



Highly Automated Driving – Validation and Test

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Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

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    - Sensor Validation BMW
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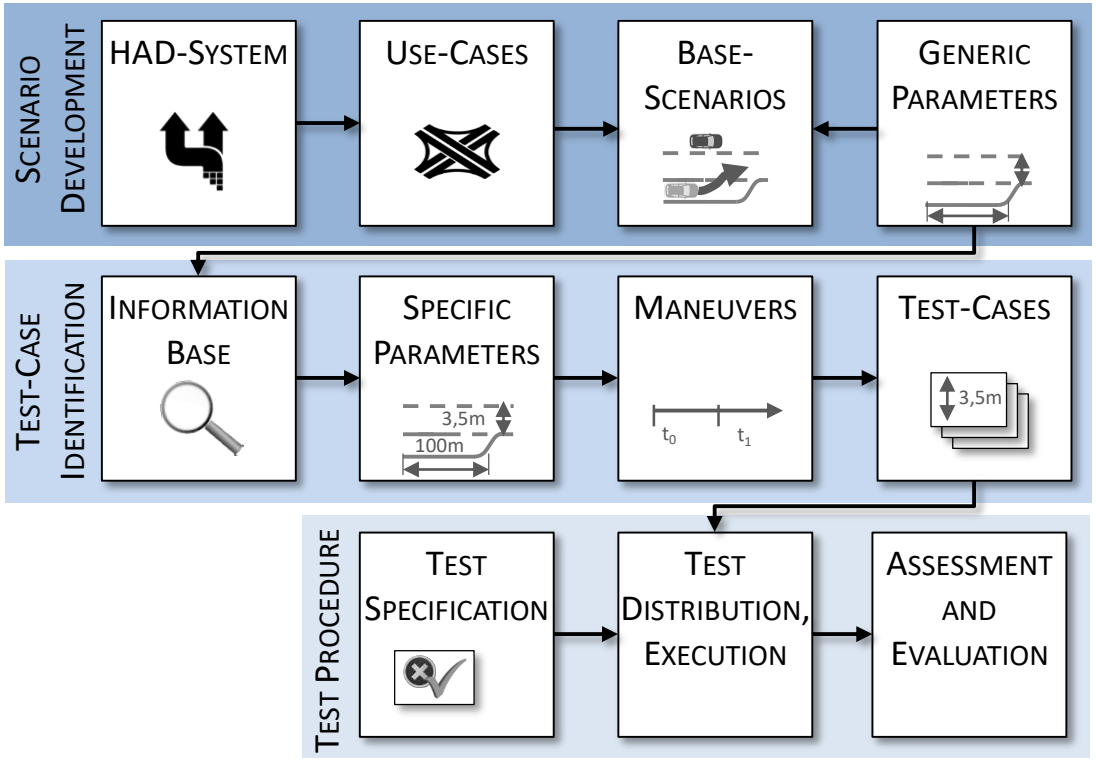
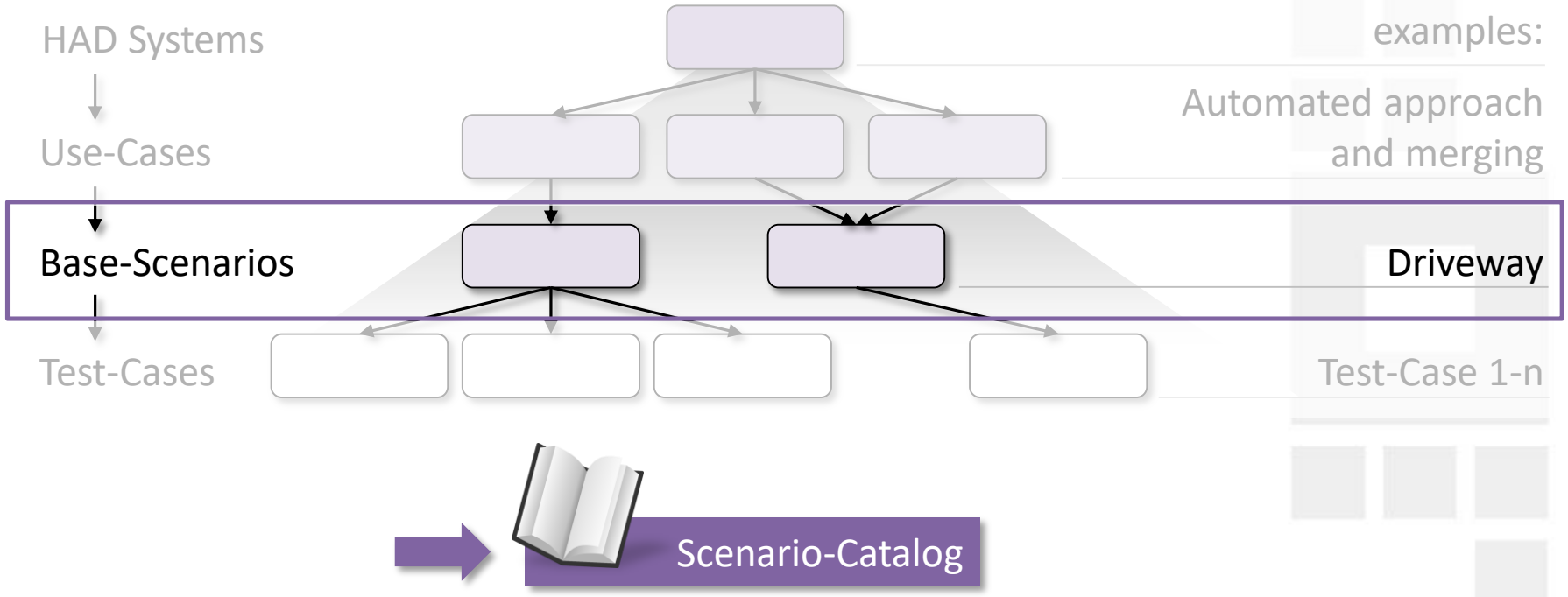
- Assessment (real world data)

