Public relations

- Public & politic reactions in case of accidents
- Customer acceptance
- Cyber security
- Ethic

Technical

- Functional safety & Reliability in all conditions (Traffic, Weather & Road)
- Infinite high number of test cases
- Complex and new technology
- Time & Cost pressure during development

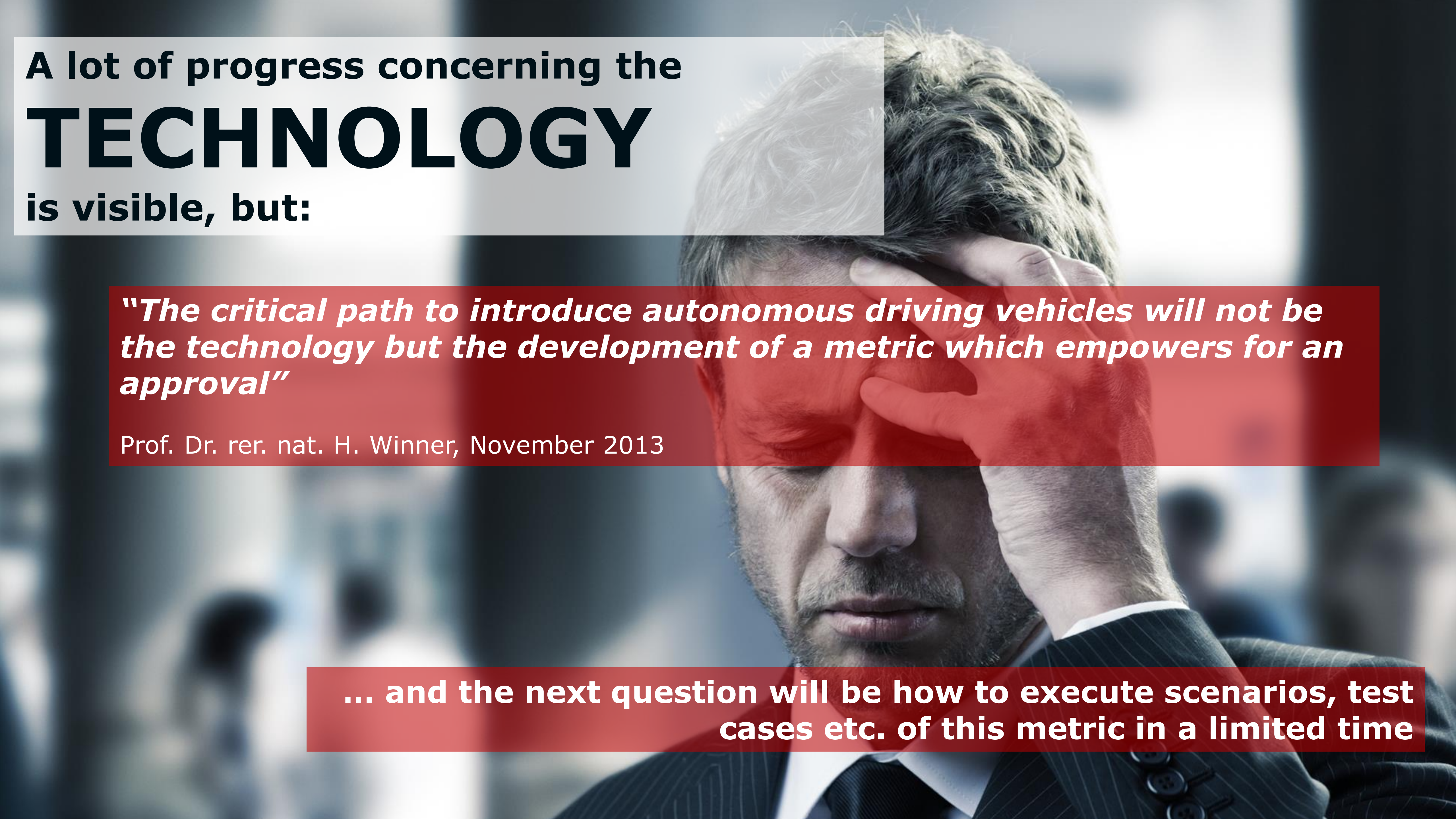
Legislative

- Homologation criteria
- Responsibility in case of accident

The rocky road to ADAS/AD

Development, Validation and Homologation

Now
Level 5 Future
Driver's License
Regulations
?
?
Responsibility


A lot of progress concerning the
TECHNOLOGY
is visible, but:
"The critical path to introduce autonomous driving vehicles will not be the technology but the development of a metric which empowers for an approval"
Prof. Dr. rer. nat. H. Winner, November 2013
... and the next question will be how to execute scenarios, test cases etc. of this metric in a limited time

"The biggest hurdle is validation to confirm that the system does not cause failures. One has to execute 250 million test kilometers"

Bosch Executive Director.

Same approaches as 36 years ago?

Mercedes-Benz 190 E (1982) - Demonstration and advantages of ABS

New and Innovative Approaches in

Testing and Validation

are necessary!

Facing the Challenges of Development and Homologation of Autonomous Driving Using Virtual Approaches

AVL

Vehicle Validation and Self Driving Vehicle

NVIDIA

Driving Software and Digital Driver

TÜV SÜD

Legislation, Regulations and Conformity

Regulation for Homologation and Approval of AV

Dr. Houssem Abdellatif

Global Head Autonomous Driving and ADAS

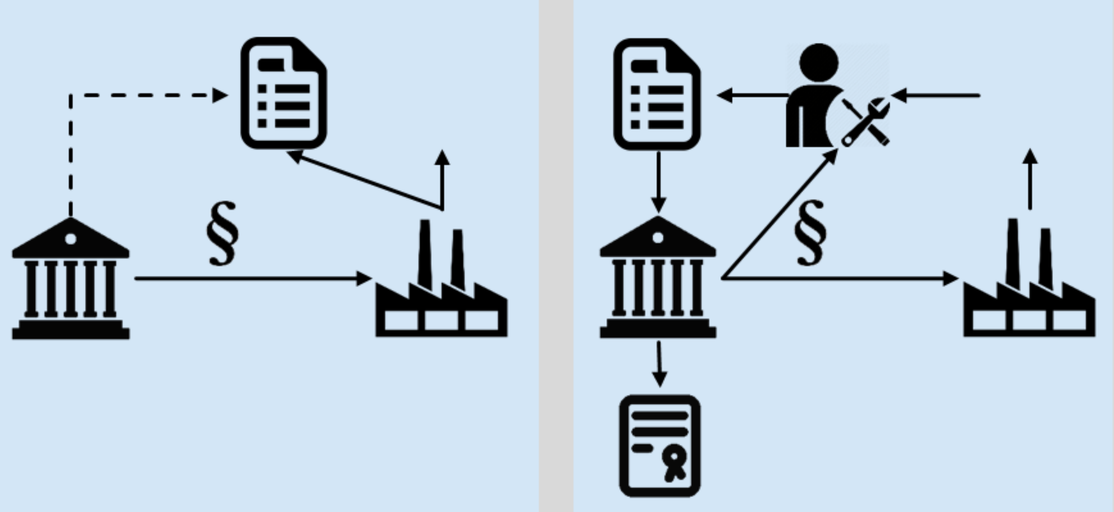
HOMOLOGATION Qu'est-ce que c'est?

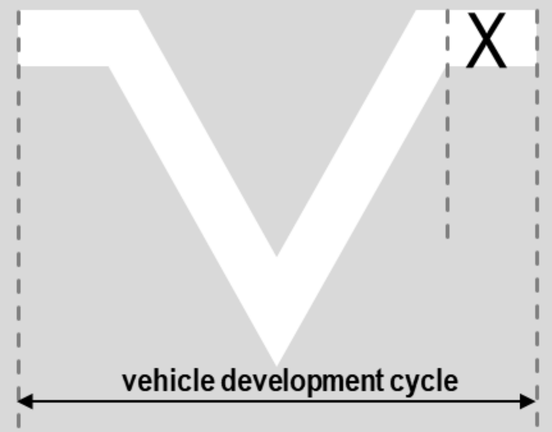
Definition

Homologation refers to the certification process of a product (vehicle) granting that it complies with all local standards and legal regulations such as safety and environmental regulation.

