Autonome Mobilität im öffentlichen Nahverkehr unter widrigen Wetterbedingungen am Beispiel "AutBus"

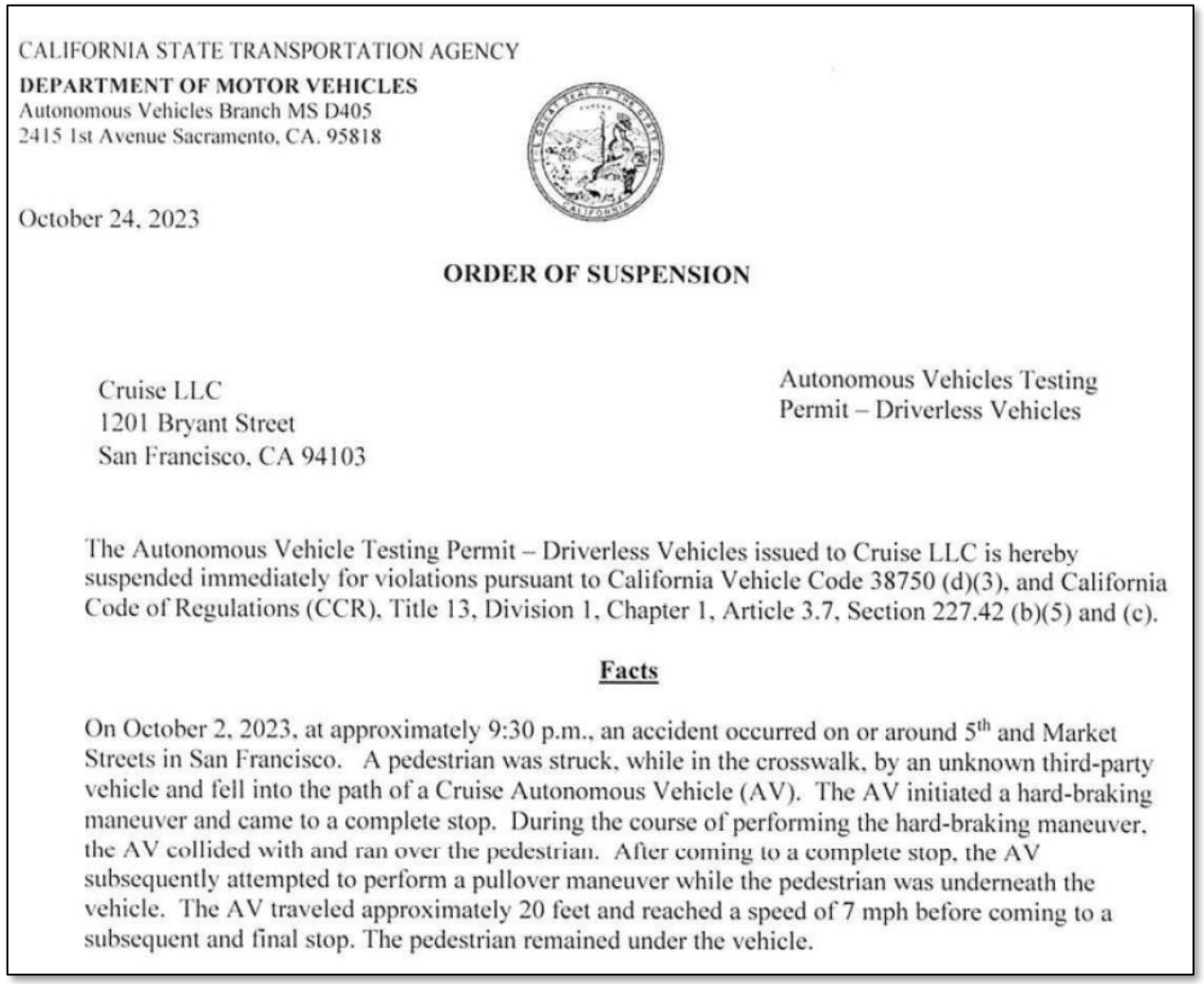
Dr.-Ing. Armin Engstle

AVL List GmbH (Headquarters)

Agenda

1. **Status Autonomous Driving**: US vs. Europe — **Strategy**
2. **Status „AutBus“** — **Technology**
3. **EE-Architecture and Sensorconcept AutBus**
4. **Sensortesting in Adverse Weather Conditions** — **Perception**
5. **Lidar Measurements in Rain and Fog**
6. **Summary - Outlook**

US: **Robotaxi-approach / Ride hailing** (= holistic ODD)



CALIFORNIA STATE TRANSPORTATION AGENCY
DEPARTMENT OF MOTOR VEHICLES
Autonomous Vehicles Branch MS D405
2415 1st Avenue Sacramento, CA. 95818

October 24, 2023

ORDER OF SUSPENSION

Cruise LLC
1201 Bryant Street
San Francisco, CA 94103

Autonomous Vehicles Testing Permit – Driverless Vehicles

The Autonomous Vehicle Testing Permit – Driverless Vehicles issued to Cruise LLC is hereby suspended immediately for violations pursuant to California Vehicle Code 38750 (d)(3), and California Code of Regulations (CCR), Title 13, Division 1, Chapter 1, Article 3.7, Section 227.42 (b)(5) and (c).

