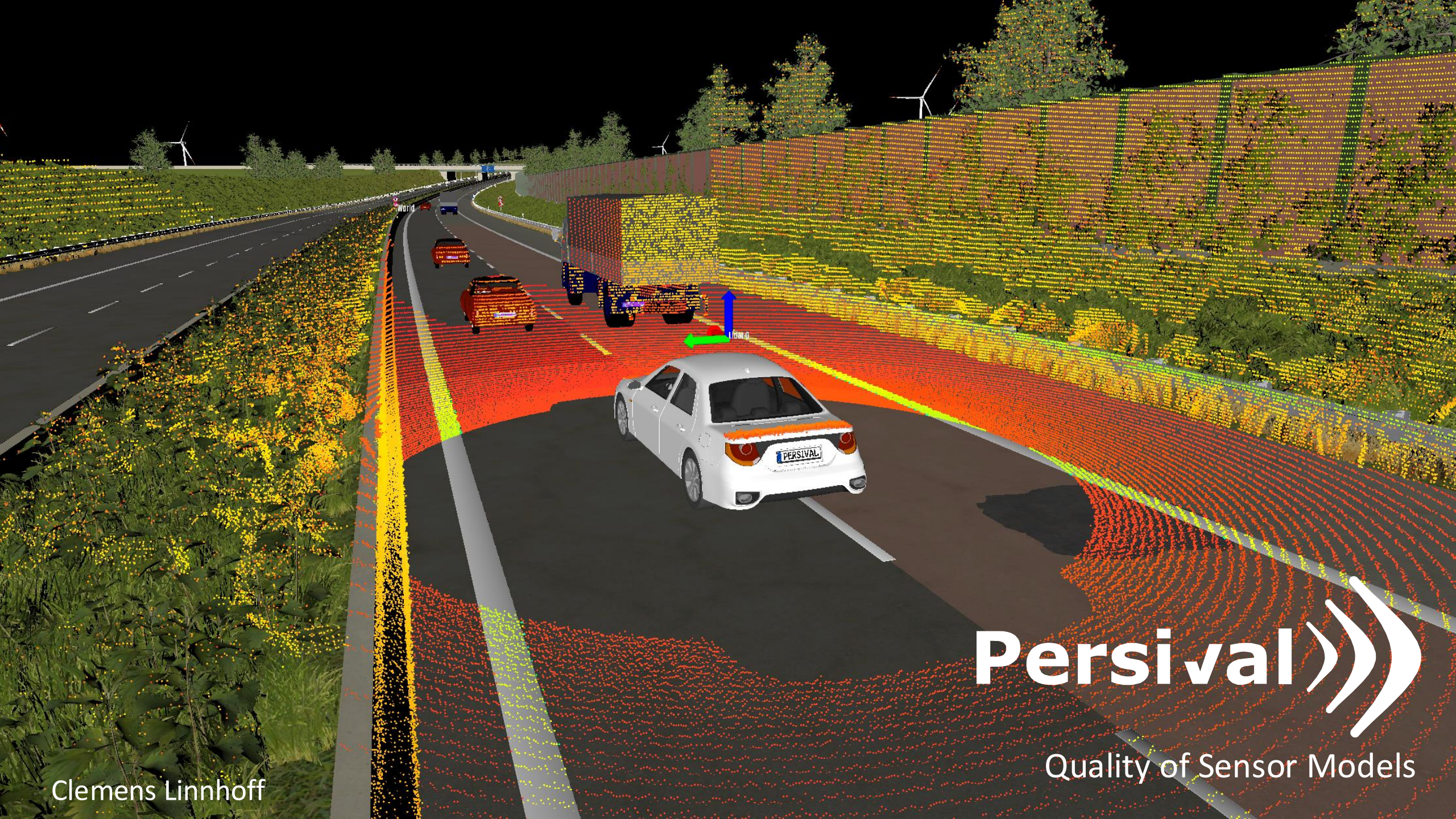


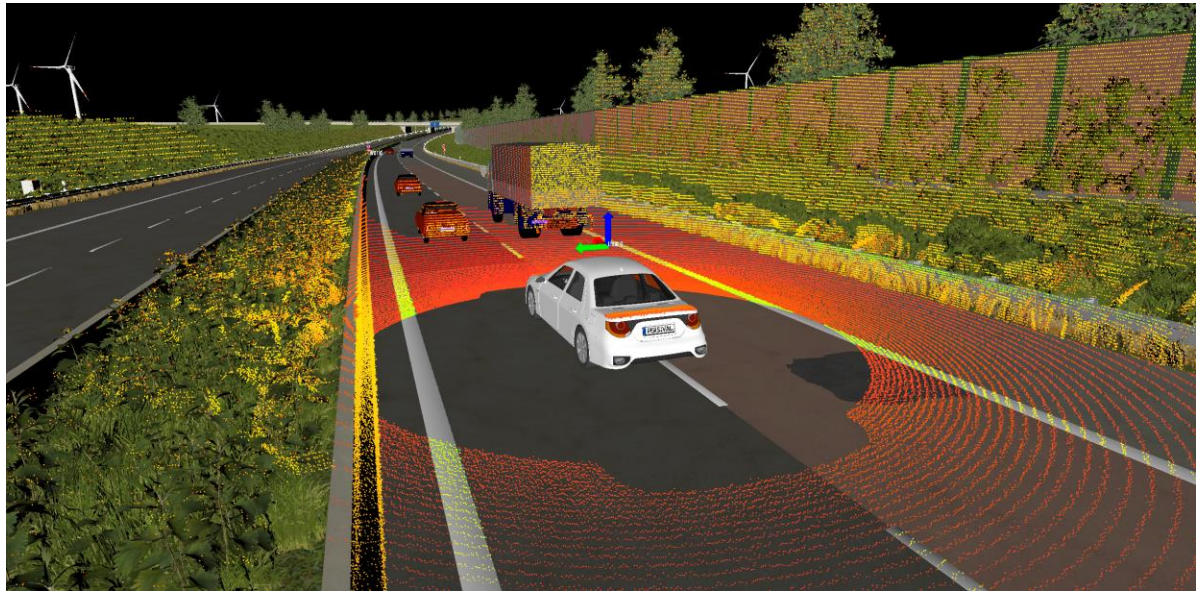
Persival

Quality of Sensor Models

Clemens Linnhoff

Persival at a Glance

Perception Sensor Simulation & Model Validation



Project highlights

- Automated testing of sensor models for BMW using a CI-pipeline in GAIA-X4PLC-AAD
- Sensor model validation with Virtual Vehicle in a project with Volkswagen and Infineon
- Lidar simulation for Digitale Schiene Deutschland by Deutsche Bahn AG.

Dr.-Ing. Philipp Rosenberger, CEO

Founding member of the Change Control Board (CCB) for the ASAM Open Simulation Interface

Expert in DIN and ISO working groups on sensor simulation standards

Dr.-Ing. Clemens Linnhoff, CTO

Sub-Library Maintainer for sensor models at asc(s e.V. – ENVITED Open-Source Model & Simulation Library (OpenMSL)

