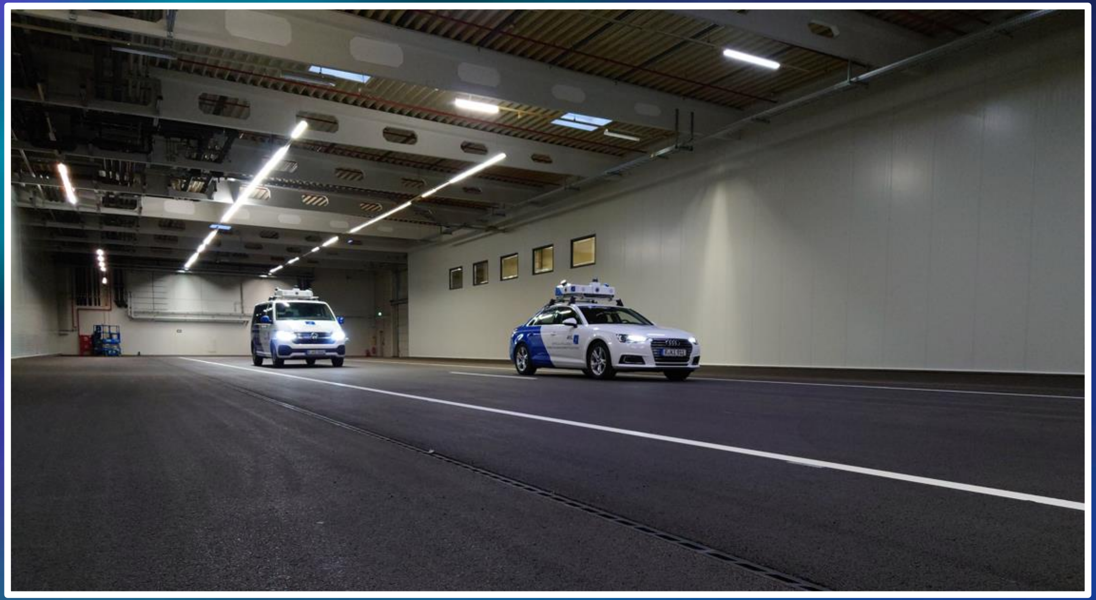
Center for Mobility and Sensor Testing Roding

Armin Engstle, Diego Turrado Blanco
Webinar, 12.05.2022



Today's Presenters

Dr.-Ing. Armin Engstle

Head of Innovation Lighthouse ADAS/AD

M. Sc. Diego Turrado Blanco

Senior Software and Functions Engineer ADAS/AD

Today’s Agenda

1. About us
2. Introduction: Sensortesting in adverse weather conditions
3. Targets / Major Requirements Sensor Test Center Roding
4. Service Offering
5. Testing & Validation Approach
6. DGT Calibration
7. Summary

Facts and Figures

2008

Founded

620

Employees

10%

Of Turnover Invested in Inhouse R&D

100%

Integrated into the worldwide AVL network

ONE

Partner as a subsidiary to AVL List GmbH

> 20 mio

Vehicles with our technology on the road

As a software and hardware developer we are leading innovation

Global Footprint

6 engineering locations

Global customer support network

17 partner locations inside AVL

Legal basis
Vehicle with automated/autonomous driving function

Bundesrat Drucksache **86/22**

24.02.22

Vk - In - Wi

Verordnung
des Bundesministeriums
für Digitales und Verkehr

Verordnung zur Regelung des Betriebs von Kraftfahrzeugen mit automatisierter und autonomer Fahrfunktion und zur Änderung straßenverkehrsrechtlicher Vorschriften[1]

A. Problem und Ziel

Die Entwicklungsdynamik im Bereich des automatisierten, autonomen und vernetzten Fahrens ist ungebrochen hoch. Um die Potenziale dieser Technologien heben zu können und die Teilhabe der Gesellschaft daran zu ermöglichen, bedarf es der Umsetzung weiterer Schritte zur Einführung entsprechender Systeme in den Regelbetrieb. Anknüpfend an die bisherigen rechtlichen Vorgaben des Achten Gesetzes zur Änderung des Straßenverkehrsgesetzes zum Betrieb von Kraftfahrzeugen mit hoch- und vollautomatisierter Fahrfunktion stellt sich die Notwendigkeit dar, über die im öffentlichen Straßenverkehr bereits mögliche Erprobung autonomer, führerloser Fahrzeuge hinauszugehen und deren Regelbetrieb einzuleiten. Zunächst sollen autonome Fahrzeuge dafür in festgelegten Betriebsbereichen eingesetzt werden können. Mangels internationaler, harmonisierter Vorschriften bedarf es bei derart weitreichenden technischen Entwicklungen Regelungen des Gesetzgebers zum Betrieb von Kraftfahrzeugen mit autonomer Fahrfunktion sowie zu den Anforderungen an die Beteiligten und an das Kraftfahrzeug selbst.

B. Lösung

Ein geeigneter Rechtsrahmen soll durch Ergänzung bestehender Regelungen des Straßenverkehrsrechts geschaffen werden. Aufgrund dieses Rechtsrahmens können autonome Kraftfahrzeuge im öffentlichen Verkehr betrieben werden, sofern diese Fahrzeuge und deren jeweilige Betriebsbereiche für die jeweiligen Fahrzeuge durch die zuständigen Behörden genehmigt worden sind.

