

fka

ika

RWTH AACHEN  
UNIVERSITY

**Institute for Automotive Engineering (ika), RWTH Aachen University  
fka GmbH**

**Introduction**





## Insights into Road Vehicle Research



Foundation of the chair for Automotive Engineering 1923

Prof. Lutz  
1902



Institute for automotive engineering and piston engines

Prof. Langer  
1906



Institute for automotive engineering 1972

Prof. Helling  
1971

+



Institute for automotive engineering 2008

Prof. Gies  
2008

+



2015

fka  
SILICON VALLEY



Univ.-Prof. Dr.-Ing. Lutz Eckstein  
Director and Chair, Institut für Kraftfahrzeuge (ika), RWTH Aachen University

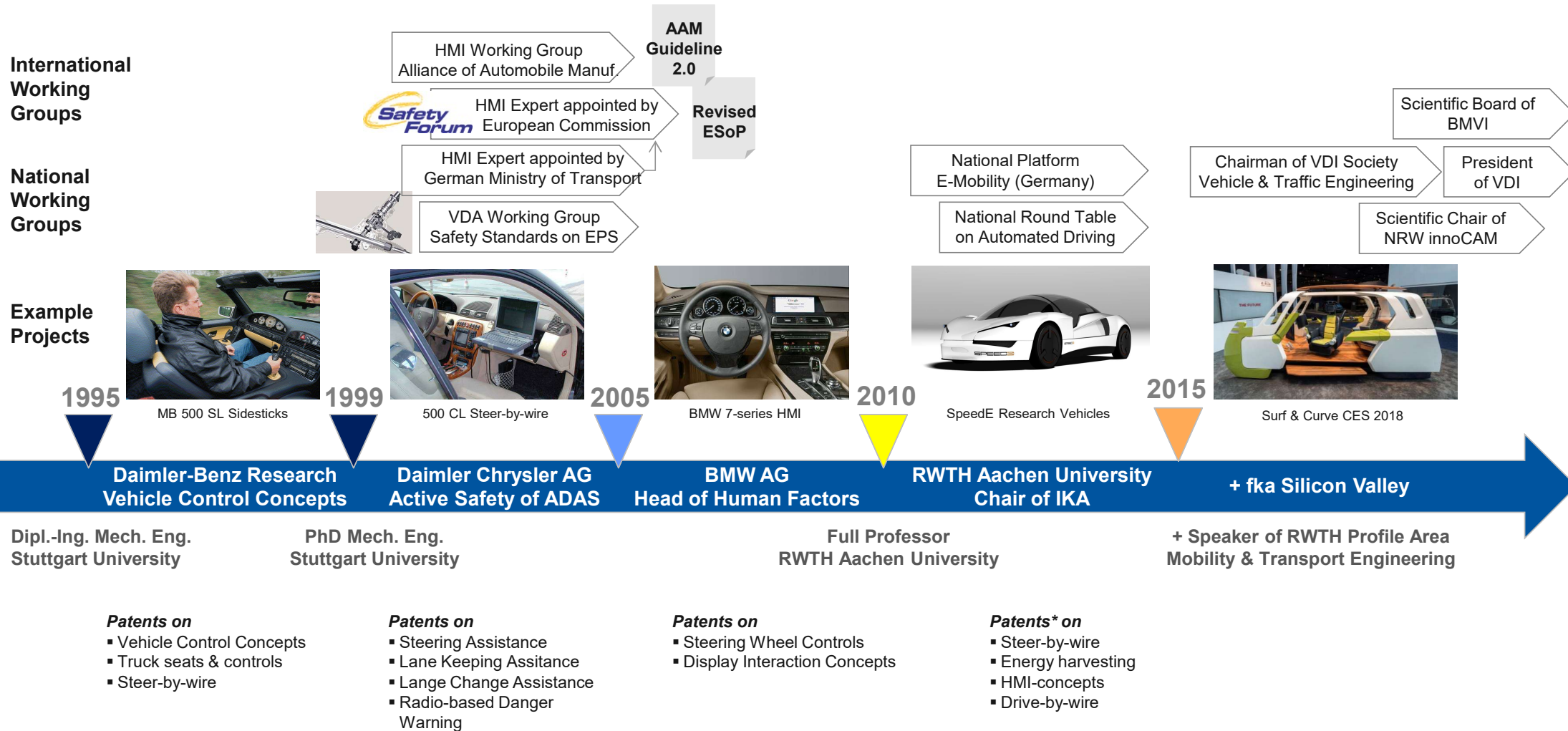
# Introduction

## Personal History of Lutz Eckstein

### International Working Groups

### National Working Groups

### Example Projects



# I. Introduction

## Mission of ika and fka



### Leading Education and Research in Automotive Engineering



#### > Education

- Profound & interdisciplinary education on a high level
- Early introduction of students into research projects
- Tailored training for professionals

⇒ ***Creativity and internationalisation***

#### > Public funded Research

- Research on fundamentals and innovative concepts
- excellent basis for IP and publications
- Formation of national and international networks

⇒ ***Perception as creative minds & coordinators***

#### > Industrial Research

- Transformation of IP into innovation
- neutral, competent partner with focus on technology
- development of personality and project management

⇒ ***Social responsibility***



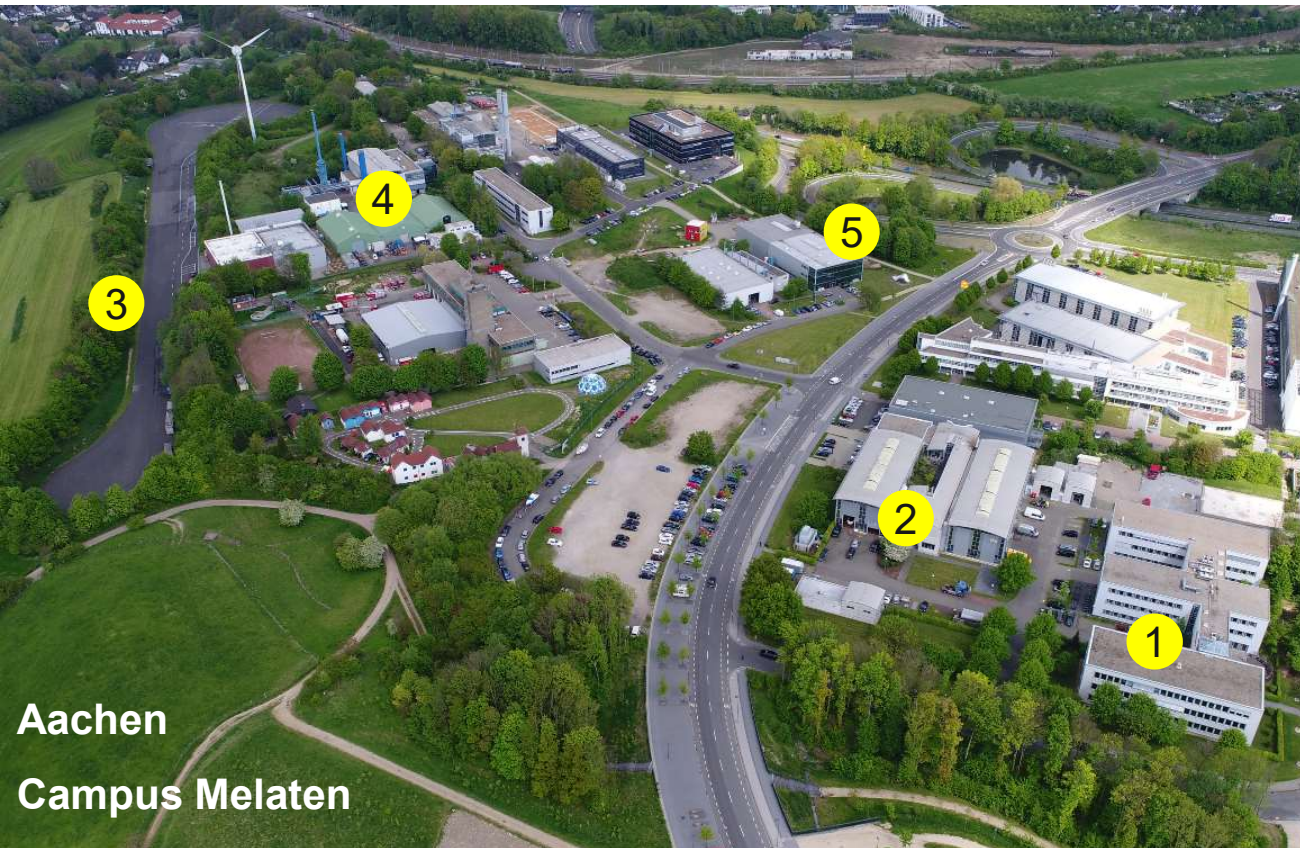
**Creating Ideas and Driving Innovation  
for Safe, Efficient and Exciting Mobility**





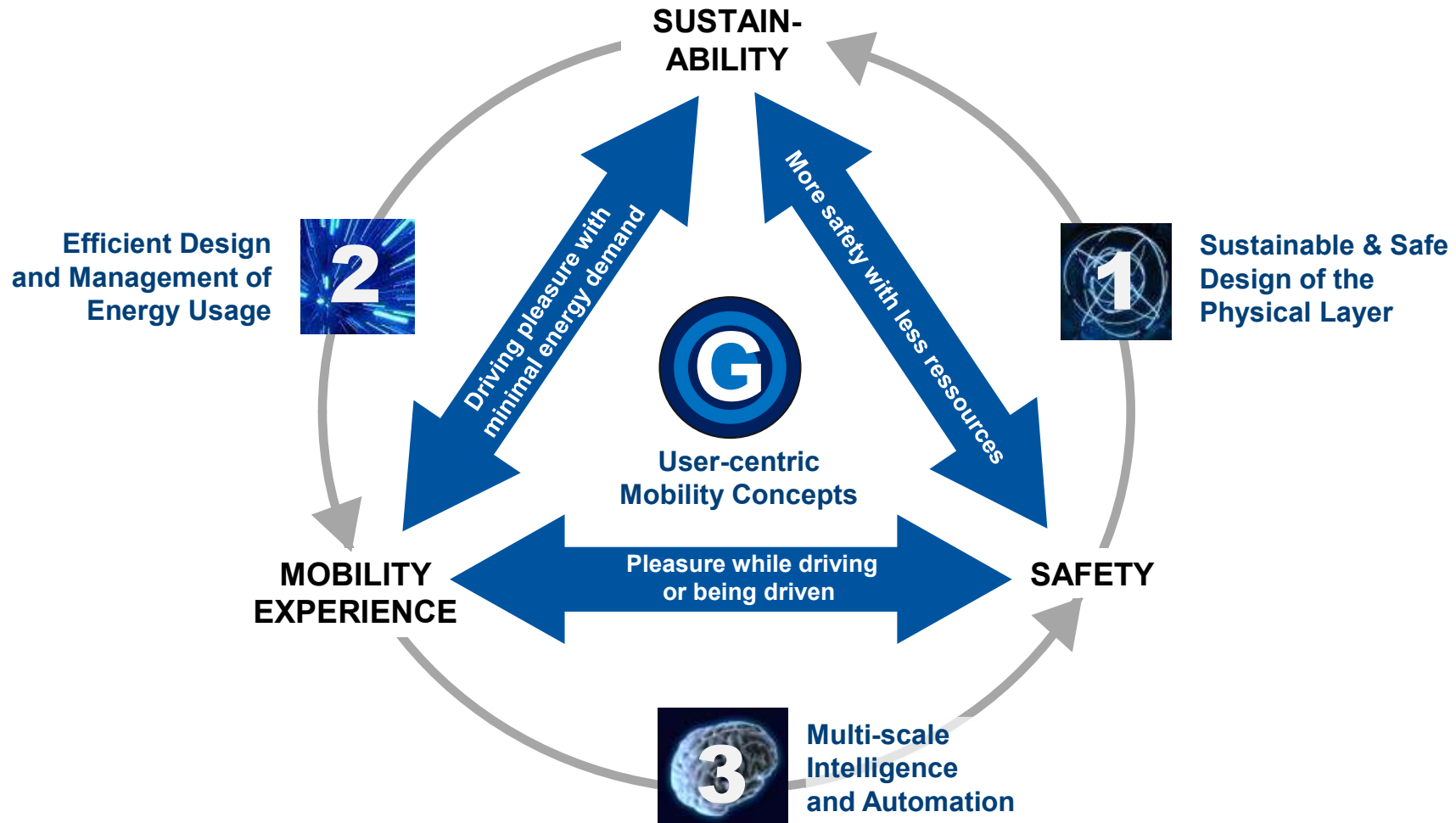
# Introduction

## Infrastructure and test tracks



- 1 Office building & German Design Studio Aachen
- 2 Lab-building
- 3 ika-Test track
- 4 Test bench building
- 5 Centre for metal construction ZMB
- 6 High fidelity driving simulator
- 7 Aldenhoven Testing Center (ATC)
- 8 fka Silicon Valley, Santa Clara, CA

