# The Role of Simulation in Development and Testing of Autonomous Vehicles

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Driving Simulation Conference – DSC 2017, Stuttgart 2017-09-06

# The Role of Simulation in Development and Testing of Autonomous Vehicles

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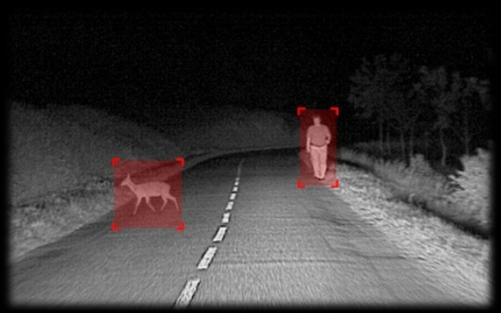
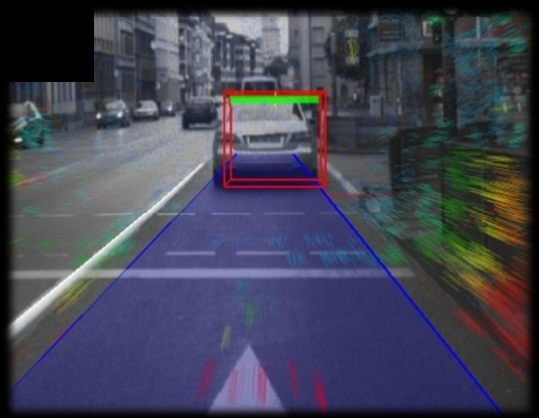
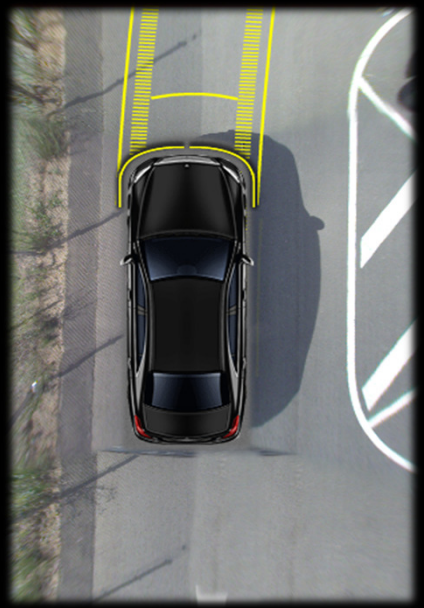
# Where Are We Now?

Mercedes-Benz

# Mercedes-Benz Intelligent Drive







**Active Distance Assist DISTRONIC**
- Route based speed adjustment
- Active Speed Limit Assist

**Car-to-X Communication**

**PRE-SAFE® PLUS**

**ATTENTION ASSIST**

**Beltbag**

**Active Steering Assist**
- Active Lane Change Assist
- Active Emergency Stop Assist

**PRE-SAFE® Sound**

**Active Blind Spot Assist**

**Active Lane Keeping Assist**

**Remote Parking Assist**

**Active Brake Assist**
standard with Pedestrian Detection, in combination with Driver Assistance package with Cross-Traffic Function and Congestion Emergency Braking Function

**MULTIBEAM LED**
- ULTRA RANGE high beam

**Evasive Steering Assist**

Mercedes-Benz

Mercedes-Benz

Intelligent Drive

# What is the Challenge ?

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# Stages of Autonomy (NHTSA Logic)

**Level 0**
No automation

Driver in charge

**Level 1**
Function-specific automation

Single control functions such as speed selection, braking or lane keeping are automated

**From here:**

**Level 2**
Combined function automation

More than one control function is automated

Driver expected to be available for control at all times and on short notice

**To here:**

**Level 3**
Limited self-driving automation

Vehicle takes control most of the time

Driver expected to be available for occasional control with comfortable transition times

**Level 4 / 5**
Full self-driving automation

Vehicle takes control all of the time

Driver not expected to be available for control at any time

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# Safety and Automation: A Major Challenge

Accidents are almost all due to human error.

We have
with some success
automated to intervene
when people do
something wrong.

*On the German Autobahn, every 7.5 million km we <u>may</u> catch an error.*

Humans do much more right when driving than they do wrong.

We now aim at
automating those things
that people do right.

*We have to drive those 7.5 million km and <u>must</u> not fail a single time.*

## Safety of autonomous vehicles

***Before an autonomous vehicle***

***will drive you anywhere,***

***it has to prove that***

***it will not drive you into trouble !***

# How to Manage Risk?

# Methods from other high tech fields with controlled risk

Aerospace industry

Electrical power systems

Production automation

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# Safety assessment of driving situations

