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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

Author(s): Sajin.Gopi@AVL.com

Co-Author(s): Hans-Michael.Koegeler@AVL.com
Gregory.Light@AVL.com
Many others....

Approved by: Hans-Michael Koegeler

Project Leader: AVL

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Customer: [ENABLE-S3 Consortium](#)

Project: Testing & Validation of Highly Automated Systems

Task ID:

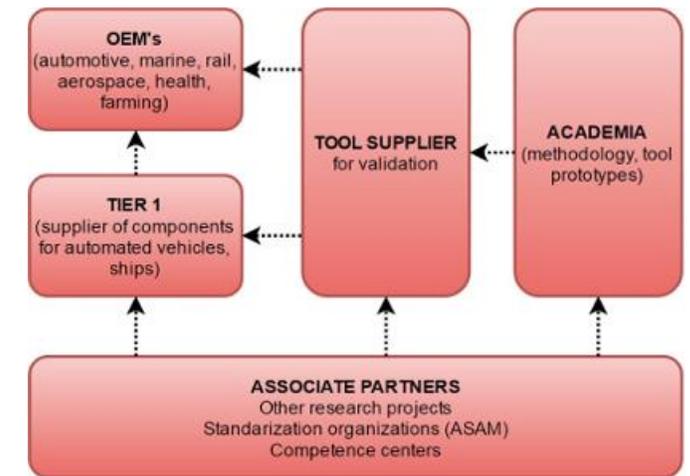
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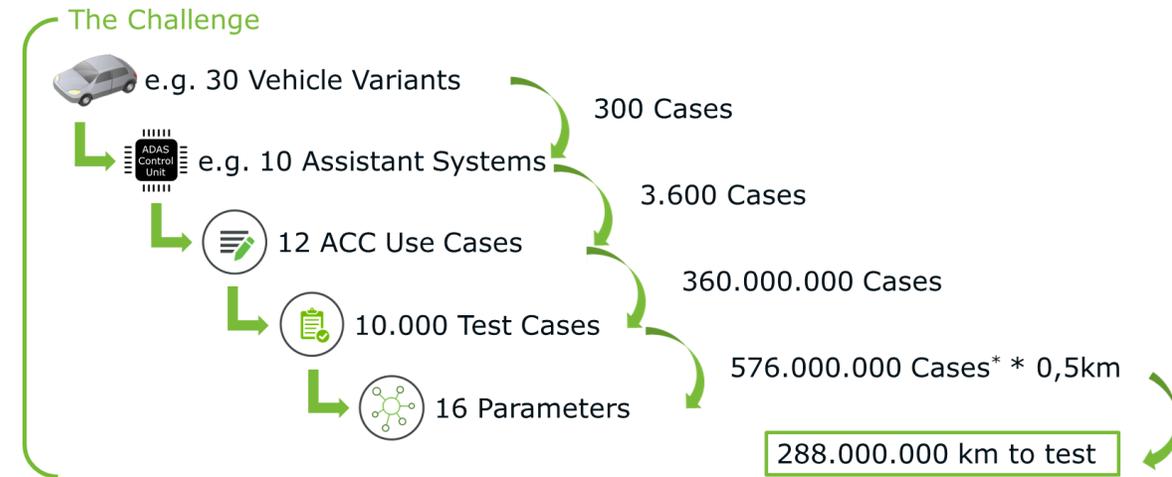
Highly automated and autonomous systems in different domains (automotive, aerospace, rail, maritime, health care and farming) are basically facing the same challenges. Exploding complexity or a nearly infinite number of possible environmental scenarios which need to be considered are just a few of them. 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:



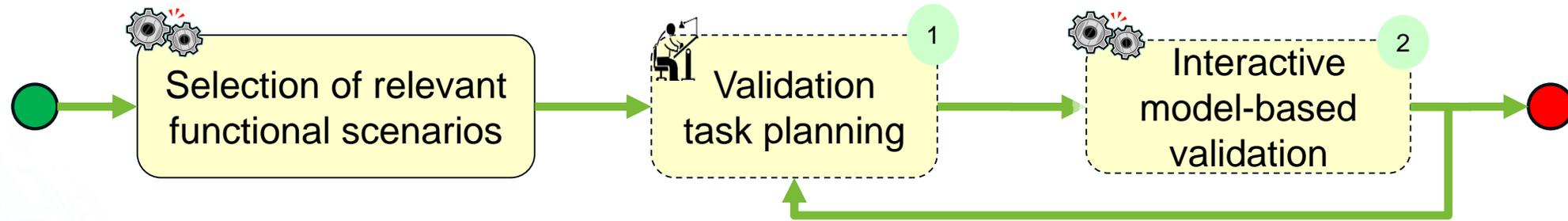
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WHY CAMEO for ADAS?

- 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

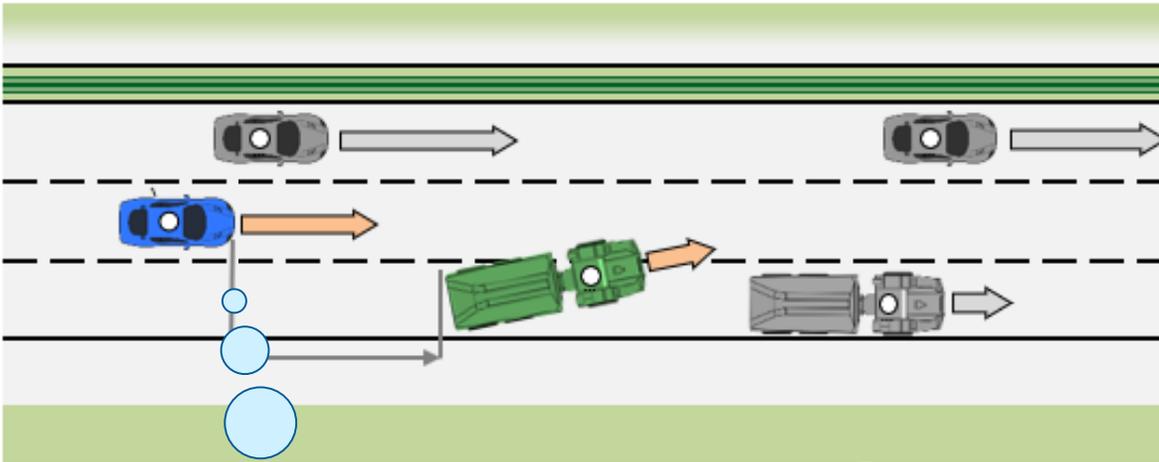


WHAT IS KPI MODEL BASED VALIDATION?