No homologation → No CoC → No sales

Self certification vs. type approval 3rd party principle



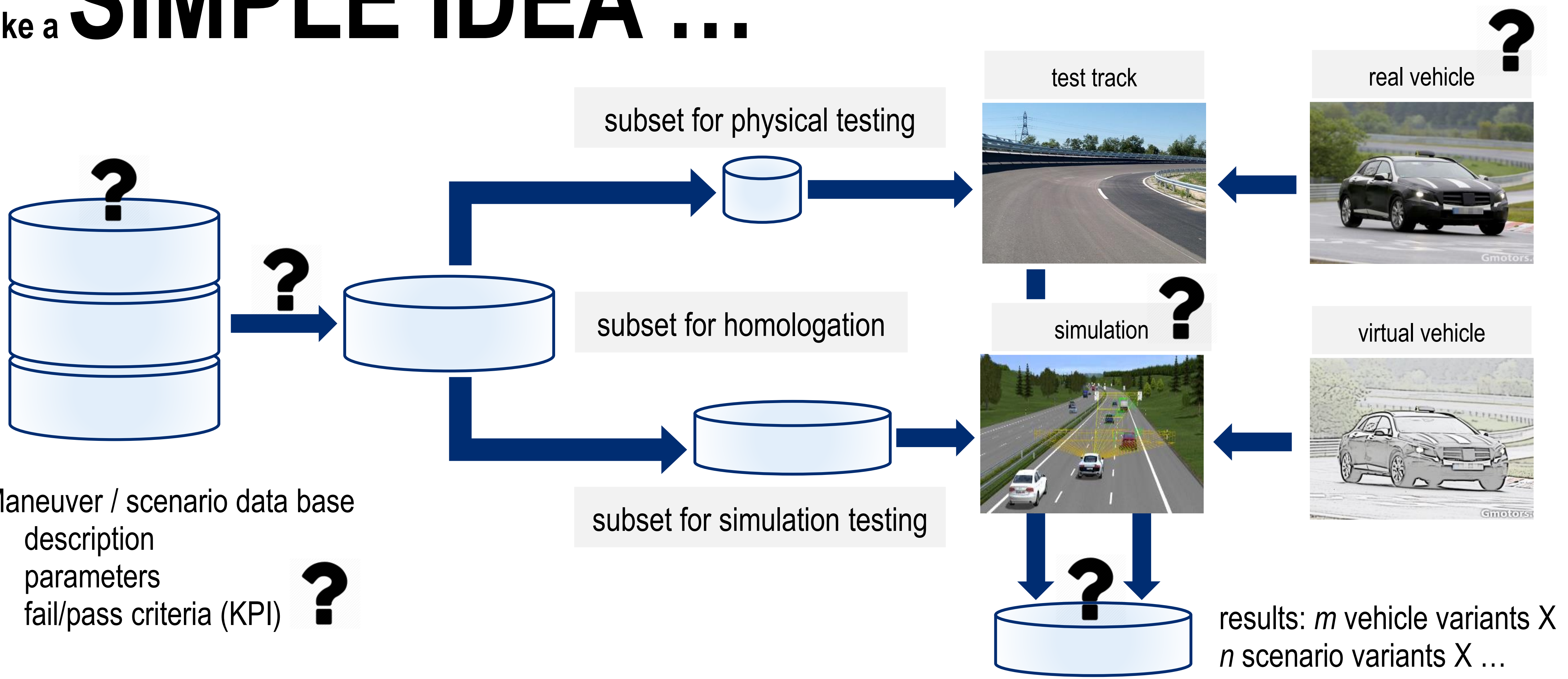


Type Approval in vehicle development

- Last step of development
- Accomplishment of the v-cycle
- legal and technical approval of the concept

- European Union: Directive 2007/46/EC Type approval, tests are based on United Nations Economic Commission for Europe (UN/ECE) procedures;
- North America: Federal Motor Vehicle Safety Standards (FMVSS) regulations released by the NHTSA;
- Australian Design Rules (ADR) regulations;
- Japan follows UN/ECE regulations and their own Test Requirements and Instructions for Automobile Standards (TRIAS) regulations;
- Other countries that accept or base their own regulation on those mentioned above, following the latest release or previous versions of the regulations.

Take a SIMPLE IDEA …

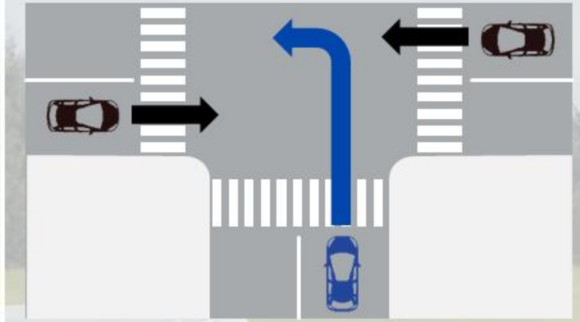


⇨ A 6 Points Approach to realize this Idea to empower for Approval

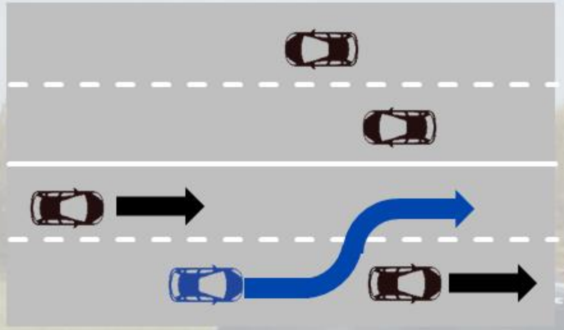
① Establish SCENARIO-BASED TESTING as State of the Art

A scenario is a description of a driving situation

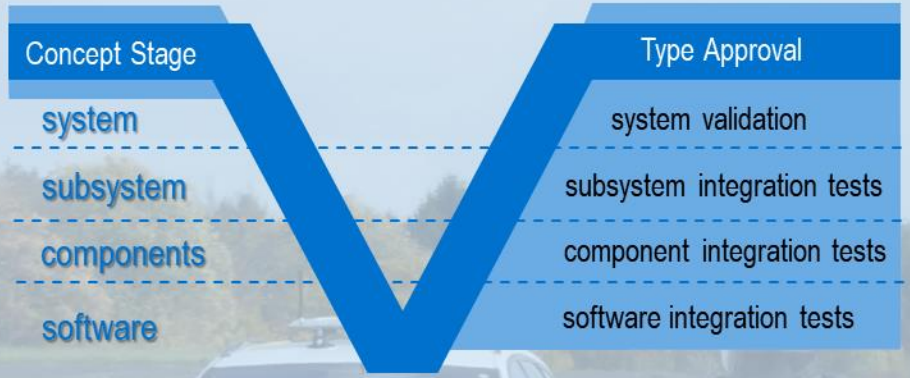
a) Left turn in road junction



b) Overtaking on a dual carriageway



Using scenarios from concept to approval



② Show Me The

Data Base!!

Scenario Definition

- A uniform definition of scenarios and their respective abstraction layers is needed
- A universal scenario description should be provided and supervised

Availability and access

- Data base should be hosted by a neutral instance and made accessible by public (by everyone!)