**Drive carefully:**

Look ahead,
drive predictively,
know your limits

**Master extreme situations:**

Detect dangers early and
react fast & appropriately

**Limit the consequences:**

Provide suitable
protection

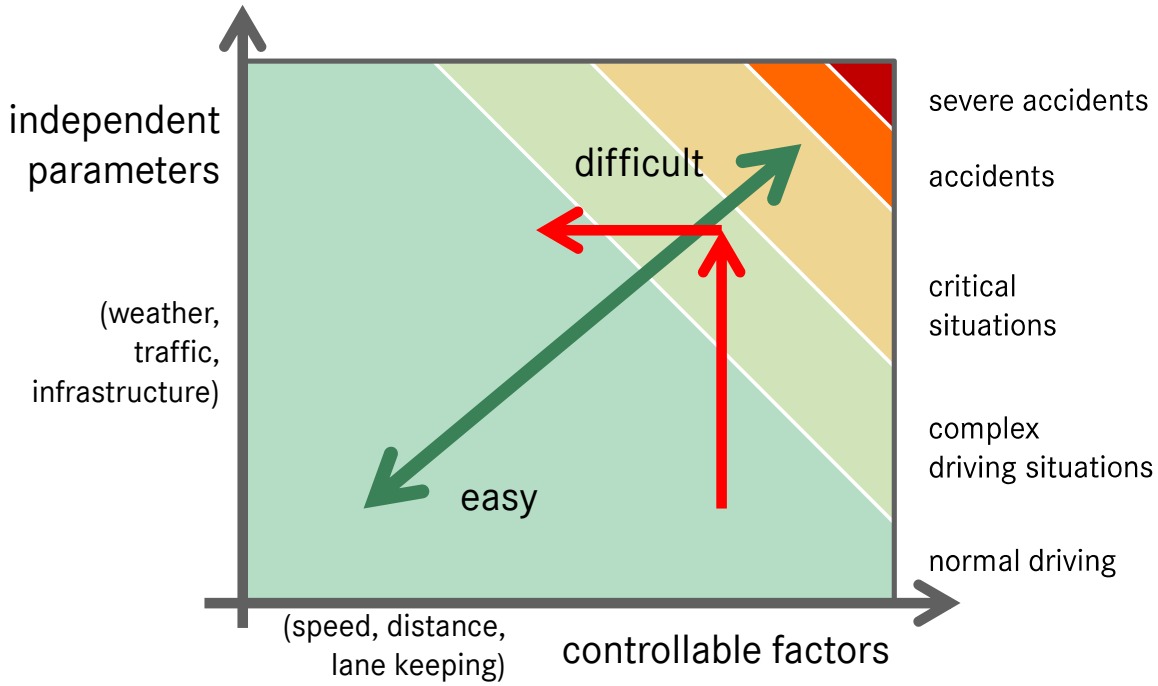
$$R = E\,(1-C)\,S$$

- R: Risk
- E: Exposure
- C: Controllability
- S: Severity

**New option with autonomous driving** | **Active safety** | **Passive safety**

# Vehicle response upon changing conditions

Verify, that vehicle avoids uncontrollable situations by adequate behaviour



# Five Categories of Reasons for Exposure to Accidents

1. Failure of components and hardware deficiencies
2. Deficiencies in sensing road, traffic and environmental conditions
3. Deficiencies in control algorithms (complex and difficult situations)
4. Behaviour-dependant accidents (adequate behaviour and rule compliance)
5. Faulty driver and vehicle interaction (mode confusion and false commanding)






**design specific** **external conditions**

Source: H.P. Schöner: Challenges and Approaches for Testing of Highly Automated Vehicles; 3rd CESA Automotive Electronics Congress, Paris 2014

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# Testing Platforms and the Importance of Simulation

| Category Platform | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| HIL | **X** | X[1)] | X | | |
| SIL | | X[1)] | **X** | **X** | |
| Test Area | X | X[2)] | X | X | X |
| Field Test | | **X** | | X | X |
| Driving Simul. | | | | | **X** |






1) requires sensor models
2) requires specific test modules

# How to Measure Controllability ?

# Dynamic Simulator in Sindelfingen



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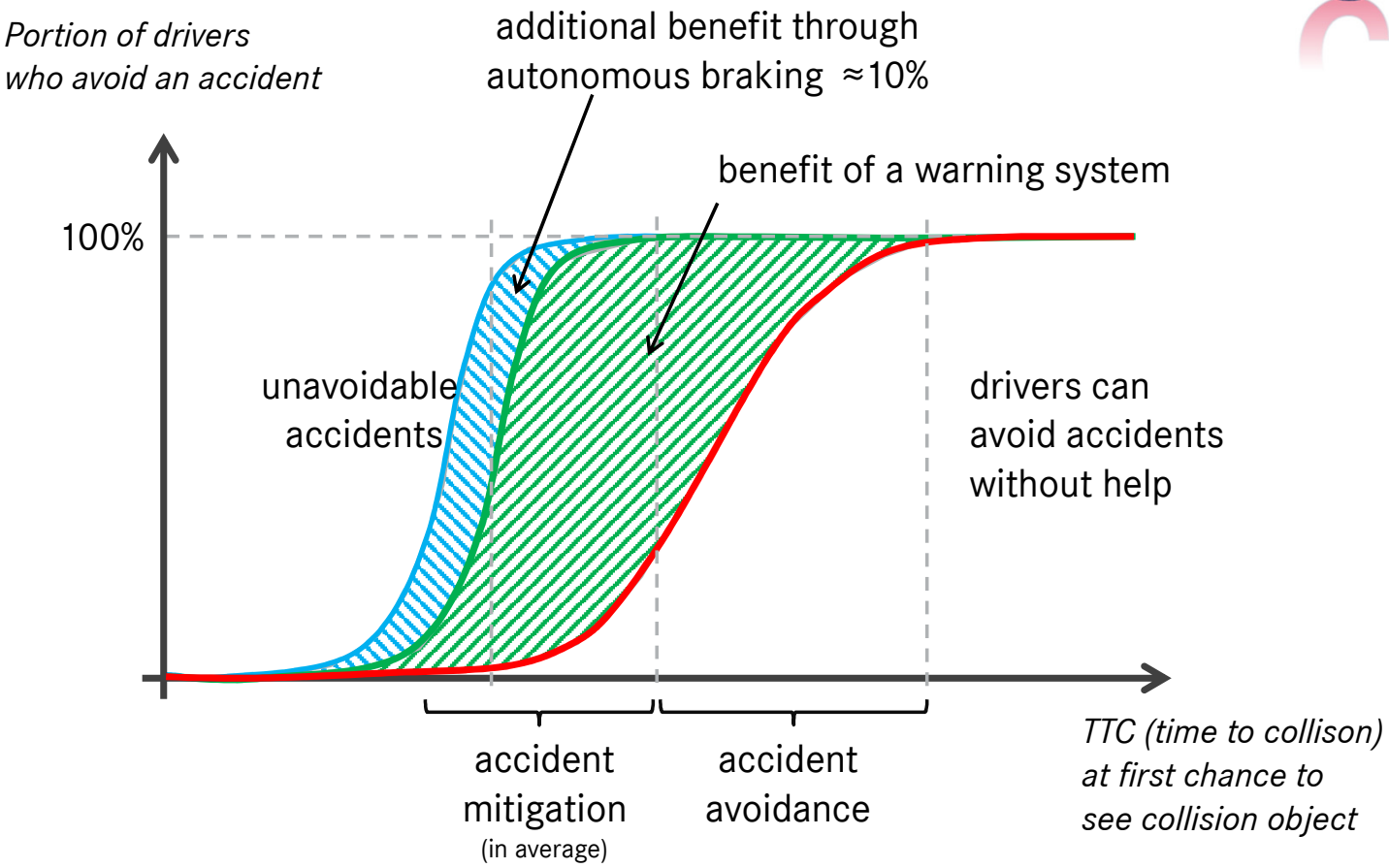
# Controllability of traffic accidents