Page 2: "The regulation governs […]
- "type approval of motor vehicles with autonomous driving function to road traffic",
- "market surveillance of motor vehicles with autonomous driving function"

Page 25: Response to environmental conditions:
"Weather, environmental, and road infrastructure conditions (for example, rain, smoke obstructions to visibility, potholes) are to be considered in the speed and travel profile."

Page 32: Testing and test cases: "Test cases must provide sufficient test coverage for all scenarios, test parameters, and environmental conditions."

Page 40: Performance of tests: "The compliance to requirements can also be checked by means of suitable simulation. For doing so, the simulation tools must be validated. The validation of the simulation tools must be carried out by means of comparison to a representative selection of real tests."

Data Driven Development at the OEMs

WAYMO **2020**

20+
Million
Self-Driven Miles

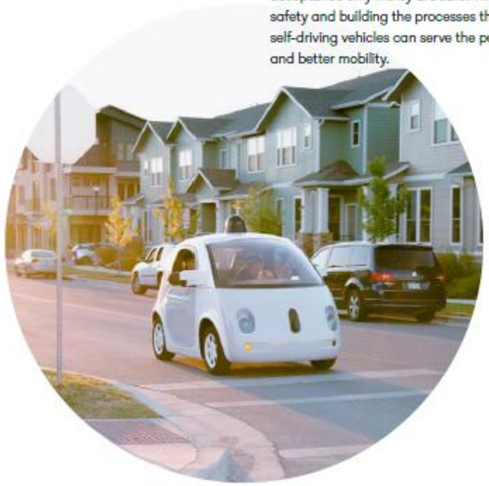
15+
Billion
Simulated Miles

Every year, 1.35 million lives are lost to traffic crashes around the world, and in the U.S. the number of tragedies is growing. We believe our technology could save thousands of lives now lost to traffic crashes every year.

Our commitment to safety is reflected in everything we do, from our company culture, to how we design, test and deploy our technology. In this Safety Report on Waymo's fully self-driving technology (which we call the "Waymo Driver"), we detail Waymo's work on—and our commitment to—safety. This overview of our safety program underscores the important lessons learned through the 20+ million miles Waymo's vehicles have self-driven on public roads and through our 15+ billion miles of simulated driving.

In its 2017 automated vehicle guidance, *Automated Driving Systems 2.0: A Vision for Safety*, the U.S. Department of Transportation (DOT) outlined 12 safety design elements and encouraged companies testing and deploying self-driving systems to address each of these areas. Over the course of this Safety Report, we address each of these and outline the processes relevant to each safety design element and how they underpin the development, testing, and deployment of fully self-driving vehicles.

Fully self-driving vehicles will succeed in their promise and gain public acceptance only if they are safe. That's why Waymo has been investing in safety and building the processes that give us the confidence that our self-driving vehicles can serve the public's need for safer transportation and better mobility.



BMW **2019**

5 / 2
Million
Recorded Kilometers

240
Million
Simulated Kilometers

The first step in the process is to collect approx. 5 million kilometres (3.1 – 3.7 million miles) of real-life driving data from the test fleet vehicles. From this data, two million kilometres (1.25 million miles) of the most relevant driving scenarios and environmental factors are then extracted.

The relevance of the data collected is continuously improving thanks to the way in which qualitative data is selected using data qualification/filtering. These two million kilometres of driving data subsequently undergoes regular reprocessing as development progresses. This happens whenever a new control unit integration level (I-level) becomes available, in order to evaluate the new I-level's increase in performance.

This qualified two million kilometres of data is constantly expanded by a further 240 million kilometres (150 million miles) of simulation-generated data, which is primarily based on the relevant driving scenarios and ensures that the immense diversity of real-life driving is taken into account properly during development.

BMW GROUP
Corporate Communications

Rolls-Royce
Motor Cars Limited

Press release
Date March 27th, 2019
Subject The new BMW Group High Performance D³ platform
Page 3

The reprocessing of the two million real-life kilometres and 240 million virtual kilometres requires a high performance data platform of over 230 petabytes storage capacity and the computing power of more than 100,000 cores and more than 200 GPUs (Graphics Processing Units).

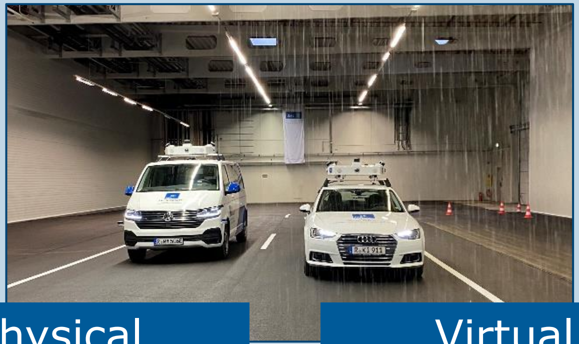
There is a 96 x 100Gbps connection between the BMW Group High Performance D³ platform and the Hardware-in-the-Loop (HiL) stations located at the BMW Group Autonomous Driving Campus. The net useable data rate is approx. 3.75 Terabit/s.

