PROJECT of the PEGASUS FAMILY

VERIFICATION VALIDATION METHODS

Mid-Term Presentation 15 / 16 March 2022

Configurable Simulation Tools for Various V&V Tasks

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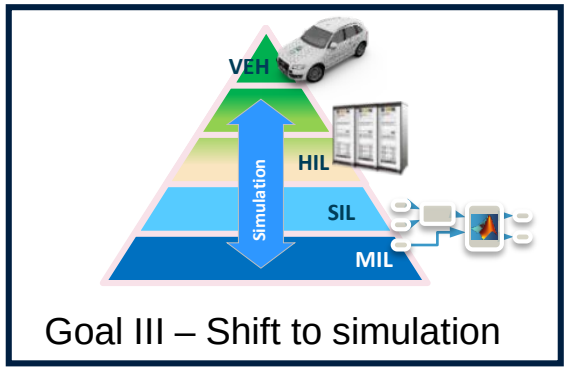
Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

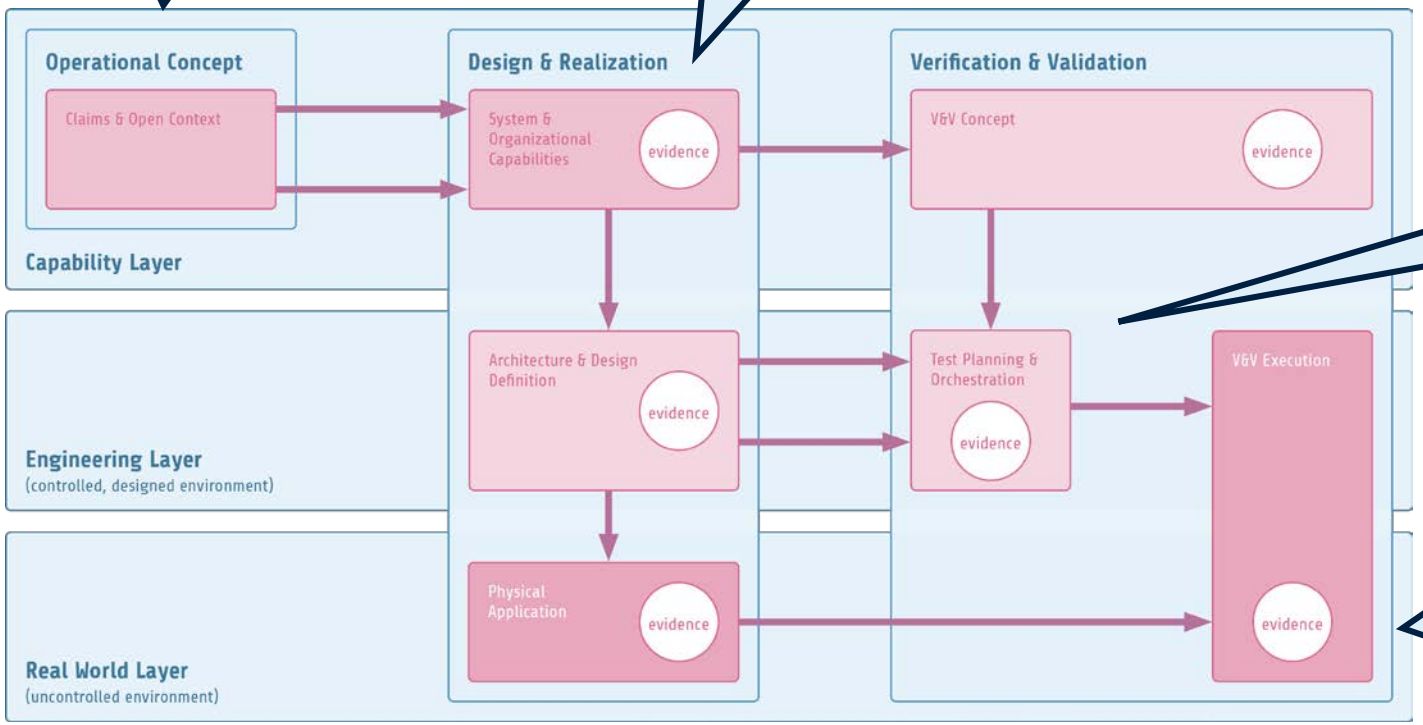
Simulation Supporting Various V&V Objectives



Goal III – Shift to simulation

Exploring the context

Identifying criticalities

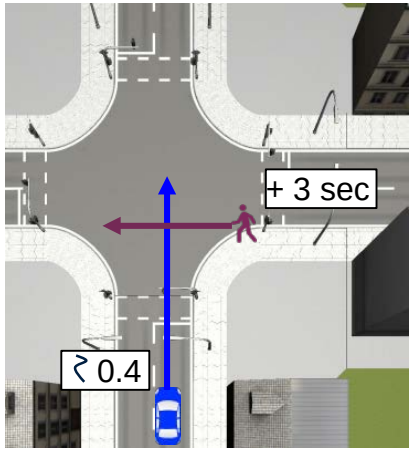


Testing concepts and designs

Virtual testing of components, subsystems, and full systems

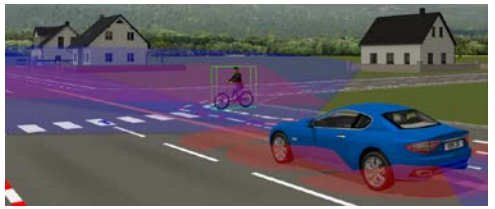
Requirements on Tools ... and their Realization