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# How to Verify Driving Functions ?

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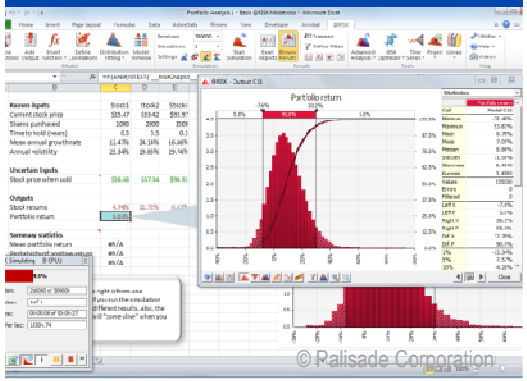
# Testing of Autonomous Functions

## Virtual tests



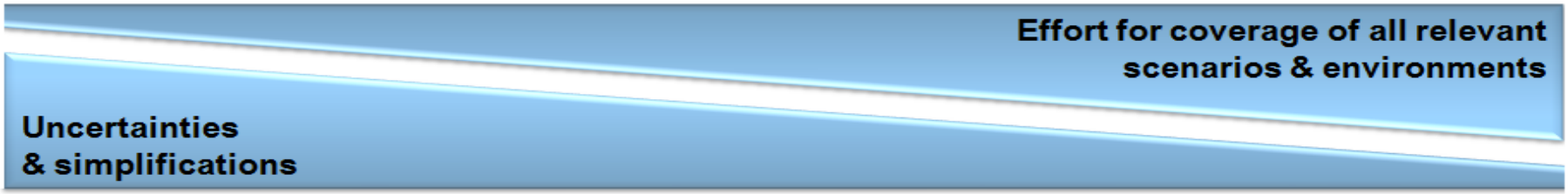

☑ Analysis of a huge number of scenarios, environments, system configurations and driver characteristics

## Proving ground tests

☑ Reproducibility by use of driving robots, self driving cars and targets; critical manoeuvres are possible

## Field tests

☑ Investigation of real driving situations and comparison with system specifications




Source: U. Steininger, H.P. Schöner, M. Schiementz: Requirements on tools for assessment and validation of assisted and automated driving systems, 7. Tagung Fahrerassistenz, München, Nov. 2015