The fleet currently numbers around 80 BMW 7 Series cars, which are in operation on the west coast of the USA, in Germany, Israel and China. The number of vehicles is set to increase to approx. 140 by the end of 2019.

Targets Center for Mobility and Sensor Testing Roding

ADAS/AD Center for Mobility and Sensor Testing Roding

Sensor Center for **adverse weather conditions**



Physical Simulation

Virtual Simulation

Real-world Ground Truth Reference **- Calibration**

ADAS/AD Center for Mobility and Sensor Testing Roding

Rain	Fog	Light

1 **DGT-Calibration facility**

2 **Sensor test bench:** physical simulation of rain, fog and sun

Basic Requirements Indoor Testing / Validation

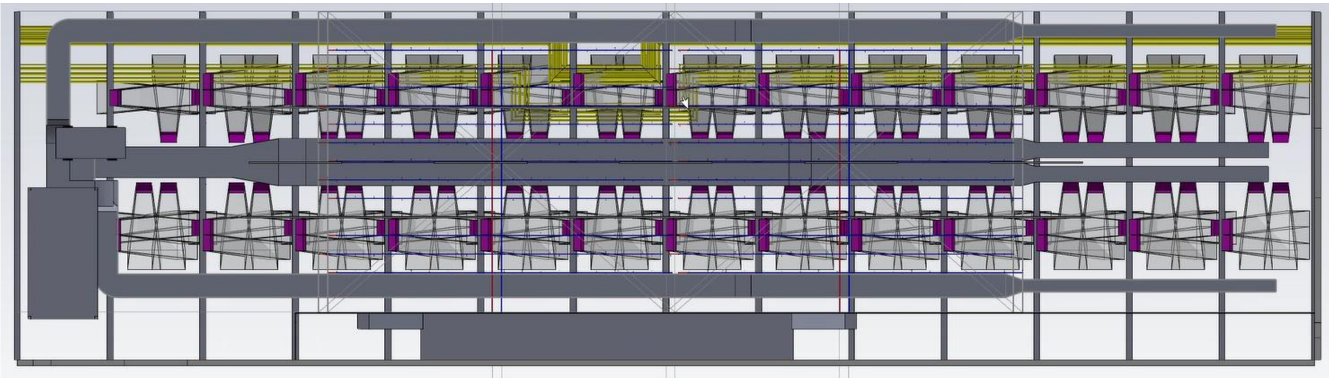
Reproduceable

- **Holistic Automation** of the complete testbench
- **End-to-End, automized Documentation and Monitoring** of all calibration parameters and results of the testbench

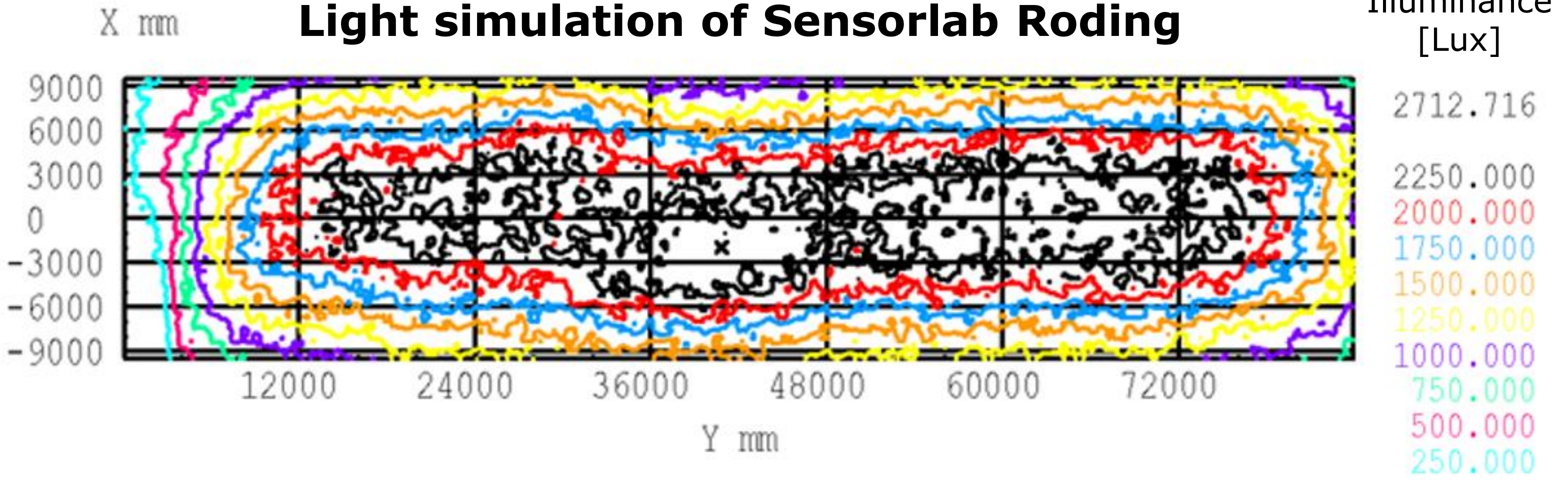
Realistic

- **Environmental conditions**: Adverse Weather (rain, fog, light), street, radar reflections, etc.
- **Static vs. Dynamic**: relative movement of the sensor (system) / vehicle