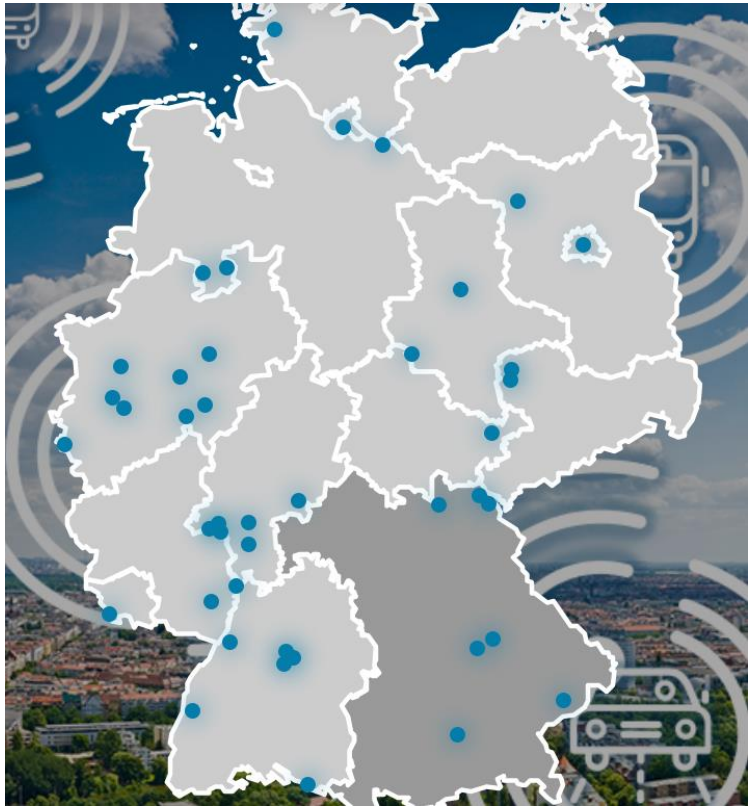
Facts

On October 2, 2023, at approximately 9:30 p.m., an accident occurred on or around 5th and Market Streets in San Francisco. A pedestrian was struck, while in the crosswalk, by an unknown third-party vehicle and fell into the path of a Cruise Autonomous Vehicle (AV). The AV initiated a hard-braking maneuver and came to a complete stop. During the course of performing the hard-braking maneuver, the AV collided with and ran over the pedestrian. After coming to a complete stop, the AV subsequently attempted to perform a pullover maneuver while the pedestrian was underneath the vehicle. The AV traveled approximately 20 feet and reached a speed of 7 mph before coming to a subsequent and final stop. The pedestrian remained under the vehicle.

- On 01.10.2023 the Department of Motor Vehicles (DMV) **suspended the Autonomous Vehicle Testing permit issued to the company "Cruise LLC"** (GM daughter) due to a critical accident.
- In 2022 Cruise has been driving **550.000 Miles without safety driver** in California.
- The average distance between „Disengagements" **for Cruise** was **95.901 Miles in 2022** (Source: DMV Disengagement Reoports; https://www.dmv.ca.gov/portal/vehicle-industry-services/autonomous-vehicles/disengagement-reports/)
- Distance between accidents with personal injuries: **2.2 – 12 Mio. Km** (Prof. Winner, Absicherung Automatisiertes Fahren, 2013)

Germany: **„Autonomous" public transport** in restricted ODDs

Innovationlandscape:
Autonomous Busses BRD



- In more than **45 German cities** trial projects with autonomous peoplemovers in public transport are operated.
- Major field of application is the **urban driving** with velocities of **15 – 20 kph** in the city centres with the autonomous shuttles from Easymile or Navya.
- Exceptions are the activities from MOIA and VWN in Hamburg as well as the „Absolute-Project" in Saxony.

Quelle VDV Die Verkehrsunternehmen:
https://www.vdv.de/innovationslandkarte.aspx
(checked: 26.08.2022, 10:15 am)

E/E architecture AutBus

AVL AD Construction Kit:

AVL GT Sensorhead: current uses Lidar und GNSS

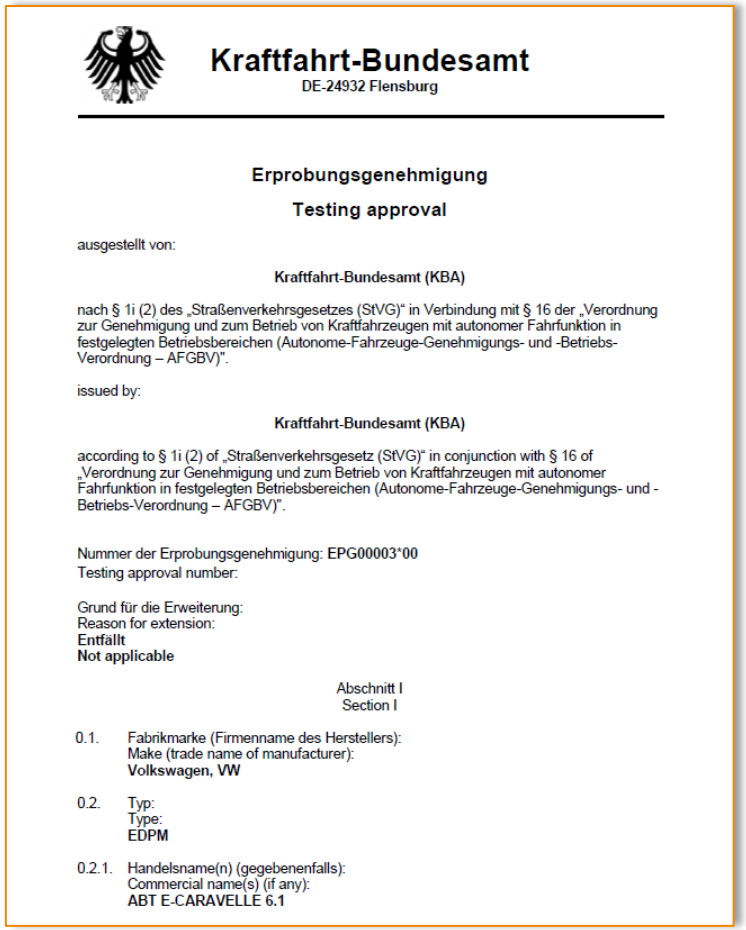
E/E-Integration controller unit AVL Ajunic

