virtual vehicle

ENABLING **FUTURE VEHICLE** TECHNOLOGIES

The Integration of virtual testing into the type-approval process

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CEO

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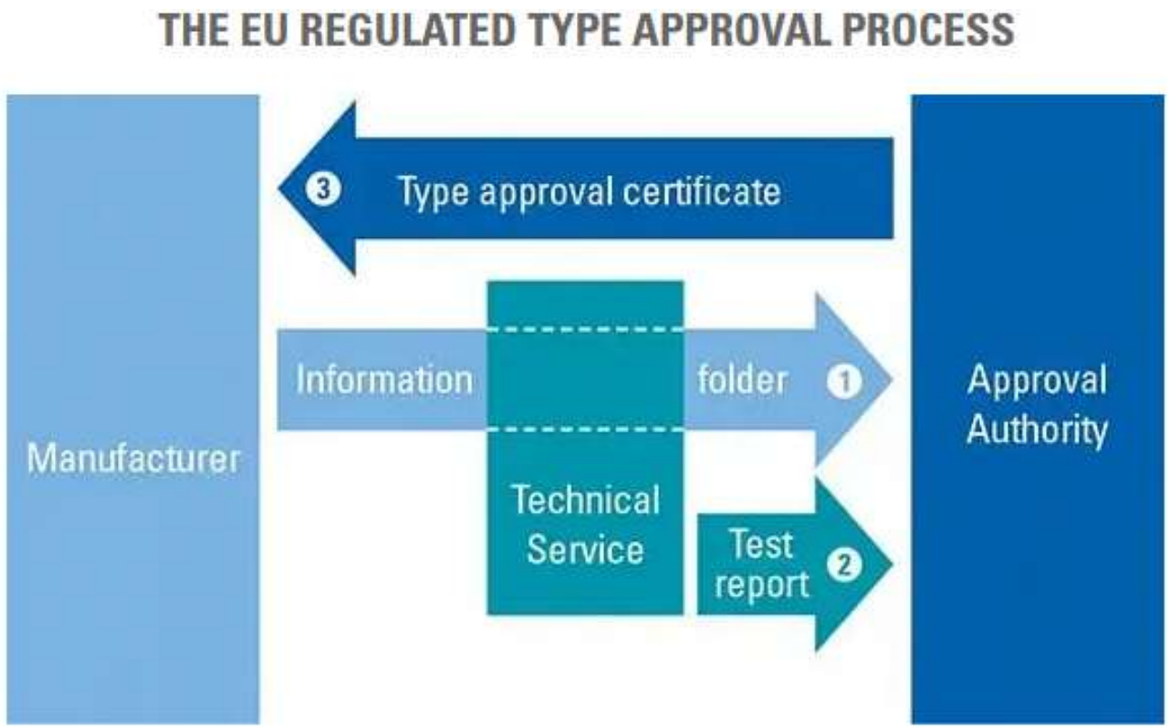
www.v2c2.at

Agenda

1. Introduction Type Approval and Virtual Testing
2. Research Center: System Simulation and Virtual Validation
3. Examples and Case Studies

Products and their market entry:



https://www.tuvsud.com/en-us/industries/mobility-and-automotive/automotive-and-oem/homologation-and-global-market-access/ece-vehicle-certification

Examples:

CARS

TRAINS

CONSUMER (DURABLE) GOODS

How to maintain type approval for devices that are constantly evolving?

Type Approval in the past and currently,

(currently and) in future

Type Approval - Homologation: An overview in context of AD

Safety of automated driving systems and connected vehicles (functional safety and validation methods, cybersecurity, data recorder/storage etc.)

Vehicle dynamics
(steering, braking, etc.)

Advanced Driver Assistance Systems
(Remote control maneuvering, remote parking, automated steering systems etc.)

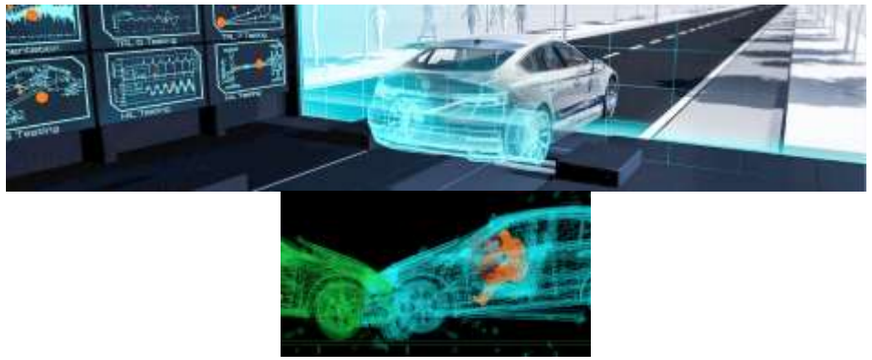
In the past:

- **Hardware was tested**: engine, brakes, tyres etc. The installed parts/systems are subjected to specific tests.
- Currently about **150 UNECE-regulations** have been rolled out which are to be considered during manufacturing and tested during homologation processes.
- Increased digitalisation/electrification. **Large amount of control units** in a single car (about 120 CU).

In the future:

- **Software-defined vehicle**
- Less but more **powerful control units** 1000s of functions
- Software updates & HW updates **Over-the-air updates** (OTA)
- Confirm type approval?
- Type approval tests and processes need to be adjusted and updated

Virtual Testing (VT) in different stages:



Research/Development

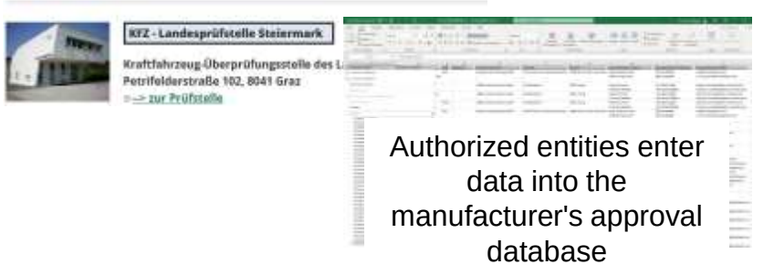
- VT is established & used e.g. often in-house tools and own workflows/processes;
- NO productcs

Consumer Testing

- Beginning of virtualisation
- First applications of standardised VT methods e.g. ; EuroNCAP TB024 Pedestrian Human Model
- virtual testing working groups
  VTC (Crashworthiness) und VTA (Avoidance);

Regulations

- Credibile, trustworthy, standardised simulation/updates/services; UNECE R66, R157;



Authorized entities enter data into the manufacturer's approval database

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Research Center for System Simulation and Virtual Validation

Woldwide renowned partner

2002-2007
Foundation & Networking

Initiation of a research center for **virtual vehicle development**

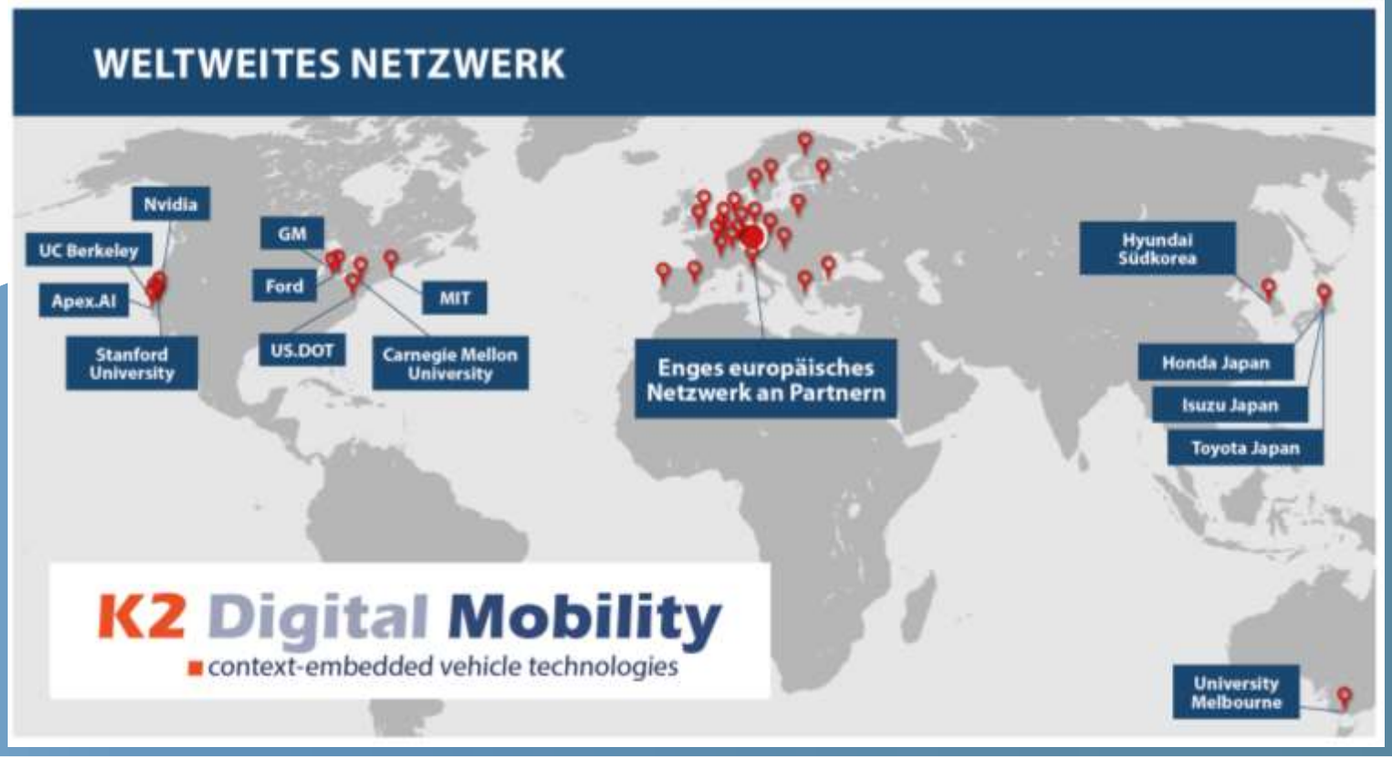
2008-2017
Build & Growth

- R&D center for **sustainable mobility**;
- pillars
  - EU-projects and
  - contract research

established

2018-2026
Long-term establishment & stability

- Recognized international player,
- Strategic Partner Road & Rail,
- Bringing innovations to market



Today, VIRTUAL VEHICLE is Europe's largest research center for virtual vehicle development

VIRTUAL VEHICLE Partner Netzwerk

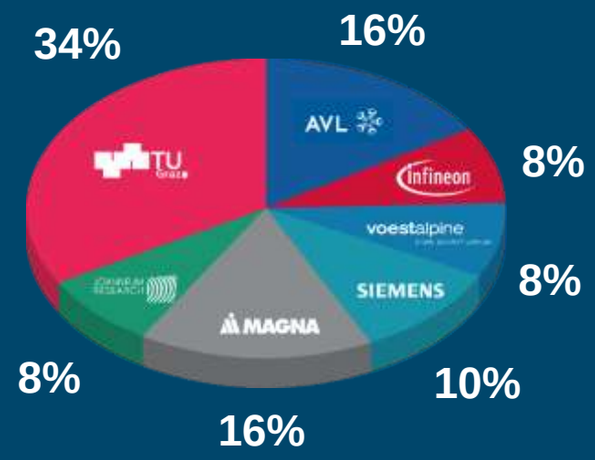
International industry- and research network