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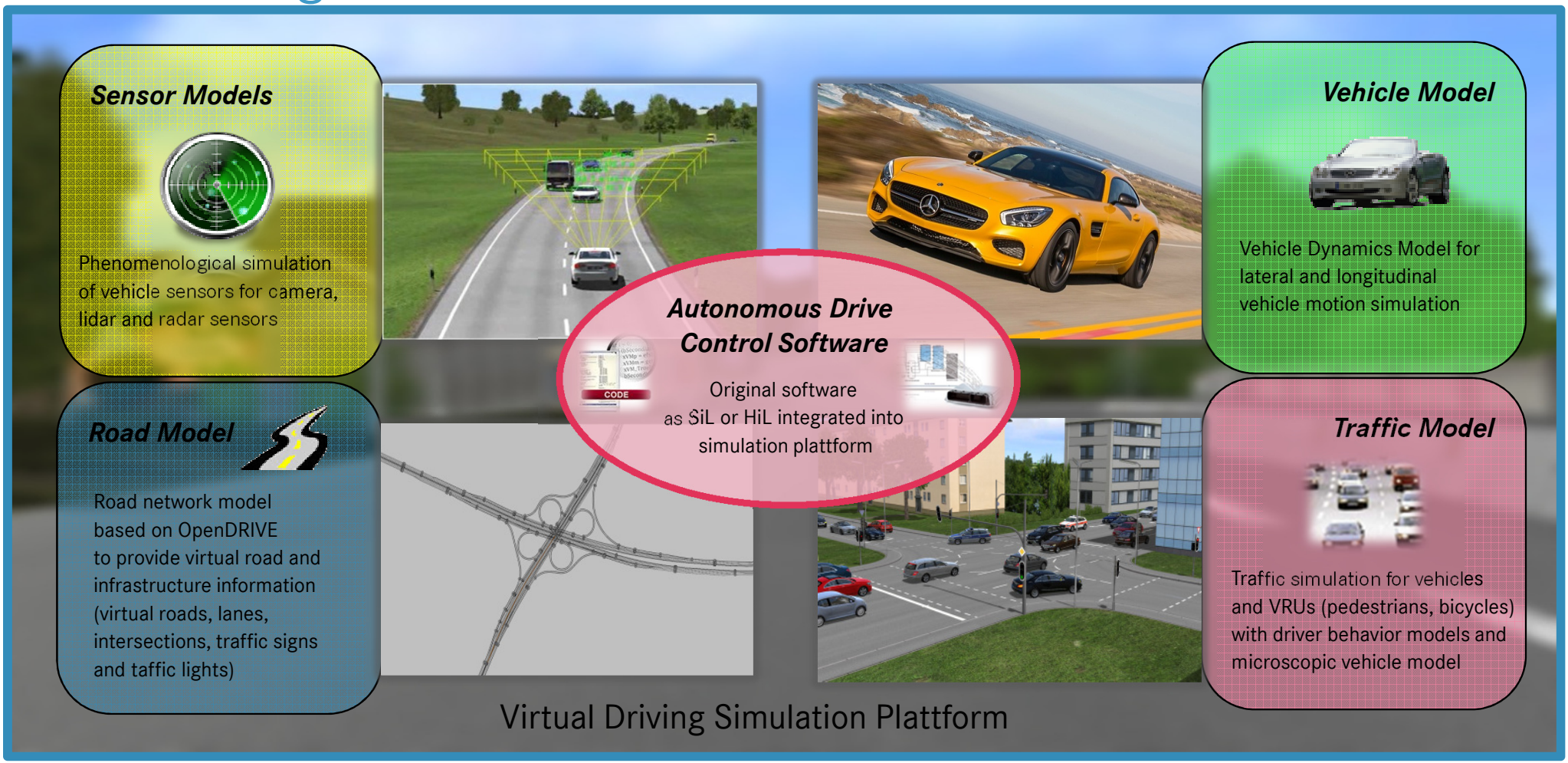
# Virtual Driving with Model Based Simulation