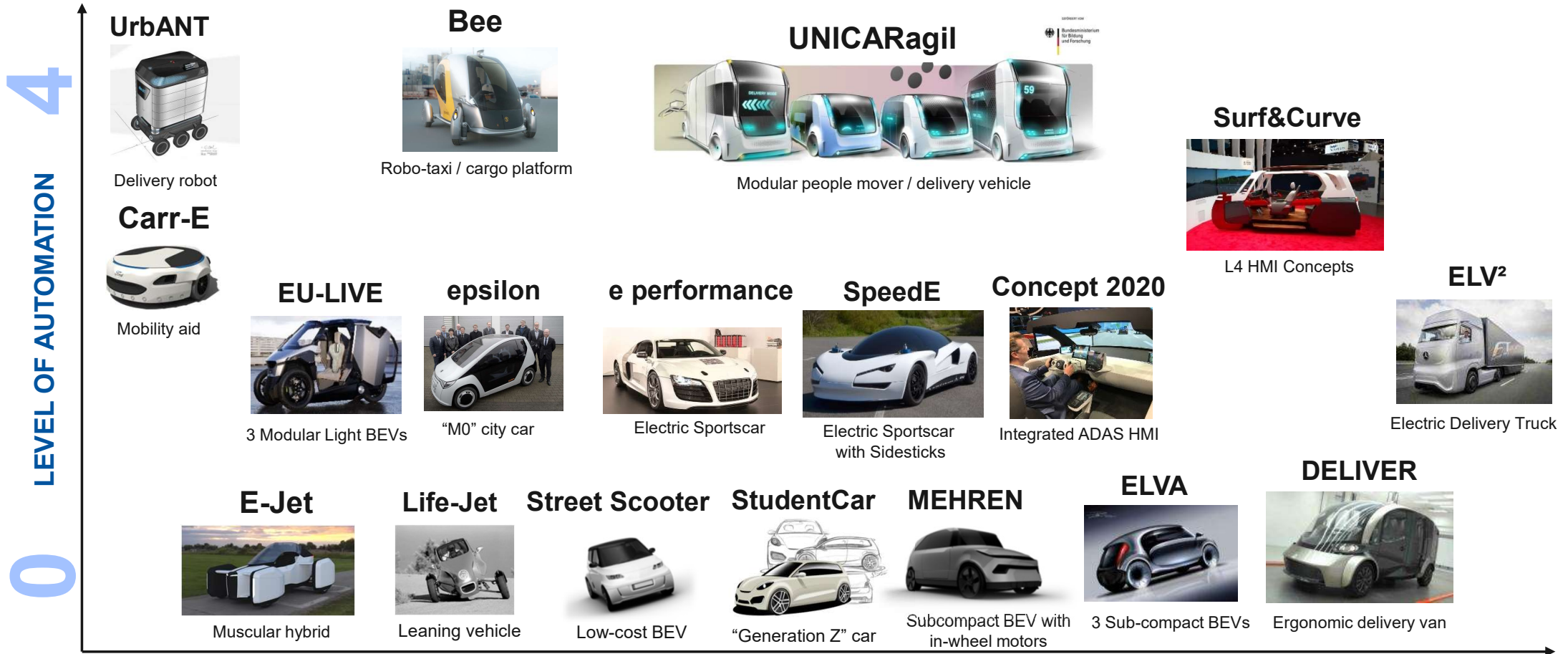
# Goal Safe & Sustainable Mobility Experience





# Vehicle & Mobility Concepts

## Selection of Published Projects

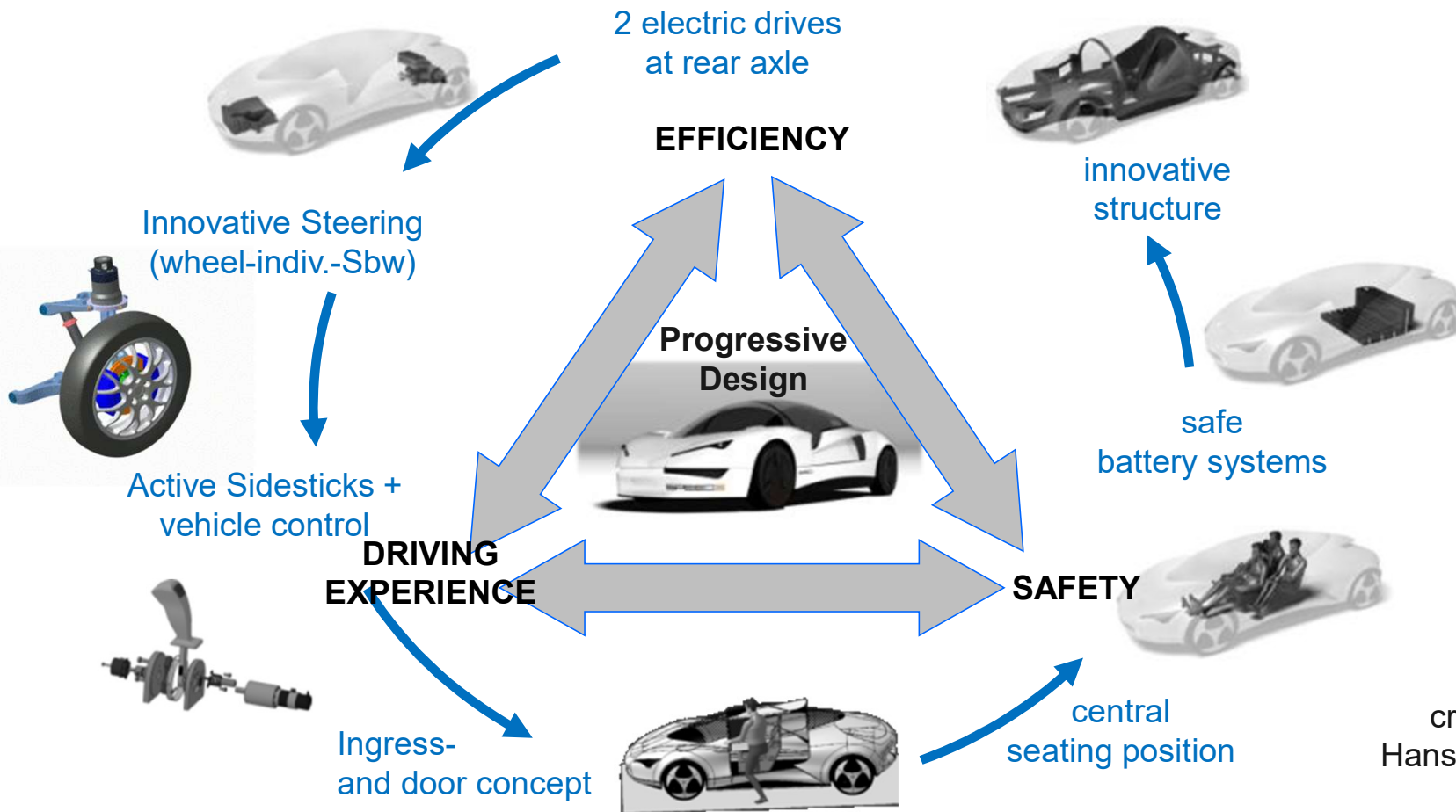


# Future Vehicle Concepts

## Turning E-mobility into E-motion – SpeedE

<https://www.ika.rwth-aachen.de/de/forschung/projekte/elektromobilit%C3%A4t/1862-speede.html>

<https://www.youtube.com/watch?v=MQjtNjF5d3I>



Neutral Research Platform  
created by ika with support of  
Hans-Hermann VOSS foundation



# Future Vehicle Concepts

## Amplify human power – research vehicle E-Jet



# Automated Driving – Level 1 + 2

## Integrated ADAS & Digital Cockpit



### Facts

- Electrified vehicle with **level 2** automation
- Integration of all ADAS in two dedicated driving modes
  - Active Driving with “Guardian Angel”
  - Level 2 Automation
- Steering sement
- Mirror replacement system
- Combination of Instrument Cluster and Head Up Display
- Developed on behalf of ZF
- Presented on **CES 2018** in Las Vegas

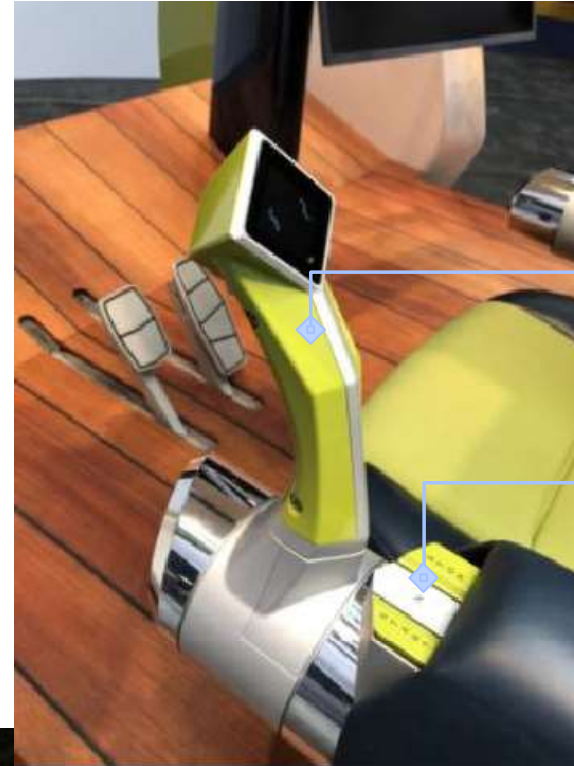




# Automated Driving Level 4 Interior and HMI



Concept „Surf & Curve“  
by fka for Body Control Systems  
CES 2018



Active Sidesticks  
for steering and influencing  
of trajectories in AD-Mode

Start – D/N/R – Stop  
for intuitive mode

Attention Director  
Applying **torque** to turn  
the seat back straight



# Architecture for Driverless Vehicles

UNICARagil funded by



Bundesministerium  
für Bildung  
und Forschung



## Cloud / Backend

- User Interaction
- Digital Traffic Twin based on Sensor Fusion
- Collective Traffic Memory by Learning from Experience

## Traffic Centre

- Navigation & Observation
- If required: tactical decisions

## Intelligent Infrastructure

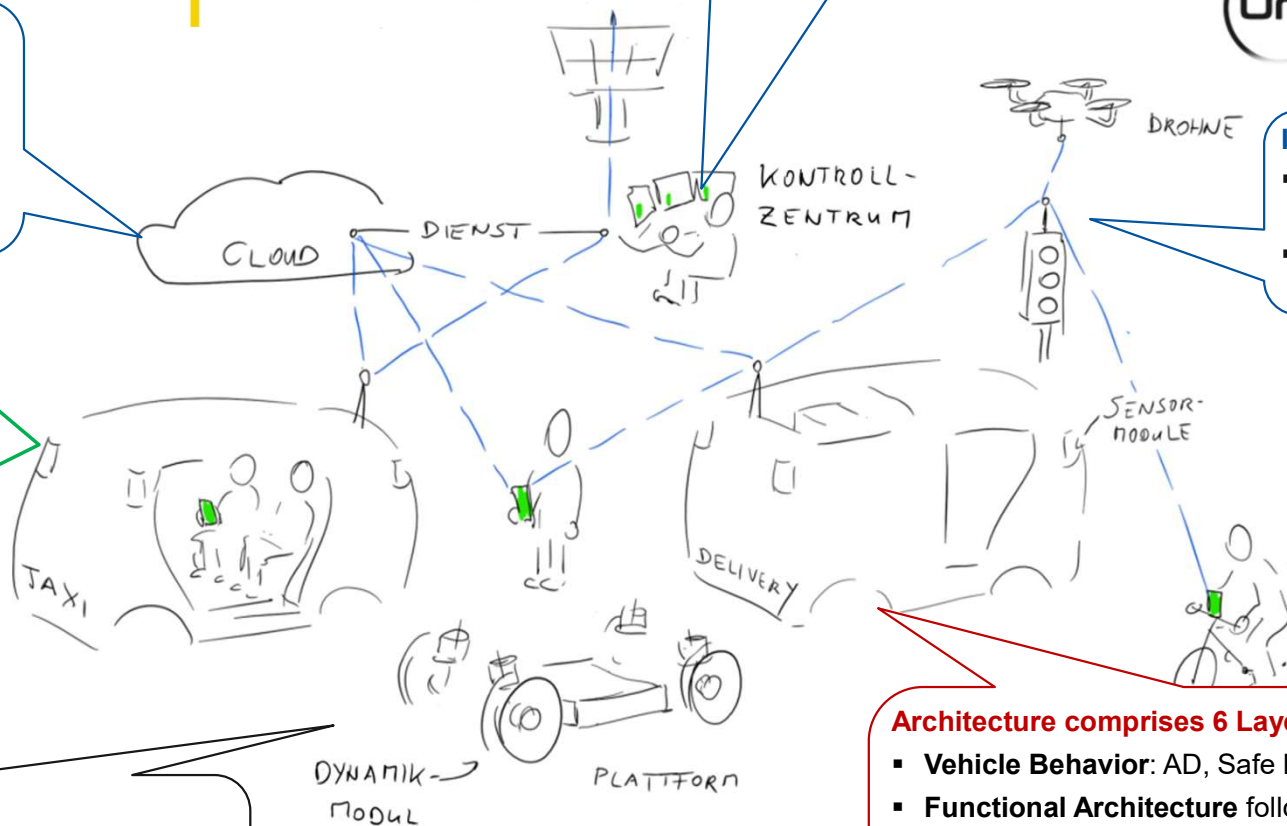
- Combination of Road Side Units and 'Info Bees'
- Contribution to Traffic Twins based on Edge Computing

