PEGASUS

Effectively ensuring automated driving.

PEGASUS

Prof. Dr.-Ing. Karsten Lemmer | April 6, 2017

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Starting Position for Automated Driving

Top issue!	Technology works	Confidence	Testing differently
			
automated driving is tomorrow's subject matter (together with electric driving)	basic functionality is technologically given has been demonstrated in various projects	high standards regarding quality and performance of the automated vehicle ➔ measures that product needs to meet	existing measures for testing and release are insufficient, too cost-intensive and too complex

➔ Consequently, the introduction of highly automated driving features today can only be achieved with great expenditure.

Current State of Development of Highly Automated Driving

Prototypes

- multitude of prototypes built by OEM with HAD-functionality
- evidence, that HAD is technologically possible
- partially tested in real traffic situations
- test drives involve backup safety driver

Lab / Test Ground

- individual analyses to optimize prototypes
- current test stands/ test grounds do not provide enough test coverage for all HAD features currently in focus
- there is no procedure for adequate testing (particularly performance) of HAD-systems

Products

- no release or introduction of variety of HAD-features without sufficient assurance

current status

OEM = Original Equipment Manufacturer HAD = Highly Automated Driving

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- individual ana… optimize pr…
- current … ground… enough… for all … currentl…
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Advancement through PEGASUS

current status

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PEGASUS Key Figures

project for the **e**stablishment of **g**enerally **a**ccepted quality criteria, tools and methods as well as **s**cenarios and **s**ituations for the release of highly-automated driving functions

42 months term	January 2016 – June 2019
17 partners	▪ OEM: Audi, BMW, Daimler, Opel, **Volkswagen** ▪ Tier 1: ADC Automotive Distance Control, Bosch, Continental Teves ▪ Test Lab: TÜV SÜD ▪ SMB: fka, iMAR, IPG, QTronic, TraceTronic, VIRES ▪ scientific institutes: **DLR**, TU Darmstadt
Affiliated partners & Subcontracts	▪ i.a. BASt, IFR, ika, OFFIS
Project volume	▪ approx. 34,5 Mio. EUR ▪ subsidies: 16,3 Mio. EUR
Personnel deployment	▪ approx. 1.791 man-month or 149 man-years

Project coordination, Project office

Central Issues of the PEGASUS Project

What level of performance is expected of an automated vehicle?
How can we verify that it achieves the desired performance consistently?

Scenario Analysis & Quality Measures

What human capacity does the application require?

What about technical capacity?

Is it sufficiently accepted?

Which criteria and measures can be deducted from it?

Implementation Process

Which tools, methods and processes are necessary?

Testing

How can complete-ness of relevant test runs be ensured?

What do the criteria and measures for these test runs look like?

What can be tested in labs or in simulation? What must be tested on test grounds, what must be tested on the road?

Reflection of Results & Embedding

Is the concept sustainable?

How does the process of embedding work?

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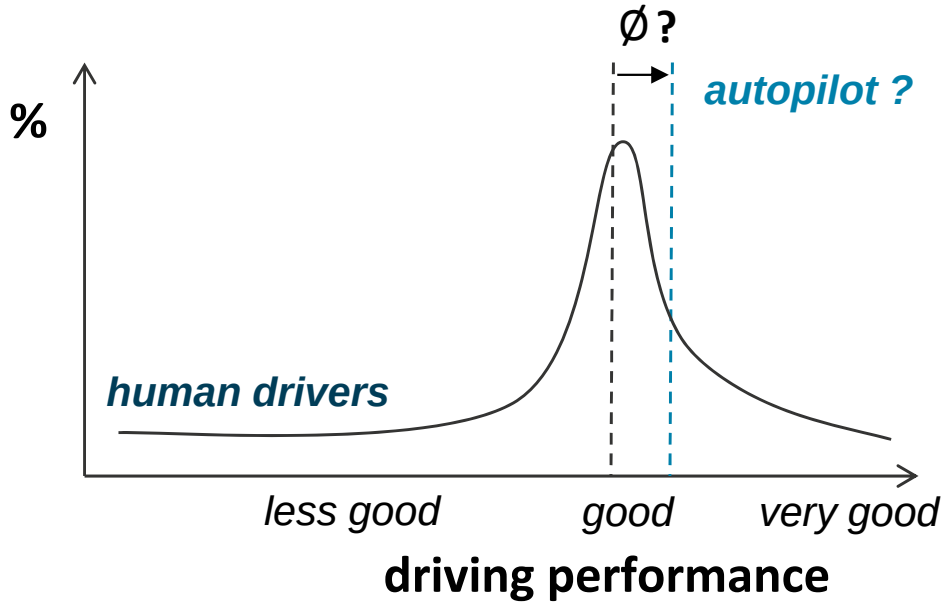
Scenario Analysis and Quality Measures