INDUSTRIE

WISSENSCHAFT

RAIL-SPECIFIC

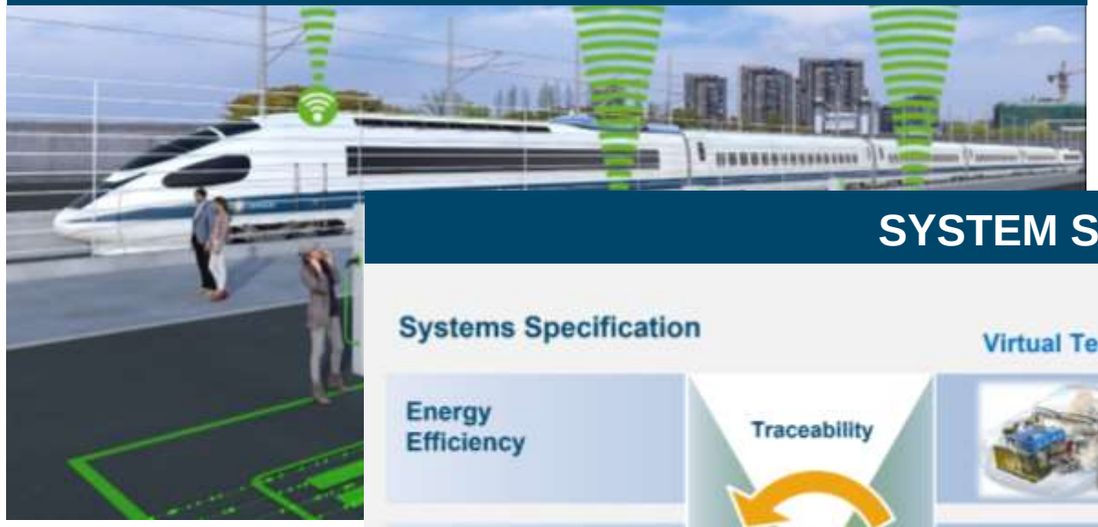
Shareholder



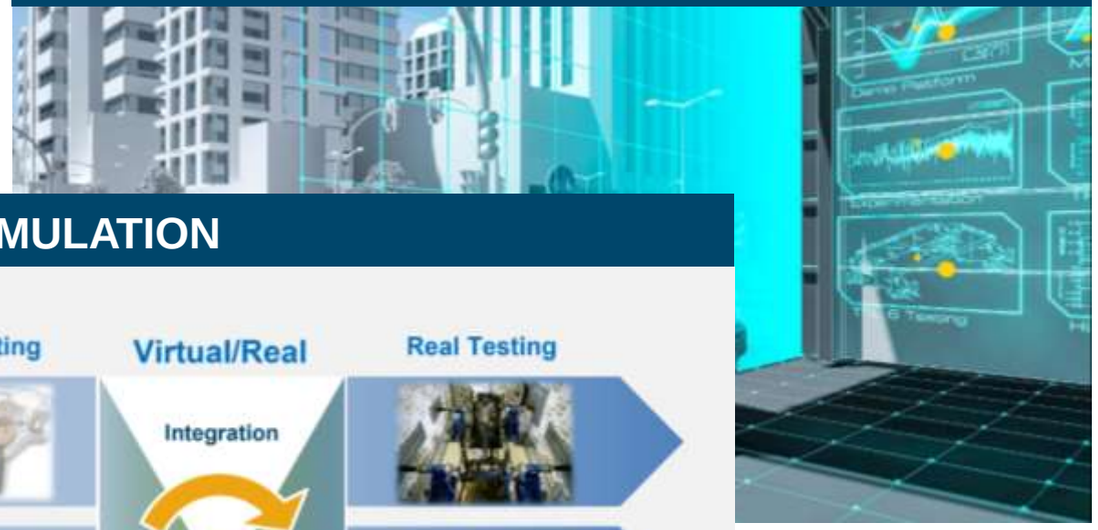
Stuff 310

Fields of Expertise

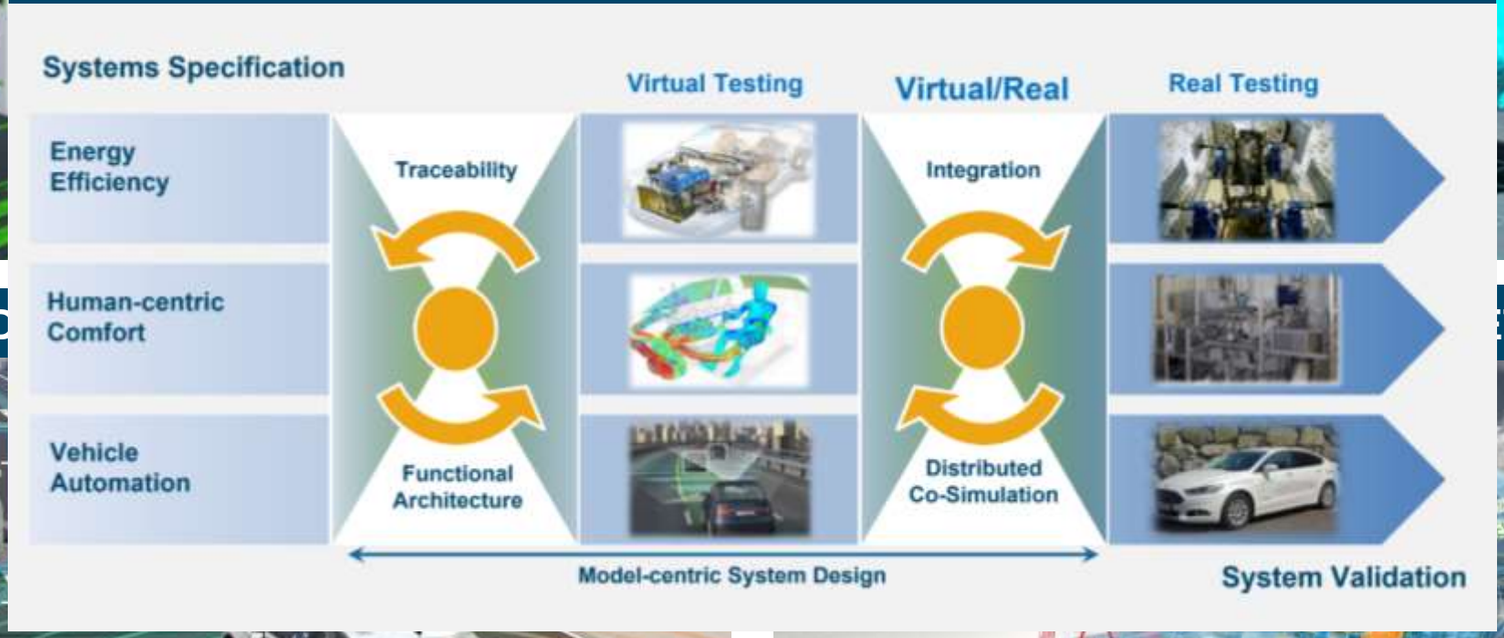
GREEN DIGITAL MOBILITY



VIRTUAL VALIDATION & HOMOLOGATION



SYSTEM SIMULATION



AUTOMATED/AD

TY & SECURITY

Agenda

1. Introduction Type Approval and Virtual Testing
2. Research Center: System Simulation and Virtual Validation
3. **Examples and Case Studies**

Comprehensive system simulation based on co-simulation

ICOS Independent Co-Simulation

- International key patents
- Industrialisation with AVL
- Eureka Research Award 2019
- 5-year framework agreement with VW Group
- 10-year strategy with voestalpine

Trend

2004 Start Co-Simulation

2007 Central Idea for COMET K2

2010 Patenting the core technology

2014 Development and distribution partnership

2019 Implementation for Rail Systems

2022 Digital Twin and Digitalisation

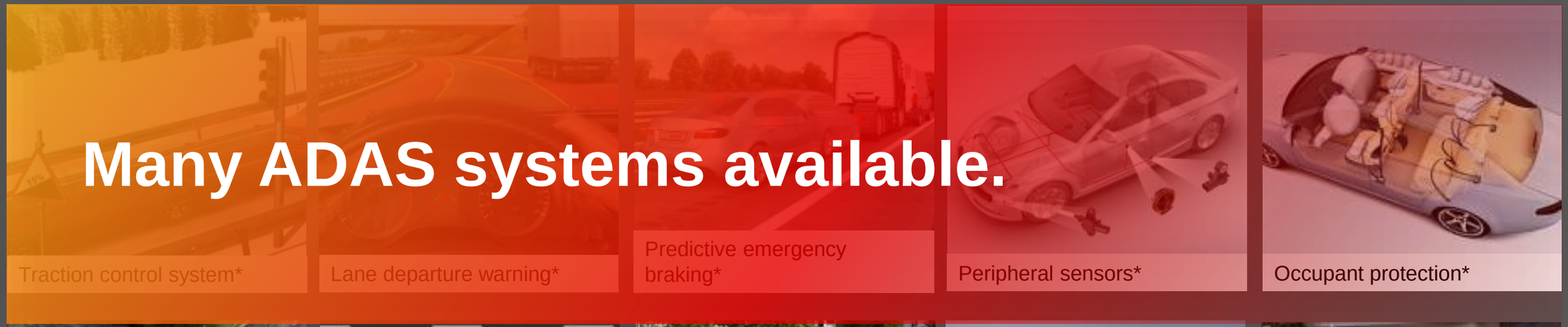
2025 Certifiable design of integrated transport and overall energy systems

Pioneering technology developed and successfully commercialised

SAFETY ASSESSMENT TOOLCHAIN

Integrated Safety Systems: Effectiveness Assessment

SAFETYASSESSMENT TOOLCHAIN



Traction control system*

Lane departure warning*

Predictive emergency braking*

Peripheral sensors*

Occupant protection*

Many ADAS systems available.

Electronic stability program*

Lane change as

Pedestrian protection*

Development Challenge:

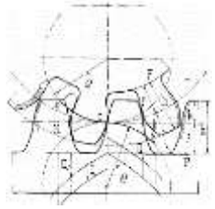
How to assess Effectiveness of Integrated Safety Systems

*Source: http://products.bosch-mobility-solutions.com/

New chances – many questions

What is the benefit of specific ADAS /ISS and their combination in new EuroNCAP ratings?

What is the best set of parameters for a specific system?



What are the risks of system failures?

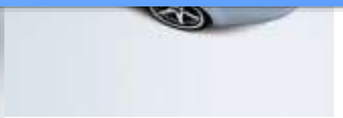
What is the benefit of specific ADAS/ISS and their combination in the field?

What are the interaction effects of different systems?

Effectiveness assessment

Lane departure

ensors



Which scenarios are relevant for the specific system?

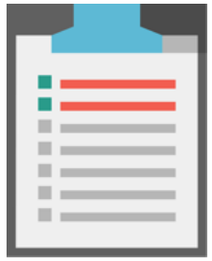
e.g. EURO NCAP www.euroncap.com

1

Electronic stability progra

nge a

How to check system behavior in that scenarios?



2

Predictive pedestrian protection*

How to score the results?

e.g. EURO NCAP www.euroncap.com

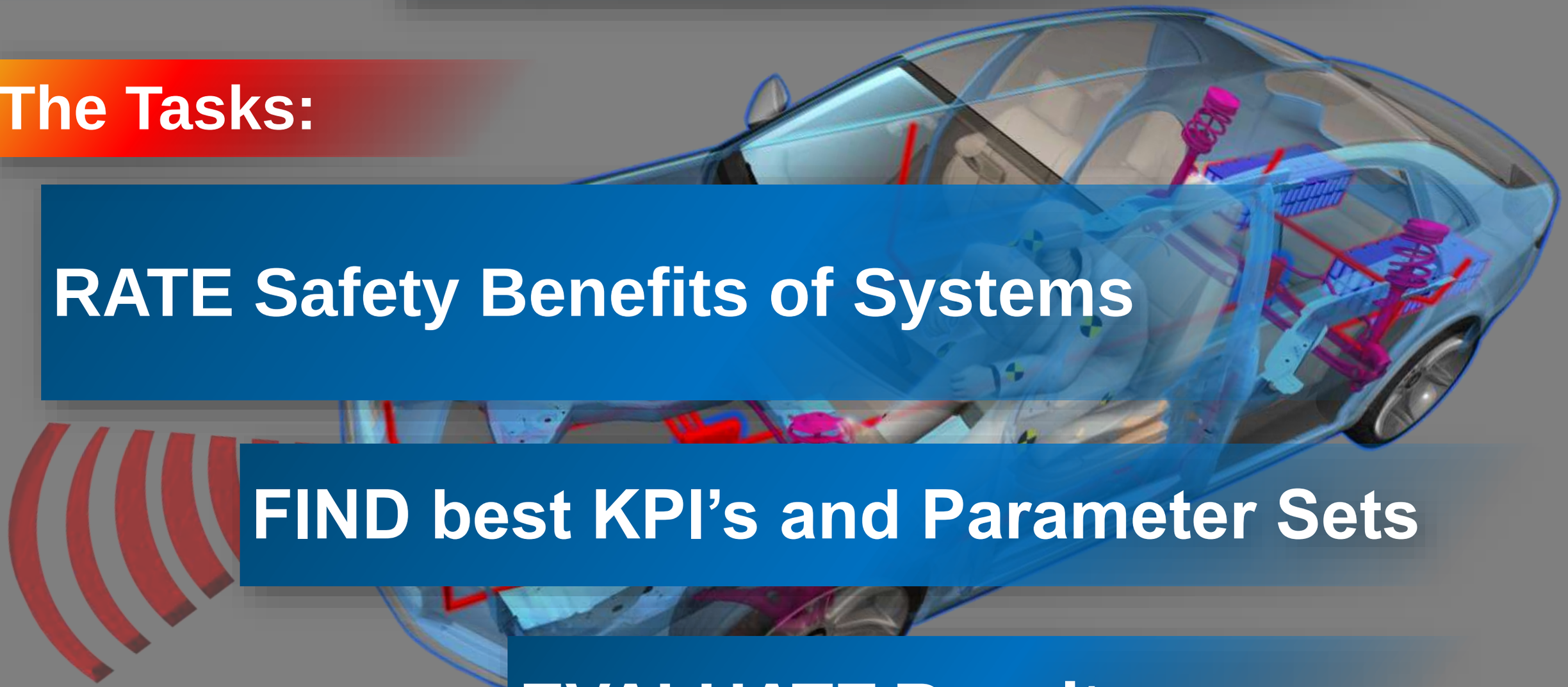
3

Pedestrian protection*

*Source: http://products.bosch-mobility-solutions.com/

SAFETYASSESSMENT TOOLCHAIN

The Tasks:

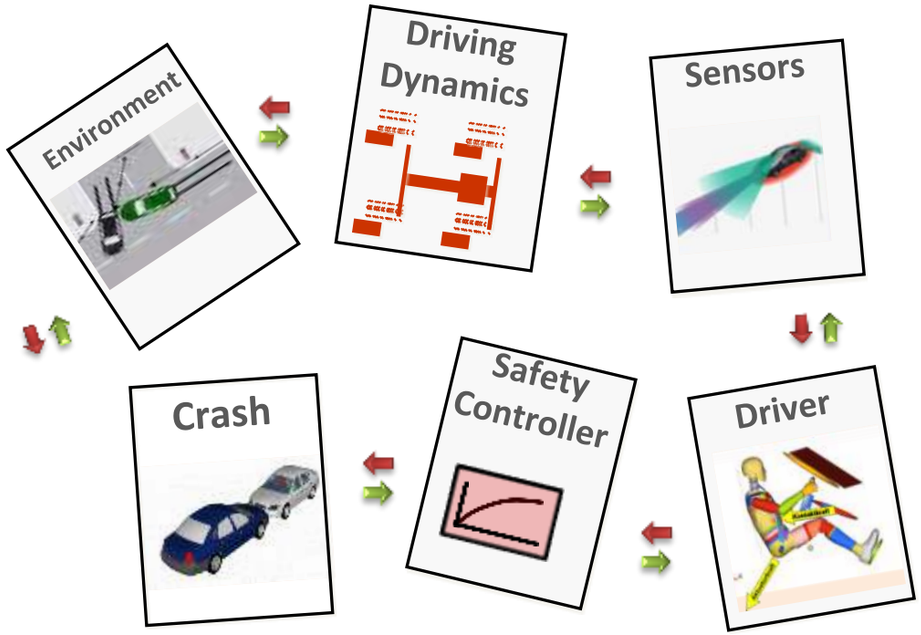


RATE Safety Benefits of Systems

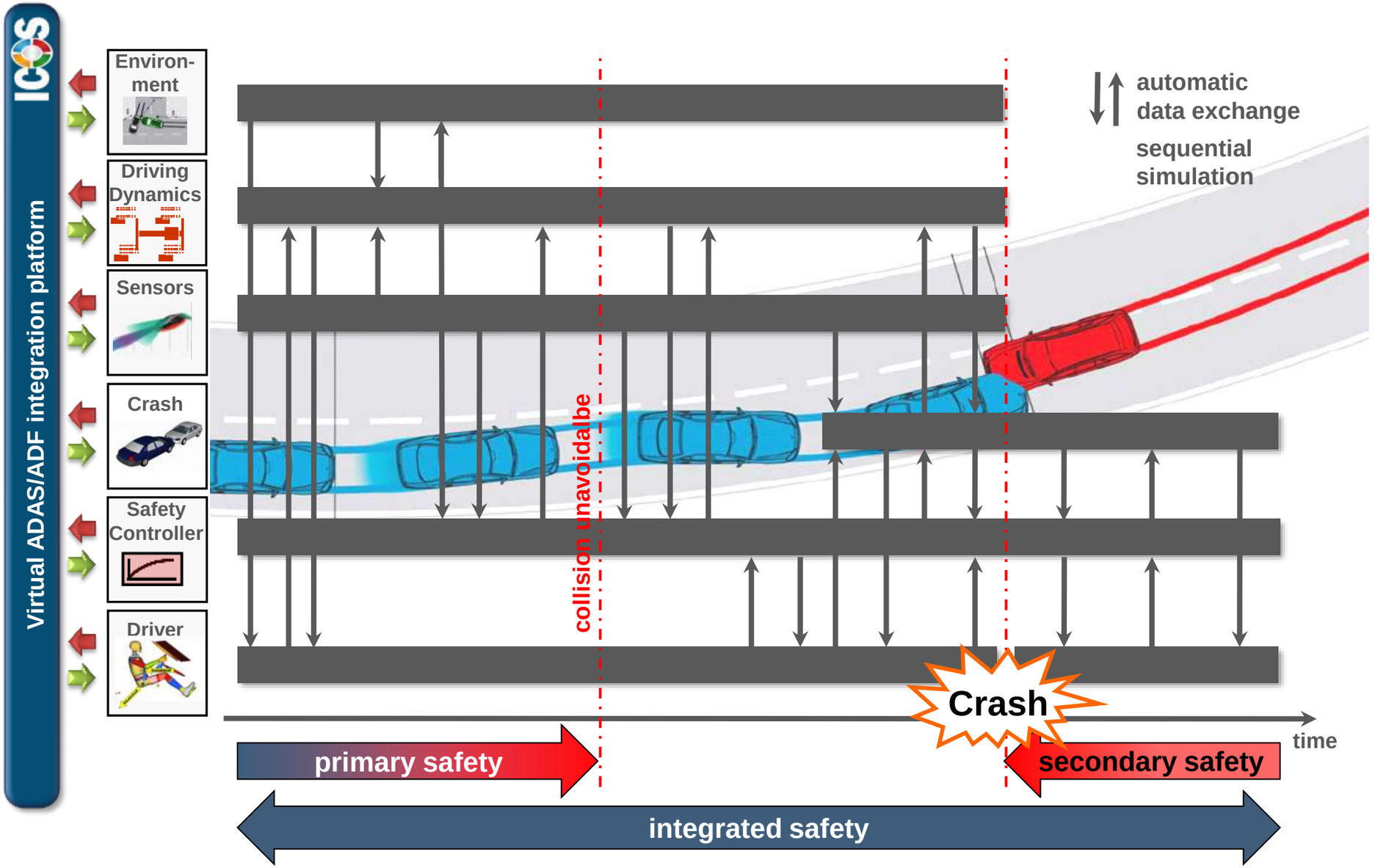
FIND best KPI's and Parameter Sets

EVALUATE Results

Continuous numerical simulation



Continuous numerical simulation



SAFETYASSESSMENT TOOLCHAIN

The Process:

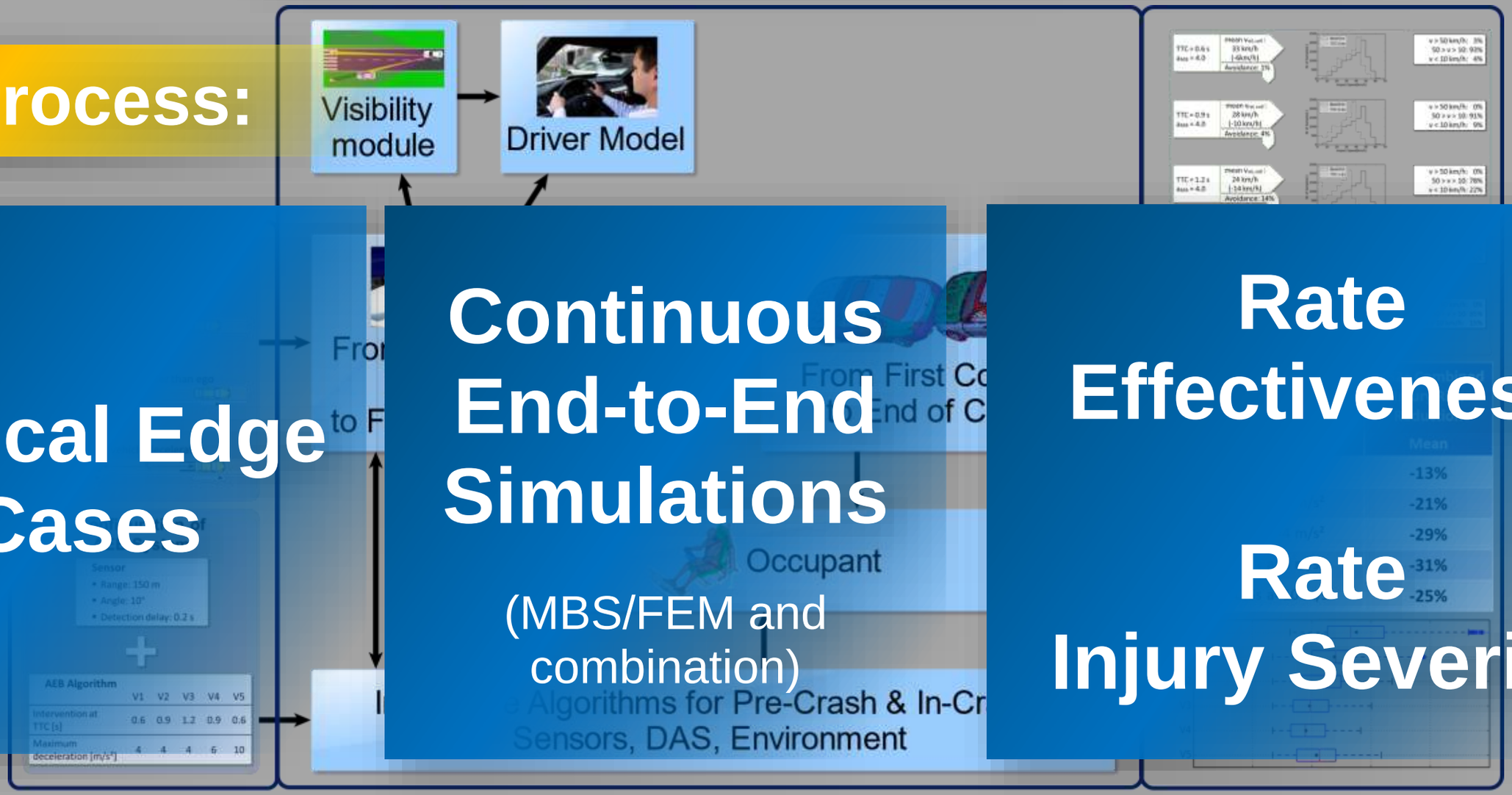
Critical Edge Cases

Continuous End-to-End Simulations

(MBS/FEM and combination)

Rate Effectiveness

Rate Injury Severity



virtual vehicle

SAFETYASSESSMENT TOOLCHAIN

The Results:

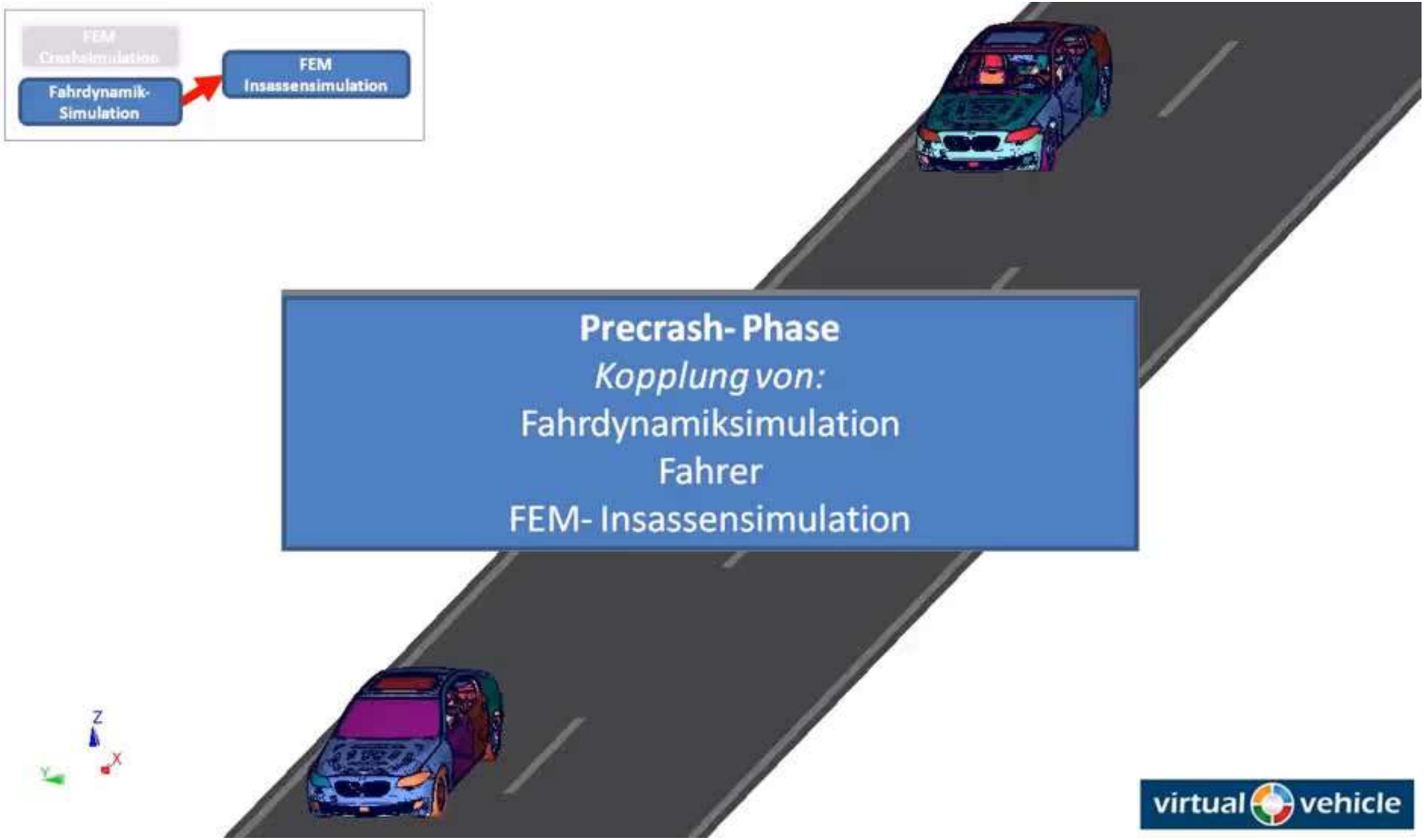
Statistical Significant

All Critical Situations

Automated Run

Easy Comparison

Effectiveness of Integrated Safety


FEM Crashsimulation
Fahrdynamik-Simulation
FEM Insassensimulation
Precrash- Phase
Kopplung von:
Fahrdynamiksimulation
Fahrer
FEM- Insassensimulation
Z
X
Y

Important

Discipline- own software

TRUSTED TOOLS

Models from development process

TRUSTED MODELS

Defined process – modular approach

PROVED METHOD

Evaluation of effectiveness

Quality of Simulation?

Readyness for Virtual Validation

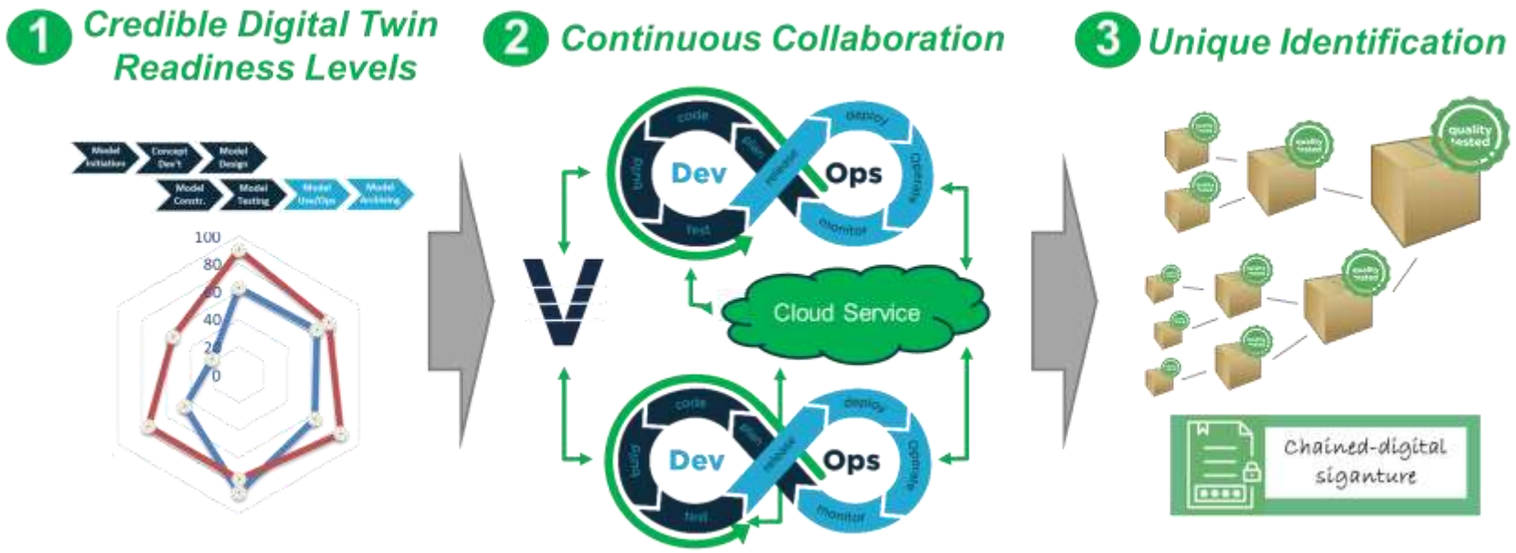

UPSIM
UNLEASH POTENTIALS IN SIMULATION

Spotlight ITEA3 Project UPSIM *(30 Partners, 6 Countries)*

Challenge: A recent market study outlines that less than 1 % of physical machines and components "… are modelled such that the models capture and mimic behavior" today!

Challenge: Currently envisioned systems complexity reaches a level where real testing will be temporally, practically and economically impossible!

Solution Approach:



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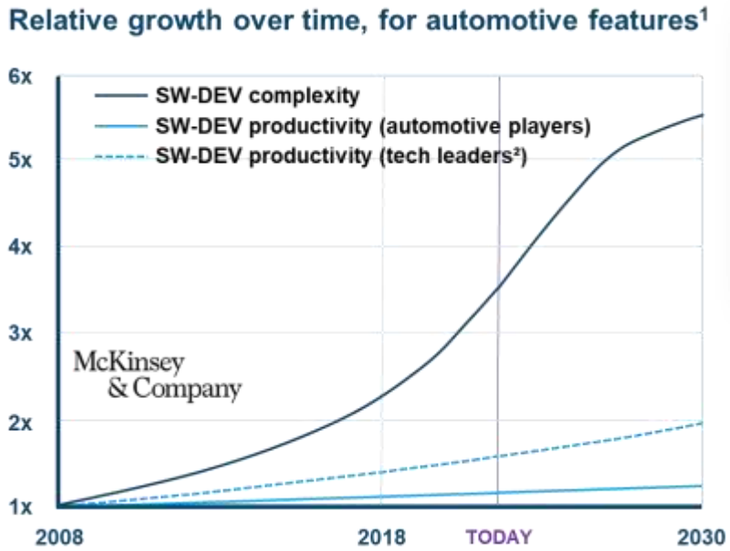
Automotive Use Case:



[1]Analysis of >200 software-dev't projects from OEMs, tier-x suppliers
[2]Top-performing quartile of technology companies
Source: Numetrics by McKinsey

UNECE

Simulation tool and mathematical models for verification of the safety concept may be used in accordance with Schedule 8 of Revision 3 of the 1958 Agreement, in particular for scenarios that are difficult to track on in real driving conditions. Manufacturers shall demonstra simulation tool, its validity for the scenario concerned a performed for the simulation tool chain (correlation physical tests).

"Proposal for a new UN Regulation on uniform provisions of vehicles with regards to Automated Lane Keeping Syst

(ECE/TRANS/WP.29/2020/81)

absence of specific processe

ISO

Tolerances allowed between metrics obtained from physical testing and simulation

Metric	Test run	Tolerance
First peak yaw rate ($\dot{\psi}_1$ in Figure 2)	Last run without ESC intervention First run with ESC intervention Last run	±15 %
Time of yaw rate crossing zero (T_C in Figure 2)	Last run without ESC intervention First run with ESC intervention Last run	±0,1 s
Second peak yaw rate ($\dot{\psi}_2$ in Figure 2)	Last run without ESC intervention	±20 %
	First run with ESC intervention	±25 %
	Last run	±25 %
Lateral displacement of the vehicle C.G.	Last run without ESC intervention	±15 %
	First run with ESC intervention	±18 %
	Last run	±18 %

"Passenger cars — Validation of vehicle dynamic simulation — Sine with dwell stability control testing"

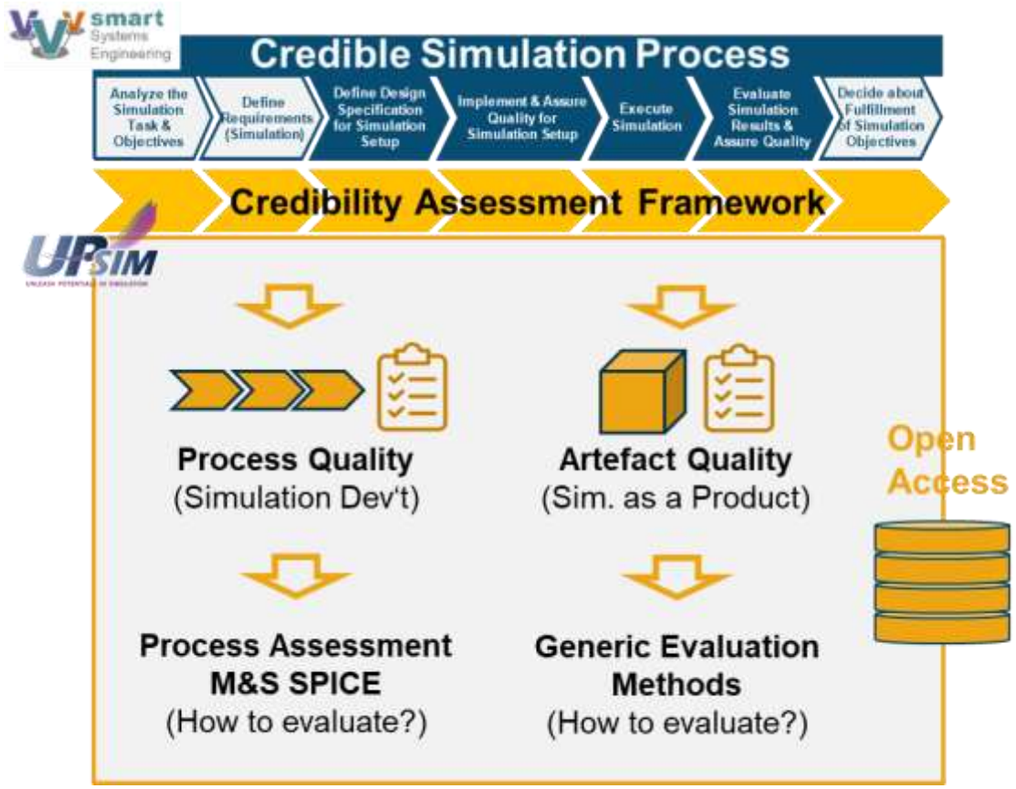
(ISO 19365:2016)