- 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

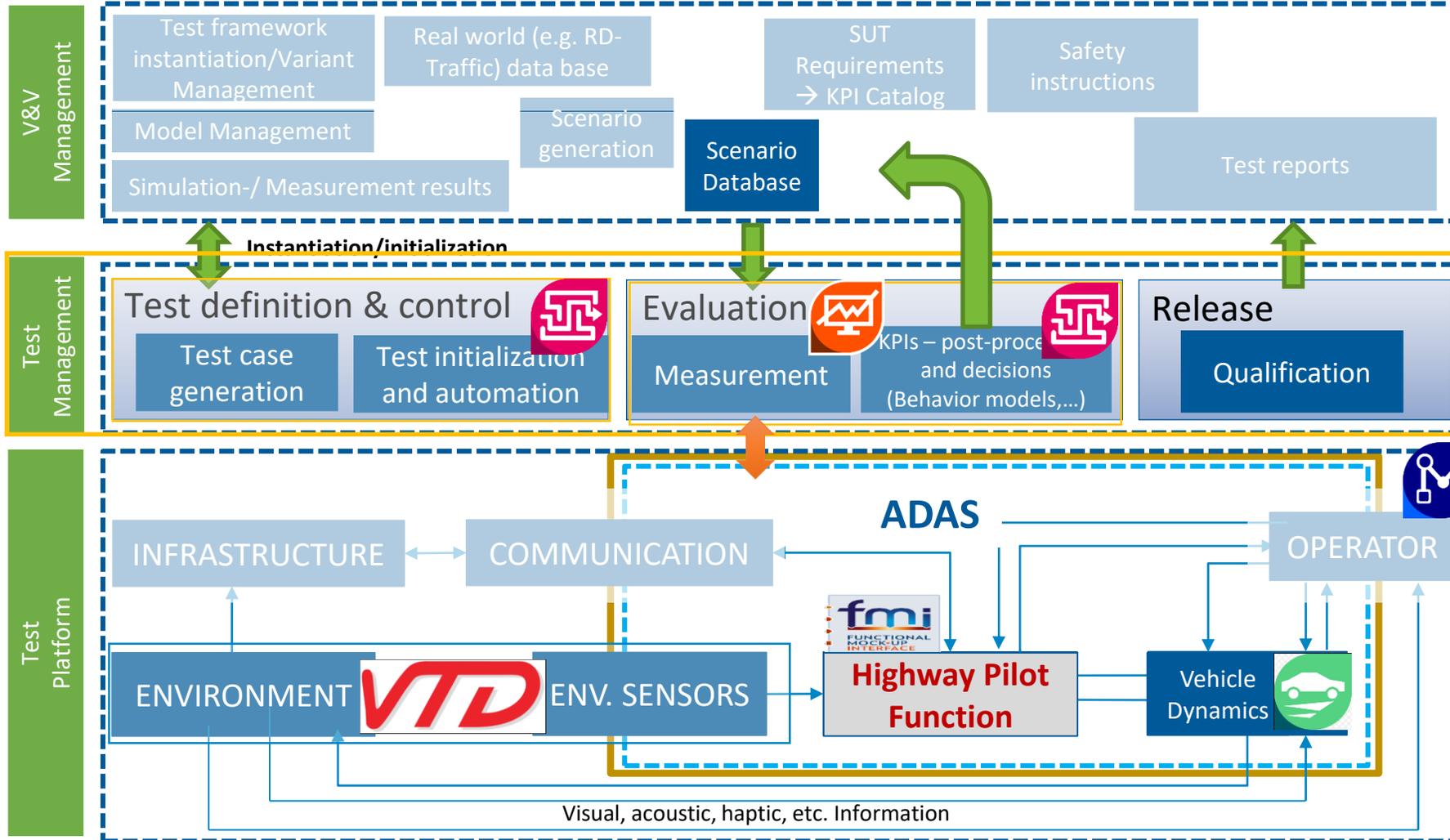


in front, from right

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

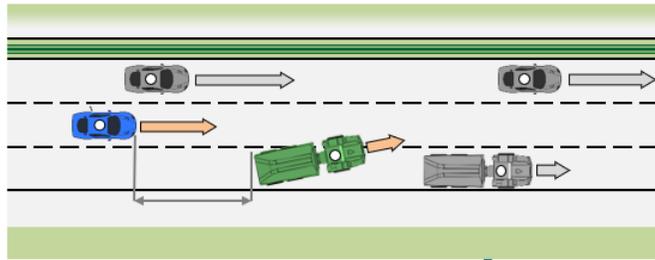
- AVL CAMEO**
Active DoE for KPI model generation
- AVL CONCERTO**
KPI calculation

- AVL Model.CONNECT**
supporting FMU co-simulation via FMU
- fmi**
FUNCTIONAL MOCK-UP INTERFACE

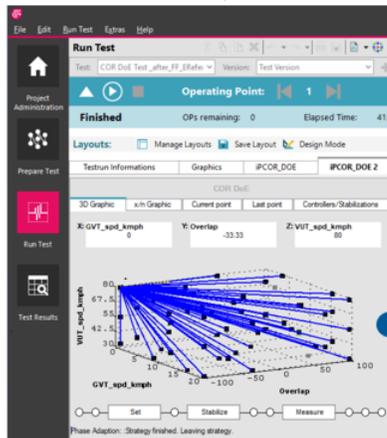
- AVL VSM**
Vehicle Simulation Model

- VTD** **VIRES VTD**
Virtual Test Drive

KPI MODEL-BASED VALIDATION PROCESS



e.g.: "Cut in on Highway"