Lead of ASAM OpenMATERIAL

+

1 Senior Engineer for Measurement Systems

1 Senior Engineer for V&V

1 Senior Engineer for R&D

1 Physicist for Modeling and Simulation

1 3D Artist

2 Software Developers

3 Mechanical Engineers

1 Financial Controller and 1 Executive Assistant

Spin-off from

TECHNISCHE UNIVERSITÄT DARMSTADT FZD

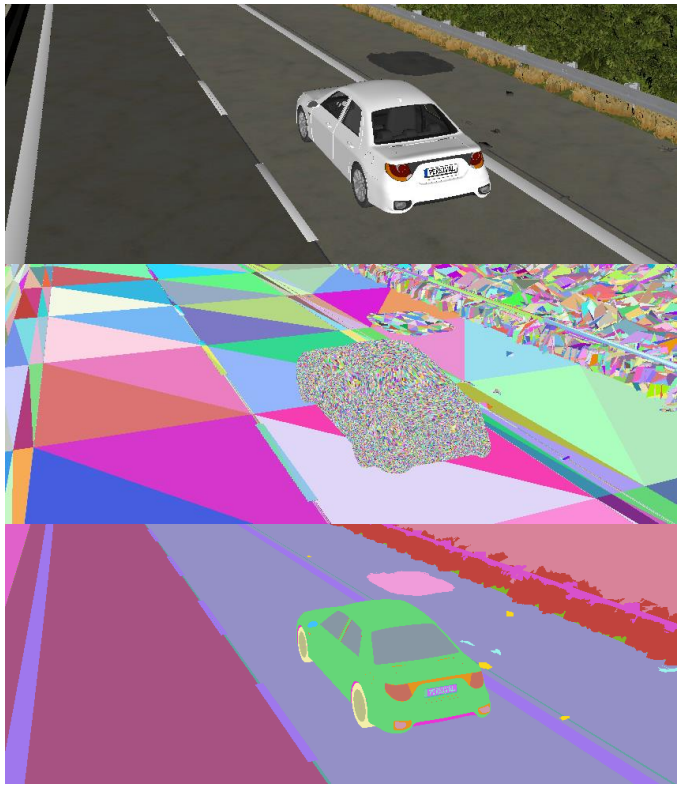
Founded: 2021

Validation in Steps

3D Environment

3D Geometries

Material Parameters

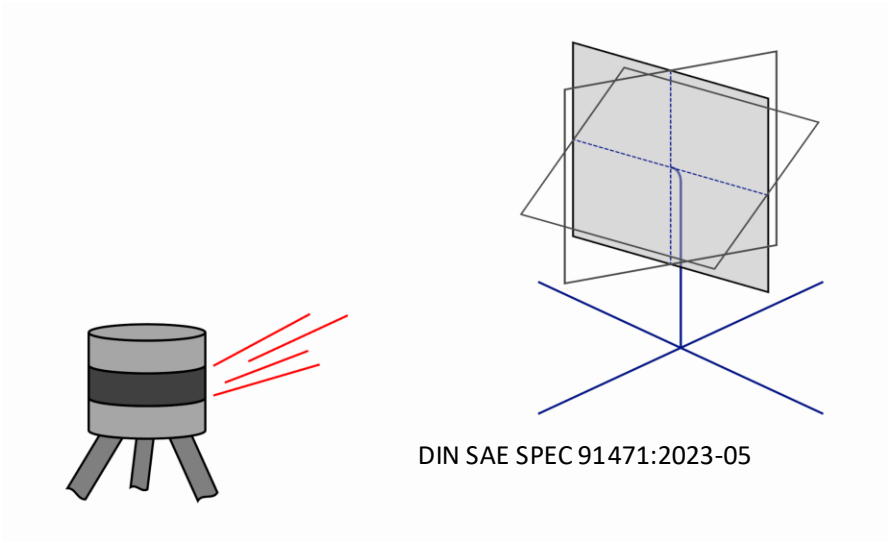


Base Sensor Performance