Steering / Bracking: Schaeffler Paravan

Additional Lidar und Radar-Sensors: chassis integrated

Complete AVL AD Driving Stack: SW and Function development + calibration

Official Start of “AutBus” **trial period:** 13.07.2023



Kraftfahrt-Bundesamt
DE-24932 Flensburg

Erprobungsgenehmigung

Testing approval

ausgestellt von:

Kraftfahrt-Bundesamt (KBA)

nach § 1i (2) des „Straßenverkehrsgesetzes (StVG)“ in Verbindung mit § 16 der „Verordnung zur Genehmigung und zum Betrieb von Kraftfahrzeugen mit autonomer Fahrfunktion in festgelegten Betriebsbereichen (Autonome-Fahrzeuge-Genehmigungs- und -Betriebs-Verordnung – AFGBV)“.

issued by:

Kraftfahrt-Bundesamt (KBA)

according to § 1i (2) of „Straßenverkehrsgesetz (StVG)“ in conjunction with § 16 of „Verordnung zur Genehmigung und zum Betrieb von Kraftfahrzeugen mit autonomer Fahrfunktion in festgelegten Betriebsbereichen (Autonome-Fahrzeuge-Genehmigungs- und -Betriebs-Verordnung – AFGBV)“.

Nummer der Erprobungsgenehmigung: EPG00003*00
Testing approval number:

Grund für die Erweiterung:
Reason for extension:
Entfällt
Not applicable

Abschnitt I
Section I

0.1. Fabrikmarke (Firmenname des Herstellers):
Make (trade name of manufacturer):
Volkswagen, VW

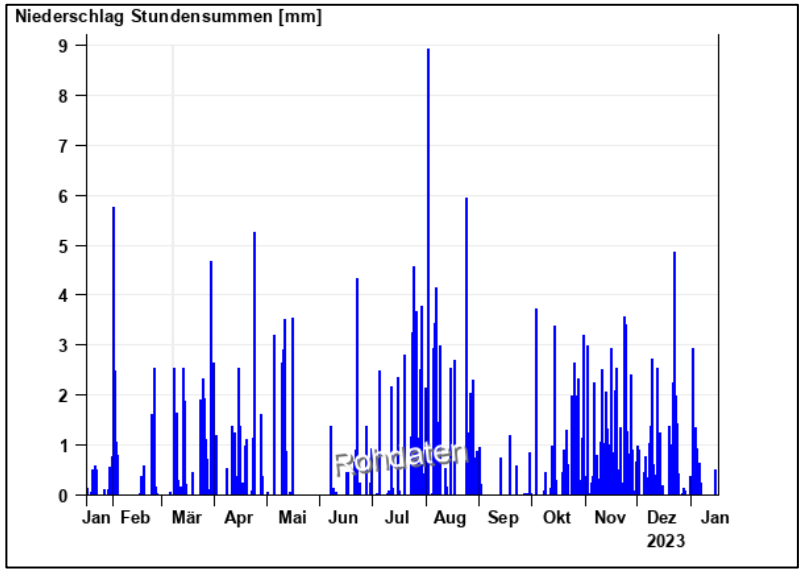
0.2. Typ:
Type:
EDPM

0.2.1. Handelsname(n) (gegebenenfalls):
Commercial name(s) (if any):
ABT E-CARAVELLE 6.1

- Receival of the official „Trial allowance“for public road testing from the german KBA **18.04.2023**
- **Safety driver** can override the autonomous driving function by touching the actuators at anytime
- Maiden trip on **13.07.2023** with Minister Aiwanger
- **Public transport** trial period: 15.07. – 15.08.24