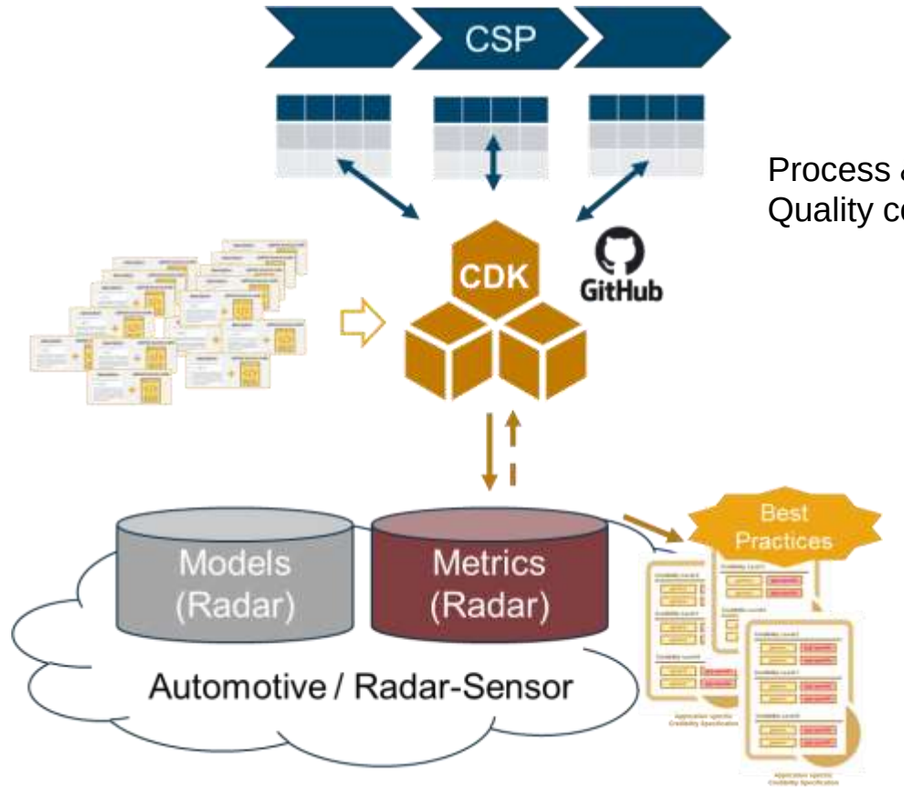
unassertive validation criteria

Spotlight ITEA3 Project UPSIM *(30 Partners, 6 Countries)*

Main Aim: "transparent and bilateral understanding of Modelling and Simulation Quality"

Sustainable Results: Open Access standard for Credible Simulation and a Credibility Assessment Framework, including a Credibility Development Kit





Process & Artefact Quality covered

2015: First autonomous research car in Austria

Success Story „Connected and Automated Driving“

- 2015 First AD vehicle in Austria
- More than 20 EU projects
- International top position (cooperation Stanford, MIT, Univ Pittsburgh, NVIDIA, Apex.AI)
- Showcases at CES in Las Vegas

2012
Sensors Perception

2016
Premiere: L4 driving functions on public roads in AUT

2017
Setup ALP.Lab

2018
Endowed Professorship Automated Driving

Coordinator Project GENDrive

2019
First victory at RoboRace

2020
EU Projekt „SHOW“

2021
ZeroOne: EV Concept Car for AD & Interieur

2022
Remote SW Deployment

Failsafe systems

2025
Certified SW Stack

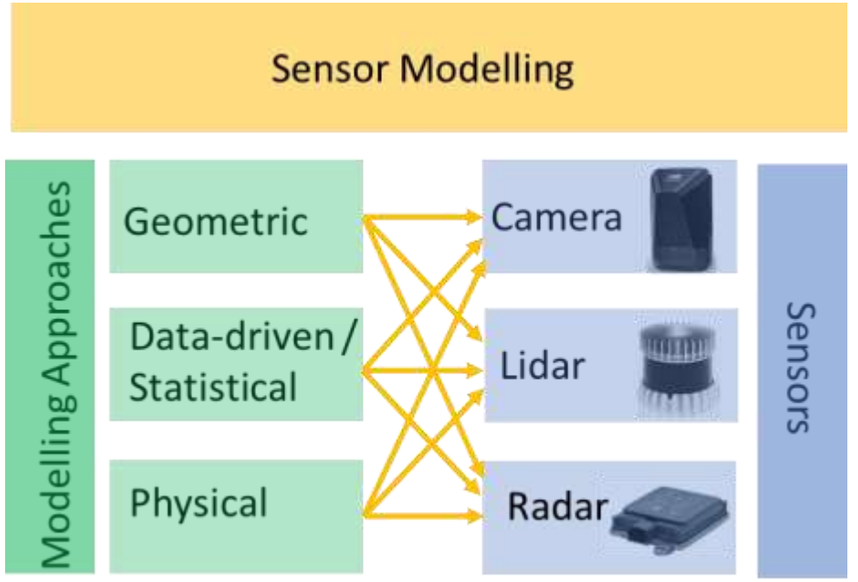
Virtual Validation & Sensor Modelling

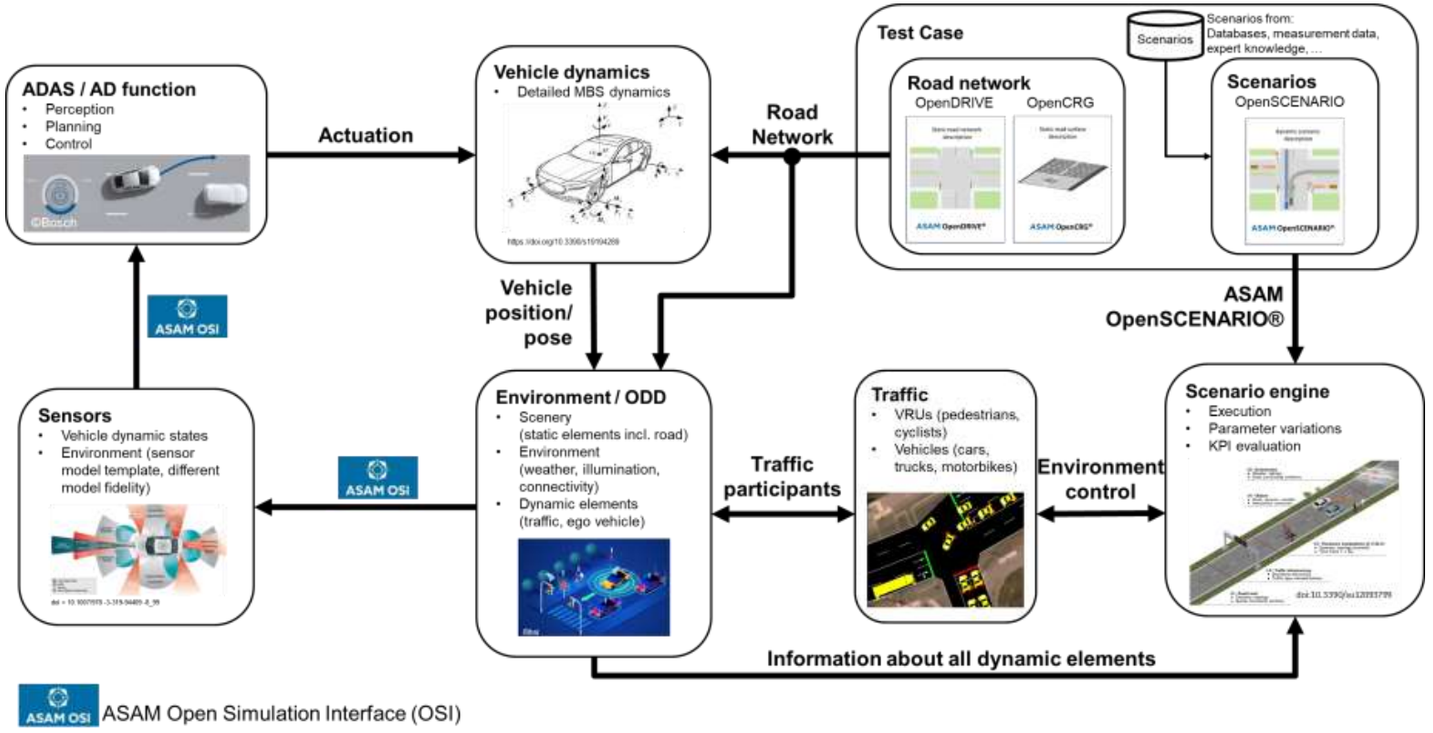
SENSE – K2DM

- 2018 - 2021
- 1.2 Mio €
- Sensor Model Development
- 4 Journal Publications

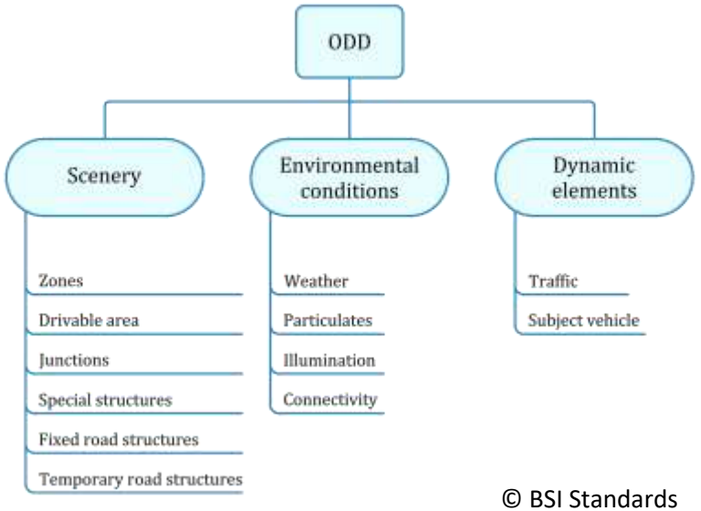
Road2VV – K2DM

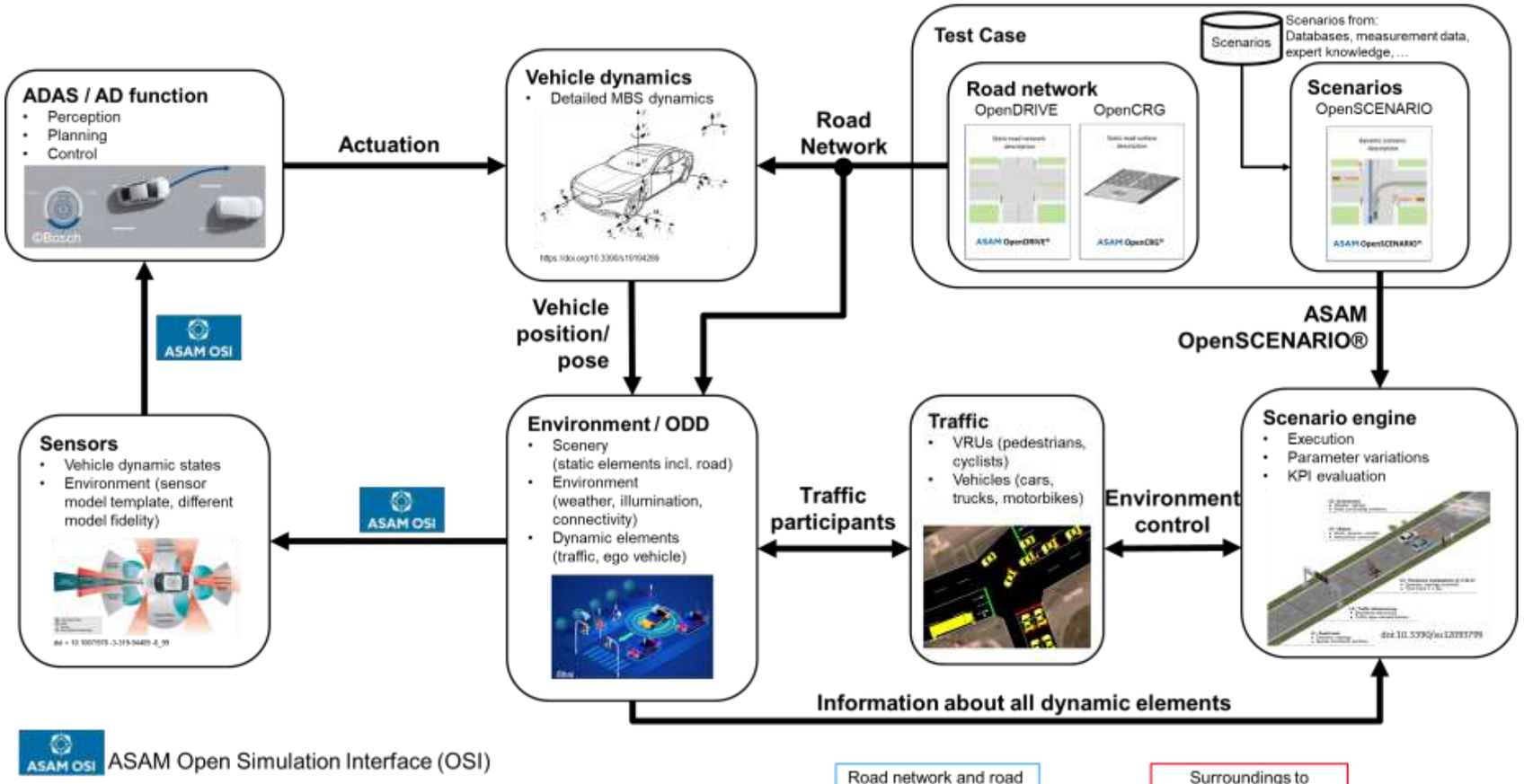
- 2021 – 2024
- 1 Mio €
- Follow-up of SENSE
- Virtual Validation of AD-functions

