Tagung Automatisiertes Fahren

Erstellung und Optimierung von Fahrszenarien zur optimalen Testabdeckung automatisierter Fahrzeuge

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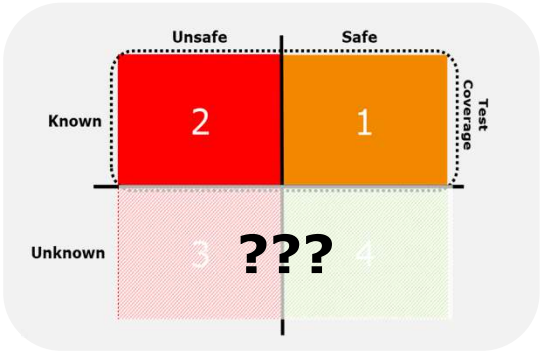
Today’s Agenda

1. **Scenario based requirements engineering to check SOTIF**
2. **Scenario based testing workflow**
3. **Test Methodologies with optimized coverage**
4. **Summary**

Introduction and System Development - Considering already SOTIF



Function and System Specification is derived

Vehicle Mission Profile

Feature Description incl. Operational Design Domain

Use Cases

SOTIF Risk Assessment / HARA

External Sources
e.g. SOTIF Standard, NCAP, GIDAS, BAst

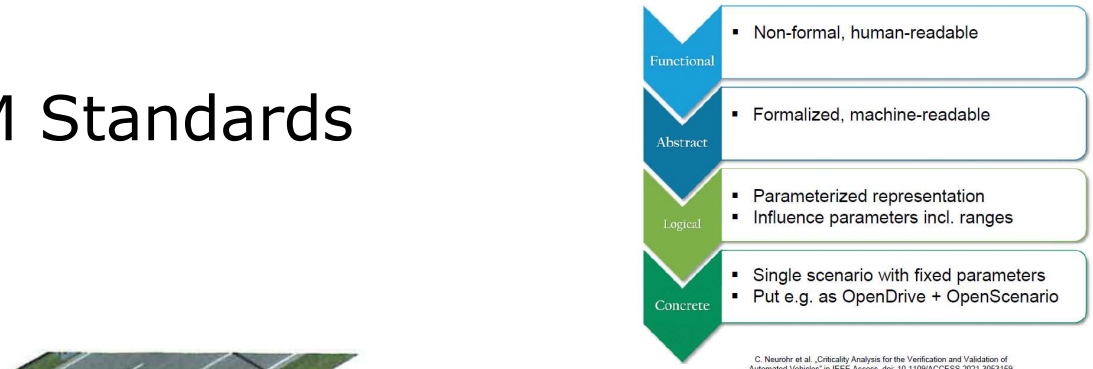
Input by safety argumentation

Known Scenarios
→ Manual Derivation e.g. from SOTIF HARA
→ Real World Driving Scenario Samples

Unknown Scenarios
→ Real World Unknown Scenarios/Black Swan
→ Automatic Derivation e.g. via simulations

Input for
→ Scenario Based Requirement Engineering
→ Scenario Based Testing

Scenario Based Testing – Research and related ASAM Standards



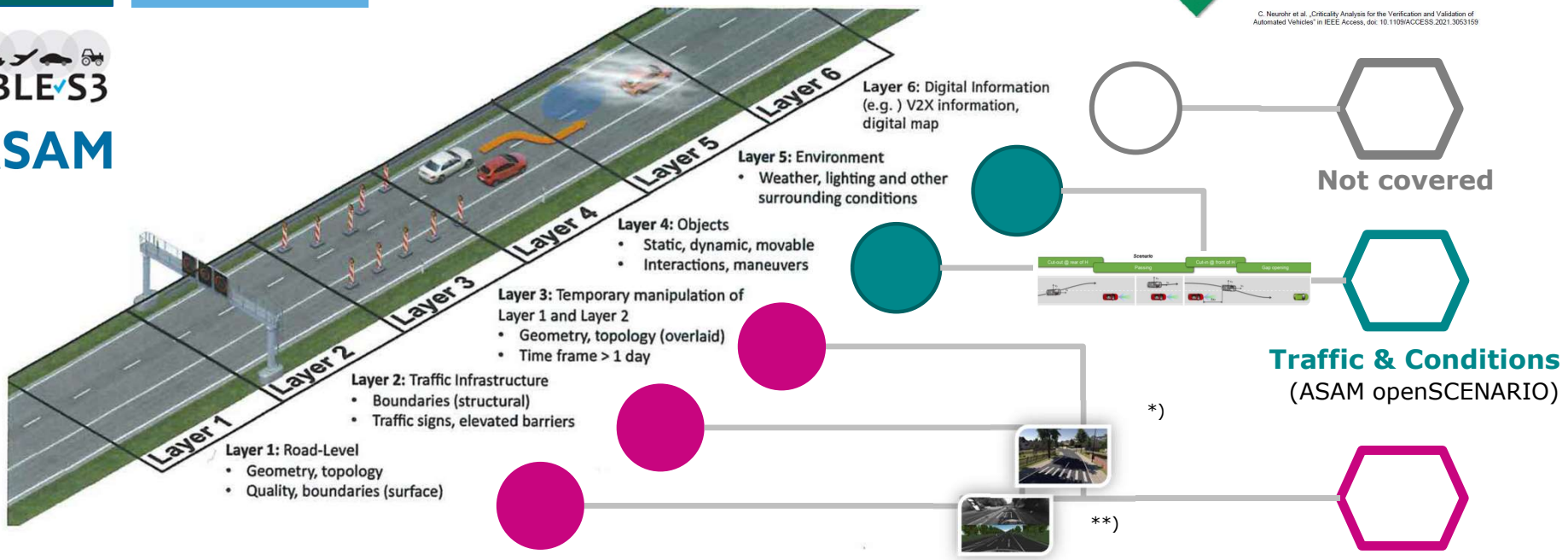
C. Neurohr et al. „Criticality Analysis for the Verification and Validation of Automated Vehicles" in IEEE Access, doi: 10.1109/ACCESS.2021.3053159