Background lighting



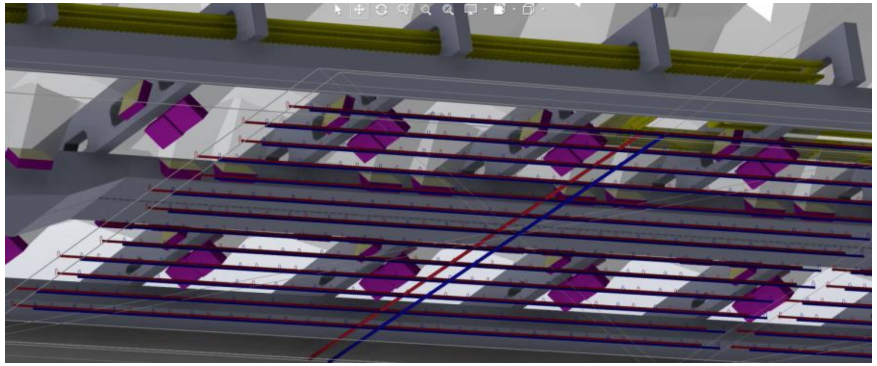
Light simulation of Sensorlab Roding



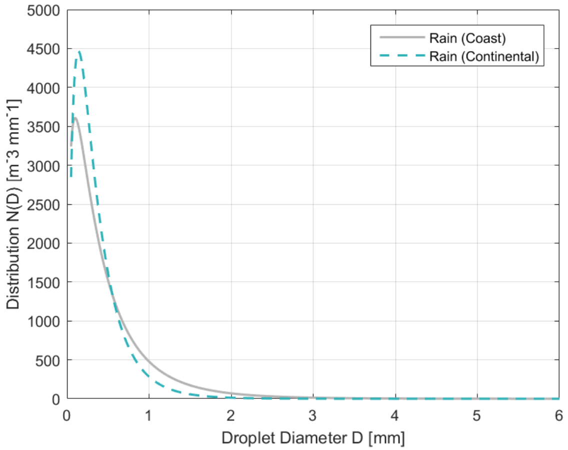
Major Requirements

- Maximum Day illuminance derived from NCAP: **2.000 lux** (10 cm above asphalt / street)
- **Diffuse indirect background light**, spotlight not directly visible for the vehicle sensors
- Possibility to modulate **color temperature** and light intensity to recreate dusk and dawn.
- **No unrealistic reflection** on wet street

Rain facility



Dropsize distribution



Falling distance

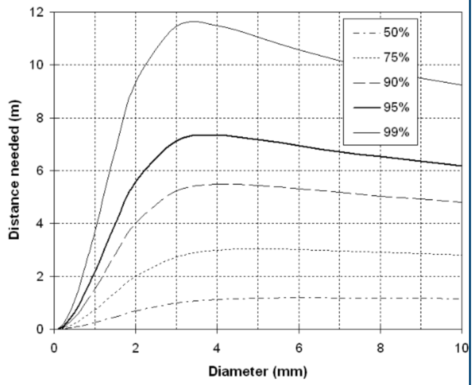


Figure 5: Falling distance needed by raindrops to obtain 50%, 75%, 90%, 95% or 99% of their terminal velocity as a function of drop diameter.

Source: Hasirlioglu, S.: A Novel Method for Simulation-based Testing and Validation of Automotive Surround Sensors under Adverse Weather Conditions. Linz, Johannes Kepler University, Thesis, 2020

Major Requirements

- **Rain intensity**: from 5 mm/h up to 98 mm/h (heavy rain wrt DWD: 15–25 mm/h)
- Realistic **drop size distribution** and **falling velocity**
- **Water recycling** for environmental protection
- **Air-ventilation** and **heating system** shall counteract on humidity.
- **Sophisticated control system** to modulate rain.