How good is good enough?

Which functional performance do highly automated driving functions need to be accepted by driver and society?



➔ To answer this question **generally accepted quality criteria, tools and methods** are developed.

- employed to the sample application of the highway chauffeur

Scenario Analysis and Quality Measures

Results are e.g.:

System boundaries
Metric perspectives
Classes of automation risks

Deduction of requirements based on the accepted measure of quality

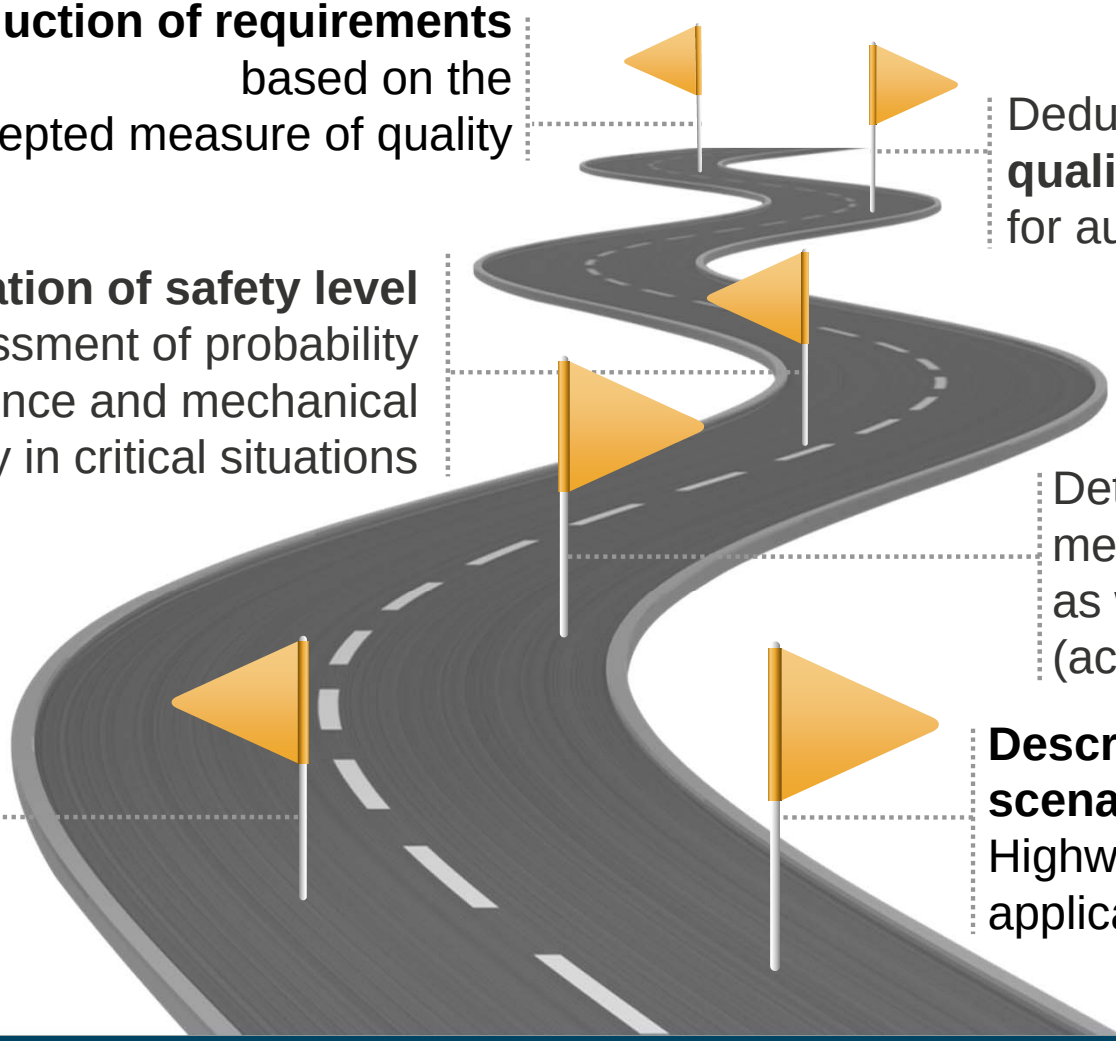
Deduction of an **accepted quality measure** for automated driving features