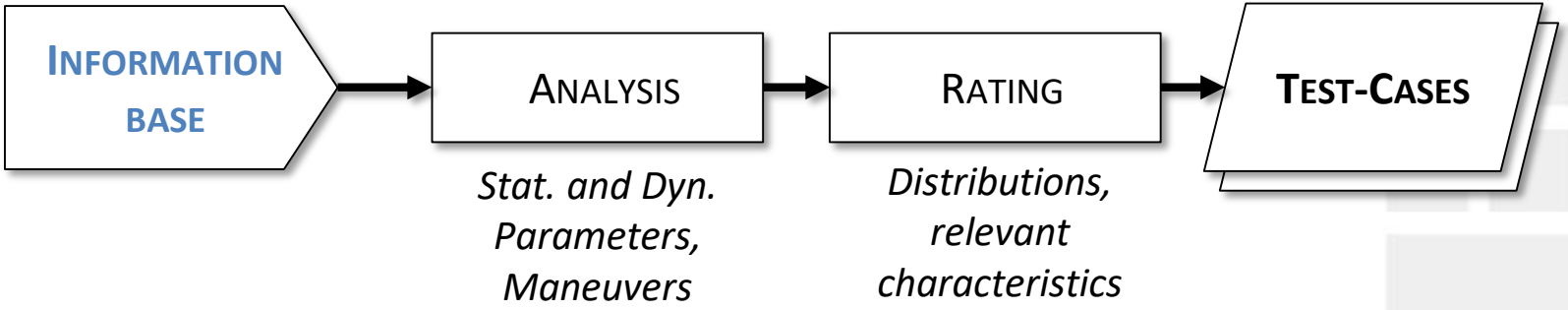
Overall Methodology

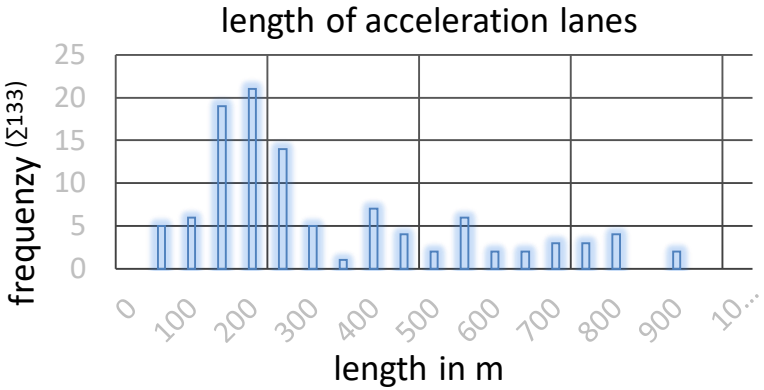


Scenario Development

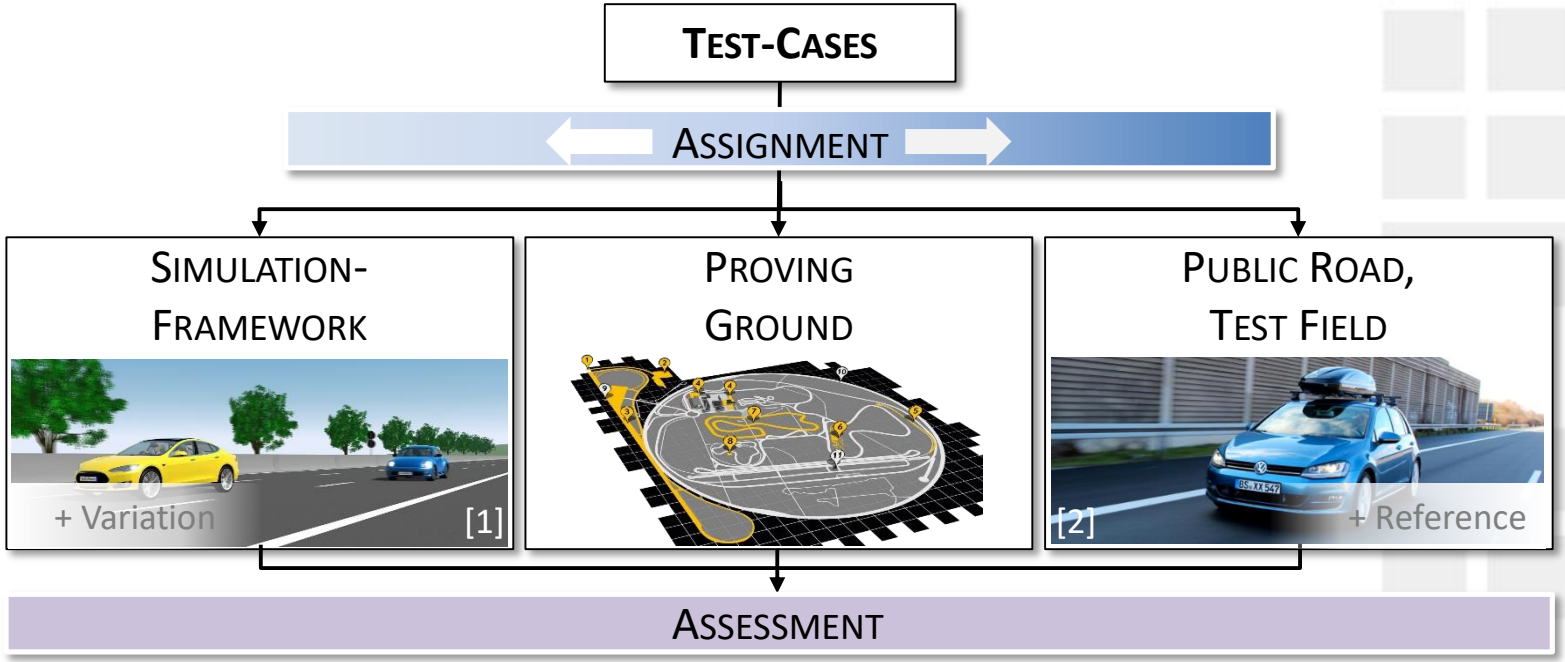


Test-Case Identification





Test Procedure

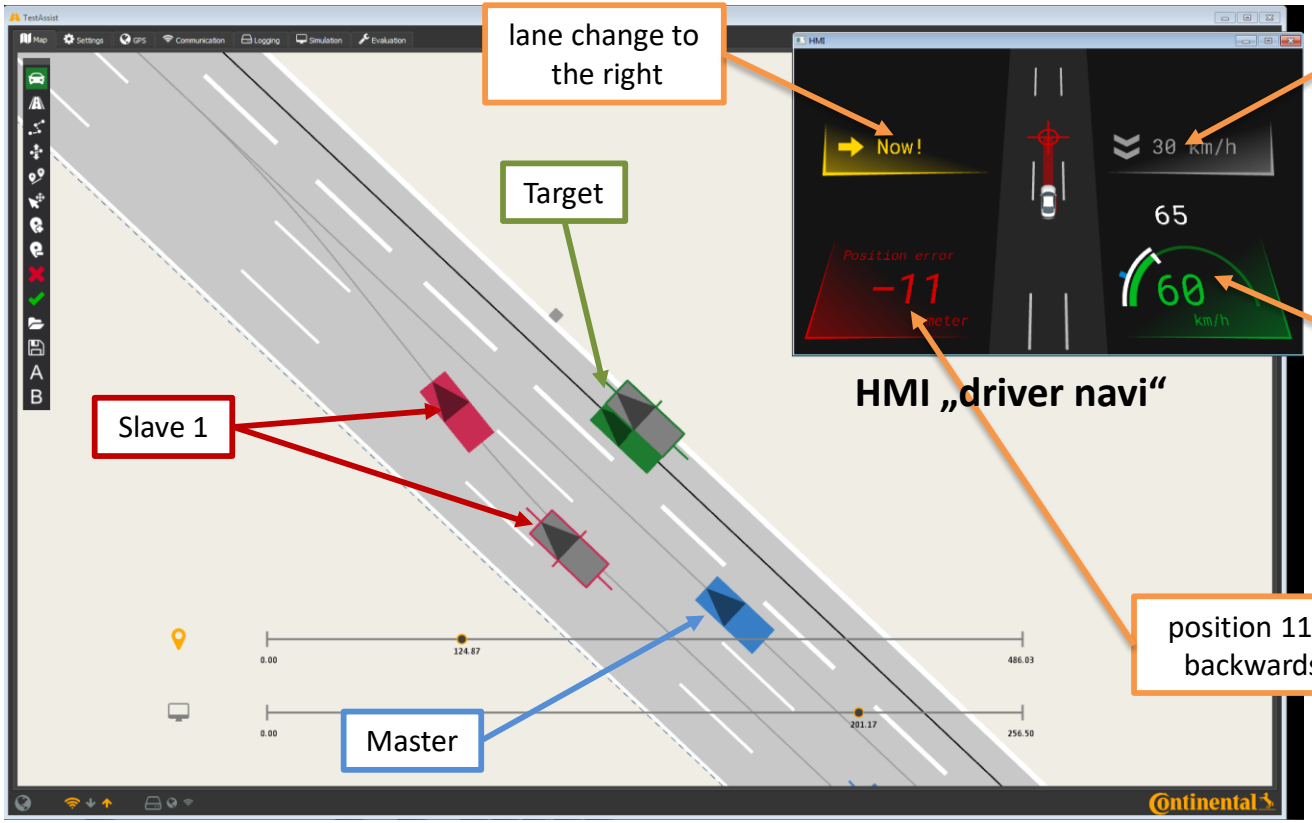


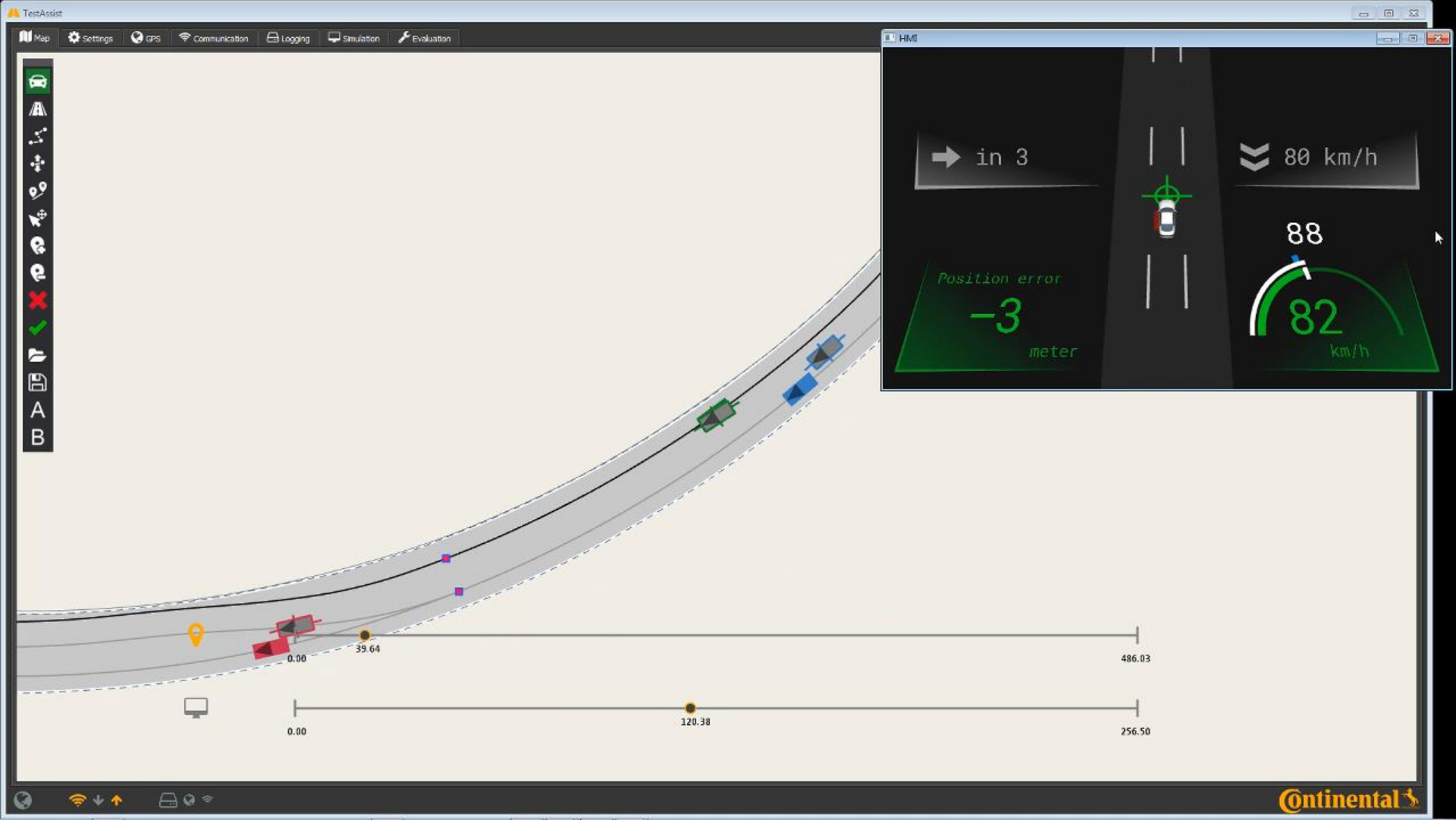
Testspecification

- Example from Test Catalog

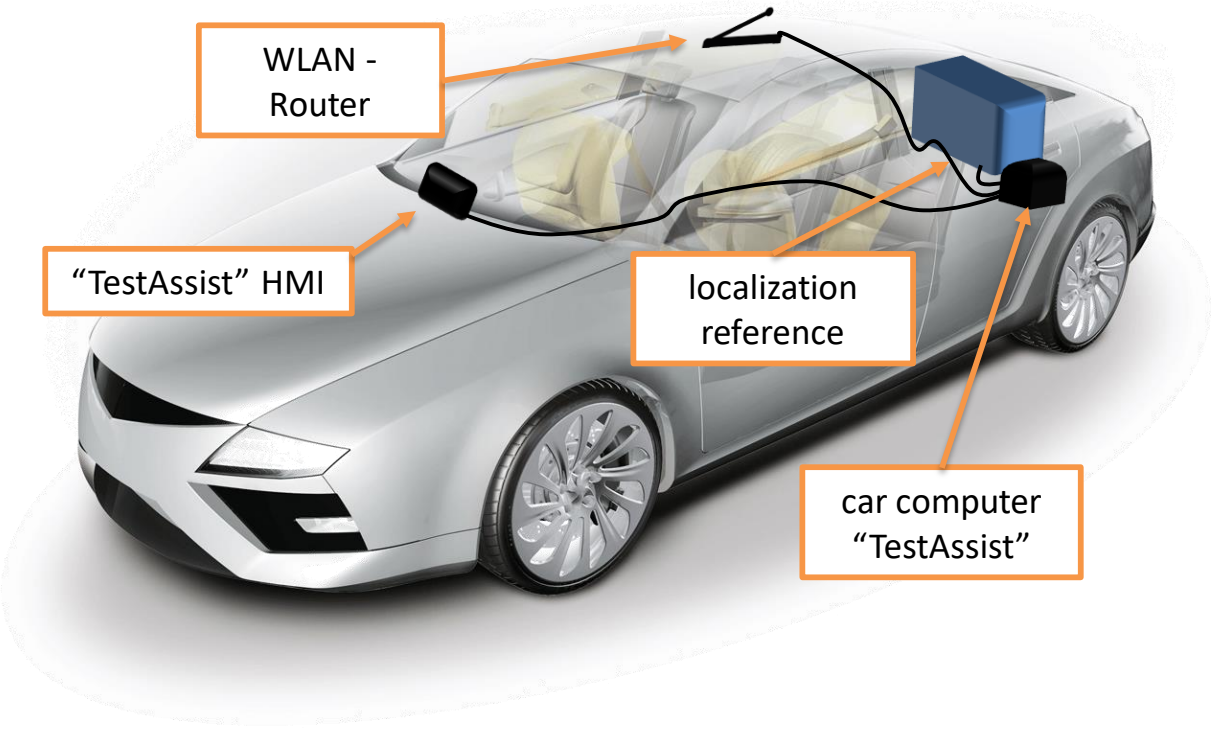
	A	B	C	D	E	F	G	H	I	J	K
1							*AP5 Absicherung - Erprobung und Validierung*			*Testfälle: 74*	V3.3
2							*UAP5.2 Testprozedur*				30.05.2018
3							***Testkatalog***				
4		**TF-ID**	**Typ**	**Rahmenbedingung**			**Beschreibung**	**Wert**	**Einheit**	**Umgebung**	**Kommentar**
82	TK_1.1.3	1.1	Testfall				Auffahrt ohne Vorausfahrenden in ausreichend große Lücke			Prüfgelände, TestAssist	
83	TK_1.1.3	1.1.1	Szenerie Element	Rampe							
88	TK_1.1.3	1.1.2	Szenerie Element	Beschleunigungssteifen							
93	TK_1.1.3	1.1.3	Szenerie Element	Durchgehender Fahrstreifen							
96	TK_1.1.3	1.1.4	Szenerie Element	Verkehrsregelung							
100	TK_1.1.3	1.1.5	Dynamisches Element	Verkehr							
101	TK_1.1.3	1.1.5.1	Dyn. Rahmenbedingung	Verkehr			Anzahl Targets	2			