PEGASUS

VERIFICATION VALIDATION METHODS

ENABLE-S3

ASAM



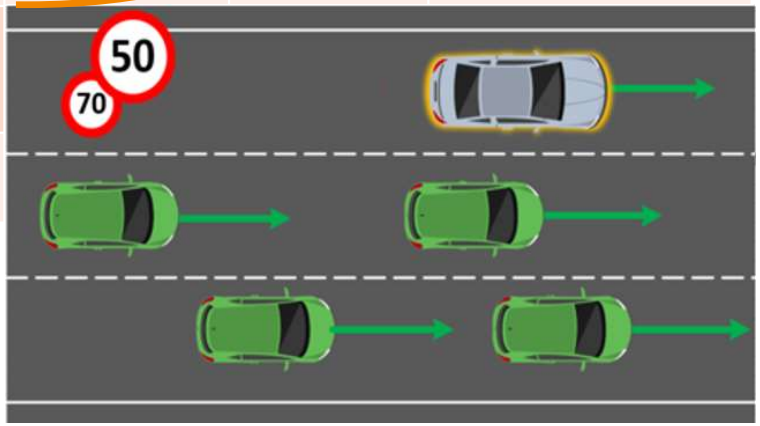
*) https://triangraphics.de/service/#driving

**) https://www.atlatec.de/simulation.html

APPLICATION – **Functional Scenario** Aspects

Functional Scenario is a high-level description of a scenario by several keywords, executed by the feature.

Road level 1	Traffic Infra-structure 2	Temporal modifications 3	Objects 4	Environ-ment 5	Digital Info 6	Figure
Road type Highway	Traffic sign – speed order	Temporal lane markings - none	Object type - cars	Weather - all	Digital info - none	
Driving lanes – singles	Lane Markings – dashed, solid	Lane count reduced - none	Initial ego movement - all	Light - all		
Multilane – separated contraflow		Cancel traffic sign - none				
Road layout – straight, curve						



APPLICATION – **Logical Scenario** Aspects

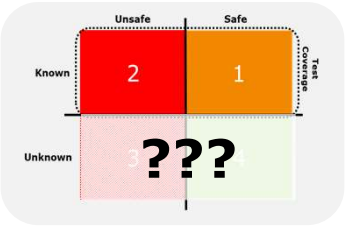
Logical Scenarios describe the scenario with help of concrete, measurable, physical parameter ranges

Road level 1	Traffic Infra-structure 2	Temporal modifications 3	Objects 4	Environment 5	Digital Info 6	Trigger condition
Number of lanes - 3	Traffic sign – ID [271, 273]	no temporal lane markings	Object length, width, height [m]	Humidity [0-100%]	Digital info - none	Feature on/off
Curve Radius >500m	Traffic sign value [50,70]	Lane count reduced - none	Ego initial velocity [60 - 130km/h]	Percipititation [0–10 l/ mm2/h]		Cut in, out
Road gradient [-5% to+5%]	Lane width [2,7 -5m]	Cancel traffic sign - none	TOF initial velocity [60 - 130 km/h]	Temperature [-20 to +50 grad Celsius]		
	Lane marking types [dashed, solid]		Ego initial position [x m]	Sun elevation, azimuth angle		
			…	Illumination in Lux		

AVL Scenario Designer

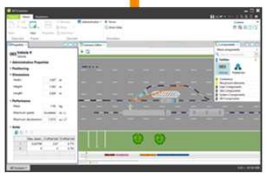
Feature behavior (KPIs), Minimal Risk Maneuver (MRM, MRC) → acceptance criteria

AVL Scenius™
Scenario Based ADAS/AD V&V Solution + Workflow



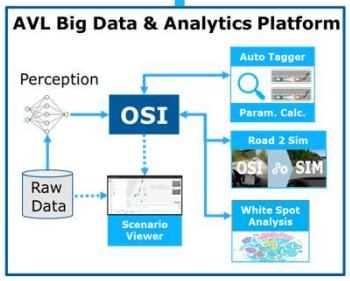
Test requirement engineer | **Test planning engineer** | **ADAS Test Engineer**

Scenario Design



Ground Truth Measurement

Scenario Creation



Scenario Management

ASAM OpenSCENARIO®

Scenario Data Base

ASAM OpenDRIVE®

ASAM OpenCRG®

Functional

Logical_01

Logical_02

Logical_nn

Safety critical → "Corner Cases"