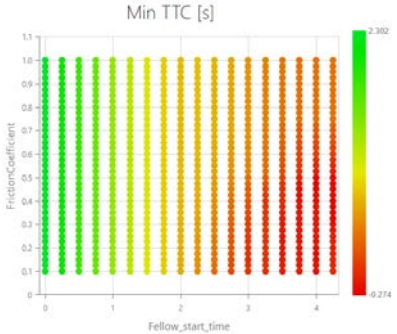
- **Scenario-based** simulation
  - **Detailed** simulation of **concrete** scenarios
  - **Exploration** of **logical** (parameterized) scenarios



Parameter variation
- Starting time
- Friction coefficient
- …

- Simulation **frameworks** and **models**
  - Supporting **standard scenario formats** (e.g. ASAM **OpenSCENARIO** and **OpenDRIVE**)
  - **Higher** simulation **control** on top of single run capabilities

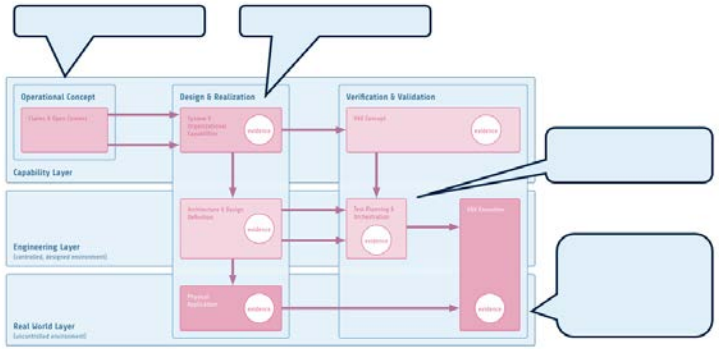




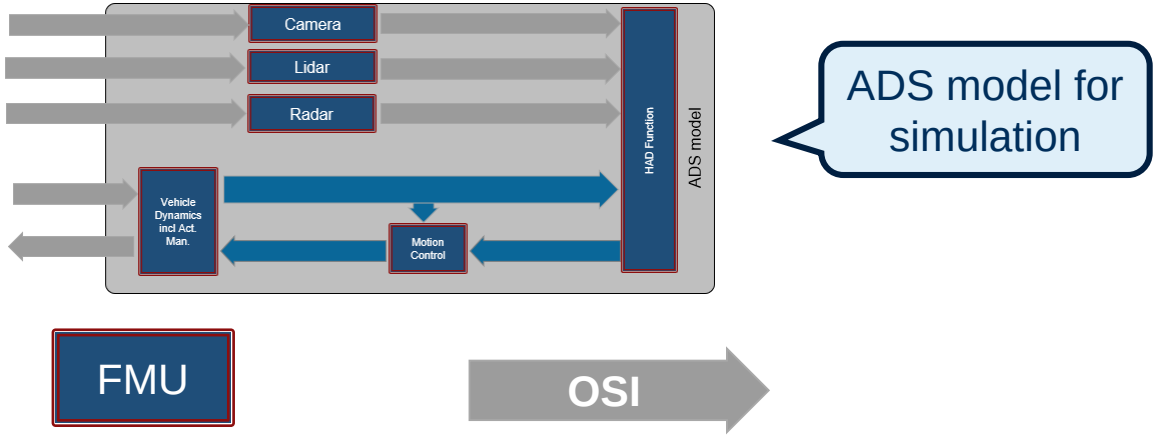
Requirements on Tools ... and their Realization

VERIFICATION VALIDATION METHODS

- **Various applications** in V&V
  - Different test **objects**
  - Different **abstraction** levels
  - Different simulation **objectives**



- **Flexibility** and **configurability** via support of a standard-based, common architecture concept
  - **FMI** standard for simulation architecture
  - ASAM **OSI** standard for component messages
  - **Library** of models and components



