



CAMEO for ADAS: ENABLE-S3 KPI MODEL-BASED VALIDATION

AVL SIMULATION MEETS TESTING CONFERENCE 2019

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CAMEO for ADAS: ENABLE-S3 KPI Model-Based Validation

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Project: Testing & Validation of Highly Automated Systems

Task ID:

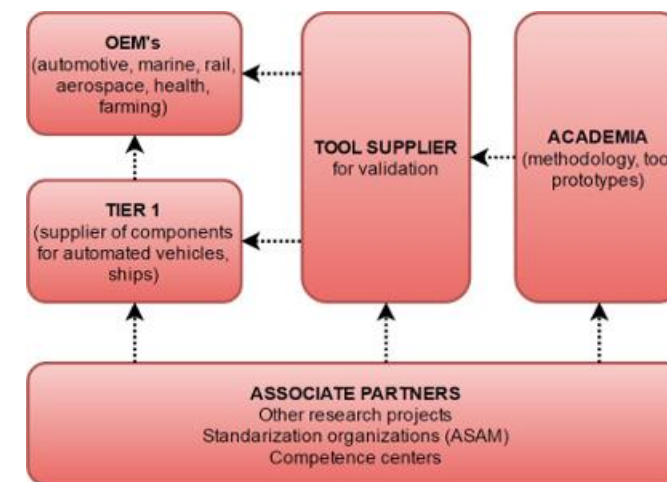
Department: AST, PEI, TSI

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Highly automated and autonomous systems in different domains (automotive, aerospace, rail, maritime, health care and farming) are basically facing the same challenges. Exploding complexity or a nearly infinite number of possible environmental scenarios which need to be considered are just a few of them. The ENABLE-S3 consortium combines **experts from six different domains with tool suppliers and academia** in order to cope with the main testing challenges. The project consortium covers the supply value chain of the validation process in the industry as shown:

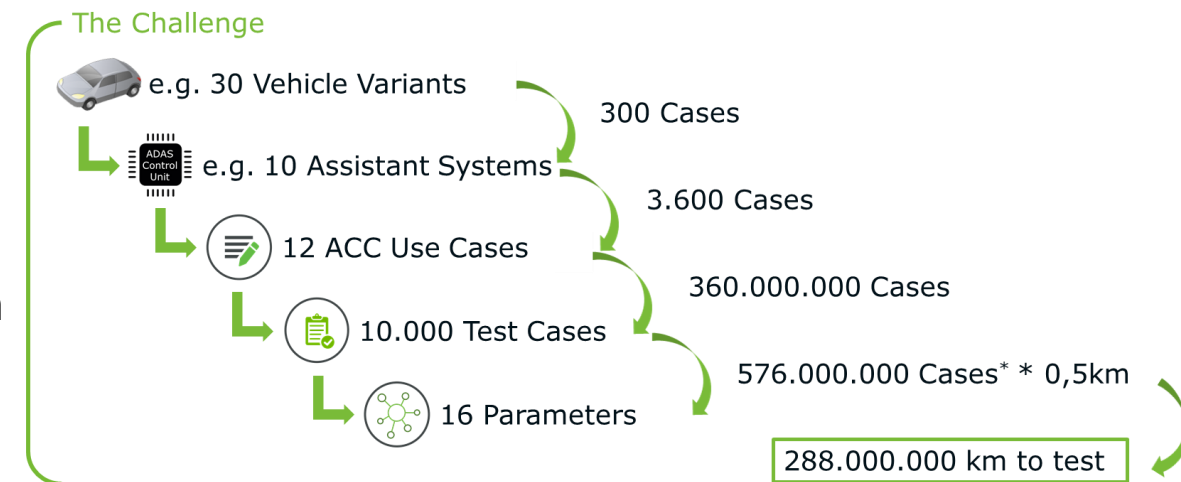


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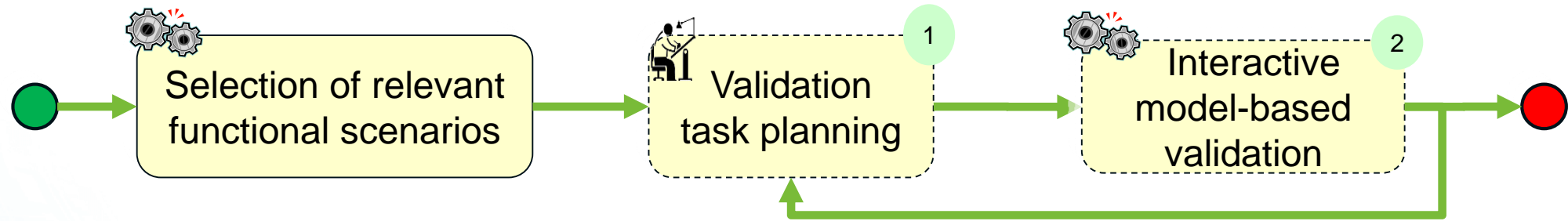
WHY CAMEO for ADAS?



- 1) When ADAS testing is required?
- 2) Determining which traffic scenarios / cases are relevant for ADAS testing?
 - In virtual solutions, simulations allow beyond Real-Time → many tests are possible, but the
 - full system integration might not be available, or simulation may not be realistic enough?
- 3) What are and how to identify Corner Cases?
 - Edge vs. Corner
- 4) As soon as hardware is available
 - transition to Real-Time only for system validation
- 5) **To find relevant Corner Cases, close to an accident and use them in testing**
 - in [AVL DRIVING CUBE](#), or a Proving Ground

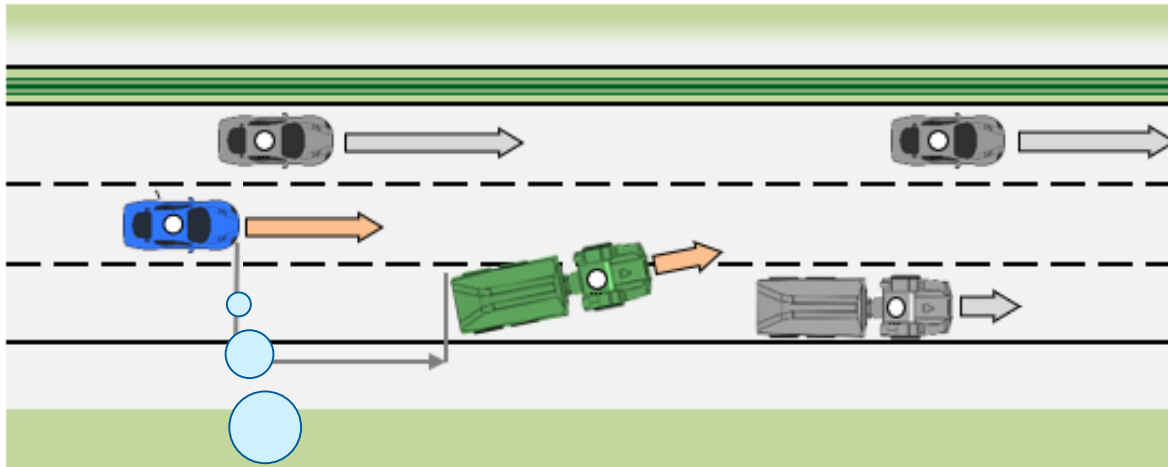


WHAT IS KPI MODEL BASED VALIDATION?



- Key Performance Indicators (KPIs) rate the resulting danger
- KPI models allow to estimate them throughout the whole variation space
- Relevant Corner Cases → close to an accident, are found efficiently!
- Use Corner Case scenarios on [AVL DRIVING CUBE](#) or Proving Ground

HOW TO APPLY SYSTEMIC VARIATION TO THE TRAFFIC SCENARIO OF THE AUTOMATED VEHICLE?