Test Optimization | Test Dashboard

Test Generation

Test Allocation

Test Data Base

Concrete
= Test Case
∞ → xxx

Simulation

AVL Driving Cube

Proving Ground

https://scenius-sandbox.megatron.atgrz.onprem.avl.zone/

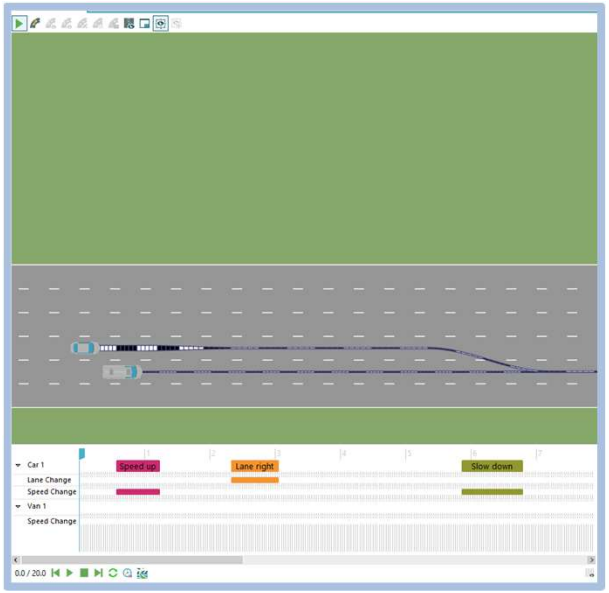
AVL SCENIUS™ Scenario Designer
Pre knowledge: – extract scenarios - ready for Virtualization

For an easy ADAS test scenario design, editing, parametrization and verification.

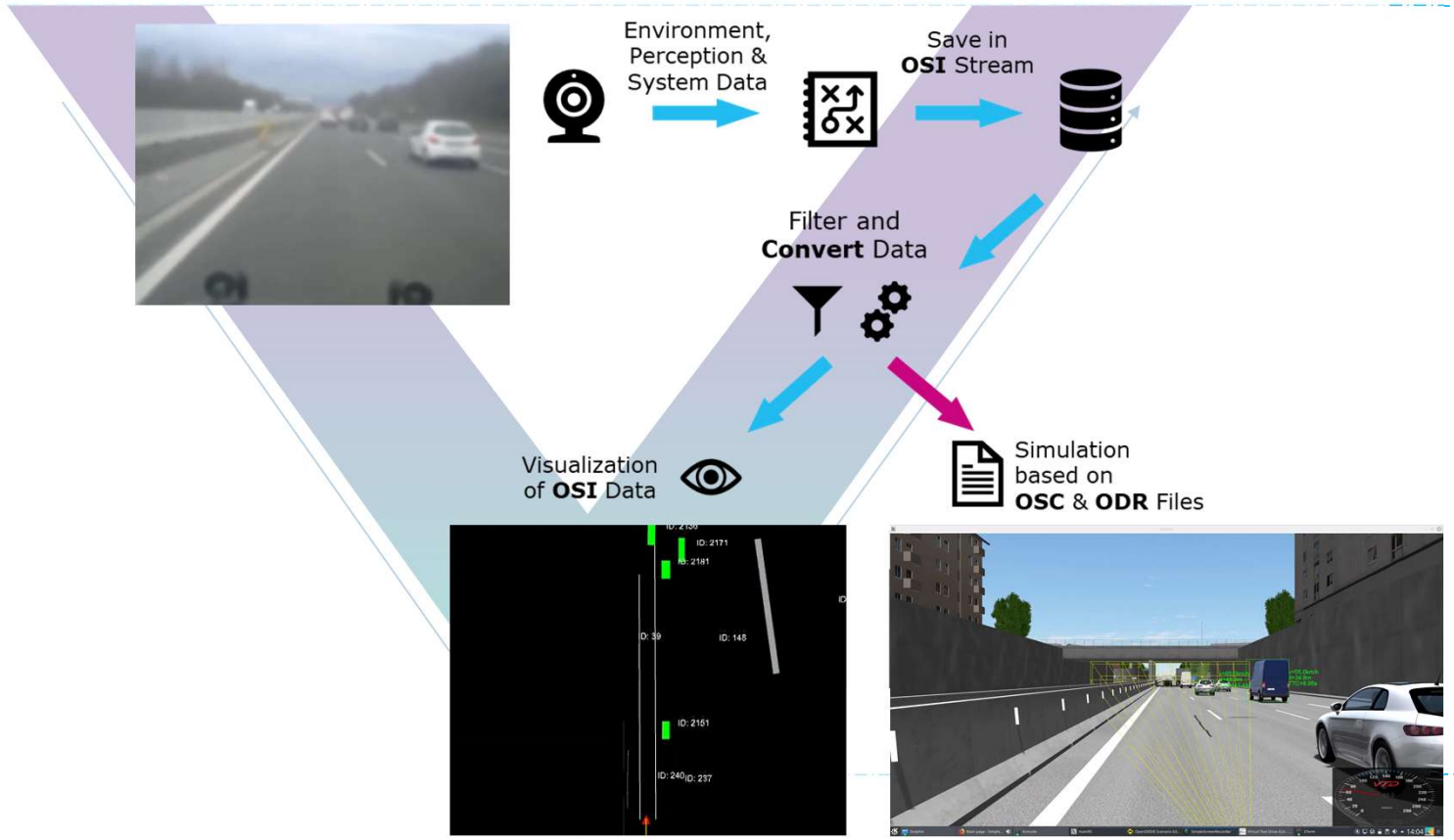
ASAM OpenSCENARIO®

AVL Scenario Designer

- Based upon OpenSCENARIO 1.0 and executable in different environments (MiL/SiL, cloud, HiL/ViL, Proving Grounds)
- Important for standardizing ADAS scenarios from different sources
- Integrated in AVL Test Case Generator and Scenario Data Manager toolchain
- Open for user defined actions and objects
- Finding ideal routes with editing possibility
- Scenario verification with fast playback
- Leading the way for OpenSCENARIO 1.x and 2.0

