# Verifikation und Validierung von automatisierten Fahrzeugen

Bridging the Gap between Real Word Test Driving and Simulation for Automated Vehicles

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Realize innovation.

# TASS International
## Expanding our solution for Autonomous Driving

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A Siemens Business

***Since 2017***

**Domain expertise, software solutions and services in automotive high growth segments:**

**Autonomous driving**

**Advance driver assistance systems (ADAS)**

**Integrated safety (active and passive)**

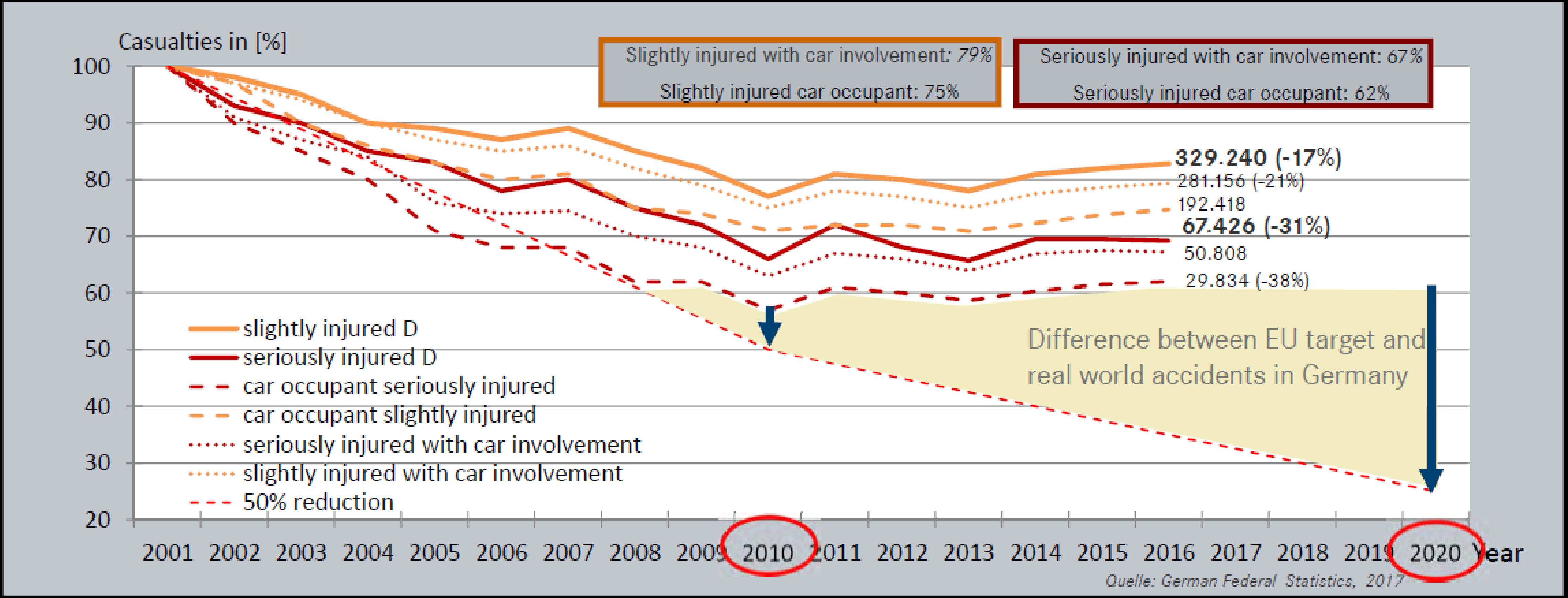
**Tire modelling and testing**


COURTESY: TEMPE POLICE
Exterior View
abc ACTION NEWS
SAFETY
FIRST

# Accident Statistics Germany: EU-Targets

## Almost Stagnation of the Numbers for slightly and seriously injured People since 2010

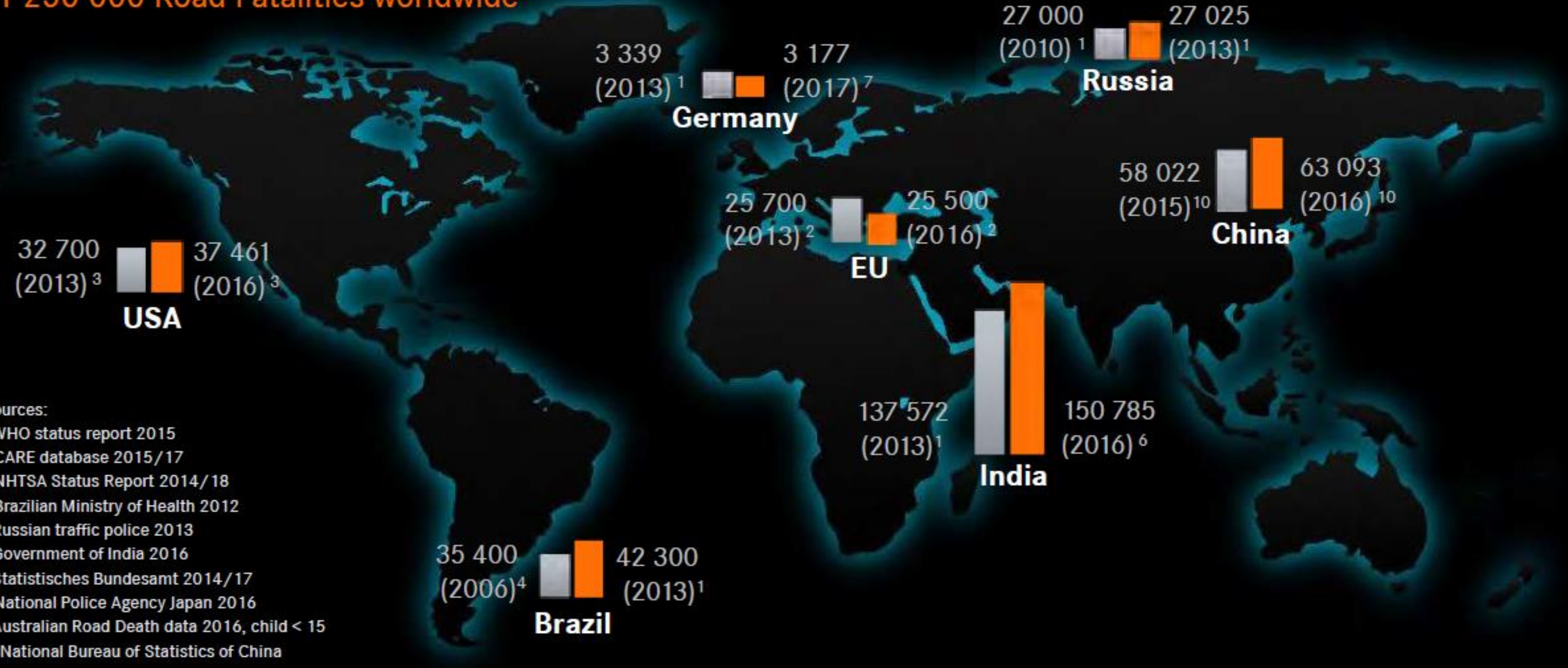
Mercedes-Benz Safety




- EU 2010 target: 50% reduction of seriously injured people was almost reached (44%)
- EU 2020 target: Another 50% reduction of seriously injured people does not appear to be viable anymore.