Beam Pattern / FoV / Antenna Diagram

Detection Ranges

Intensities



DIN SAE SPEC 91471:2023-05

Example Today

Advanced Effects

Weather Influence

Dynamic Effects

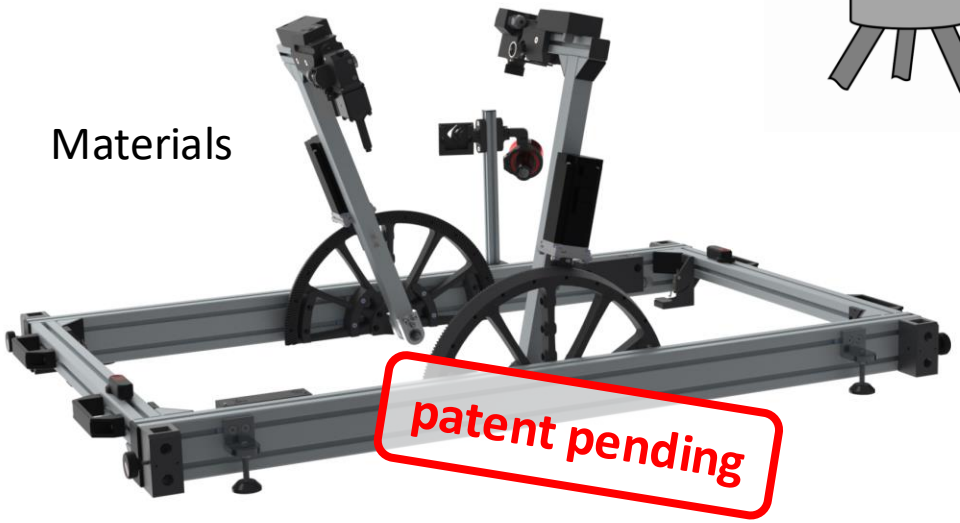
Persival

General Validation Procedure

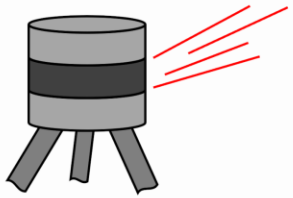
Measurements for Credible Simulation

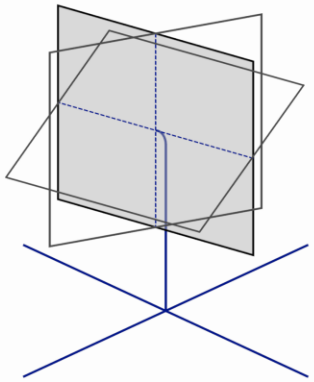
Measure → Re-simulate → Compare → Evaluate

Materials



Sensor Performance





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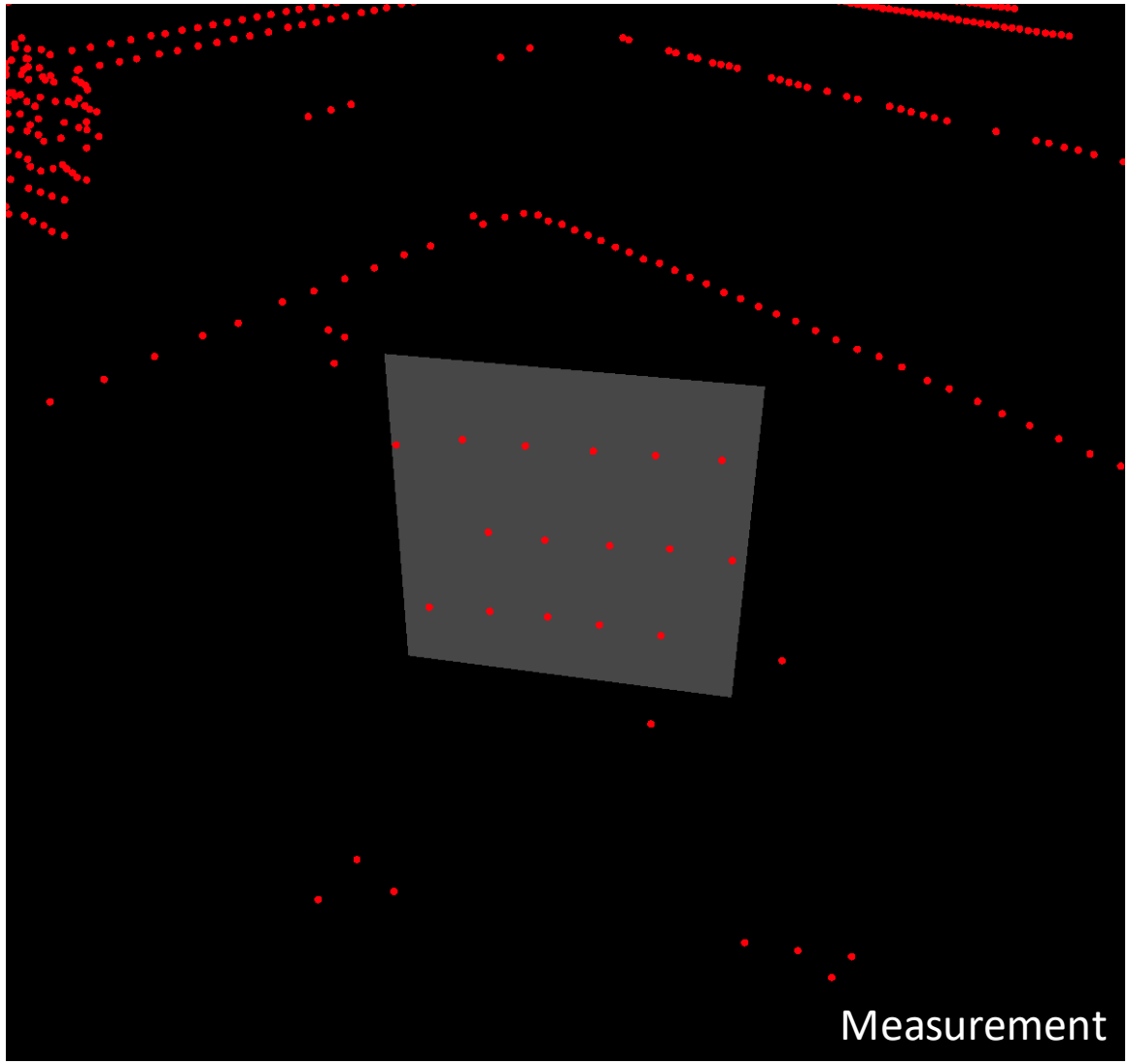
Weather Influence