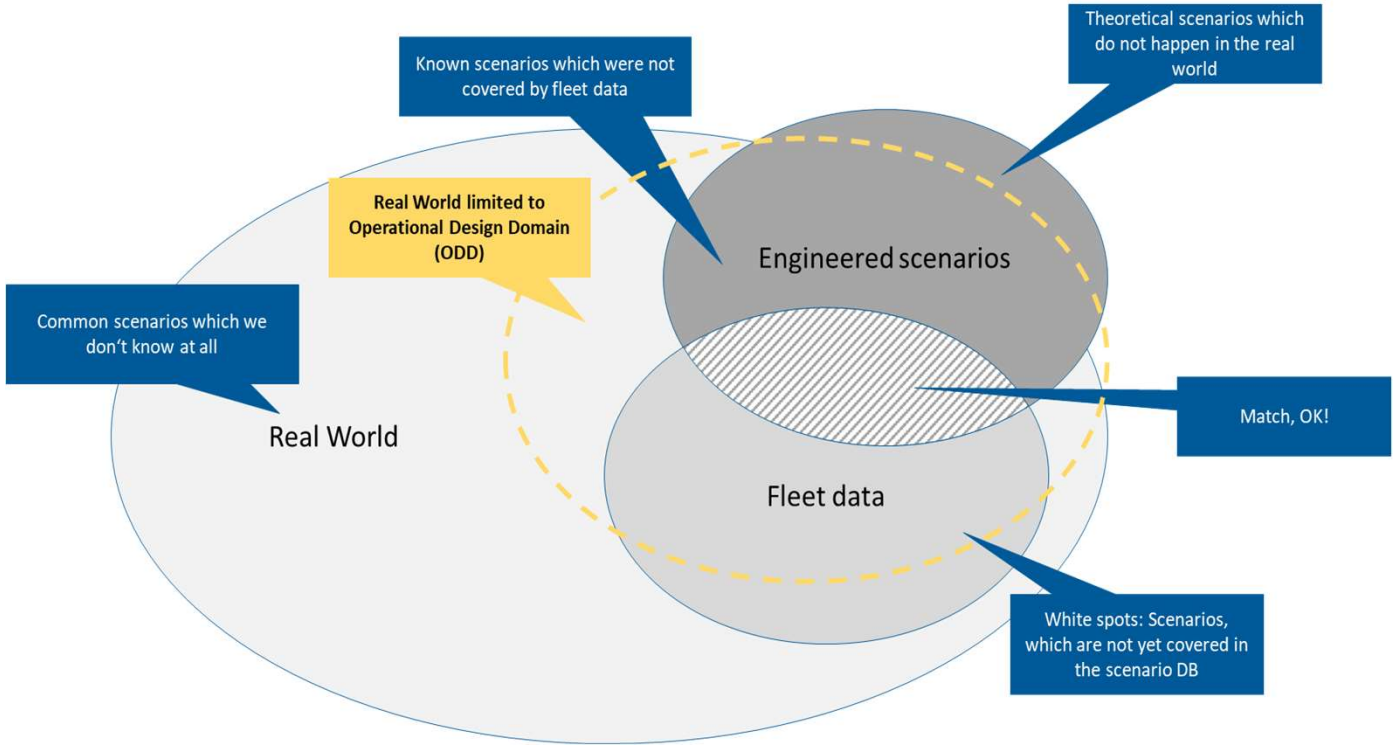


Test Case Generation Methodologies
Fleet data – extract scenarios - ready for Virtualization