Pass/Fail Criteria

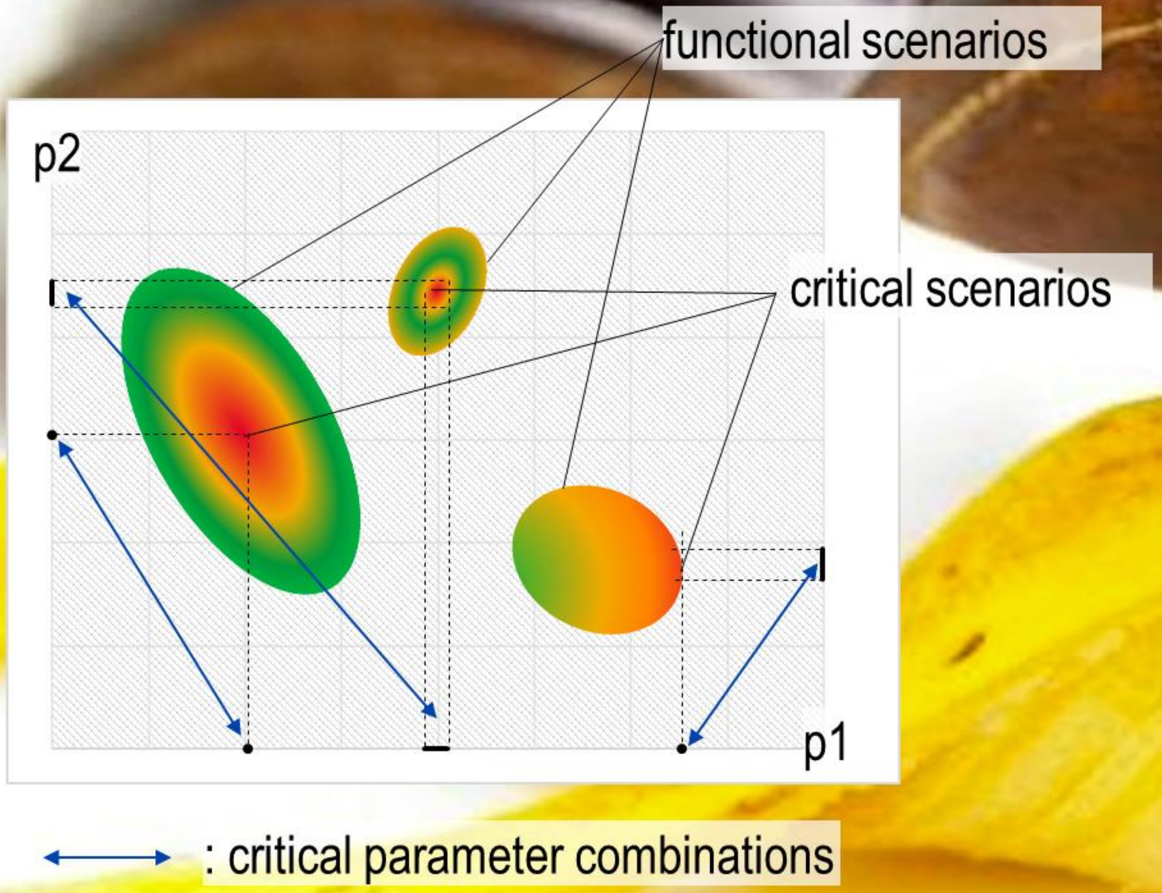
- Multiple criteria to be defined and associated to each scenario
- Relevance of pass/fail criteria to be defined by the use case (safety, comfort, customer experience, country & cultural relevance)

Monitoring and Supervision

- A committee and/or organization is to be defined that is responsible for updating and grooming the data base: increase, precise, delete, correct scenarios and pass/fail criteria

What is enough?

③ The CRITICALITY COVEARGE



Criticality Metrics

- A uniform definition of criticality metrics with respect to pass/fail criteria and the respective use case
- What are the most critical scenarios?

Criticality Coverage

- Define a criticality selection method
- Define a criticality threshold for validation and for verification

4 Use SIMULATION for Approval

Using simulation

- Enable the use of simulation in the homologation process, e.g.
  - UN/ECE R140 for the approval of Electronic Stability Control
  - UN/ECE R79 (new Release) for the approval of (automatic) steering
  - Next?
- Extend the purpose of simulation use to more then just variants verification to enable scale-out effects

Using the right simulation

- Obligate the validation of simulation tool and its trustworthiness as an integral part of the homologation process
- Define how to demonstrate the trustworthiness in
  - Perception (e.g. Sensor simulation)
  - Interpretation (e.g. sensor fusion)
  - Reasoning (e.g. decision algorithms)
  - Acting (e.g. E/E and control algorithms)
  - Executing (e.g. Vehicle Dynamics)
- Enforce standards for simulation and simulation interfaces, enforce affordable and/or open-source solution

⑤ Consider

FUNCTIONAL SAFETY Assessment

Industry					
International Standards	DO-178B/C	EN 50128 EN 50129	ISO 26262	IEC 62304	IEC 60880
Mandatory Submission of Documents to Regulator	✓	✓	✗	✓	✓
			Change This!		

6

Close the Loop by

REAL-WORLD DRIVING

Event Data Recorder

- Obligate the integration of Event Data Recorder in automated vehicles
- Define the set of necessary data to be logged for safety monitoring and accident reconstruction

Real-World Driving (Field Tests)

- Define categories, e.g. highway, city center, suburbs, rural areas, etc..
- Manufacturers conduct supervised/witnessed real-world driving tests

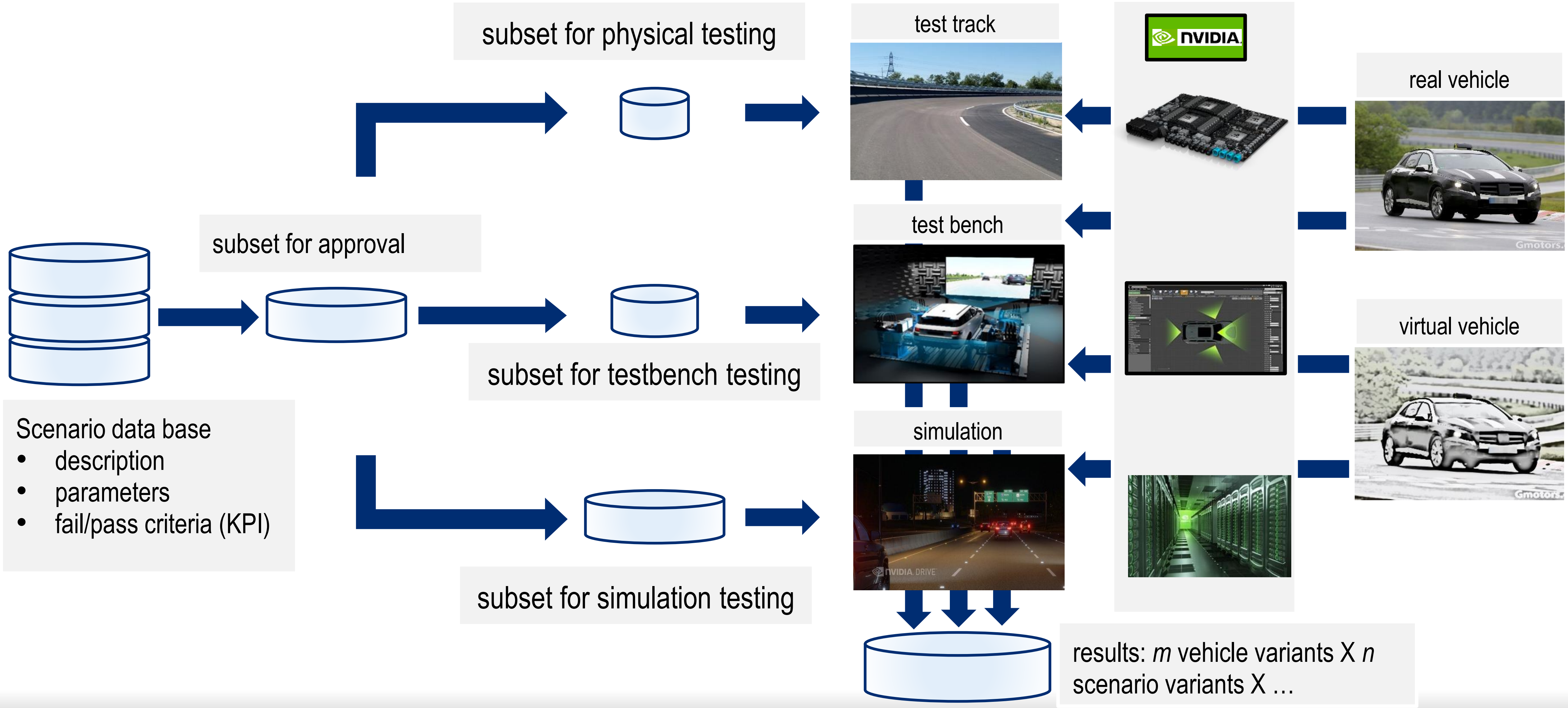
Feedback into Homologation

- All approval related and relevant field tests to be documented and to be submitted with logged data
- Submit data to scenario supervision committee (see Point 1)

Critical Issues

- In case of critical issue, consider this in the product correction
- Provide proof of consideration with test results, e.g. simulation, real vehicle testing