# Accident Statistics Worldwide
## Motivation for Further Safety Initiatives

1 250 000 Road Fatalities worldwide[1]




Sources:
- [1] WHO status report 2015
- [2] CARE database 2015/17
- [3] NHTSA Status Report 2014/18
- [4] Brazilian Ministry of Health 2012
- [5] Russian traffic police 2013
- [6] Government of India 2016
- [7] Statistisches Bundesamt 2014/17
- [8] National Police Agency Japan 2016
- [9] Australian Road Death data 2016, child < 15
- [10] National Bureau of Statistics of China

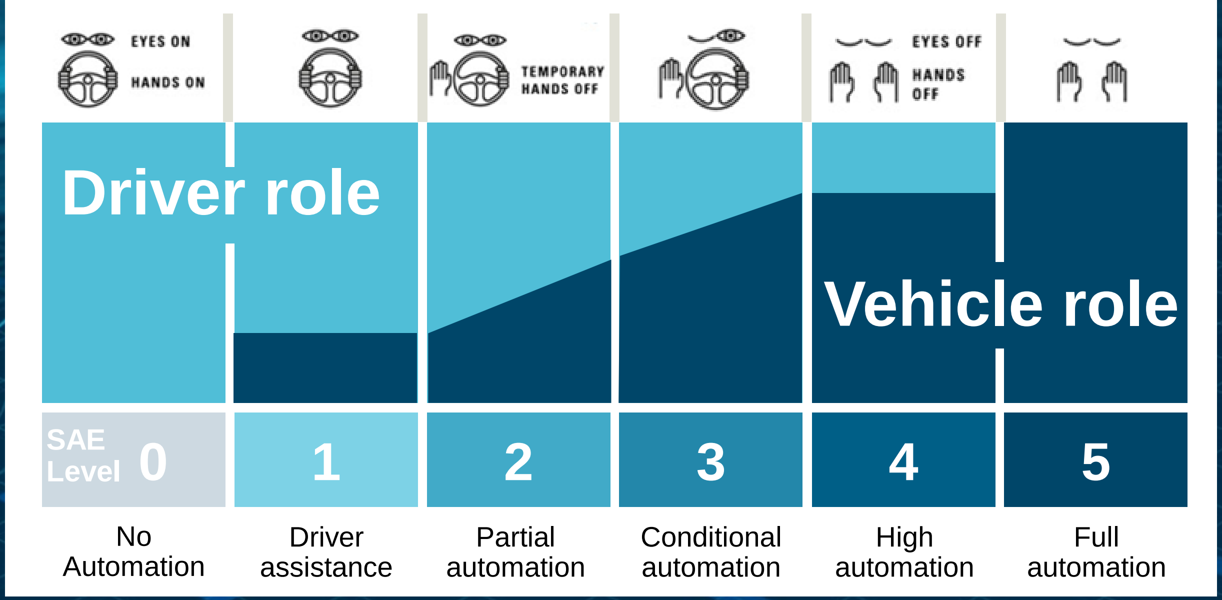

Automation can reduce the largest risk…
The Driver!

# Addressing engineering challenges for autonomous driving …

## FROM ADAS TO AUTONOMOUS DRIVING …

**“14.2 billion kilometers of testing is needed”**
Akio Toyoda, CEO of Toyota
Paris Auto Show 2016

**“Design validation will be a major – if not the largest – cost component”**
Roland Berger
“Autonomous Driving” 2014



# Vehicle Certification

*Proving compliance to meet regulatory and liability requirements*

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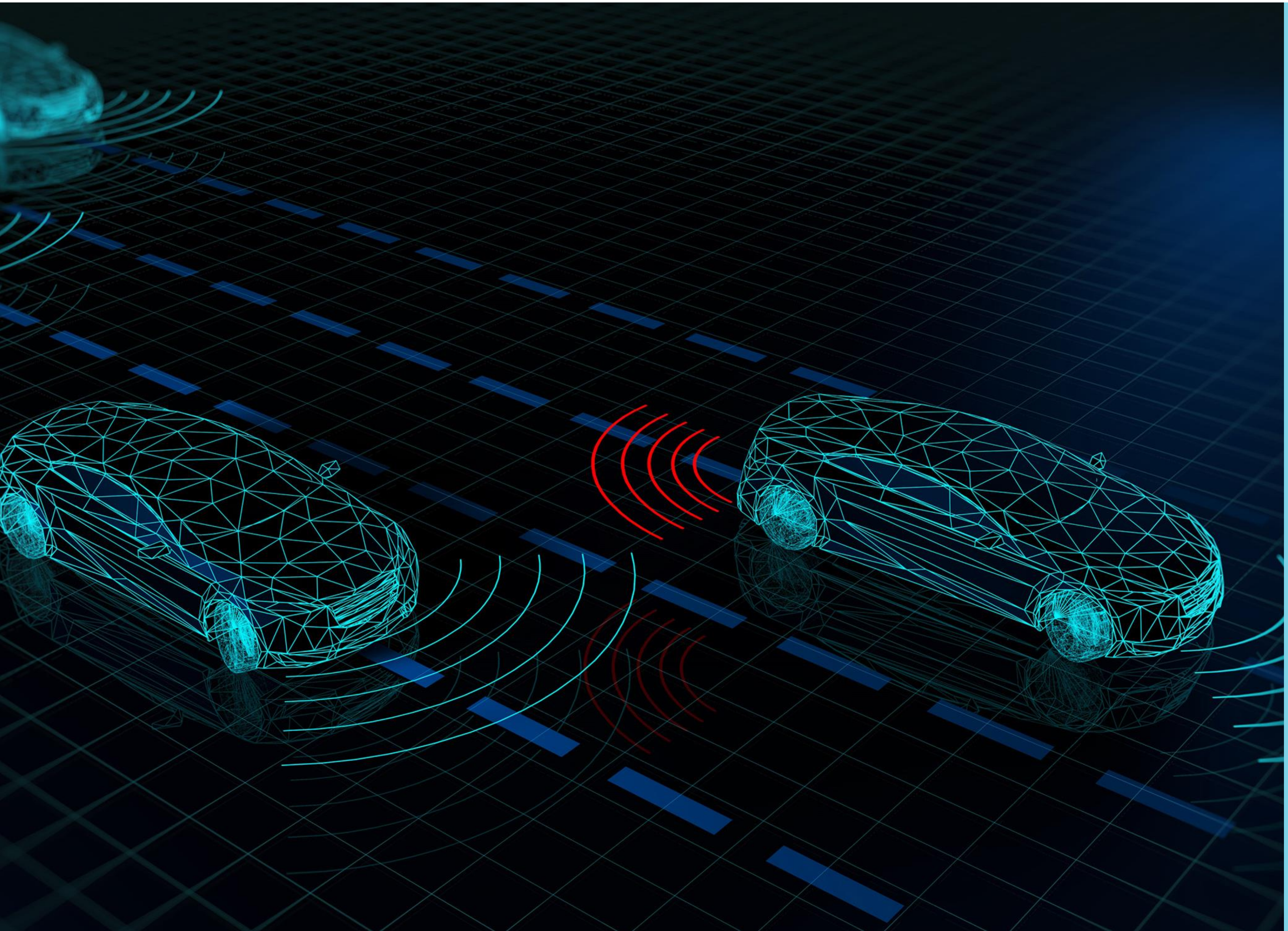

BUSINESS PROBLEM

**Reaching Level 4/5 autonomous vehicle certification is not feasible with physical testing.**

# Bridging the Gap between Simulation and Physical Testing

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## Why Bridging?

To connect virtual and real world testing with the purpose to:

1. Increase effectiveness and efficiency
   (saving time, saving money)
2. Enhance quality and robustness
   (less risks, better products&services)

# Bridging the Gap between Simulation and Physical Testing

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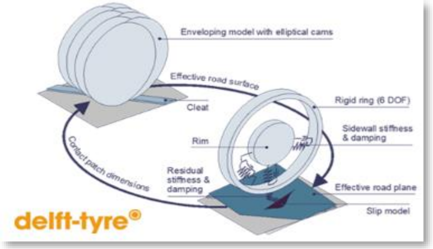
## Main pillars:

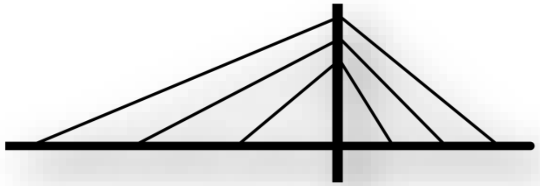
1. Suite of simulation models with various levels of fidelity & performance

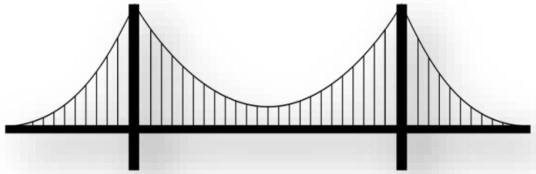
2. Using measurement data for model correlation & model validation