FMU: Functional Mock-up Unit

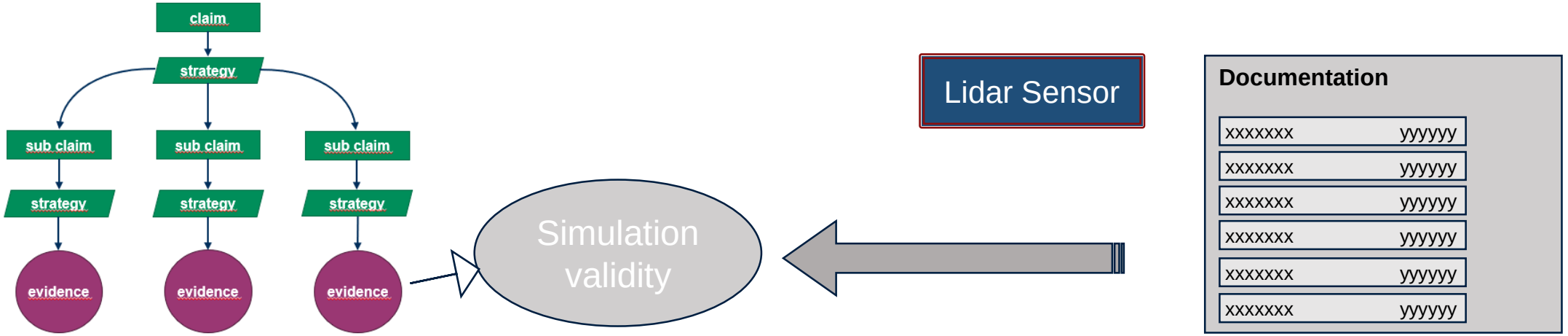
FMI: Functional Mock-up Interface

OSI: Open Simulation Interface

ADS: Automated Driving System

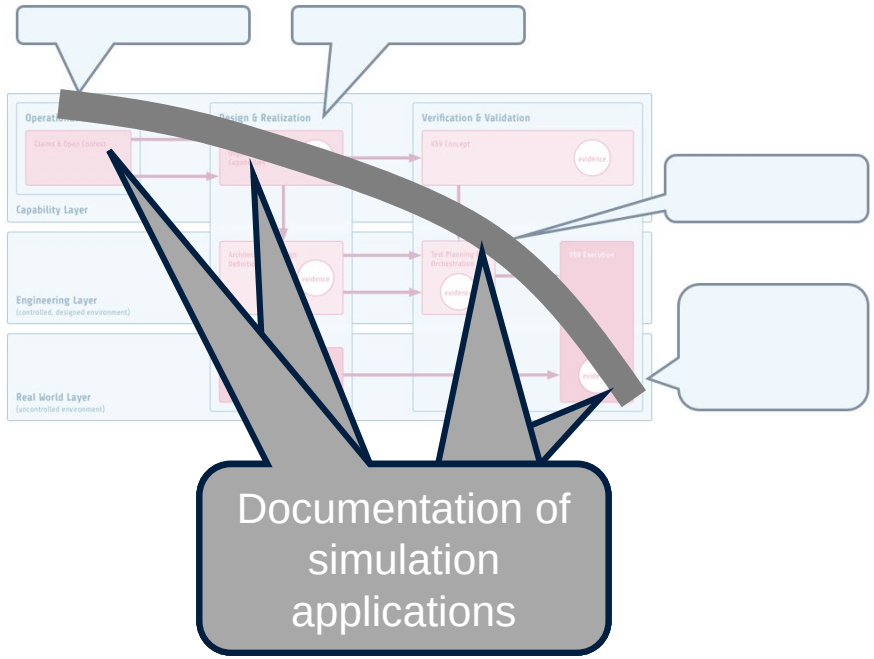
Requirements on Tools ... and their Realization

- Generation of **evidence** for safety argumentation
- (Preparations for) **validated** components and configurations
  - Thorough **documentation** of development and verification of simulation components