## Vehicle Intelligence (E/E)

- Sensor Modules provide Environment Model Segments
- Cerebrum takes tactical decisions and plans trajectories
- Brain stem controls motion and provides 'safety reflexes'
- Fault tolerant Spinal Cord controlling the vehicle's 'limbs'

## Modular Physical Platform

- Scalable Platform for different vehicle sizes
- 4 Dynamic Modules for Steering, Acceleration and Deceleration based on 48 Volts
- 4 exemplary Vehicle 'hats' for different purposes



## Architecture comprises 6 Layers

- Vehicle Behavior: AD, Safe halt, MD
- Functional Architecture following the A-Model
- SW: Automotive Service Oriented Architecture
- Electronics: layered fault tolerant architecture
- Electrical Architecture: fault tolerant 12 V + 48 V
- Modular Physical Architecture

[www.unicaragil.de](http://www.unicaragil.de)



# Architecture for Driverless Vehicles

## UNICARagil – 4 Prototypes address different Use-Cases




autoTAXI  
Taxi Service

The autoTAXI prototype is a compact, futuristic vehicle with a rounded front and a large windshield. It is shown in a city street at night, with buildings and streetlights in the background. The word 'TAXI' is visible on the front of the vehicle.



autoELF  
Private  
Butler / Nanny

The autoELF prototype is a small, boxy vehicle with a large windshield and a prominent front grille. It is shown in a modern building entrance at night, with a person in a wheelchair nearby. The word 'ELF' is visible on the front of the vehicle.



autoCARGO  
Pick-up /  
Delivery Service

The autoCARGO prototype is a large, boxy vehicle with a large windshield and a prominent front grille. It is shown in a modern building entrance at night, with a person in a wheelchair nearby. The word 'CARGO' is visible on the front of the vehicle.



autoSHUTTLE  
Public Transport  
System

The autoSHUTTLE prototype is a large, boxy vehicle with a large windshield and a prominent front grille. It is shown in a modern building entrance at night, with a person in a wheelchair nearby. The word 'SHUTTLE' is visible on the front of the vehicle.

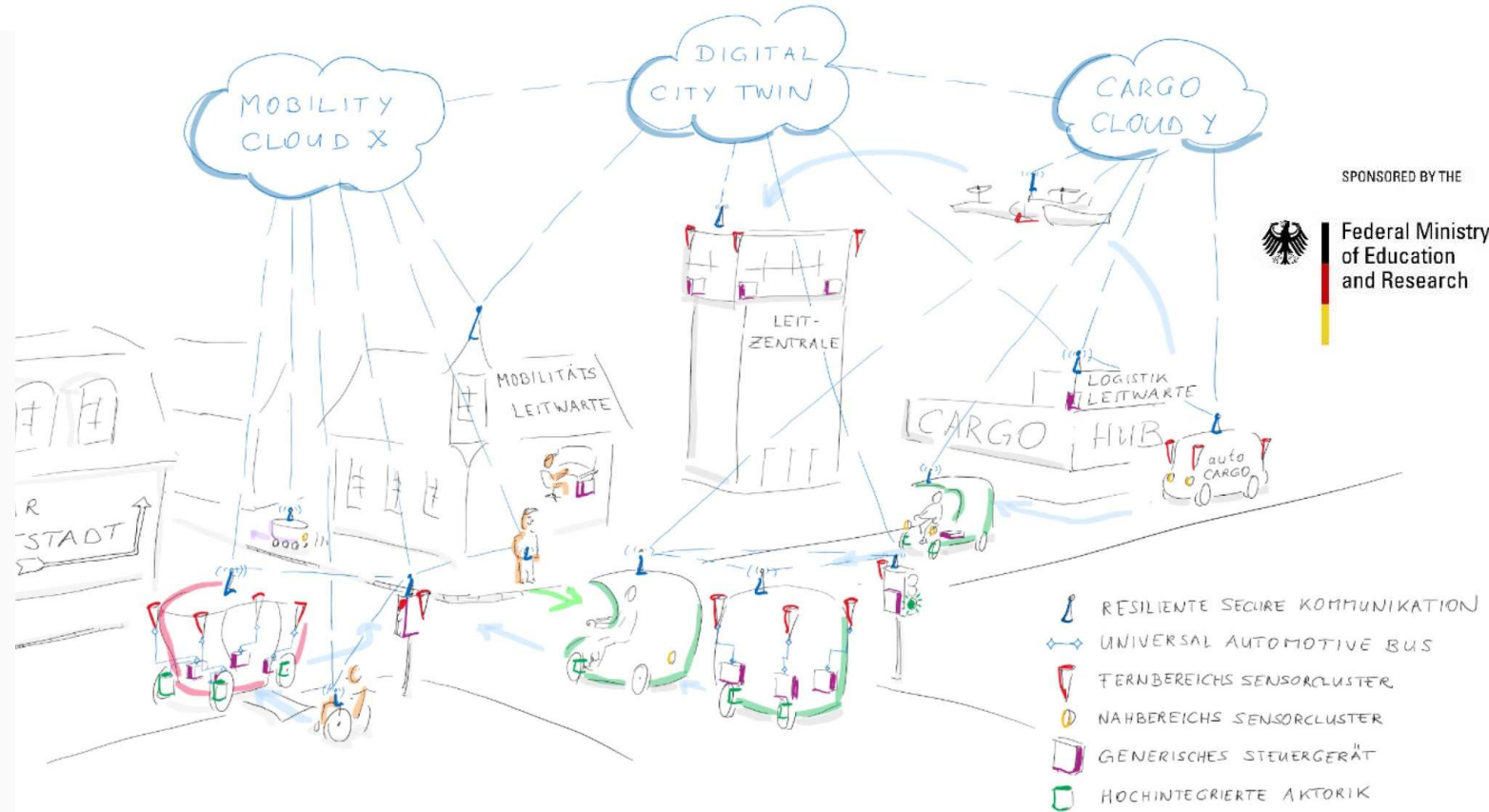
GEFÖRDERT VOM

# Architecture for Sustainable Mobility

## AUTotech.agil – Mobility Architecture of the Future

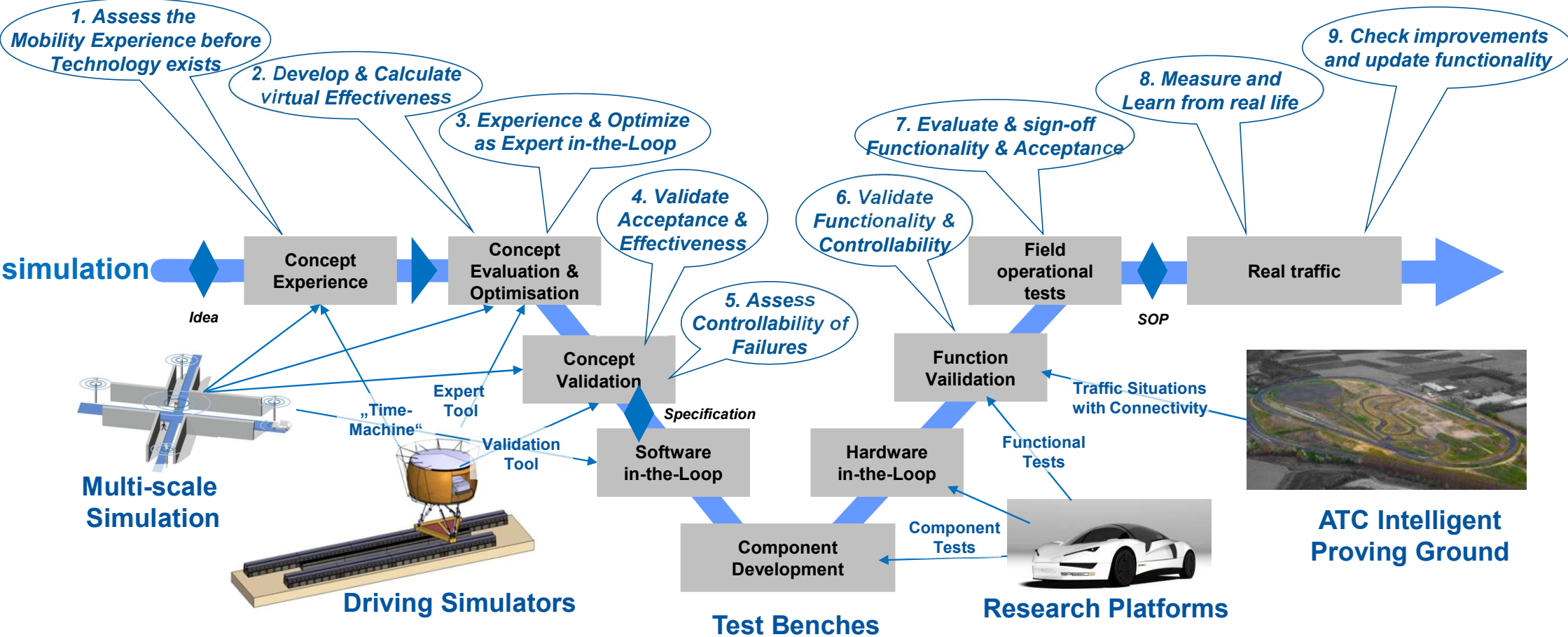
### KEY FACTS

- Based on UNICARagil, combining 17 Institutes and 13 companies
- **Flexible Distribution of Intelligence** by orchestrating services inside and outside vehicles.
- Intelligence & Effizienz by **digital twin** of traffic, systems and components
- **Agile Updates & Upgrades** of SW-Services based on their explicit quality
- **Tools & Methods** for development and tests of service-oriented E/E-Architectures
- **Compatibility** with ROS2 and AUTOSAR adaptive as well as various compute platforms