Ego Vehicle
equipped with
"Highway Pilot"

**Corner Case:
Concrete Scenario
close to accident!**

Functional Scenario



vehicle cutting in

Logical Scenario

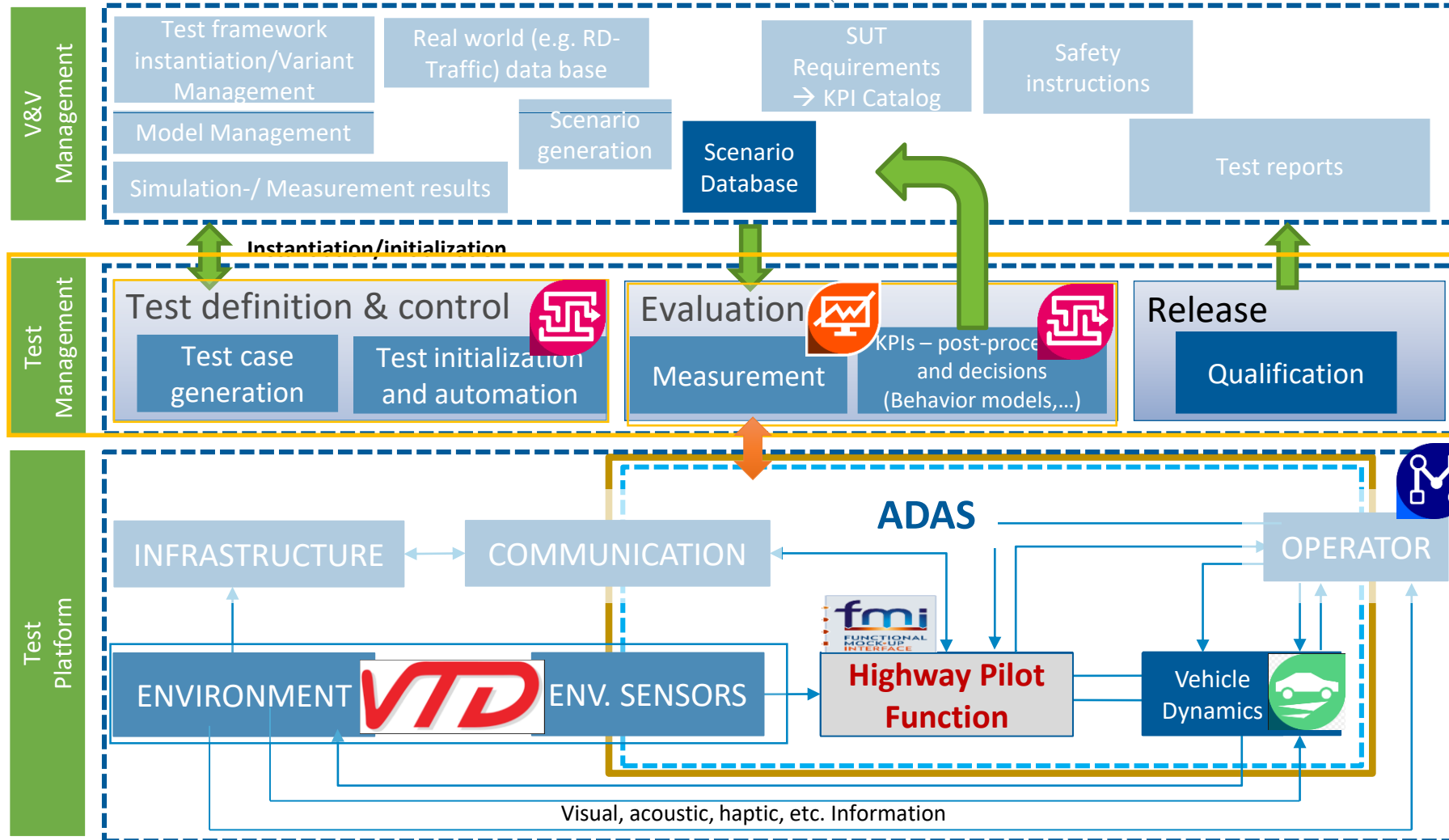


in front, from right

Concrete Scenario

- $v_Target = [100....\mathbf{130}....150]$ km/h
- $Cut_in\ distance = [20....\mathbf{60}....100]$ m
- $Cut_in_velocity = [40....\mathbf{70}....90]$ km/h
- $Split\ Mu = [0.1...1]$