Measurement Example

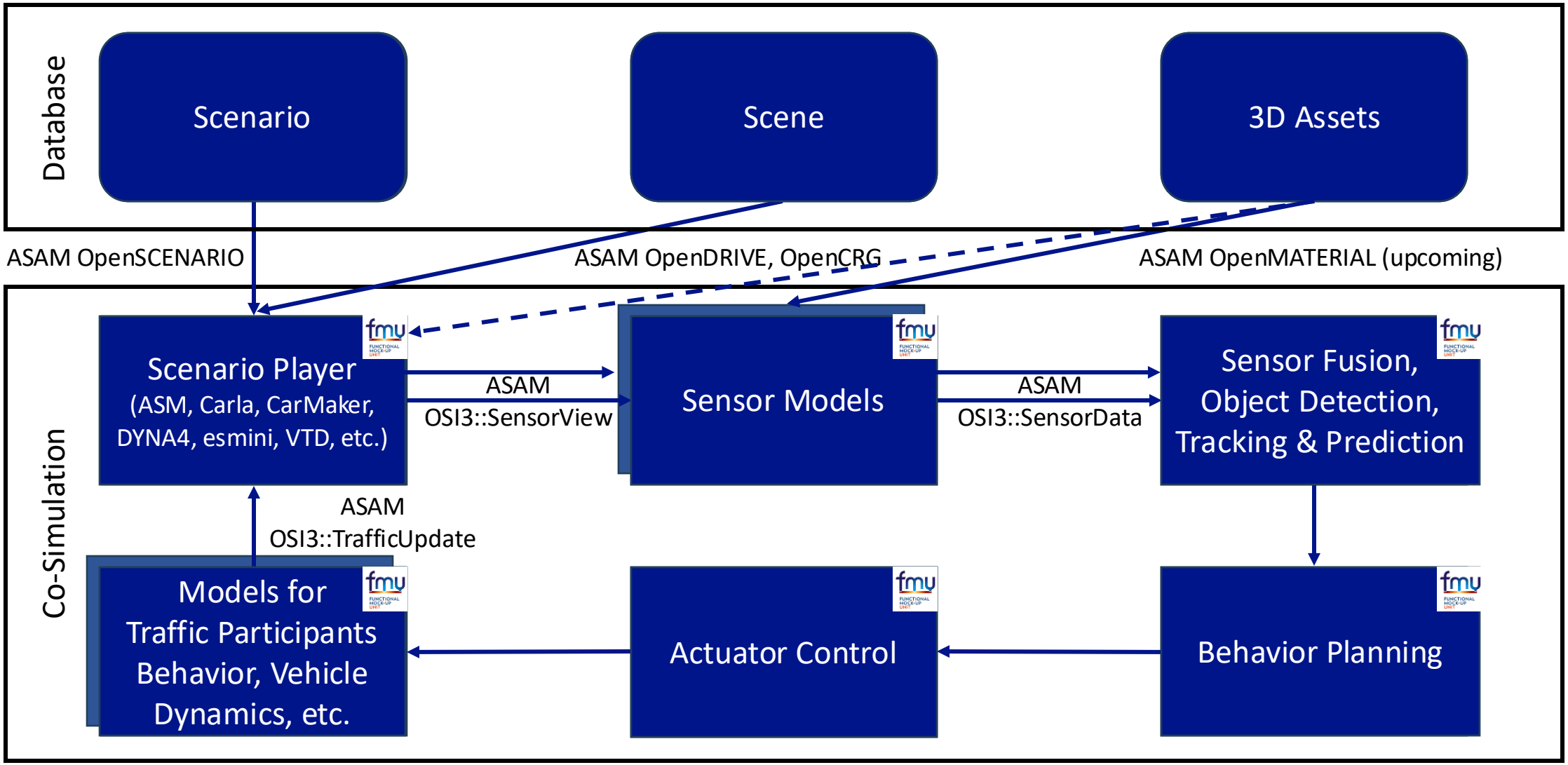
Measure | Re-simulate | Compare | Evaluate



- 10 % Lambertian Target
- 25 m Distance
- 0° Rotation

Simulation Architecture

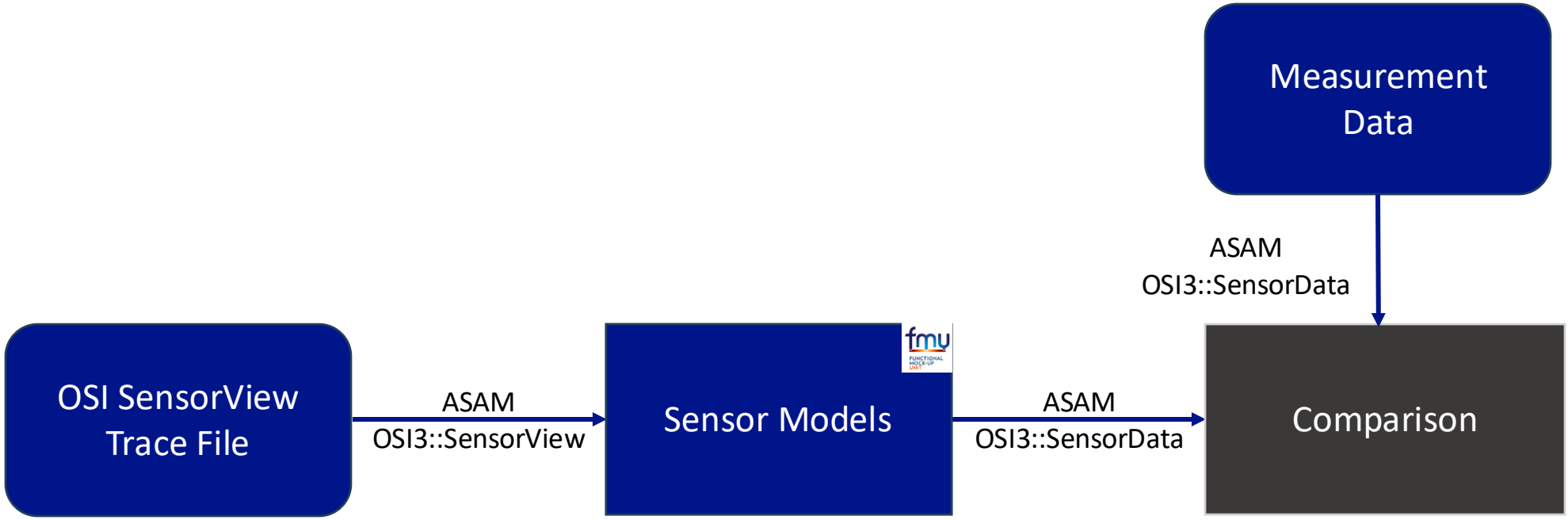
Measure | Re-simulate | Compare | Evaluate