Sensorlab Roding **Services**

Sensor-Level

Raw-Data-Level

Sensor-Perception

1. Lidar in Rain / Fog
2. Camera with light

Virtual Sensor-Model

System / Vehicle-Level

Static Ego-Vehicle

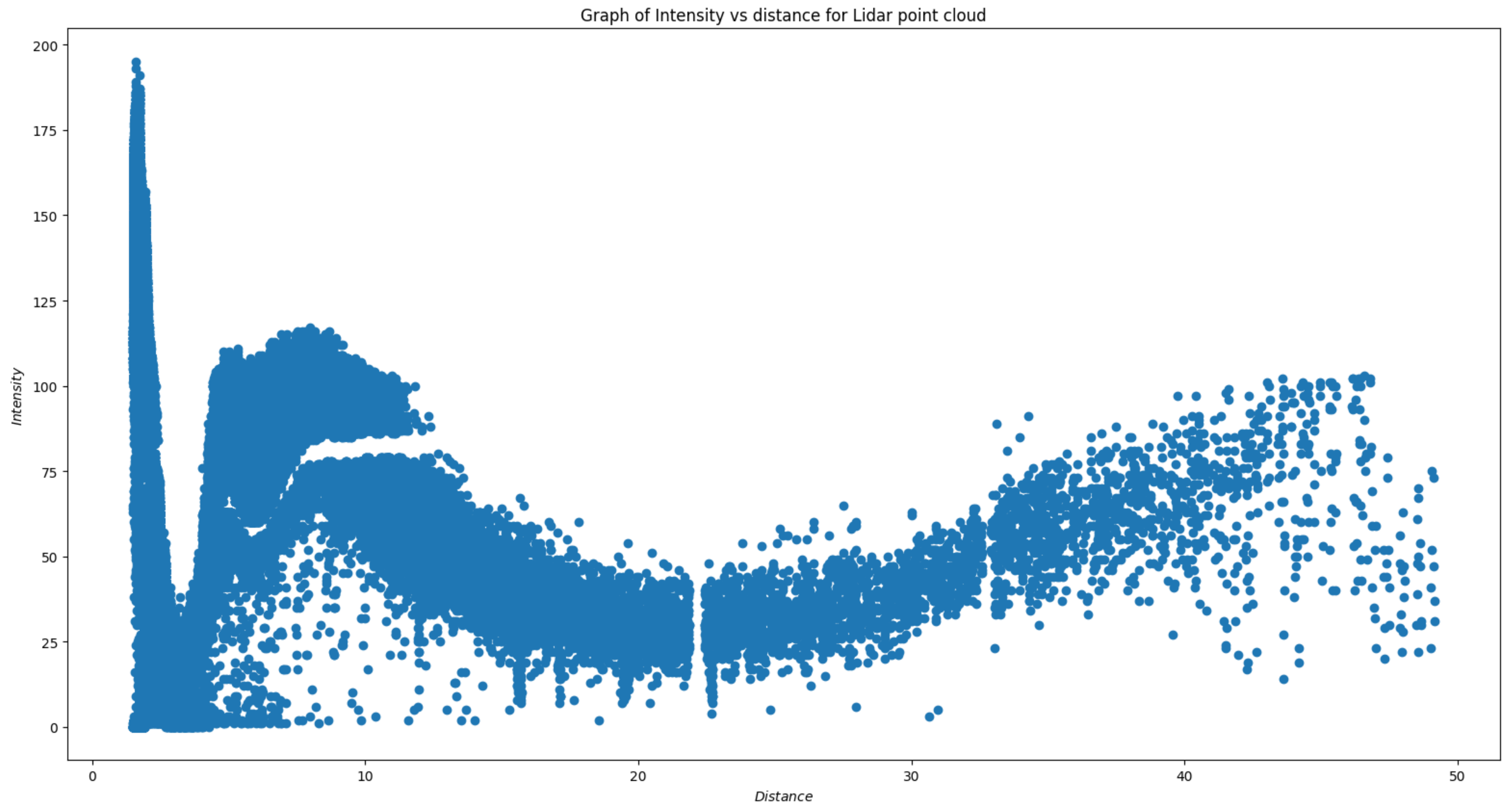
- Simplification
- Rest-Bus-simulation

Dynamic Ego-Vehicle

- Limited velocity
- NCAP Standards require constant velocity for x m

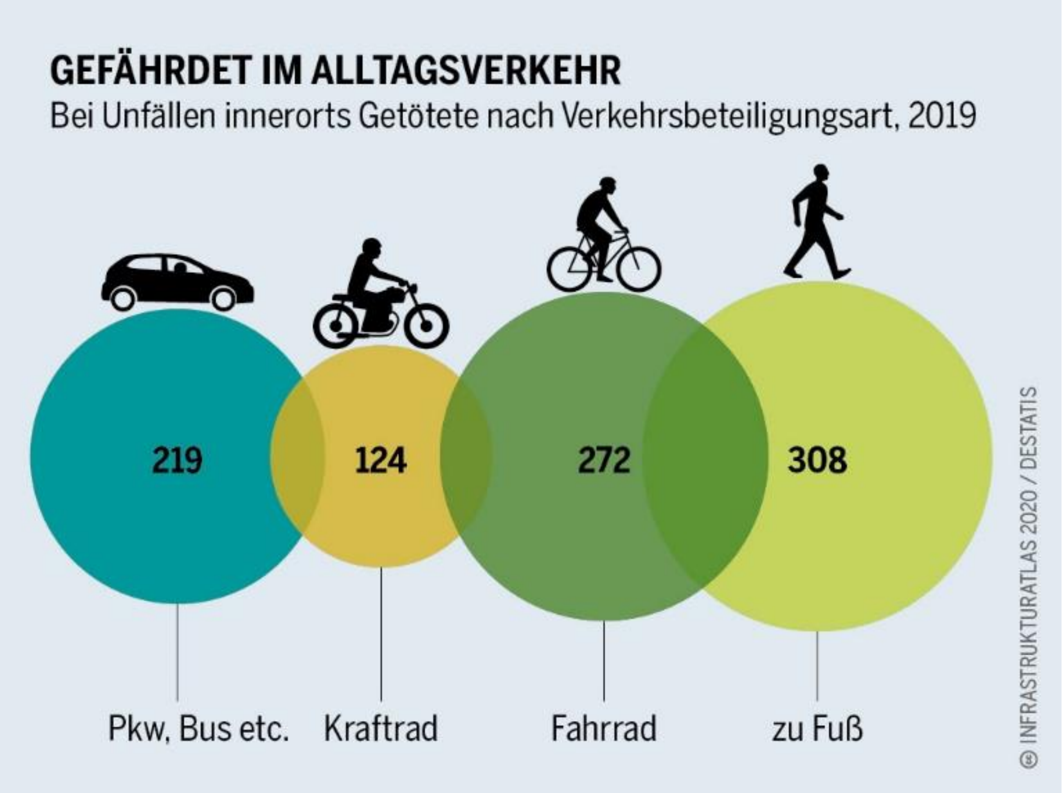
1. Physical simulation confirm virtual simulation for weather effects
2. Variation of paramters in virtual simulation