Combining Tools (Tool Chain) for Concise Approval



Virtual Testing & The Toolchain

Dr. Tobias Dueser

Department Manager
Advanced Solution Lab

AVL

A seamless but open toolchain with new approaches is necessary

AVL

Simulation

Virtual TESTING

Proving Ground

Real World

Maneuver, Scenario, Test Case Abstraction incl. KPIs

Environment Abstraction

Vehicle Abstraction

Same Results

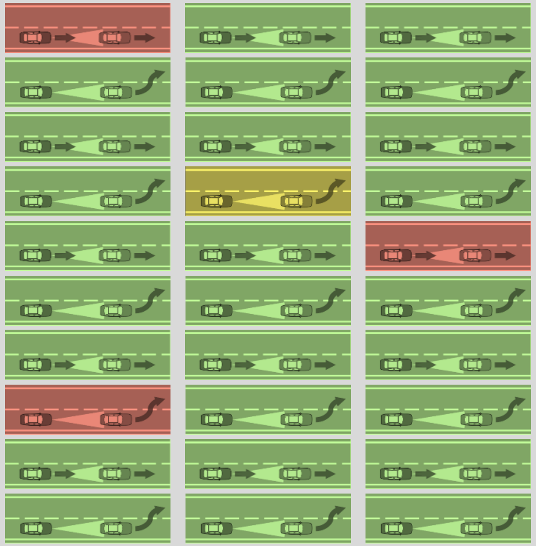
The most efficient validation will be done by those who will use the best combination…

Public

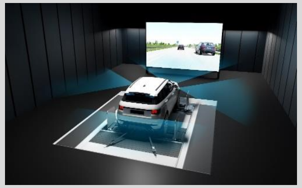
Insights: Approach for the best combination…

Simulation

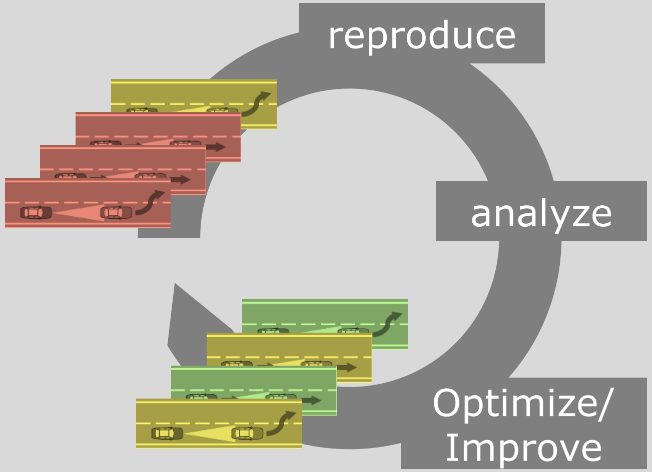
Scale Testing of Variants
(Vehicle Configurations and Scenarios)



Virtual TESTING



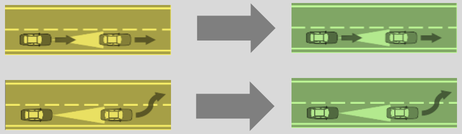
Integrate, Analyze and Improve



+ specific test cases which cannot be done in simulation

Proving Ground | Real World

Finalize and Confirm



+ specific test cases which cannot be done in simulation and/or Virtual Testing

<u>Remark:</u>
Focus of this slide is system (vehicle) validation. In addition there will be component test beds like HiL, Sensor Test Beds, etc.

Toolchain Validation
Example Vehicle Dynamics

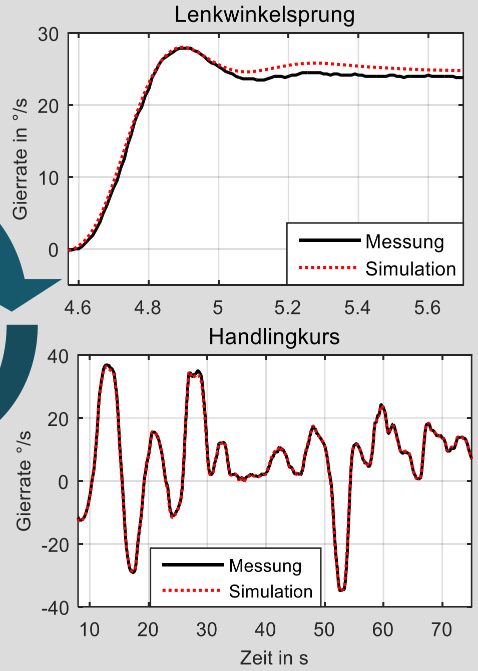
"The validity of the applied modelling and simulation tool shall be verified by means of comparisons with practical vehicle tests. The tests utilized for the validation shall be the dynamic maneuvers (…)"

Source: Uniform provisions concerning the approval of passenger cars with regard to Electronic Stability Control (ESC) Systems, ECE R140

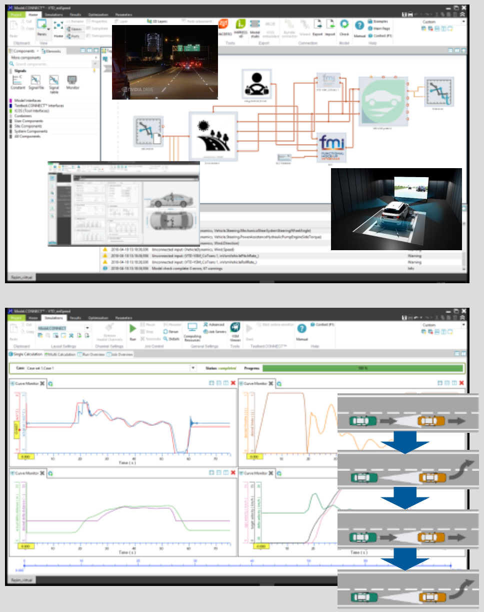
Determination and Identification of Parameters

Parameterization of Simulation Models

Correlation Results and Approval of Simulation



Usage of Simulation for ADAS/AD Validation



Mandatory Preparation (Validation and Approval of Models and Toolchain)

ADAS/AD Validation

Toolchain Validation
Example Vehicle Dynamics

Challenge Co-Simulation (1)

Boundary Conditions:

In the area of simulation there is not only ONE tool or ONE model. Different tools have different advantages, different models are for different use cases (e.g. dynamic scenarios require complex vehicle dynamics)

Example bandwidth based on customer use cases

#	Powertrain	Vehicle Dynamics	Environment	Function
1	CUS Simulink	MSC ADAMS	VIRES VTD	CUS FMU
2	AVL VSM	AVL VSM	CUS Tool	ROS1 Node
3	Real on Test Bed	Real on Test Bed	VIRES VTD	On control unit
4	CUS Simulink	CUS Simulink	IPG CarMaker	ROS2 Node

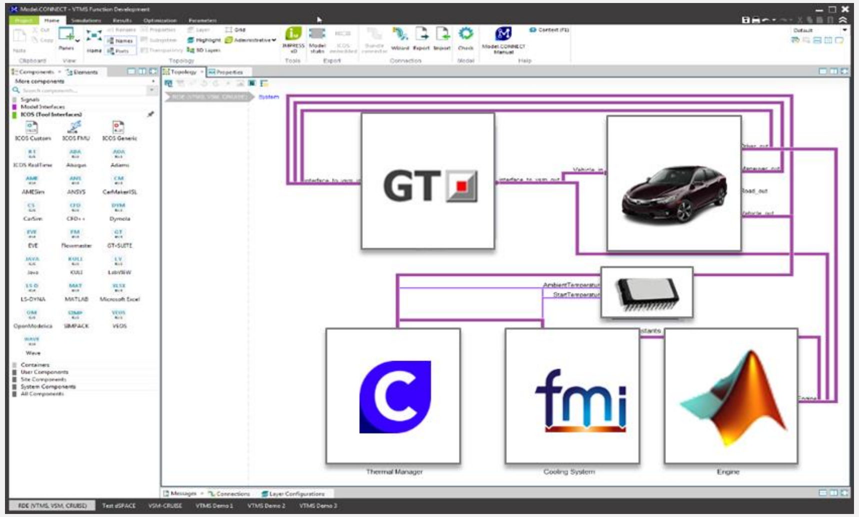
… and the landscape is broad!

Requirements and Challenges (Overview):

An open integration platform is crucial!

The platform need to combine simulation and real components up to the real vehicle

Integration on simulation level is more the exchanging signals!