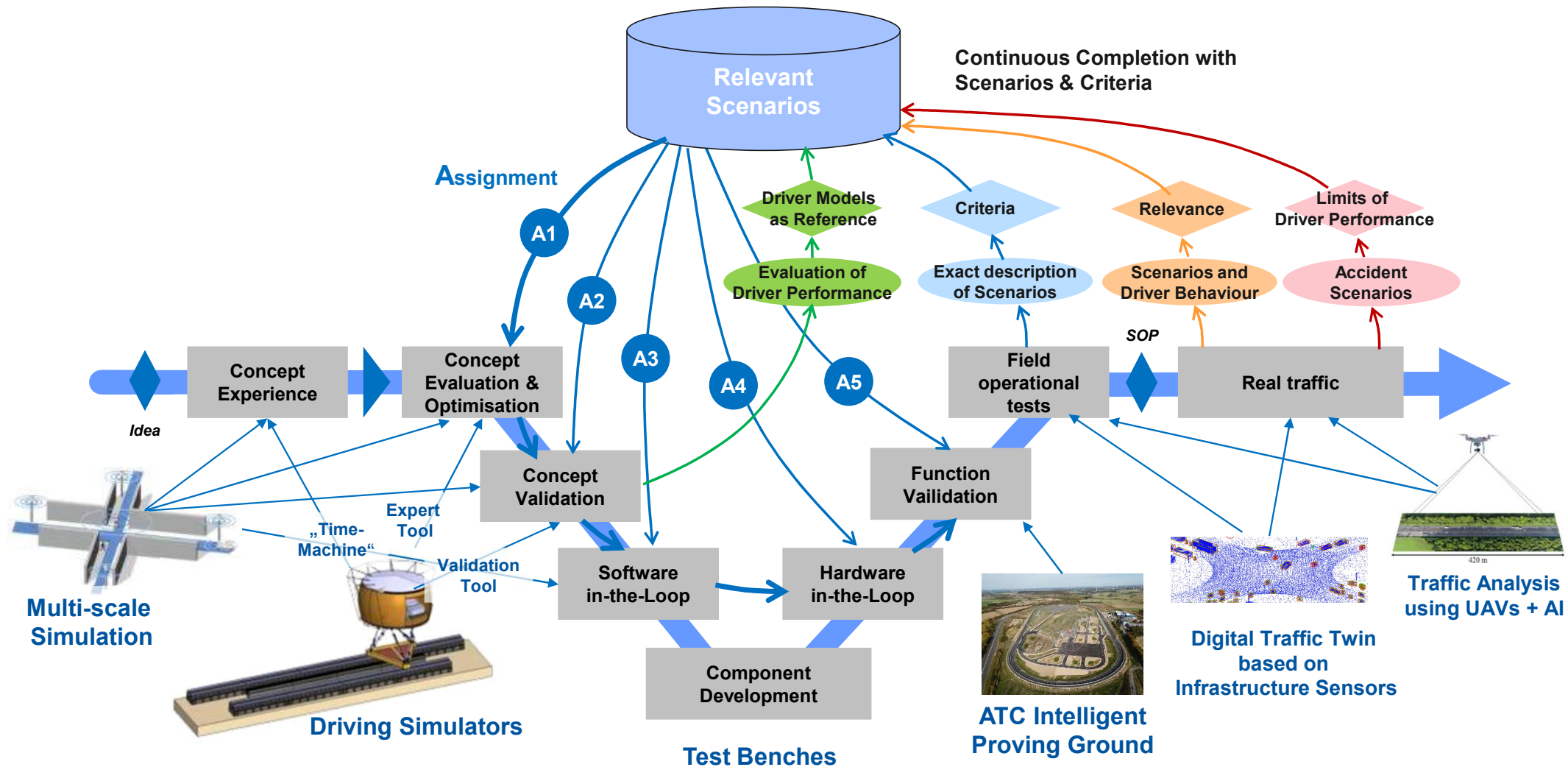
# Methodological Approach

## User-centric Conception and Development of Mobility & Vehicles

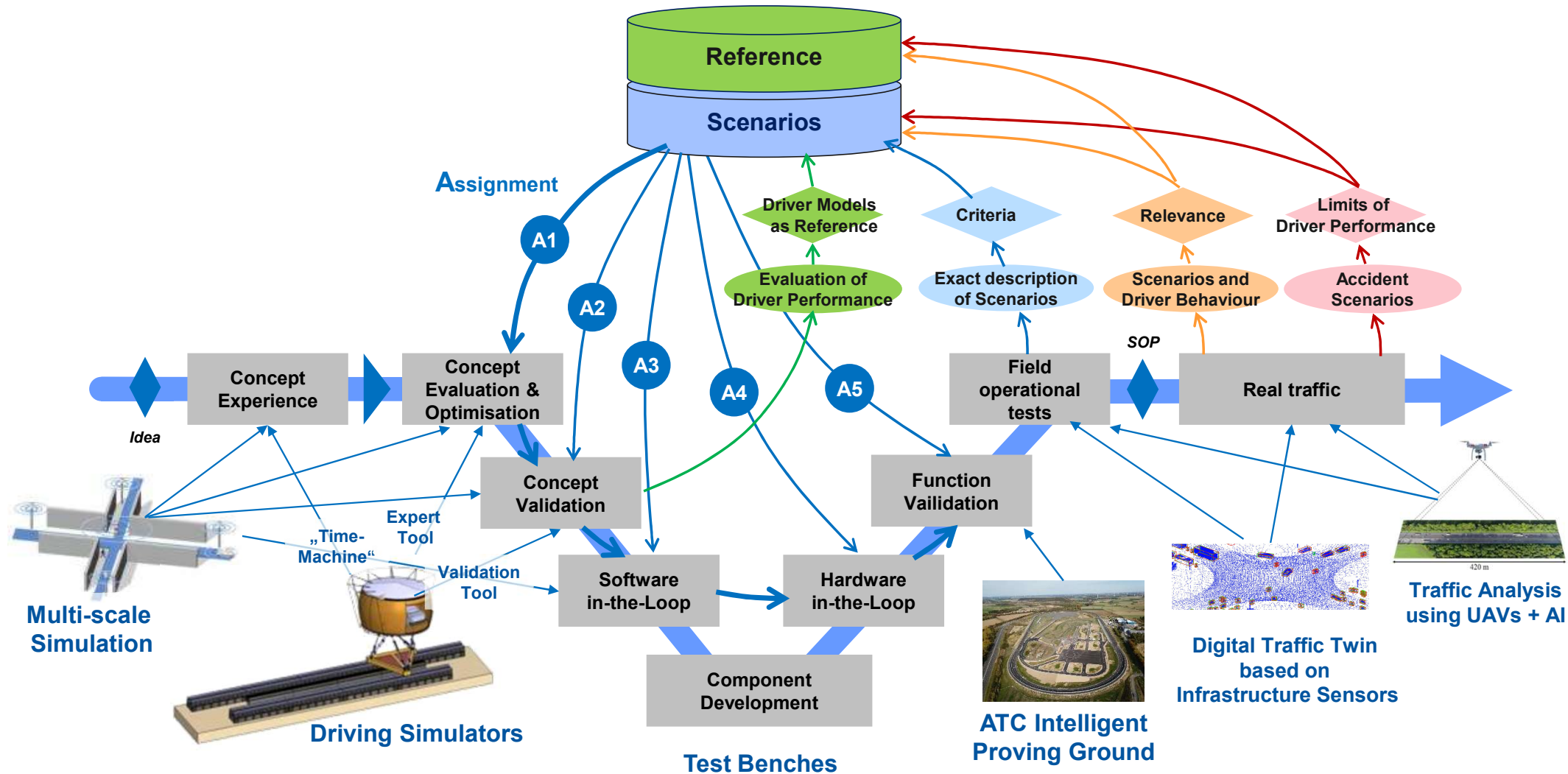




# We grow a Database of Relevant Scenarios Fundament for Updates and Upgrades of Software Defined Vehicles



# We create Driver Models as a Reference Fundament for Updates and Upgrades of Automated Driving





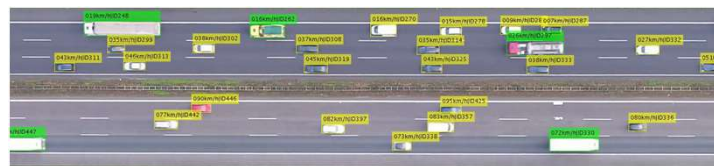
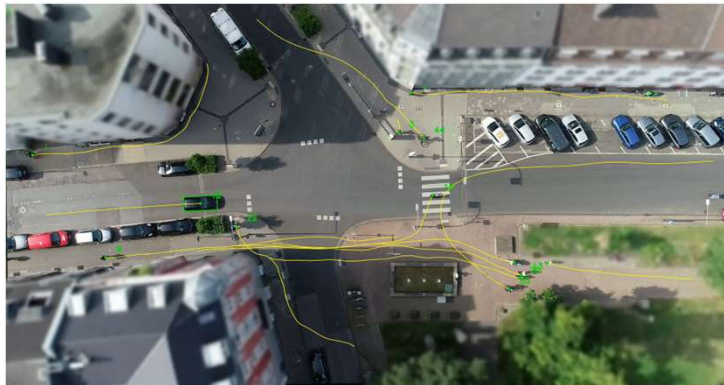
www.levelXdata.com  
 Example: Trajectory Datasets



<b>Location</b>	Aachen (Germany)
<b>Road Type</b>	Unsignalized intersection
<b># Locations</b>	4
<b>Dataset size</b>	10 hours
<b>Segment length</b>	80-110 meters
<b>Road Users</b>	All road users (incl. VRU, trailer, bus,...)
<b>Accuracy</b>	10 centimeters

<b>Location</b>	Aachen-Cologne (Germany)
<b>Road Type</b>	German Autobahn (Fwy)
<b># Locations</b>	6
<b>Dataset size</b>	16.5 hours
<b>Segment length</b>	420 meters
<b>Driven distance</b>	44.500 km
<b>Road Users</b>	Vehicles (car, truck)
<b>Accuracy</b>	10-20 centimeters

<b>Location</b>	Aachen region (Germany)
<b>Road Type</b>	Roundabouts
<b># Locations</b>	3
<b>Dataset size</b>	6 hours
<b>Segment length</b>	Up to 140 meters
<b>Road Users</b>	All road users (incl. VRU, trailer, bus,...)
<b>Accuracy</b>	10 centimeters



# Automation of 3<sup>rd</sup> Dimension offers a huge Potential Synergies on Technology, Testing & Mobility Services



REFERENCE FOR PERCEPTION

AUTOMATED TRAFFIC ANALYSIS

CONTRIBUTE TO DIGITAL TWIN OF TRAFFIC

MEDICAL SERVICES

LAST MILE DELIVERY

NEW MOBILITY CONCEPTS

no obstruction, highly efficient



© fka

"Info Bees" deliver additional information



Project VISION @ fsd

Delivery of medical goods from a Van

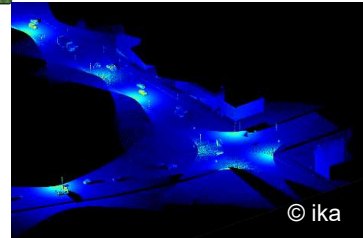


© joby aviation

AI-based extraction of trajectories, scenarios



© fka



© ika

Preview for Police & Emergency Vehicles



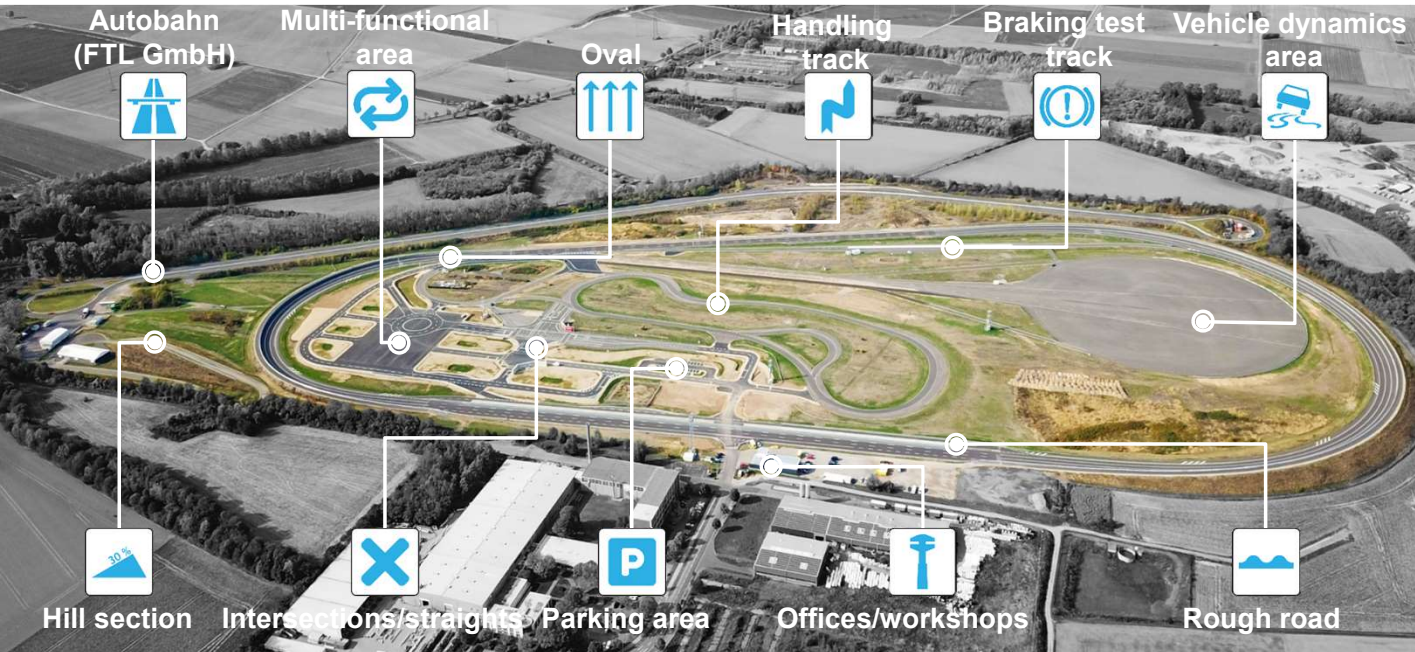
© UNICARagil

Automated VTOL Aircraft

Many Synergies with regard to Technology, Testing and Mobility Services



# Automation of 3<sup>rd</sup> Dimension offers a huge Potential ATC is complemented by Center for Vertical Mobility



## Aldenhoven Testing Center (ATC)

- Oval: 120 kph without sideforces
- Handling, braking, road excitations ...
- Urban driving environment with additional intersections, roundabouts to depict **urban driving scenarios**