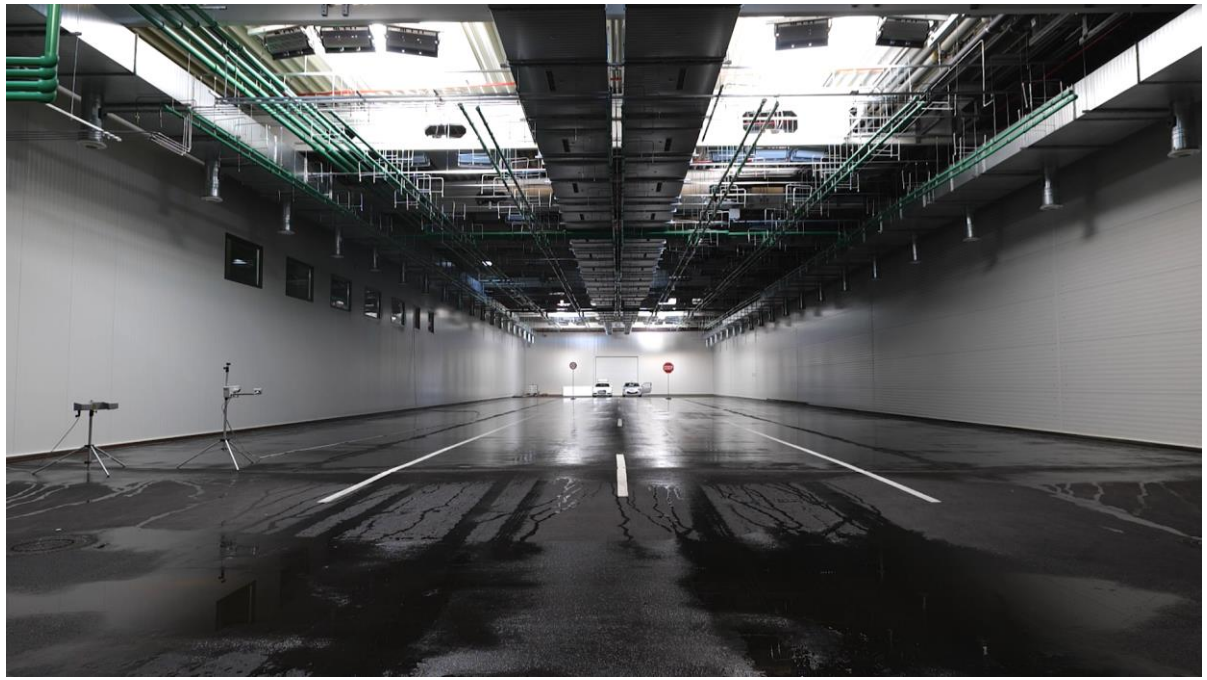
Historisches Foto an der Bushaltestelle nach einer makellosen Jungfernfahrt mit strahlenden Gästen und dem Kopf von AVL (von links): Dr. Armin Engstle, Leiter von AVL in Roding, MdL Dr. Gerhard Hopp, Rodings Bürgermeisterin Alexandra Riedl, Landrat Franz Löffler, Wirtschaftsminister Hubert Aiwanger und AVL-Geschäftsführer Dr. Georg Schwab. Fotos: Josef Heigl

Target AutBus: Autonomous public transport in rural areas



- Connecting the local recreation area of the village “Neubäu am See” with the train station (1,4 km)
- Feasibly high fog penetration due to the lake, rain precipitation is given with approx. 800 mm/h
- MOIA (Ridepooling Company): „We earn best, when it is raining!“
- Kelride: „All-weather capability is a prerequisite for an autonomous public transport!“

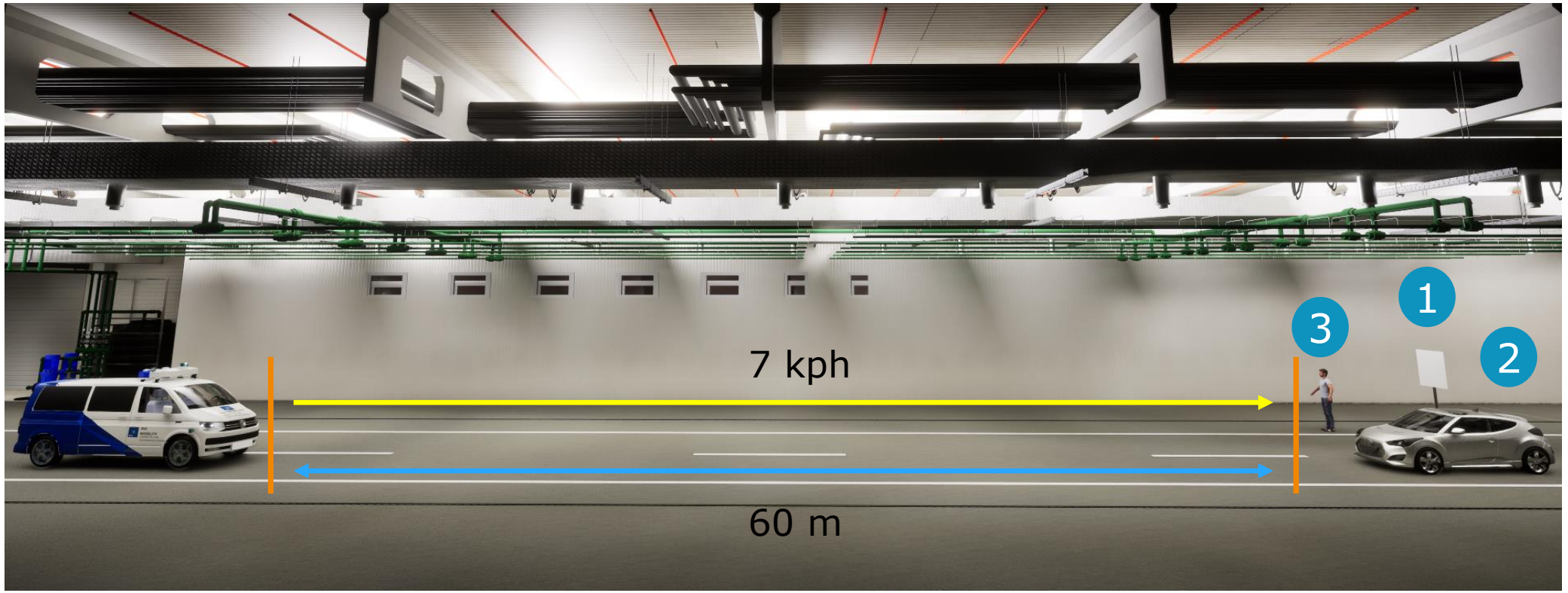
AVL Weatherbench: Real vs. Digital Twin



Chracteristics Weatherbench:

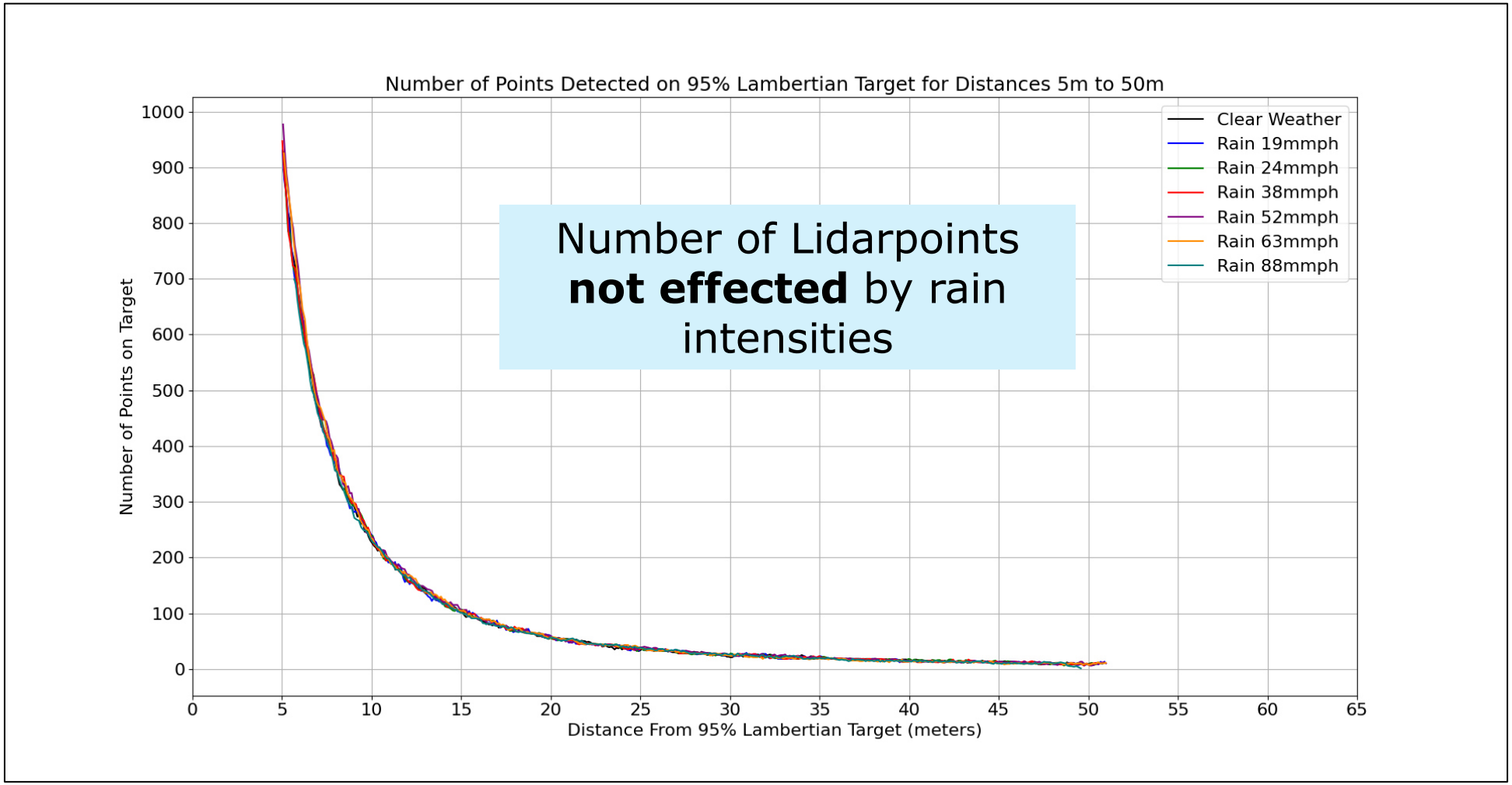
- Dimensions: 86 m x 19,5 m
- Rain rates: ranging from 15 mm/h – 115 mm/h with realistic Drop-Size distribution and falling velocity
- Minimum Fog visibility range: 7 m, with realistic Drop-Size distribution
- Light: indirect light reflected from a lambertian reflector; in total 90 kW of electric light power