102	TK_1.1.3	1.1.5.2	Sequenz	Verkehr	Egofahrzeu						
103	TK_1.1.3	1.1.5.2.1	Testschritt	Verkehr	Egofahrzeu	Initialwer	Startspur	Rampe			
104	TK_1.1.3	1.1.5.2.2	Testschritt	Verkehr	Egofahrzeu	Initialwer	Startpunkt	160	m		Vor Beschleunigungsstreifenbeginn
105	TK_1.1.3	1.1.5.2.3	Testschritt	Verkehr	Egofahrzeu	Initialwer	Funktion	ja			HAF-Funktion an/aus
106	TK_1.1.3	1.1.5.2.4	Testschritt	Verkehr	Egofahrzeu	Initialwer	Geschwindigkeit	60	km/h		
107	TK_1.1.3	1.1.5.2.5	Testschritt	Verkehr	Egofahrzeu	Zielwert	Spurwechsel	190	m		Nach Beschleunigungsstreifenbeginn
108	TK_1.1.3	1.1.5.2.6	Testschritt	Verkehr	Egofahrzeu	Initialwer	Endpunkt	300	m		Nach Beschleunigungsstreifenbeginn
109	TK_1.1.3	1.1.5.3	Sequenz	Verkehr	Target 1						
110	TK_1.1.3	1.1.5.3.1	Testschritt	Verkehr	Target 1	Initialwer	Startspur	1			
111	TK_1.1.3	1.1.5.3.2	Testschritt	Verkehr	Target 1	Initialwer	Beschleunigung	0	m/s^2		
112	TK_1.1.3	1.1.5.3.3	Testschritt	Verkehr	Target 1	Initialwer	Geschwindigkeit	90	km/h		
113	TK_1.1.3	1.1.5.3.4	Testschritt	Verkehr	Target 1	Zustand	Startpunkt Spurwechsel Ego	240	m		Nach Beschleunigungsstreifenbeginn