## All relevant communication Technologies

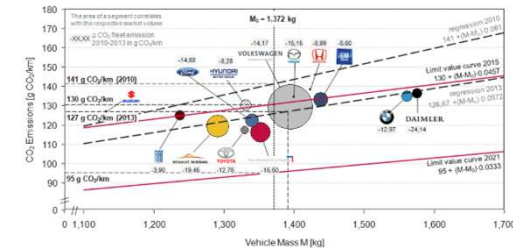
- Vodafone 5G Mobility Lab: all globally relevant cellular technologies decoupled from public networks
- ACCorD: V2X road side units with HD sensors; intelligent street lights
- Simulated Galileo signals

## Global Tests of Automation & Connectivity

- Various international communication scenarios can be depicted;
- Effects of jamming and spoofing can be investigated => functional safety
- Ideal to evaluate future technologies without risk for public

# Summary

- Automotive sector faces numerous challenges – reducing CO<sub>2</sub>-emissions is one strong driver for innovation.
- Vehicle architecture will change significantly – physically, energetically and logically.
- Electrification of drivetrain facilitates revolutionary chassis and steering concepts, turning E-mobility into E-motion.
- Connectivity and automated driving will not only change driving experience – both facilitate new vehicle concepts and business models.
- New category of light vehicles (M0) filling the gap between current M1 and L7e vehicles is driven by individual mobility and possibly also by new players.
- Challenges require new concepts of interdisciplinary and international research





## Contact



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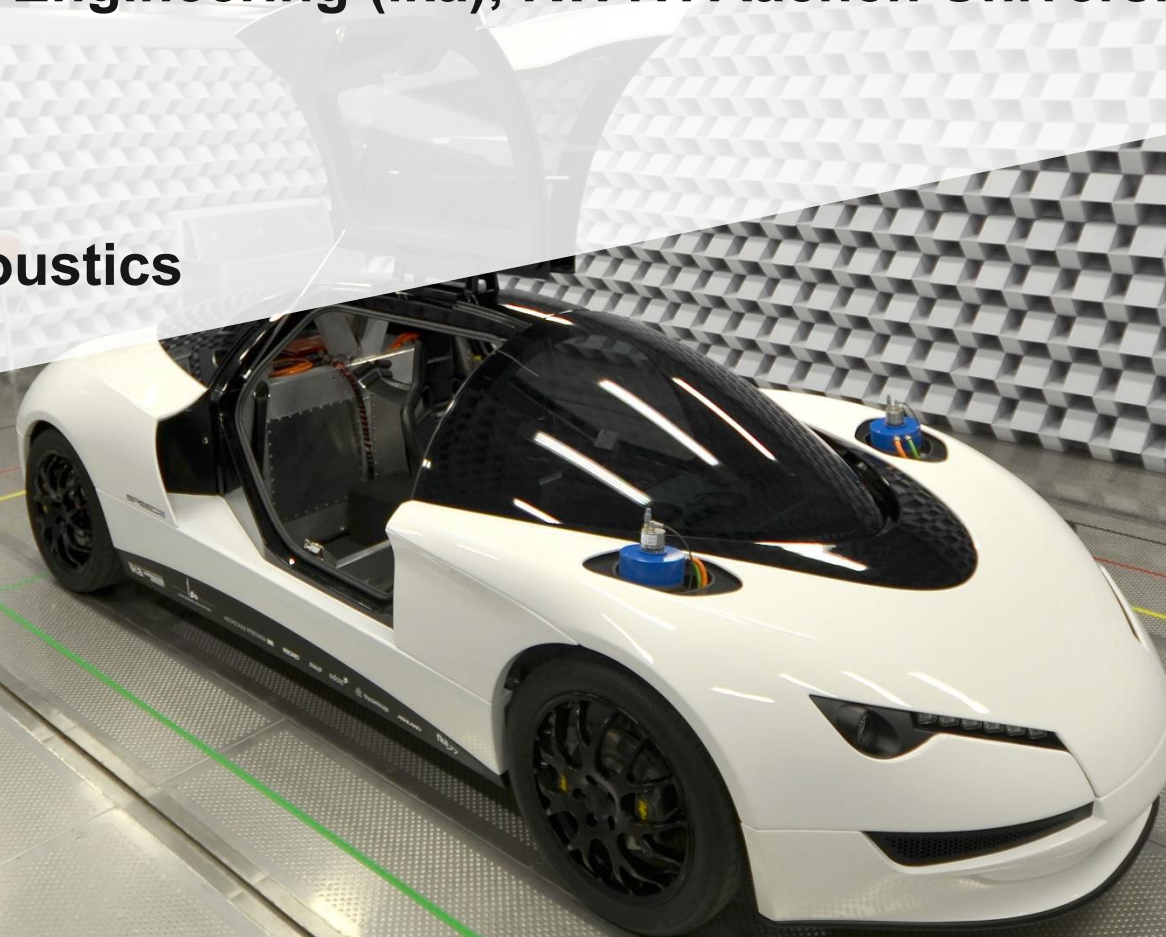
Fax +49 241 – 80 22147

Email [eckstein@ika.rwth-aachen.de](mailto:eckstein@ika.rwth-aachen.de)

Internet [www.ika.rwth-aachen.de](http://www.ika.rwth-aachen.de)

**Institute for Automotive Engineering (ika), RWTH Aachen University  
fka GmbH**

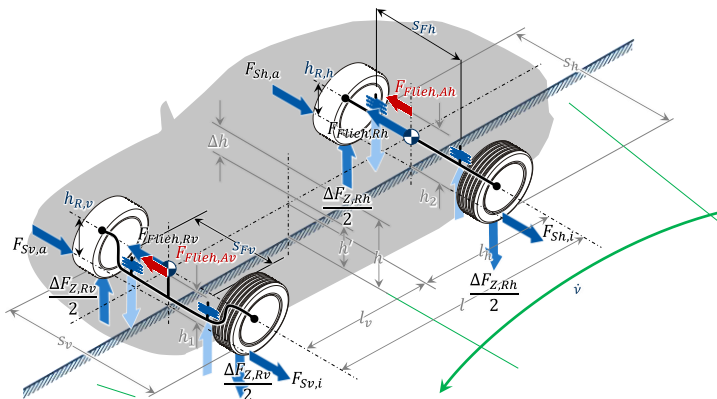
**Vehicle Dynamics & Acoustics  
Chassis & NVH**



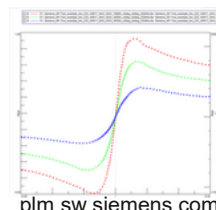
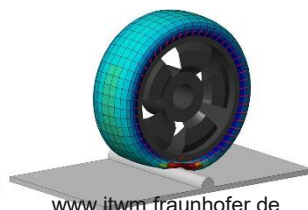
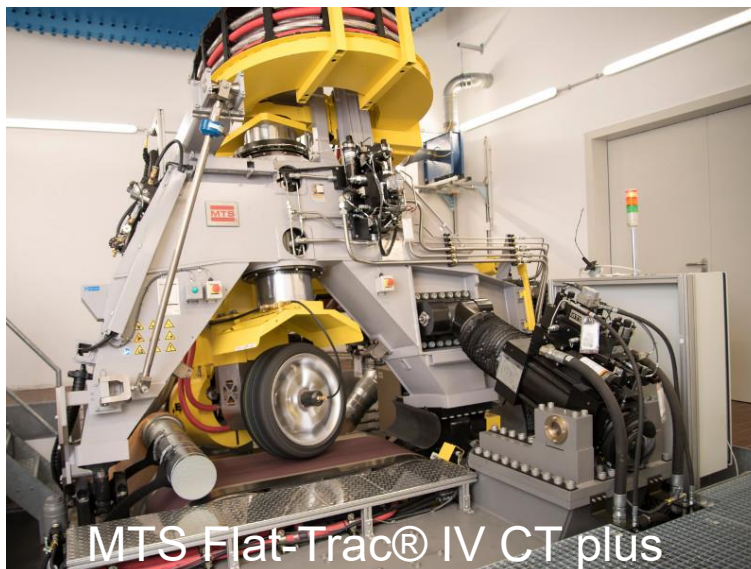


