“Simulation enables validation of automated driving”

12th A3PS Conference am November 9th and 10th, 2017

Dr. Michael Stolz, Prof. Daniel Watzenig
Control Systems
Department Electric/Electronics & Software
VIRTUAL VEHICLE Research Center

VIRTUAL VEHICLE Research Center is funded within the COMET – Competence Centers for Excellent Technologies – programme by the Austrian Federal Ministry for Transport, Innovation and Technology (BMVIT), the Federal Ministry of Science, Research and Economy (BMWFW), the Austrian Research Promotion Agency (FFG), the province of Styria and the Styrian Business Promotion Agency (SFG). The COMET programme is administrated by FFG.

Contents

- ADAS introduction
- ADAS Challenges in a nut-shell
- Validation of HAD
- The role of Simulation

Contents

- ADAS introduction
- ADAS Challenges in a nut-shell
- Validation of HAD
- The role of Simulation

Automated Driving -- A Common Trend

Bertha Benz Drive

2013 - Mercedes

Super Cruise

2014 - GM

Motorway Pilot

2011 - BMW

Automated Driving

2014 - Honda

Piloted Parking

2012 - Audi

Highway Pilot

2014 - PSA

Drive Me

2013 - Volvo

Automated Driving

2014 - Renault

Field Test on Highway

2013 - Nissan

Highway Pilot

2013 – Toyota/ Lexus

Automated Driving

2015 Daimler Future Truck MB

Automated Highway Driving

2015 Freightliner Inspiration Truck

Automated Transport Solution

2015 Scania Trucks

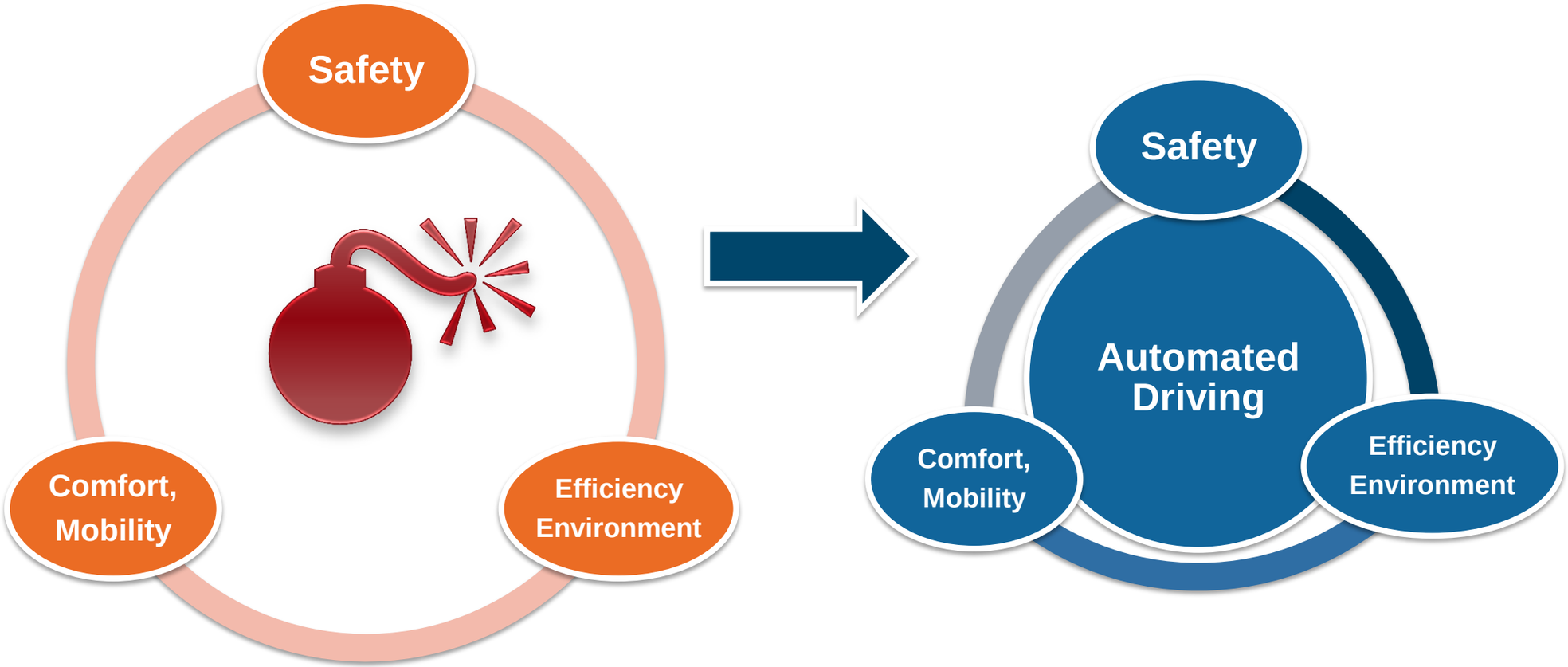
Automated Driving

Volvo Trucks