Determination of safety level through assessment of probability of occurrence and mechanical manageability in critical situations

Determination of human and mechanical **performance** as well as **effectiveness** (accident avoidance potential)

Determination of critical **traffic situations**

Description of application scenario (sample application: Highway Chauffeur + enhanced application scenario)



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Implementation Process

Analysis

of modification needs of existing metrics and automobile series development processes

1

Transfer

of systematic scenario guidelines into process steps in consideration of system classifications and levels of vehicle utilization

2

Transfer

of target value parameters into process steps

3

Preparation

of requirements definition for simulation, lab tests, test ground and field coverage

4

Refinement

of the guidelines for required documentation of process steps

5

Guidelines and Protocols

for the documentation of technological state-of-the-art compliance during the development process

6

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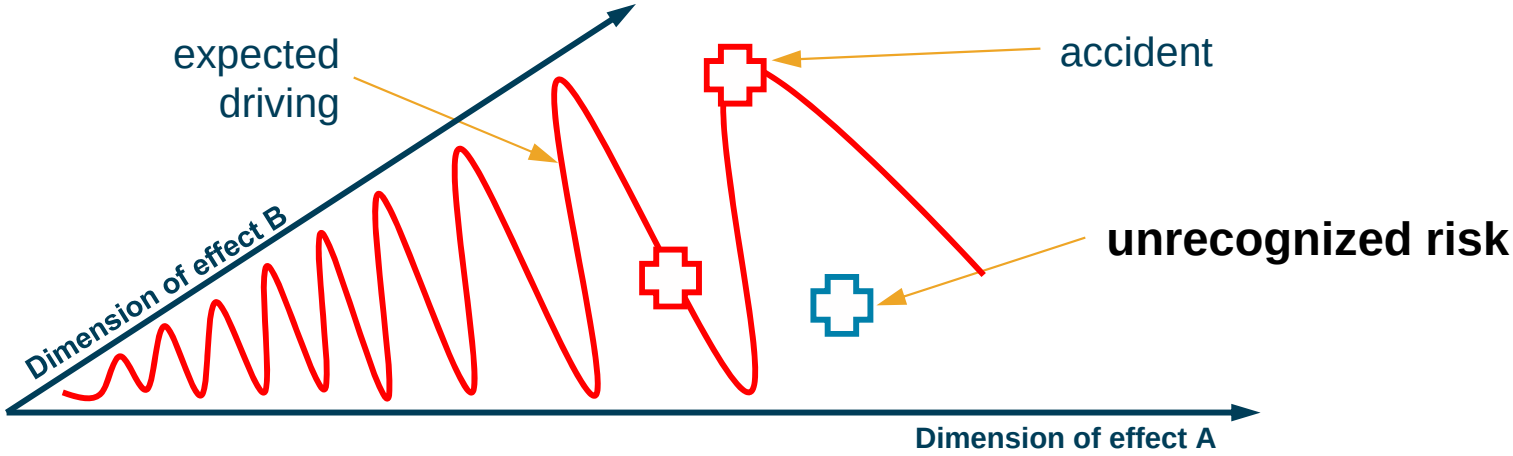
Testing

- What does a test strategy need to look like to cover the range of situations sufficiently?
- How can all safety relevant scenarios in the application scope of the function be ensured?
- How can we determine the functional limitations – and prove that we rule them?
- How can we verify and validate our test methods, test instances and test results?