HOW TO APPLY KPI MODEL-BASED VALIDATION TEST SYSTEM



Extension of existing tools to enable KPI Model Based Validation



AVL CAMEO
Active DoE for KPI model generation



AVL CONCERTO
KPI calculation



AVL Model.CONNECT
supporting FMU co-simulation via FMI

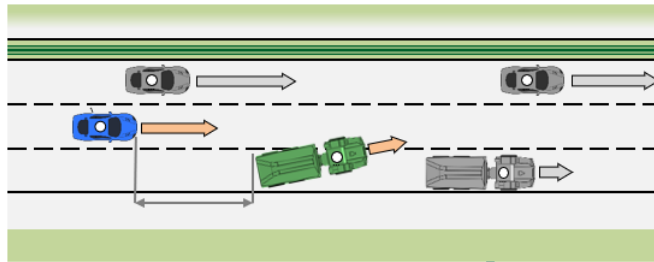


AVL VSM
Vehicle Simulation Model

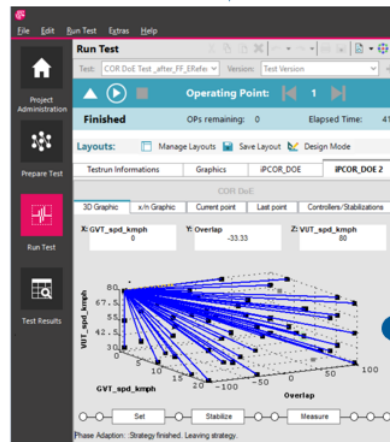


VIRES VTD
Virtual Test Drive

KPI MODEL-BASED VALIDATION PROCESS

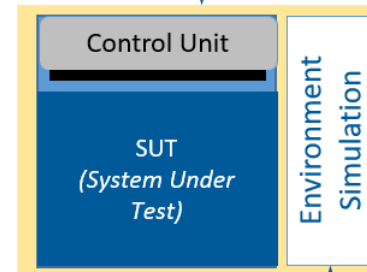


e.g.: "Cut in on Highway"



Task Planning:
Functional
Scenarios

Verification



Intelligent
Scenario variation:
Concrete scenarios

- 1) Ego start velocity
- 2) Target distance set on ACC
- 3) Cut in Distance
- 4) Preceding Vehicle cut in velocity
- 5) Driver parameter of cut in vehicle
- 6) Road friction
-
-

ADAS-Function working area
and the Corner Case Scenarios

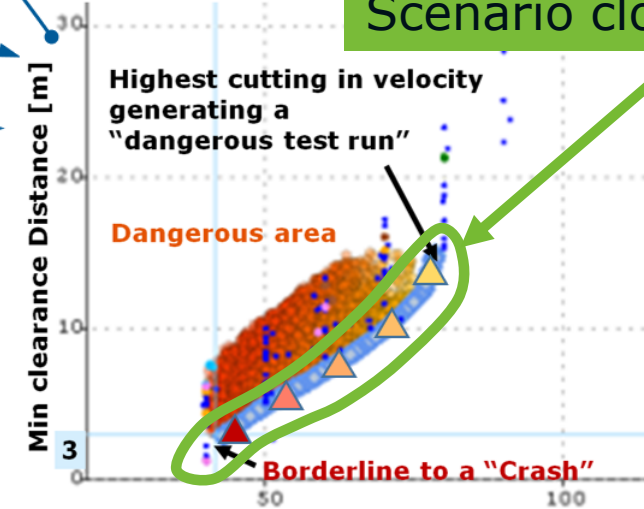


Corner Case:
Scenario close to accident!