114	TK_1.1.3	1.1.5.4	Sequenz	Verkehr	Target 2						
115	TK_1.1.3	1.1.5.4.1	Testschritt	Verkehr	Target 2	Initialwer	Startspur	1			
116	TK_1.1.3	1.1.5.4.2	Testschritt	Verkehr	Target 2	Initialwer	Beschleunigung	0	m/s^2		
117	TK_1.1.3	1.1.5.4.3	Testschritt	Verkehr	Target 2	Initialwer	Geschwindigkeit	90	km/h		
118	TK_1.1.3	1.1.5.4.4	Testschritt	Verkehr	Target 2	Zustand	Abstand	100	m		zu Target 1

Concept “TestAssist“ Software




TestAssist
Map
Settings
GPS
Communication
Logging
Simulation
Evaluation
HMI
in 3
80 km/h
88
Position error
−3
meter
82
km/h
A
B
0.00
39.64
486.03
0.00
120.38
256.50
Continental

Concept “TestAssist“ Hardware

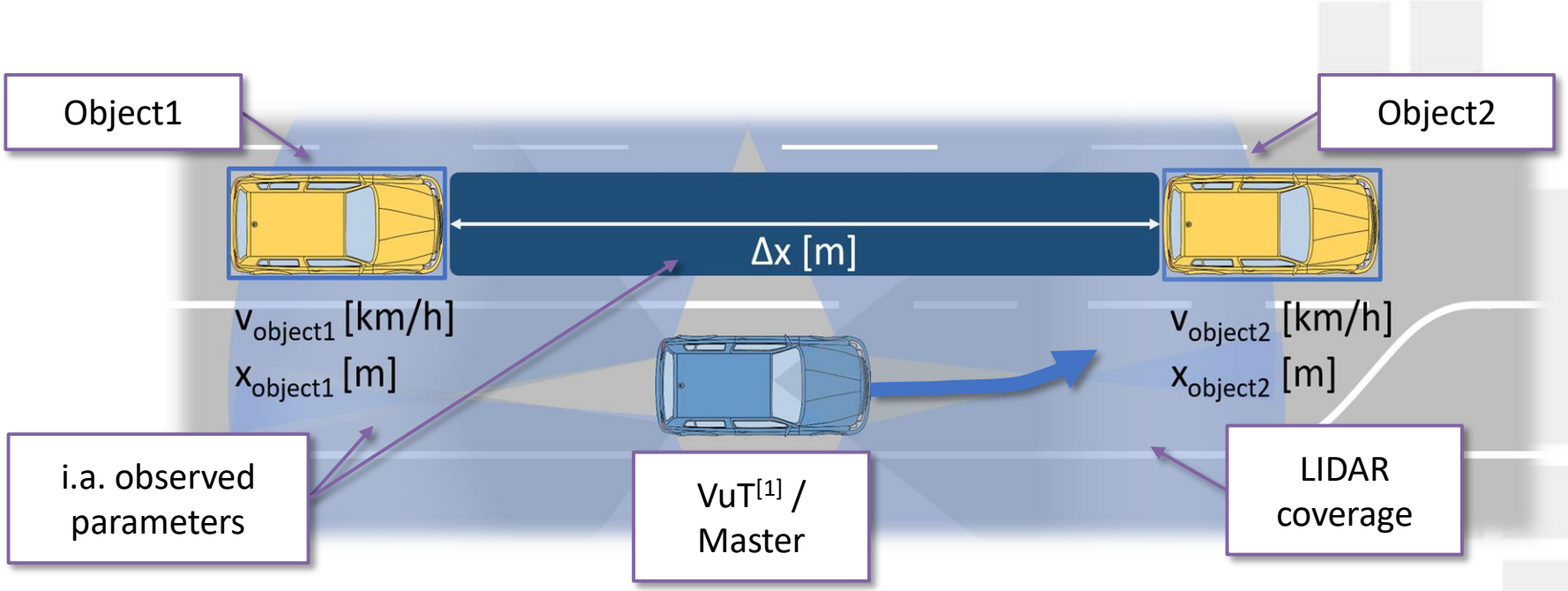


Tool “TestAssist“

- Planning scenarios for each vehicle (Target, Master, Slave 1 and 2)
- A high accurate map is used (OpenDrive)
- Simulation of planned scenarios with moving vehicles – useful for:
  - Briefing test drivers
  - Optimizing the test case
- Definition of the test case is saved in a “json” file
- Positioning & moving data from a test run are saved in a “Logging” file (10 to 20ms step)
- Replaying of test runs and comparison real vs. planned test cases