Challenge Co-Simulation (2)

Requirements and Challenges (Details):

Technical View:

- Multi-domain development
- Multi-tool approach
- Multi-vendor
- Dynamic coupling
- ➢ **Virtual prototype representation**

Mathematical View:

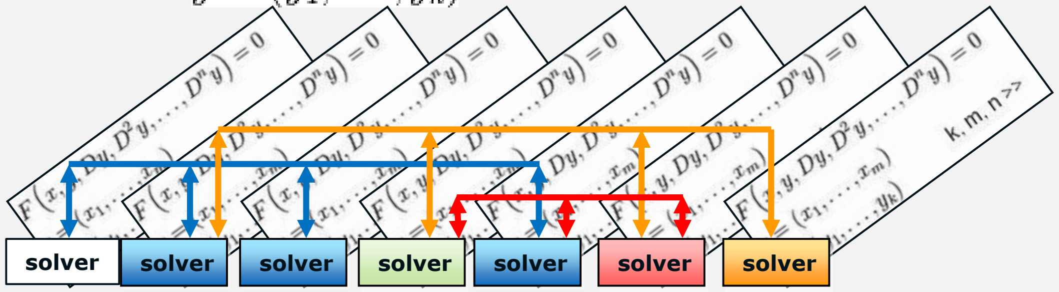
- Multi-method
- Multi-solver
- Multi-rate
- Dynamic coupling
- ➢ **Coupling error**

$$F\left(x, y, Dy, D^2y, \ldots, D^ny\right) = 0$$

$$x = (x_1, \ldots, x_m)$$

$$y = (y_1, \ldots, y_k)$$

k, m, n >>

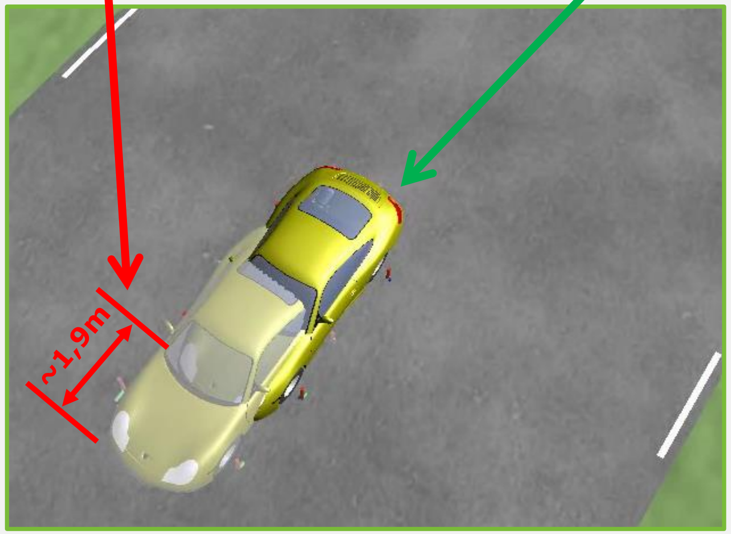


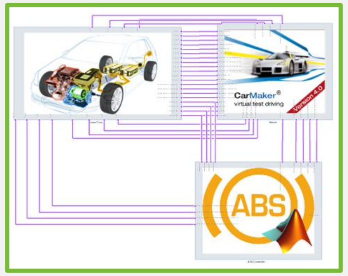
Example:

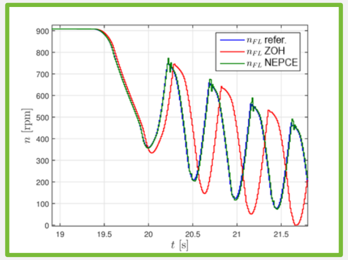
AEB Scenario:
"Full braking after acceleration to 100 km/h"

Significantly longer braking distance (~1.9 m) due to coupling error!