Optimization
Variants
Target &
Constraints

Behavior
Safety KPI's

- e.g.:
- Min clearance distance
 - Drivers comfort rating
 -
 -



Step 10: Select the relevant scenario starting
parameter sets, for the next development
environment

USE CASES OF KPI MODEL-BASED VALIDATION



1)Euro NCAP Validation for “State of the Art” AEB: Automatic Emergency Braking

- with only 50% of “State of the Art” effort, same result is achieved

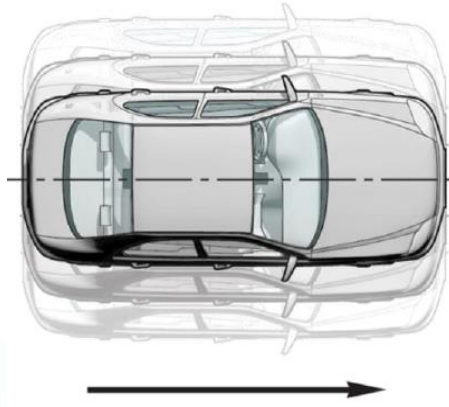
2)Highway Pilot: Much more complex Scenarios:

- Application of the KPI Model-Based Validation led to:
 - ✓ Corner Case definition for relevant test cases in the next development environment
 - ❖ greatly reduced the number of non-relevant test cases
 - ✓ KPI Models are prerequisite and input to an “Accident – rest risk estimation”, using real world Traffic Scenario distributions. (ongoing research)

Use Case 1: Euro NCAP Validation - AEB FF DoE as "State of the Art" vs. KPI Model-Based Validation Active DoE



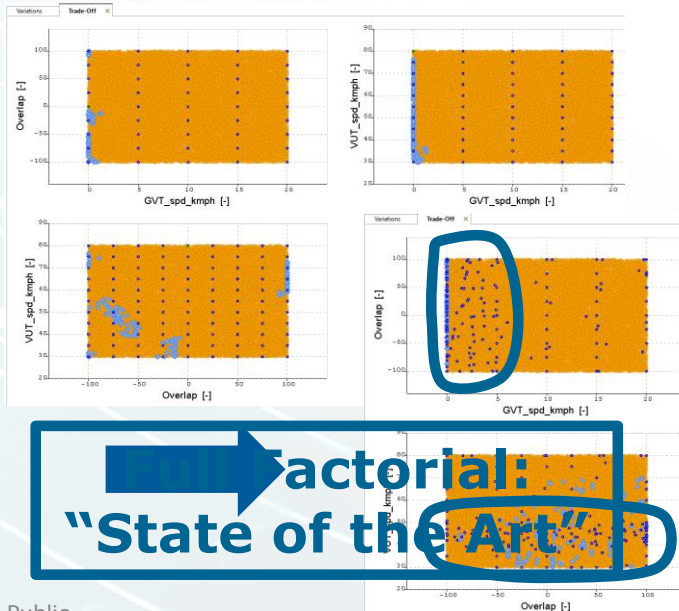
Overlap /
Deviation:
50%
25%
0%
-25%
-50%