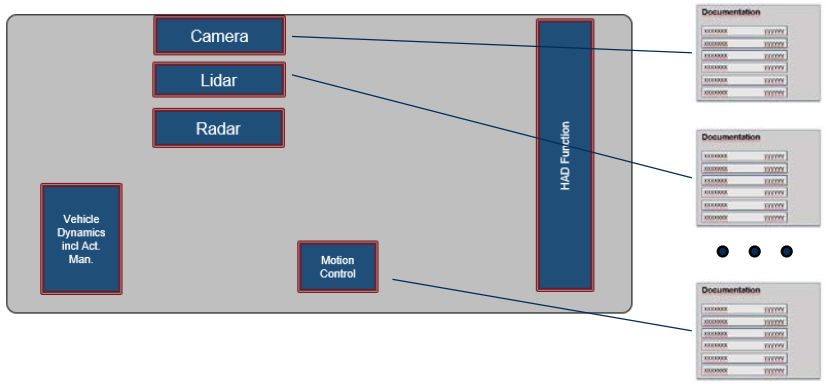


Requirements on Tools ... and their Realization

- **Industrial** applicability



- Data formats and tools for **process integration**

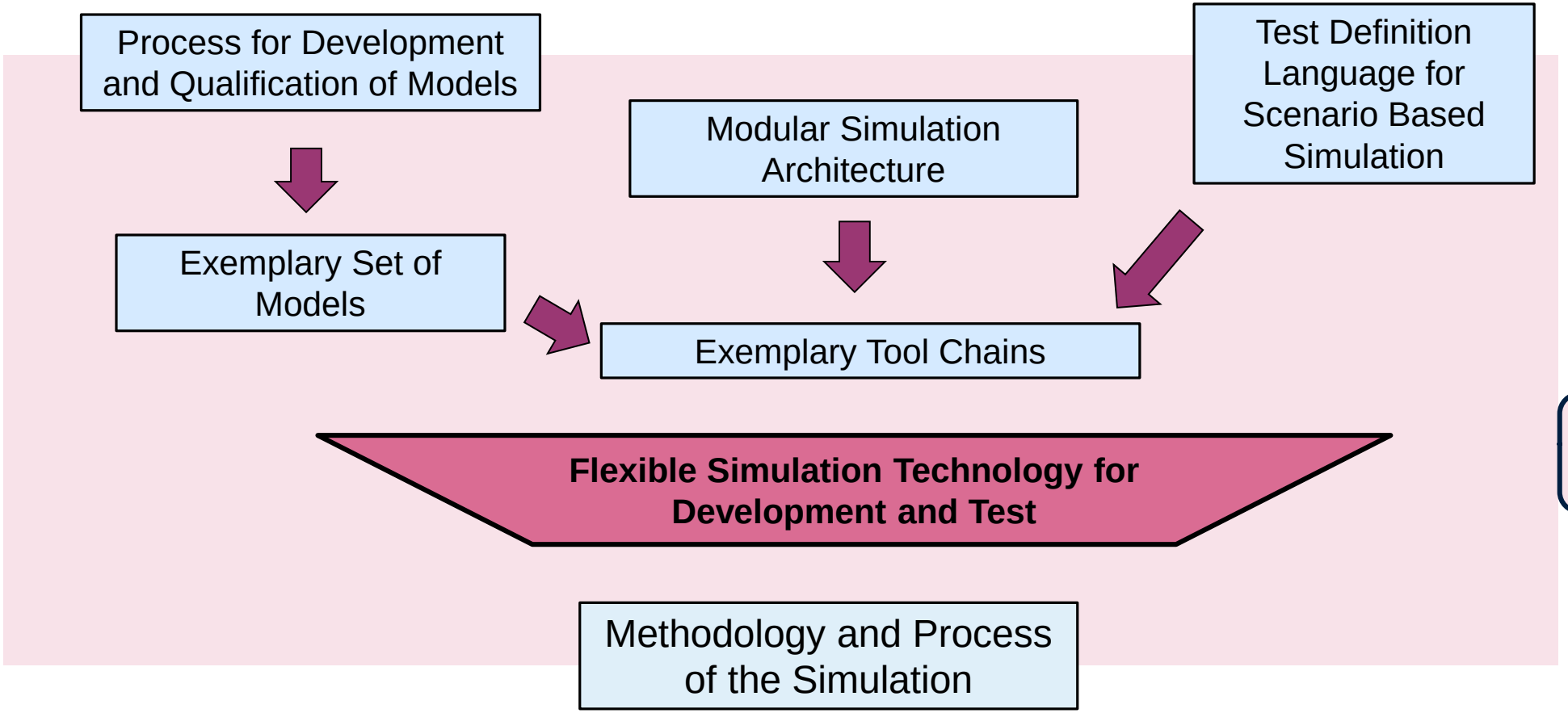


Simulation Resource Meta Data (SRMD)

Tool for tracing

TRACY

The SET Level Approach – Simulation-based Engineering and Testing of Automated Driving