Motivation / Vision of Automated Driving

Question: *„Why automated driving ?“*

Answer: *„It is a new answer to competing design targets.“*



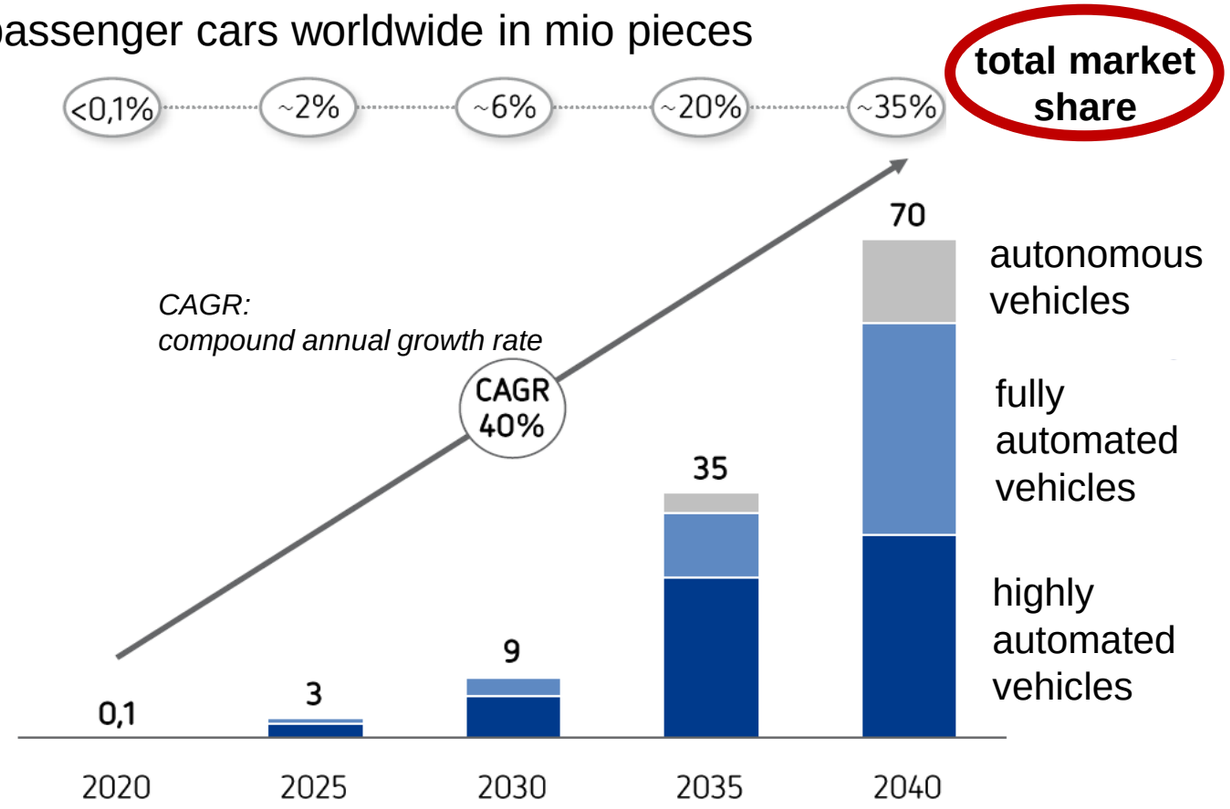
Which expectations do we have on ADAS ?

Increased Safety	**„Vision Zero“**: Increased safety in traffic, less accidents → **~ 90% of all accidents are caused by driving failures** → **~ 70% of all fatal accidents in GER are due to driving failures**
Increased Traffic Efficiency	**Optimized traffic flow**, better use of traffic space → **estimates are ~80% increase of traffic flow possible** → **~56 min. free time per day through piloted driving (for US)**
Reduced Emission	**„Zero Emission“** Reduction of fuel consumption and Emission → **~23 to 39% savings in fuel consumption on highway**
Give Mobility to Handicapped	**Enhance/Enable mobility** for handicapped, old and unexperienced persons → **addresses demographic change**
New Fields of Business and Innovation	New fields of business through innovation impulses Important future factor for regional/national economy

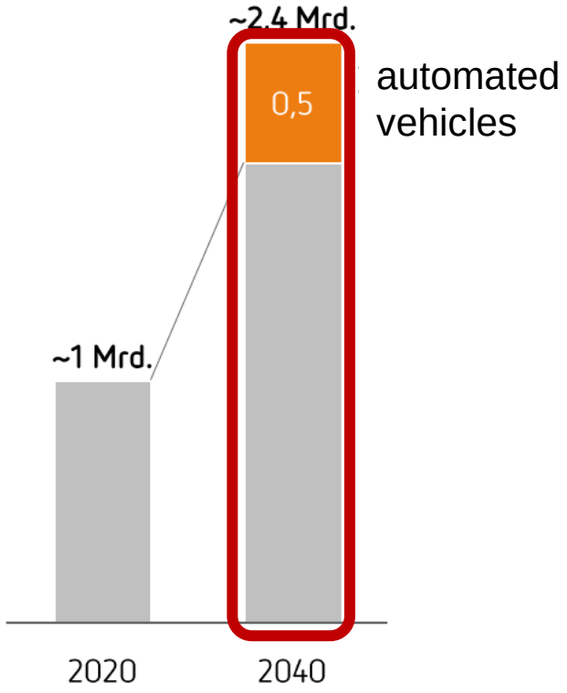
Sources:
Shladover, Steven, Dongyan Su and Ziao-Yun Lu (2012), Impacts of C-ACC on Freeway Traffic Flow, 91st Annual TRB Meeting
Atiyeh, Clifford (2012), Predicting Traffic Patterns, One Honda at a Time, MSN Auto, June 25
US Department of Transportation Highway Safety Administration (2011), Report # FHWA-PL-II-022)
Tech.AD, Conference on Automated Driving, Berlin, 2015

Future role of ADAS ?