Persival

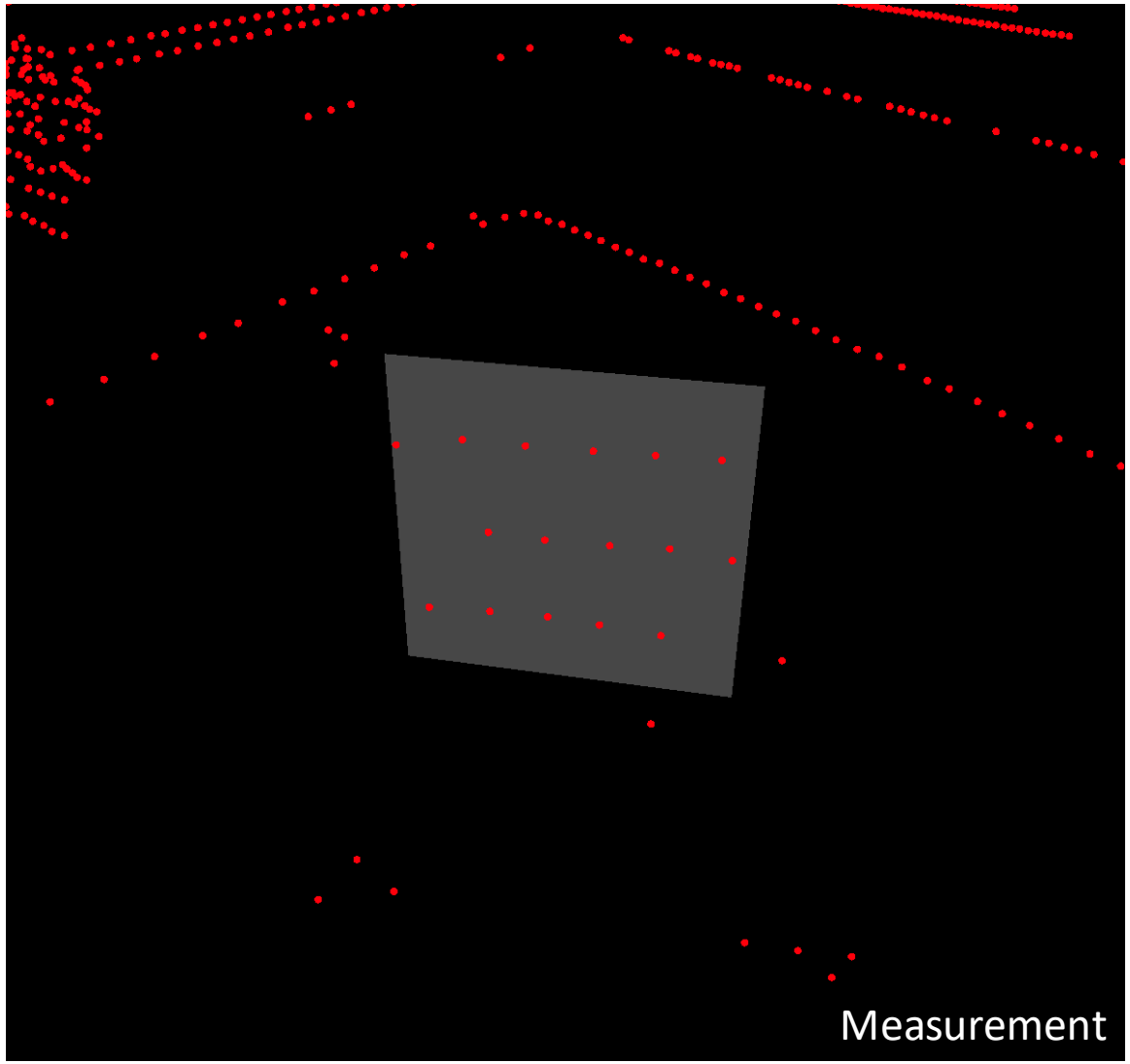
Easy Re-Simulation of Independent Models