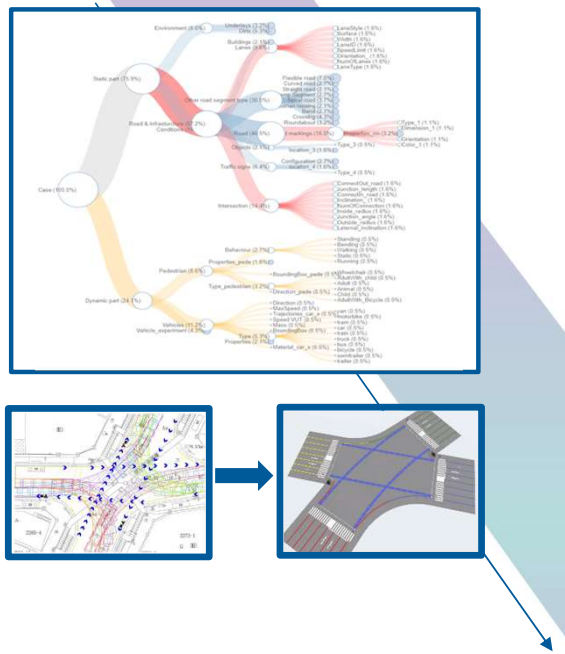


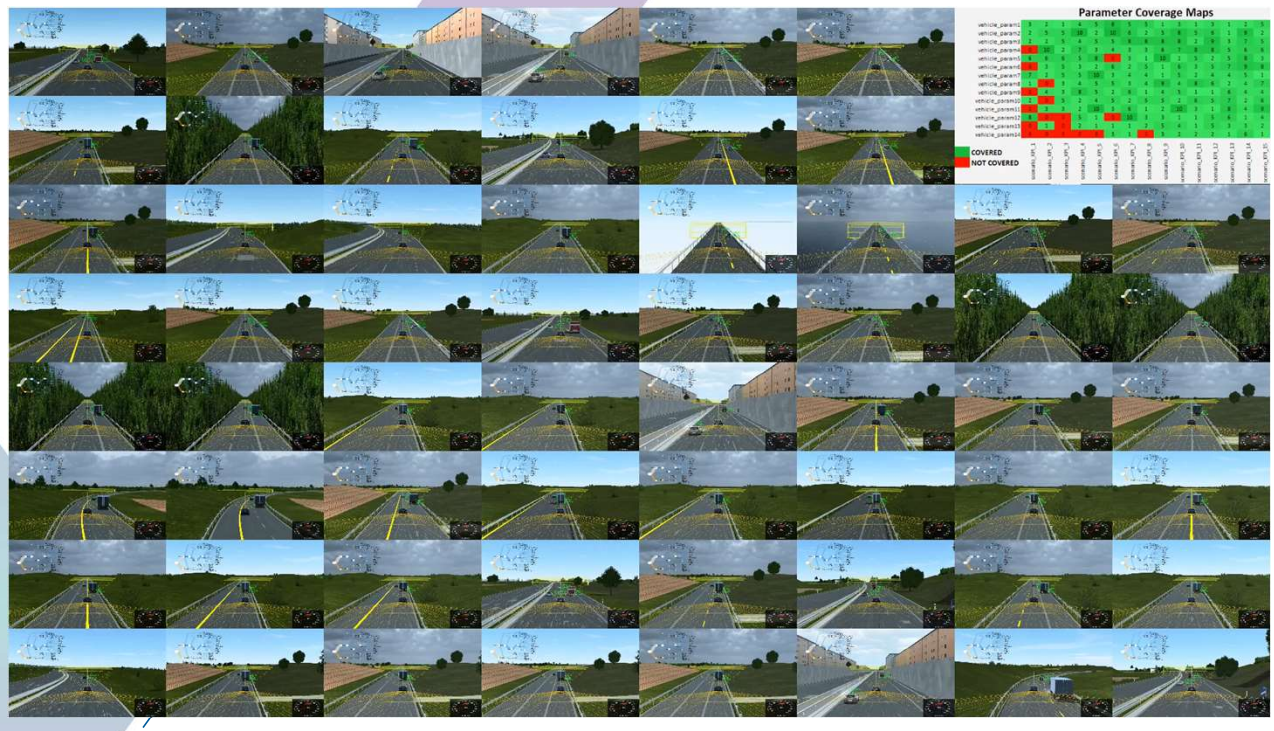
Basically 2 Test Case Generation Methodologies: **Data Driven** input + Engineered, **Knowledge Based** input

Real driving data analysis
Comparison of engineered scenarios with fleet data
For statistics and later evaluation, key characteristics need to be analyzed in the data and defined (KPIs)



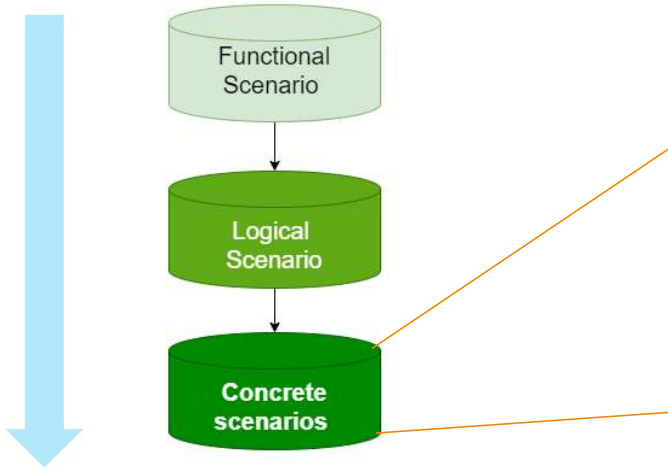
Test Case Generation Methodologies – Ontology-based Combinatorial Testing → **Logical Scenarios**