AutBus measurement set-up for **Lidar evaluation**

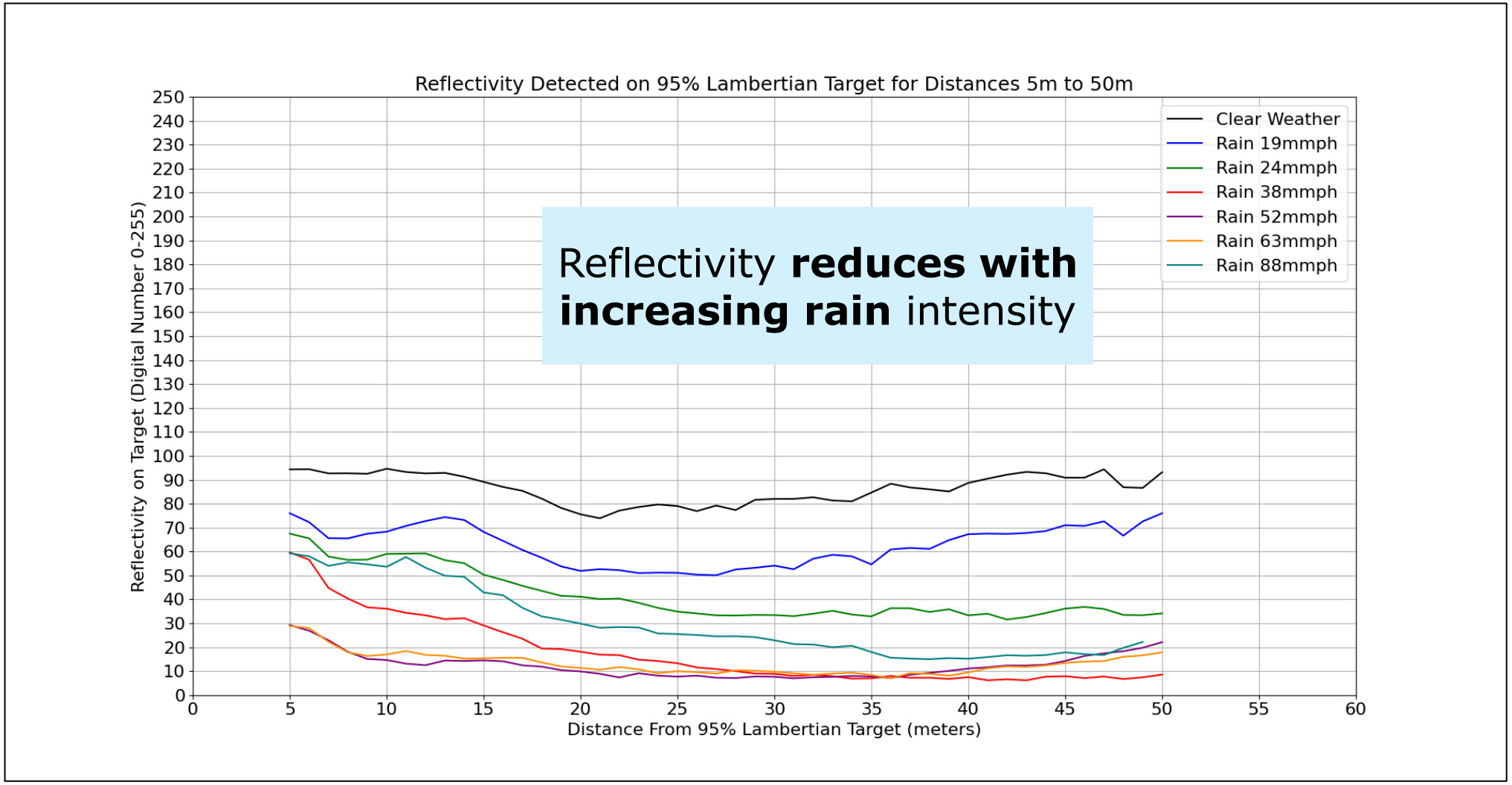


- **Raw-data level**: How many points are received back, how is reflectivity changing?
- **Perception level**: How is Precision changing depending on distance and disturbance?

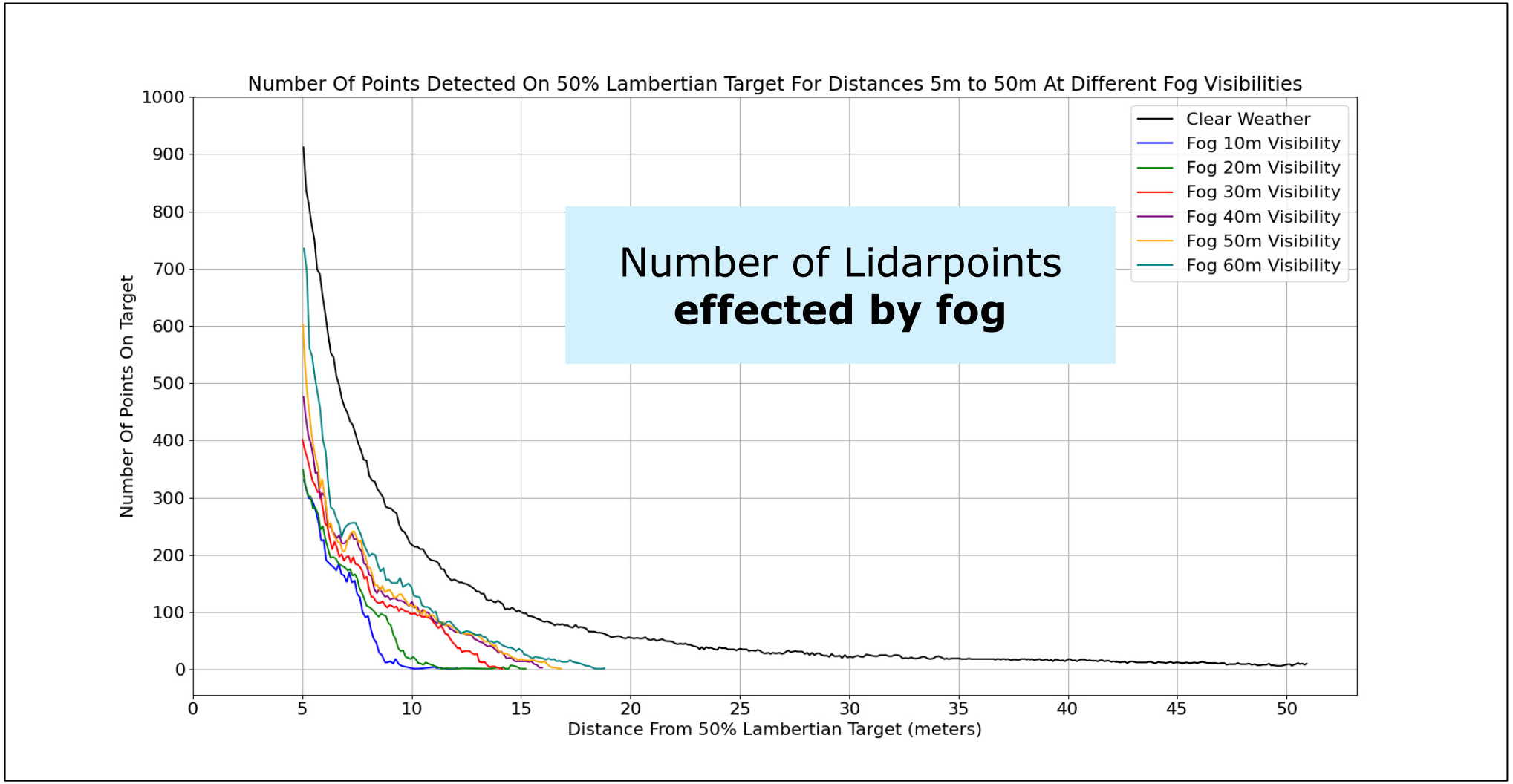
Rain: Number of Lidar points as a function of distance



