New levels at comfort, safety & efficiency

Driver Assistance and Autonomous Driving

Opportunities, Challenges, Solutions

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Content

- **Levels of ADAS and Autonomous Driving**
- **Motivation for ADAS and AD**
- **Challenges**
- **Solutions:**
  - **Human centric approach with objective assessment**
  - **Combined road and virtual development approach**
  - **Cloud based ADAS/AD testing, application and validation**
- **Conclusion, questions, discussion**

Levels of Autonomous Driving

SAE

0	1	2	3	4	5
No Automation	**Driver Assistance**	**Partial Automation**	**Conditional Automation**	**High Automation**	**Full Automation**
Zero autonomy; the driver performs all driving tasks.	Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.	Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.	Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice. **2019 ?**	The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle. **2021 ?**	The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle. **2026 ?**

Driver controls the function → **Machine controls function**

NHTSA USA	No Automation	Function-specific Automation	Combined Function Automation	Limited Self-Driving Automation	Full Self-Driving Automation
BASt D	Driver only	Driver Assistance	Partial Automation	Highl Automation	Full Automation

Motivation for Autonomous Driving

THE MAIN THREE DRIVERS

▶ Safety („zero fatalities“)

95% of all accidents happen today due to human errors

▶ Comfort, services & business

Germans spend 560 million hours per year searching parking space

Use free time to work, eat, sleep, …

▶ Emission and energy reduction

Intelligent routing, platooning, efficient operation

Levels of Autonomous Driving

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Driver controls the function → **Machine controls function**

Driver has free

Driver can do different activities

New car usage with levels 3-5

Passenger transport from A to B plus …

Give the customer Time …

Living Room

Shopping

Relax

Work

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ADAS/AD challenges

Human acceptance

- Do we trust the machine ?
- Fun and comfort being driven ?
- Perceived safety

Safety & security

- Functional safety
- Data security
- Safety

Development time & cost

- Validation effort (L3+)
- High number of scenarios
- Calibration effort
- Time to market, cost

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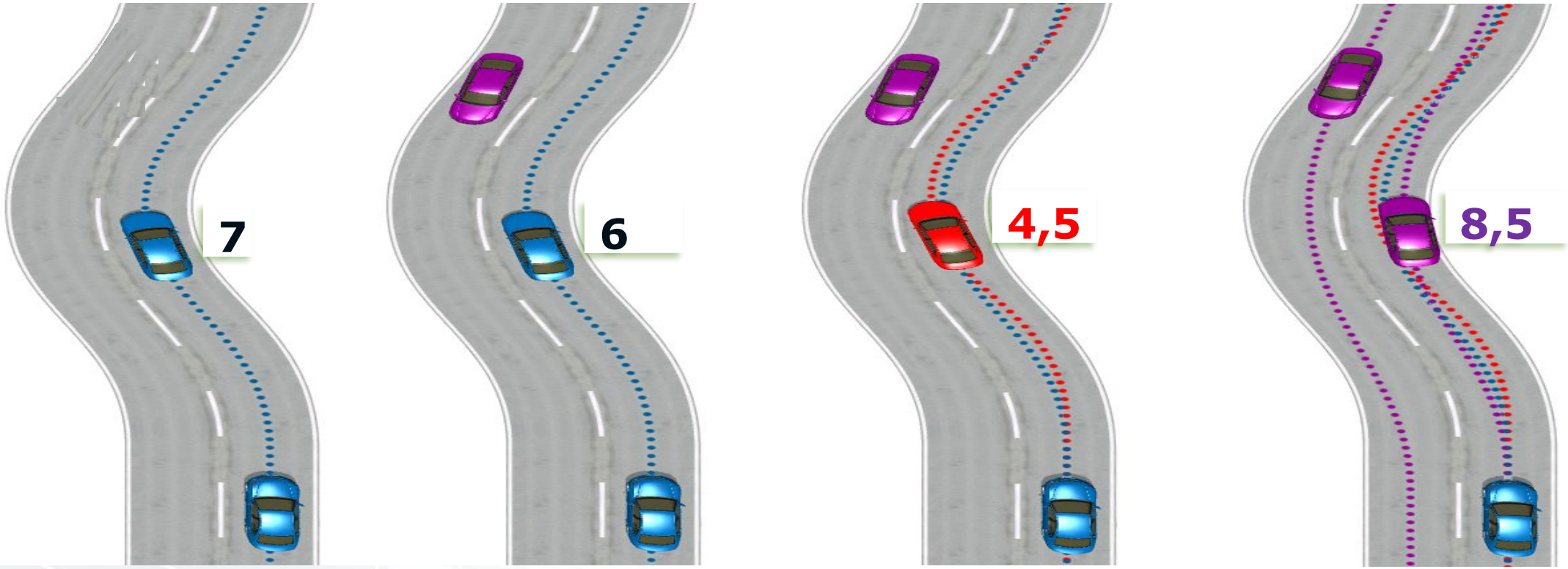
LKA / ACC ON
MOVIE

Human centric approach

1. Understand human demands, 2. Objectify human feeling
3. Apply objective methods in the complete development process

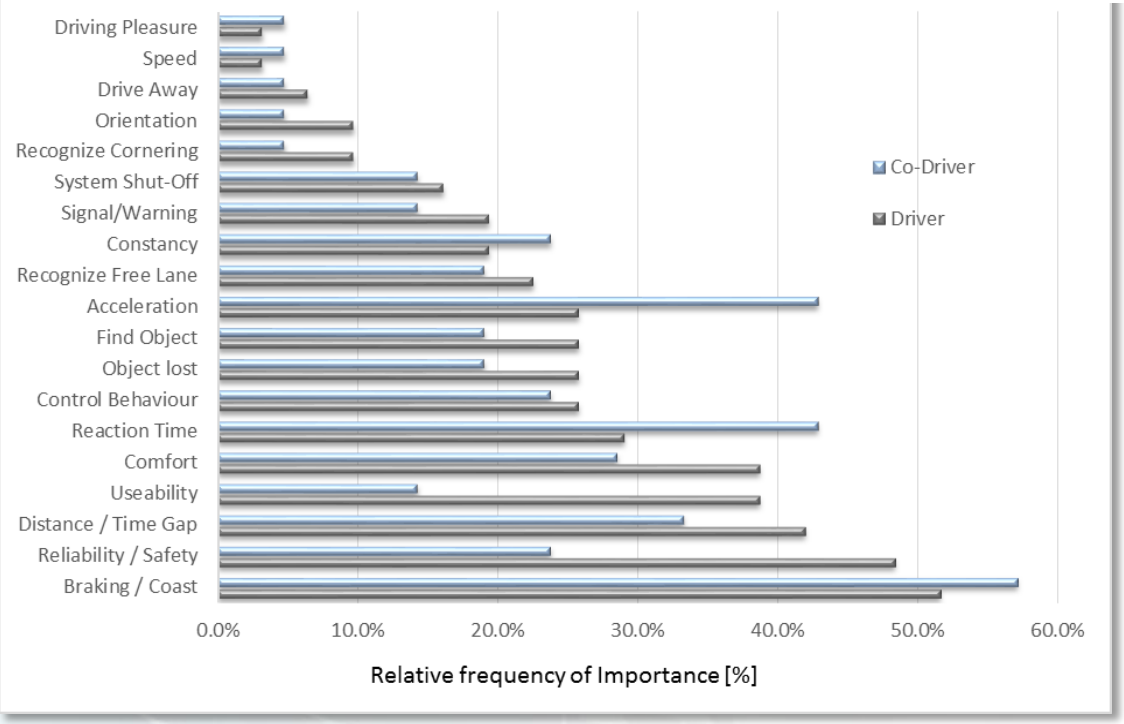


1. Permanent lane centering is not perceived well
2. A good lateral control informs about object detection (e.g. via small path correction)

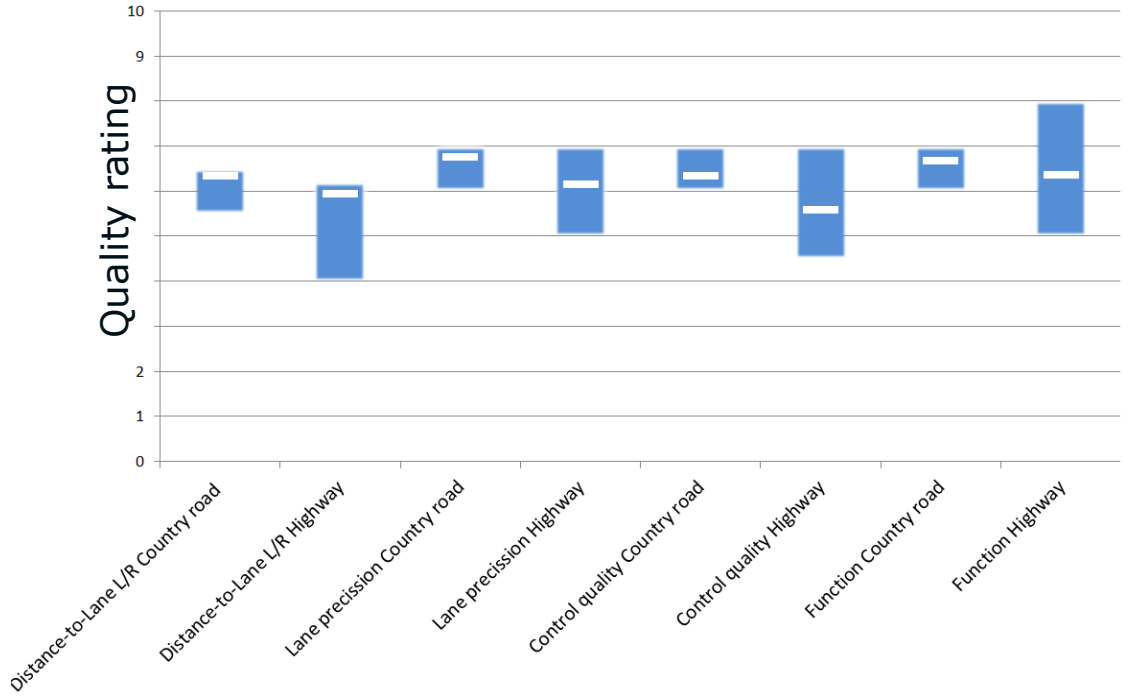
Human centric approach

1. Understand human demands, 2. objectify human feeling
3. Apply objective methods in the complete development process

Importance of ACC criteria, customers



Subjective LKA ratings, experts

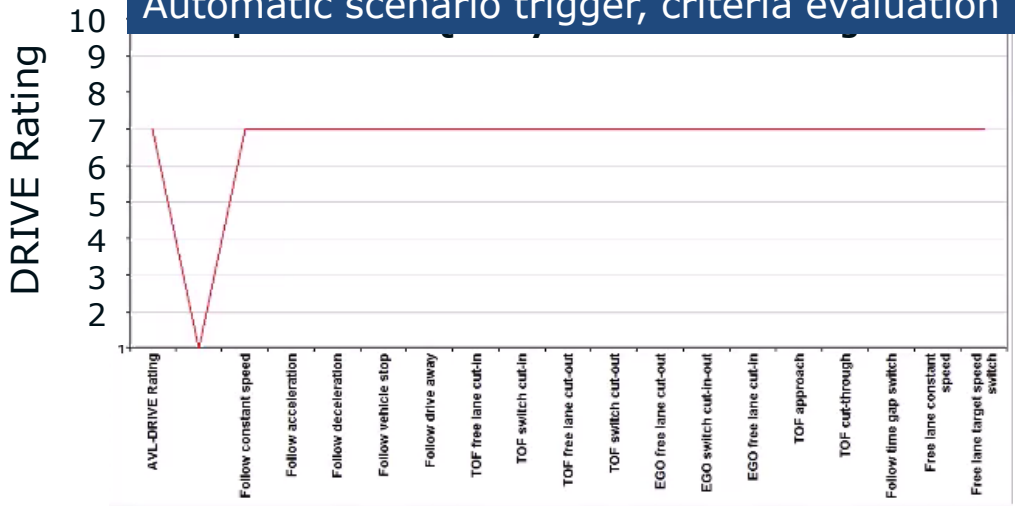


Perceived safety, safety and comfort are the most important criteria

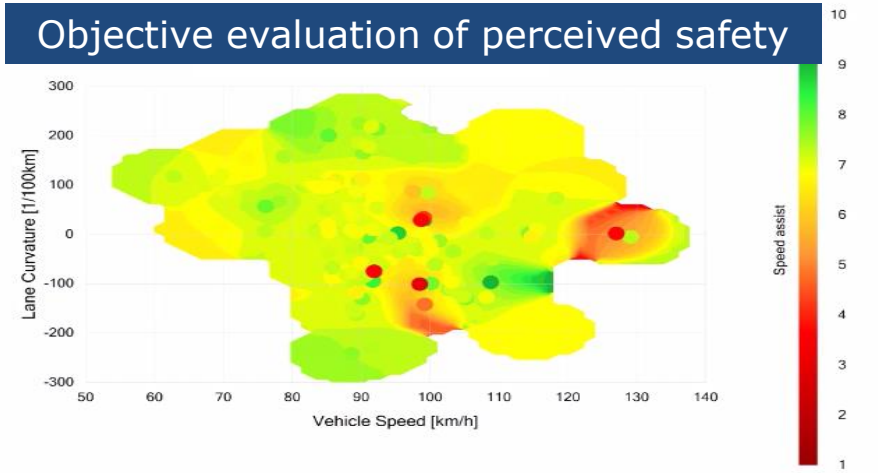
Objective ADAS/AD Assessment

- **Automatic real time evaluation of L2-L5**
  - **Safety, perceived safety, comfort**
  - **Automatic evaluation, one click reporting**

Automatic scenario trigger, criteria evaluation



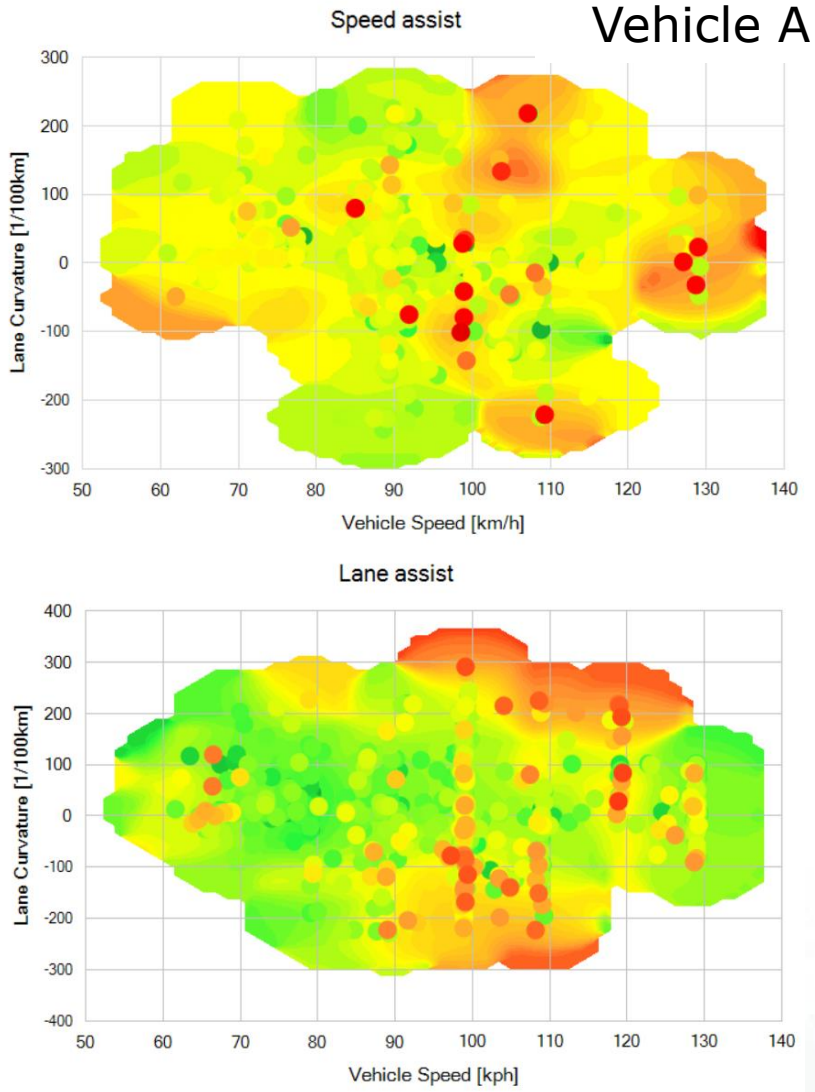
Objective evaluation of perceived safety



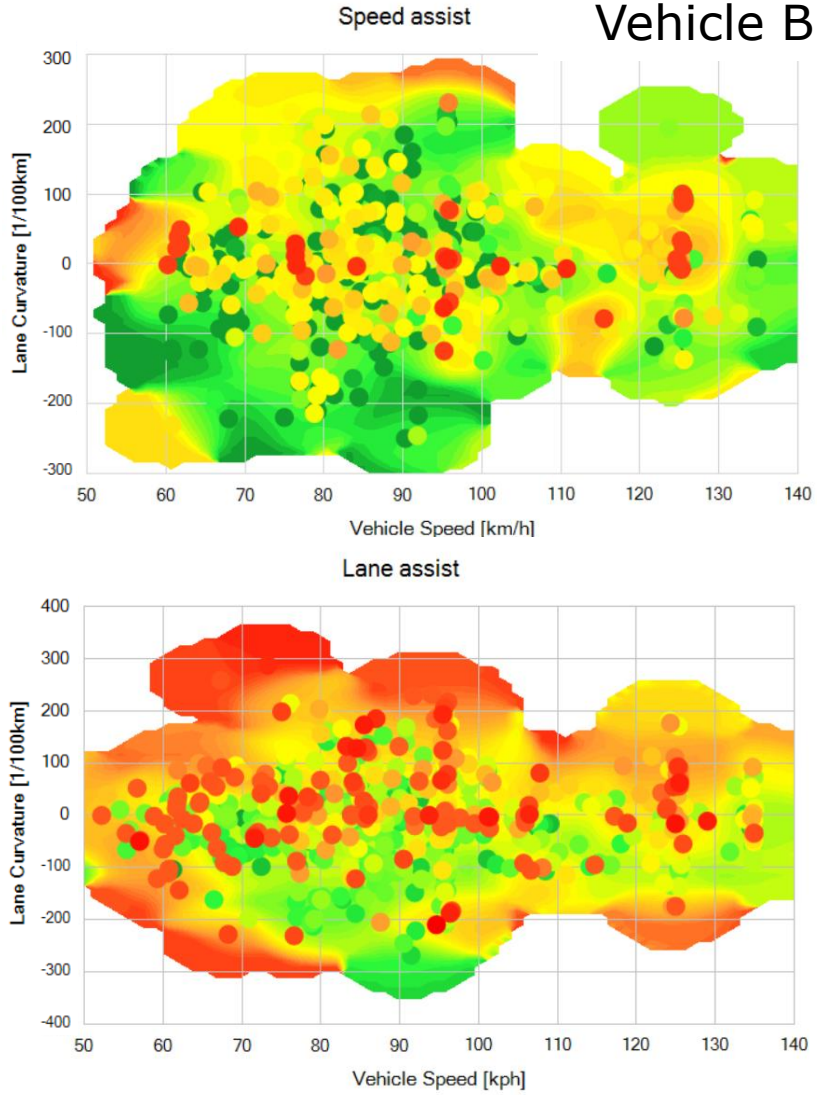
Consideration of human feeling, objective development targets

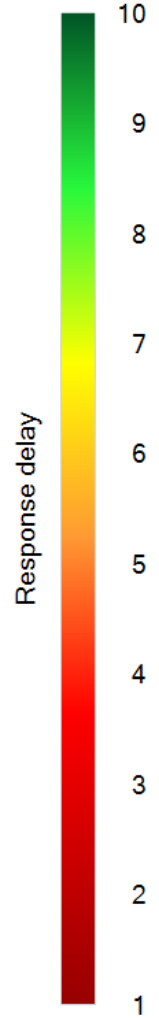
Perceived quality rating comparison

Vehicle A

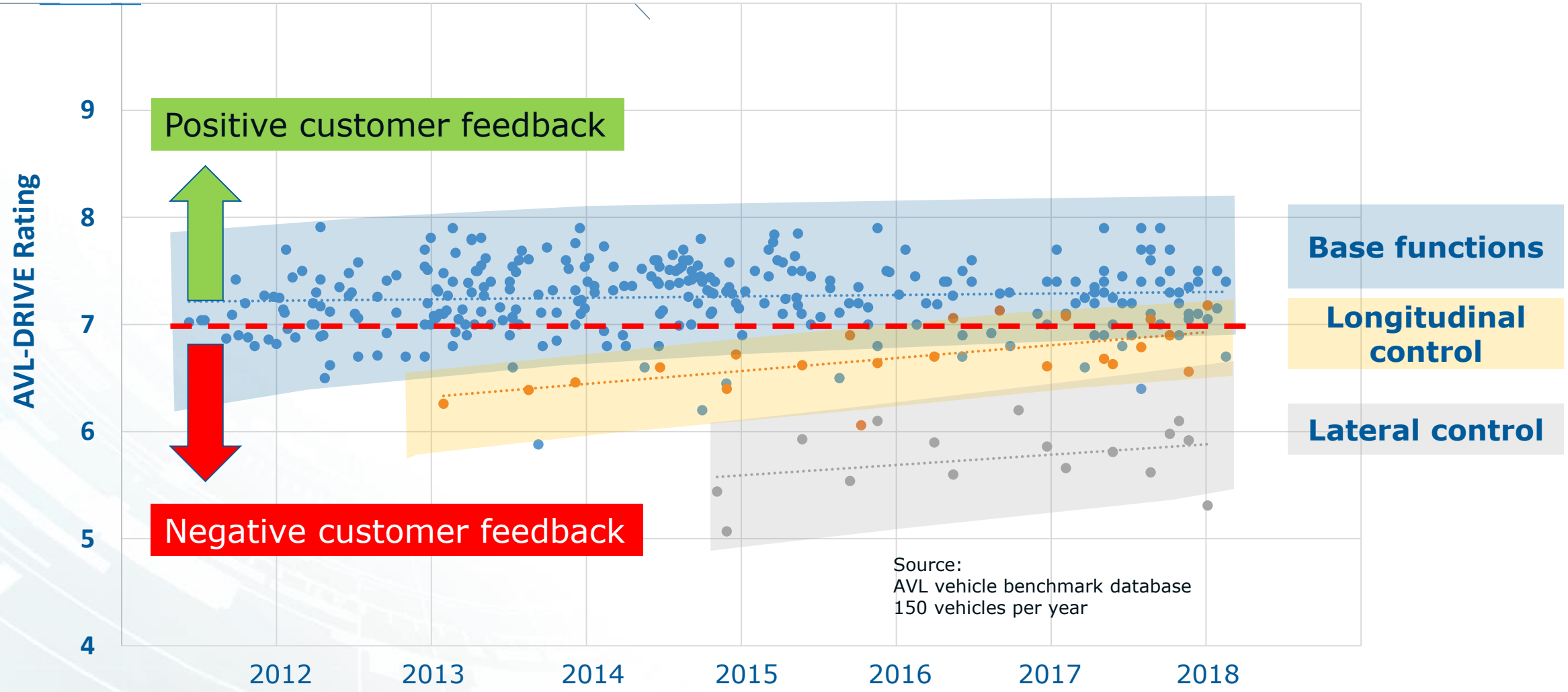


Vehicle B





AVL Vehicle Benchmark Database



Many lateral control systems are still critical in terms of perceived safety and comfort

ADAS/AD challenges

Human acceptance

- Do we trust the machine ?
- Fun and comfort being driven ?
- Perceived safety

Safety & security

- Functional safety
- Data security
- Safety

Development time & cost

- High number of scenarios
- Huge calibration effort
- Validation effort (L3+)
- Time to market, cost

Why so much testing necessary for Level 3+ ? 1/2

The Challenge

e.g. 30 Vehicle Variants

300 Cases

ADAS Control Unit e.g. 10 Assistant Systems

3.600 Cases

12 ACC Use Cases

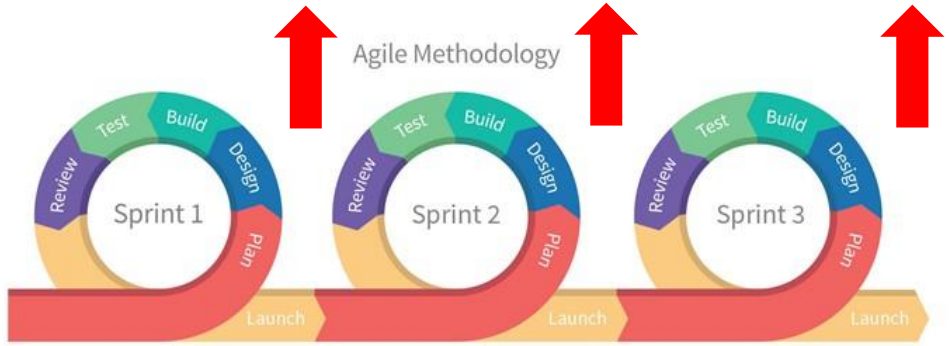
360.000.000 Cases

10.000 Test Cases

576.000.000 Cases * 0,5km

16 Parameters

288.000.000 km to test



Why so much testing necessary for Level 3+ ? 1/2

Safety of human driving - 2015

How much safer must AD drive than humans ?

10x	100x	1000x	10.000x	safer
130.000	13.000	1.300	130	fatals/year
5 Mio.	500.000	50.000	5.000	injured

1 fatal accident per 11 Mio. km in Germany
Necessary AD testing

110 Mio.	1,1 Bio.	11 Bio.	110 Bio. km

Testing duration: 100 cars, 10^5km/car/year:

11	110	1.100	11.000 years

Traditional testing approach not applicable -> New solutions required !

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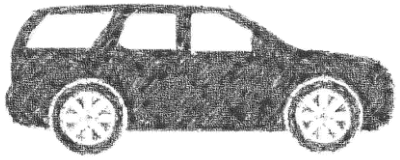
AVL Approach for Combined Road and Virtual Development

Real world
- ✓ *Testing*
- ✓ *Automated assessment*
- ✓ *Validation*

Model build up

Validation check



Virtual world
- ✓ *Simulation*
- ✓ *Assessment*
- ✓ *Optimisation*
- ✓ *Validation*

Variation of Scenario

Validation check

Cloud/Cluster
- ✓ *Simulation*
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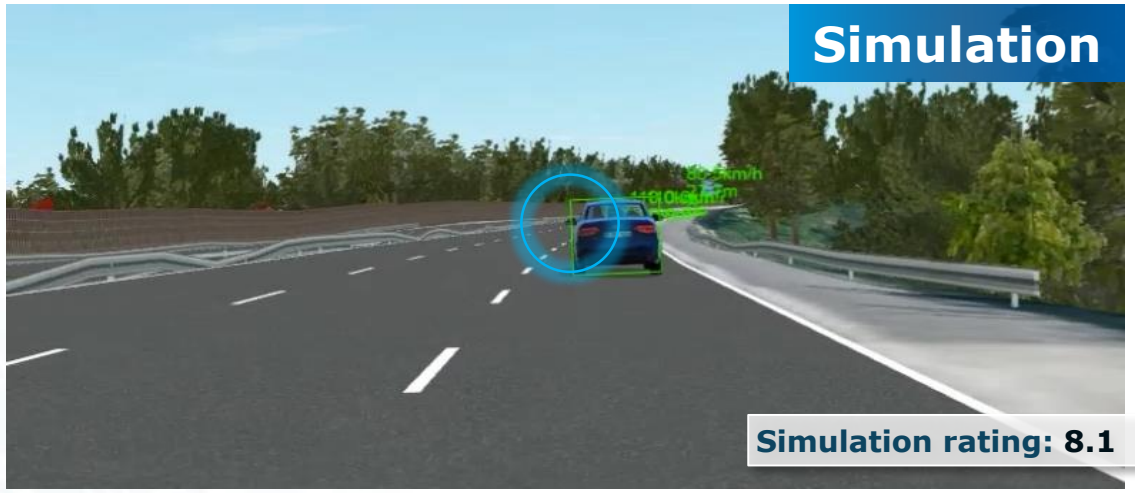
- ✓ *Validation*

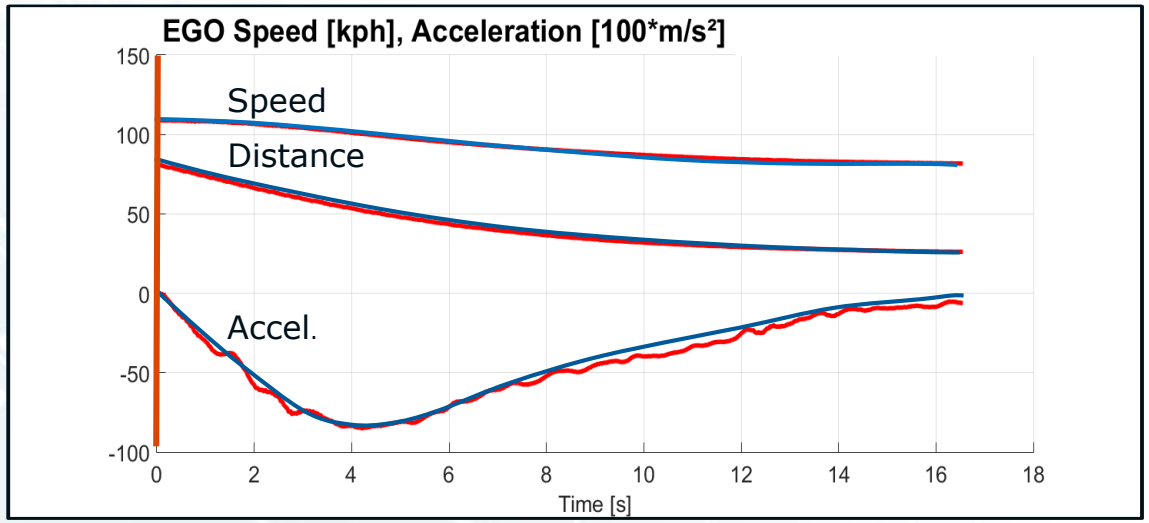
2.000 validated km/week

6.000 validated km/week

100 Mio. virtual validated km/week

Human centric scenarios plus safety relevant scenarios (NCAP)





CRITERIA	ACC			
	PERCEIVED SAFETY		COMFORT	
Response Delay	8.2	8.5	7.7	8.0
Min. Acceleration	8.3	8.5	7.4	7.8
Fallback Distance	8.7	8.2	8.2	7.9
Control time	-	-	6.8	7.2
Ax Roughness	-	-	8.1	8.7
	Road	Simulation	Road	Simulation

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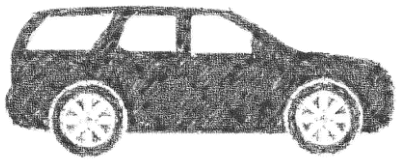

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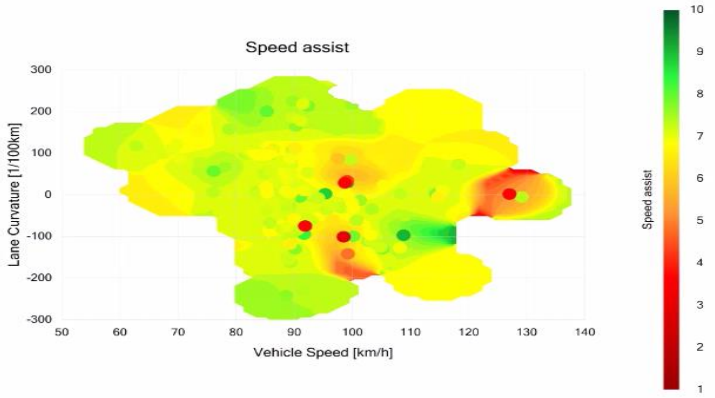
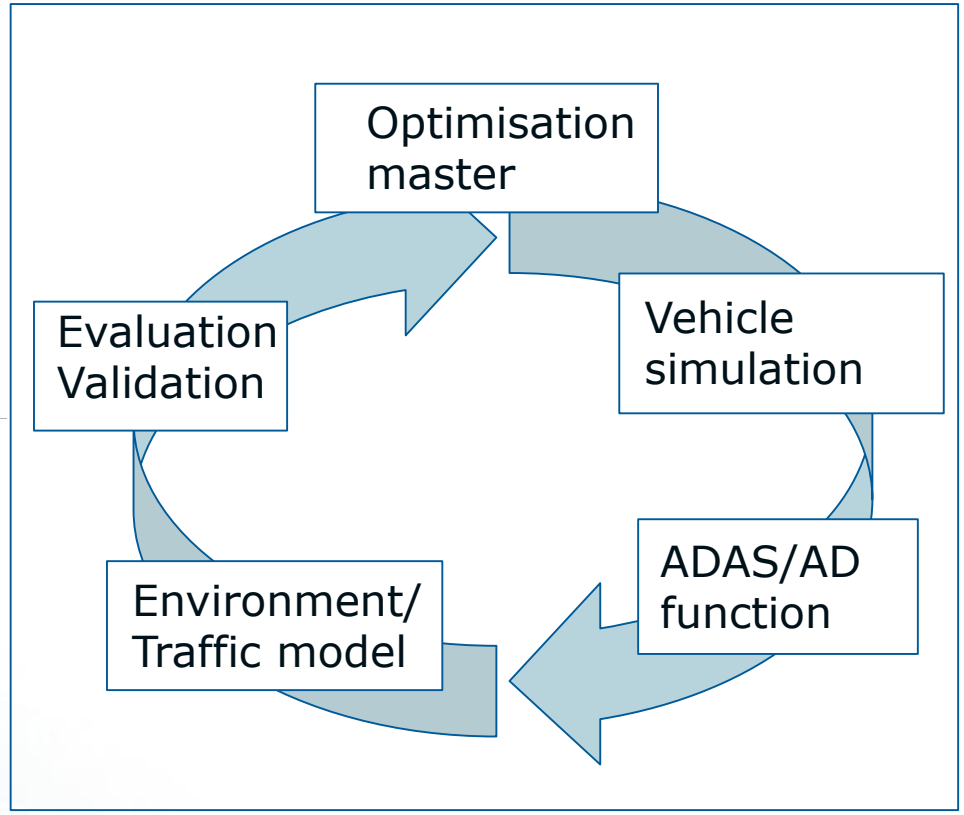
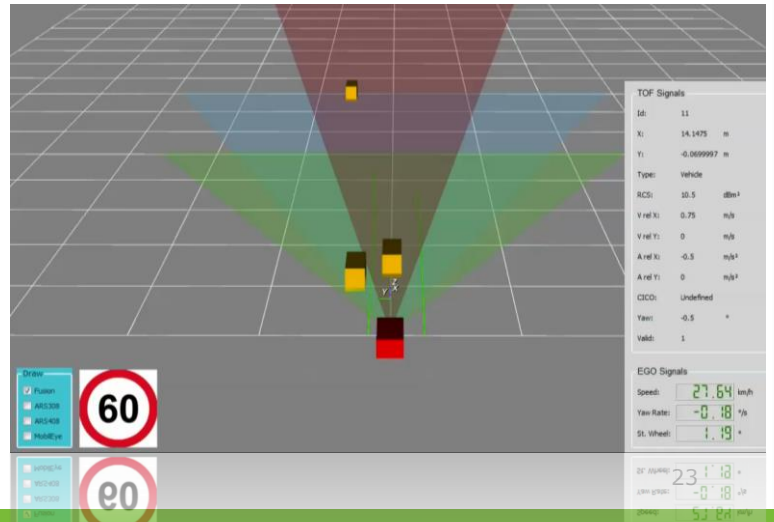
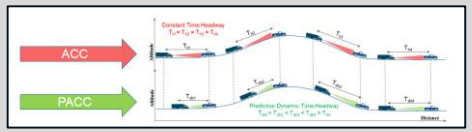
Closed loop approach for virtual testing, optimization, application and validation



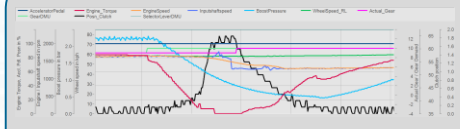




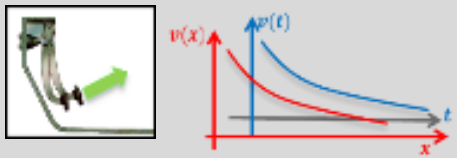
Combined energy consumption minimizing and ADAS control using simulation



PREDICTIVE ADAPTIVE CRUISE CONTROL



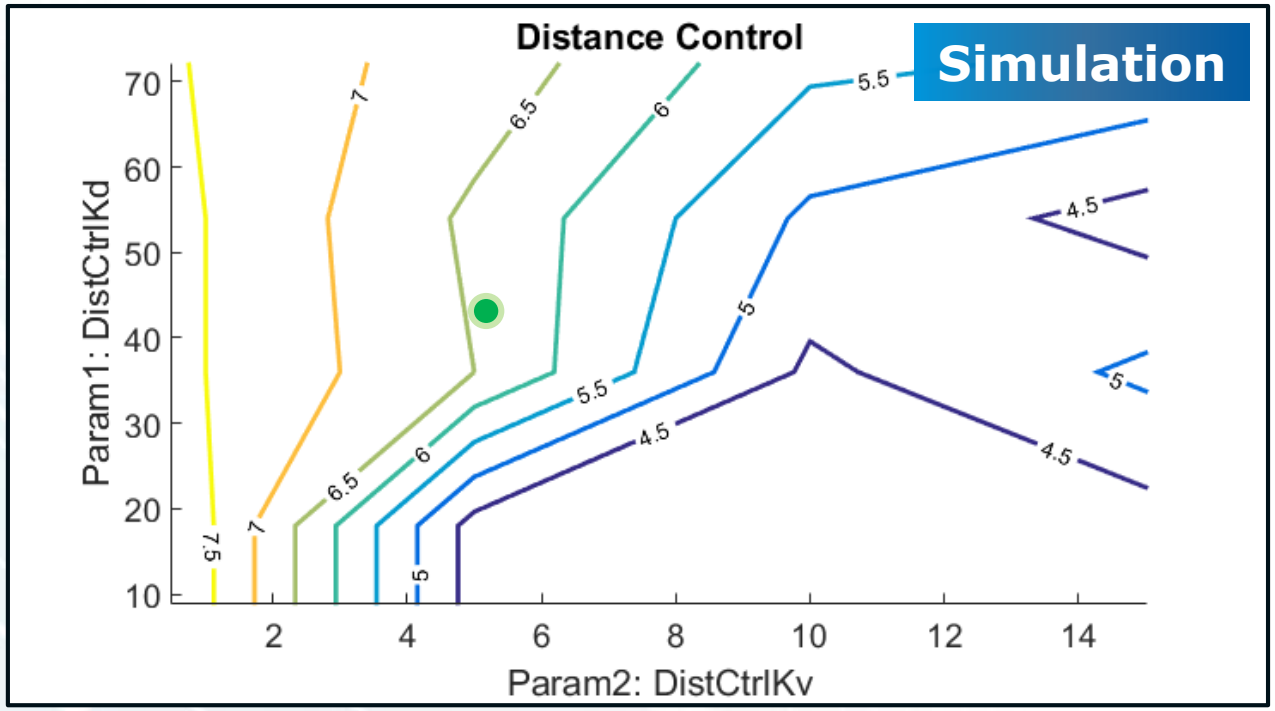
PREDICTIVE SHIFTING

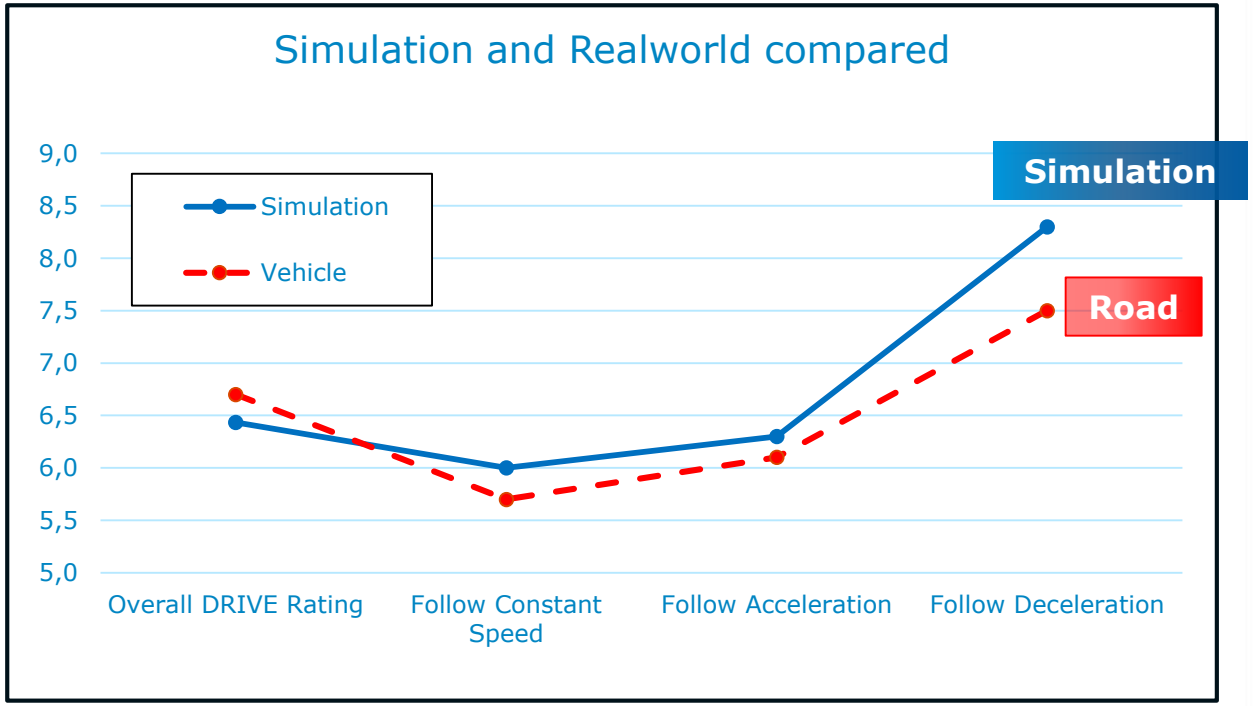


COASTING ASSISTENT

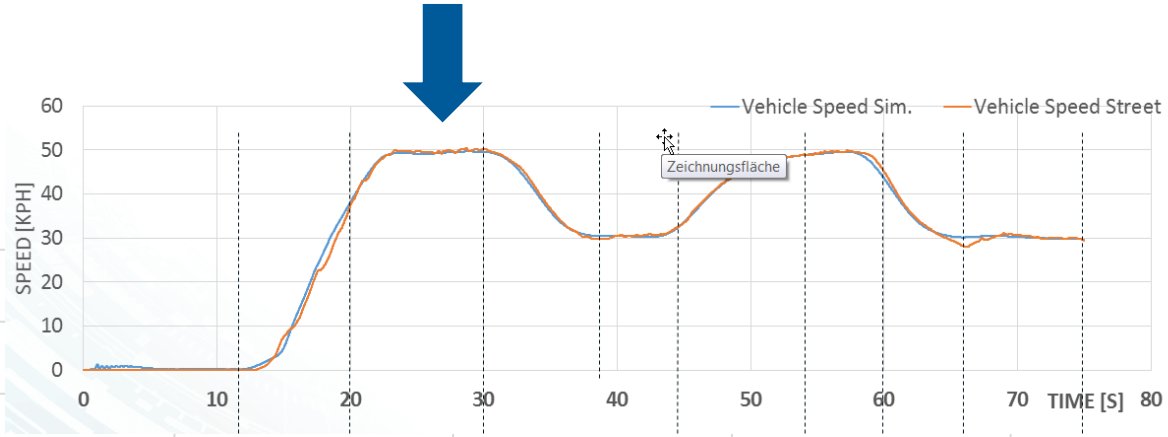
3% fuel saving with predictive adaptive cruise control plus acceptable perceived safety for all

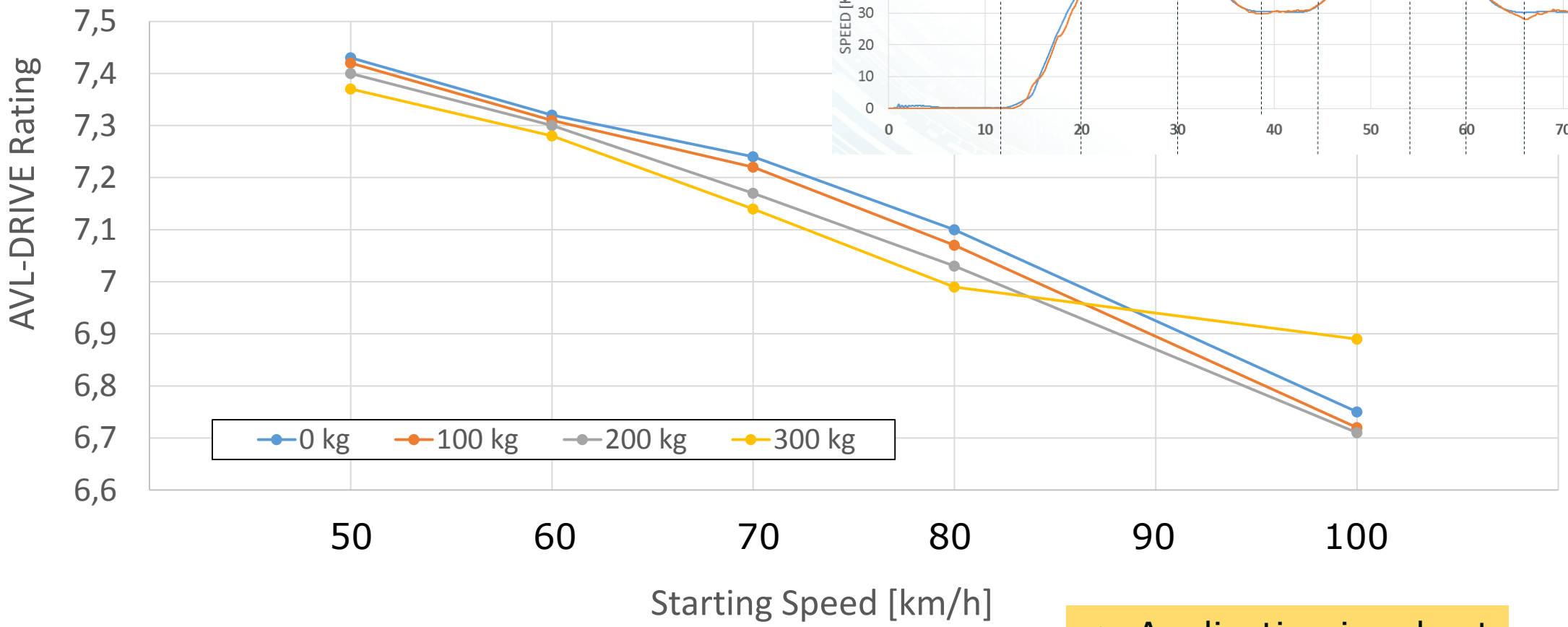
Virtual optimisation / application of ACC parameters





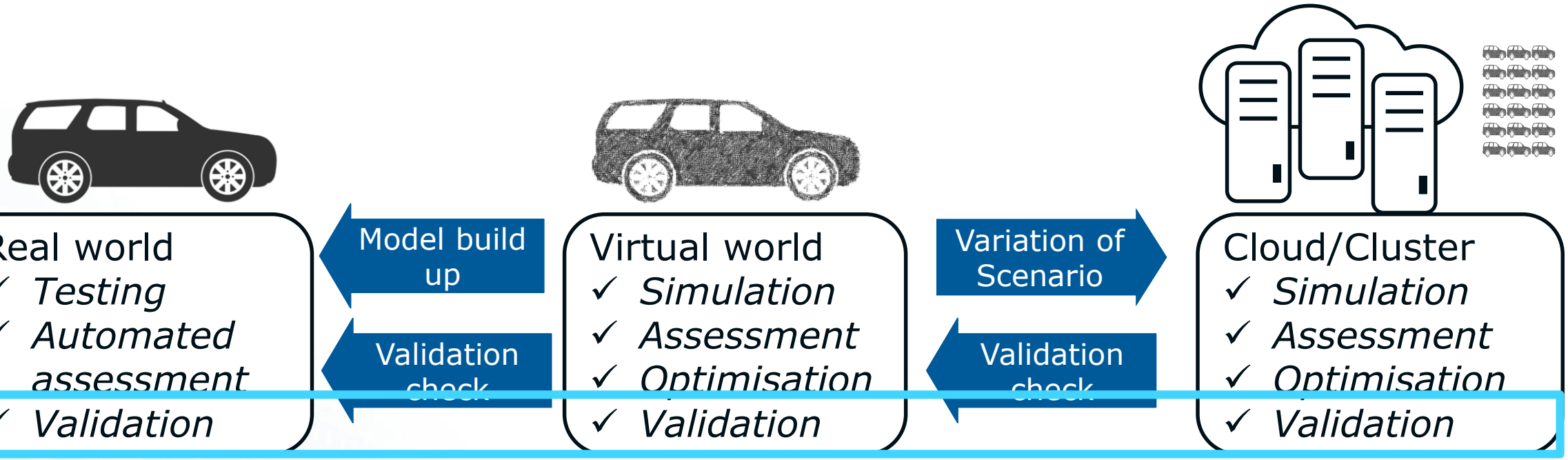
Robustness test of ADAS function





-> Application is robust

AVL Approach for Combined Road and Virtual Development

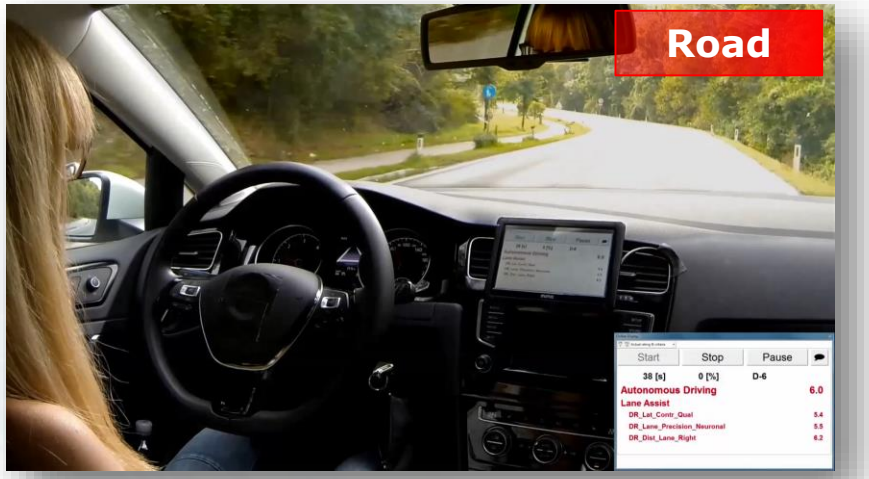


2.000 validated km/week

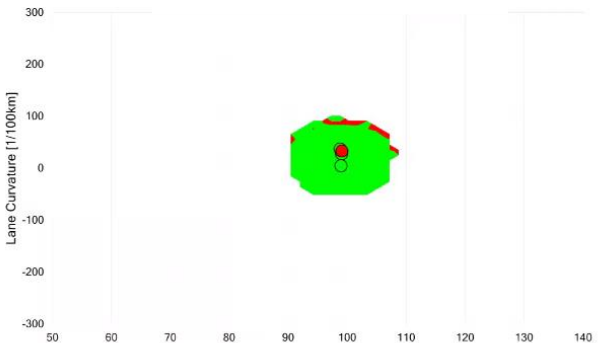
6.000 validated km/week

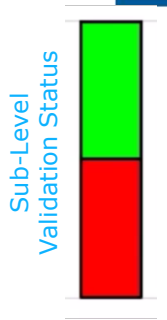
100 Mio. virtual validated km/week

ADAS Quality Validation in AVL-DRIVE ADAS

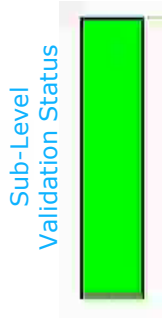


Longitudinal control quality

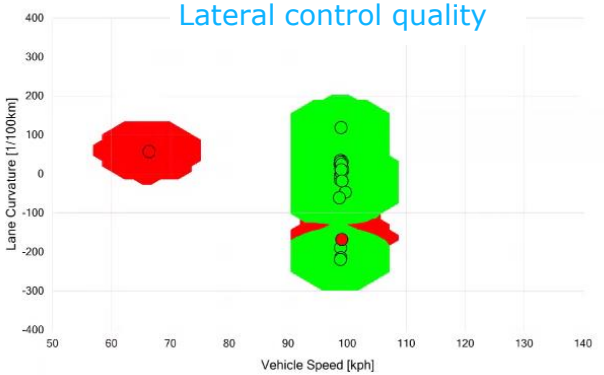


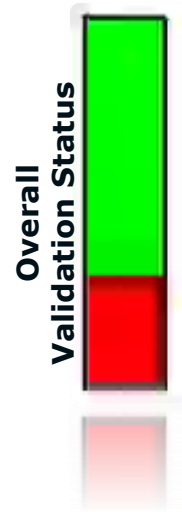


Lateral control quality



Lateral control quality





Objective automated real time validation is key for time saving virtual development

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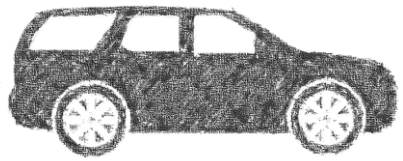
AVL Solution for AD Validation – Combined Road and Virtual Validation

Real world
- ✓ *Testing*
- ✓ *Automated assessment*
- ✓ *Validation*

Identification Virtualization

Correlate Results

Virtual Validation



Virtual world
- ✓ *Simulation*
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Variation of Scenario

Virtual Validation

Cloud/Cluster
- ✓ *Simulation*
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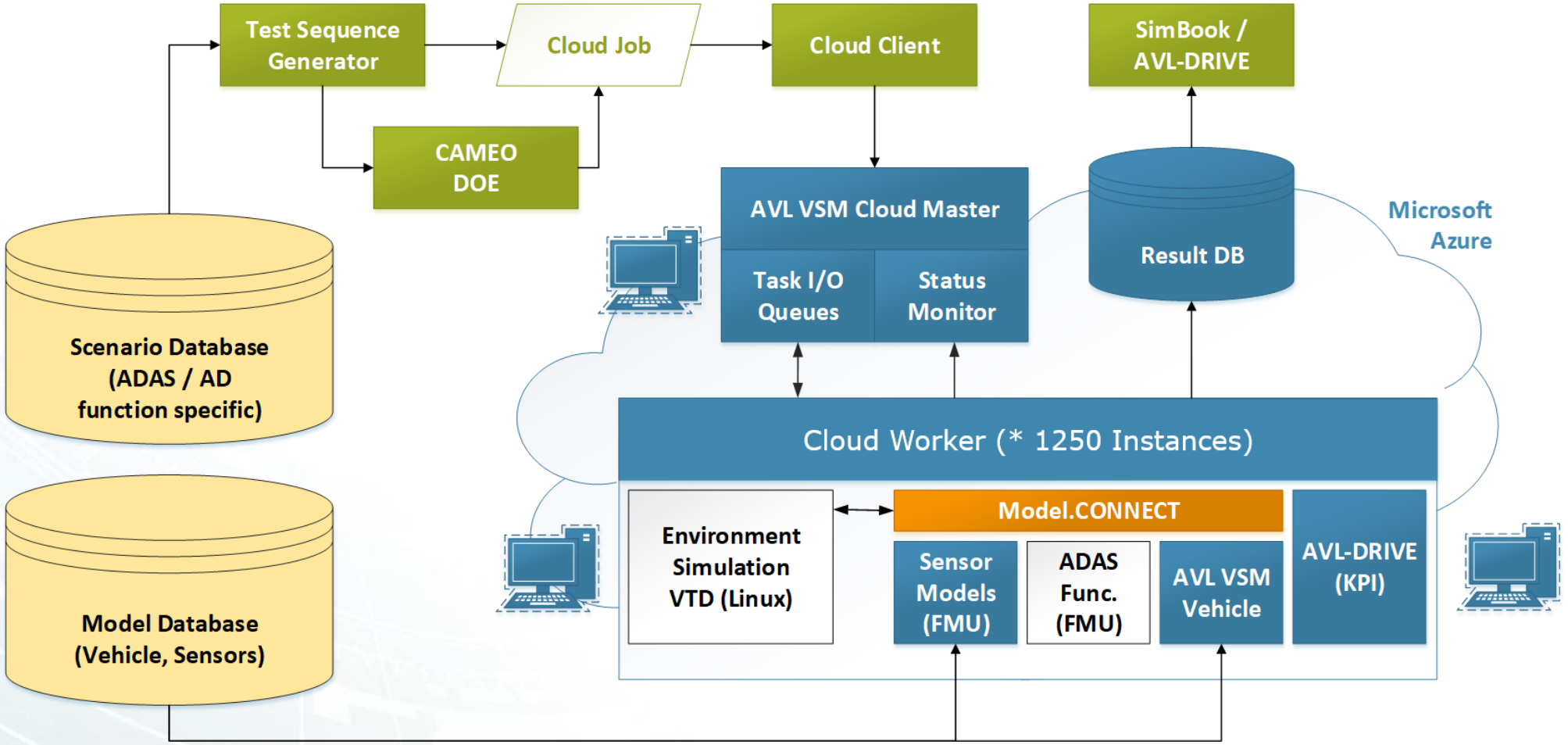
2.000 validated km/week

6.000 validated km/week

12 Mio. virtual validated km/week

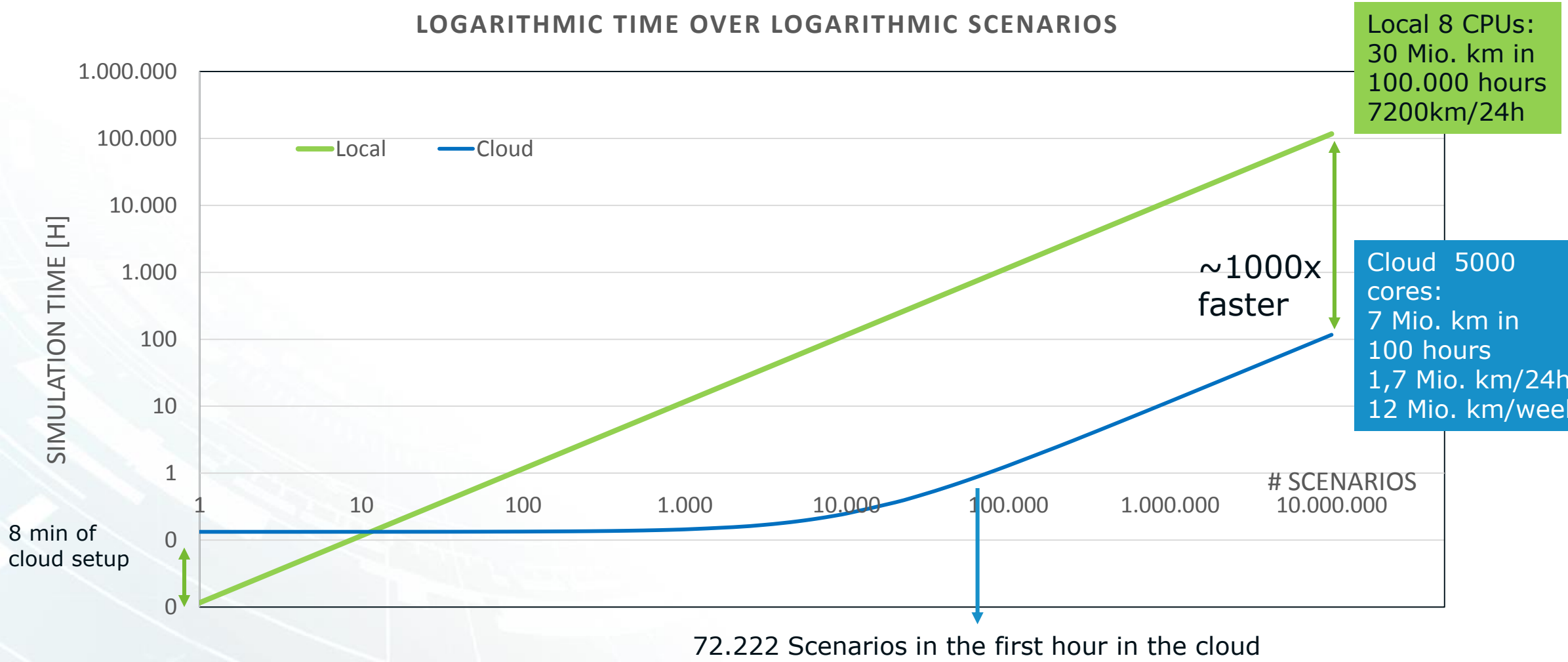
Combined road and virtual validation enables L3+ validation at reasonable cost and time

Block diagram for closed loop cloud based development with 5000 cores



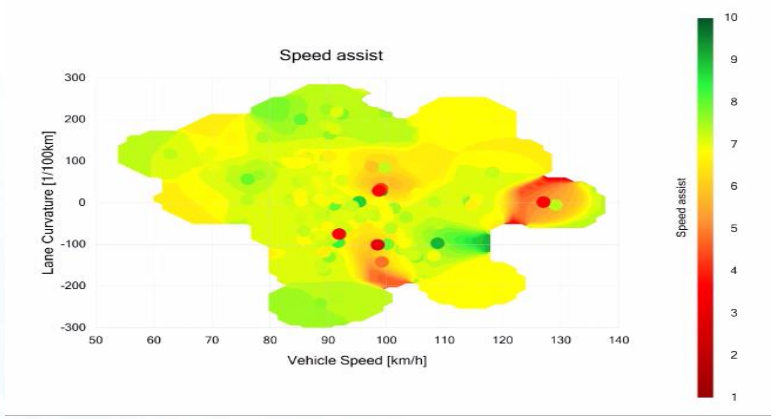
Used for testing, assessment, application and validation

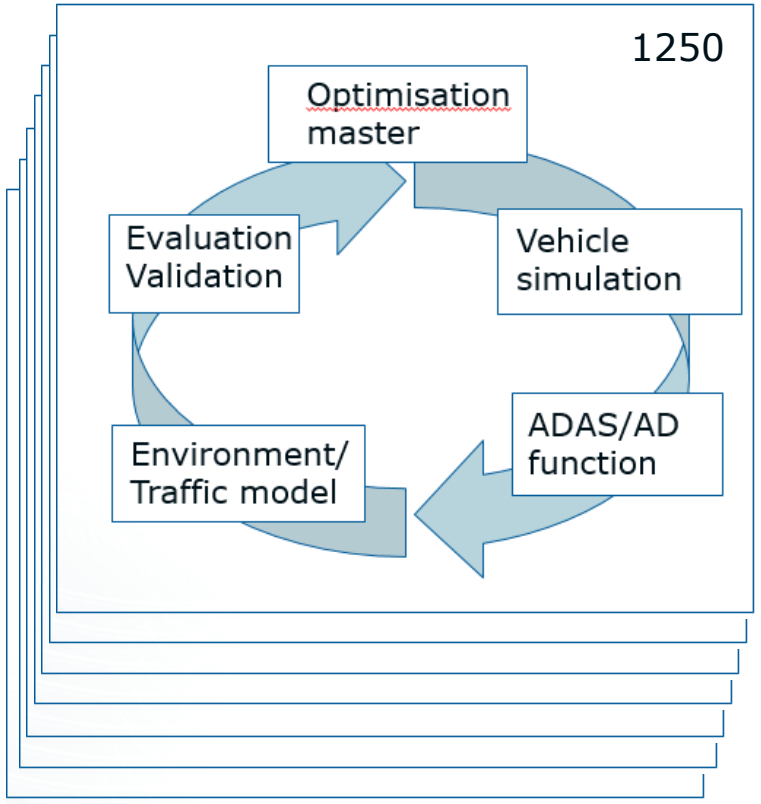
Simulation speed example between local CPU versus cloud with 5000 cores

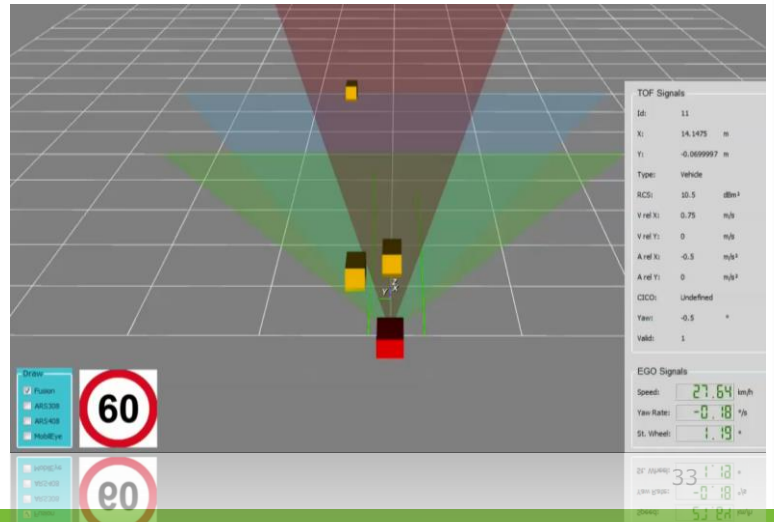


Quality validation in the cloud

5000 cores -> 4*1250 single instances

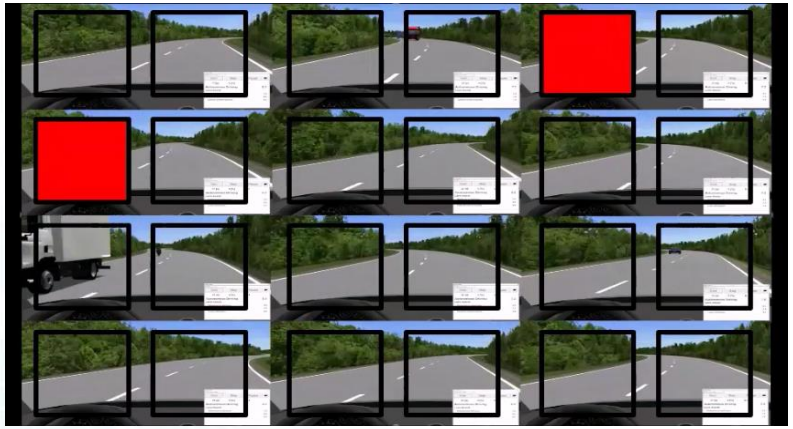




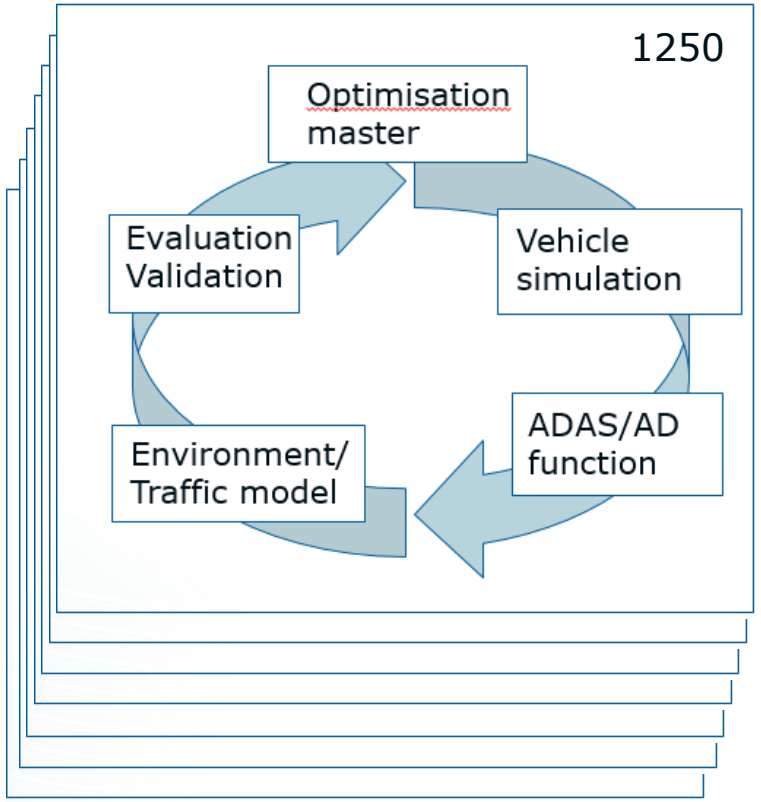


Quality validation in the cloud

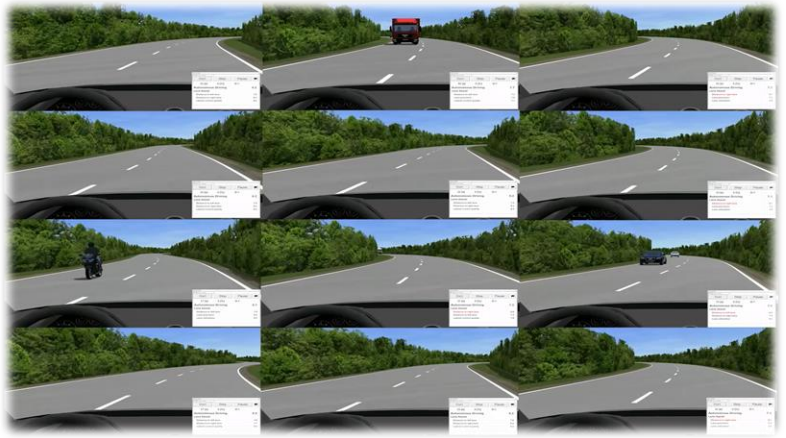
1250 cores for quality validation



5000 cores -> 4*1250 single instances

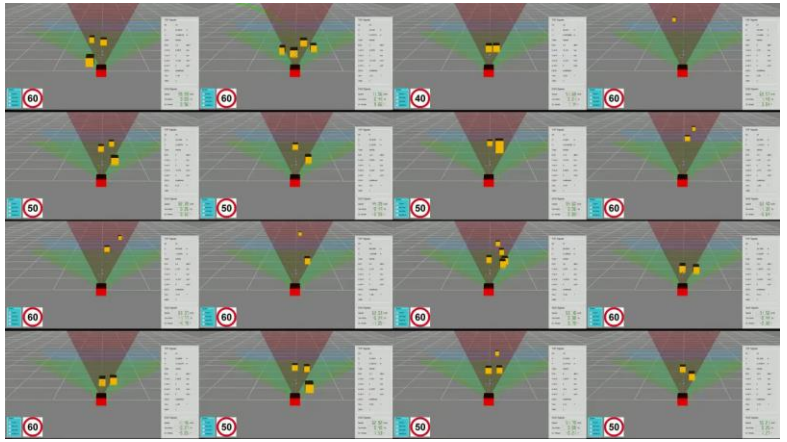


1250 cores for vehicle simulation



1250 cores for environment/traffic model

1250 cores for environment detection



Status 6/2018:
1,7 Mio. virtual validated km/day
12 Mio. virtual validated km/week

Development Workflow in the AVL ADAS Development Center

Road / track
vehicle
Tests
Evaluation
Validation

Test master
Scenario catalog

- Synthetic
- Euro-NCAP
- Real life

Simulation/
cloud master

Attributes
evaluation

Vehicle model

Quality
validation

5000 cores

AD function

Environment/
Traffic model

50 Mio. virtual validated km/week

Human
tests

Driver simulator

Driving cube

Vehicle
tests

Relevant use cases

Content

- **Levels of ADAS and autonomous driving**
- **Motivation for ADAS and AD**
- **Challenges**
- **Human centric approach, objective assessment**
- **The challenges development time and cost, validation effort**
- **Combined road and virtual development approach**
- **Cloud based ADAS/AD testing, application and validation**
- **Conclusion, questions, discussion**

Conclusion

- **Autonomous Driving will be a game changer (Time, safety, CO_2, emissions)**
- **Many challenges: Safety, customer, development time**
- **Vehicle testing not any more possible (12.000 years) – Virtual solutions**
- **Objective methods for evaluation, application and validation**
- **Customer centric approach: Perceived safety, customer centric scenarios**
- **Combination with simulation, cloud/cluster for virtual development**




Thank you for your attention !


Thank You
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