Correct (co-)simulation result with NEPCE*) in Model.CONNECT™

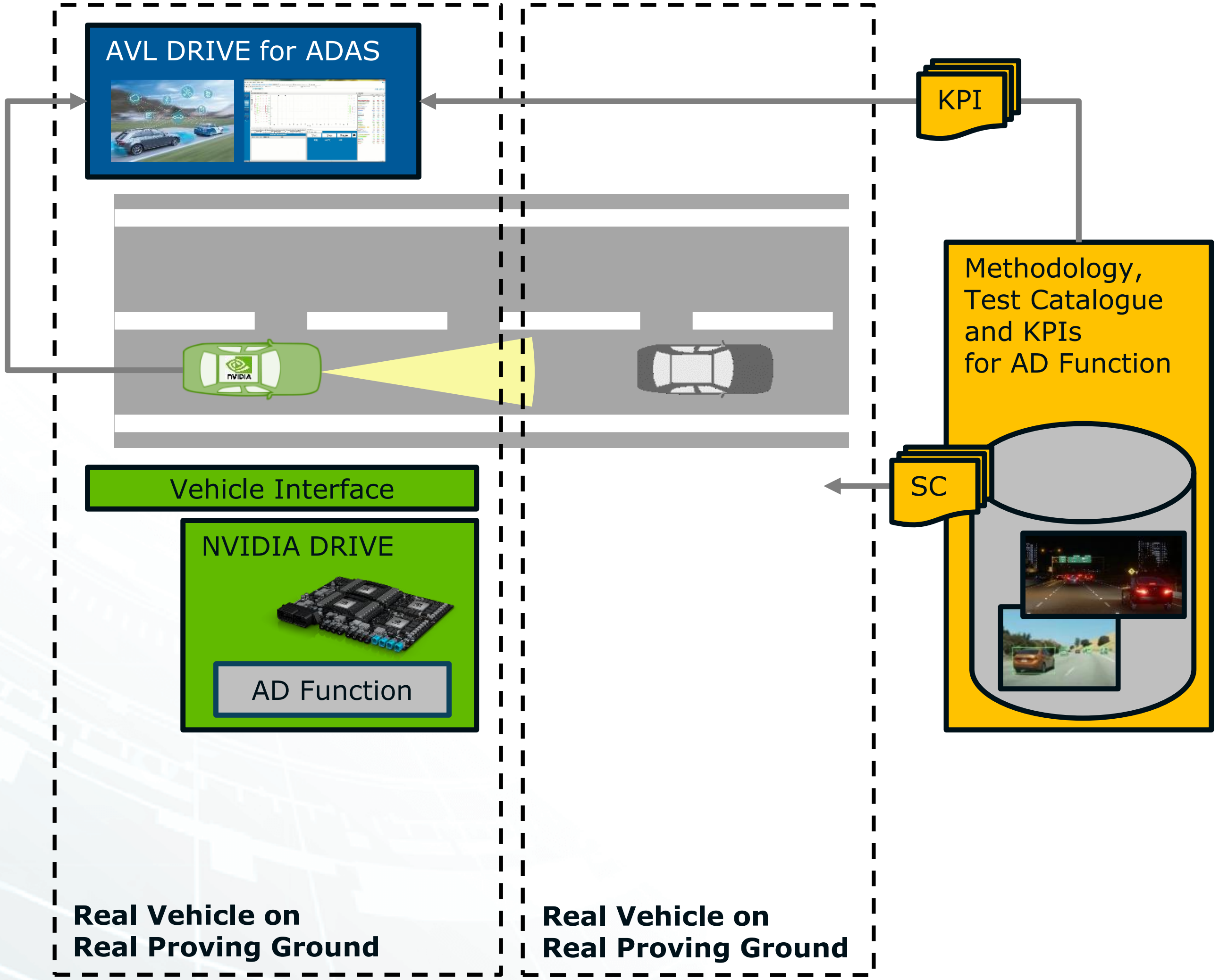






*) NEPCE … Nearly Energy Preserving Coupling Element

Implementation with NVIDIA Tools
Reference: Proving Ground



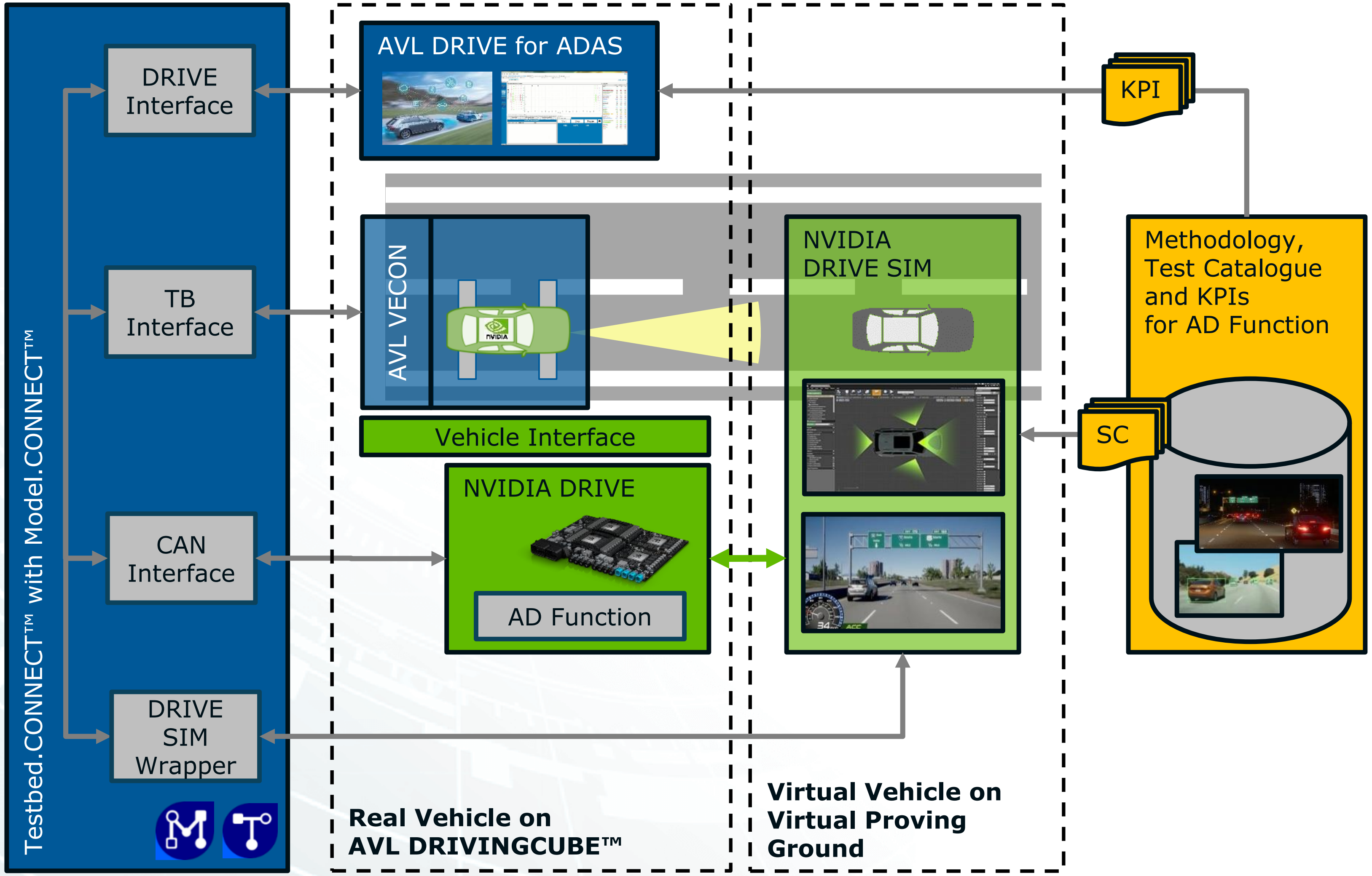
Proving Ground

- + very close to the real operation
- – expensive, high effort, less repeatability

Vehicle Under Test

Public

Implementation with NVIDIA Tools
Virtual Testing @ the AVL DRIVINGCUBE™



Virtual Testing

- + close to real operation, chassis dynos are already established for homologation (emissions)
- – limited in terms of lateral dynamics

Vehicle Under Test

The AVL DRIVINGCUBE™…

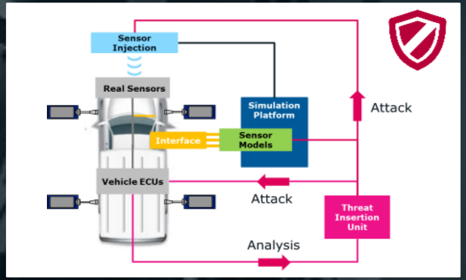
…as vehicle integration lab

Different functions and perceptions must be evaluated at a certain time in the vehicle.

The DRIVINGCUBE is the only test environment for reproducible and repeatable test on vehicle level!

… for security testing

Hacking attacks to evaluate the security of the vehicle must also be performed during operation of the vehicle.
Do you want to try an attack on a highway at high speed?



… to reproduce critical scenarios and tests

Critical Scenarios (in general or determined out of simulation) must be analyzed on vehicle level in a reproducible way.

… as most efficient test instance for a lot of use cases

For vehicles of category M_1, N_1

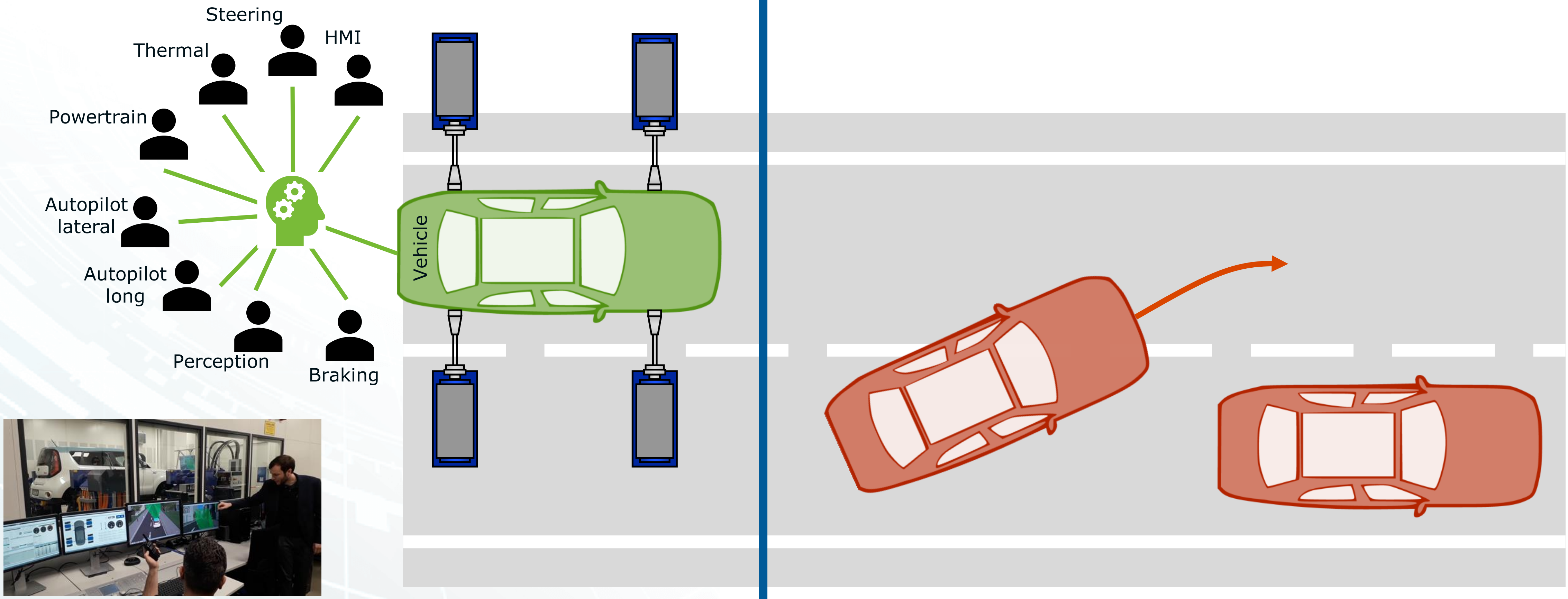
Speedrange	*1*	*>130 km/h*
Maximum value for the specified maximum lateral acceleration		3 m/s²
Minimum value for the specified maximum lateral acceleration		0.3 m/s²

Different uses cases in validation and also homologation can not be executed efficiently in other test instances (e.g. ECE 79: LKA above 130km/h)

