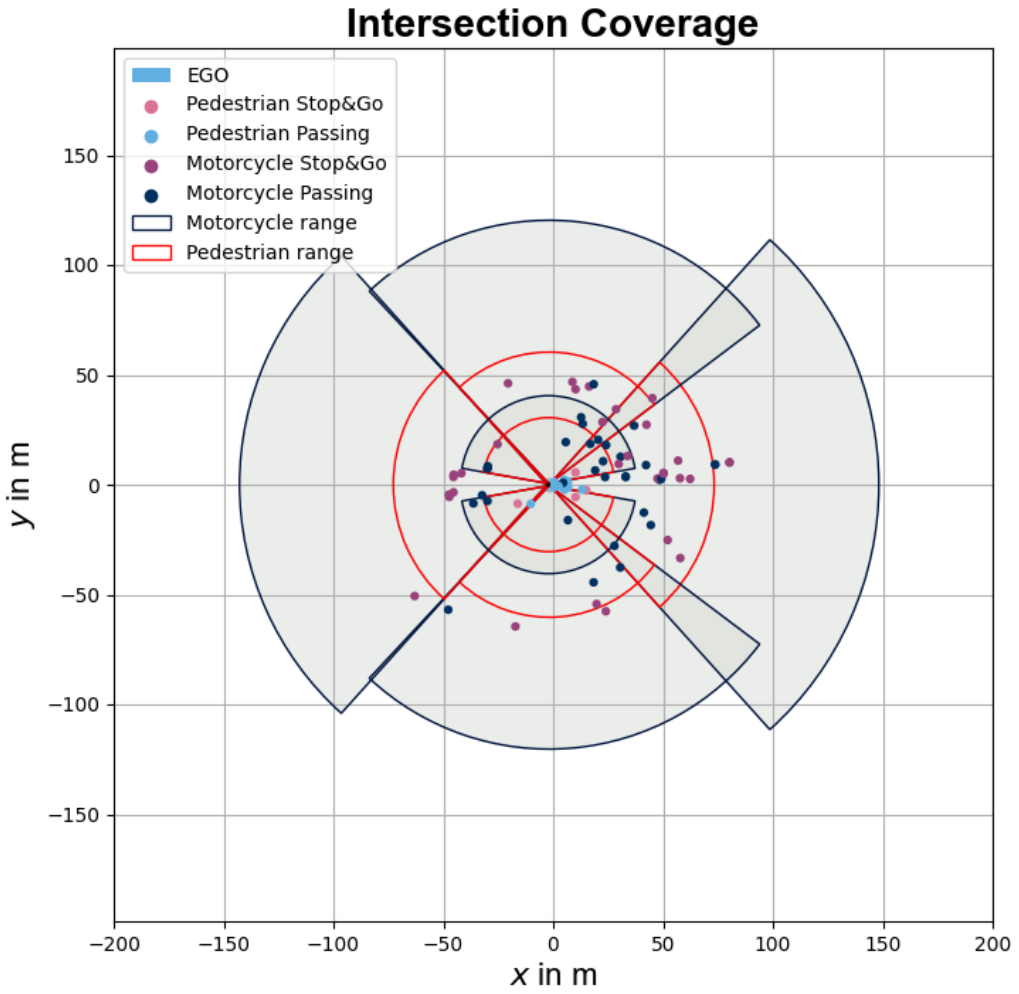


Results from Requirements

Area 400x400m

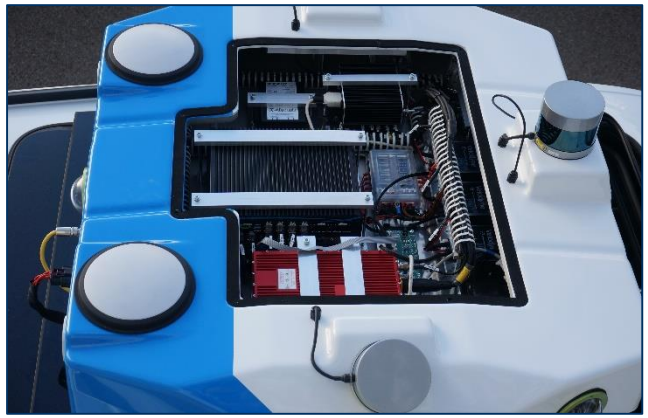


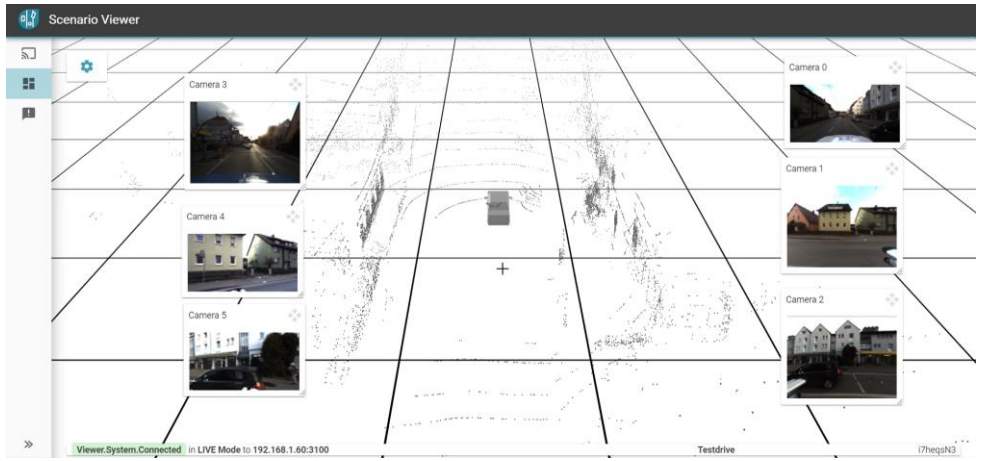
Sensor Coverage



Insights in Data Capturing Vehicle

- Sensor setup selection done
- Commissioning completed
- First data capturing done
- Modular approach for Sensor under Test integration





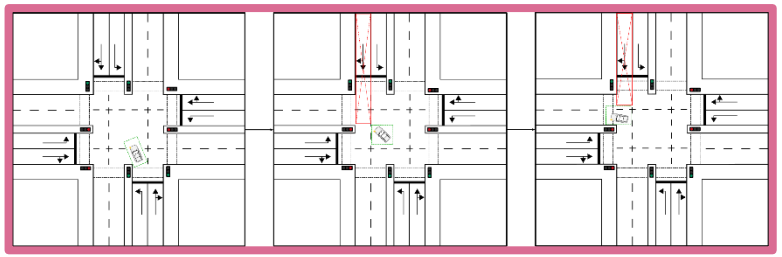