  → **Related to absolute positions based on topographical surroundings**

Concept “Testmanager“ IfF TUBS



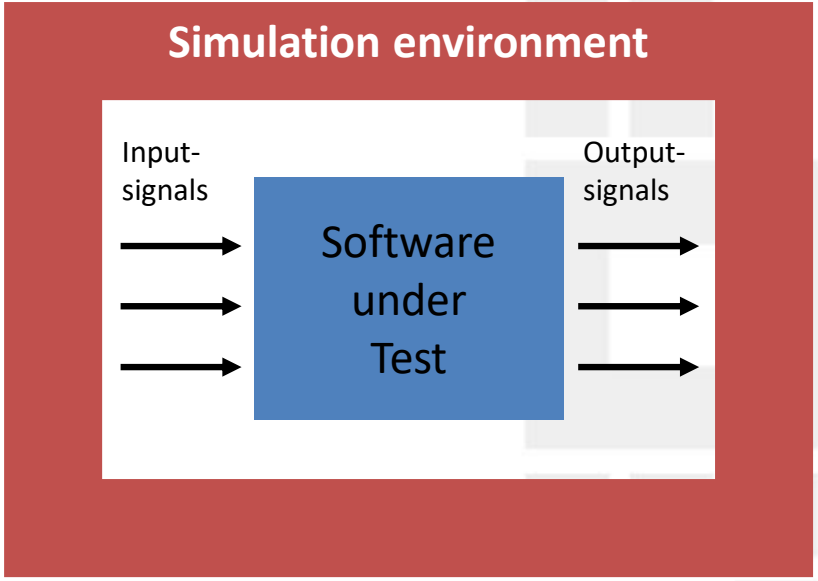
Tool “Testmanager“ IfF TUBS

- Tool-Chain for the observance of test parameters and precise test execution in reality
- Planning and Definition of complex highway scenarios
- Test Instructions for a high precise execution
- Evaluation of run test-cases [Quality-Index]
- Visualization via mobile device or Car-PC
- No additional hardware needed in object vehicles
- Based on LIDAR-Sensors and WLAN Communication

  → **Related to relative positions of object vehicles**

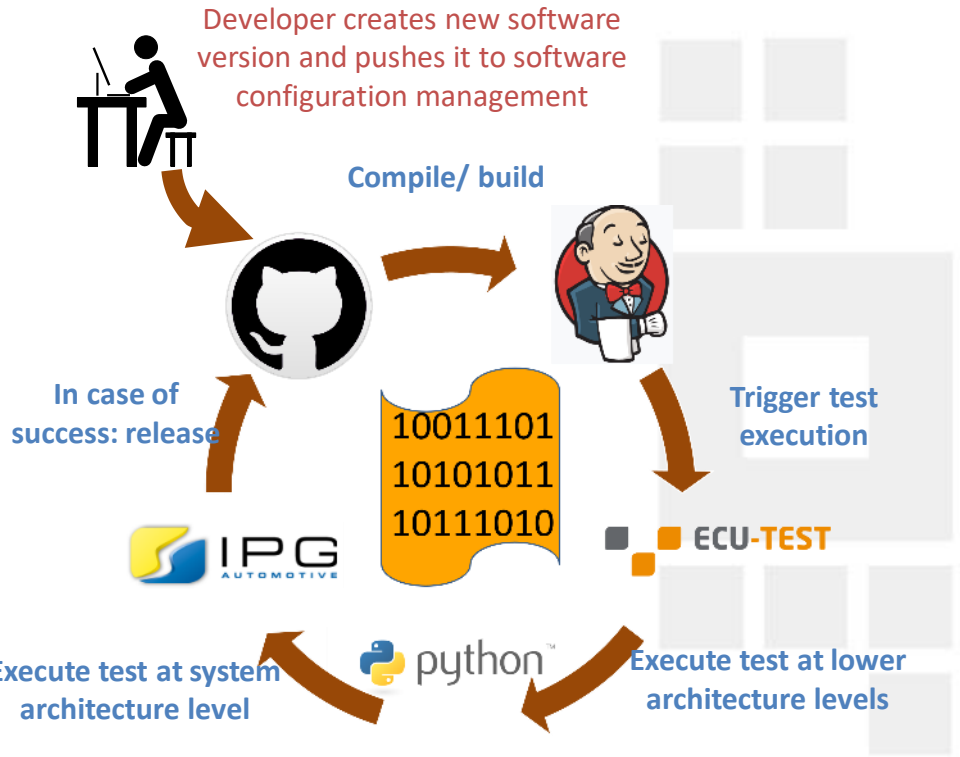
Simulation as a Tool

- The simulation environment consists of models that generate signals for input over time or receive them as output of the system under Test (SuT)
- Open loop vs. closed loop:
  - Closed loop considers feedback of the SuT
- Virtualization of the outer environment is utilized to test the SuT



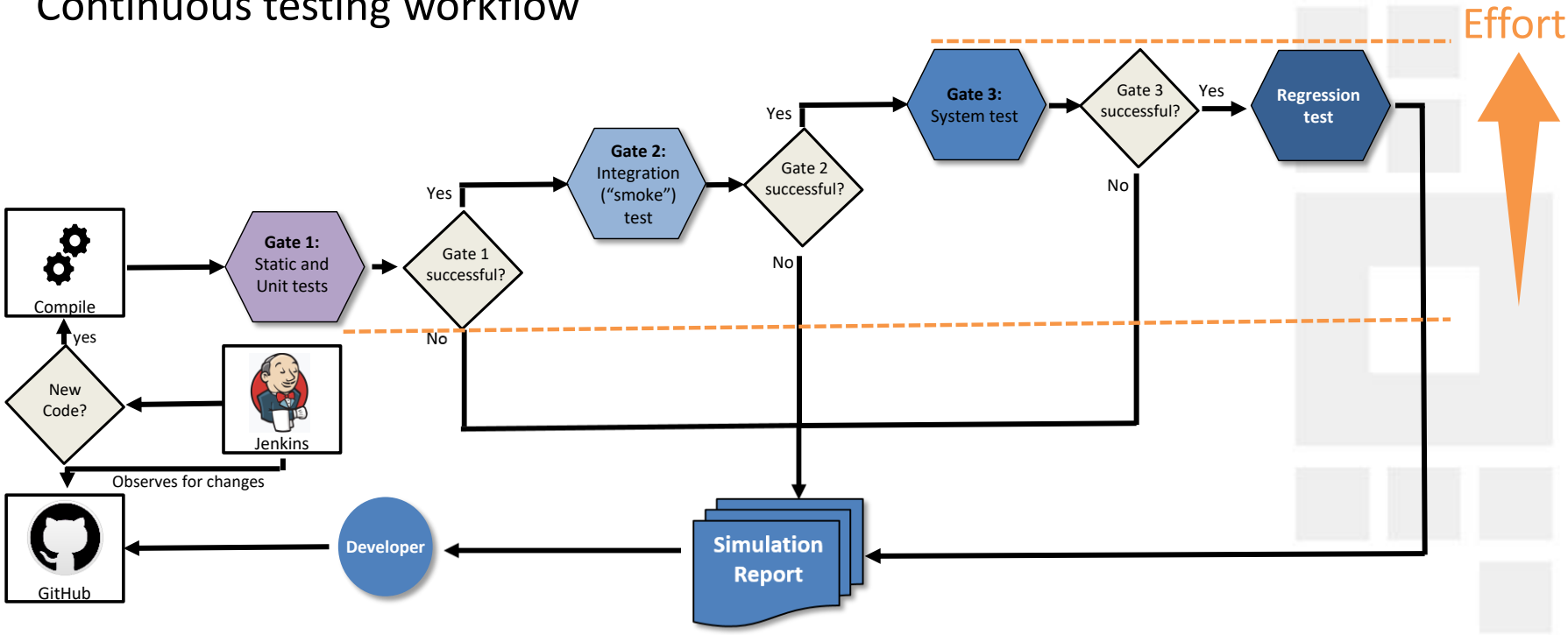
Simulation as a Tool

- Continuous testing describes a method which aims to give early feedback about software development from source code level to product level
- Automated execution of
  - Software build
  - Tests
  - Analysis
  - Reporting to stakeholders