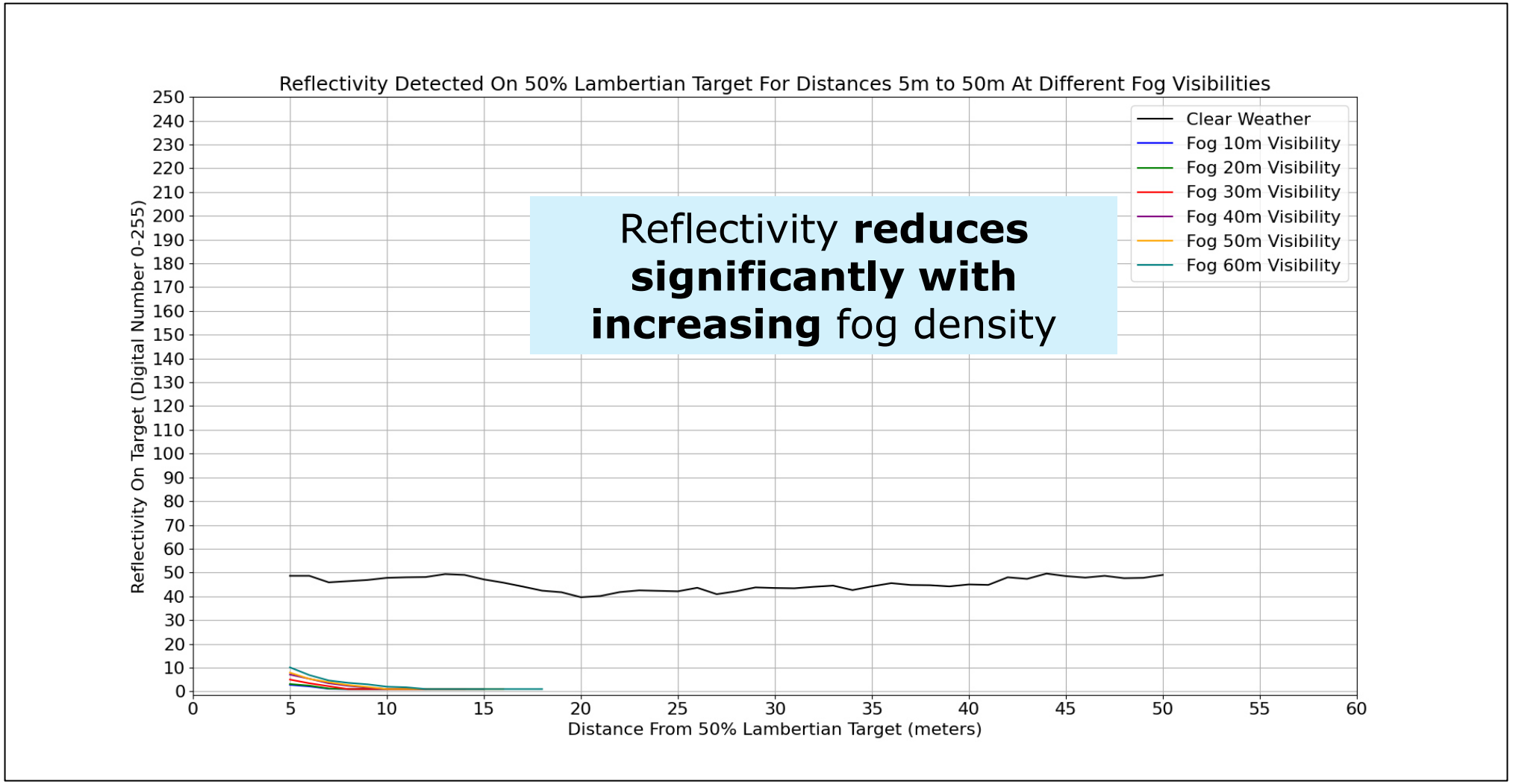
Reflectivity as a function of distance **@ different rain rates**