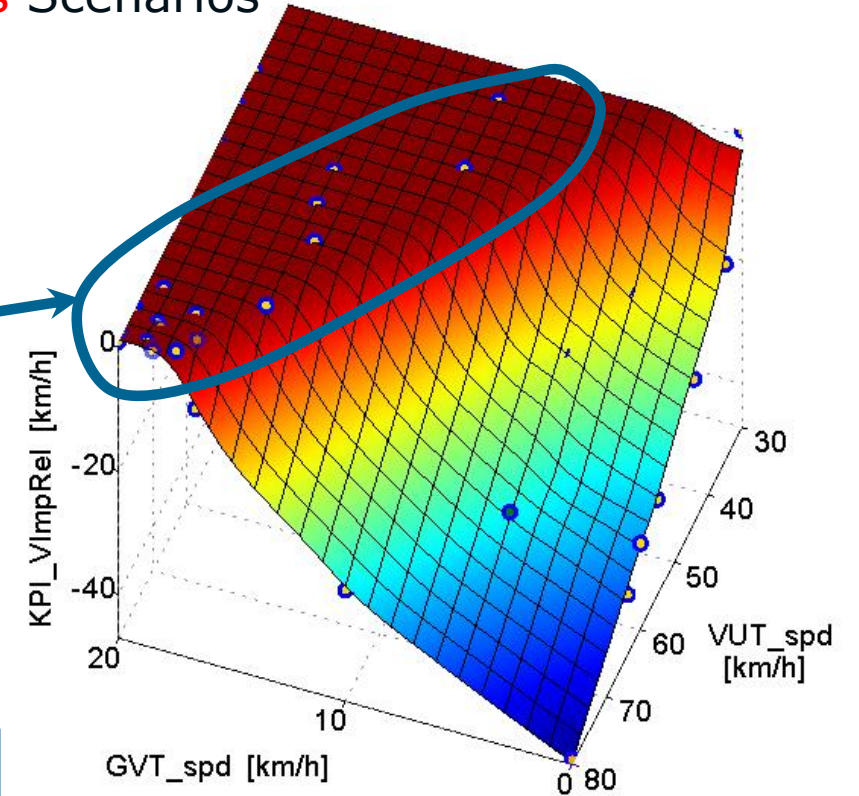
CCRm and CCRs Scenarios

GVT Velocities:
0, 5, 10, 15, 20 km/h

VUT Velocities:
30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 km/h



Relevant
"Corner Cases"

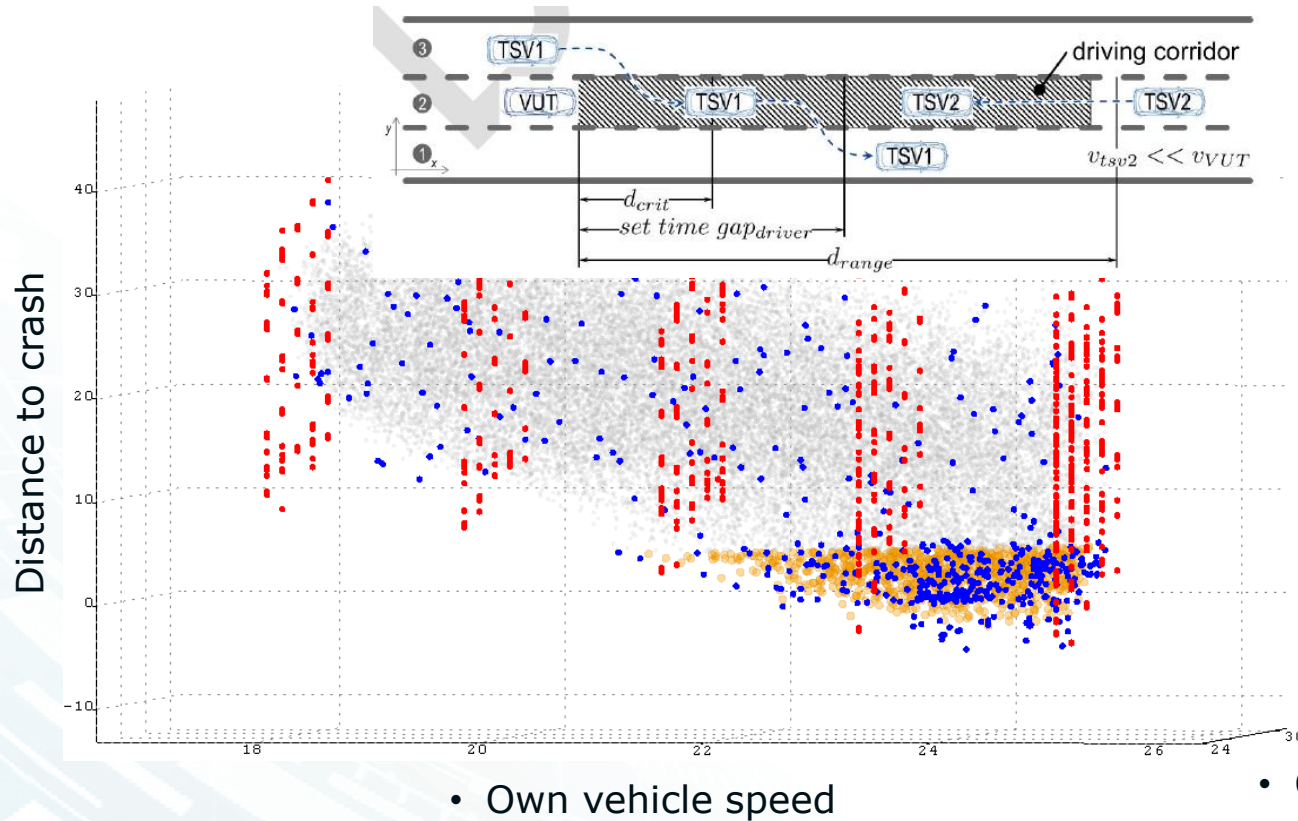


Factorial:
"State of the Art"