market of automated / autonomous vehicles
passenger cars worldwide in mio pieces



number of cars total worldwide



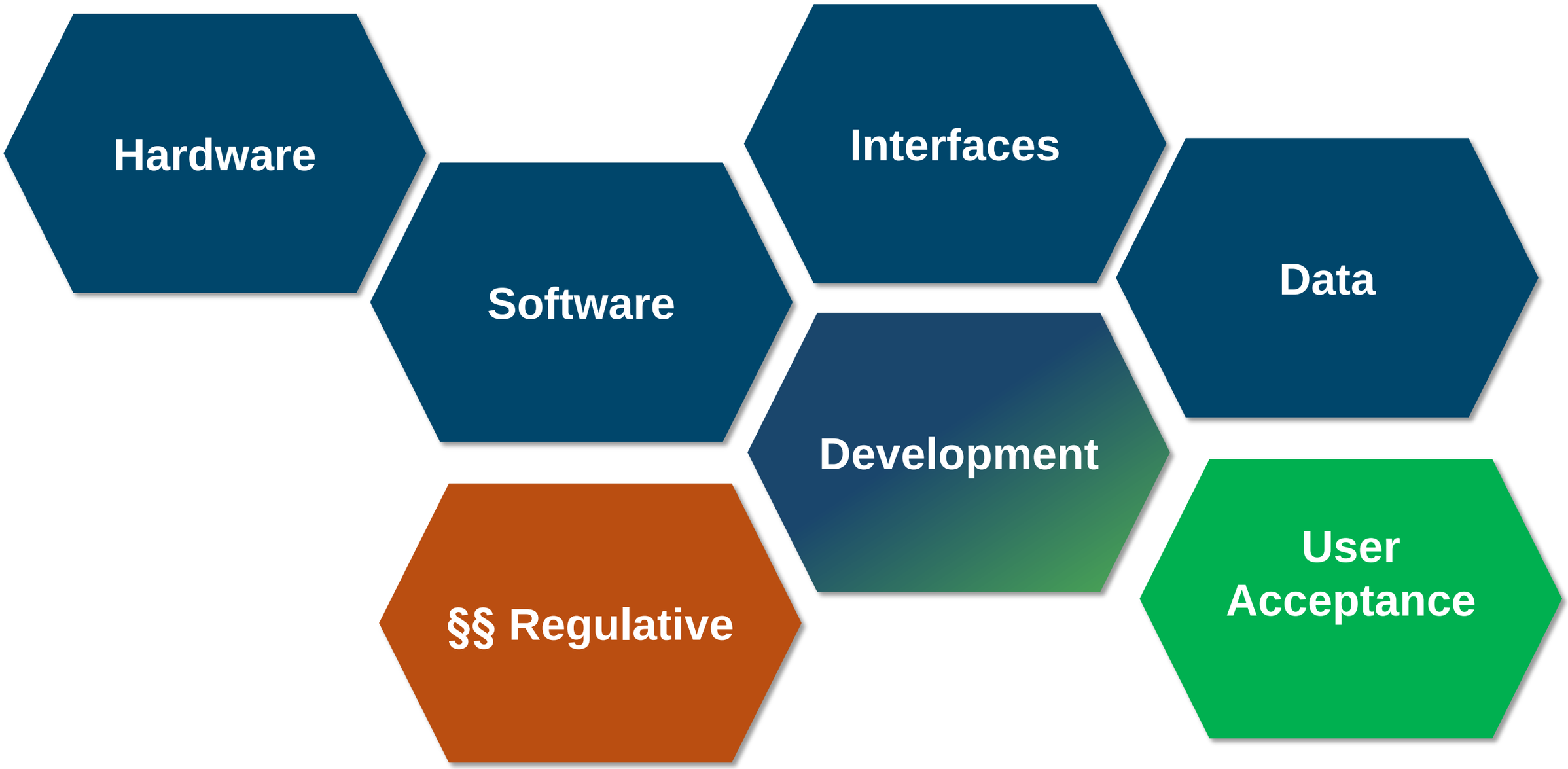
Quelle: Berylls Strategy Advisors

- *AD will strongly influence automotive industry (increasing market share)*
- *Mixed traffic will last long*
- *HAD will lead to further increase the value of software within cars (now ~30%)*