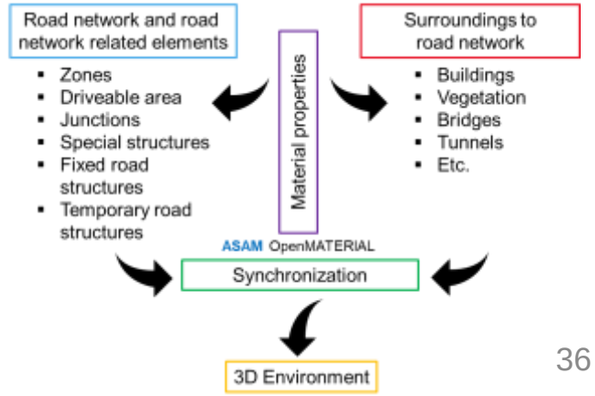




Virtual Validation & Sensor Modelling



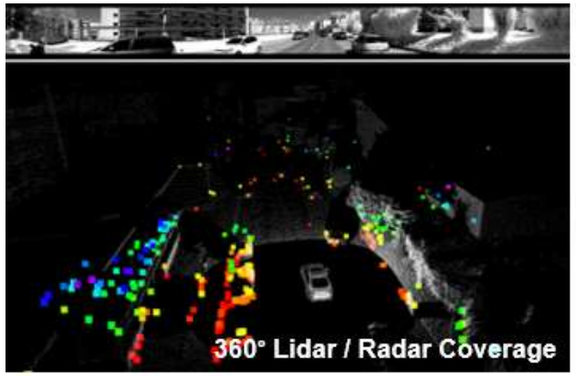


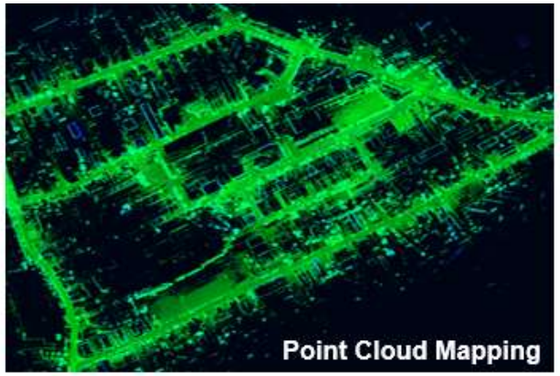


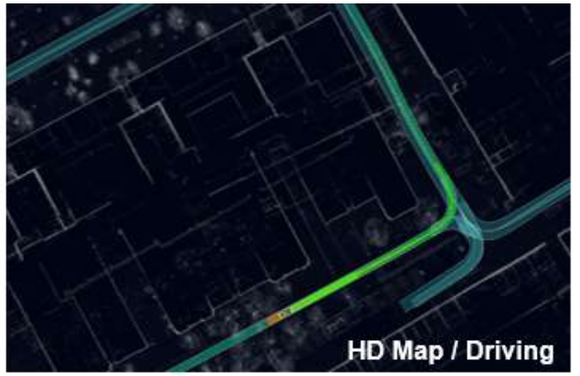
Automated Driving

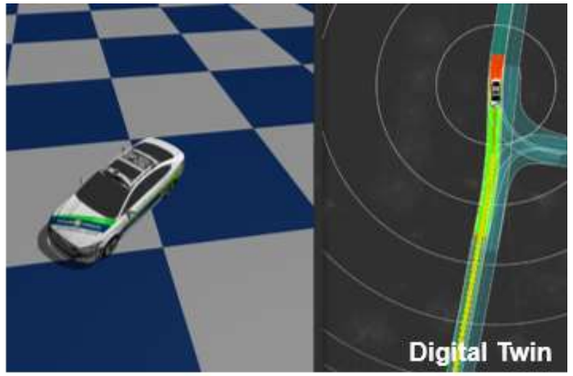
AUTOWARE

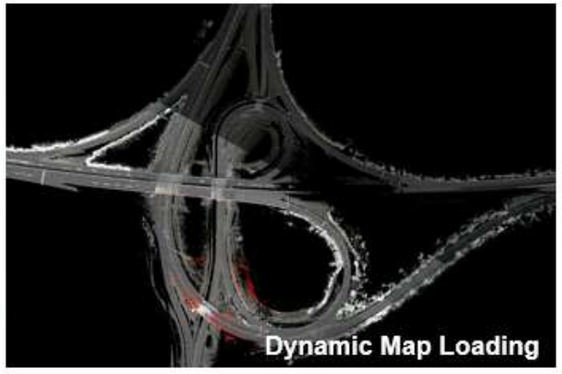
virtual vehicle

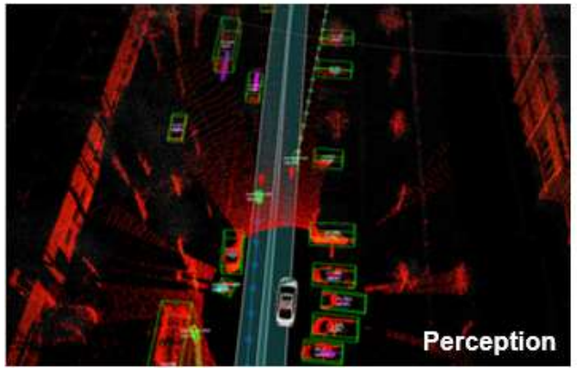


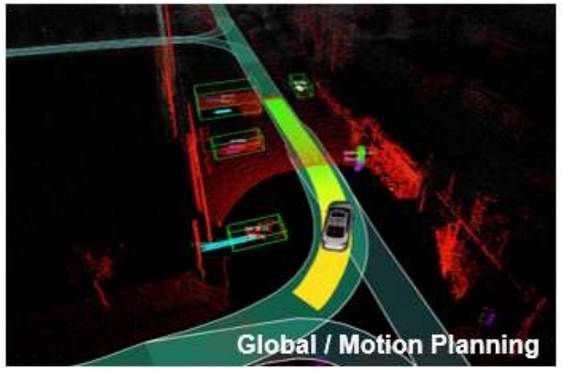


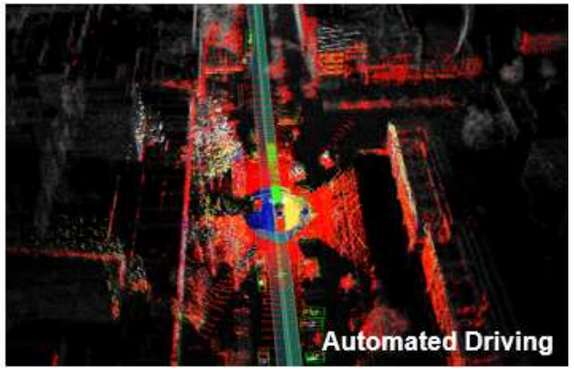




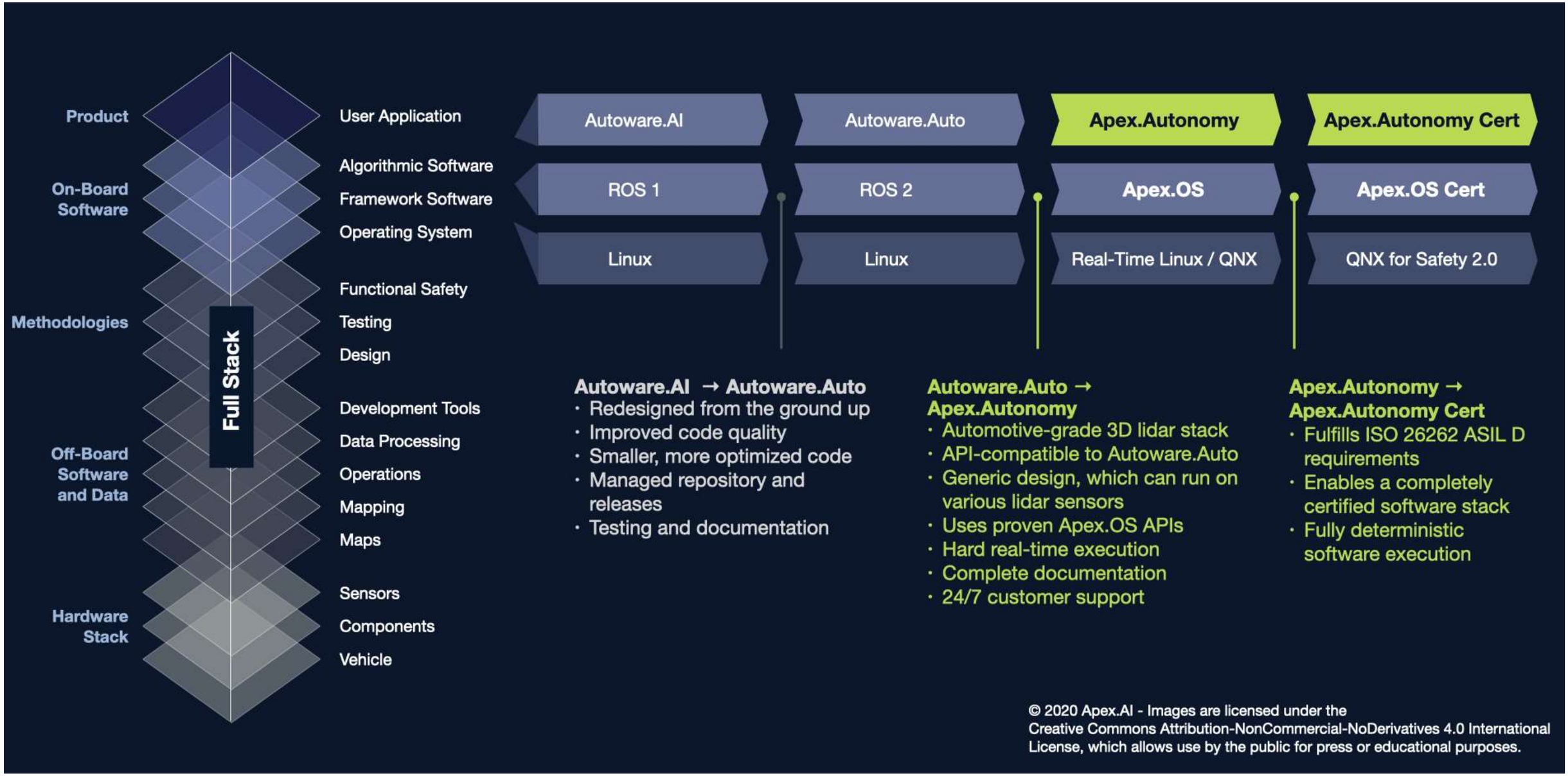








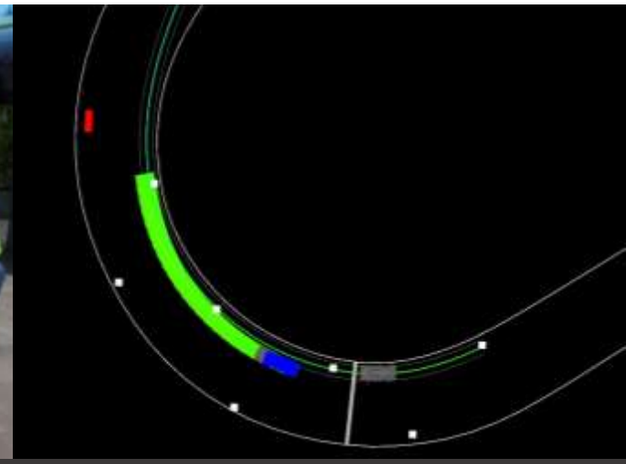
Motivation ROS1 / ROS2 / Apex.OS ®



We make autonomous racing happening.