Active DoE finds 201
Tests cases more in the
relevant area of interest

Use Case 2: Highway Pilot study: "Cut in / Cut out"

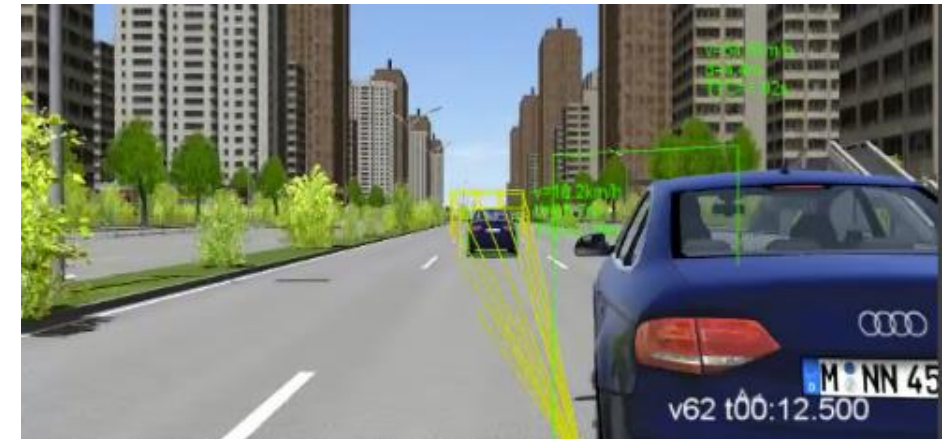
FF DoE vs. KPI Model-Based Validation with Active DoE