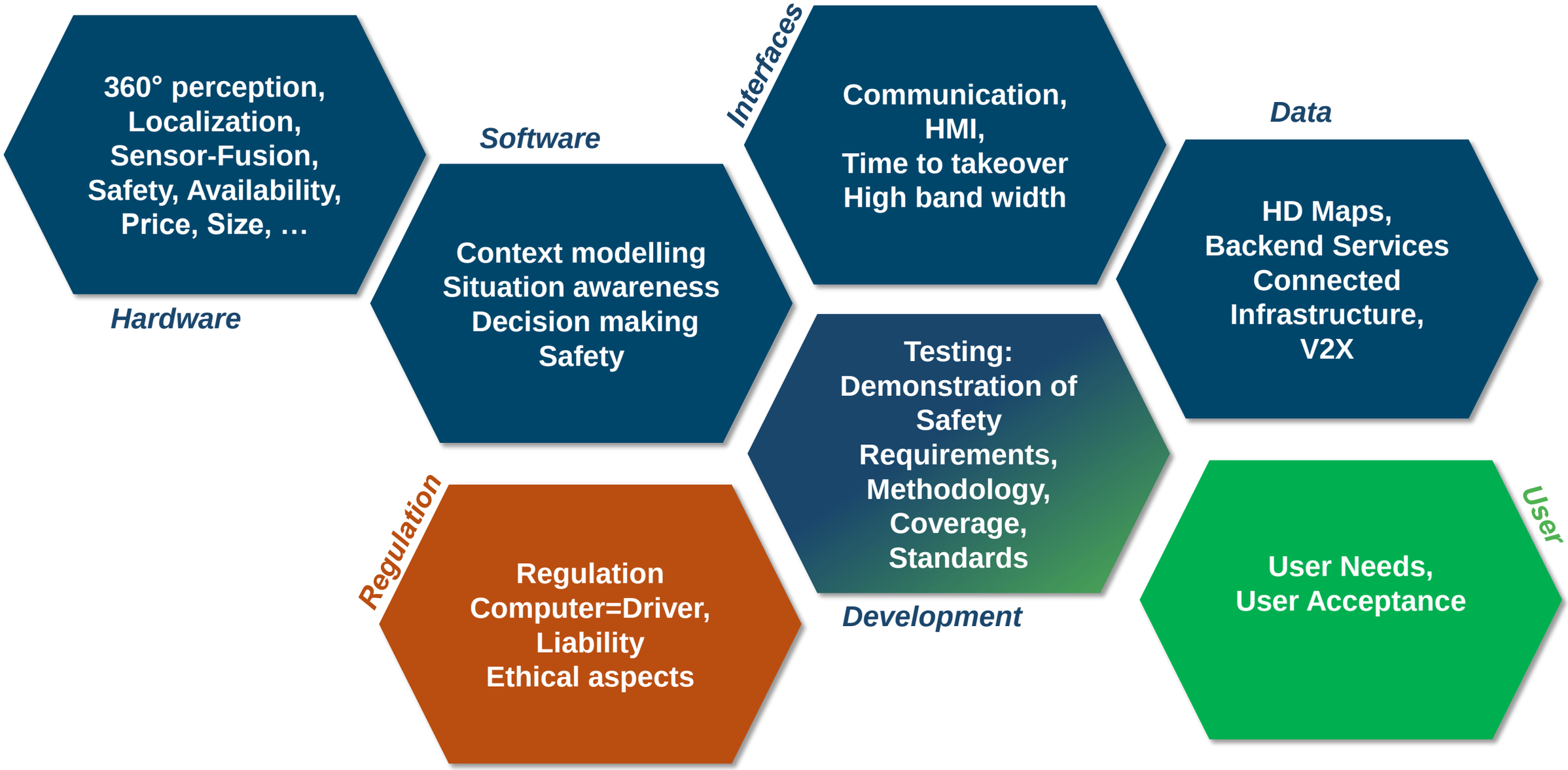
Contents

- ADAS introduction
- **ADAS Challenges in a nut-shell**
- Validation of HAD
- The role of Simulation

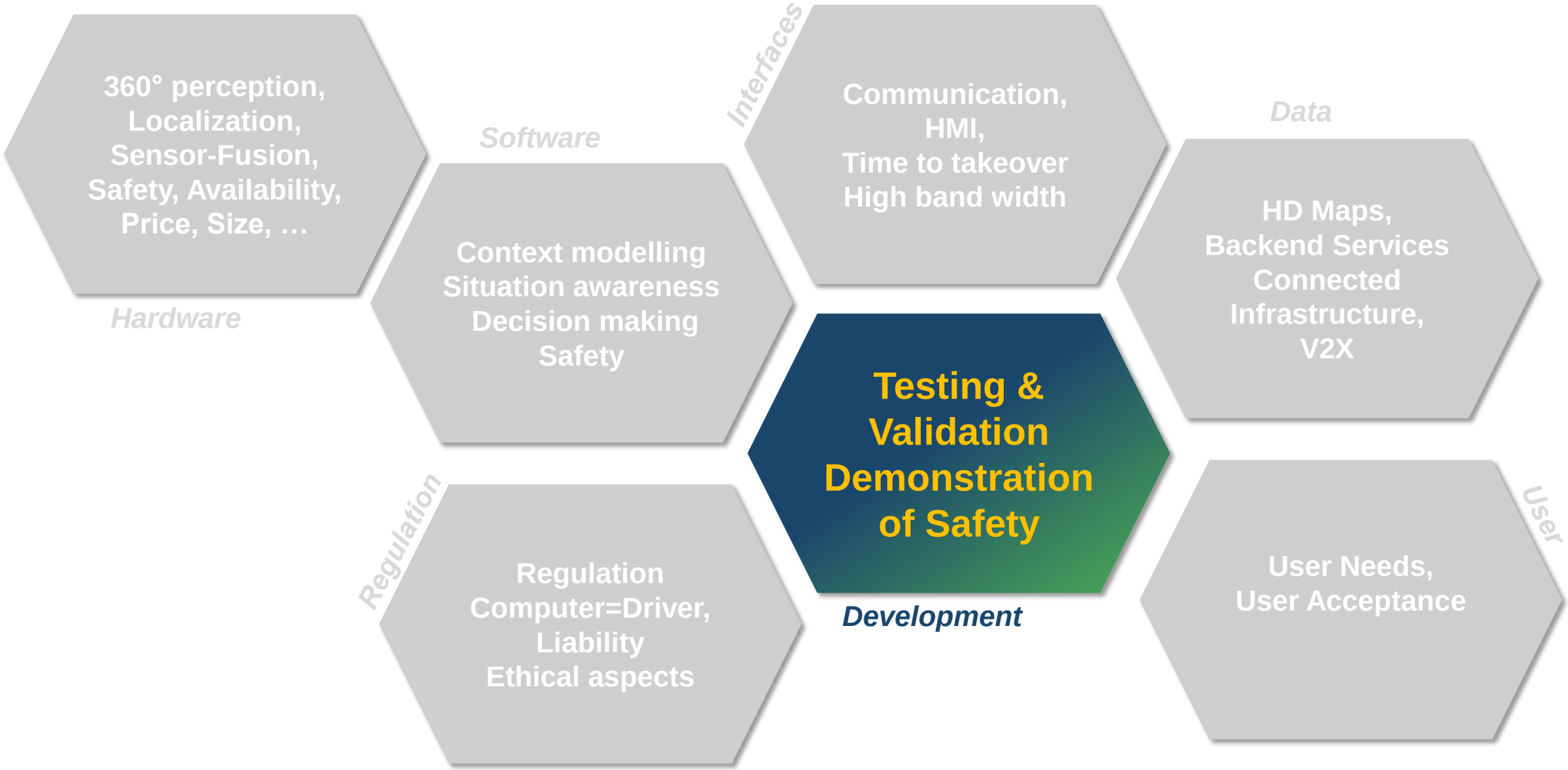
What are the over all Challenges?



What are the over all Challenges?



Focus on Validation Challenge



Contents

- ADAS introduction
- ADAS Challenges in a nut-shell
- **Validation of HAD**
- The role of Simulation

Taxonomy

Validation [ˌvælɪˈdeɪʃən] *N*

"A statement on the system-under-test
that is expressed quantitatively
under a set of specified conditions
with the knowledge of an ideal result"

From "Testing of advanced driver assistance towards automated driving:
A survey and taxonomy on existing approaches and open questions",
2015, IEEE 18th International Conference on Intelligent Transportation Systems, Stellet et al

(test-object)
(metric)
(test-scenarios)
(reference).

"What are the challenges validating ADAS/HAD ?"

→ "Defining, selecting & executing the test-scenarios"

Validating ADAS/HAD

"What are the challenges validating ADAS/HAD ?"

→ "Defining, selecting & executing the test-scenarios"

Reasons are:

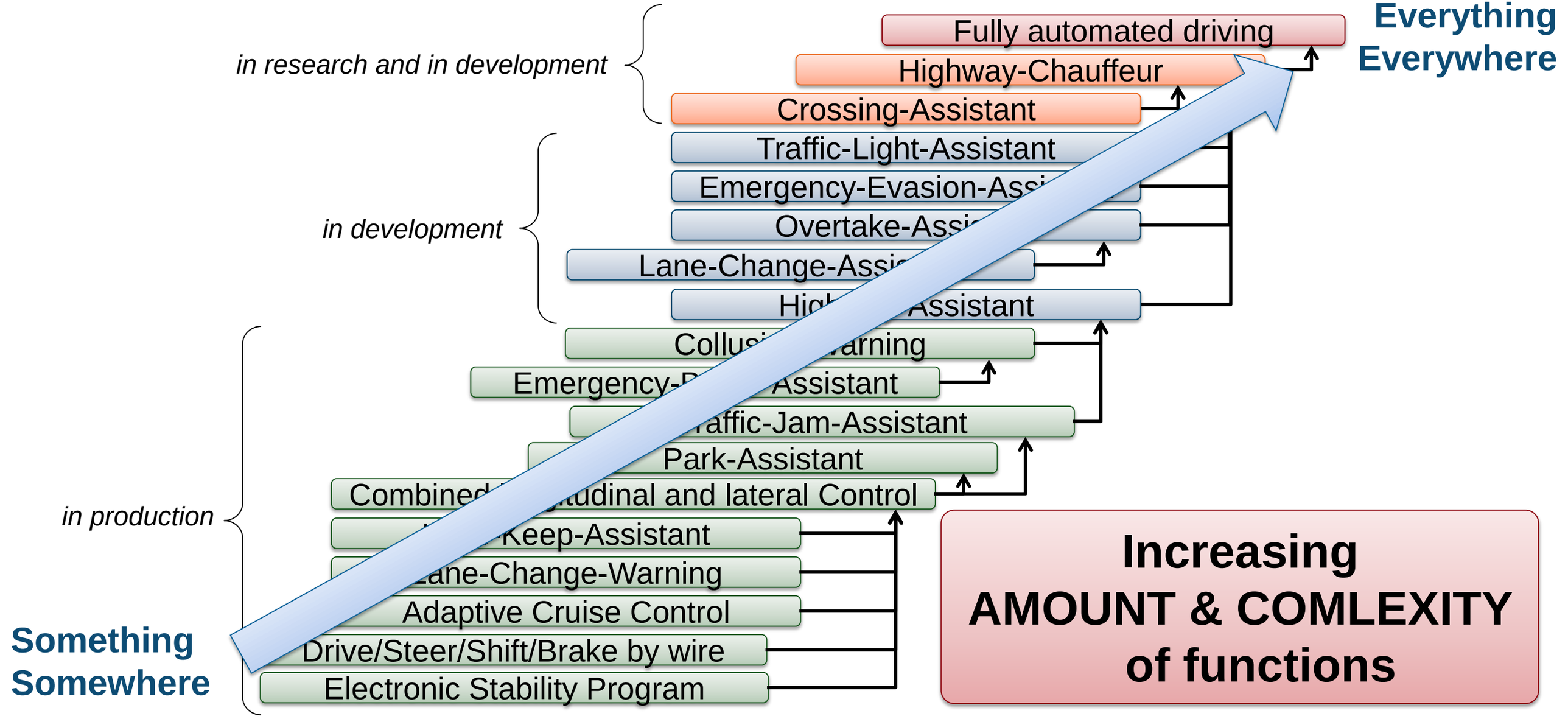
→ *Amount of functions*

→ *Complexity of functions*

→ *Connectedness and interaction*

→ *Comparison to humans*

ADAS→HAD Evolution of complexity



Crucial Step in Development: Level 2 → Level 3

up to Partly-Automated

LEVEL 0-2

(Fallback is human driver)

Automate correcting only in case of errors (ABS/ESP/...)
→ chance to improve dedicated situation

from Highly-Automated

LEVEL 3-

(fall back human driver is missing !)

Automate driving in all standard situations.
→ risk to fail in one of many different sit.

Human drivers make errors – but relatively few.
Human drivers make a lot more correct, than they do wrong!

Source: According to slides from Eberhard Zeeb, Stuttgard 09/2015, DAIMLER

HAD Validation: Real tests alone are not enough

	Accidents with people hurt	Driving distance	Distance between two accidents
Germany all Vehicles	300.000	$7{,}1 \cdot 10^{11}$ km	2,0 Mio. km
Germany cars	180.000	$6{,}0 \cdot 10^{11}$ km	3,3 Mio. km
Highway all vehicles	Approx. 18.000	$2{,}2 \cdot 10^{11}$ km	**12,0 Mio. km**

[Source: H. Winner, 6. FAS Academy Munich, 29th November 2013, based on ADAC Statistics Report, 2010 – 2012]

Problem:

- Effort factor:

ADAS / conventional = x1000

➢ Infeasible

Validation example: Automated Driving on Highway

For statistic relevance (95% significant)
“better as (average) himan driver”,
100~240 Mio km tests required [Prof. Winner]

i.e. 1000 Fahrzeugleben lang (ein Fahrzeugleben = ca.250 000 km)
Übliche Freigabetests bestehen aus einigen hunderttausend km
[Bartels & Ruchatz, at Automatisierungstechnik 2015;63(3), p168-179]

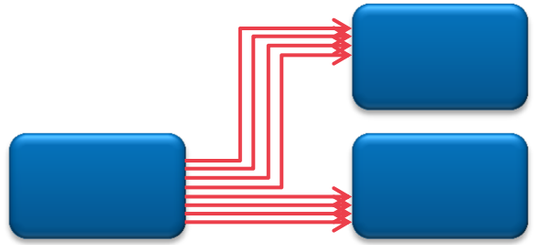
Test object HAD: Conclusion / Challenges

Challenges (due to differences to conventional systems) :

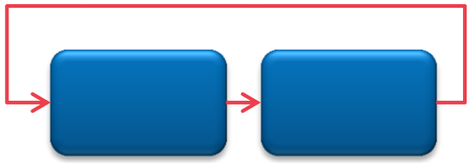
- Amount → Number of parts increases (mostly due to software)
  each part needs testing

...

- Complexity → Number of interfaces,
  → Number of influence factors
  → Number of tests explodes



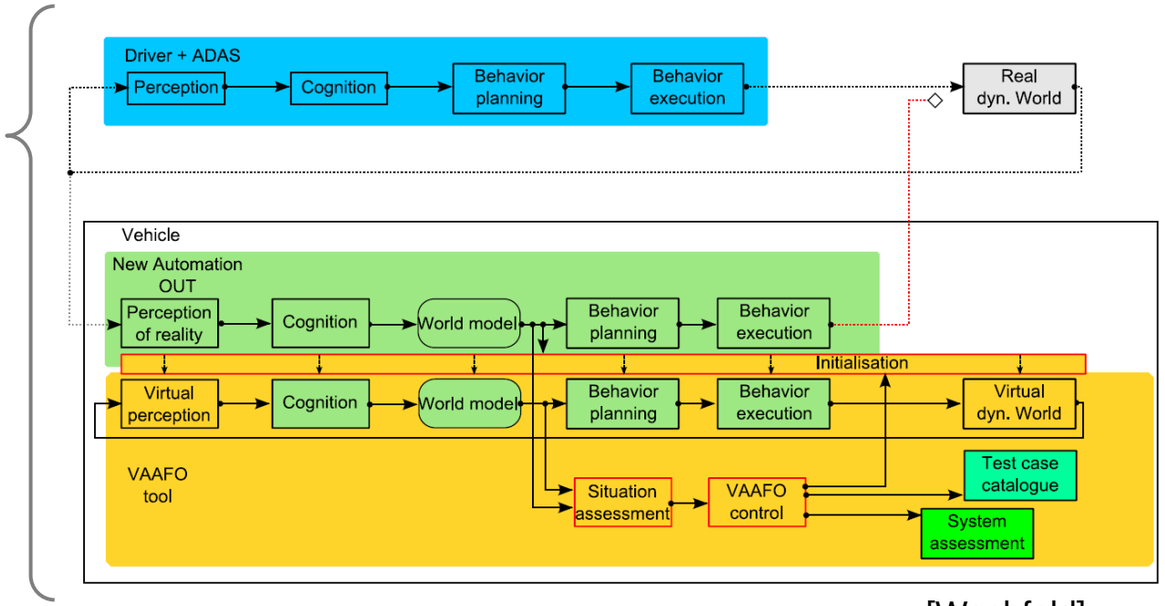
- Interaction → System parts should/must be tested in compound (closed-loop)



- Comparison with human driver → indirect judgement and low error rate,
  → many km for significance

Approaches for Validation of HAD [Winner]

- Multi stage **maturity level model** (CMMI, SPICE)
- Open-loop (offline perception-tests)
- V-Modell (Use-case → Test-case)
- Endurance tests (~10^5-10^6km, accelerated)
- X-in-the-Loop (more tests by virtual reality)
- Complicated tests (quality insetead of quantity)
- “Trojan Horse” (10^8-10^9 km/a possible.)
- Stepwise increase features in releases
- ...



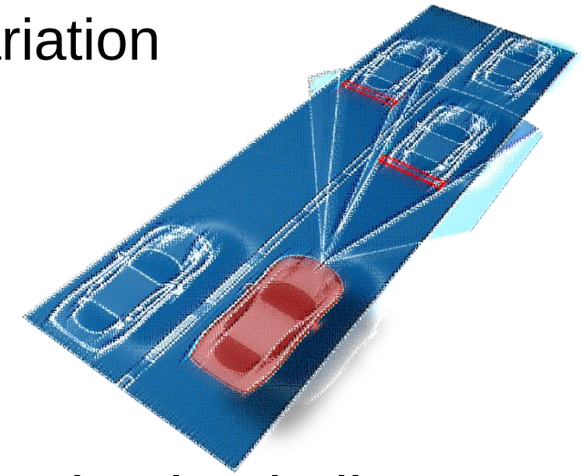
[Wachfeld]

[Winner] Absicherung automatischen Fahrens, Prof.Dr.rer.nat.H.Winner, 6.FAS-Tagung München, 29.11.2013
[Wachfeld] Virtual Assessment of Automation in Field Operation, A New Runtime Validation Method, Walther Wachfeld and Hermann Winner

Types of Validation

Scenario-based (like black-box-testing)

- Driving task 1 + variation
- ...



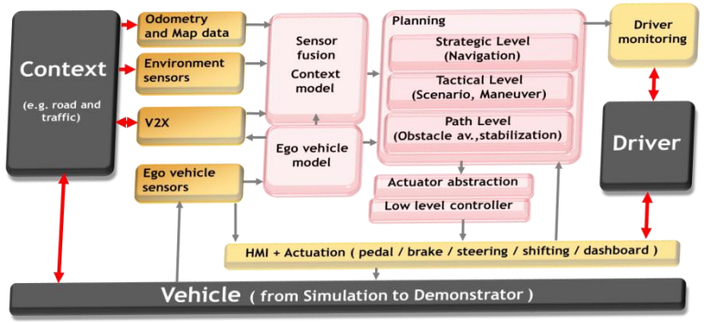
Assumption: Success also in similar situations

Pros: Interaction included

Cons: Indirect judgement, tremendous effort due to testing full system

Function-based (architecture based) (like grey box testing)

- Perception
- Decision
- Path-planning
- Stabilization



Assumption: Success if all parts work

Pros: modular testing possible, insight into system

Cons: Interaction (closed-loop) not included

ADAS/HAD needs combination of both approaches + acceleration by simulation

Contents

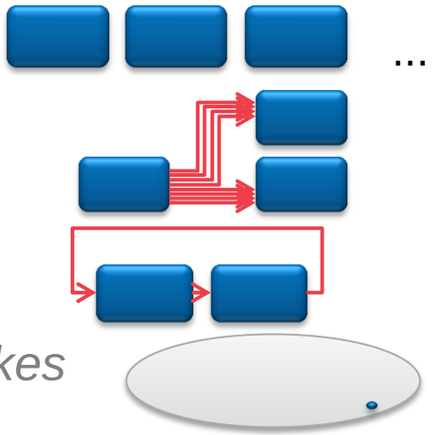
- ADAS introduction
- ADAS Challenges in a nut-shell
- Validation of HAD
- The role of Simulation

What is the Role of Simulation for Validation?

Validation of ADAS and HAD new challenges

(in contrast to conventional development):

- *Number of components:* *increasing software in the car*
- *Complexity:* *number of interfaces and dependencies*
- *Interaction:* *closed-loop with environment*
- *Benchmark is human driver:* *indirect measure of quality by few mistakes*



Simulation has the following potential:

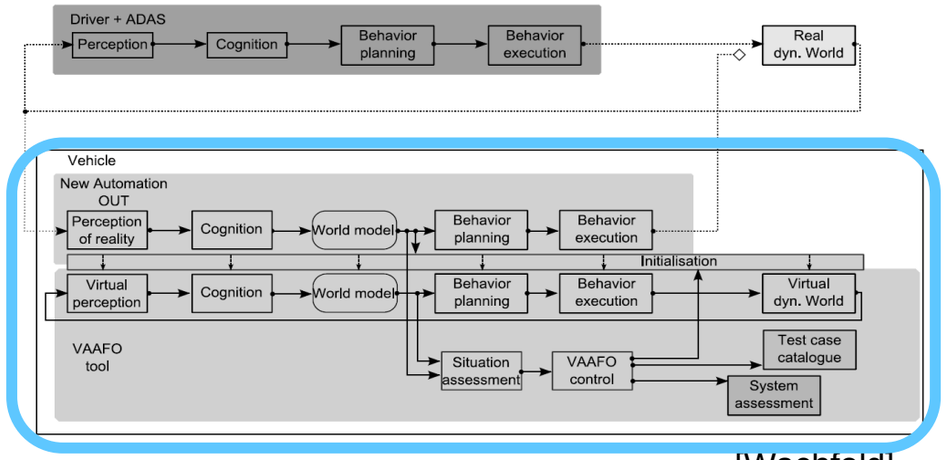
- Virtual Development & „front loading“ → DO THINGS EARLIER
- Seamless Development → DO THINGS AUTOMATED
  (link with requirements, do batch testing,... → DO THINGS MORE EFFECTIVE
- Simulation based Testing/Validation → DO MORE TESTING, BE FASTER
  (co-Simulation, over night-testing)

Role of Simulation for ADAS Validation extends

From development…

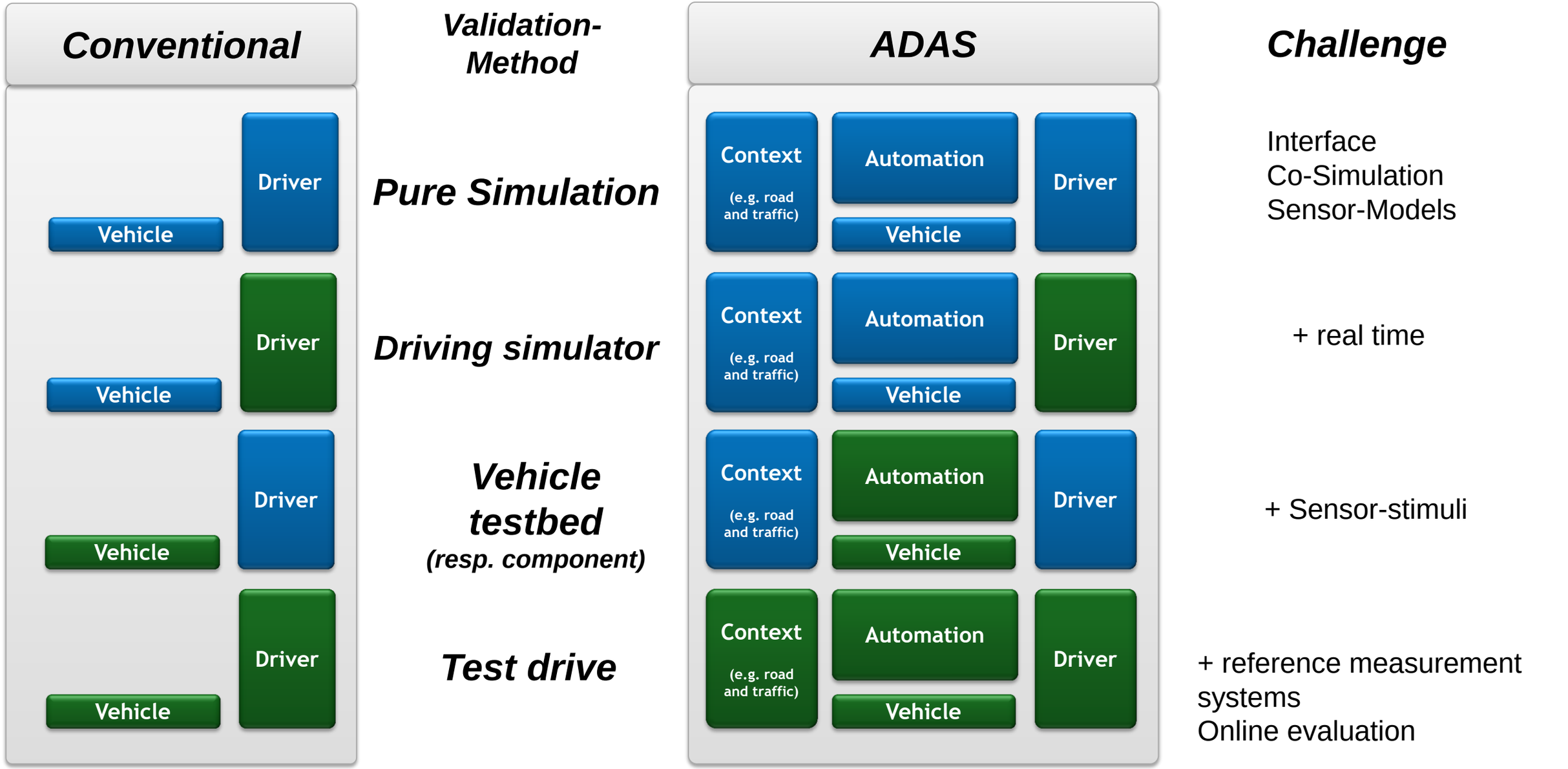
- Real Test
- **X in the Loop Testing**
- **Simulation Testing**
- Software Testing

…to online operation



[Wachfeld]

Challenges for Simulation in Validation of HAD



Summary

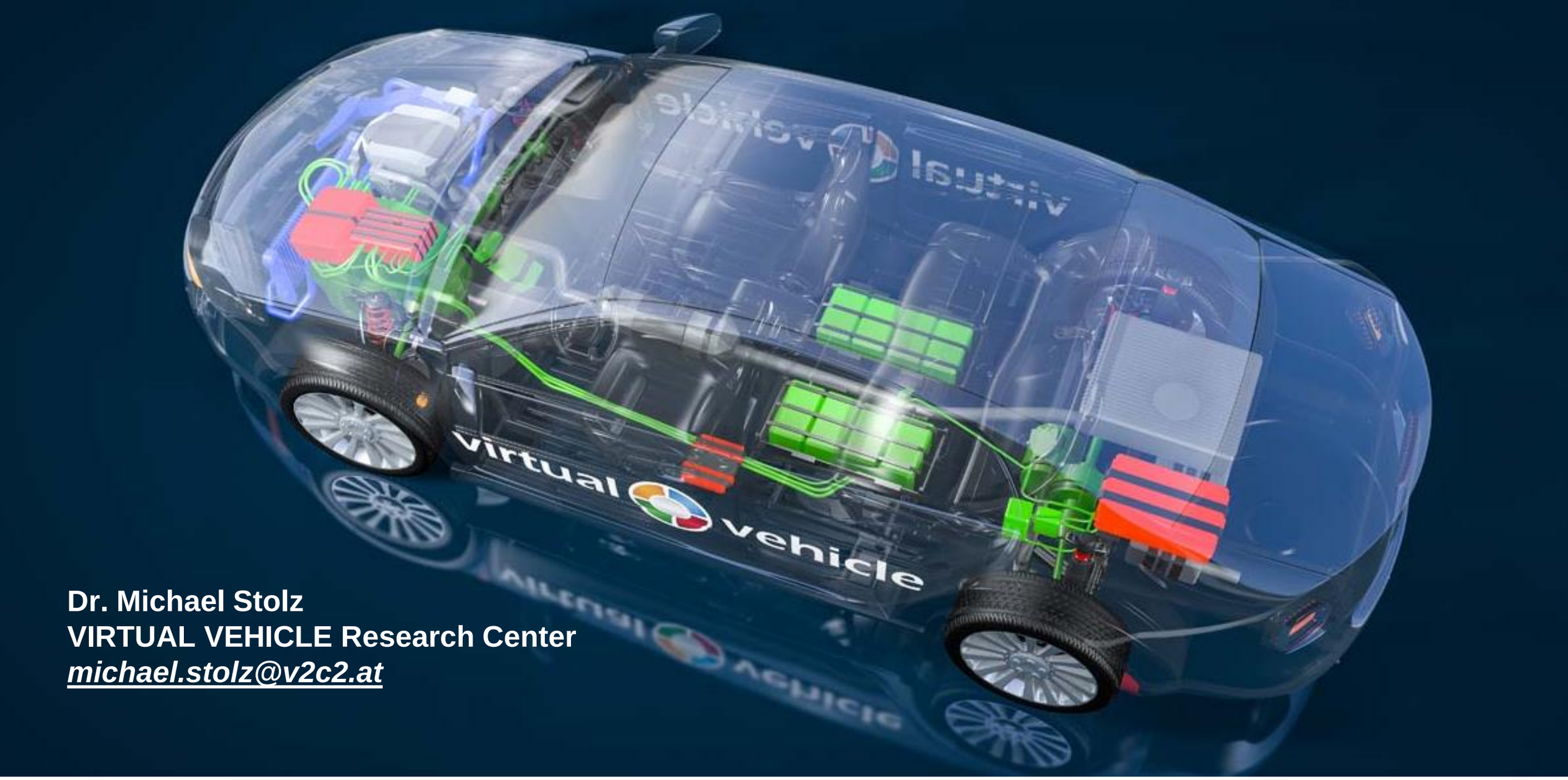
Simulation is advantageous in development,

but necessary for Validating HAD.

Simulation enables to validate earlier, automated, more effective, faster and cover more test cases.

Still there are challenges to be met to fully use simulation to validate HAD

Co-simulation, common architecture for automated vehicles, sensor-models, sensor stimulation, real-time capability, mixed real-/virtual demonstrators,…



Dr. Michael Stolz
VIRTUAL VEHICLE Research Center
michael.stolz@v2c2.at