ARG
autonomous racing · graz





10
Team Members

2
Organizations

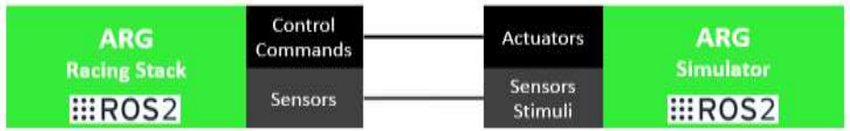
1
Goal

virtual vehicle TU Graz

Take autonomous driving to the limit

Development and Validation Levels

ARG Development Environment (team members)

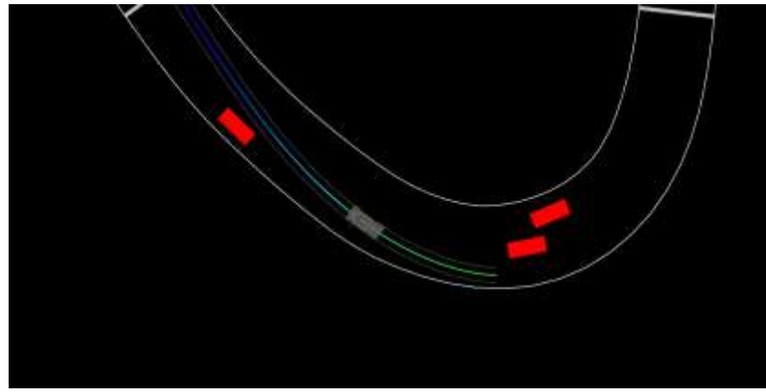


Desktop Computer / Notebook

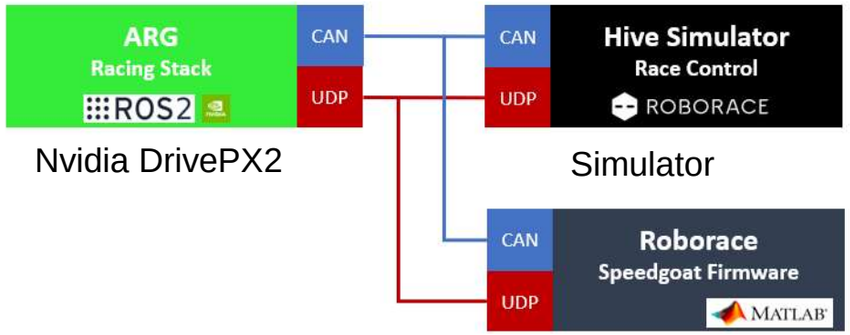
Software Stack Simulator

- Algorithm Development
- Scenario Variation
- System Optimization

+ Faster than realtime
+ Easy to use
- Limited sensor/vehicle model
- No execution on real hardware



Roborace HiL



Nvidia DrivePX2

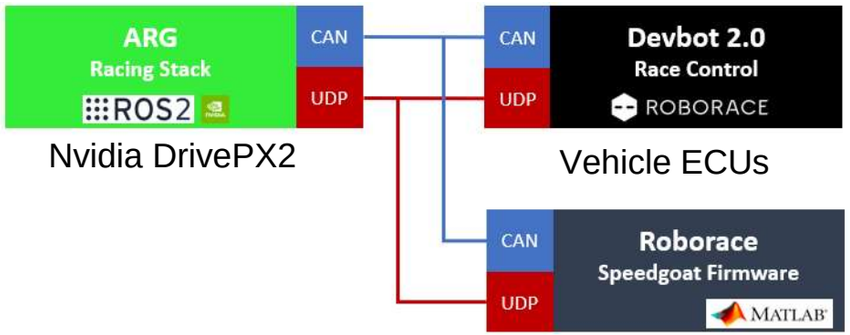
Simulator

Speedgoat

- Algorithm Tuning
- Functional Tests
- Timing Evaluation

+ Real hardware behaviour
- Realtime
- Limited on available hardware

Roborace Devbot 2.0



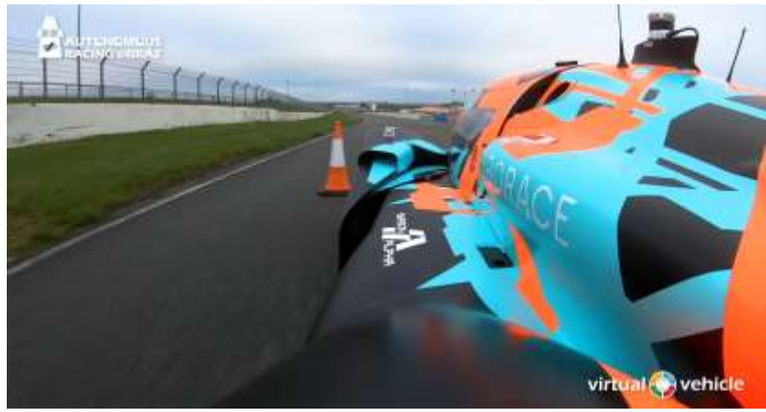
Nvidia DrivePX2

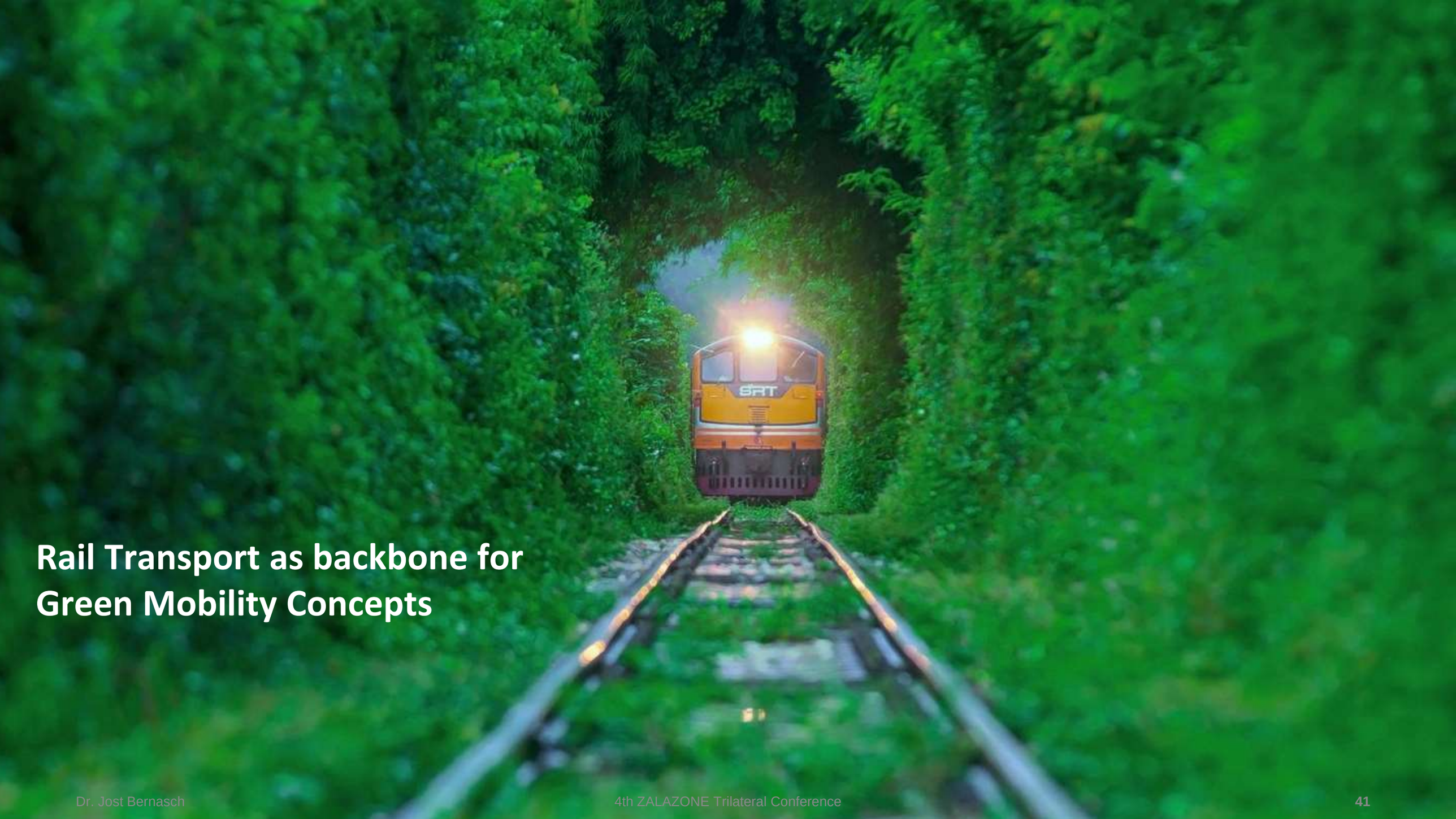
Vehicle ECUs

Speedgoat

- Test and training session
- Final parameter tuning

+ Real vehicle behaviour
- Failures not acceptable
- Limited time
- Time consuming





Rail Transport as backbone for Green Mobility Concepts

Virtual validation and commissioning: Example Rail Systems

Ambitious Goals:

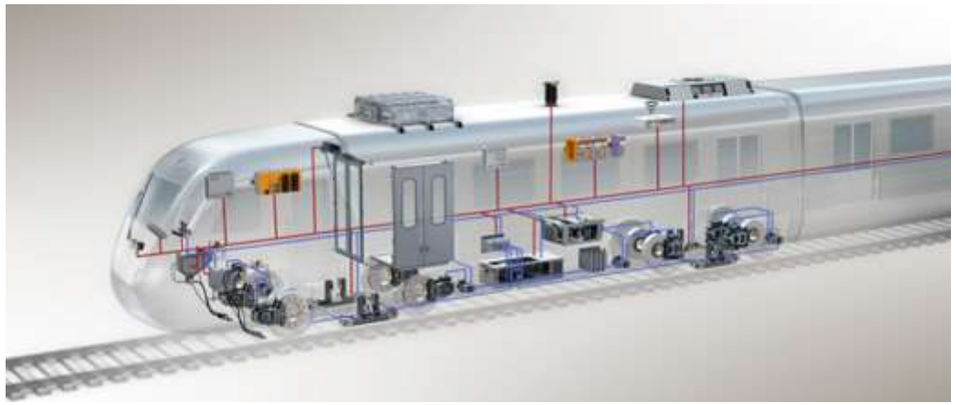
Development | **Approval** | **Operation**

- **Product development times reduced by 60%**
- **Technical risk minimisation**

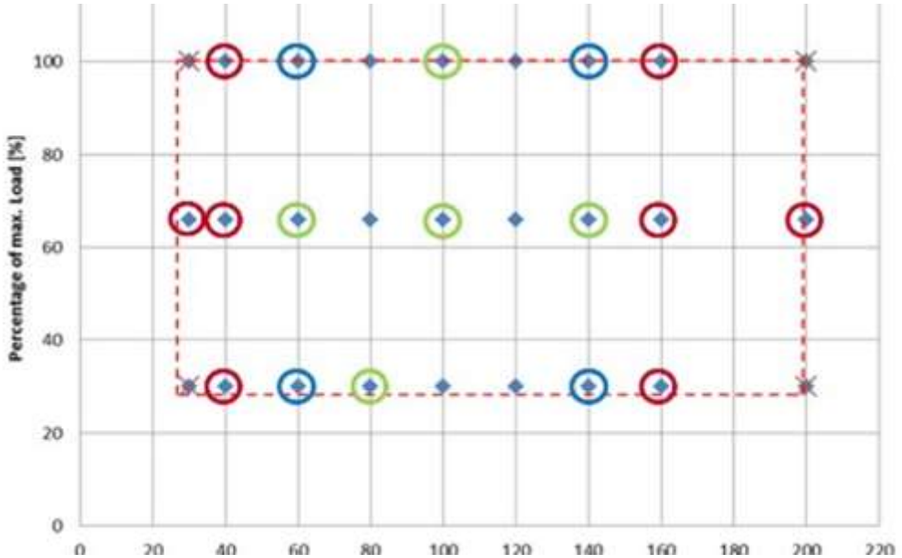
- **Reduction of test drives and testing effort by 90%.**
- **Faster approval**

- **Availability increased to 99%**
- **Monitoring and Digital Twin**

Spotlight Project VVC (Partner: Knorr Bremse)

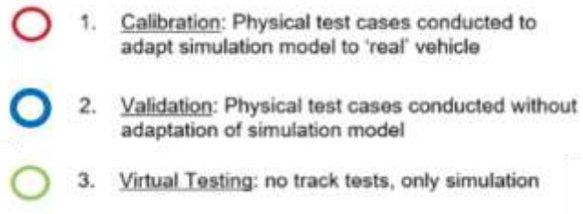


Number of tests for approval:
3 (weight) x 9 (init. speed) x 4 (stochastic) = 108
Duration: 2-3 months, costs: ~~€€€€~~



Virtual Validation for Certification (VVC)

- Idea: Calibration and validation for virtual tests



- Realisation of process, simulation tool, methods for **partial-virtual type-approval (VIF K2 project)**

- **Challenges**
  - Today: Standards landscape (TSI LOC&PAS) does not accept virtual tests

- **Initiatives to enable VVC:**
  - Cooperation with standardisation organisations (ERA, NB-Rail) Platform: Shift2Rail PIVOT2
  - CEN TC256 SC3 WG55 "Simulation" (new work item proposal), allow simulation as an option where previously only real test was allowed
  - UpSim project: Quality metrics for modelling and simulation e.g. ISO 33000


STANDARDS

Spotlight Project P.E.A.R.S.