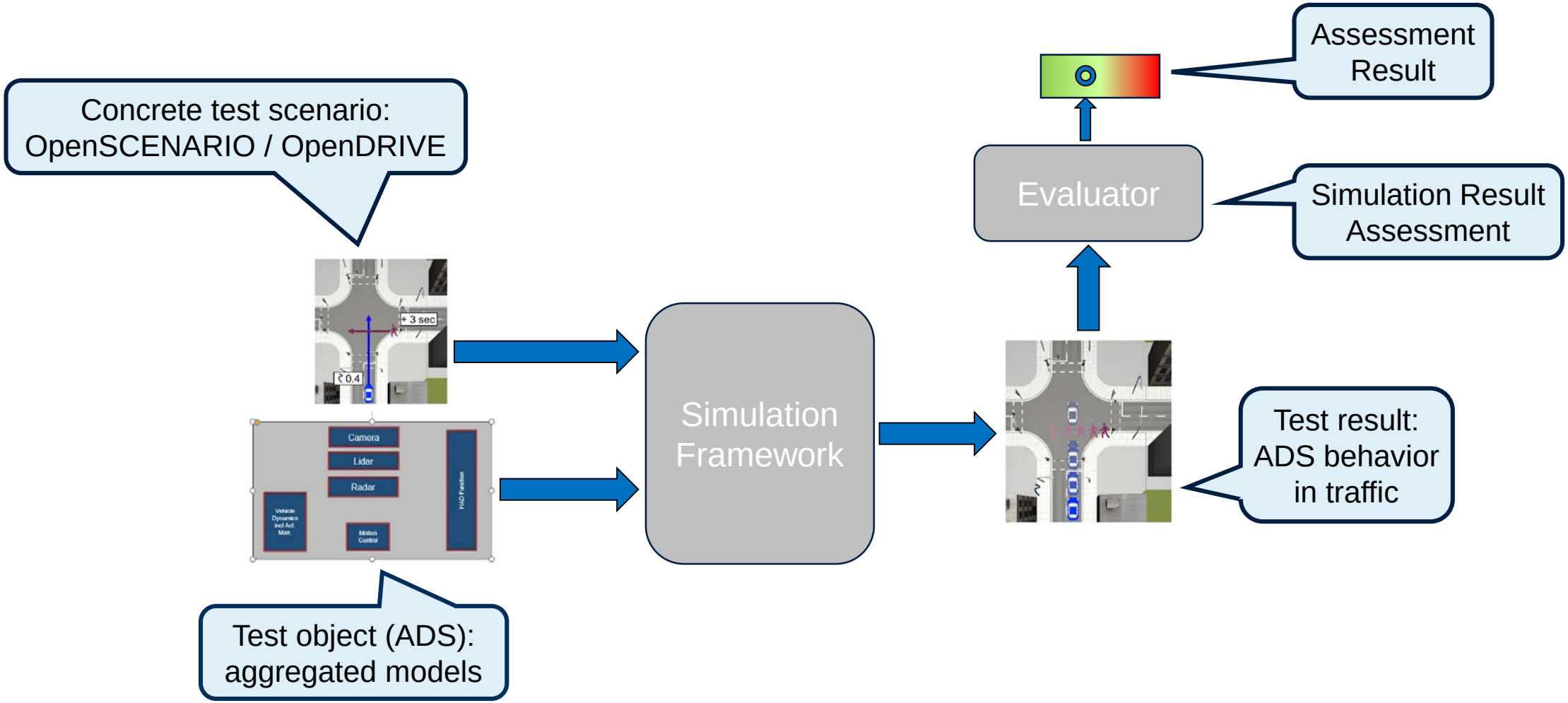


SET Level
Cooperation project funded by the German Ministry for Economic Affairs and Climate Action