Intensity vs. Distance at **95% Reflectivity**



Improving Road Safety

Further improving **road safety of „Vulnerable Road Users (VRUs)“** by active safety systems



"In 2013, 216 cyclists died in traffic accidents in built-up areas in Germany. Since then, this figure has increased every year." (Source Destatis Infrastructure Atlas 2020)

The risk of accidents involving VRUs will continue to increase as a result of the mobility revolution and the resulting increase in the use of alternative means of transport such as bicycles, e-bikes and e-scooters.

In 2018, more than 5000 personal injury crashes were due to visibility impairment caused by fog, rain, and blinding sun (and others).

Importance of Indoor Sensortesting

Why Indoor Sensortesting in adverse weather conditions is important!

Source: https://www.euroncap.com/de/euro-ncap/zeitachse/ (access: May, 10th 2022)

- EURO NCAP **AEB Tests** are mainly performed @ daytime but **majority of crucial accidents happen during adverse weather** and / or adverse light conditions!
- Reproducibility of adverse weather conditions **outdoor is not possible** and **indoor it's a challenge**! → Indoor testing of rain, fog, light
- **Virtual Testing for parameter variation** is going to play a major role! → Virtual Testing / Scenario variaton
- Criticality of the whole topic "**explodes**" for Autonomous Driving → Prepare for AD!

Indoor Euro NCAP VRU test plus virtual parameter variation

Indoor Test

1

Indoor NCAP VRU
- vehicle **dynamic**
- 5 rain classes
- V_max < 30 km/h

↔

2

Indoor NCAP VRU
- vehicle **static**
- 5 rain classes
- Variation of distance

HIL

3

Parametervariation HIL
- VRU clothing
- Variation rain classes
- V_max with respect to NCAP

Simulation

4

Parametervariation in Simulation
- VRU clothing
- Variation rainclasses
- V_max with respect to NCAP

AVL Dynamic Ground Truth System (DGT)

Independent Reference System
for vehicle type approval

KBA TÜV SÜD DEKRA

Statistical comparison:

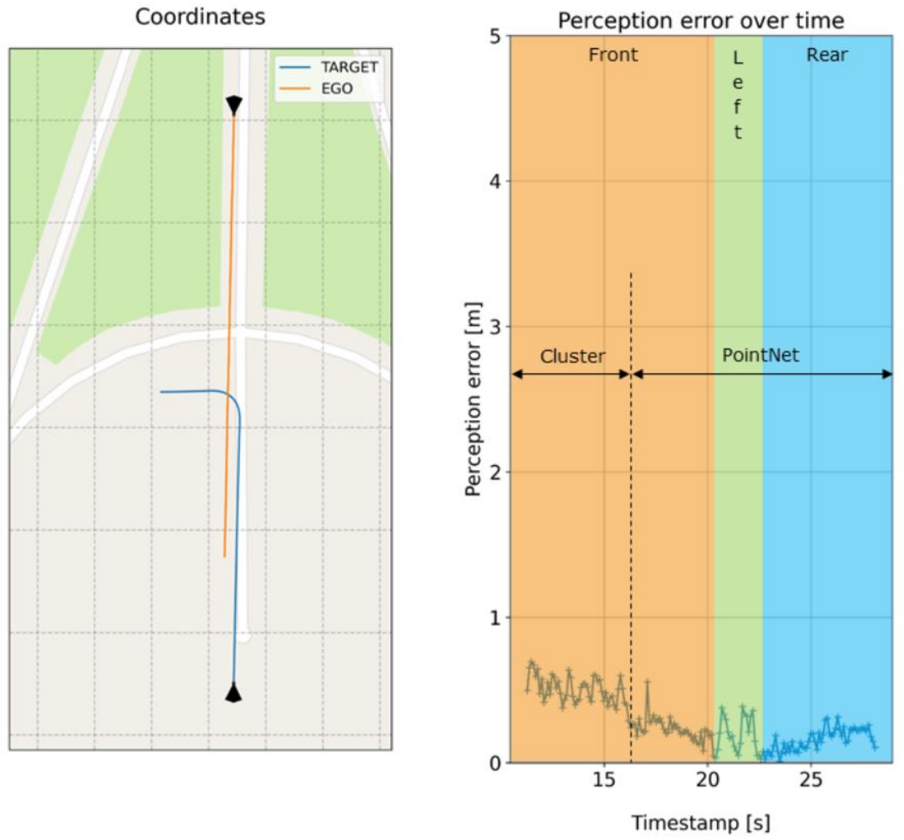
- When has the object been detected?
- Is this performance sufficient for type approval?