### Testing

#### Function development



#### Tyre technology



#### Acoustics

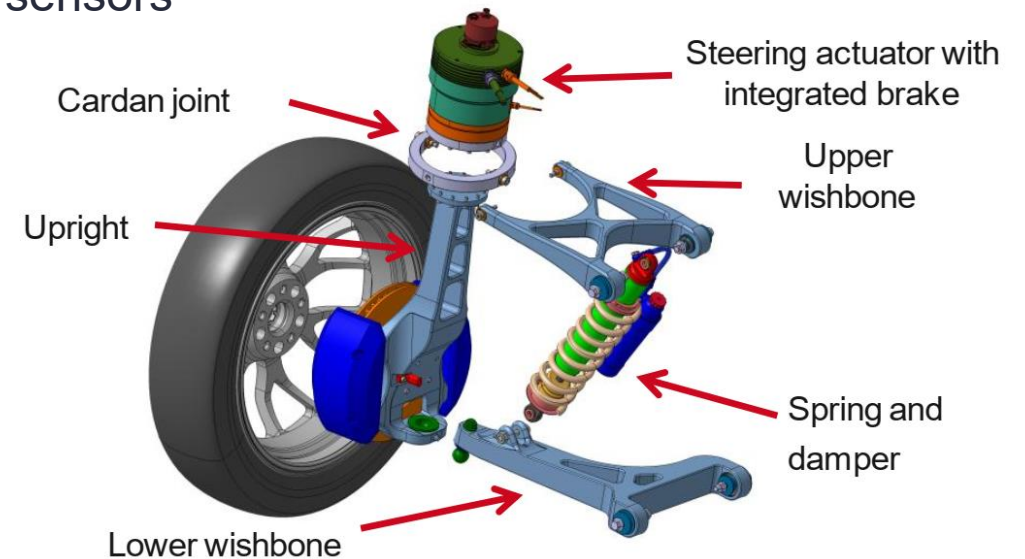






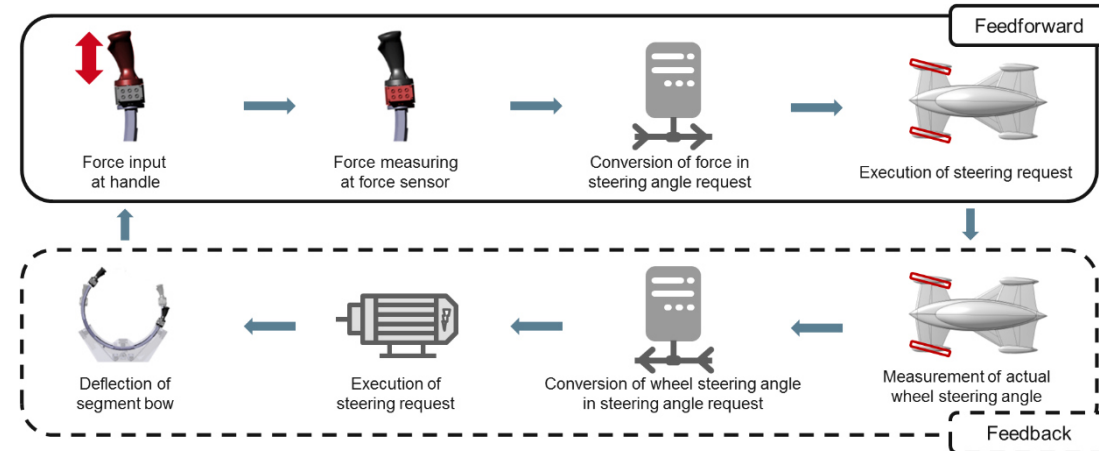
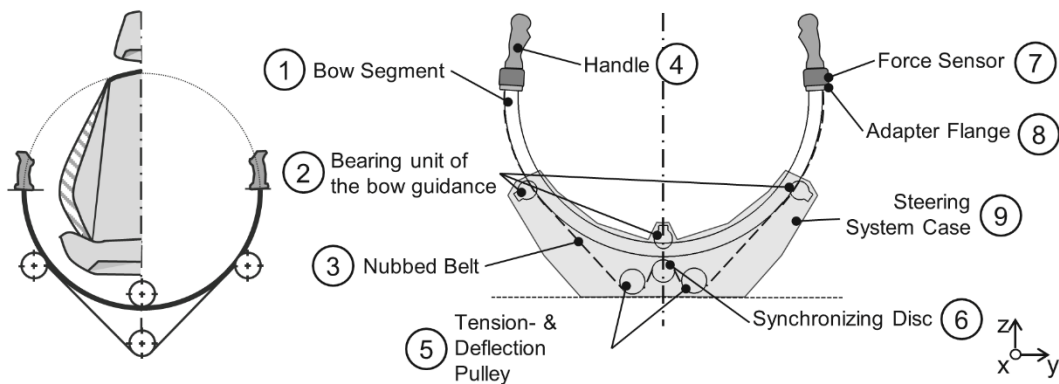
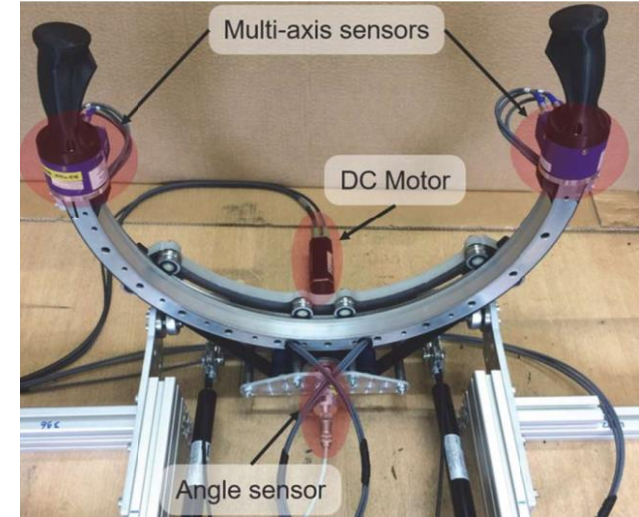
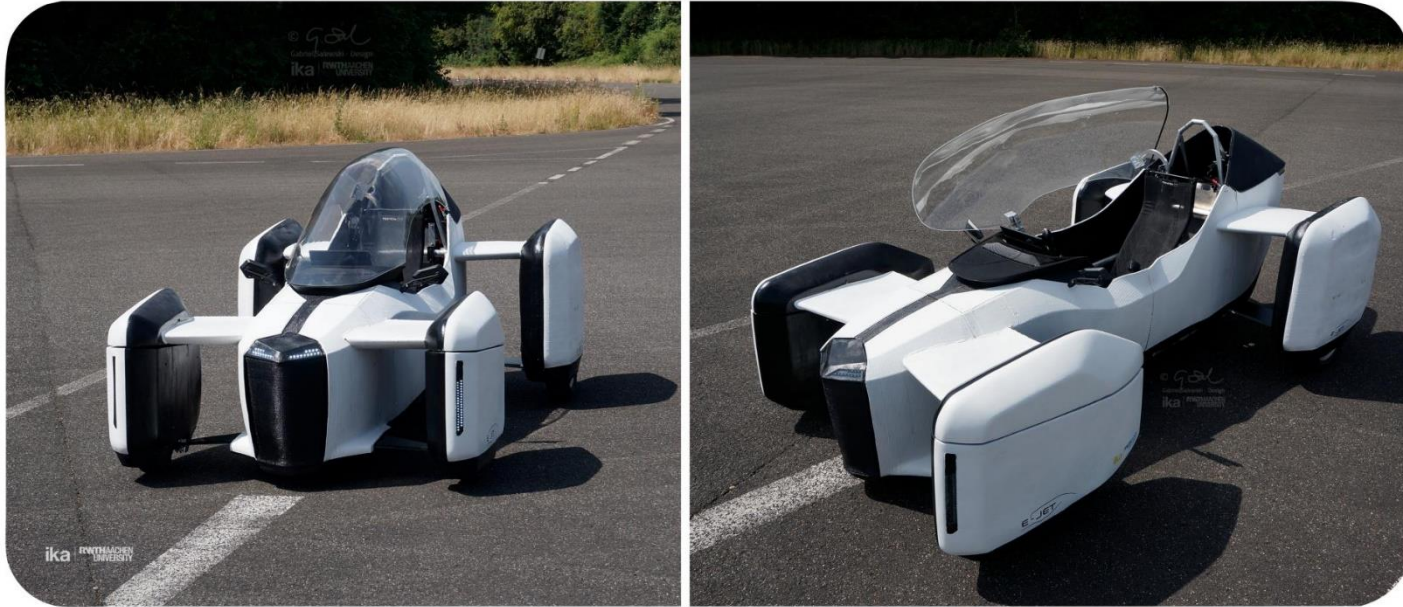
# SPEED

- Double wishbone suspension
- Steering angle range: 60°/90°
- Steering actuator:
  - 48 V motor (max 450 Nm, max 2.3 kW, 1:100)
  - 24 V brake
  - Temperature sensors
  - Output torque and position sensors
- Sidestick
  - Steer-by-torque
    - Force input, angle output
  - Strain gauge based
  - $\pm 30^\circ$  rotation
  - Electric motor for feedback (max 30 Nm, max 150 W)



# Vehicle Dynamics & Acoustics / Chassis & NVH

## E-Jet SteeringBow





# Vehicle Dynamics & Acoustics / Chassis & NVH

## UNICARagil Shuttle

GEFÖRDERT VOM



Bundesministerium  
für Bildung  
und Forschung



- Double wishbone suspension
- Steering angle range: 66°/93°
- Steering actuator:
  - 48 V motor
  - 24 V brake
  - Temperature sensors

- Output torque and position sensors

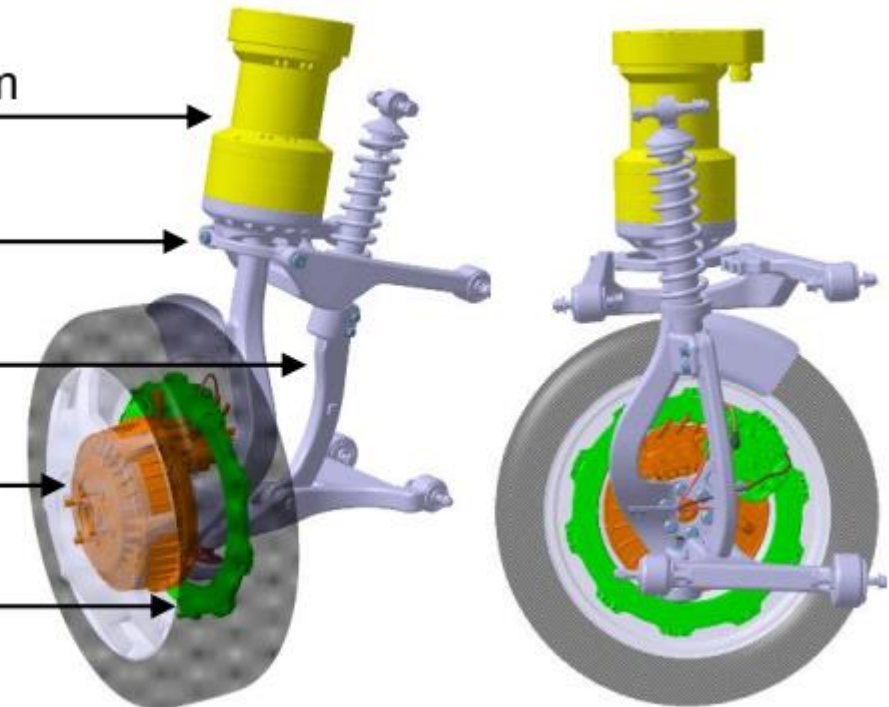
Steer-by-wire System

Cardan joint

Damper strut

Wheel hub motor

Perimeter brake





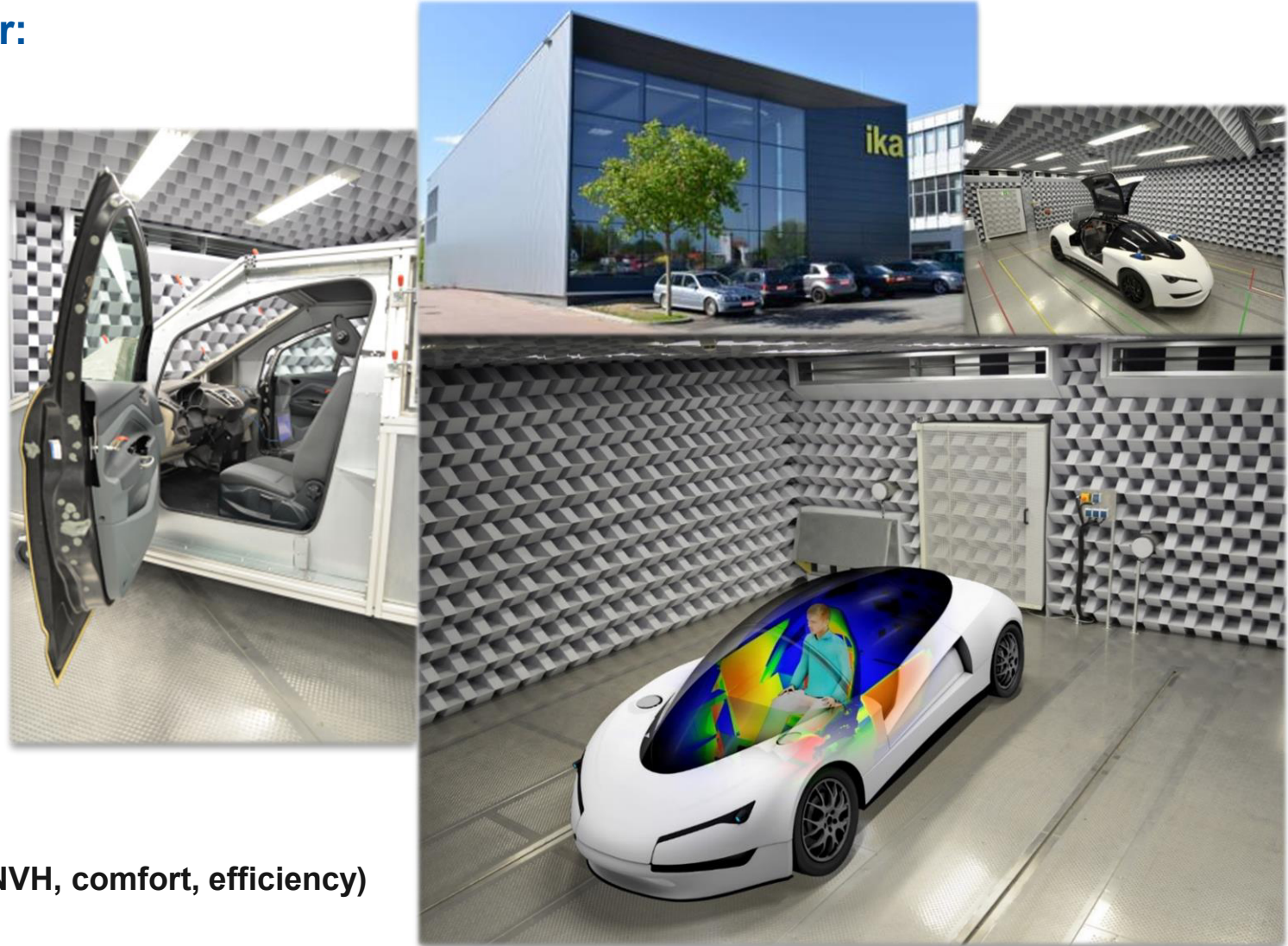
### Temperature-controlled acoustic chamber:

- Temperature range: -20 °C bis 40 °C
- Dynamic: 0.5 K/min for temperature profile setting
- Semi-anechoic chamber (class 1 certification)
- Background noise level:
  - < 20 dB(A) (10.5 kW internal load)
  - < 40 dB(A) (full load)
- Dimensions: 9.4 m x 7.0 m x 2.8 m (L x W x H)