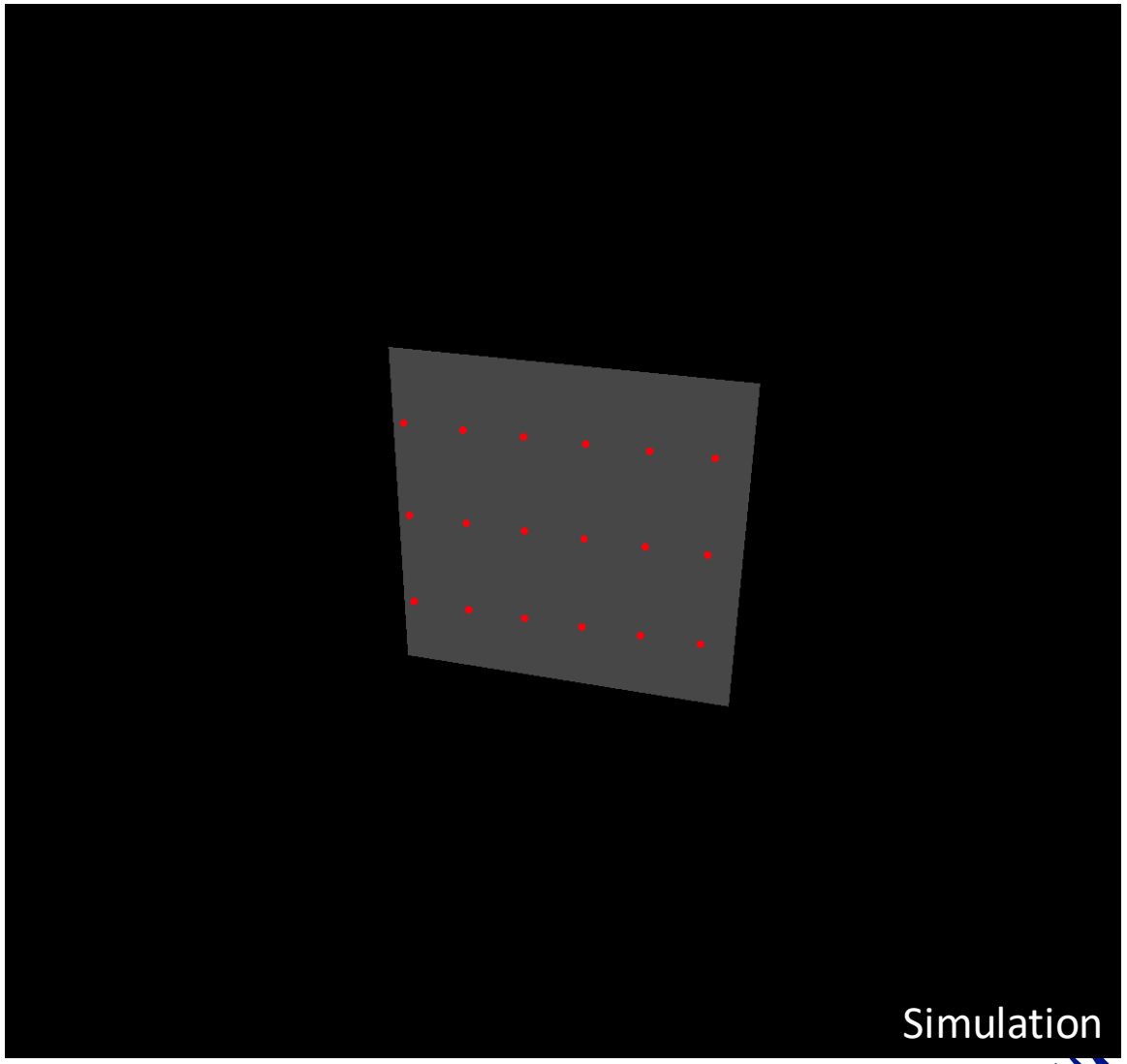
Measure | Re-simulate | Compare | Evaluate



Measurement Example

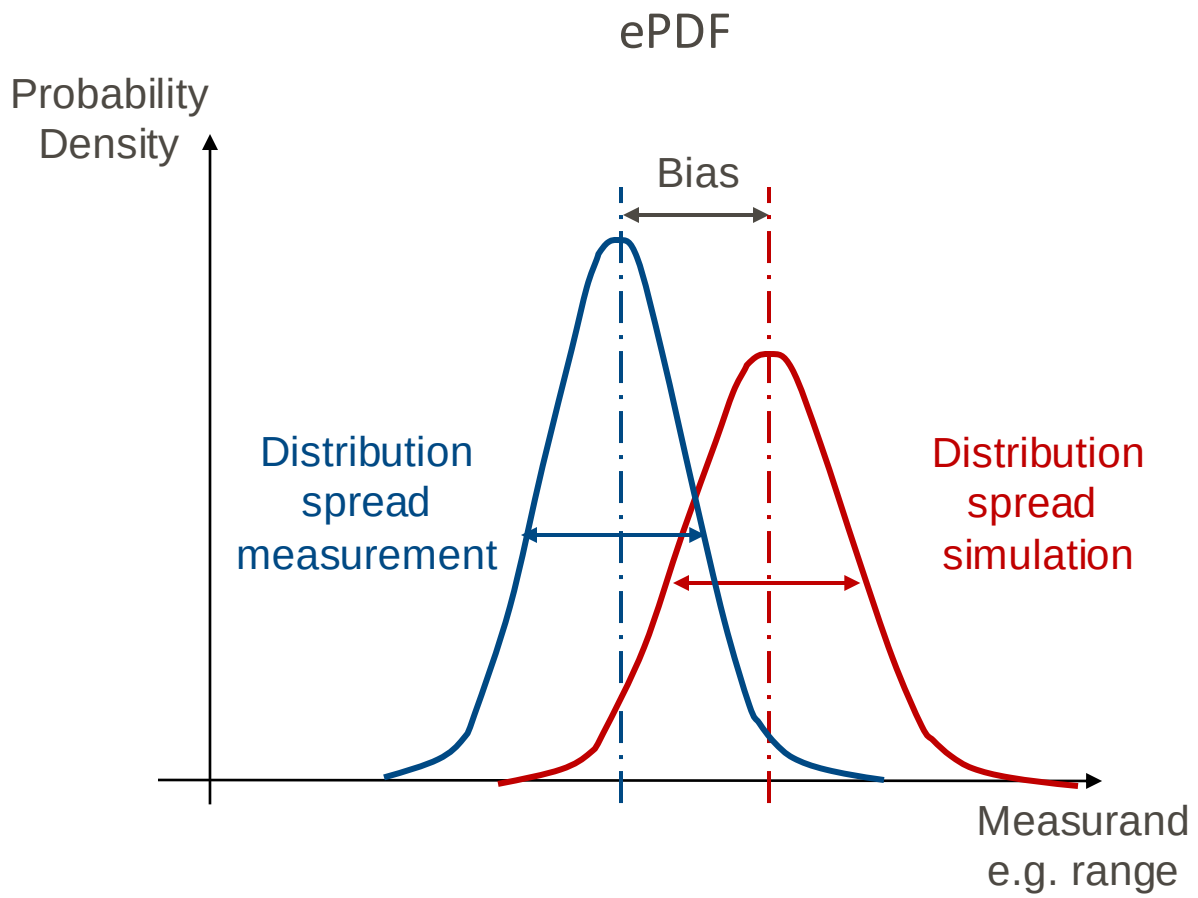
Measure → Re-simulate → Compare → Evaluate