PROSPECTIVE EFFECTIVENESS ASSESSMENT FOR ROAD SAFETY

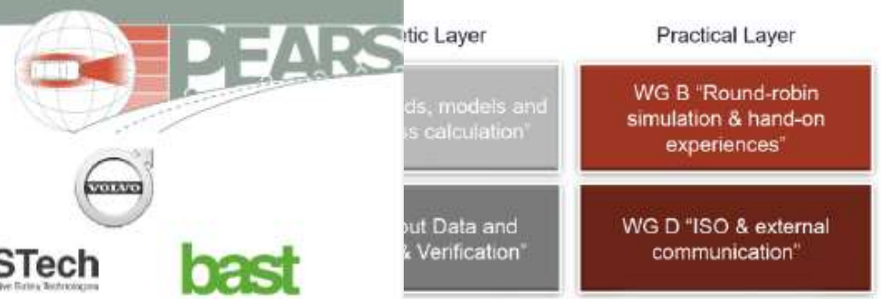
A comprehensible, reliable, transparent, and accepted methodology for quantitative assessment of vehicle-integrated crash avoidance technology by virtual simulation

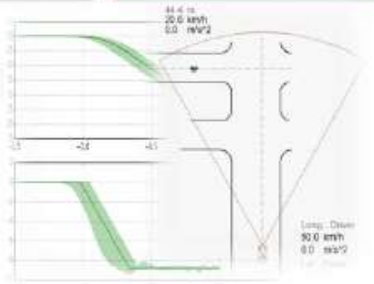
Established in 2012

ISO Standard

The P.E.A.R.S. Initiative - Partners

BMW GROUP, TOYOTA, VOLKSWAGEN, VOLVO, Continental, DENSO Crafting the Core, ZF, ASTech, bast, VUFO, TÜV SÜD, UTAC CERAM, TNO innovation for life, LAB, Allianz Center for Technology, GENERALI, jenIOT, Swiss Re, virtual vehicle, TU Graz, ika RWTH AACHEN UNIVERSITY, Technische Universität Berlin, UNIVERSITY OF LEEDS, Technische Hochschule Ingolstadt, Fraunhofer IPK INSTITUTE PRODUCTION SYSTEMS AND DESIGN TECHNOLOGY, Fraunhofer IVI, TECHNISCHE UNIVERSITÄT DRESDEN





- **ISO 21934 work items** technology by virtual si
  - Part 1: State-of-the-art and general method overview (Technical Report).
  - Part 2: Guidelines for application (Technical Specification - under preparation).
- **Publications:** ESV – 2015, 2017, 2019

Spotlight Project EUREKA TestEPS

Value of the project

- Virtual Testing of the full driving function & the perception system

Roadmap for virtual homologation

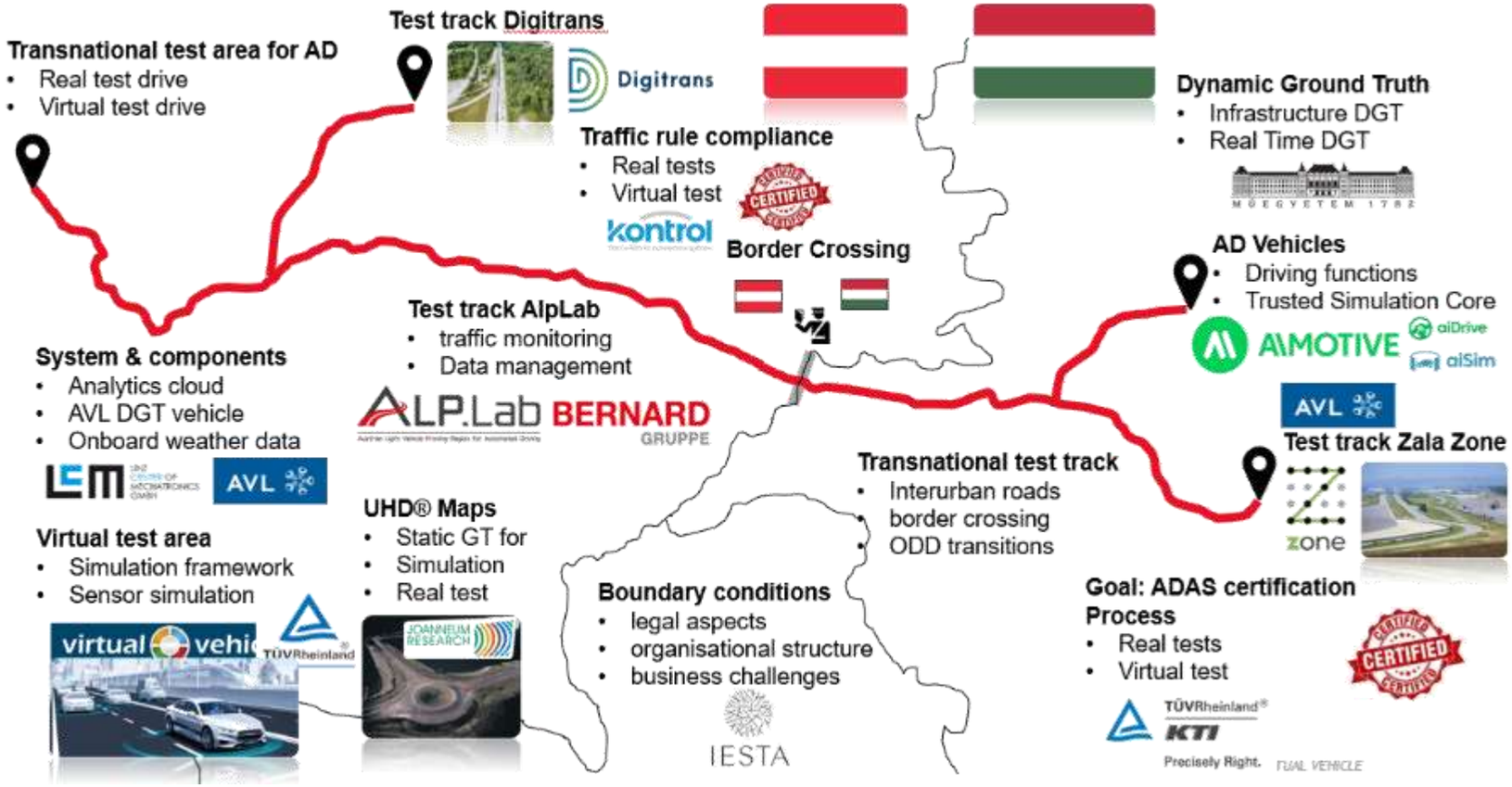
- What are the fidelity levels / credibility suitable for homologation?

Challenges

- Certification will require a smart combination of Virtual & Physical Testing
- Fostering collaboration beyond borders

EUREKA testEPS Vision:

Certified automated driving functions and environmental perception systems (EPS) for robust and safe operation of automated mobility



Spotlight Mobile HiL-Platform - SPIDER

Autonomous platform for verification and validation of sensor systems, vehicle software and control algorithms.

- Target vehicle imitation (max. speed: 50 km/h)
- Precise repetition of test scenarios (4-wheel-drive)
- Road legal

Development of tailor-made test scenarios.

- Risk assessment and test concept development
- Identification of edge cases and critical test scenarios

Spotlight „Austria goes NCAP“

Safety Labs Austria - Overview

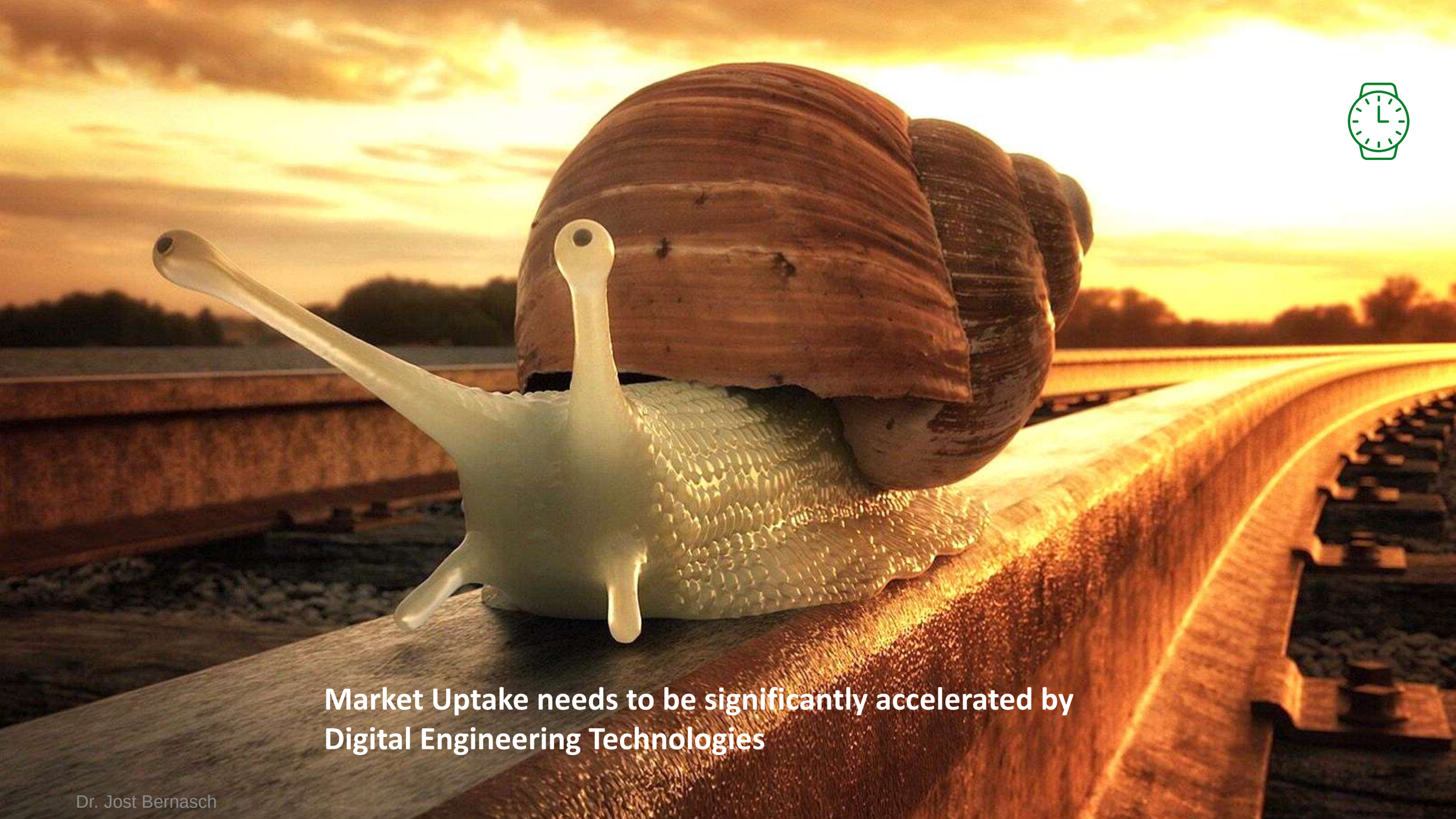
Austria has been an official EURO NCAP member since 2022.

Vehicle testing will be carried out at the Safety Labs Austria:

Passive Safety: Capgemini engineering

Active Safety: DSD ALP.Lab

Virtual Testing: TU Graz, virtual vehicle



Market Uptake needs to be significantly accelerated by Digital Engineering Technologies

Summary

1. Due to complexity of systems there is a high demand of Virtual Testing.
2. Virtual Vehicle works on and pushes virtual testing in Rail and Automotive
3. Type approval will require a smart combination of Virtual & Physical Testing;
4. Acceptance of virtual testing for homologation process
   ➔ credible system simulation, verified processes (UPSIM)
5. Virtual Vehicle actively participates in international committees (EuroNCAP)


virtual vehicle
GREEN DIGITAL MOBILITY
Thank You!
AUTOMATED DRIVE
AUTOMATED DRIVE