Testing

Ensurance trap*:

- Up to now the system‘s behaviour in traffic has been considered as mere stochastic process.
- This equates the attempt to cover the state space representatively simply through driving.

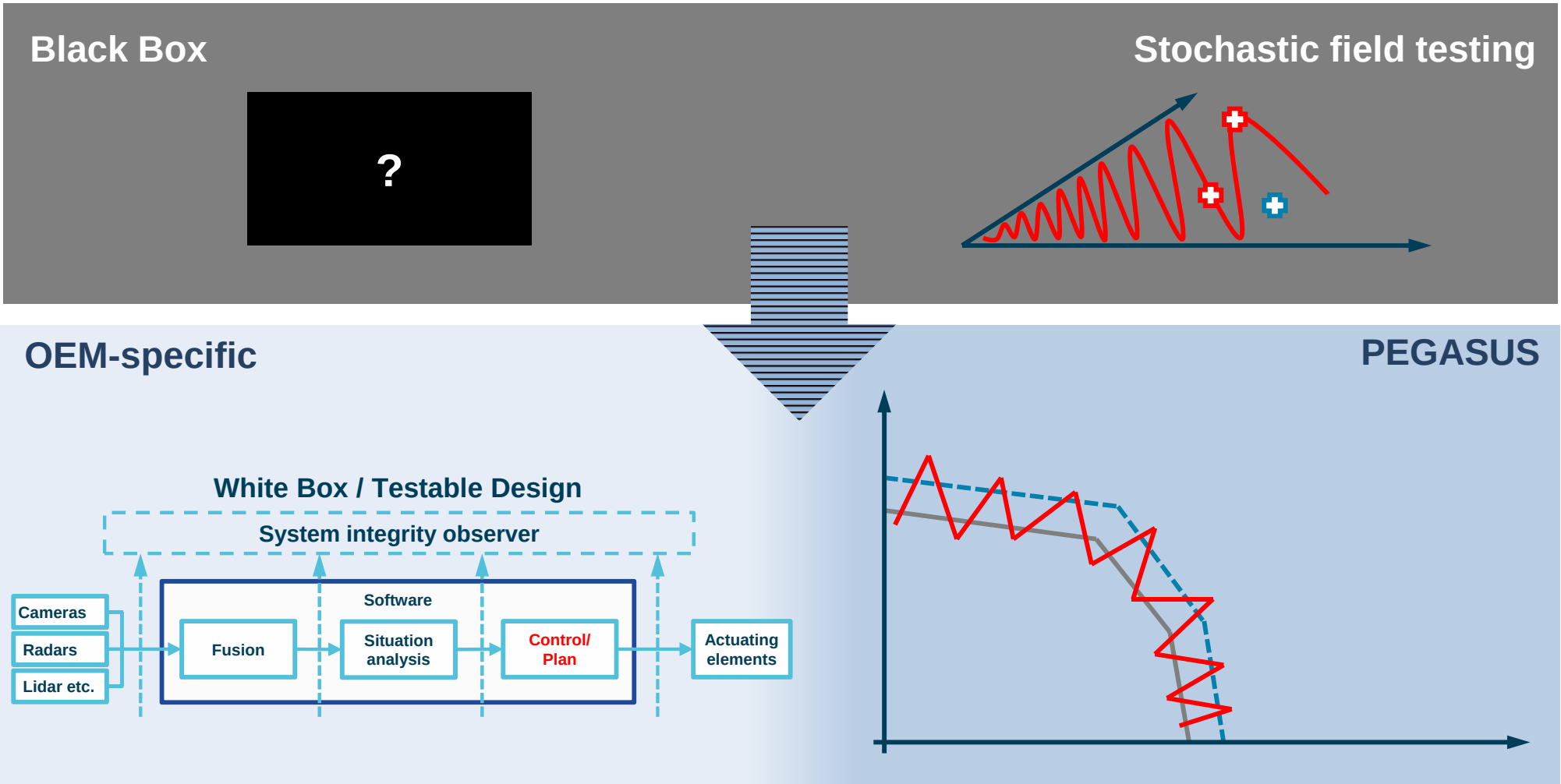


If the previous method would be transferred to highly automated driving, 240 million kilometer* of driving would be necessary!