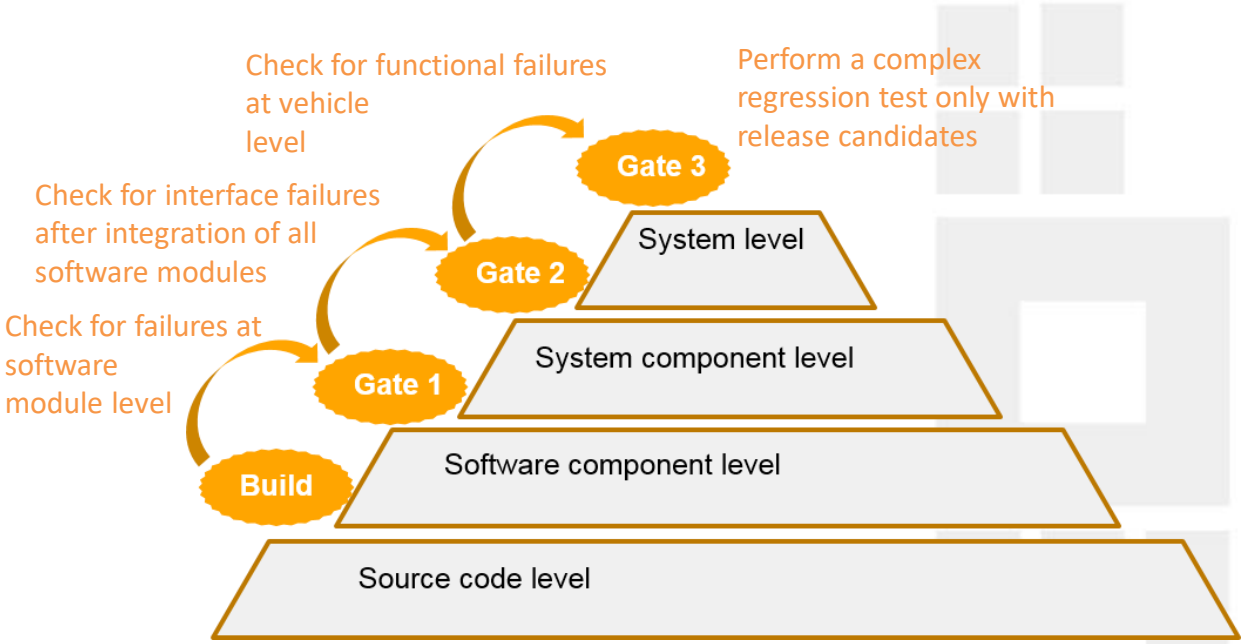
Simulation as a Tool

Continuous testing workflow



Simulation as a Tool

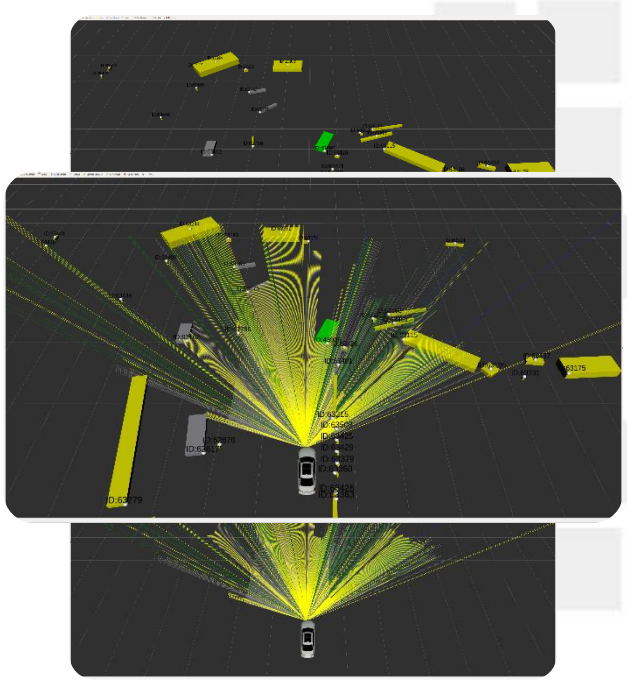
- By this approach early feedback could be given to developers
- Failures could be localized easier
- Real vehicle testing is done only with high mature software



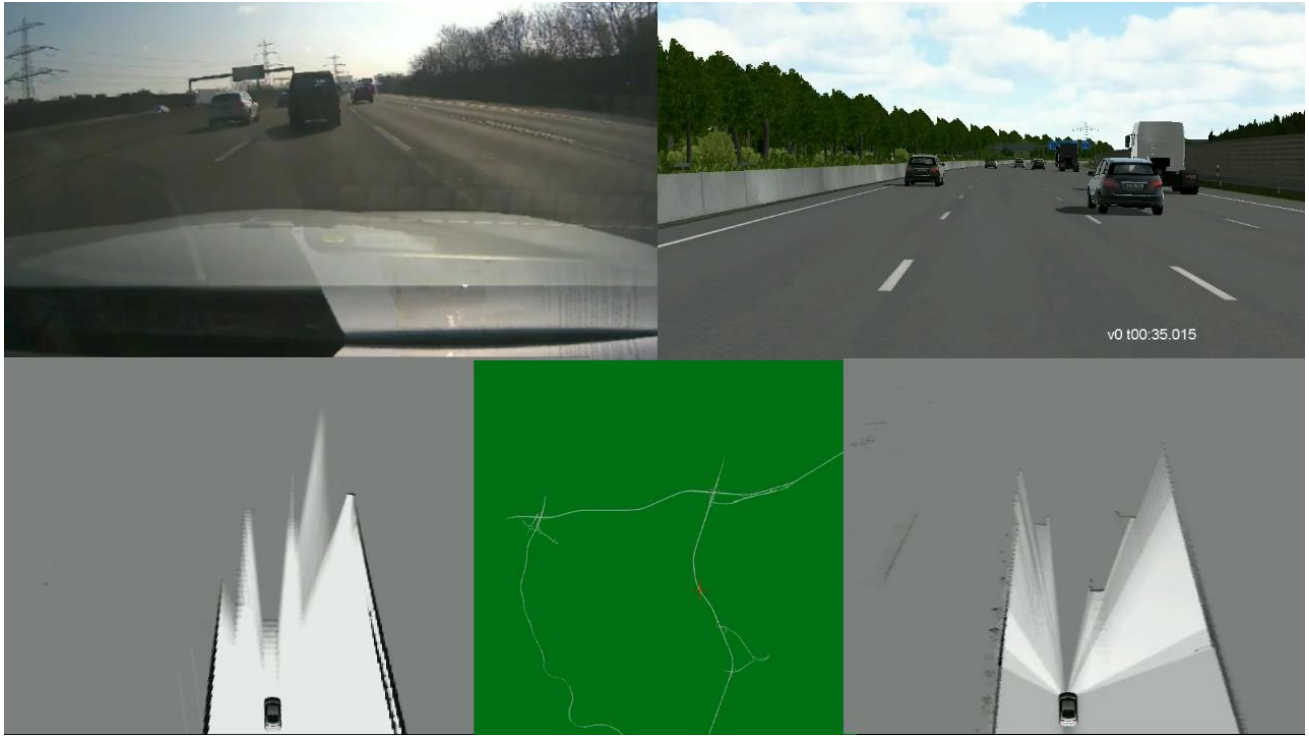
Simulation: Sensor Modelling

- High-Level Sensor Models
  - Object Lists
  - Statistical Approach

- Low-Level Sensor Models
  - Sensor specific i.e. Point Cloud
  - Ray Tracing Approach