# Example: Real world scenario and its simulation


Use Case: function development for complex traffic scenarios

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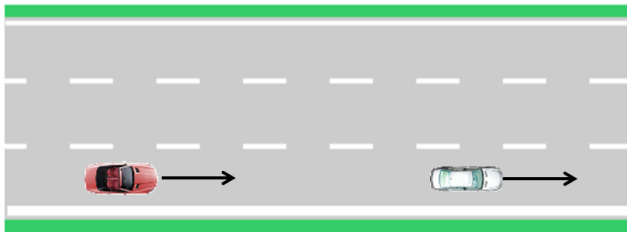
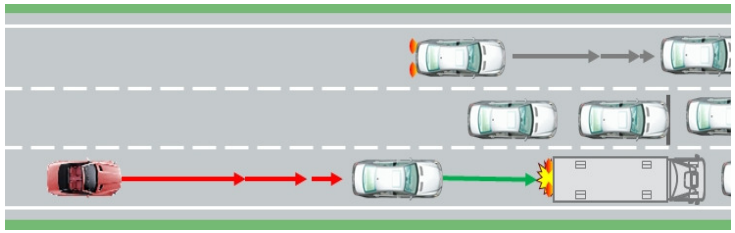
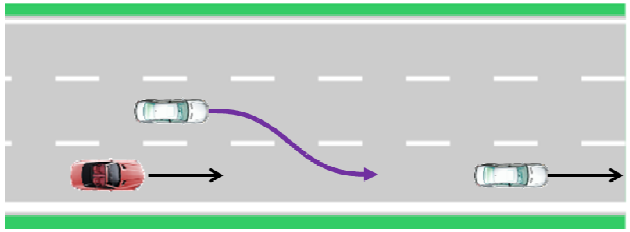
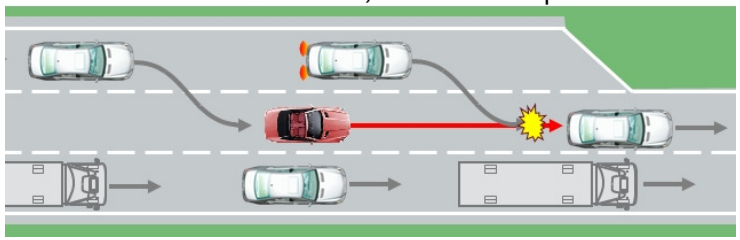
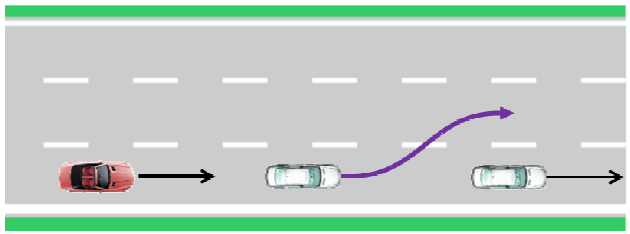
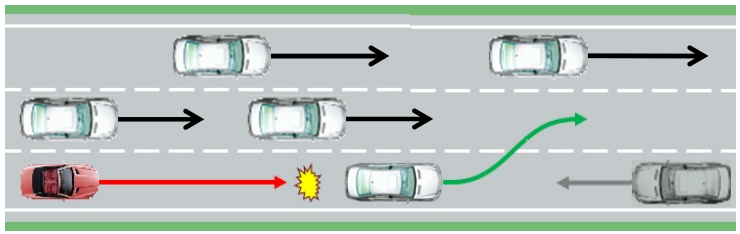
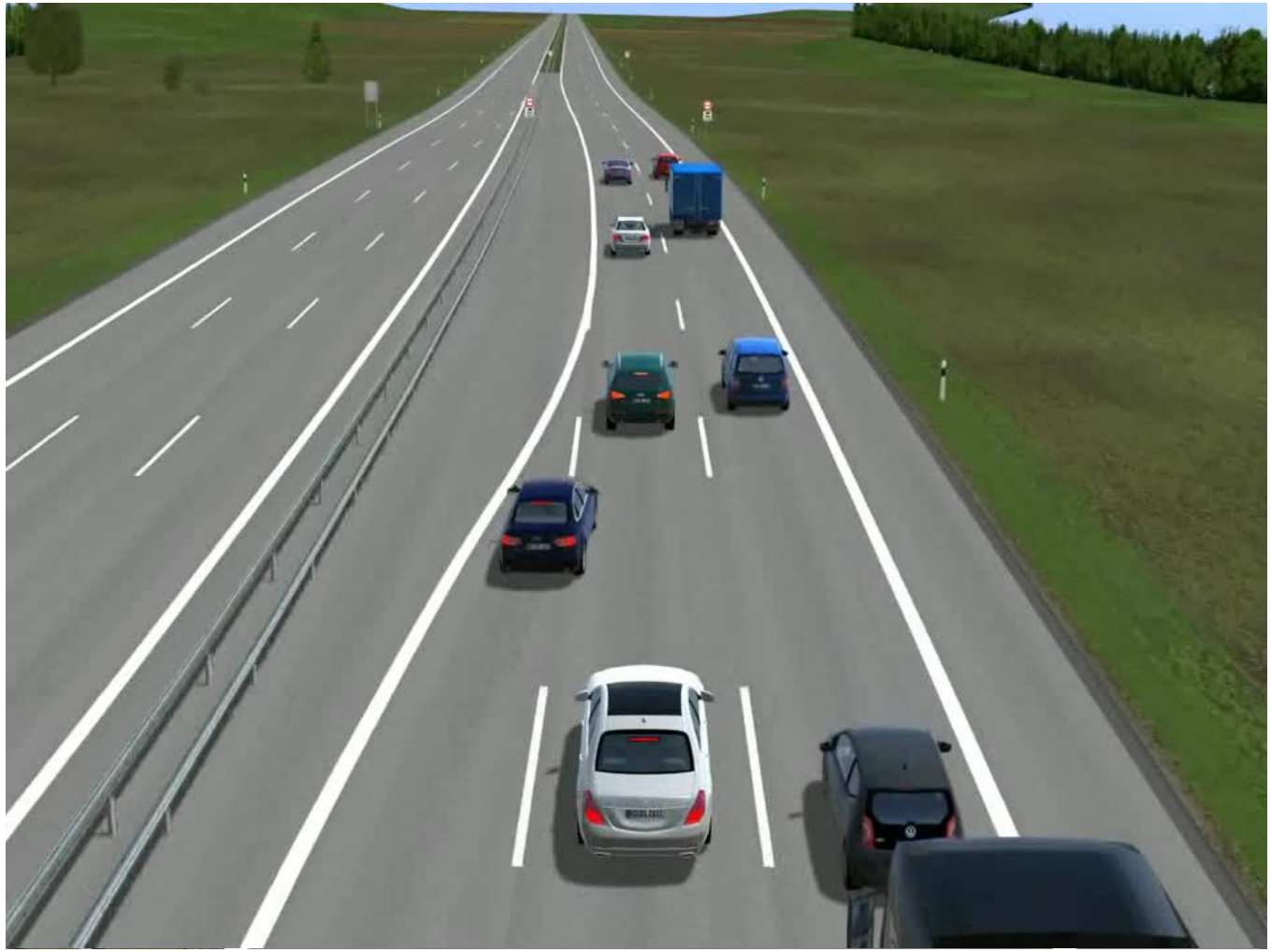
# Challenging Traffic Situations !

(as discussed within PEGASUS project)

| Base Scenario | Critical scenario |
| --- | --- |
| Following | Preceeding car drives into traffic jam without braking |
|  |  |
| Cut-in | Cut-in vehicle brakes hard, no evasion space |
|  |  |
| Cut-out | Car cuts out just before obstacle or oncoming car |
|  |  |

# Simulation:
# Cut-in scenario



# Validation of Simulation:  Cut-in with high relative speed

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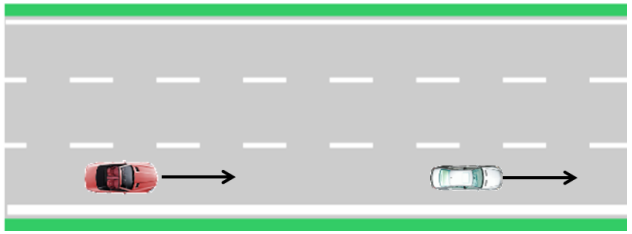
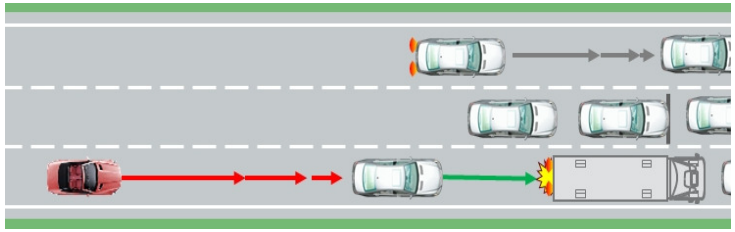
# Challenging Traffic Situations