### Interior space demonstrator:

- Generic vehicle cabin
- Examination of **energy consumption and comfort** (thermal, acoustic) of new interior components
- Simple geometries → **fast and cost-effective** prototype manufacturing
- Easy integration

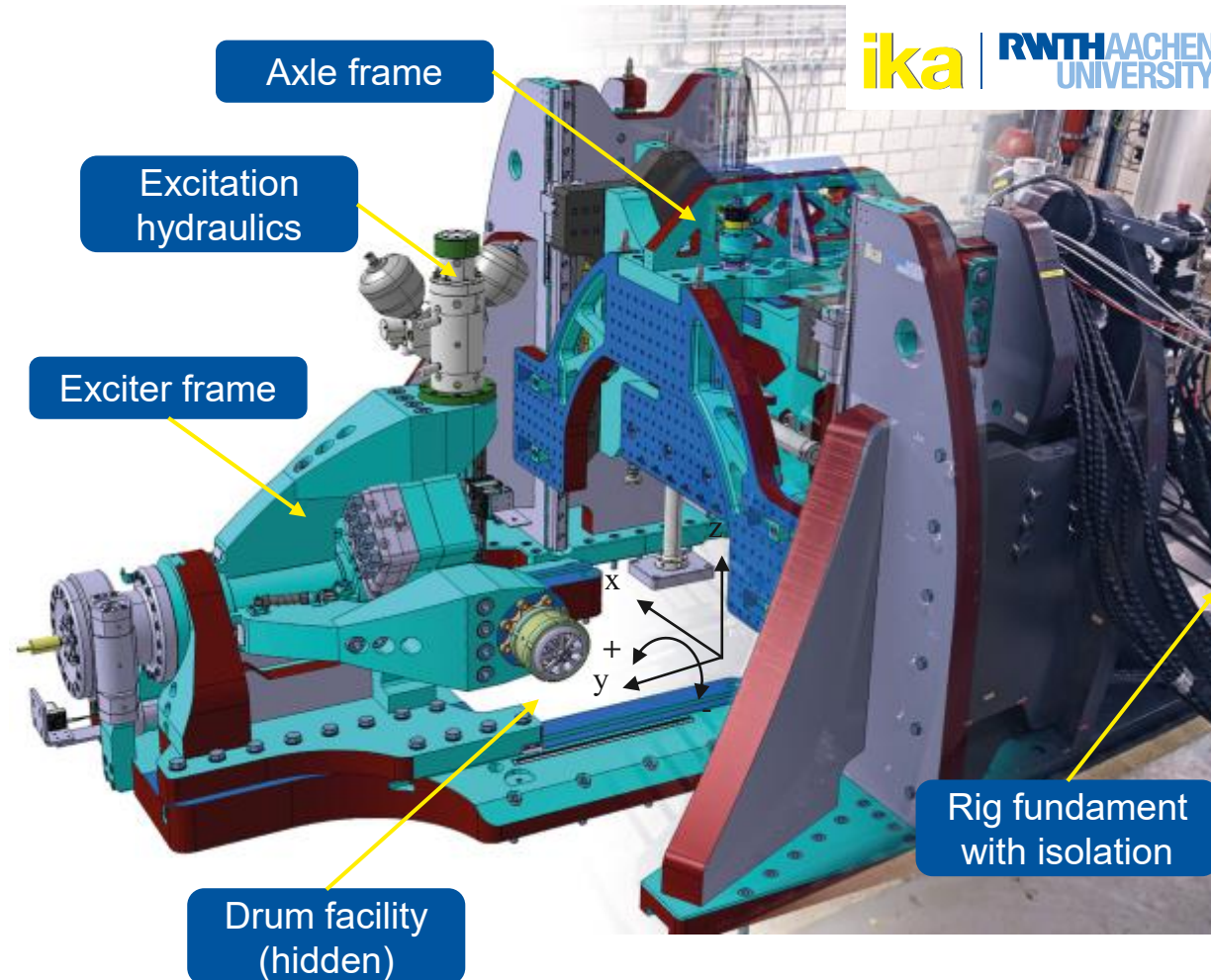
- ➔ **Component testing and verification (e.g., NVH, comfort, efficiency)**
- ➔ **User studies with complete vehicles**



### Key facts

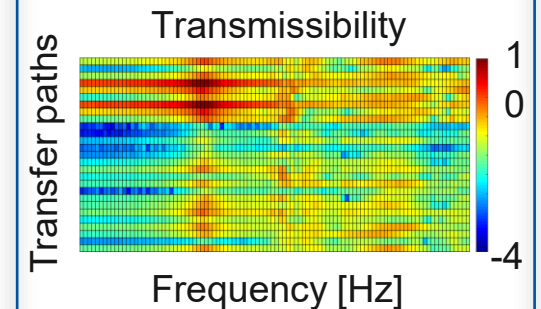
- Mounting of complete suspensions on the rig
- Excitation with cleats on drum up to 20 mm height  
→ Impact road NVH
- Excitation with two hydraulic cylinders up to 250 Hz  
→ Asphalt surface
- Ability to move the main assemblies in all three directions in space by hydraulics as well as to rotate the exciter frame in xz-plane  
→ Excitation in x-, z- directions or in xz-plane  
→ Application of defined wheel loads

### Development of a suitable concept and buildup of a test rig for suspension investigations considering customer specifications



### Data evaluation

- Test series: frequency sweep, amplitude sweep, wheel travel sweep or pink noise
- Measurement of static preloads at suspension attachment points
- Suspension input and transfer stiffness evaluation as well as transmissibility analysis