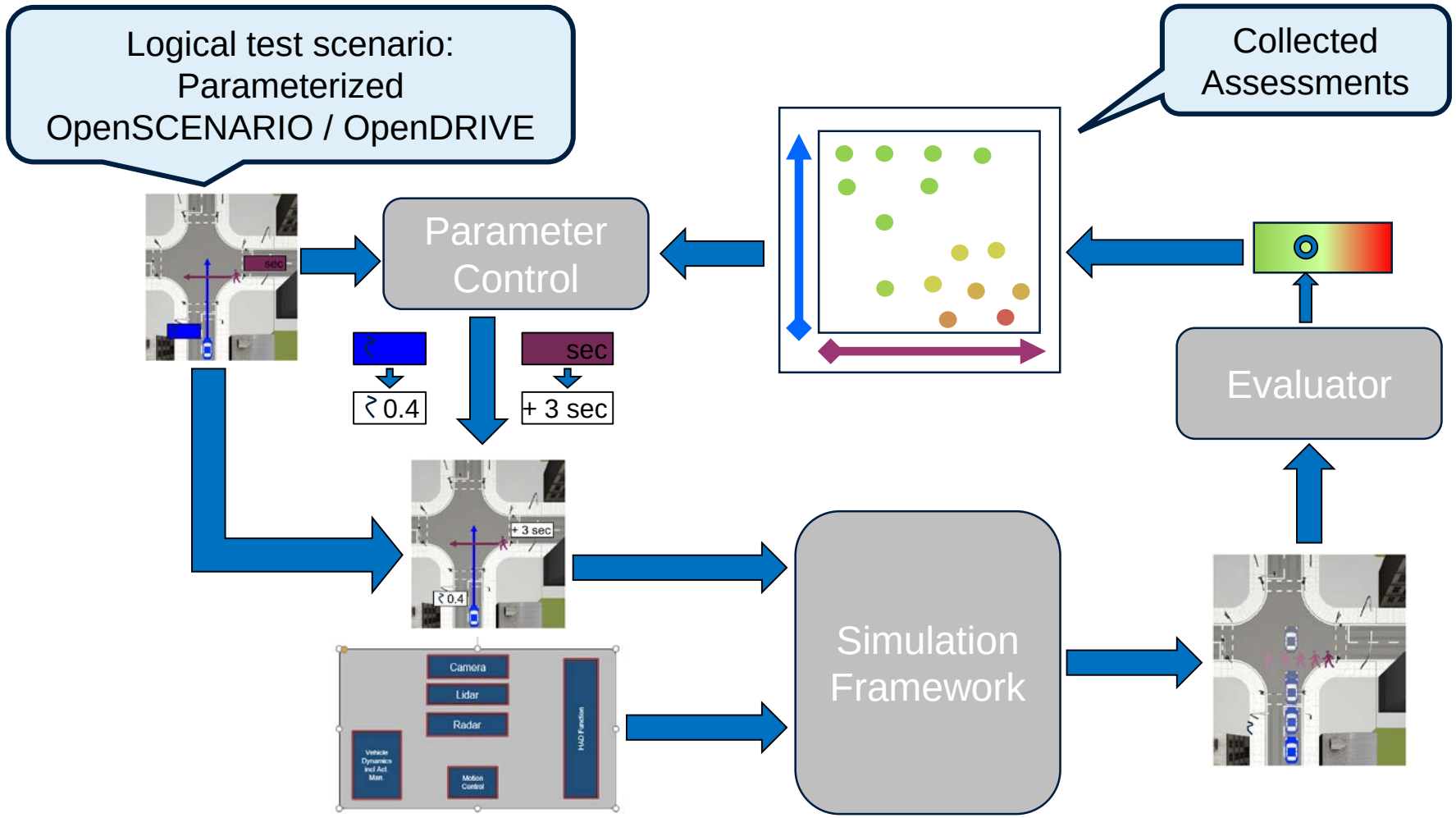
https://setlevel.de/

Imported into VVMethods

Simulation Illustration: Single Simulation Run

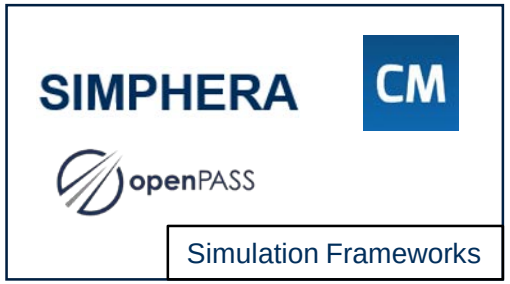


Simulation Illustration: Scenario Exploration



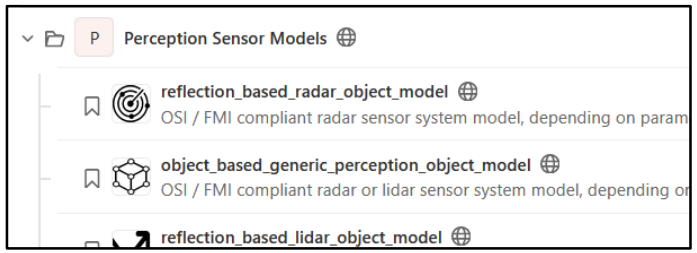
Results from SET Level

- **Simulation frameworks** supporting the modular integration architecture
  - **Available** for usage in industry and academia
    - **Commercial**: SIMPHERA (dSPACE), CarMaker (IPG)
    - **Non-commercial**: OpenPASS (Eclipse), Research Implementation (DLR)