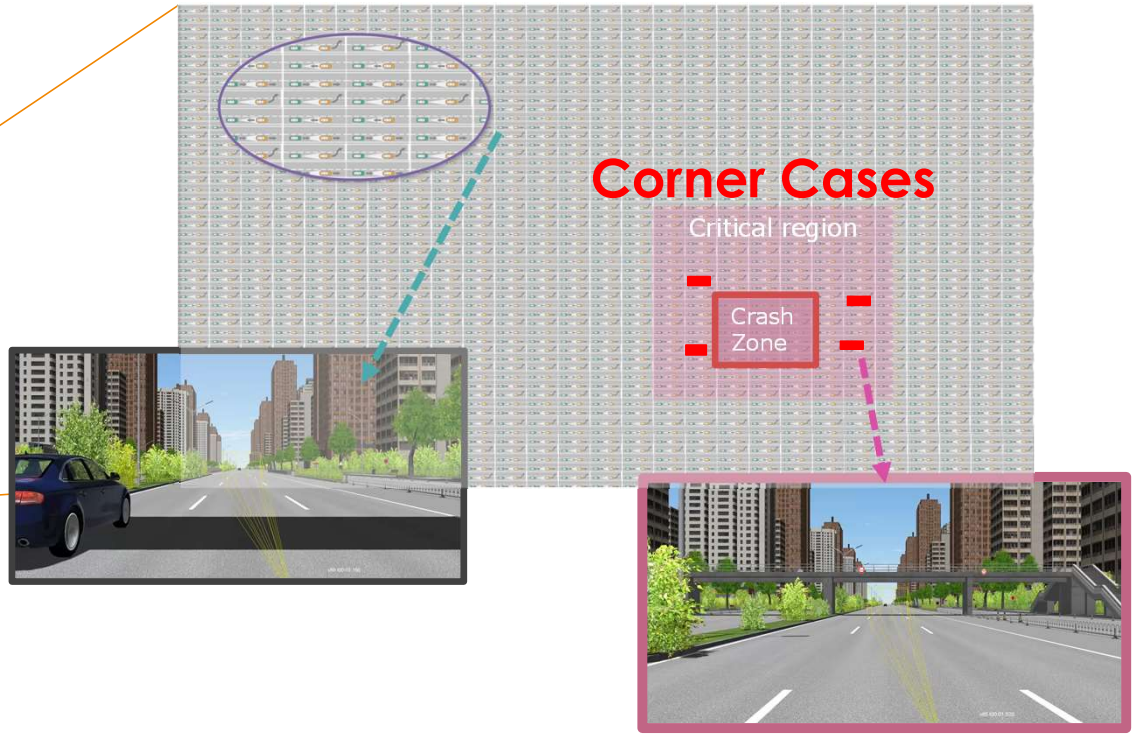




What are **Corner Cases** within a **Logical Scenario**? (e.g.: “Cut in cut out from left to right”)