...as vehicle integration lab:
Details

AVL

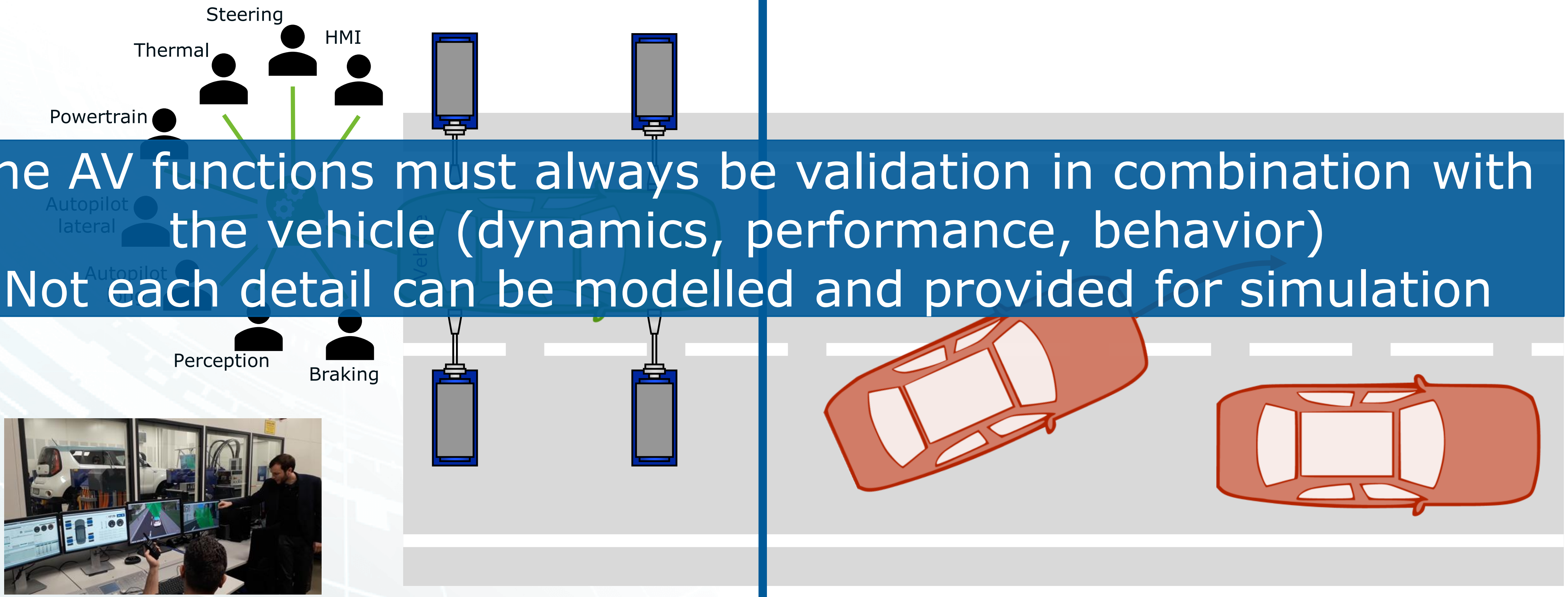
DRIVINGCUBE
as vehicle integration lab



Public

...as vehicle integration lab:
Details

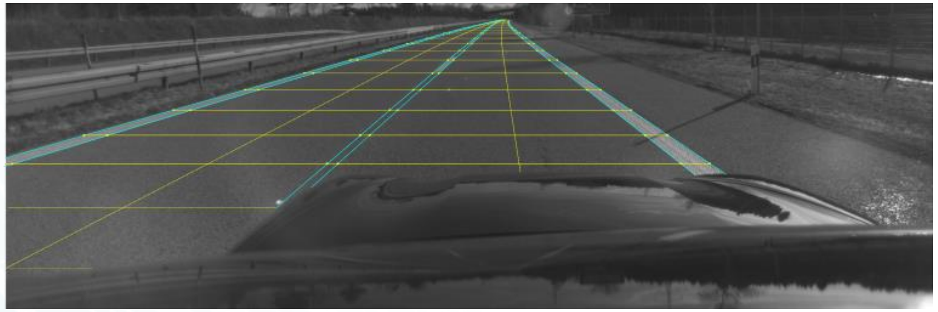
DRIVINGCUBE
as vehicle integration lab



The AV functions must always be validation in combination with the vehicle (dynamics, performance, behavior)
Not each detail can be modelled and provided for simulation

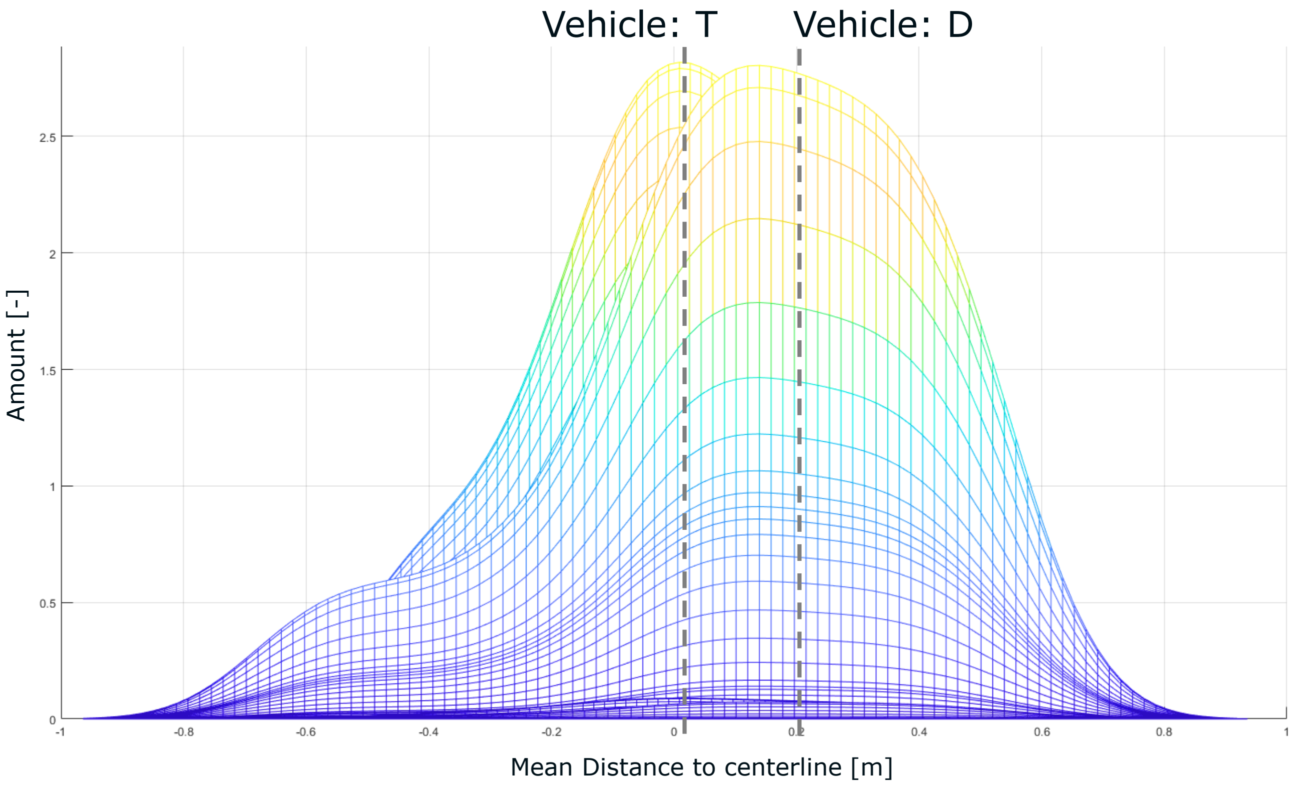
...as vehicle integration lab:
Use Case / Example

Evaluation of a Lane Keep Assist:



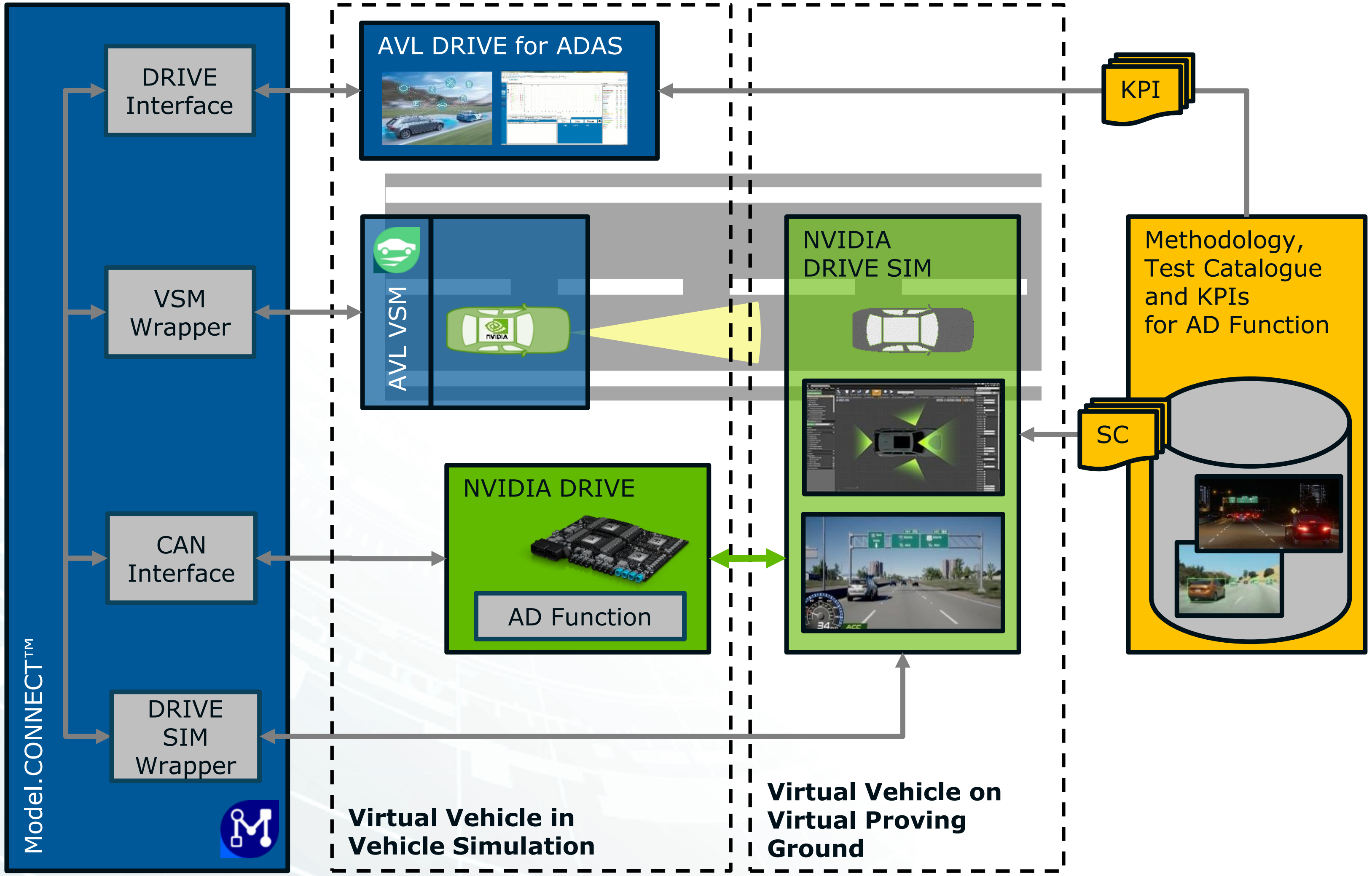
KPI: Curve-Cutting-Gradient (CCG)

- Calculate Distance to centerline (D2L) by using Ground-Truth-Maps
- Evaluate (de)position of VUT during driving with LKAS



In a study with one of our research partners we figured out that even in one model series (so nearly the same vehicle – Vehicle T and D) a LKA function behaves completely different and the calibration of this function had to be adapted.

Implementation with NVIDIA Tools
Architecture Simulation

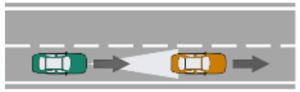


Simulation

- + fast, flexible and cheap in operation, there are already ESC homologation
- – processes in simulation is only as good as the model(s)

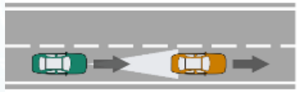
Vehicle Under Test

First Results / First Comparison



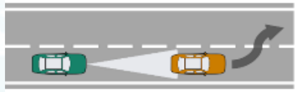
Scenario 1:

From standstill follow-up with 50 km/h reducing to 30 km/h back up to 50 km/h and 30 km/h again



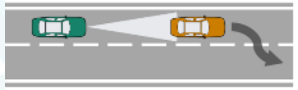
Scenario 2:

From standstill follow-up with 80 km/h reducing to 60 km/h back up to 80 km/h



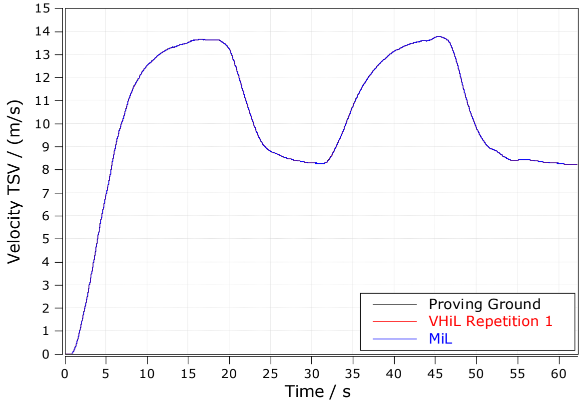
Scenario 3:

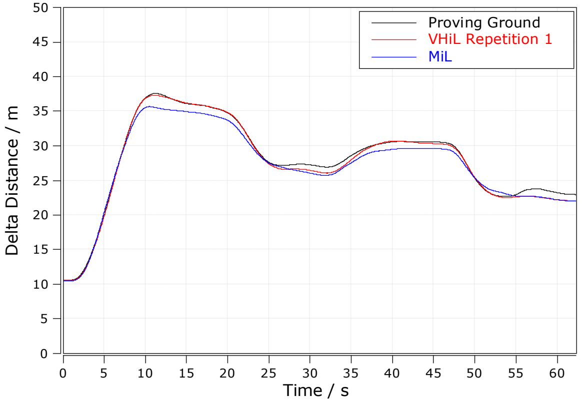
From standstill follow up with 60 km/h, TSV pull out left, VUT accelerate to 80 km/h

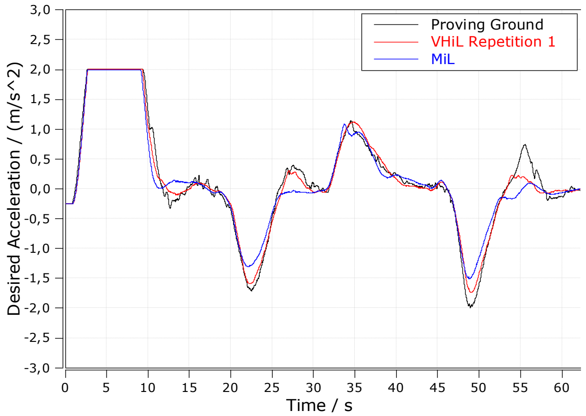


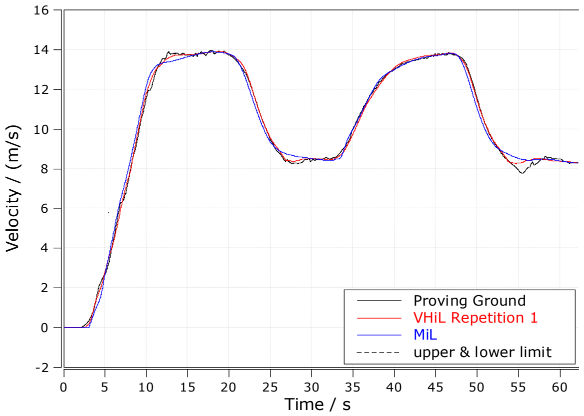
Scenario 4:

From standstill follow up with 60 km/h, TSV pull out right, VUT accelerate to 80 km/h









Riedmaier, S.; Nesensohn, J.; Gutenkunst, C.; Düser, T.; Schick, B.; Abdellatif, H.: **Validation of X-in-the-Loop Approaches for Virtual Homologation of Automated Driving Functions**, GSVF Symposium 2018, Graz

Validation and Homologation of Autonomous Driving will be a challenge

Partnering is extremely important to join the forces

The most efficient validation and homologation will be done by those who will use the best combination of different test environments

NVIDIA, TUEV SUED AND AVL will push this topic together