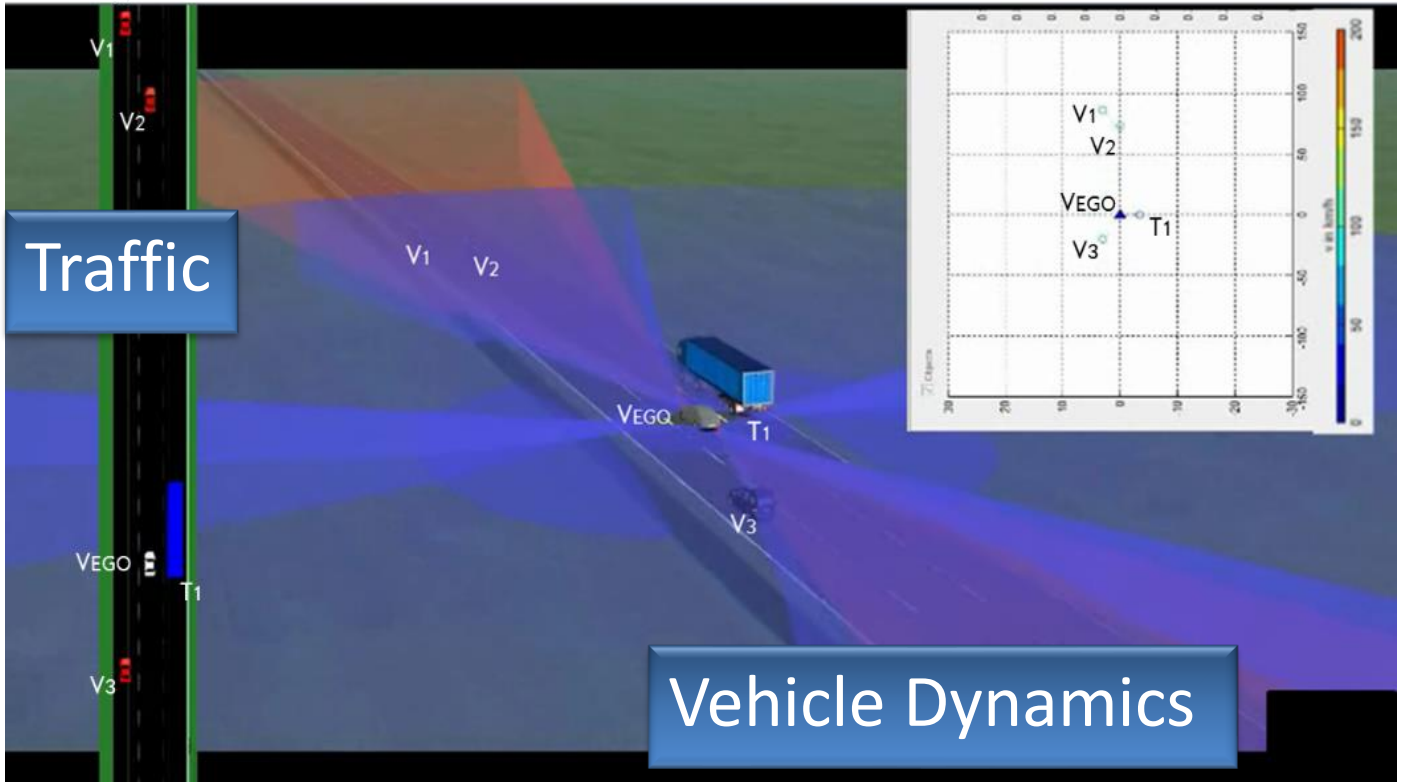


Simulation: Validation of Sensor Models

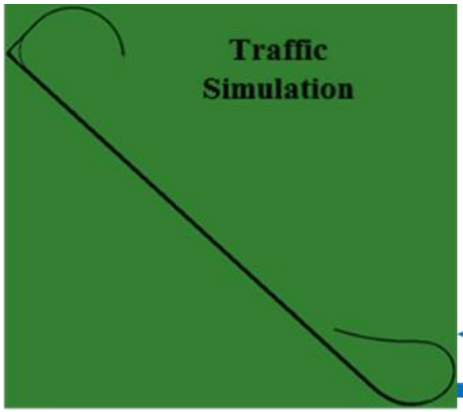


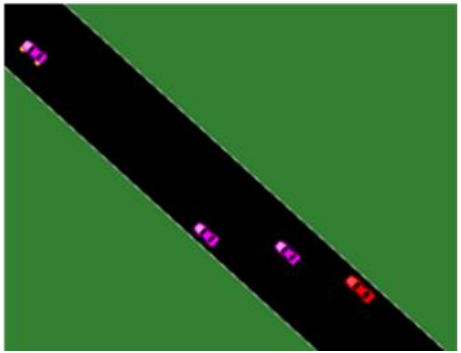
- Visit our Simulation Demo on the Main Floor