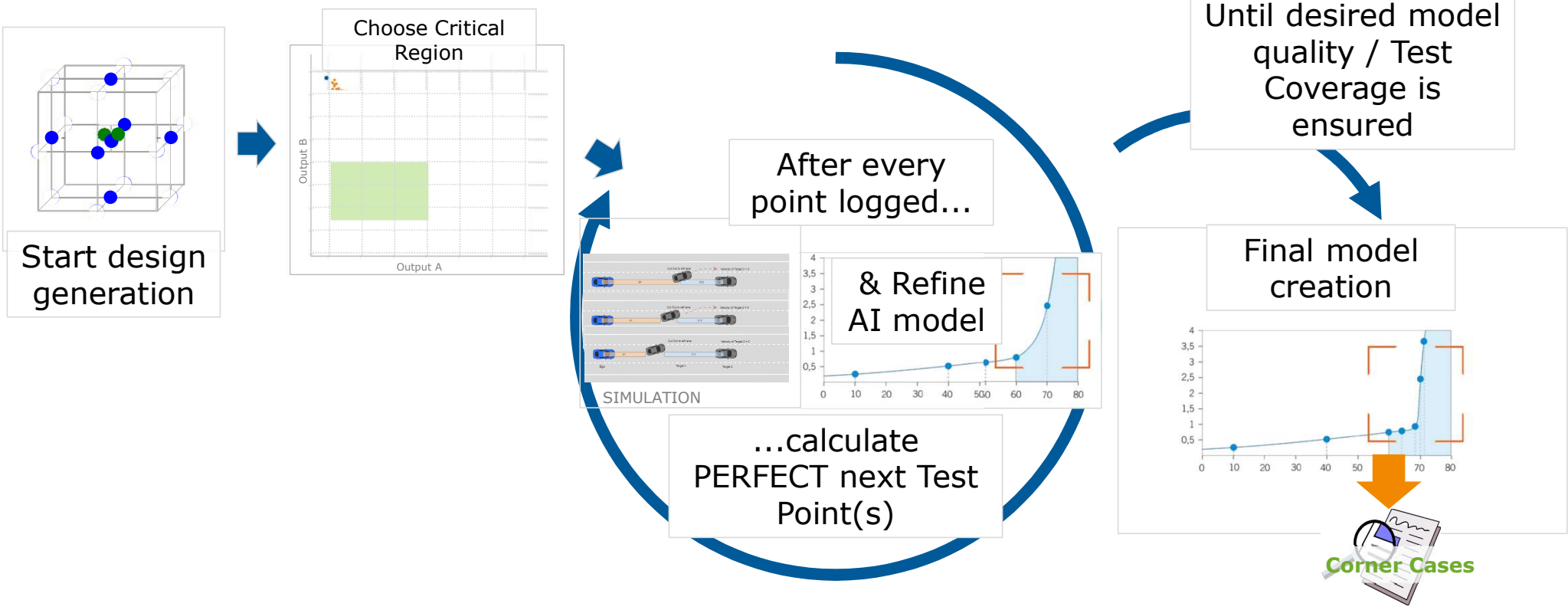
Requirement Driven Approach





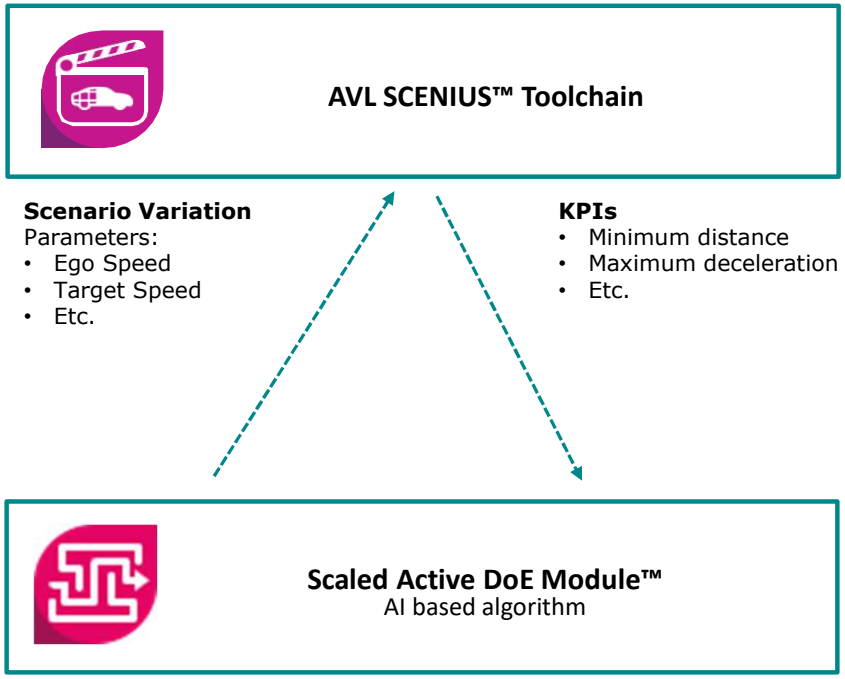
How to detect **Corner Cases** inside a **Logical Scenario**?