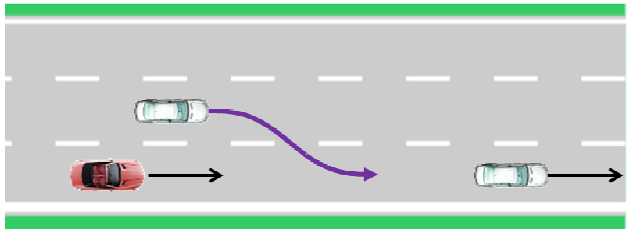
Following



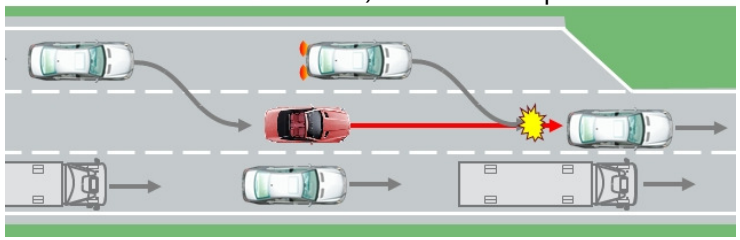
Preceeding car drives into traffic jam without braking



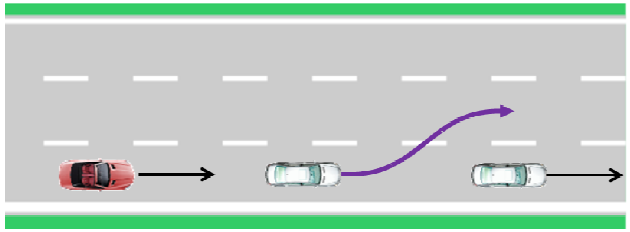
Cut-in



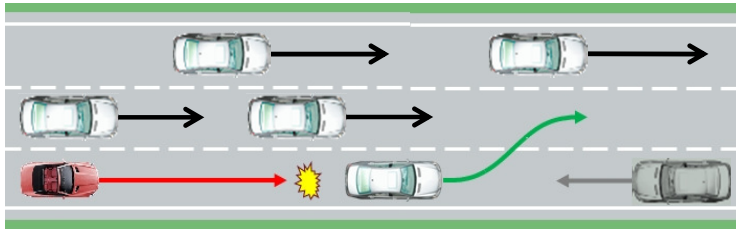
Cut-in vehicle brakes hard, no evasion space



Cut-out



Car cuts out just before obstacle or oncoming car



Use Case: function development for collision avoidance scenarios

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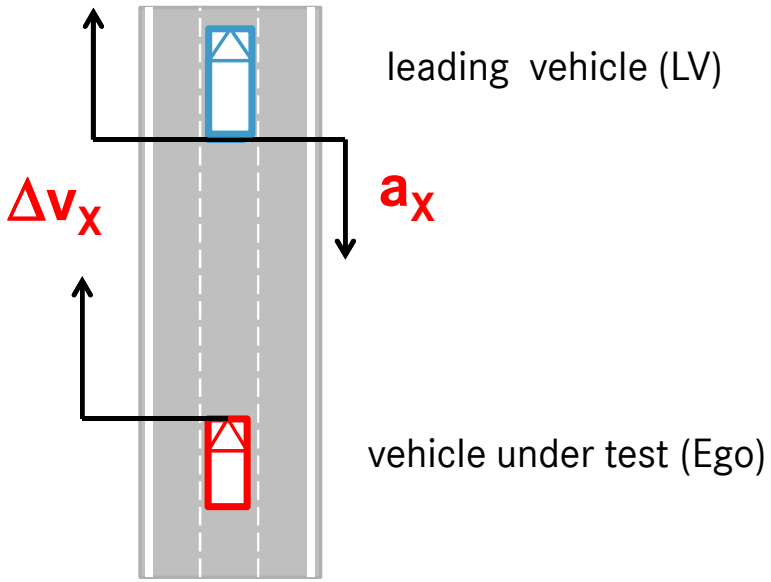
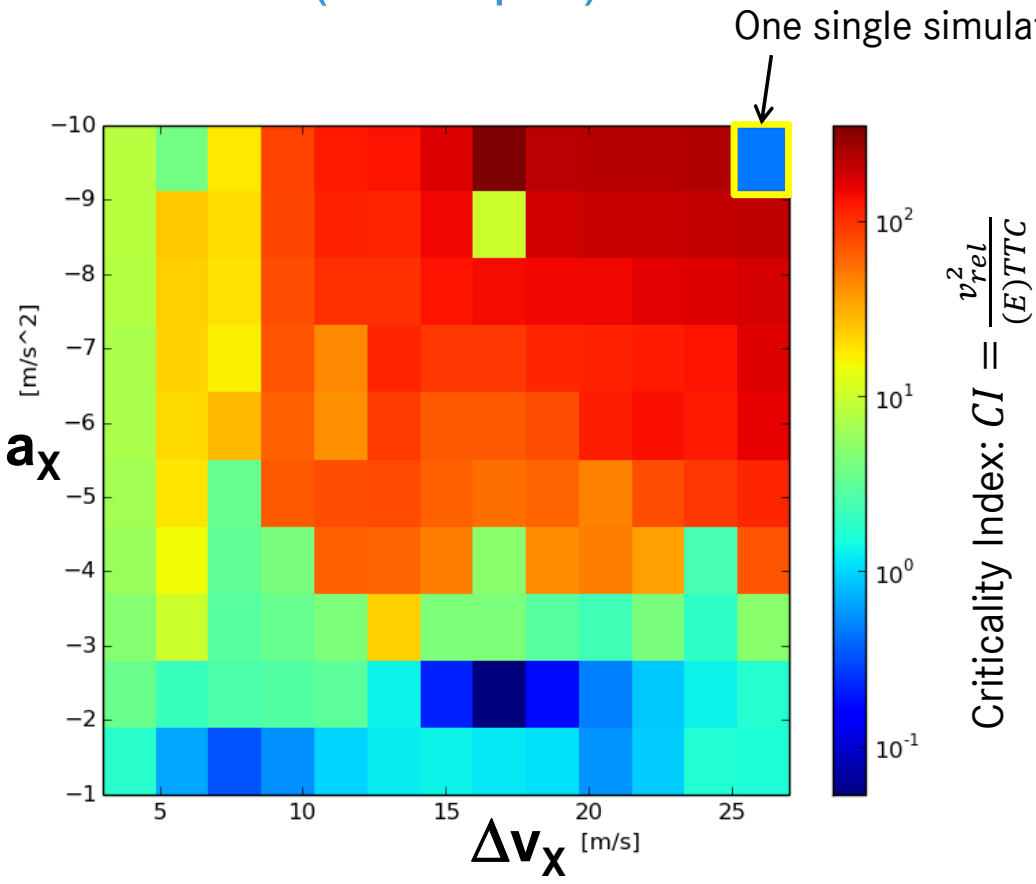
# Batch Simulation of Collision Avoidance (example)