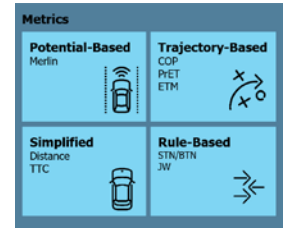
Simulation Frameworks

- **Model library**
  - Sensors, traffic participants etc

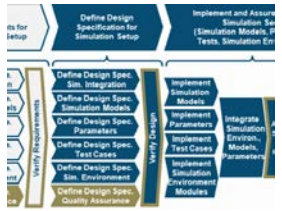


https://gitlab.setlevel.de/open/models

- Library for **criticality metrics**
  - **CriSys** by ZF



CriSys Illustration

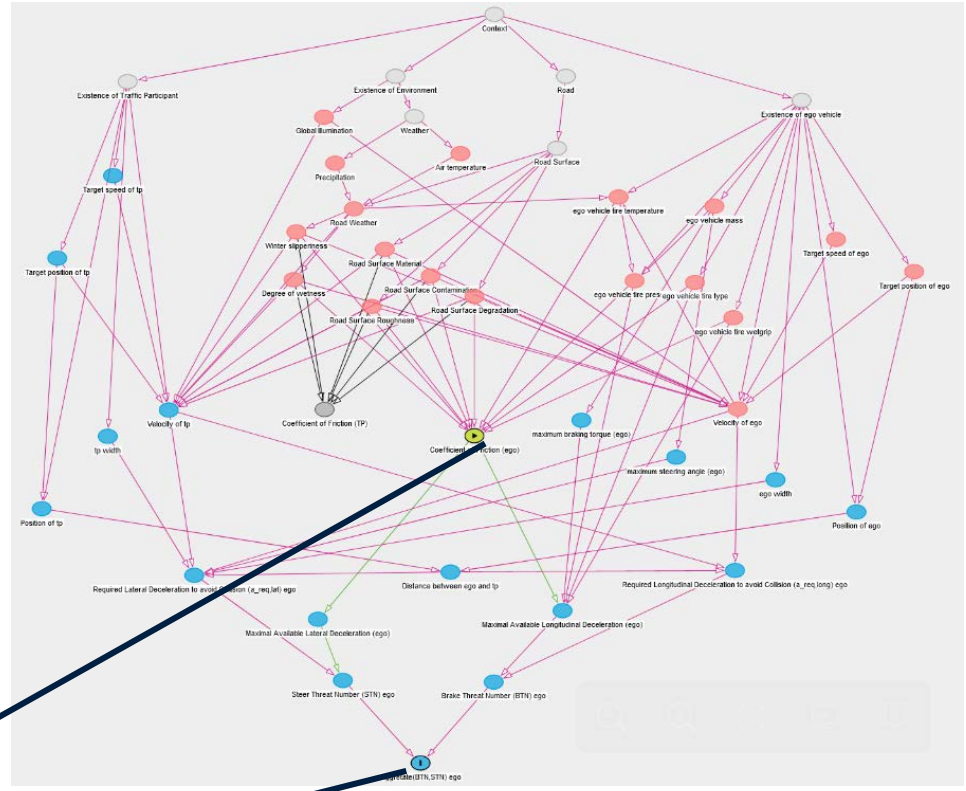

CSP excerpt

- **Process** and **traceability** support
  - **C**redible **S**imulation **P**rocess (**CSP**)
  - **S**imulation **R**esource **M**eta **D**ata (**SRMD**)

Application Illustration: … for Criticality Analysis

- The **friction coefficient** value and its influencing variables are supposed to be factors contributing to **criticality**
  - A **causality graph** models such causality **hypotheses**

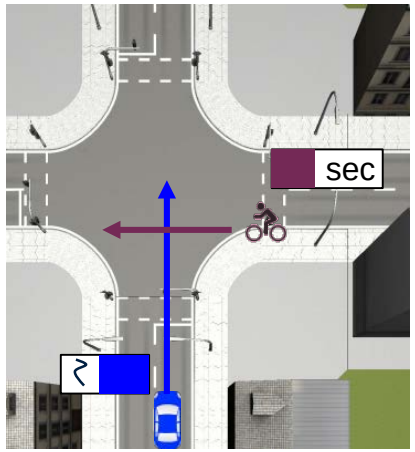
- **Simulation** is used to **confirm** these hypotheses

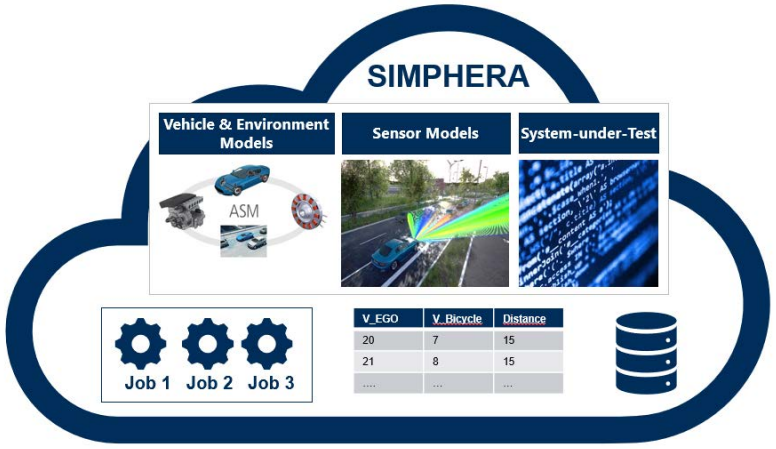


Causality Graph for friction-related criticality

Simulation Setup

- **Logical scenario**
  - Cyclist crossing trajectory of vehicle
  - Parameters
    - **Friction coefficient**
    - **Cyclist start time**
- **Criticality metrics: Min TTC**
- **Simulation tool**
  - **SIMPHERA** (dSPACE)
  - **Instantiated** with **ADS** model
  - Discrete **grid cover** of parameter space
  - **Parallelized** execution (cloud)

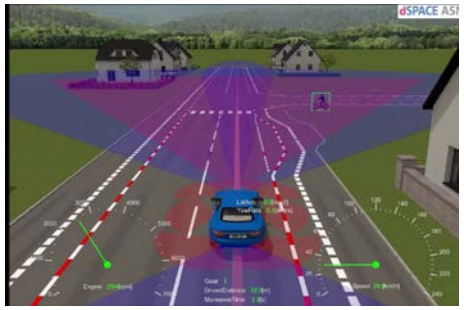




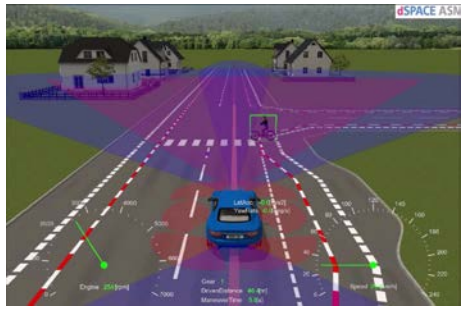
TTC: **T**ime **T**o **C**ollision

Simulation Results (Sample Video)