Task Planning:
Functional
Scenarios

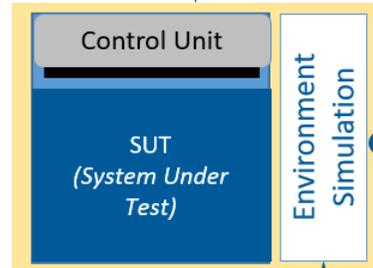


ADAS-Function working area
and the Corner Case Scenarios



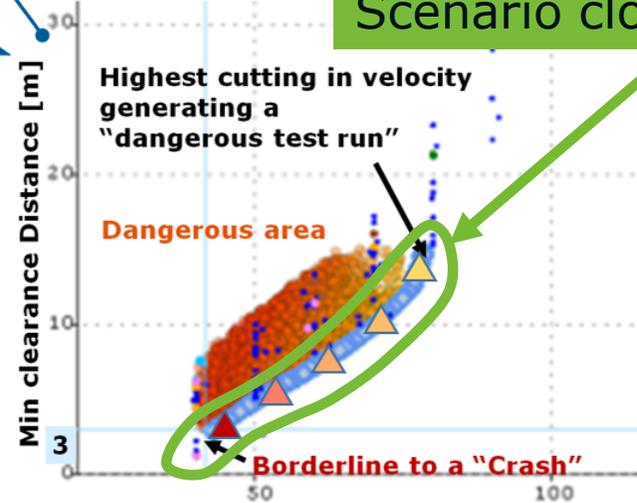
Corner Case:
Scenario close to accident!

Verification



Behavior
Safety KPI's

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



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
-
-

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

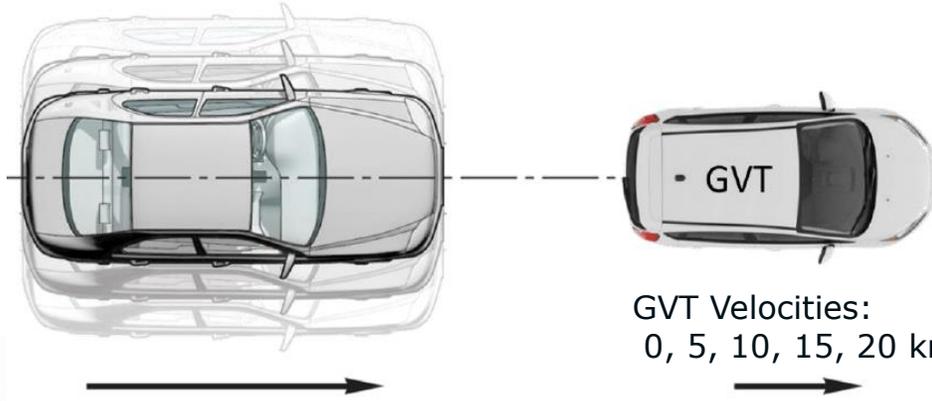
2) Highway Pilot: Much more complex Scenarios:

- 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



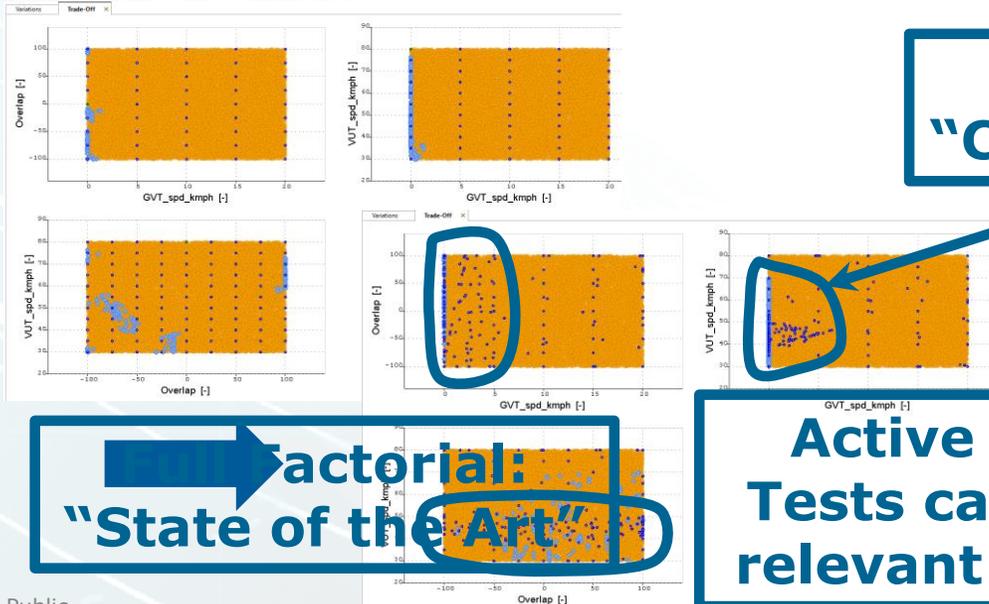
Overlap /
Deviation:
50%
25%
0%
-25%
-50%