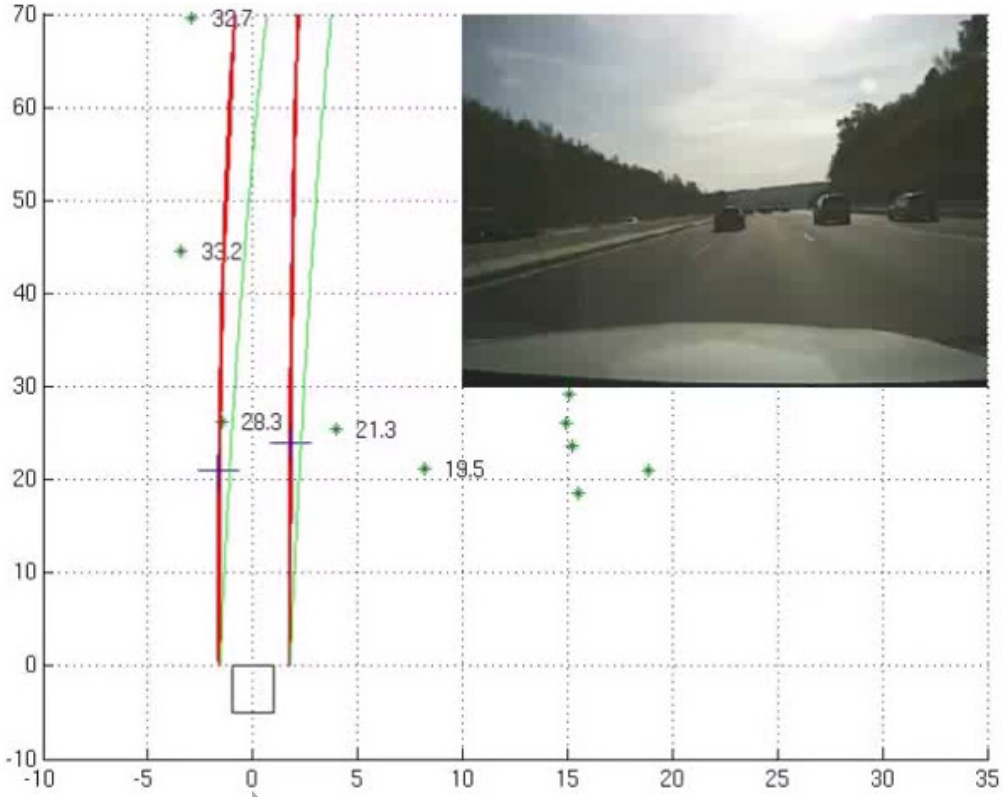




Use Case: verification of collision avoidance and quality measure for safe driving