Vehicle to be homologated

BMW Audi Mercedes-Benz

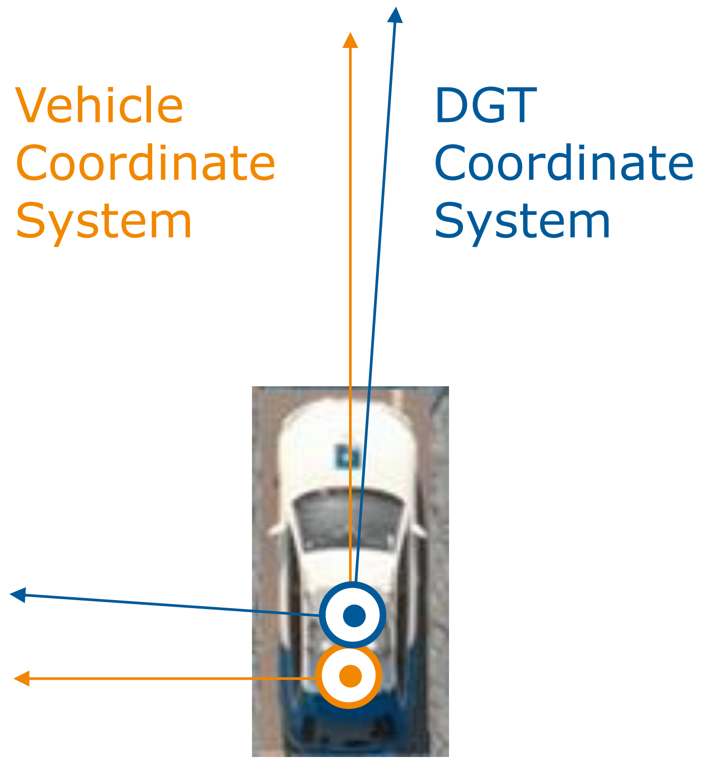
Target of DGT Calibration

Positioning accuracy of DGT < 0,5% relative to distance



1° of angle variation at 100 m → 1,75 m

Target: **max. 0,2°** of angle deviation



Three step approach for a precise calibration of the DGT-Reference System

1

4 x Intrinsic Calibration of DGT Cameras

2

(4 +2 +1) x Extrinsic Calibration of DGT Sensors

Matching local Sensor coordinate system to one common reference coordinate system (central lidar)

3

Extrinsic Calibration of DGT Box to vehicle

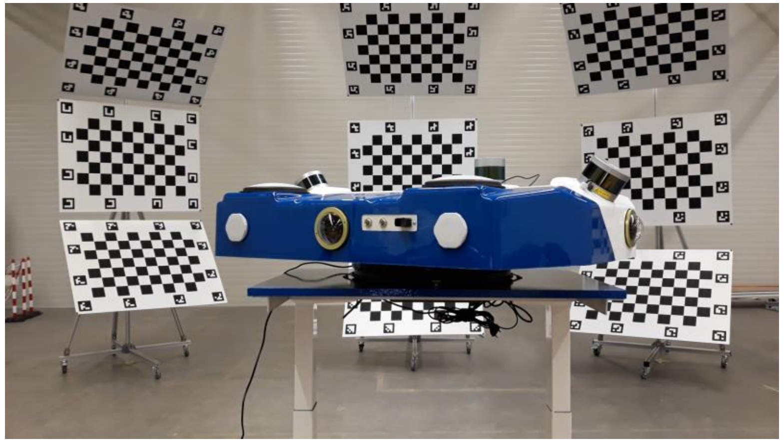
Matching the **sensor reference coordinate** system of the DGT-Box to the **vehicle coordinate system**