Scenario with five variations

- VUT velocity
- TSV1 velocity
- TSV2 velocity
- TSV1 cut in
- TSV1 cut out

Critical KPI:
Time to collision



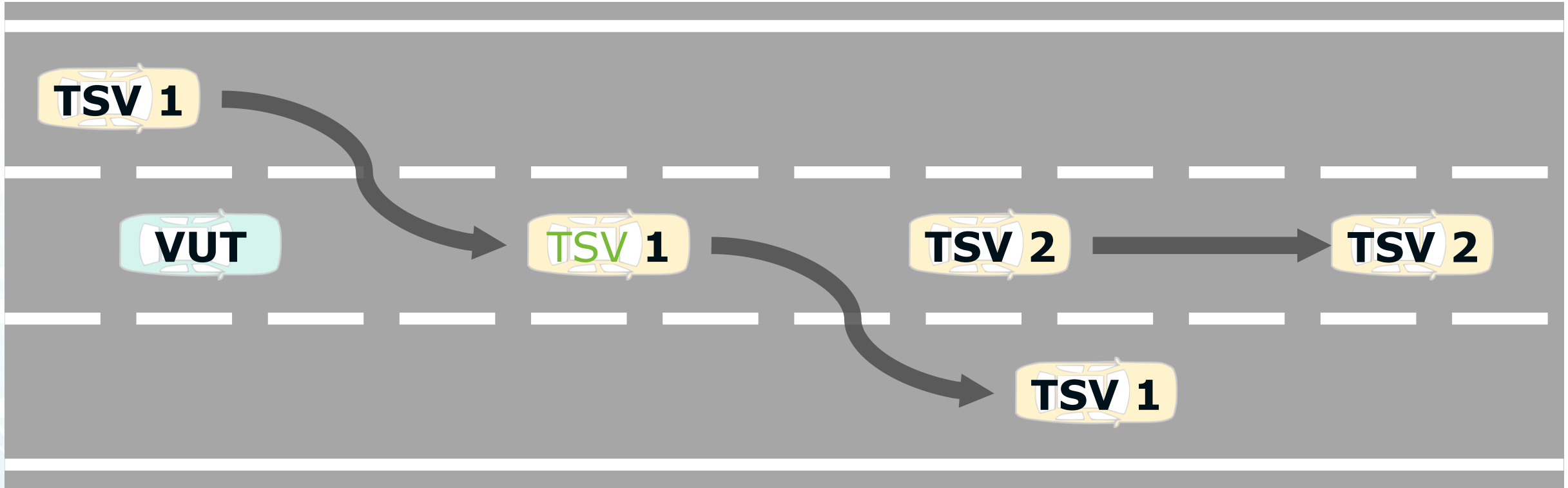
- Cut in vehicle speed

Relevant variation parameters are found using Active DoE

- **11** interesting cases found for a Full Factorial plan using **2000 observations**
- **71** interesting cases found using Active DoE using **331 observations**

ACC: Adaptive Cruise Control

Scenario: cut in from left behind and cut out



Five variations:

- VUT velocity
- TSV1 velocity
- TSV2 velocity
- TSV1 cut in
- TSV1 cut out

RESULTS: MOST CASES ARE UNINTERESTING



RESULTS: INTERESTING AND TARGET FOCUS



SUMMARY: KPI MODEL-BASED VALIDATION



EXPLOITATION:

- AVL CAMEO and AVL CONCERTO were extended in order to show:
 - ✓ Ability to reduce a massive quantities of irrelevant / non-interesting test cases
 - ✓ Efficiently pinpoints most relevant test cases in areas of interest, Corner Cases

APPLICATION:

- Frontloading these development processes in Simulation environments, i.e.: MiL, SiL, HiL, & ViL, delivers the most relevant test cases to be executed in an [AVL DRIVING CUBE](#) or Proving Ground

IMPACT:

- It is expected to reduce the number of tests to <50% compared to traditional DoE tests as it is state of the Art, i.e.: EU-NCAP; for at least the same test coverage



Thank You



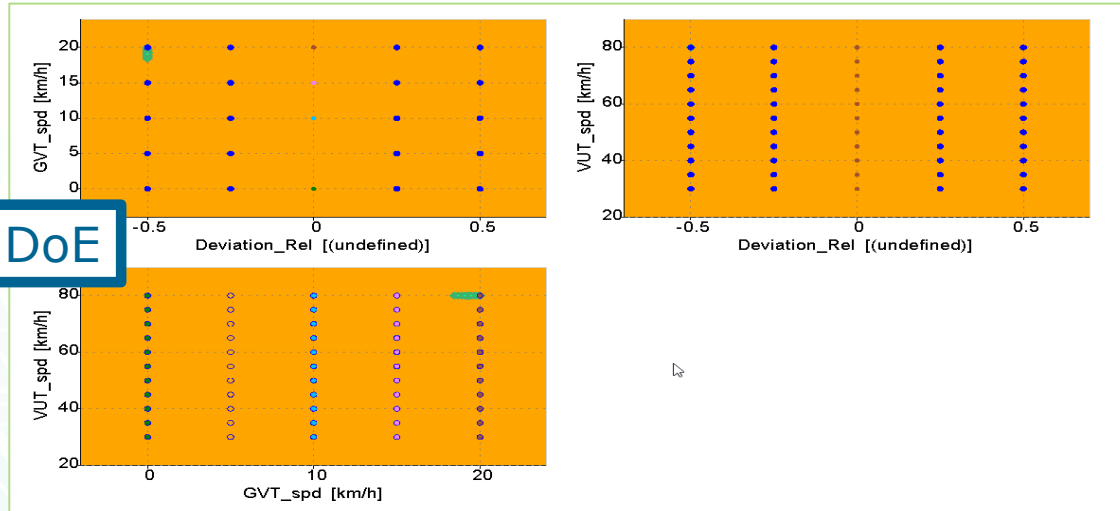
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Use Case 1: Euro NCAP Validation - AEB

FF DoE as "State of the Art" vs. KPI Model-Based Validation with Active DoE



FF DoE



Active DoE