CCRm and CCRs Scenarios

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

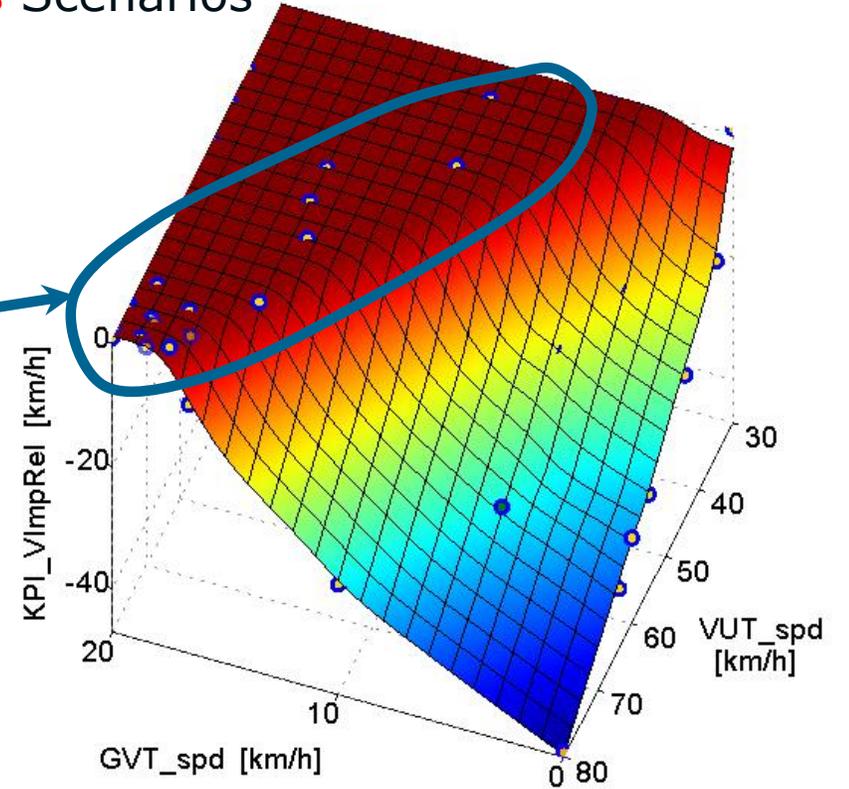
VUT Velocities:
30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80 km/h