End-Of-Line

In-Field

Intrinsic/Extrinsic DGT End-of-Line-Calibration in Roding

DGT view

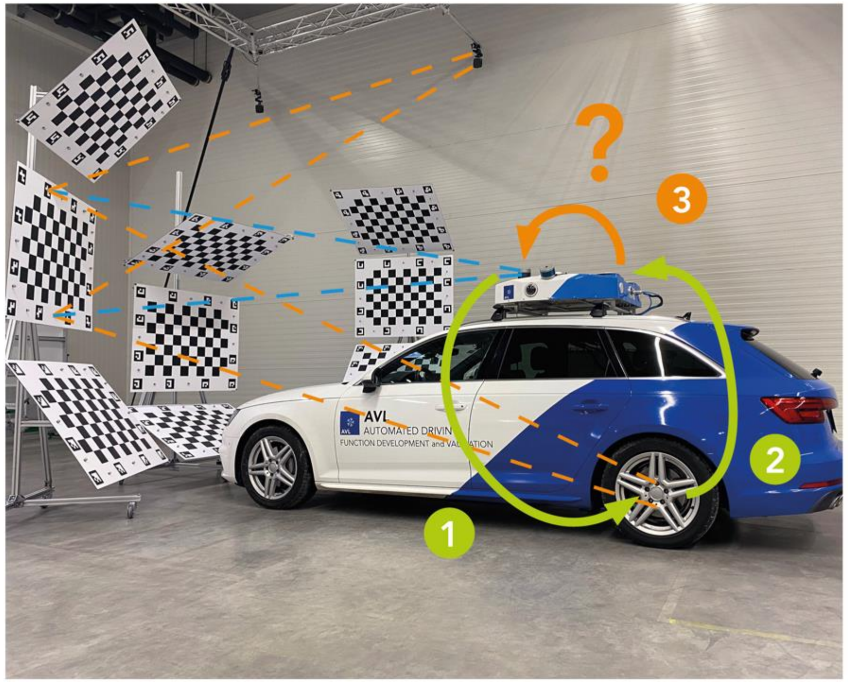


Camera view

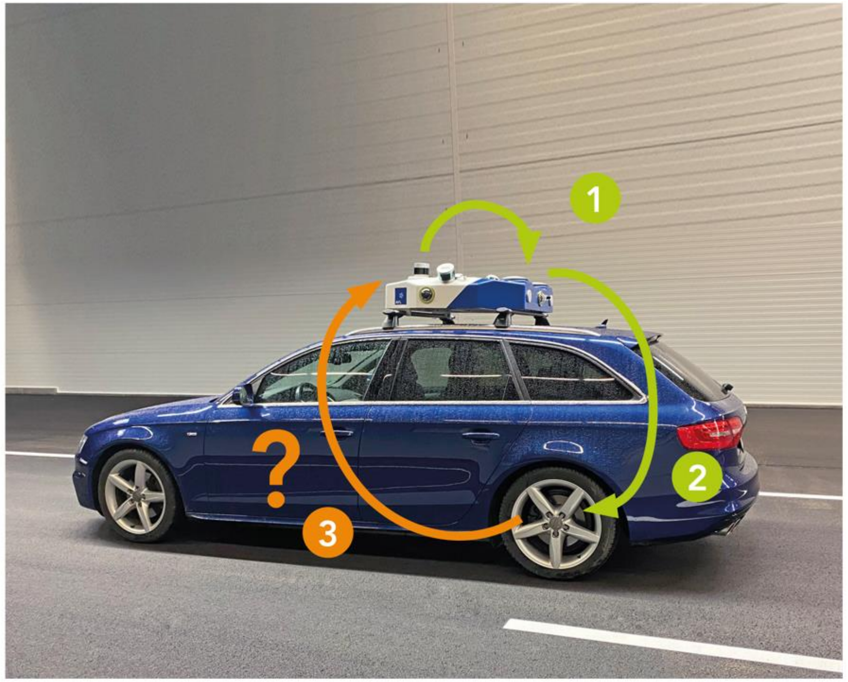
	Calibration Set-Up	Calibration KPIs
1	DGT mounted on **turntable** and **lift table**	Duration calibration data **recording < 30 min**
		Reprojection Error < 0,5 pxl
2	**Pairwise extrinsic calibration of all sensors to the central lidar**	Target object **Coverage** > 80%
		Angular deviation 0,2°

Two approaches for extrinsic "Box-to-Vehicle-Calibration"

End-of-line Calibration



In-Field Calibration



3

In Calibration bench: **GNSS to Lidar = ?**

1. Lidar to Rear axle by 3-d camera system
2. Rear axle to GNSS through GNSS calib-routine
3. GNSS to Lidar by formal combination of 1 and 2

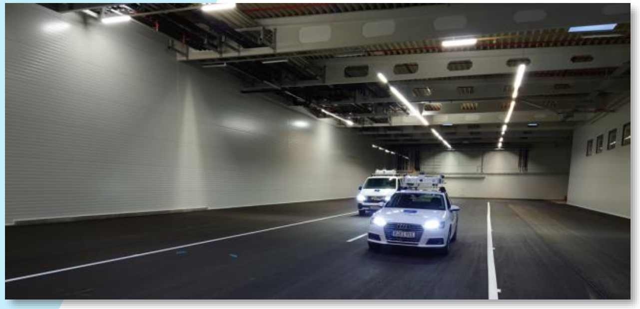
In Calibration bench: **Central Lidar to Rear axle = ?**

1. Lidar to GNSS from calibration bench
2. Rear axle to GNSS through GNSS calib-routine
3. Lidar to Rear axle by formal combination of 1 and 2

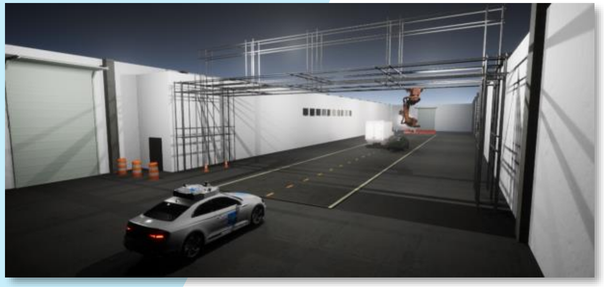
Strong support on all levels of Testing and Validation

Real – world Testing

Reproduceable Indoor testing



Virtual testing



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