Insights in Integrated Sensor under Test

- Extending the sensor suit in the vehicle, with **automotive sensors** like **Bosch Radar** and **2x Valeo LiDARs** are integrated into the vehicle, in order to capture the data parallel, which can be compared with the reference sensor data.
- **Sensor evaluation against reference system is possible**.

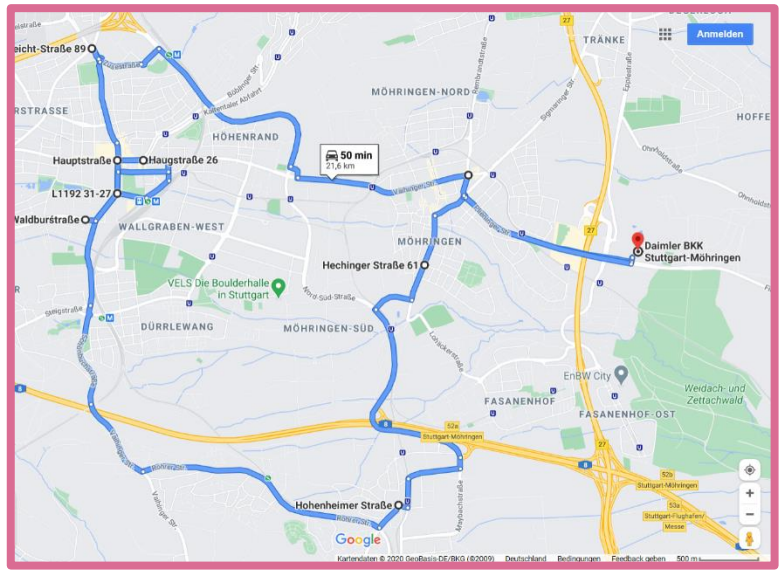
Insights in Analyzing the Drive Specification