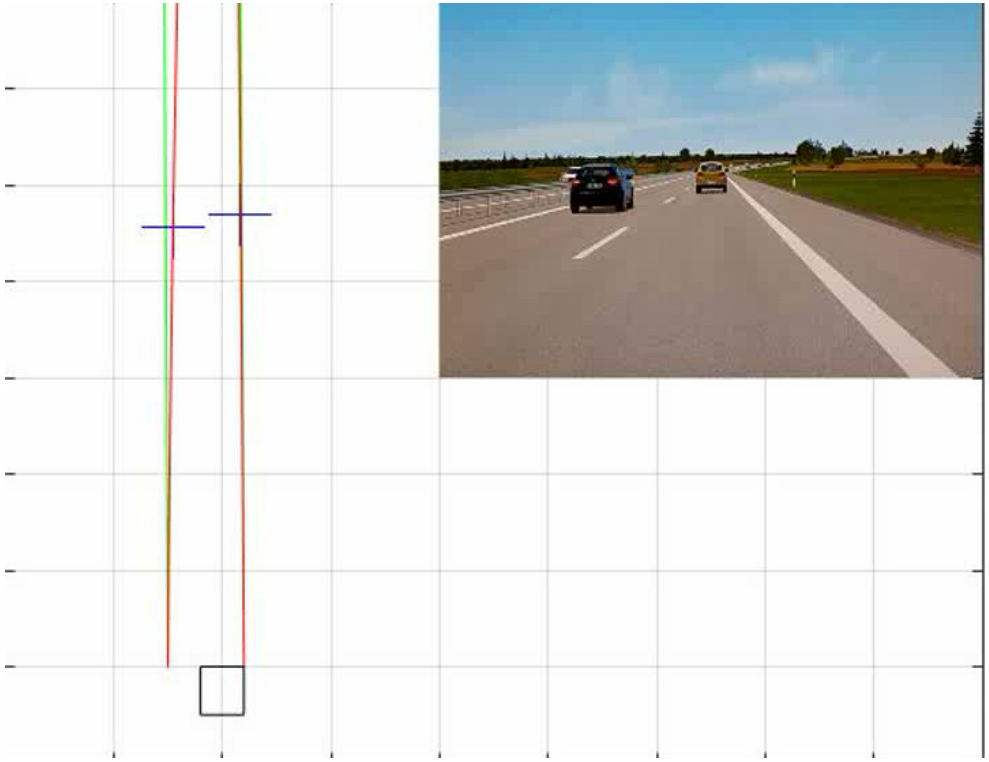
# Simulation of Lane Detection

Estimation based on sensor data
Information provided by map

## Real Data




## Simulated Data



Long distance interpretation of sensor signals requires precise maps !

# So what is essentially new for testing of autonomous vehicles ?

Methods

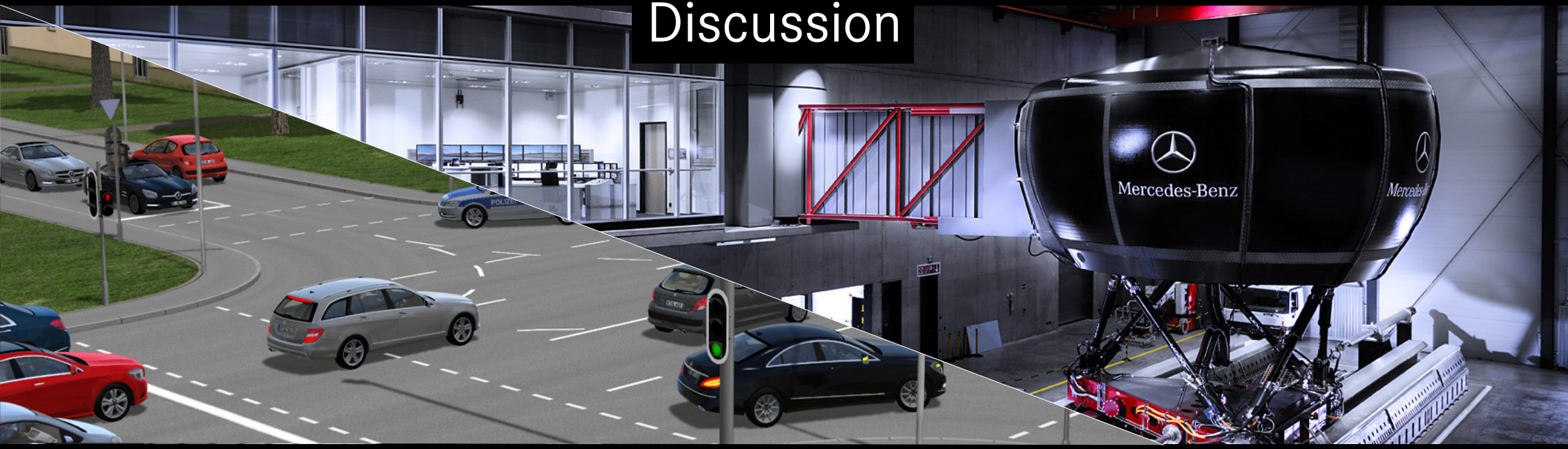
- Much more simulation, esp. for verification of control algorithms and rule compliance
- Systematic search for rare functional deficits, instead of just driving test kilometers

Functions

- Continuous assessment of and adaptation to external conditions and rules
- Judging reliably whether the limits of vehicle autonomy are close
- Announce the end of autonomous mode early enough for the driver to take over (Level 3)
- Bring the vehicle to a safe stop, if (in Level 3) the driver should fail to take over

***It requires simulation to efficiently verify the vast amount of functional requirements !***


Thank You Very Much
for Your Attention!




Driving Simulation Conference – DSC 2017, Stuttgart 2017-09-07

# The Role of Simulation in Development and Testing of Autonomous Vehicles

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Senior Manager – Driving Simulation and Testing Methods, Daimler AG, Sindelfingen

Mercedes-Benz
The best or nothing.

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# The Author

**Dr.-Ing. Hans-Peter Schöner**
Senior Manager „Driving Simulation and Testing Methods" (RD/FDS)
in Daimler‘s R&D Center „Driving Dynamics Functions and Vehicle Testing";
he is responsible for development and supply of methods for testing and validation for future chassis and assistance systems, including autonomous driving functions. This includes methods to provide reproducible testing situations on proving grounds with automatically driven coordinated vehicles, simulation methods for function development and testing, and operating the Driving Simulation Center of Daimler AG.

Dr. Schöner (born 1956 in Düsseldorf) studied Electrical Engineering at RWTH in Aachen (Germany) and has also a degree „Master of Engineering“ of Purdue University (Indiana, USA). He received his doctorate degree in 1988 with a thesis on methods for „Monitoring and Charge Control of Batteries in Electric Vehicles“ from RWTH Aachen.

From 1989 to 2004 (from 1991 on as senior manager) he worked in the field of „Actuators and Mechatronics“ as well as new automotive power supply systems at Daimler Research in Frankfurt. Since 2004 he has been heading the development of testing methods for chassis and assistance systems as well as setting up test vehicles in Sindelfingen, since 2012 in addition he is head of the Driving Simulation Center of Daimler AG.

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