Metrics for Perception Sensor Model Validation

Measure | Re-simulate | Compare | Evaluate



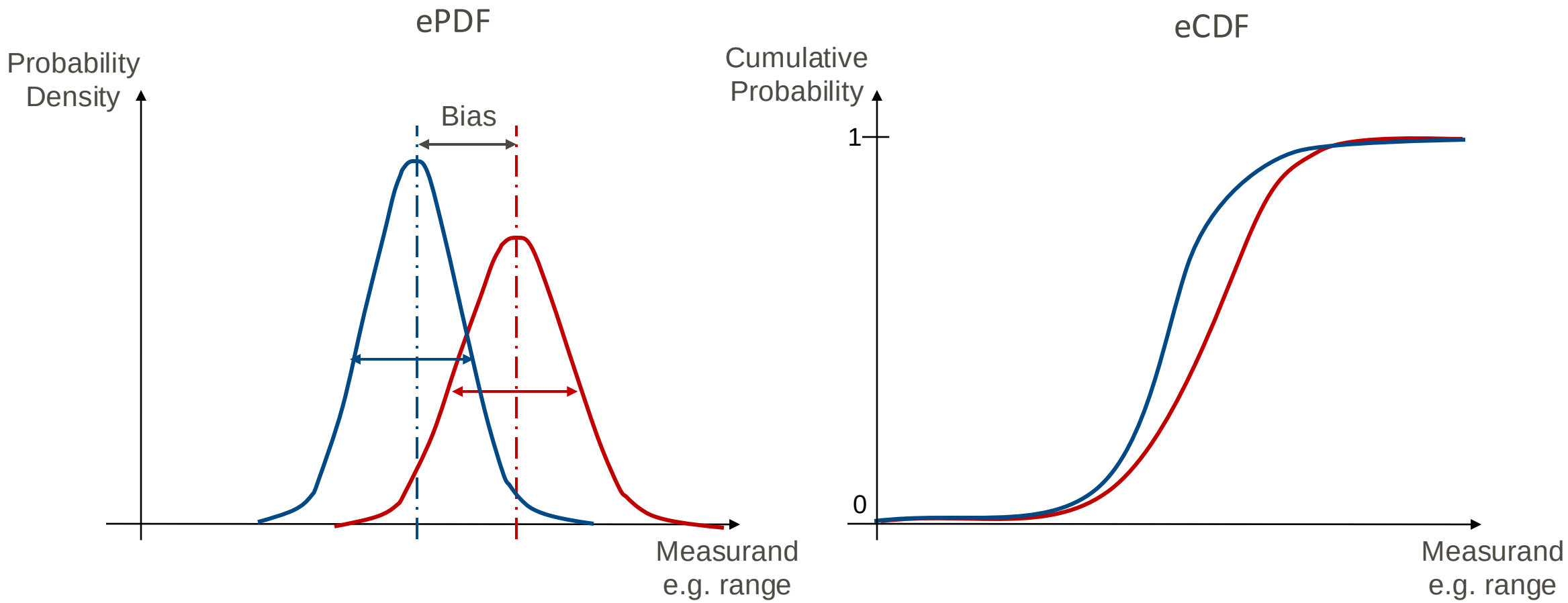
- How can we compare the bias between simulation and measurement?
- How can we determine the deviation in the distribution spread between simulation and measurement?

→ Double Validation Metric

Rosenberger: *Metrics for Specification, Validation, and Uncertainty Prediction for Credibility in Simulation of Active Perception Sensor Systems*, PhD Thesis, TU Darmstadt, Darmstadt, Germany, 2023