Active DoE workflow – AI-based Machine Learning

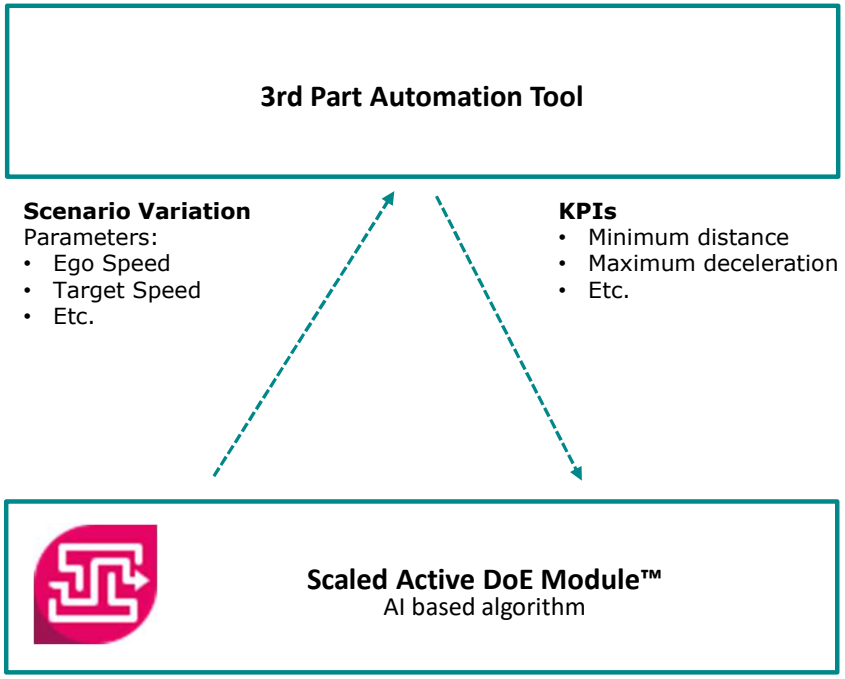


Scaled Active DoE Module™ in ADAS toolchain

Scaled Active DoE Module with AVL SCENIUS™

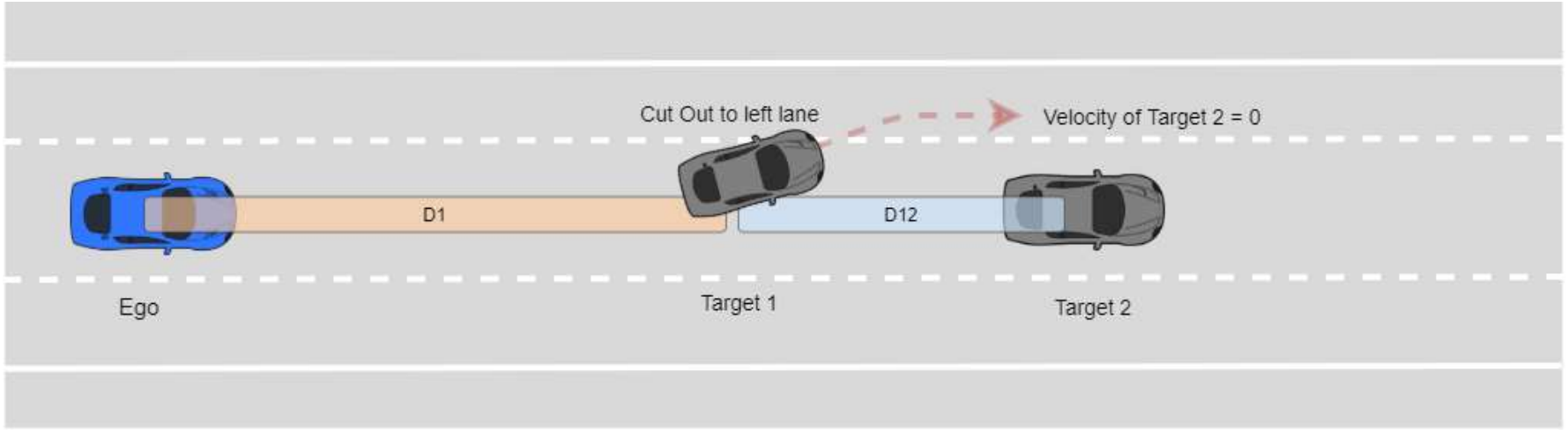


Local solution with 3rd party toolchain – Cloud Solution



The CAMEO Scaled Active DoE Module provides ultimate flexibility to integrate the power of AI-based Machine Learning Active DoE into a ADAS simulation workflow. No CAMEO Windows Client is needed, and the Scaled Active DoE Module is prepared for parallelization, cloud deployment, containerization (Docker etc.) and easy integration (REST Web-API).

e.g.: Logical scenario: “Cut out of TOF to Left Lane”



6 Variation Parameters

1. Distance to target 1 vehicle [m] *(D1 [1- 5])*
2. Distance between target 1 and target 2 vehicle [m] *(D12 [8 -15])*
3. Ego vehicle speed [m/s] *(V_ego [22.22- 36.11])*
4. Target 1 vehicle speed [m/s] *(V_Target1 [22.22- 36.11])*
5. Lane Change Controller_factor1 [no unit] *[0.1 - 1]*
6. Lane Change Controller_factor2 [no unit] *[0 -1]*

Target KPIs

Identify the critical output KPI for the system under test

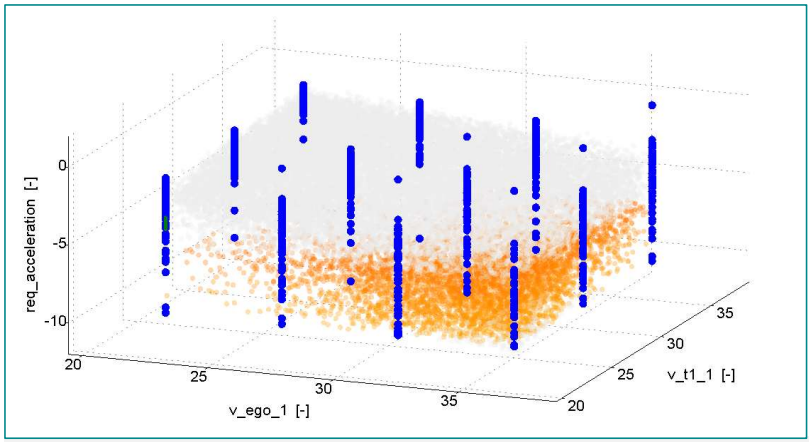
(deceleration request)

Define **the interesting region** of the output KPI, deceleration request

[-10, -6]m/s2

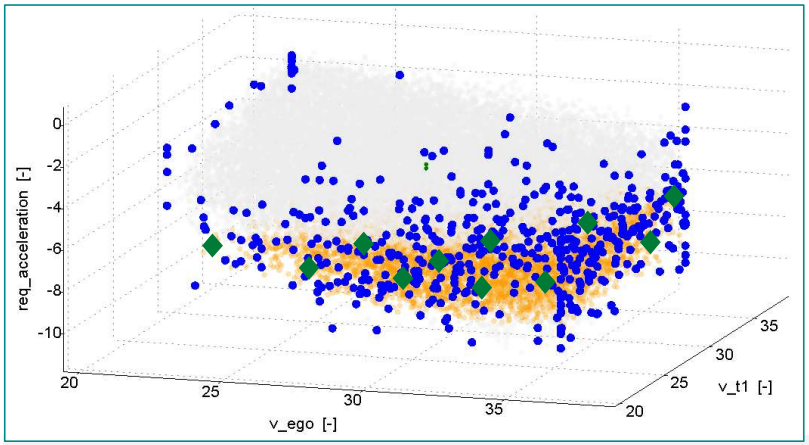
Number of Results in the Critical Region

CONVENTIONAL METHODS - FULL FACTORIAL



- 1000 simulation points
- 186 points in the critical region

CAMEO ACTIVE DoE



- 1000 simulation points
- 481 points in the critical region

95% model quality in **227** simulations with 76 (33%) of the points inside the interesting region + Corner cases e.g.: **11**

Summary

Scenario and test coverage demands for SOTIF

- Complementary to functional safety for insufficient functional performance and trigger conditions
  → Enhancement of development & testing process and methods → Safety Argumentation!
- Scenario based system requirements and failure mode input → Minimal Risk Maneuvers to be checked
- Verification and Validation strategy with many more test parameters (**Parameter explosion**)
  → Logical scenarios + KPIs: data driven approach + knowledge based approach
- Within a logical scenario: Define concrete Test Cases in order to find the
  → **safety critical corner cases** supported by **Active DoE**
- Toolchain needed for creation and management of scenarios in all levels - including Corner cases – capable to run in MiL/SiL, HiL, Driving Cube, (Proving ground)

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