**Relevant
"Corner Cases"**

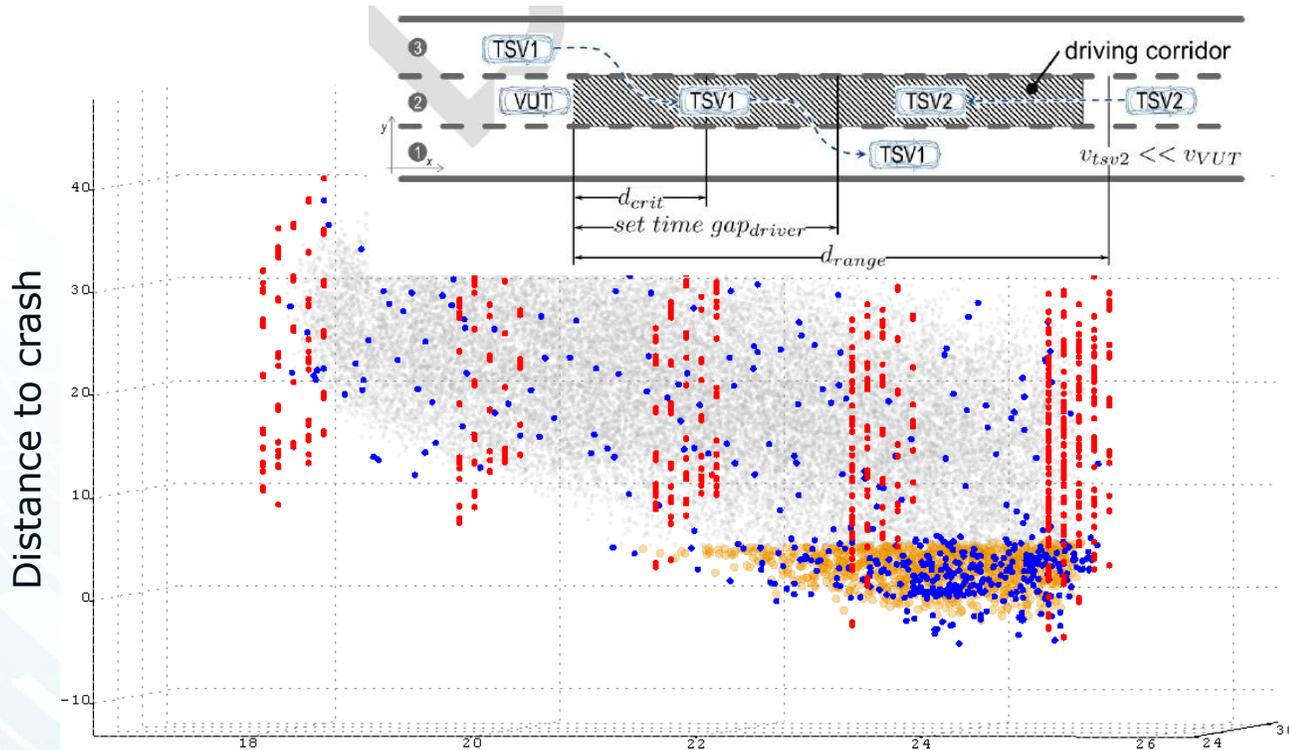
**Factorial:
"State of the Art"**

**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



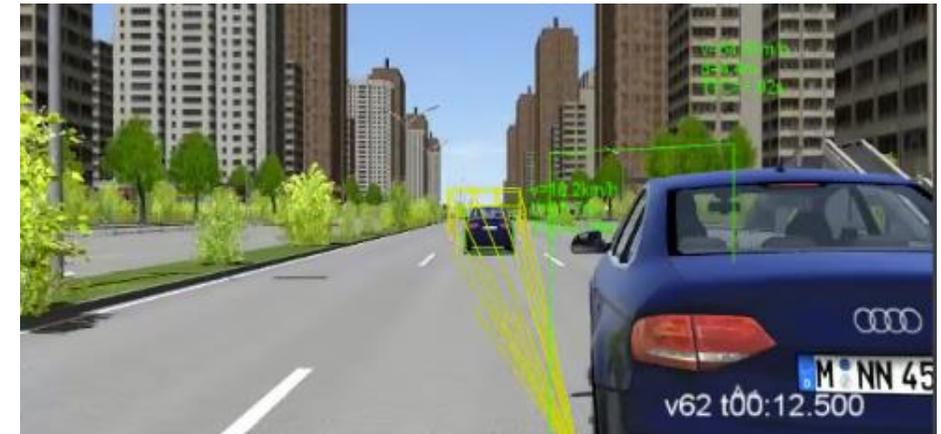
• Own vehicle speed

• Cut in vehicle speed

Scenario with five variations