* „Absicherung automatischen Fahrens“, Prof. Dr. H. Winner, 6. FAS-Tagung München, 29.11.2013

Testing

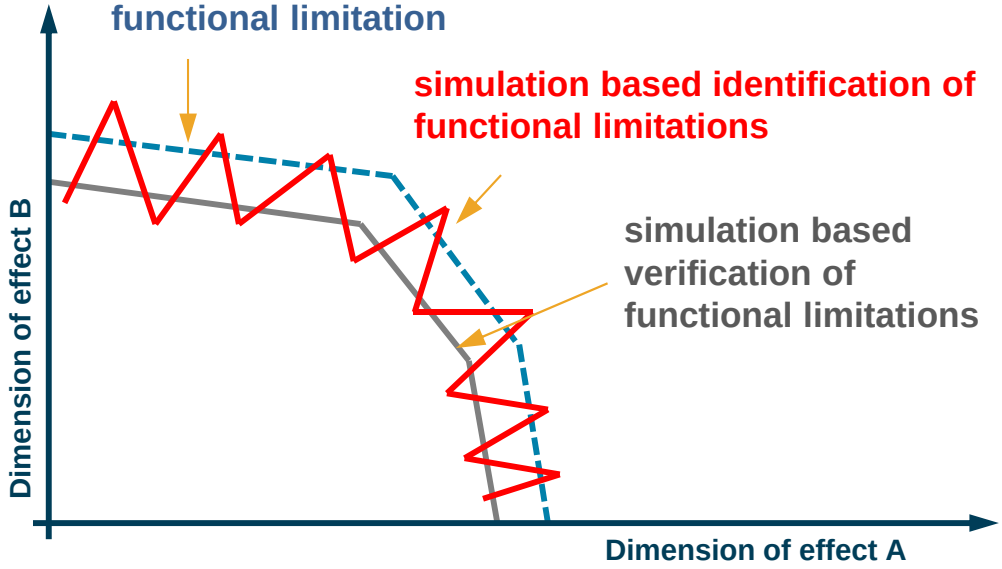
A paradigm shift is mandatory!
for a holistic approach for sufficient, complete and efficient testing of highly automated driving within the functional limits by systematic scenario creation and methods of test coverage



Testing

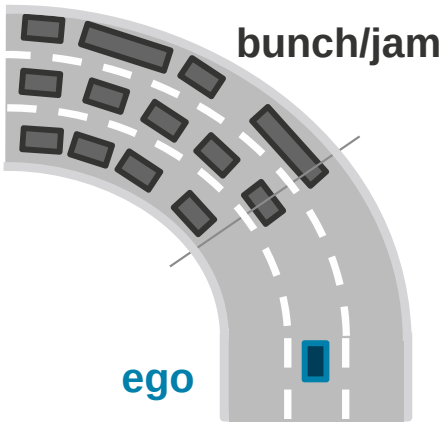
Approach:

- **iterative determination of the scenarios** for the highly automated function using simulation, test ground and field test in comparison with a central database of test specifications
- **virtualization of the test and ensuring process** to control the huge test range and volume



- **simulative determination of the functional limitation** and **proof of controllability**
- challenges for the simulation:
  - realistic models (traffic, sensors)
  - proof of realistic reproduction, that means verification and validation on test ground and in field tests
- automated identification of potential critical situations that are not yet modelled