- Analysis of the "Functional Use Case" from criticality analysis team
- Deriving the requirements for the route segments (layers 1, 2, 3) with the aid of
  - Accident Atlas
  - Google Maps
  - OpenStreetMaps
- Generation of a route based on the route segments found

Functional Use Case 1

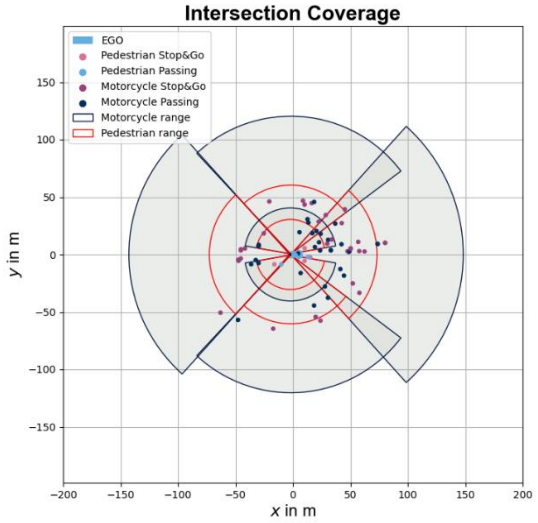


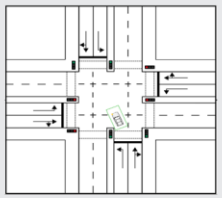
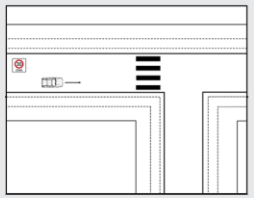
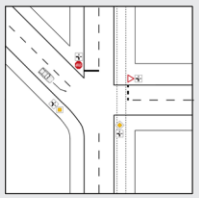
Route for first measuring drive



Summary – What We Have Achieved

- Reference measurement technology concept developed and commissioned
- Modular approach for integration and recording of Sensor-under-Test
- Process for measurement drive planning defined
- Data provisioning challenges solved inside a consortium with 20+ (from OEM, TIER1 and R&D) members
- Data format between anonymized raw data and labelling supplier aligned



	Functional Use Case 1 (FUC1)	Functional Use Case 2 (FUC2)	Functional Use Case 3 (FUC3)
Core Concept	left turn on an X-crossing with traffic lights	straight passing of a T-crossing with pedestrian crossing	left turn on a bending right of way X-crossing with an angled arm
Sketch			
Variation 1	+ oncoming traffic with right of way	+ traffic from the right with right of way	+ traffic from the right with right of way
Variation 2	+ oncoming traffic + occlusion through oncoming crossing traffic	+ pedestrian using crosswalk + bicyclist crossing in same direction + oncoming traffic wants to cross left	+ traffic, needs to give right of way + pedestrian with right of way
Variation 3	+ non-functional traffic lights + rush hour traffic	+ parking cars + bicyclist using crosswalk + occlusion of bicyclist by parking cars	+ ambulance with right of way + following car, needs to give right of way

VERIFICATION
VALIDATION
METHODS

Thank you!

Christian Gutenkunst | AVL Deutschland GmbH | Christian.Gutenkunst@avl.com

Christian Neurohr, DLR; Himanshu Walia, Xun Dai, Max Nestoriuc, AVL

PROJECT of the PEGASUS FAMILY

A project developed by the VDA Leitinitiative autonomous and connected driving

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag