Public relations
- Public & politic reactions in case of accidents
- Customer acceptance
- Cyber security
- Ethic

Technical
- Functional safety & Reliability in all conditions (Traffic, Weather & Road)
- Infinite high number of test cases
- Complex and new technology
- Time & Cost pressure during development

Legislative
- Homologation criteria
- Responsibility in case of accident

The rocky road to ADAS/AD Development, Validation and Homologation
Responsibility

Now

Driver's License

Regulations

Level 5
Future

Future

Future
A lot of progress concerning the TECHNOLOGY is visible, but:

“The critical path to introduce autonomous driving vehicles will not be the technology but the development of a metric which empowers for an approval”

Prof. Dr. rer. nat. H. Winner, November 2013

… and the next question will be how to execute scenarios, test cases etc. of this metric in a limited time
“The biggest hurdle is validation to confirm that the system does not cause failures. One has to execute 250 million test kilometers”

Bosch Executive Director.

Same approaches as 36 years ago?

Mercedes-Benz 190 E (1982) - Demonstration and advantages of ABS

New and Innovative Approaches in Testing and Validation are necessary!
Facing the Challenges of Development and Homologation of Autonomous Driving Using Virtual Approaches

Vehicle Validation and Self Driving Vehicle

Driving Software and Digital Driver

Legislation, Regulations and Conformity
Background and Homologation

Dr. Houssem Abdellatif
Global Head Autonomous Driving and ADAS
Driving Test: Human vs. Machine

Human

![Human License Plate]

Responsibility

Machine

![Machine License Plate]

Level 0:
Driver Only

L1: Assisted

L2: Partially automated

Level 1:
L1: Assisted

Level 2:
L2: Partially automated

Level 3:
Highly automated

Level 4:
Fully automated

Level 5:
Driverless

Today

Tomorrow

http://www.onlinewahn.de/generator/f-maker.htm

http://www.onlinewahn.de/generator/f-maker.htm

http://www.onlinewahn.de/generator/f-maker.htm
Homologation and Type Approval

Definition
Homologation refers to the certification process of a product (vehicle) granting that it complies with all local standards and legal regulations such as safety and environmental regulation.

No homologation → No CoC → No sales

Self certification vs. type approval 3rd party principle

Type Approval in vehicle development
- Last step of development
- Accomplishment of the V-cycle
- Legal and technical approval of the concept

- European Union: Directive 2007/46/EC Type approval, tests are based on United Nations Economic Commission for Europe (UN/ECE) procedures;
- North America: Federal Motor Vehicle Safety Standards (FMVSS) regulations released by the NHTSA;
- Australian Design Rules (ADR) regulations;
- Japan follows UN/ECE regulations and their own Test Requirements and Instructions for Automobile Standards (TRIAS) regulations;
- Other countries that accept or base their own regulation on those mentioned above, following the latest release or previous versions of the regulations.
UN/ECE-Regulation 140: Homologation of ESC Systems

Where a vehicle has been **physically tested** in accordance with [...], the compliance of versions or **variants** of that same vehicle type may be demonstrated **by a computer simulation** [...].”

| 01 | Define vehicle representative of the type to be homologated, and test it under dynamic maneuvers |
| 02 | Generate the vehicle simulation and correlate the obtained data |
| 03 | Simulate critical variants |

**Sine with Dwell (SwD) maneuver**

Approval testing & collecting data

**real Tests**

Inputs → **simulation**

**Vehicle response**

Inputs → **simulation**

**Vehicle response**

Inputs → **Correlation**

**Model validation**

**N vehicle/model variants** → **N Simulation results**

Approval & assessment of variants by using validated simulation model
ESC vs. Automated Driving

Sense and control of internal vehicle

- Similar homologation / validation architecture:
  - Environment
  - Sensor – Function / active system – Vehicle (dynamics)
  - (Driver)
- Methodology can be reused and extended to automated driving

→ Simulation aided / supported homologation of automated driving functions

Sense and control in external environment
Combining Tools (Tool Chain) for Concise Approval

Scenario data base
- description
- parameters
- fail/pass criteria (KPI)

subset for testbench testing
subset for physical testing
subset for simulation testing

results: \( m \) vehicle variants \( \times \) \( n \) scenario variants \( \times \) …

test track
real vehicle
virtual vehicle

test bench
simulation
test bench

TÜV SÜD Auto Service GmbH | GTC Europe 2018
Virtual-based Assessment for L3+AVs

Assessment Selection
- Safety Know-How
- Criticality Analysis
- Functional Decomposition

AV Assessment
- Component
- System
- Vehicle

Testing
- Simulation Framework
- Proving Ground
- Field Tests

Trustworthiness of Simulation via Validation
- Tool Chain Validation
- Vehicle Model Validation
- Sensor & Perception Validation
- World Model Validation

Evaluation
- Methods
- KPIs
- Criteria

Requirements
- Legislation
- Regulations
- Norms
- AV System Specification
- Assessment Database: Scenario, KPIs and Criteria
Virtual Testing Methods

Prof. Bernhard Schick
Professor for Vehicle Dynamics and Advanced Driver Assistance Systems
Positive driving experience remain important!
Object Hopping
Object Lost
Sudden System Drop-Out
Challenges

Subjects feel more stressed and unsaved with LKAS instead of without LKAS

Subjectively perceived stress "with" versus "without" lane-keeping assistant
"The most important thing about a ADAS/AD is that it is common used. And it's only used when it's experienced as safe, usefulness and ease of use."

People want a perceived safety of 100%.
Paradigm change

How to transfer today’s “fun-to-drive” into future “fun-to-be-driven” within an attribute-driven development?
We need a very high level of environment knowledge and anticipatory understanding of the situation!
Rule based vs. artificial intelligence

How complex, reproducible and understandable are the methods?

Sensor Input (Fused Sensors) → Maneuver Interpretation → Decision Tree Function → Output Vector

Steering Angle

Folding Level

Pooling Level

Fully Connected Level

Output Vector

Steering Torque
Lateral control in complex environments!

- markings heavily weathered
- partly no center marking
- dirty roads
- no side lines in sections
- uneven road with inclination changes
- heavy vehicle response
1 Drift Weaving
2 Sudden System Drop-Out
Learning challenges of artificial intelligence

Detailing of labeling and the process to build up the simulation environment will have an effect on the results.
A seamless but open toolchain with new approach is necessary

Simulation

Virtual Testing

Proving Ground

Real World

Maneuver, Scenario, Test Case Abstraction incl. KPIs

Environment Abstraction

Vehicle Abstraction

Same Results

The most efficient validation will be done by those who will use the best combination!
Reference: Proving Ground

- Methodology, Test Catalogue and KPIs for AD Function
- AVL DRIVE for ADAS
- NVIDIA DRIVE
- Vehicle Interface
- Real Vehicle on Real Proving Ground

+ very close to the real operation
- expensive, high effort, less repeatability
Architecture Virtual Testing @ the DrivingCube

- Close to real operation, chassis dynos are already established for homologation (emissions)
- Limited in terms of lateral dynamics
Architecture Simulation

Simulation

- fast, flexible and cheap in operation, there are already ESC homologation processes in simulation is only as good as the model(s)

Model.CONNECT™

DRIVE Interface

VSM Wrapper

CAN Interface

DRIVE SIM Wrapper

AVL VSM

AVL DRIVE for ADAS

NVIDIA DRIVE

AD Function

NVIDIA DRIVE SIM

Virtual Vehicle in Vehicle Simulation

Virtual Vehicle on Virtual Proving Ground

Methodology, Test Catalogue and KPIs for AD Function

KPI

SC

Vehicle Under Test
**First Results / First Comparison**

**Scenario 1:**
From standstill follow-up with 60 km/h reducing to 30 km/h back up to 50 km/h and 30 km/h again

**Scenario 2:**
From standstill follow-up with 80 km/h reducing to 60 km/h back up to 80 km/h

**Scenario 3:**
From standstill follow up with 60 km/h, TSV pull out left, VUT accelerate to 80 km/h

**Scenario 4:**
From standstill follow up with 60 km/h, TSV pull out right, VUT accelerate to 80 km/h

---

Validation and Homologation of Autonomous Driving will be a challenge. Partnering is extremely important to join the forces. The most efficient validation and homologation will be done by those who will use the best combination of different test environments. NVIDIA, TUEV SUED AND AVL will push this topic together.
... we can skip plan B