Generation of scenarios: levels of abstraction

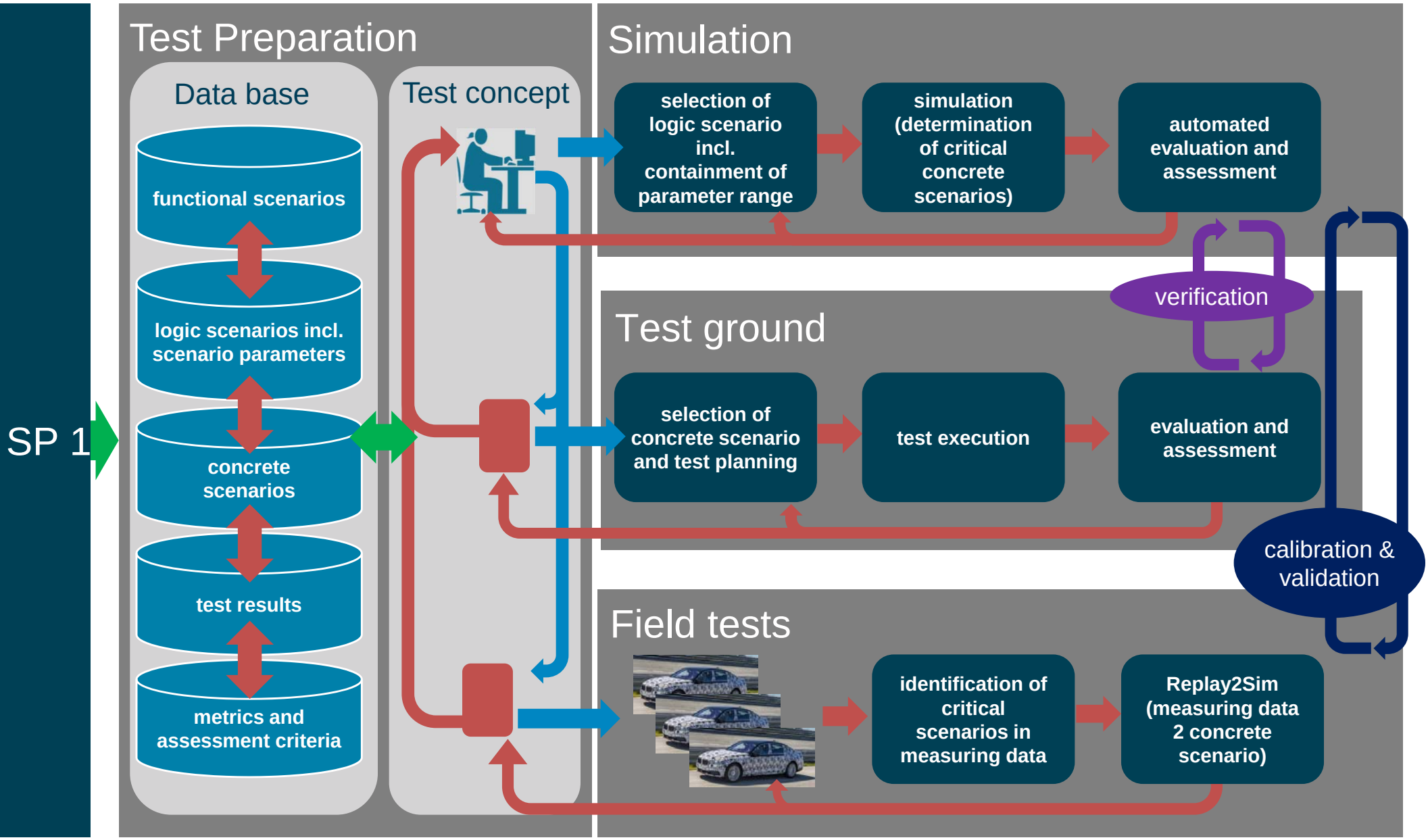


Functional scenarios	Logic scenarios	Concrete scenarios
Basis road:	Basis road:	Basis road:
highway in bend	number of lanes [2..4] curve radius [0,6..0,9] kph	number of lanes 3 curve radius 0,7 km
Stationary objects:	Stationary objects:	Stationary objects:
-	-	-
Movable objects:	Movable objects:	Movable objects:
ego, jam; interaction: ego approaches end of jam	End of jam position [10..200] m jam speed [0..30] kph ego distance [50..300] m ego speed [80..130] kph	end of jam position 40 m jam speed 30 kph ego distance 200 m ego speed 100 kph
Environment:	Environment:	Environment:
summer, rain	temperature [10..40] °C droplet size [20..100] µm rain amount [0,1..10] mm/h	temperature 20 °C droplet size 30 µm rain amount 2 mm/h

number of scenarios

level of abstraction

Testing


SP 1
Test Preparation
Data base
functional scenarios
logic scenarios incl. scenario parameters
concrete scenarios
test results
metrics and assessment criteria
Test concept
Simulation
selection of logic scenario incl. containment of parameter range
simulation (determination of critical concrete scenarios)
automated evaluation and assessment
verification
Test ground
selection of concrete scenario and test planning
test execution
evaluation and assessment
calibration & validation
Field tests
identification of critical scenarios in measuring data
Replay2Sim (measuring data 2 concrete scenario)

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Reflection of Results & Embedding

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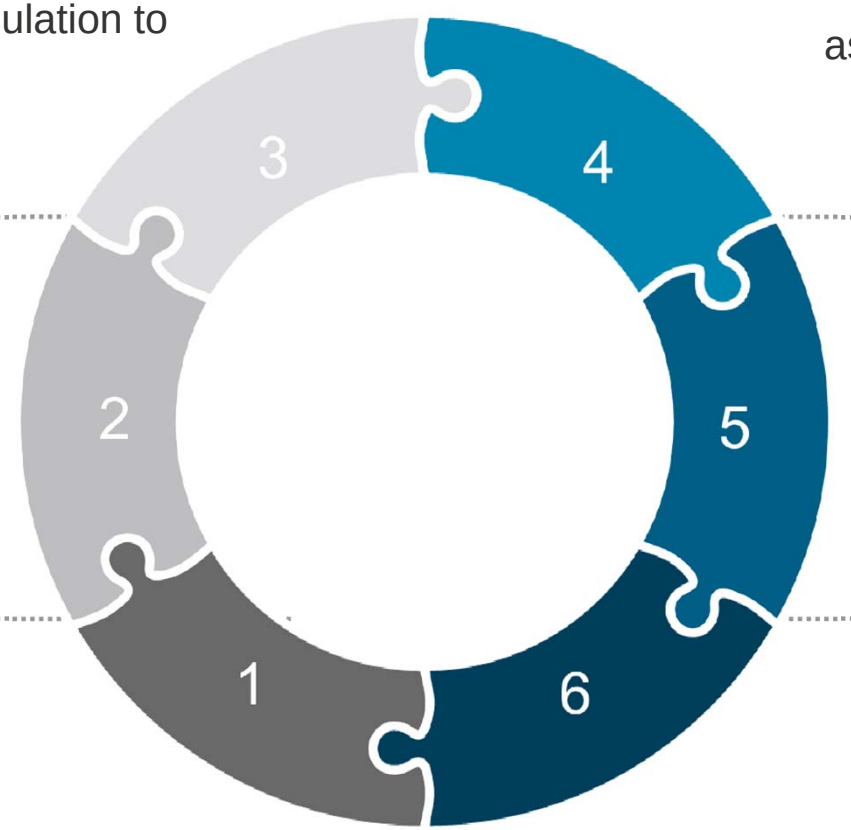
Reflection of Results & Embedding

Statement

about the distribution ratio between the applied test methods (from simulation to test ground to field test)

Proof of Concept

trough verification (1), assessment (2) and statement (3)



Assessment,

whether the test goal can be achieved with the utilized processes and methods in PEGASUS

Assistance

with embedding of acquired results with our project partners

Verification

of methods to identify relevant situations, quality and criticality measures for the assurance of HAD features