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

Critical KPI:
Time to collision

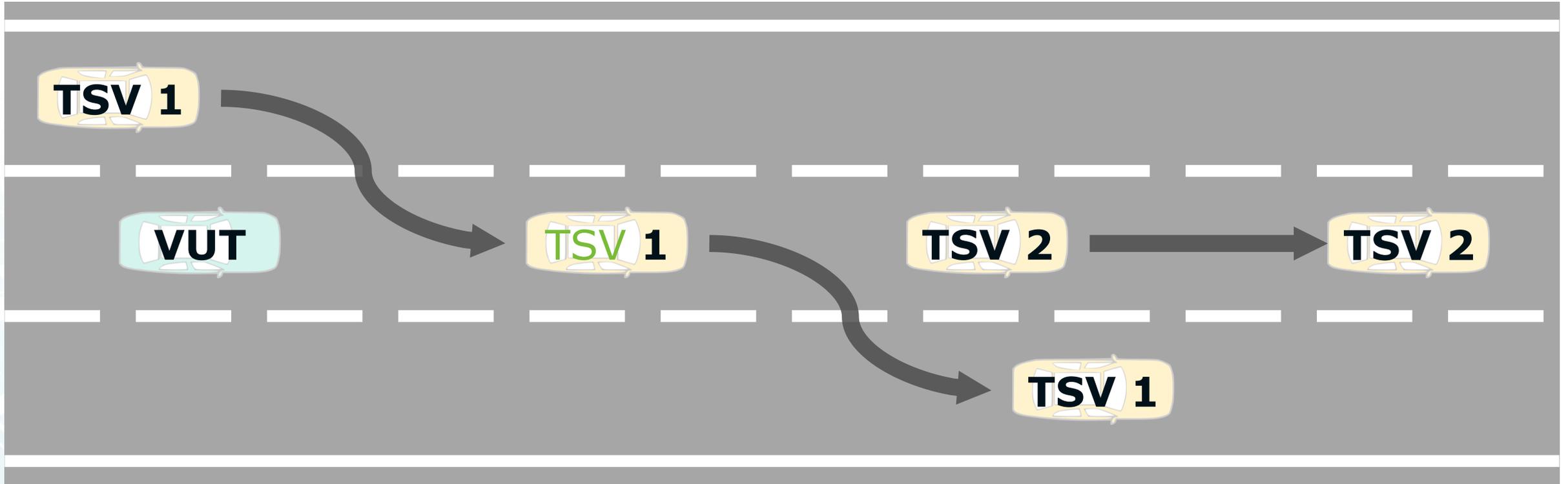


Relevant variation parameters are found using Active DoE

- **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



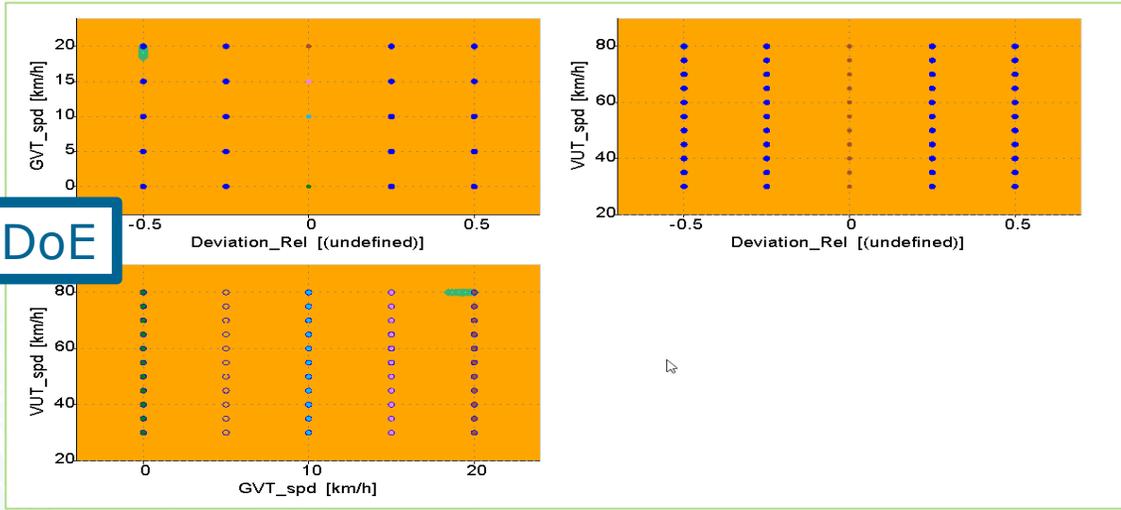