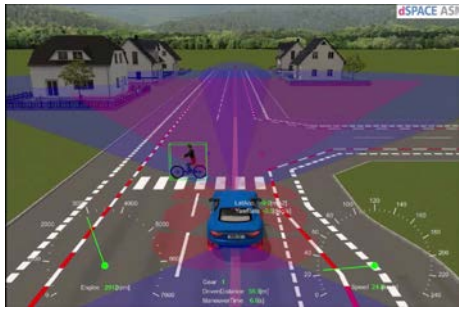
1 Start vehicle



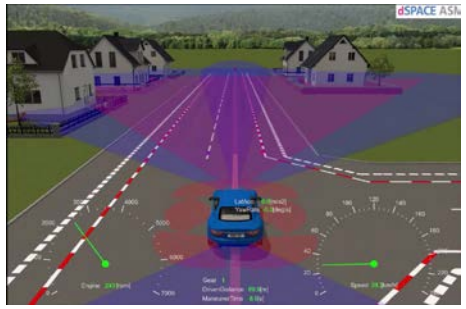
2 Both approaching



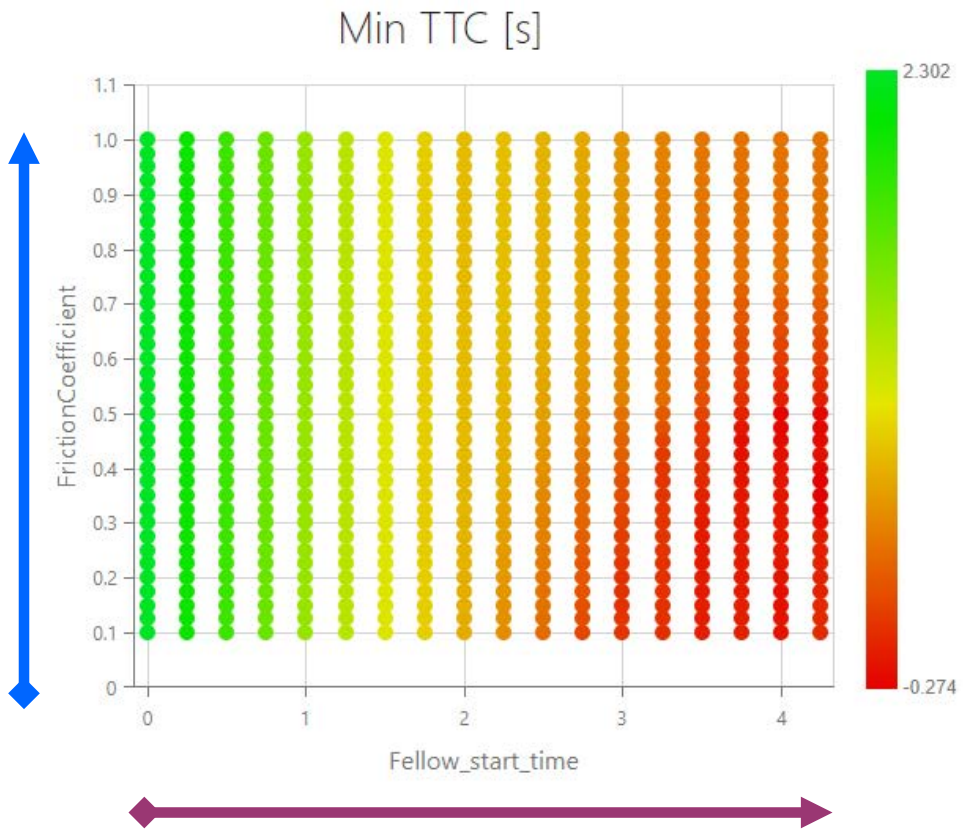
3 Imminent crossing



4 Crossing, vehicle brakes



5 Vehicle past crossing

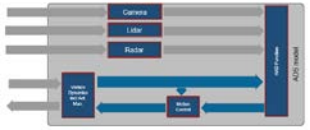


Evaluation result illustration

- Two-dimenionsal parameter space
- Observed criticality color coded

Summary

- A **configurable** set of **tools** and **components**
  - **Standard based** for flexibility and interchangeability
  - **Process** and **traceability** support for industrial application
  - Applicable for **various tasks**



- **Availability**
  - Information on **setlevel.de**
  - … and from **tool providers**

dSPACE IPG AUTOMOTIVE ECLIPSE FOUNDATION DLR Deutsches Zentrum für Luft- und Raumfahrt German Aerospace Center

- Visit the **Virtual Exhibition** for more information on:
  - **CriSys**
  - **Scenario Exploration**
  - **…**

VERIFICATION
VALIDATION
METHODS

Thank you!

Hardi Hungar, DLR

Frederik Ikemeyer, dSPACE; Tuan Duong Quang, TÜV Süd

PROJECT of the PEGASUS FAMILY

A project developed by the
VDA Leitinitiative
autonomous and connected driving

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