Lessons learned

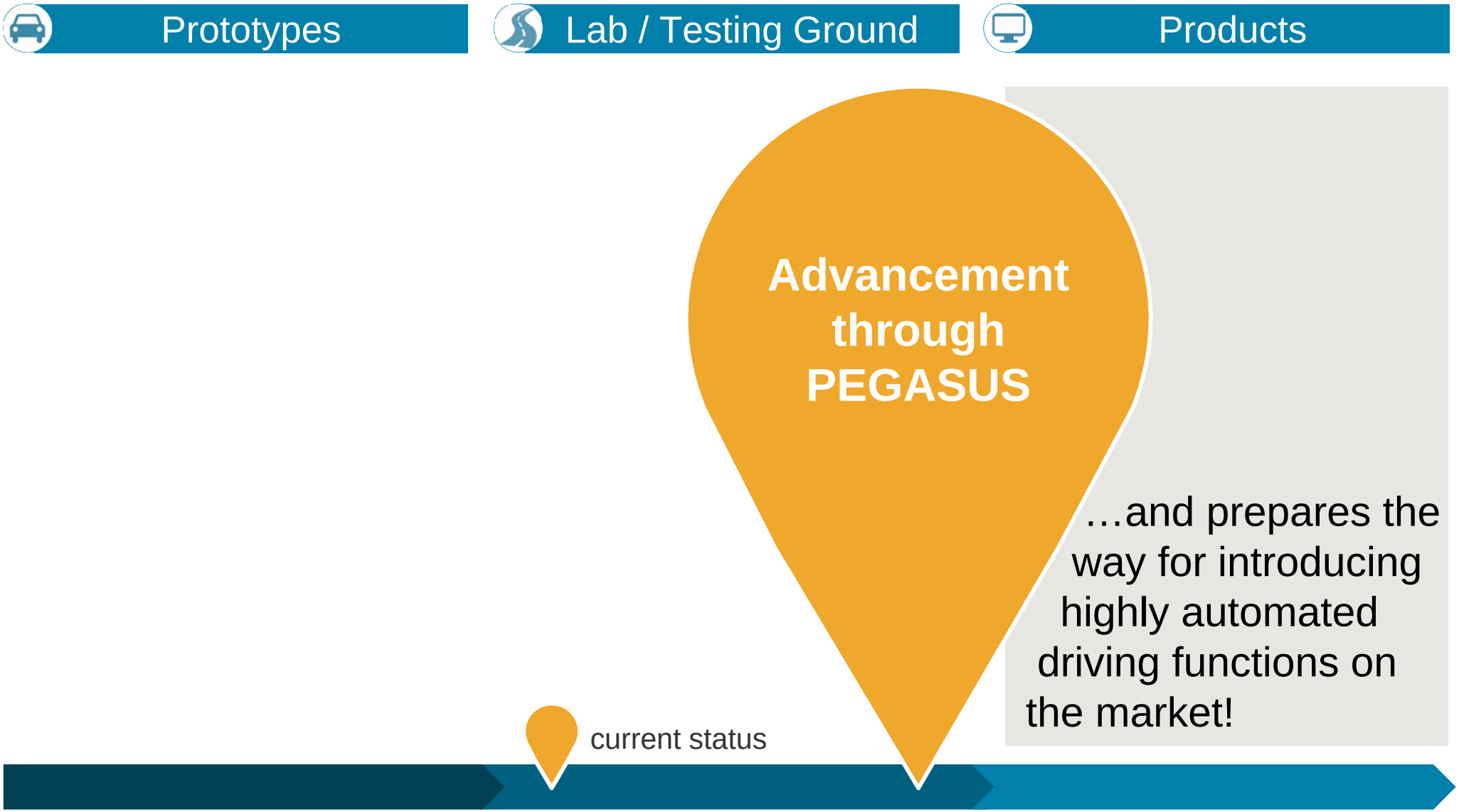
regarding the implementation of the results in existing corporate structures

Summary / Selected Goals of the Project

- development of a procedure for the determination of design criteria and establishment of quality measures
- considering the driver in regards to his abilities
- design of the development process for the release of highly automated vehicle systems
- conceptual design, assembly and demonstration of building blocks for an efficient toolchain for simulation, test ground and field test
- embedding of findings in the industry
- distribution and pioneering of a standardization

➔ All essential project results are freely accessible.

PEGASUS closes key gaps in the field of testing for highly automated driving functions



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