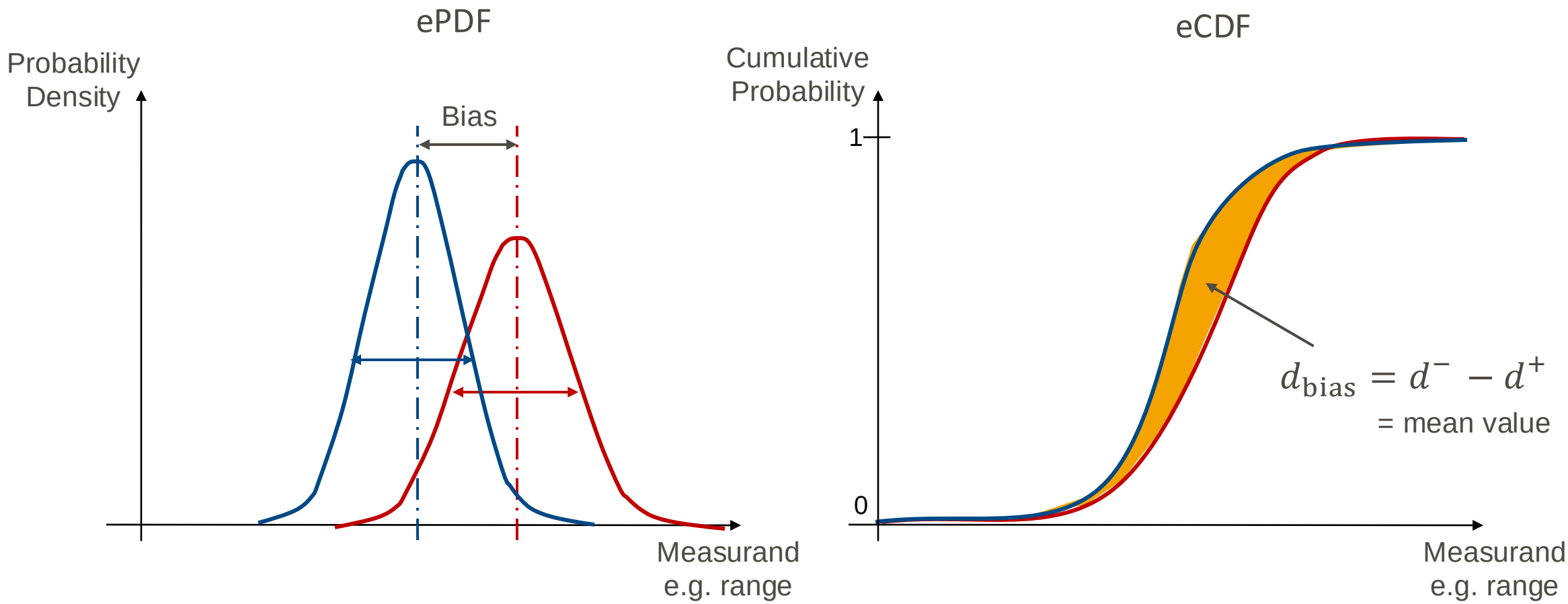
Metrics for Perception Sensor Model Validation

Measure | Re-simulate | Compare | Evaluate



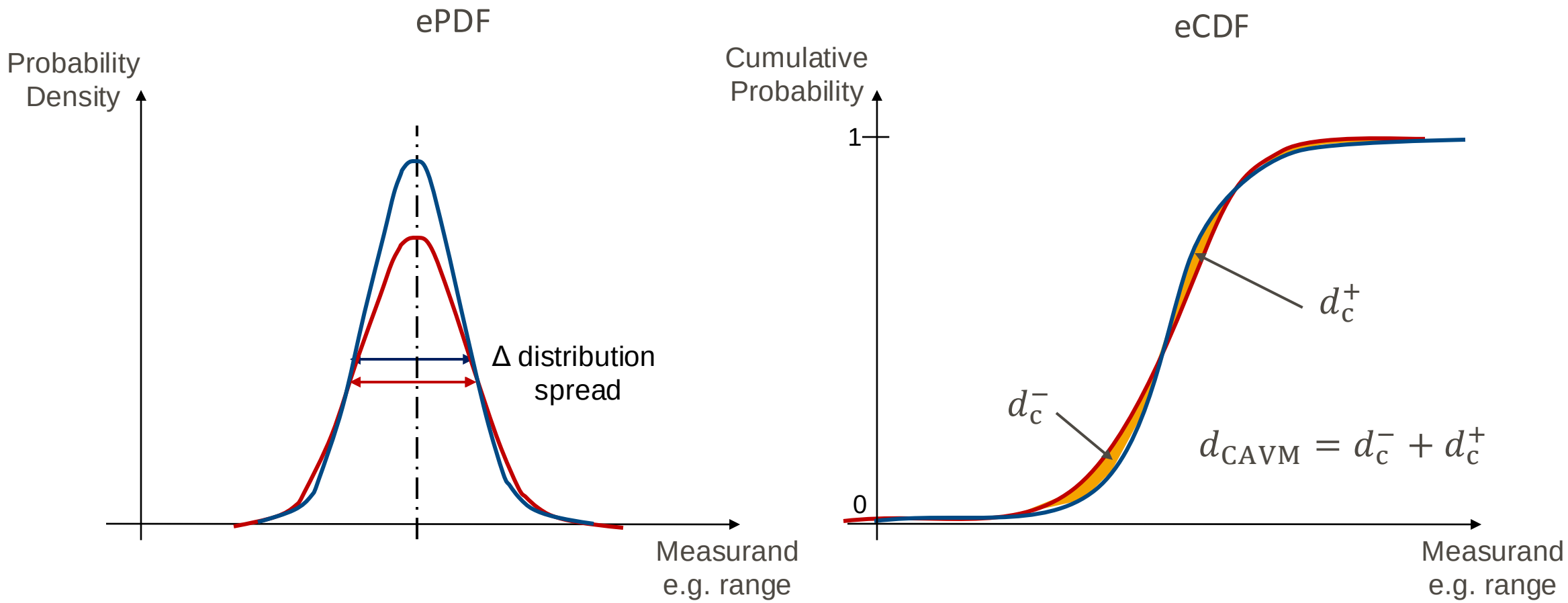
Metrics for Perception Sensor Model Validation

Measure | Re-simulate | Compare | Evaluate



Metrics for Perception Sensor Model Validation

Measure | Re-simulate | Compare | Evaluate



Double Validation Metric $= [d_{bias}, d_{CAVM}]$

Evaluate Metric Results

- This is the hardest part
- How accurate is accurate enough?
- Set pass/fail thresholds for validation metrics based on
  - General sensor performance and data sheet
  - Experience in working with the sensor
  - Sensitivity analysis of the downstream functions

Validation is an Iterative Process

- If validation fails for certain aspects
  - Find out why
  - Adjust model
  - Repeat validation process

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