Fog: Number of Lidar points as a function of distance



Reflectivity as a function of distance **@ different visibility ranges (fog)**



Vehicle detection and **classification** in rain and fog

Rain

X: Intensity

Y: mean average Precision

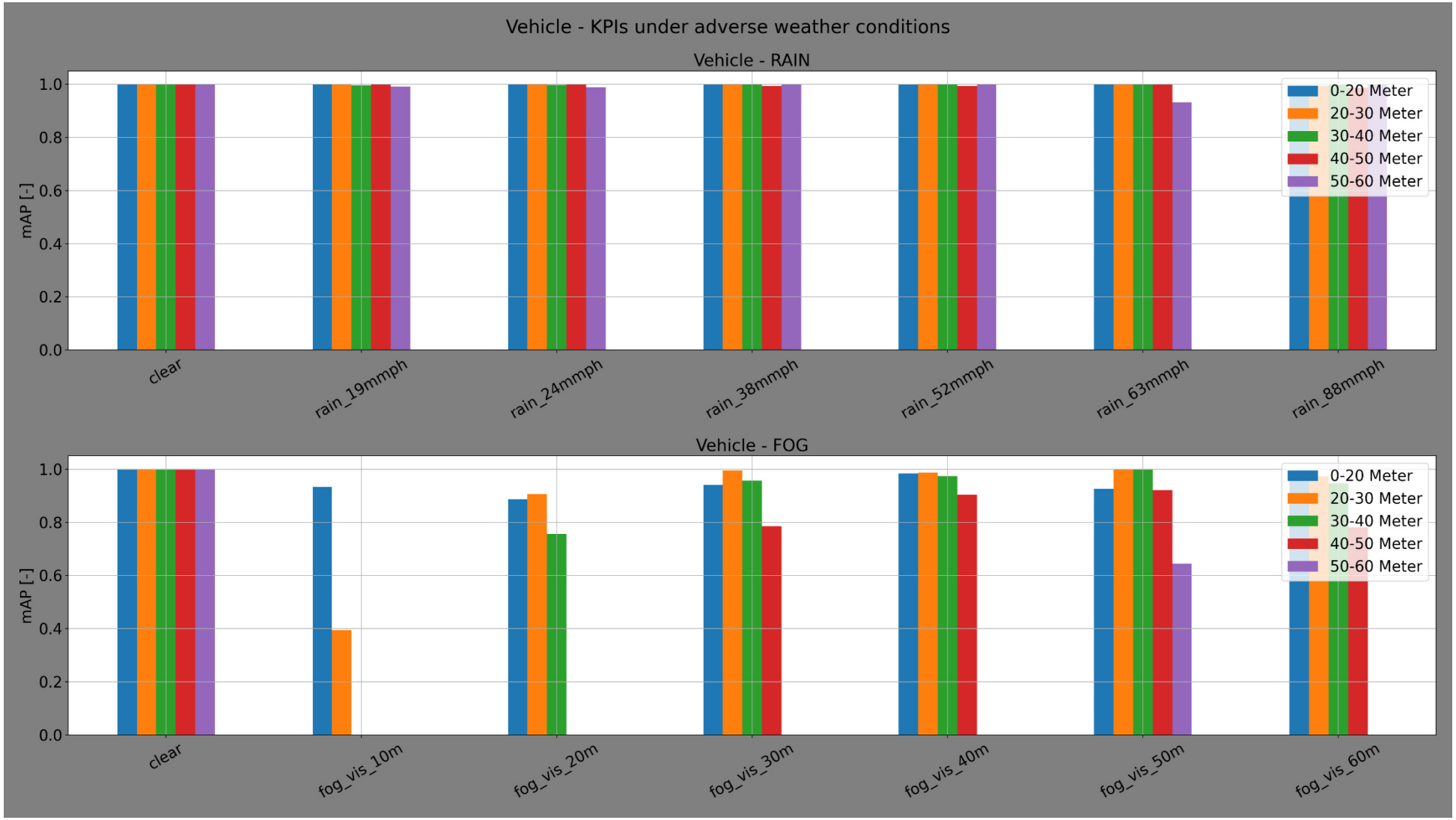
Colour: Distance Ego - Target

Fog

X: Visibility

Y: mean average Precision

Colour: Distance Ego - Target



KPI: mAP-Definition

„True positive“:

Correct

Detection &

Correct

Classification &

Position error

< 1 m or

< 5% of

distance ego to target vehicle

Solving the **„Weather Quantification issue“** is a **twofold challenge**

Testing and Validation

Serial operation

Percisely **evaluate the sensor performance in quantified weather conditions** and define the system boarders

Quantify the weather conditions in real world operation and **adapt the vehicle performance accordingly** (e.g. drive slower, hand-over or stop)

Summary - Outlook

- Adverse weather is considered to be one part of **the "long tail" of autonomous vehicle perception.**
- **Non-deterministic perception algorithm** need to be tested in a **structured way** which implies a **precise quantification** of all relevant **effects,** like e.g. weather, etc.
- With respect to a **robust environment perception** adverse weather testing and validation is already **requested** nowadays **for active safety systems like AEB (R-152!)**
- **Lidar - Measurement results**: Strong dependancy of lidar perception on fog, few(er) dependancy on rain
- **Outlook**: Creation of a edge-case dataset including a precise quantification of weather

Hochautomatisiertes Fahren 2024

08. October 2024, Dr.-Ing. Armin Engstle