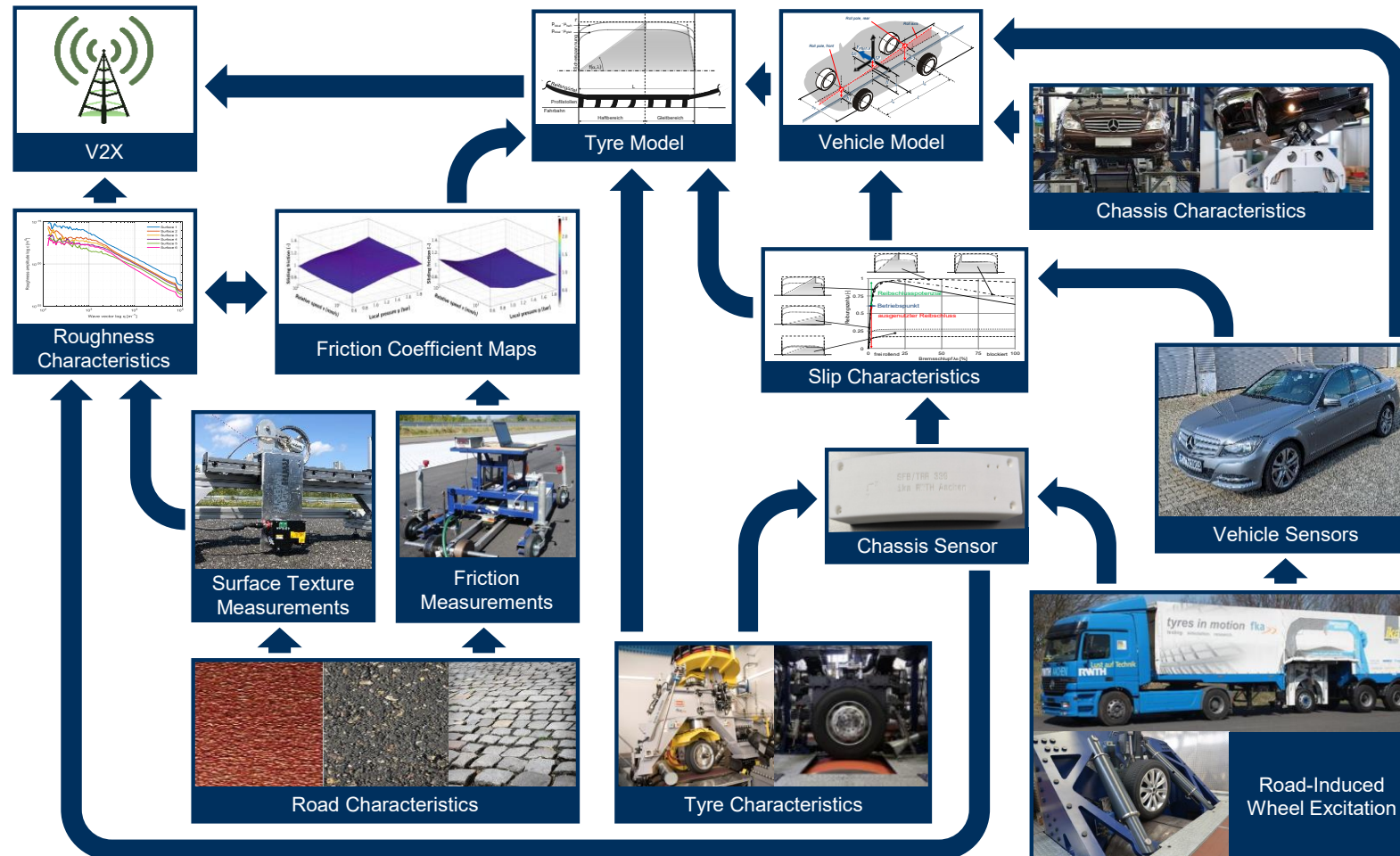


# Research Area Vehicle Dynamics & Acoustics

## DFG funded research project "SFB/TRR 339"

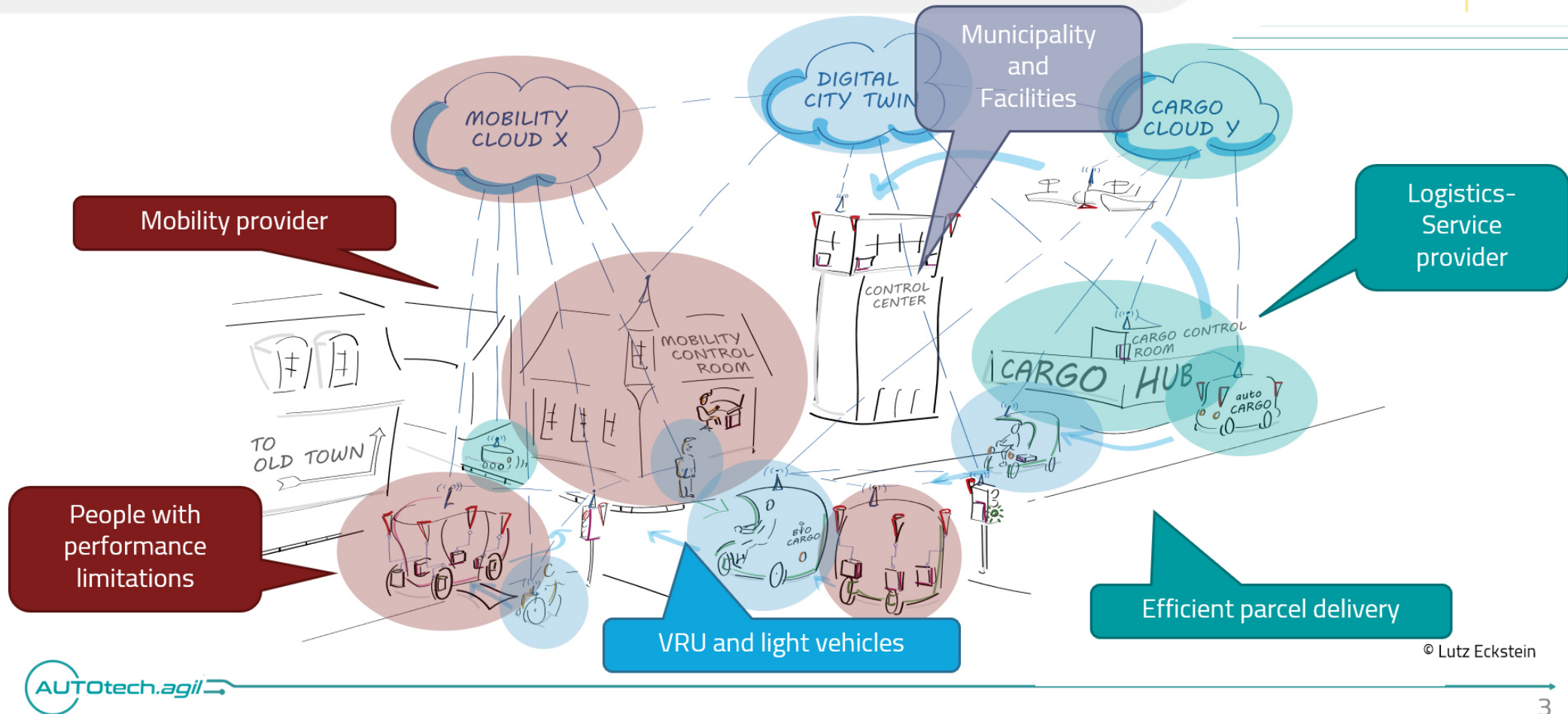


### The chassis as a data source for the digital twin of the road system



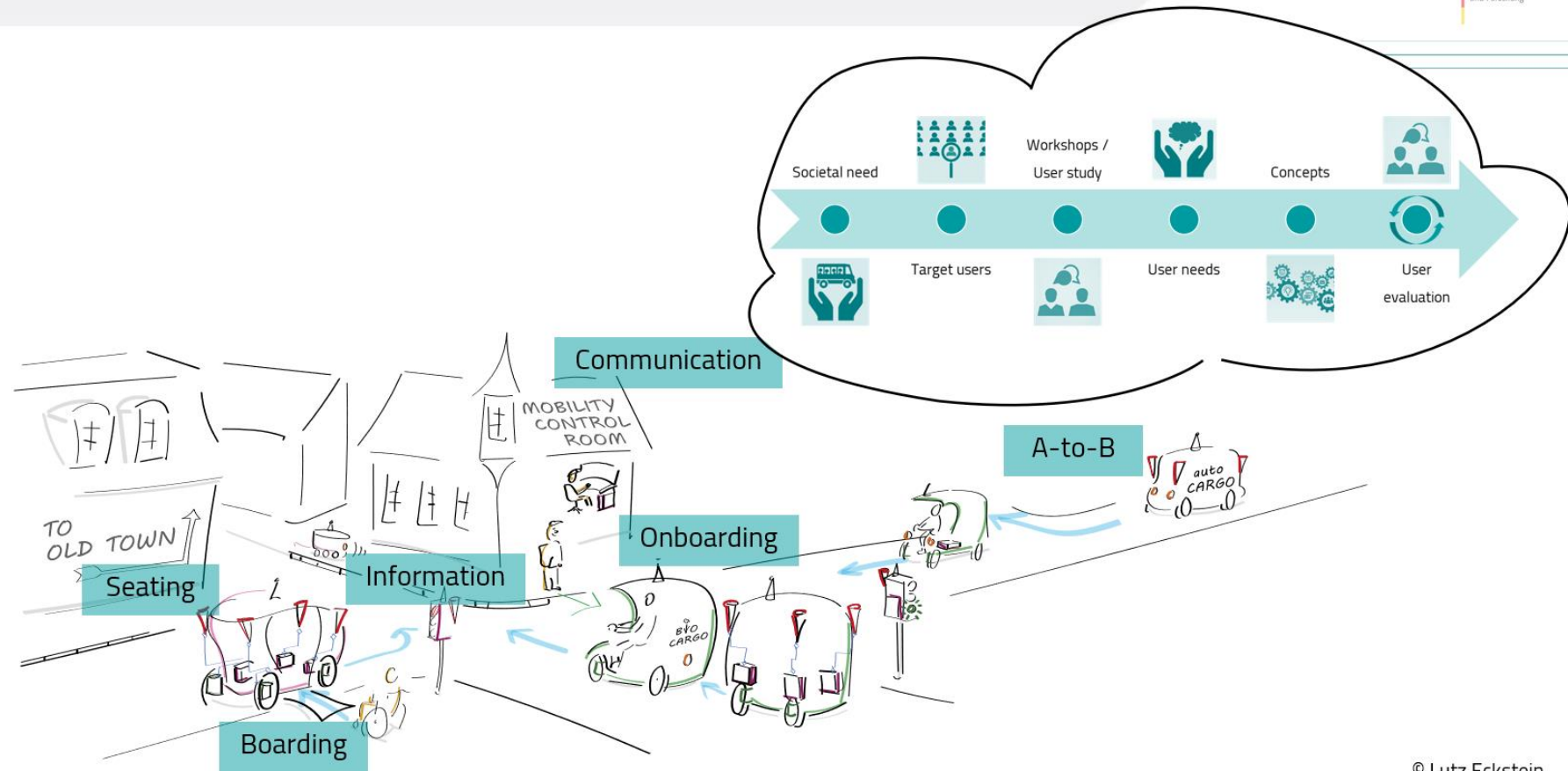


### All stakeholders should benefit



### Inclusive mobility concept instead of isolated solutions

berlin  
Bundesministerium  
für Bildung  
und Forschung



© Lutz Eckstein

# Inclusive mobility concepts in the *auto*SHUTTLE



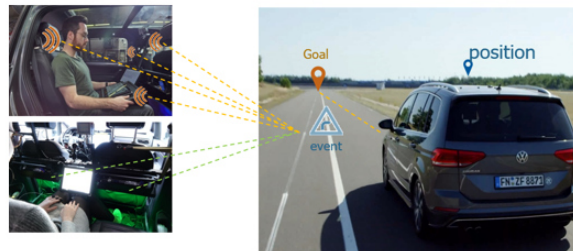
## Cabin Manager

Inclusivity through adaptive, capability- and needs-specific MMI.



## Wellbeing

Reduction of motion sickness through HMI (subliminal light and sound signals)



## Machine hearing



Interior monitoring



siren detection



Conference language  
exclusively in English.

## AAC 2024

AACHEN ACOUSTICS COLLOQUIUM

### CALL FOR PAPERS

Development and Research in Automotive Acoustics



Univ.-Prof. Dr.-Ing. Lutz Eckstein  
ika - Institute for Automotive Engineering

Univ.-Prof. Dr.-Ing. Stefan Pischinger  
ime - Chair of Thermodynamics of Mobile  
Energy Conversion Systems  
RWTH Aachen University

**November 25 – 27, 2024**

Aachen, Germany

#### Topics

##### Discussion of vibroacoustic phenomena in applications:

- ✔ Vehicle NVH (e. g. Body, Mechatronic Systems, Tire Road Noise)
- ✔ Drive Train Vibration and Acoustics (Electric Drives, Engine, Gearbox, Drive Shafts, Hybrid Propulsion Systems)
- ✔ Sound Design, Sound Quality and Human Perception in (autonomous) Vehicles
- ✔ Infotainment and Communication in (autonomous) Vehicles
- ✔ Active Systems for Noise and Vibration Control

##### Digital engineering in vibroacoustic development process:

- ✔ Measurement Technology (e. g. Structural Analysis)
- ✔ Numerical Simulation and Modelling
- ✔ Hybrid Methods (Numerical Simulation, Measurement Technology, Machine Learning, AI)
- ✔ Integration of Models in the NVH Development Process (MBSE)
- ✔ Real-time Simulation (VR, AR and MR)

Organizer:

Aachener Kolloquium GbR  
Steinbachstraße 7, 52074 Aachen, Germany  
callforpapers@aachen-colloquium.com  
[www.aachen-colloquium.com](http://www.aachen-colloquium.com)

Venue:

Eurogress, Monheimsallee 48, 52062 Aachen, Germany

Date:

October 7th - 9th, 2024

Facts:

Up to 1.000 participants  
100 international technical presentations  
Up to 60 companies at the exhibition  
Driving event as a supporting program  
Traditional banquet

Institute for Automotive Engineering (ika), RWTH Aachen University

Traffic Psychology & Acceptance





# Research Area: **Traffic Psychology & Acceptance**

Team of five Psychologists

In cooperation with **fka**

## Short profile



## Research Area Manager

### Profile Overview

Dr. phil., Psychologist

<b>2019 – today</b>	Research Area Manager, Traffic Psychology and Acceptance, ika in coop. with fka GmbH
<b>2018</b>	Call as a Professor for Psychology at HMKW Cologne (declined)
<b>2017 – 2018</b>	Team Manager “Human Infrastructure Interaction”, business unit Driver Experience and Performance, ika in coop. with fka GmbH
<b>2014 – 2017</b>	Senior Researcher / Post Doc Institute for Automotive Engineering, (ika) of RWTH
<b>2011 – 2013</b>	Researcher and Doctoral Candidate, Institute for Psychology of RWTH
<b>2006 – 2011</b>	B.Sc. & M.Sc. Psychology, RWTH Aachen University

- » (Inclusive) Mobility research
- » HMI evaluation and usability
- » Userstudies, across the tool chain ranging from lab over (high definition) driving simulation to FOT
- » Sensorimotor transformations and tool use
- » Coordinator of EU Project H2020 (MeBeSafe)

- » Development of Inventories, construction of questionnaires
- » Mobility Project (SLAM), EV and Rapid Charging
- » MeBeSafe Project, EU H2020, Coordinator, (Vol. 8 Mio)
- » UrbANT Project, Sustainable Mobility
- » ENABLE I+II+III Project Inclusive Mobility
- » BüLaMo Project on MaaS improvement



# Research Area: **Traffic Psychology & Acceptance**

Team of five Psychologists



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Department Manager

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✉ maren.klatt@ika.rwth-aachen.de



ca. 10 Student Assistants



# Research Area: **Traffic Psychology & Acceptance**

Team of five Psychologists

## Expertise

- » **Planning, conduction and analysis of user studies in the automotive context**
- » Research on and development of subjective as well as objective evaluation methods
- » Laboratory and field testing of acceptance, safety and efficiency
- » Physiological equipment and eye tracking
- » Test platforms for testing novel vehicle concepts

## Fields of Application

### Applied Basic Research

- » Psychophysiological testing
- » **Questionnaire development**
- » Development of acceptance models
- » Models on compensatory driver behavior

### Driver behavior

- » Driver distraction
- » Drowsiness, micro sleep
- » **User evaluation of concepts**

### Driver Performance

- » **Controllability of SbW and ADAS**
- » Comfort evaluation in AD: driving experience and trajectories
- » Intoxicated driving

### Inclusive Mobility

- » **Mobility for people with disabilities**
- » Elderly drivers

## Research Methods



Interviews / Workshops



Seating Buc + VR



Highly Dynamic Driving Simulator



Test Track



# Institute for Automotive Engineering (ika)

## Tool Chain – System Evaluation





# Ika: Traffic Psychology and Acceptance

## GLE Roadstudy – Entry Into Road Traffic



# Recent Project Examples

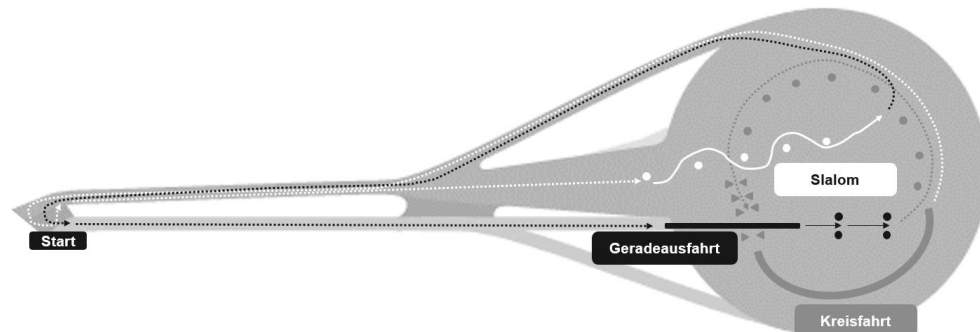
## User Studies on Controllability in SbW

### Research Topic

- Investigation of the controllability of errors of Steer-by-Wire systems
- Measurement of objective as well as subjective reactions to the error injection

### Method

- User studies ( $N \sim 168$ ) on test track of Aldenhoven Testing Center
- Six test vehicles
- Six different errors of Steer-by-Wire systems
- Three maneuvers, arranged into one parcours



### Exemplary Results

- Most of the errors parameterized by experts were controllable by everyday drivers
- However, the method used was also able to identify errors that did not meet the C0 level



### Outlook

- Study provides a basis for considering the safety requirements for Steer-by-Wire systems as part of the DIN 70065
- Transfer of the testing procedure to driving simulation

### Motivation & Objective

- The increasingly complex interaction between driver and vehicle impairs the operating safety and the user experience of modern motor vehicles
  - To face this challenge, automotive research needs to develop and evaluate intuitive operating and display concepts in a human centered process, that fulfil users characteristics and requirements
- ▼
- Human centered development of intuitive HMI concept for revolutionary technology trends (targeting 2025 and beyond)
  - an adequate way to integrate and showcase all singular developed HMI-Concepts into an appealing high quality mock-up

### Setting

- Electrified vehicle with **SAE L3** functionalities
- Concept focusses on revolutionary technology trends
- Developed on behalf of BCS
- Presented on **CES** in Las Vegas in January **2018** and Update in **2019**





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