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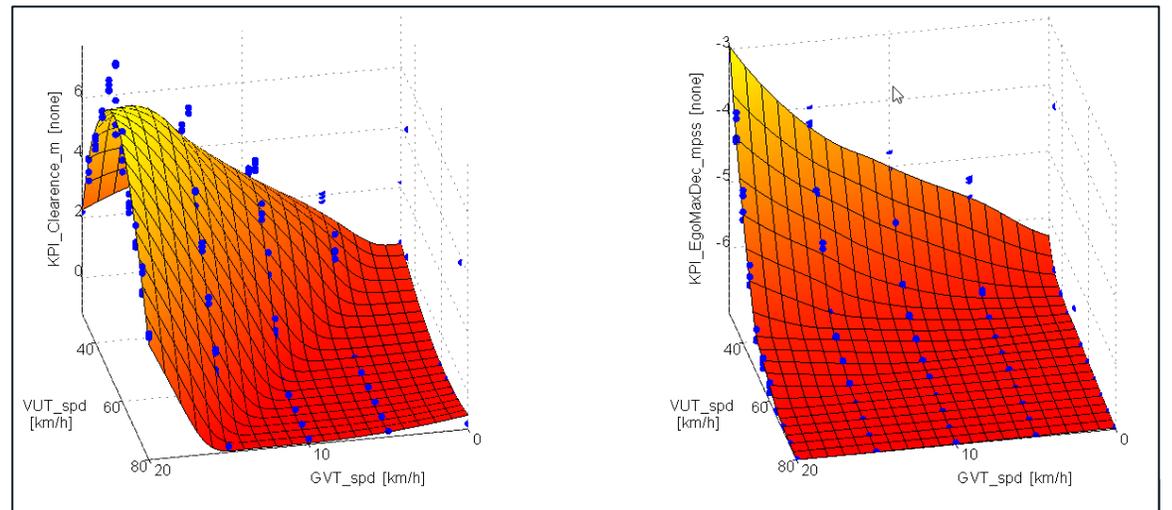
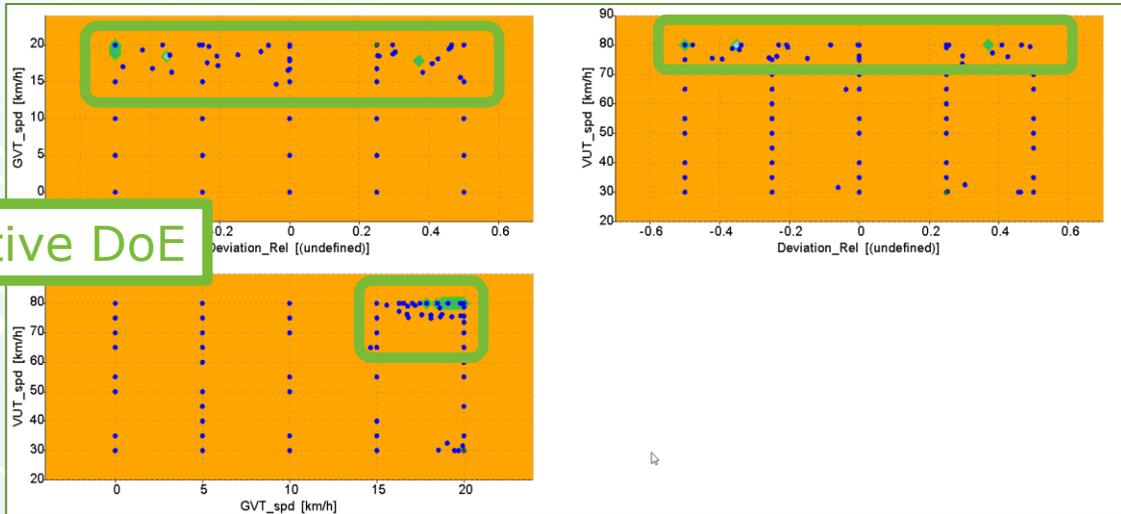
Use Case 1: Euro NCAP Validation - AEB FF DoE as "State of the Art" vs. KPI Model-Based Validation with Active DoE



FF DoE



Active DoE



140 tests more
in relevant area