3. Tool-suite used throughout the entire verification & validation










## Bridges need pillars!

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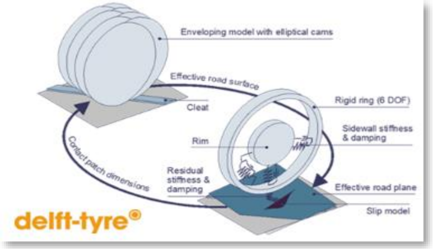
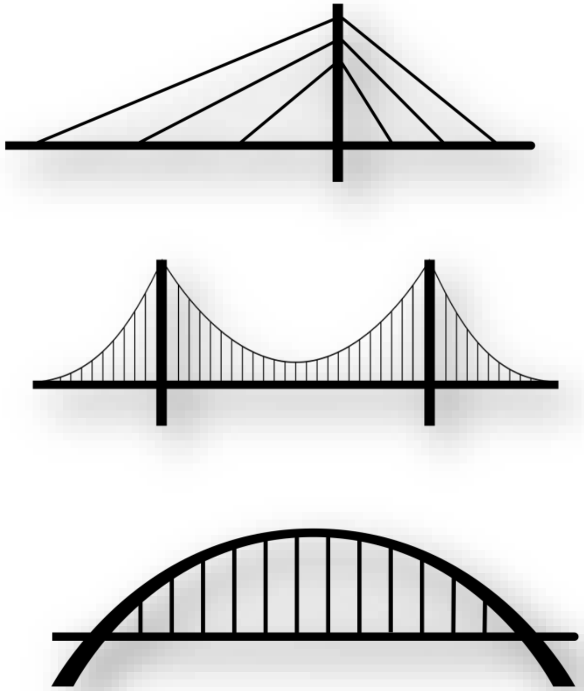


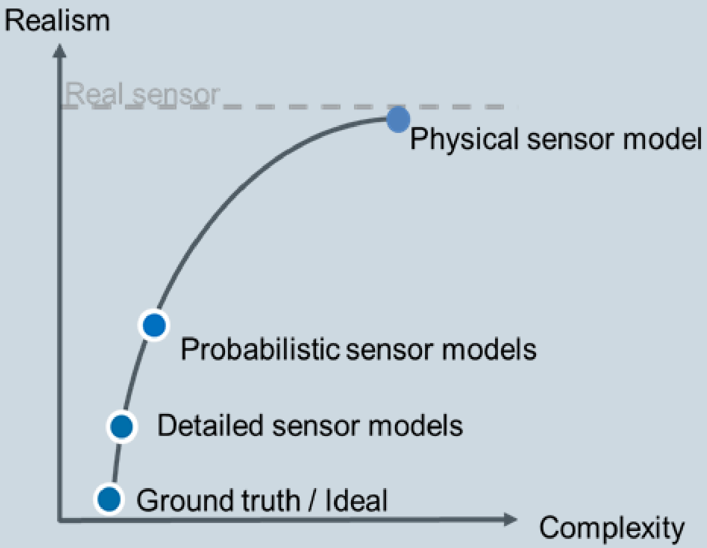



## Bridges need pillars!

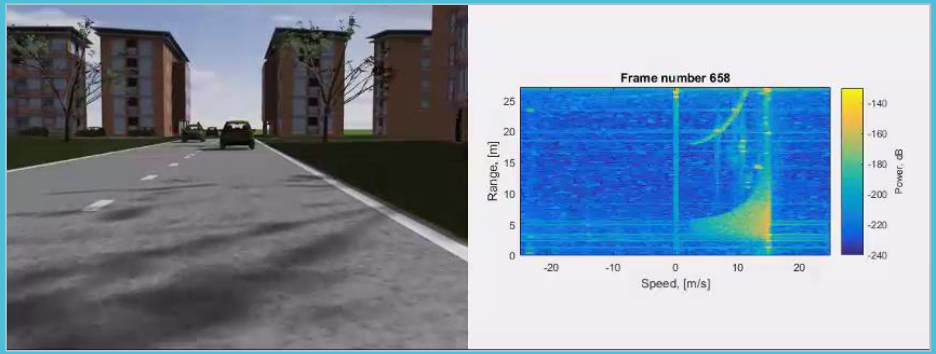
# Sensors in Environment

## Varying fidelity level sensor modelling

### Balancing accuracy and computation time of sensor simulations




**Lidar point cloud sensor**




**Physics-based Radar simulation**

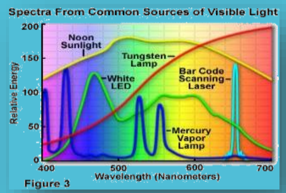
**Example: during night-time driving**

**Example: during tunnel entrance/exit**

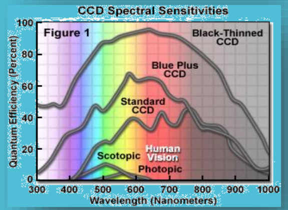
**PreScan Physics Based Camera (PBC) simulation**

# Sensors in Environment
## Raw Camera Sensor Model

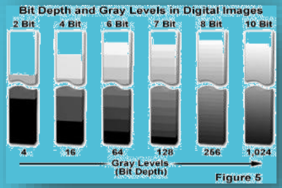
## World Model




Broad spectral range and user defined bands of interest




Increased intensities, High Dynamic Range




32bit color depth

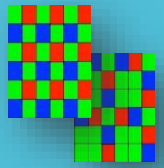
Full Spectrum

Atmospheric Model

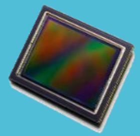
## Camera sensor

Optics

Color filter array



Shutter



Imager

## Algorithm

Object Detection & Classification

Sensor Fusion & Risk Estimation

Driver Warning & Vehicle Control

Light

Electronic signal

# Sensors in Environment
## Ground-truth annotated reference data

**Camera image**

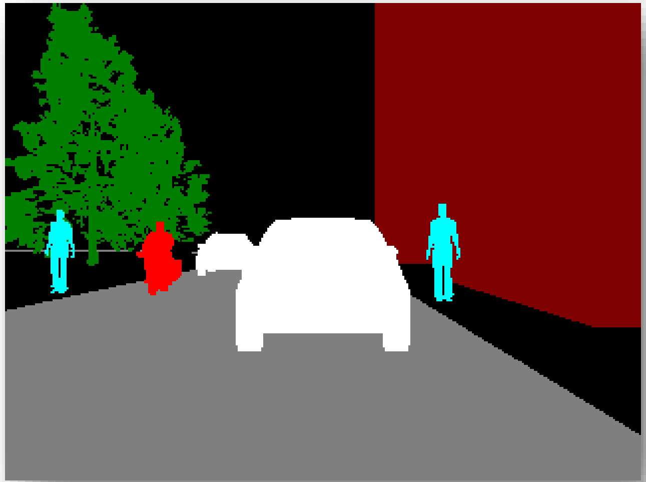
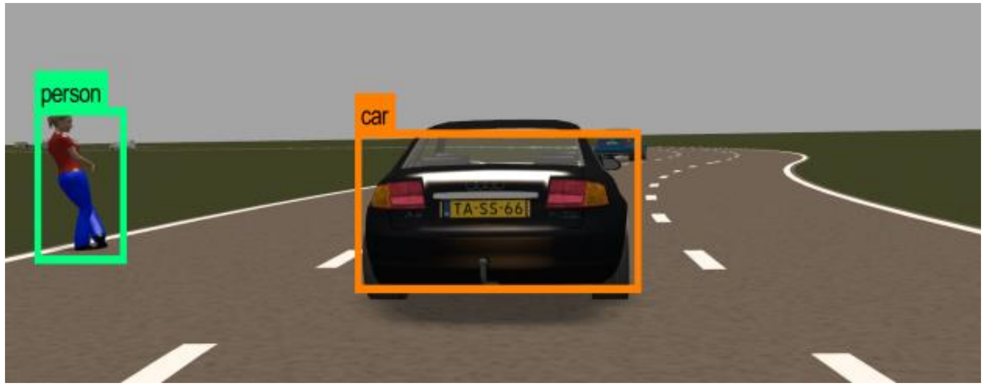


**Image Segmentation based on object types**

**Image Segmentation based on unique objects**

- ➢ Image Segmentation not only for camera simulation, but also usable for radar and lidar simulation
- ➢ Image Segmentation can be combined with other “reference sensors” (e.g. bounding boxes, depth cameras)



# Sensors in Environment
## Using for data for deep learning

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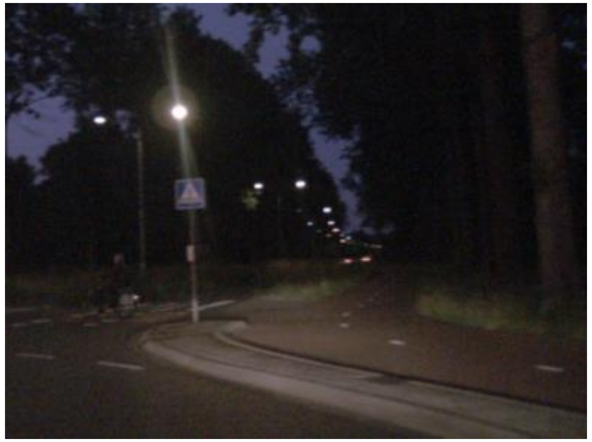
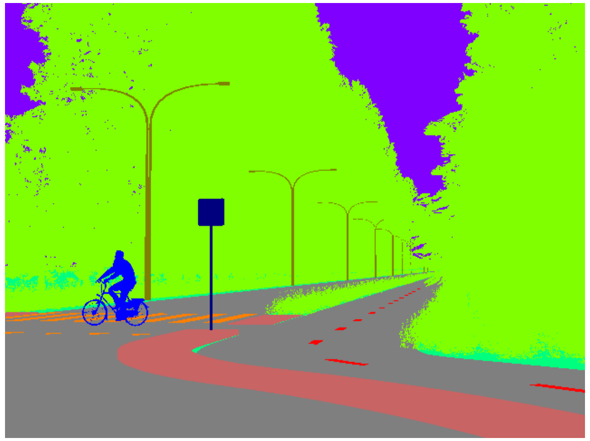
German Research Center for Artificial Intelligence





Real images from automotive camera

Synthetic images from PreScan Physics Based Camera (PBC) model

Segmented images from PreScan Image Segmentation Sensor (ISS)

# Occupant modelling for safety and comfort


Active human modelling in an autonomous evasive lane change scenario

# Occupant modelling for safety and comfort

## Braking example for AV

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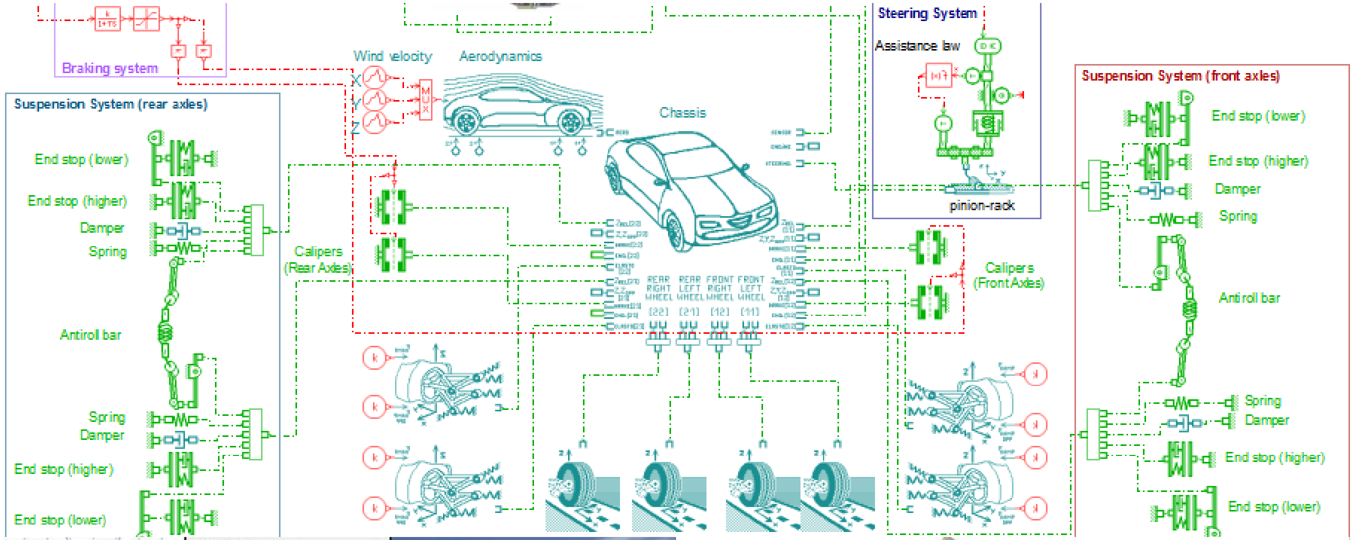
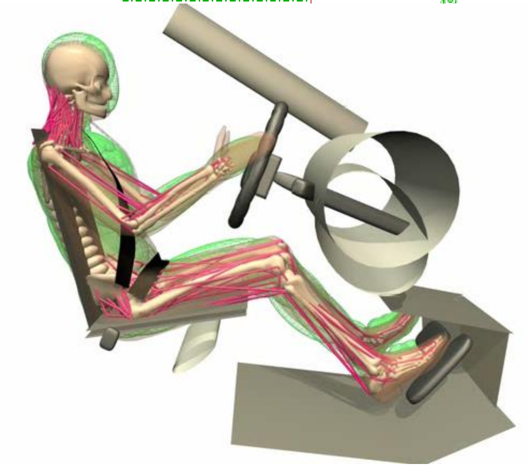
Autonomous controls simulation combined with accurate vehicle dynamics modelling to predict human behavior in pre-crash and crash stages



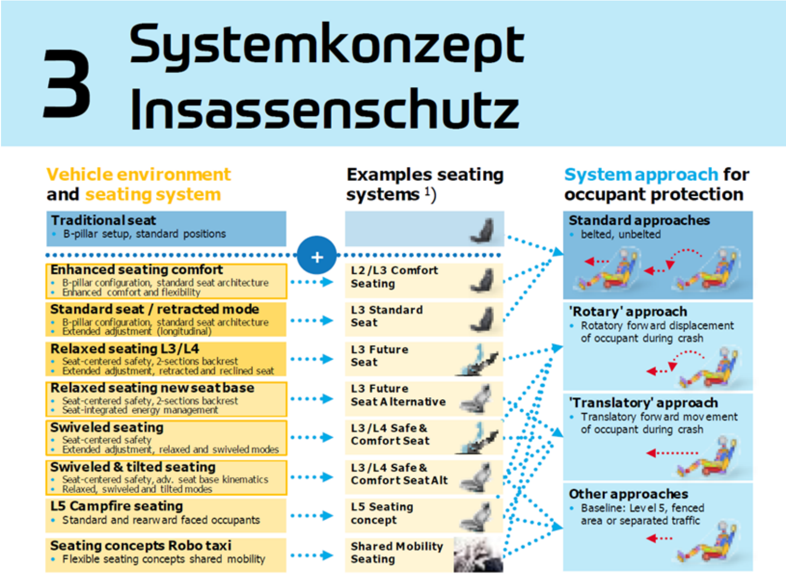




# New Mobilty Safety Requirements

(Source ZF Group, Dr. Büchsner, VDA Kongress 2018)





# Active Human Fidelity

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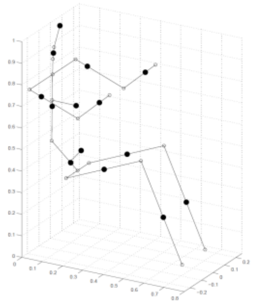
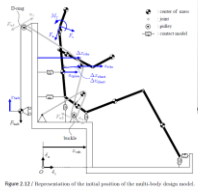
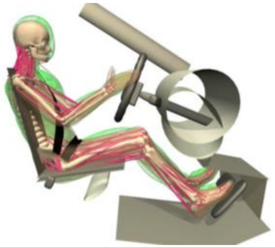
Simulation speed



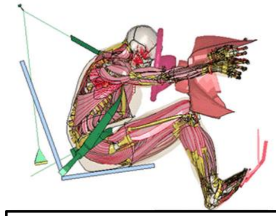


REAL-time human models for Integrated Safety system exploration

1,000,000's scenarios
(Real-time Active Humans)



10,000's scenarios
(MB models like MADYMO Active Humans)



100's scenarios
(FE models like THUMS, GHBM)

Real World Test Driving

10's scenarios

Scenario coverage

# Tyre models for scalable roads conditions and temperatures

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delft-tyre®

# Bridging the Gap between Simulation and Physical Testing

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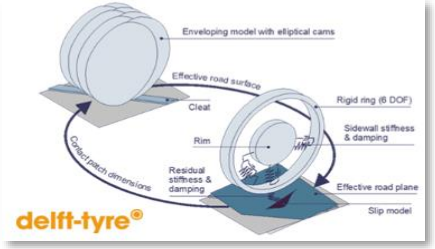
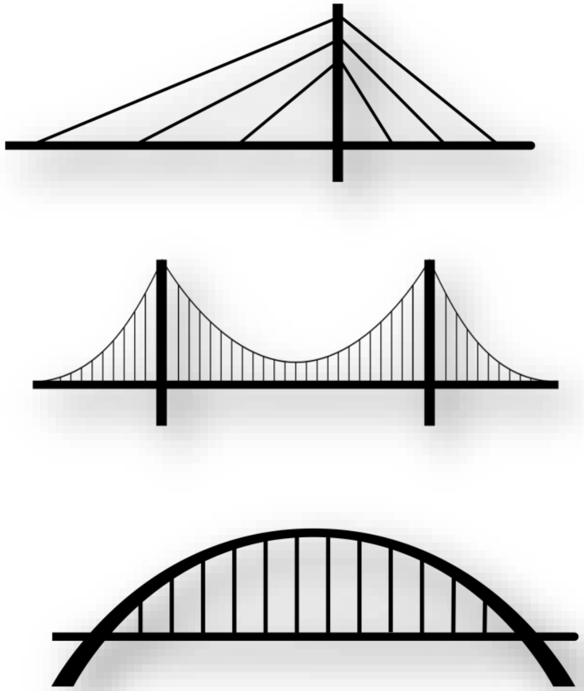
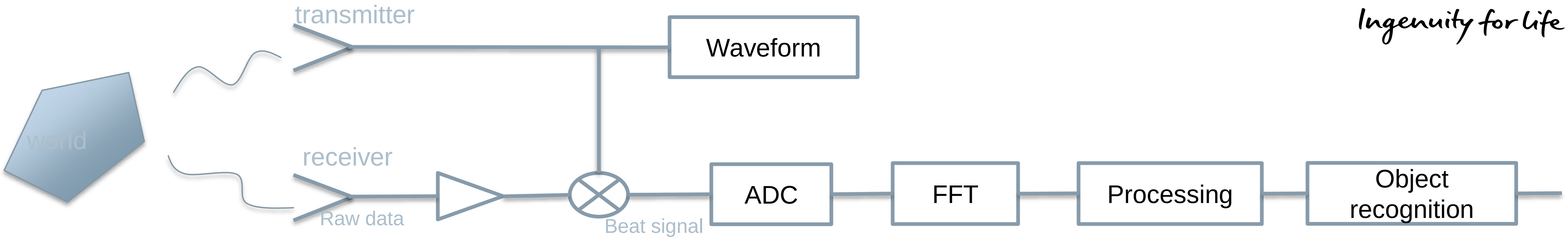


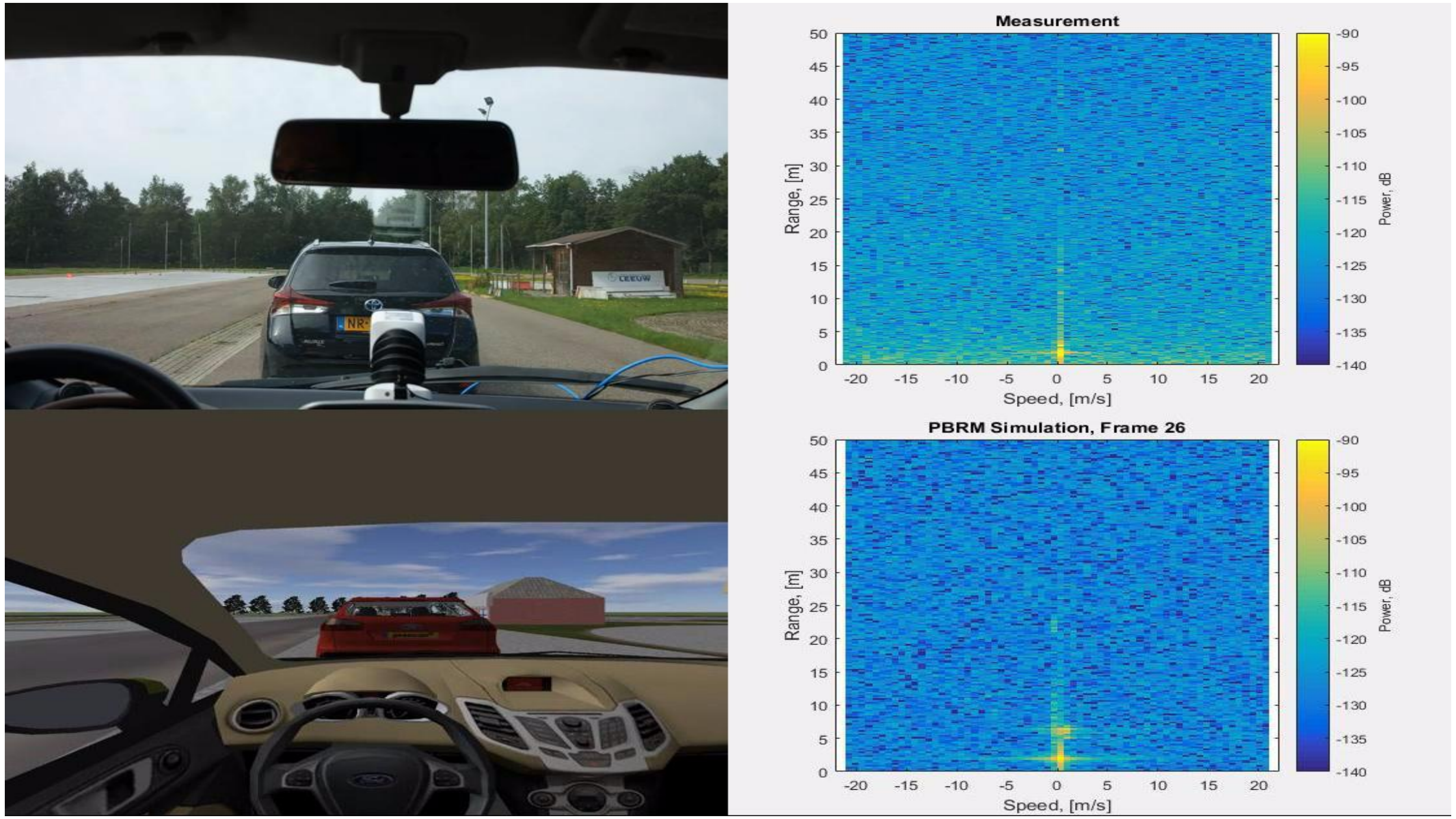






**Bridges need pillars!**

# Raw radar sensor model validation



# Example: Stochastic Sensor Model Creation

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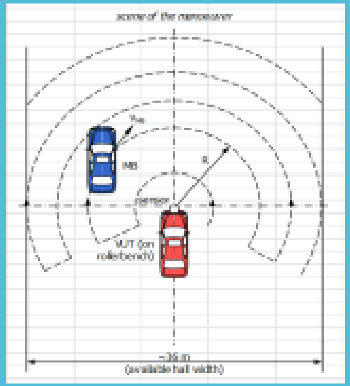
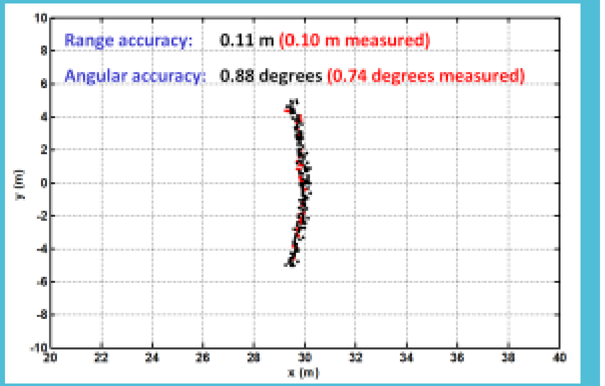
- Using measurements in laboratory to characterize sensor's
  - Range accuracy
  - Angular accuracy
  - Maximum range
  - FOV
- From multiple runs, the statistical error on range and angle is determined
- Sensor model parameters are tuned to match results of the experiments




# Validation and Verification – Scenario Modeling

## Translation real world recordings into Prescan scenario definitions

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# Validation and Verification – World Modeling

## Based on real world recording – Compatible with standard data bases

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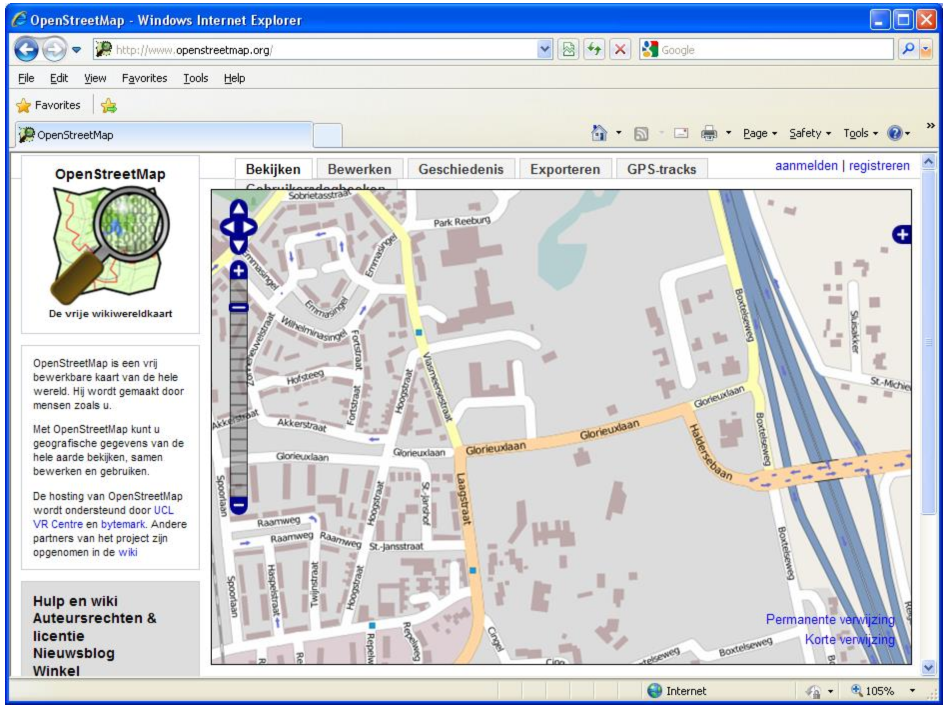
### OpenDrive / OpenScenario / Open Street Map importer

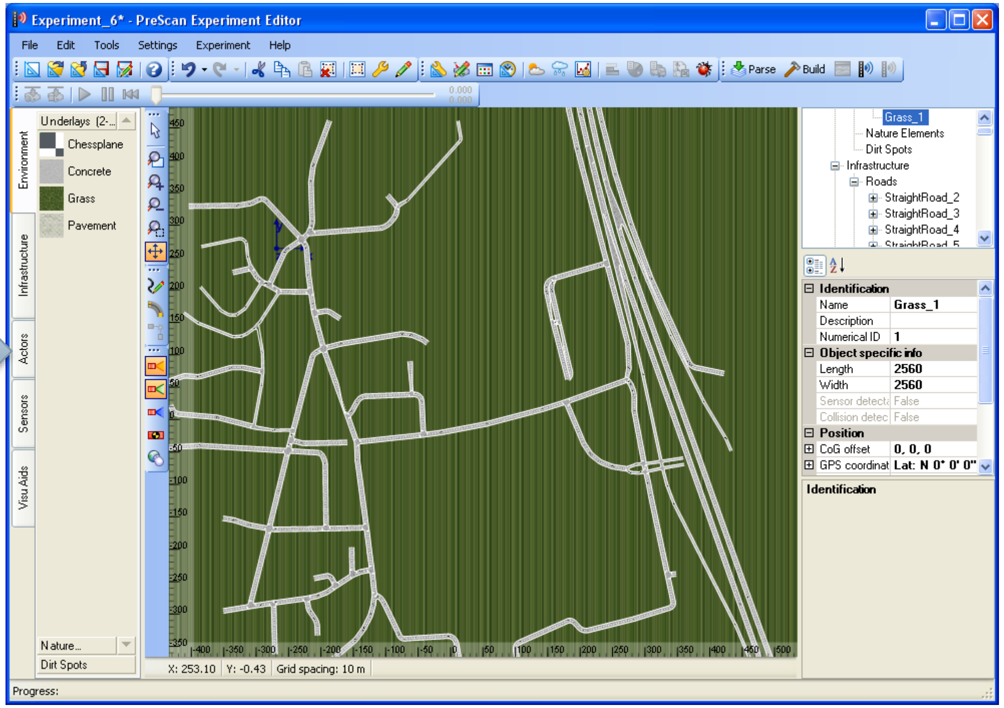
OpenDRIVE™

OpenSCENARIO

- ✓ Import a road network from OSM as an alternative to building it yourself
- ✓ The road network is automatically placed at the correct GPS location in the PreScan experiment




Open Street Map




PreScan

# Validation and Verification – Scenario Modeling

## Based on real world recording – Compatible with standard data bases

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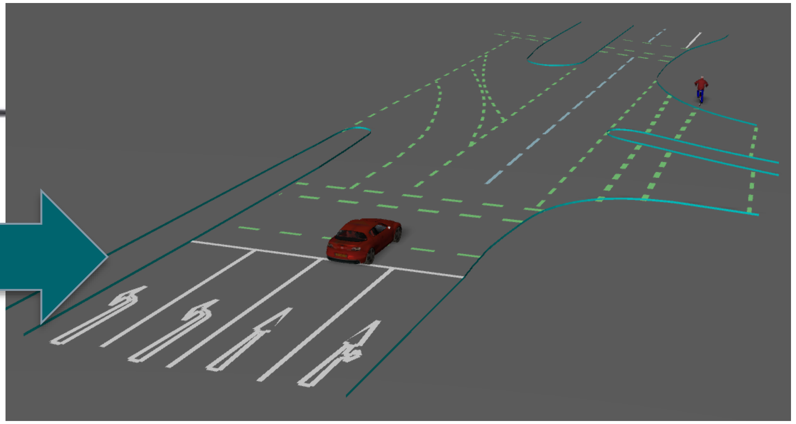
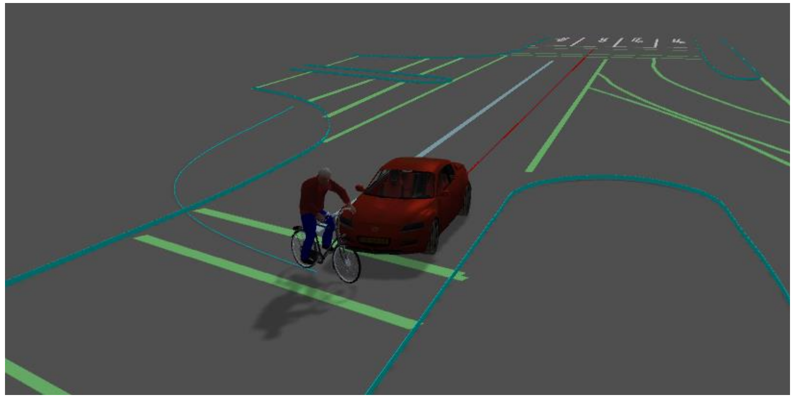
GIDAS German In-Depth Accident Study



The GIDAS database contains approximately 30.000 accidents collected since 1999

A GIDAS dataset describes the 5-second pre-crash phase of a traffic accident at 100Hz, including information about the motion of the traffic participants, the road network and the road environment



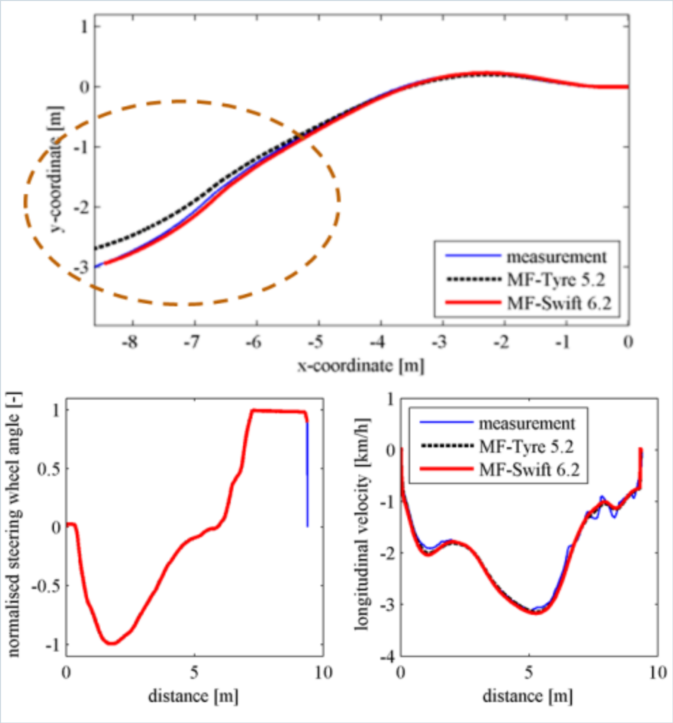
prescan

**The PreScan-GIDAS plug-in converts GIDAS datasets into PreScan experiments**

# BMW
## Trajectory planning in automated parking scenarios with Delft-Tyre

- **Tyre behavior in slow speed parking manoeuvers significantly influences the trajectory of the parking car**
- **For the design and validation of automated parking scenarios dynamic tyre behavior prediction is critical**

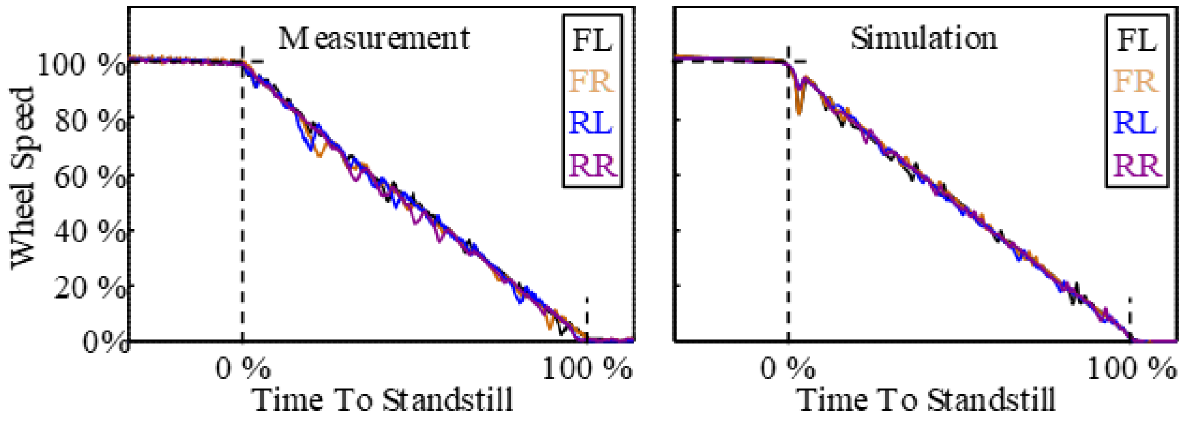
### Validation by means of instrumented vehicle tests

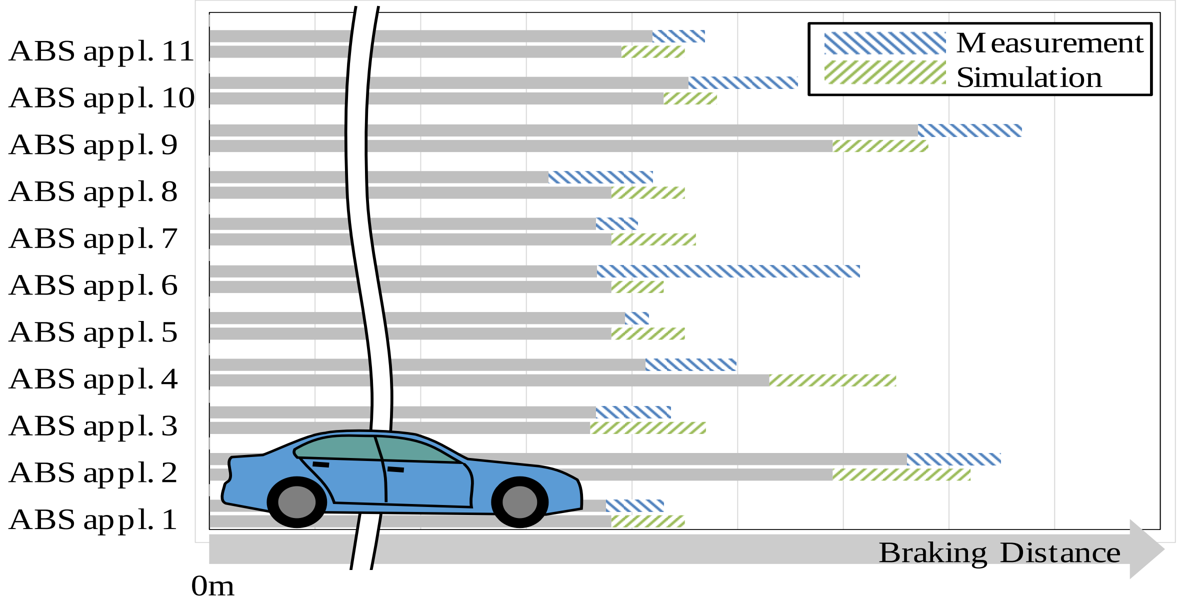



Example: Ramp steer test at 5 km/h
- Prescribed steering angle and velocity
- Measured trajectory (x,y)
- Measurements done on the vehicle to validate the Delft-Tyre models
- Comparison with MF-Tyre 5.2 (no turn slip functionality)
- Significantly improved response with MF-Swift 6.2 (with turn slip)

# Application example: ABS braking

- Comparison at vehicle level: simulation model compared with a test vehicle
- Different ABS settings have been tested with:
  - Full measurements on a closed proving ground
  - Full vehicle simulation
- Influence of ABS settions on braking distance are predicted well in simulation
- Difference between simulations and measurements is within test repeatability




ATZ worldwide, June 2017, Volume 119, Issue 6, pp 16–21

# Example: Active Human model validation

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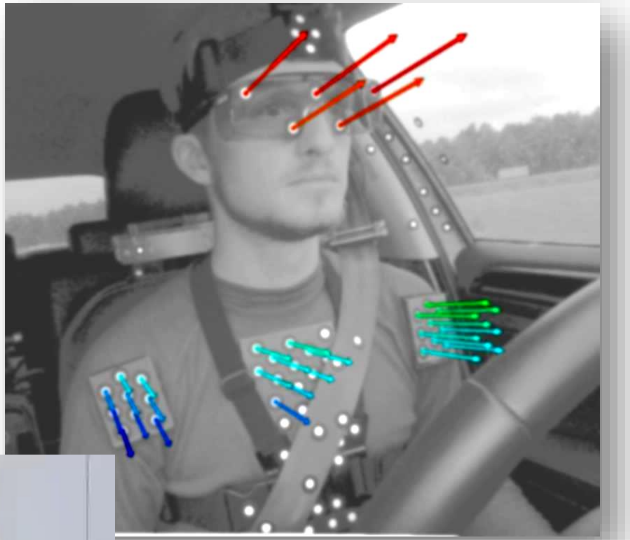
Frontal braking



Lateral acceleration

# Bridging the Gap between Simulation and Physical Testing

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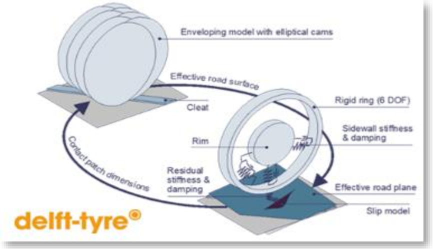


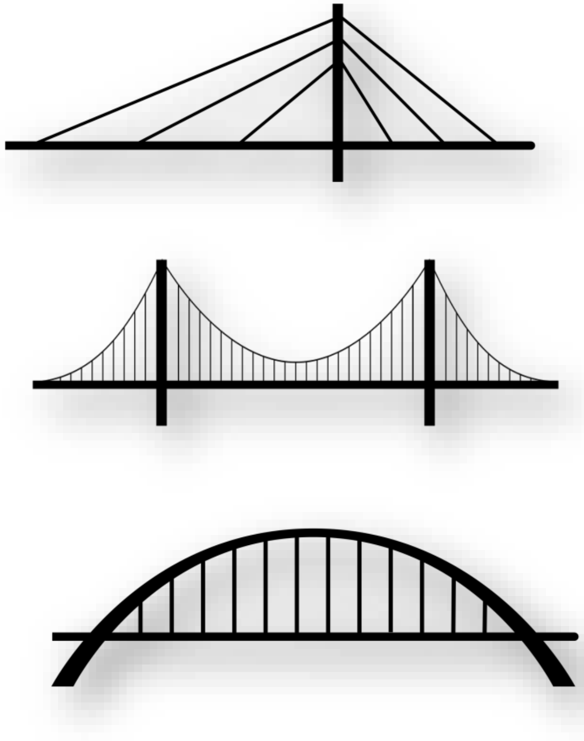




**Bridges need pillars!**

# Validation and Verification framework for AVs

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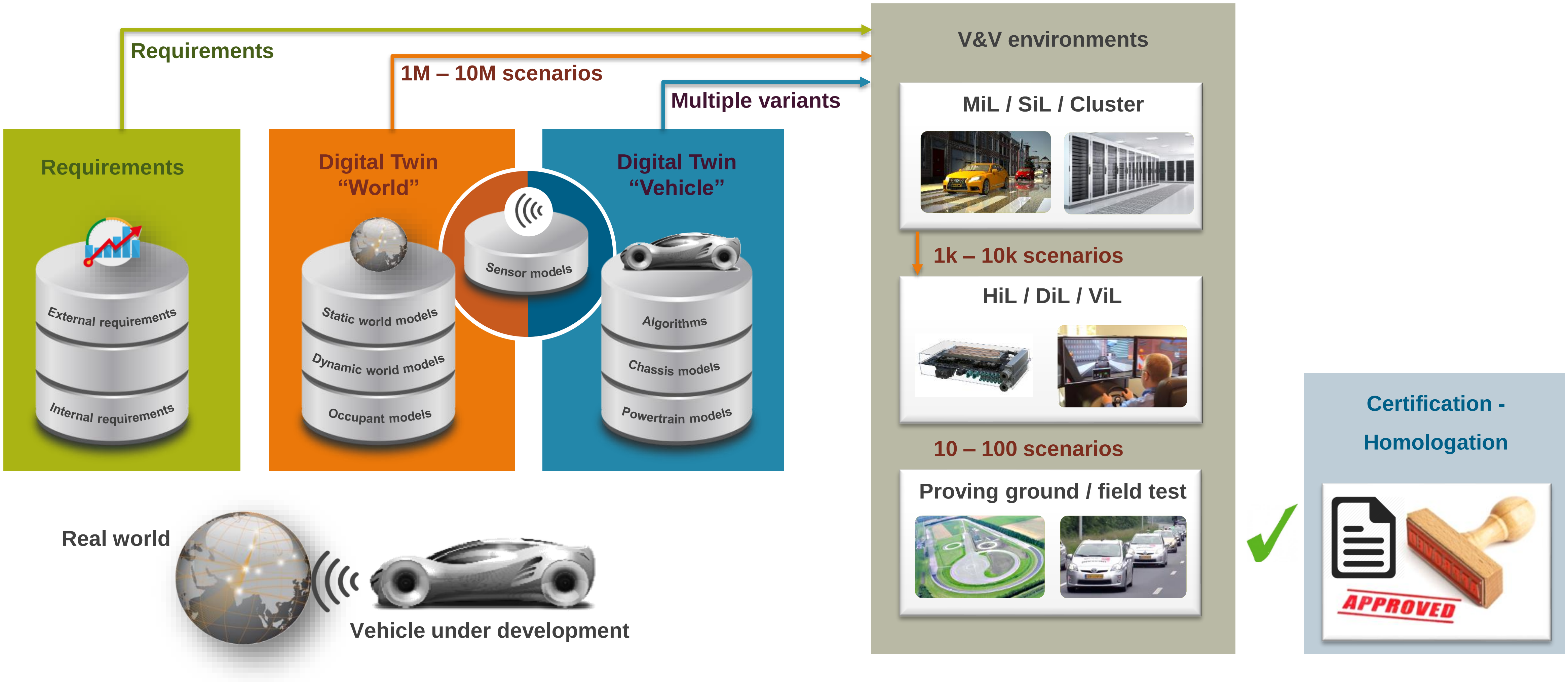

# Validation and Verification

## Real-Time Models – HIL Testing – Vehicle in the Loop Testing

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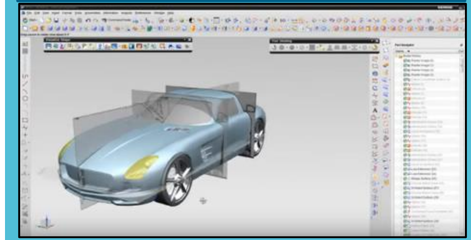
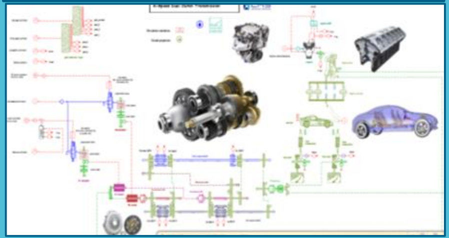
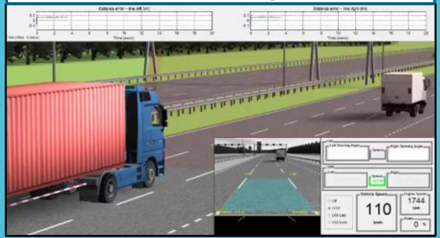
**3D Multi-Body**



**1D Multi-Physics**



**Environment, Traffic**



**Real-Time "Digital Twin"**

**Bridging between**

**Virtual and Physical**

**Prescan**

**Simcenter 3D Motion**

**Simcenter Amesim**

# Validation and Verification up to Certification

## Proving ground testing of autonomous vehicle technology

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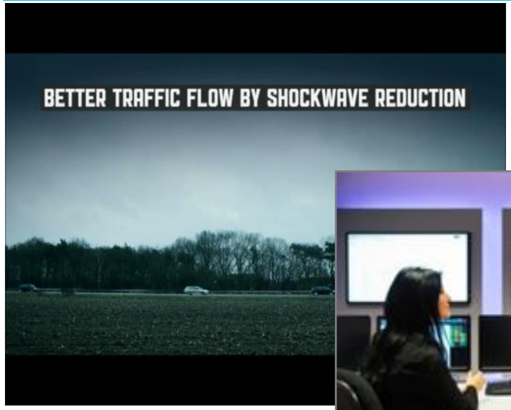
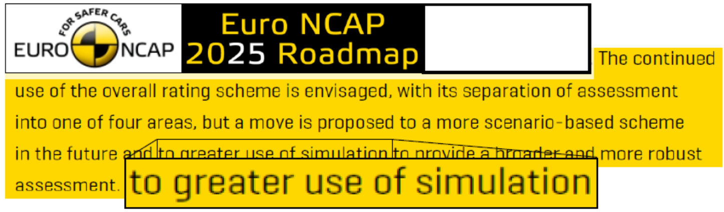
| | |
|---|---|
| **Laboratory testing** | **validating modules & systems in a controlled environment** |
| **Closed test-site testing** | **validating complete vehicle in a pre-conditioned environment** |
| **Open test-site testing** | **validating the networked system in a realistic environment** |





A270 Instrumented Motorway, Rural & Urban


EuroNCAP active safety testing


EURO NCAP FOR SAFER CARS
Euro NCAP 2025 Roadmap

The continued use of the overall rating scheme is envisaged, with its separation of assessment into one of four areas, but a move is proposed to a more scenario-based scheme in the future and to greater use of simulation to provide a broader and more robust assessment.

to greater use of simulation

# Validation and Verification up to Certification

## Willow Run American Center for Mobility

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Joint Press Release

Press

**by Siemens and American Center for Mobility**

Ypsilanti, Michigan, April 30, 2018

## Siemens strengthens position in connected and autonomous vehicles through partnership with American Center for Mobility

Siemens PLM Software and the Michigan-based American Center for Mobility (ACM) announced today a new partnership that brings Siemens' Simulation and Test solution for Automotive to ACM to support virtual and physical testing and validation of automa-

American Center for Mobility
CONNECTED. AUTOMATED. VALIDATED.

# What are we doing it for?

## Emergency brake scenario in PreScan software used by Volvo Trucks

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Jürgen Schüling
Juergen.Schueling@siemens.com
Realize innovation.