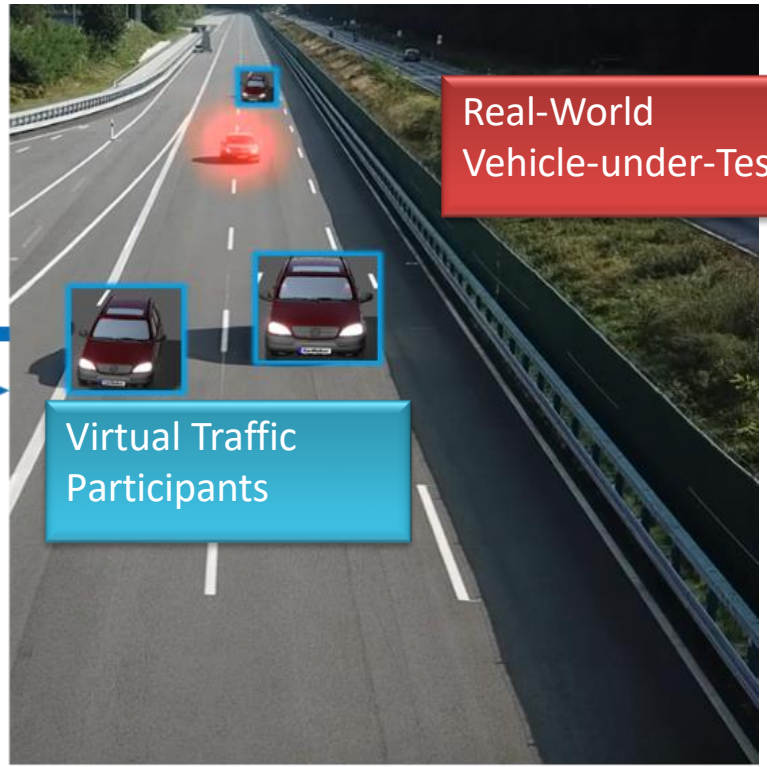
Simulation: Co-Simulation



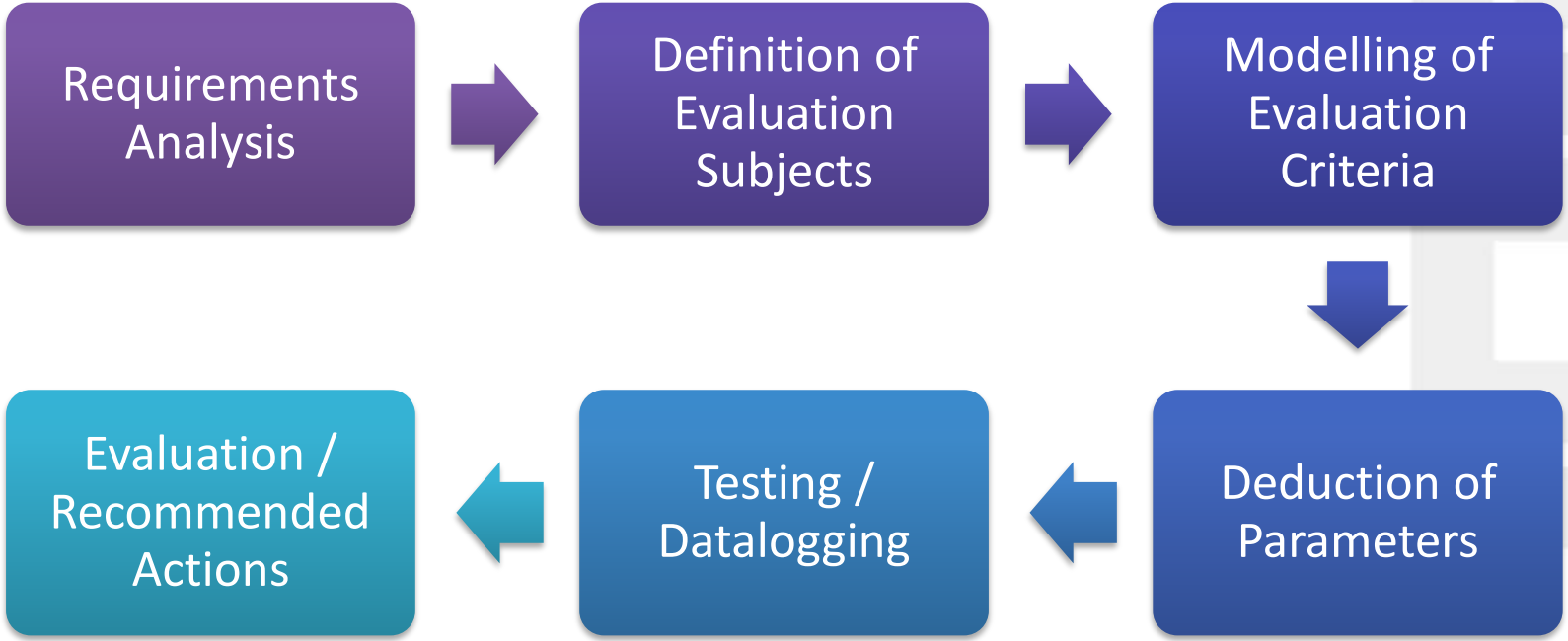
Simulation: Prototype-in-the-Loop







Assessment of Real World Data



Assessment of Real World Data

Which requirements are placed on the HAF?

Requirements Analysis

- Requirements linked to Ko-HAF project goals
- HAF has to be…
  - …safe
  - …efficient
  - …comfortable,

while performing functions at speed up to 130 km/h on highways.

Assessment of Real World Data

How to ensure that the HAF meets the requirements?

- Based on the Use-Cases and Base-Scenarios, a Scenario-Catalog had to be defined
- This led to a Test-Catalog with Test-Cases containing
  - Specific parameters
  - Maneuvers
  - Distributions
  - and relevant characteristics
- The Test-Cases were assigned to different test enviroments
  - Simulation
  - Proving ground
  - Public road

→ Matching these Test-Cases and the Requirements, a variety of Evaluation Subjects were defined

Definition of Evaluation Subjects

Assessment of Real World Data

Which criteria to use for a HAF?

Modelling of Evaluation Criteria

- A jointly agreed Logging was developed with all Partners involved
- Using a standardized “json“ architecture
- Contents of the file are based on the Evaluation Subjects
- Since all Partners developing own HAF-Vehicles, focus on quality and quantity criteria
  - Technical maturity of the HAF
  - Reliability of the functions
  - No benchmark

Assessment of Real World Data

How to rate the HAF?

Deduction of Parameters

- The Ko-HAF Logfile contains a variety of parameters such as…
  - Local ID
  - Lane ID
  - Event time
  - GPS position (long; lat)
  - Event Message
  - Ego speed
  - Vehicle position arround the Ego
  - etc…

Example from the Logfile

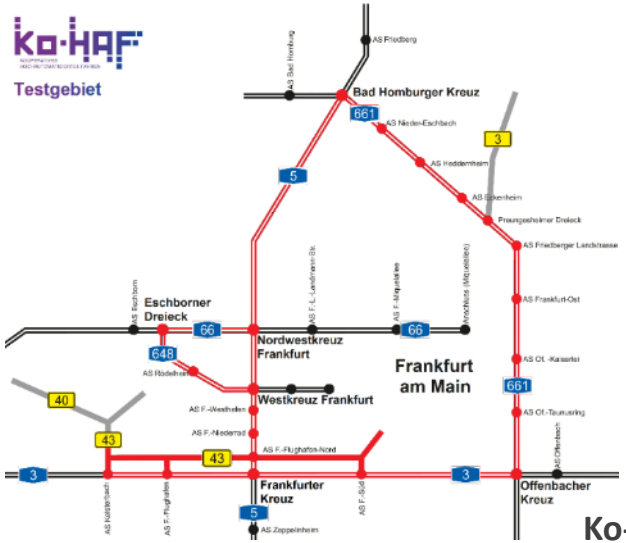
Werte - Eventeintrag	JSON Datei - Kurzname	Einheit
Name	EventName	Text
Zeitstempel	EreignisZeit	YYYY-MM-DD-HH:MM:SS.mmm
Relativer km-Stand	RelativerKmStand	Meter
Spur-ID	SpurId	In Ko-HAF keine absolute , sondern relative Nummerierung der Spuren. Details in Dokument Ko-HAF_Spezifikation_Kommunikationsschnittstellen.docx: https://service.projectplace.com/pp/pp.cgi/r1232389708 Seite 19 (siehe oberer Abschnitt)
Position	GpsPositionLat	ms arc
	GpsPositionLong	ms arc
Message	EventMessage	Freitext

Assessment of Real World Data

Which test environment fits best to HAF?

- After the assignment of the Test-Cases, testing took place in simulation, on proving ground and on public road

Testing / Logging



Ko-HAF Test area on public road

- With conclusion of the testing, each partner is providing their logfiles for evaluation
- The loggingdata of each test environment is concentrated at the Ko-HAF Safety Server

Assessment of Real World Data

Has the HAF met the requirements?

Evaluation / Recommended actions

- After completing the development and testing in Ko-HAF, the Evaluation will take place following the final presentation
- As determined by the assessment process, the evaluation is performed on the basis of the jointly agreed logging data

→ The aim of the Evaluation is to prove whether the HAF was able to fulfill all requirements and to recommend actions for further developments





Thank you

for your attention!

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aufgrund eines Beschlusses des Deutschen Bundestages