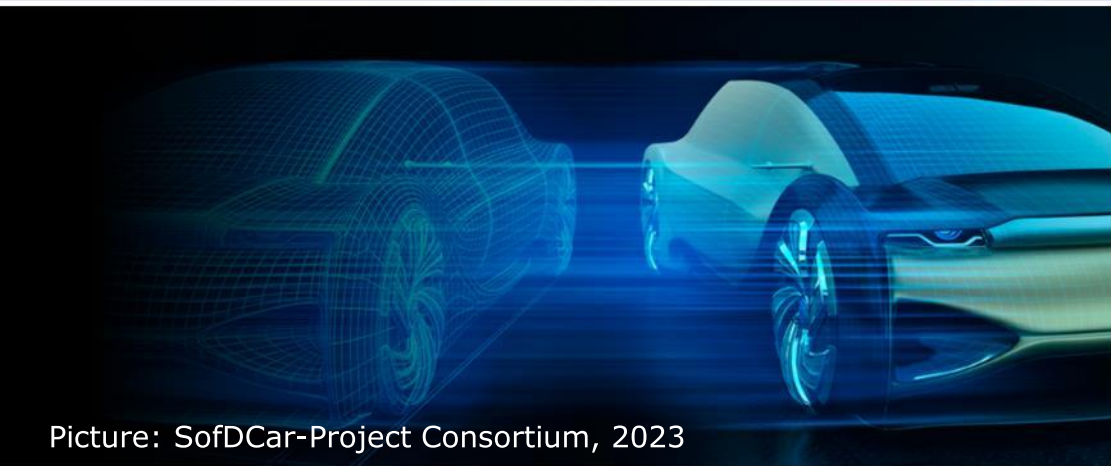
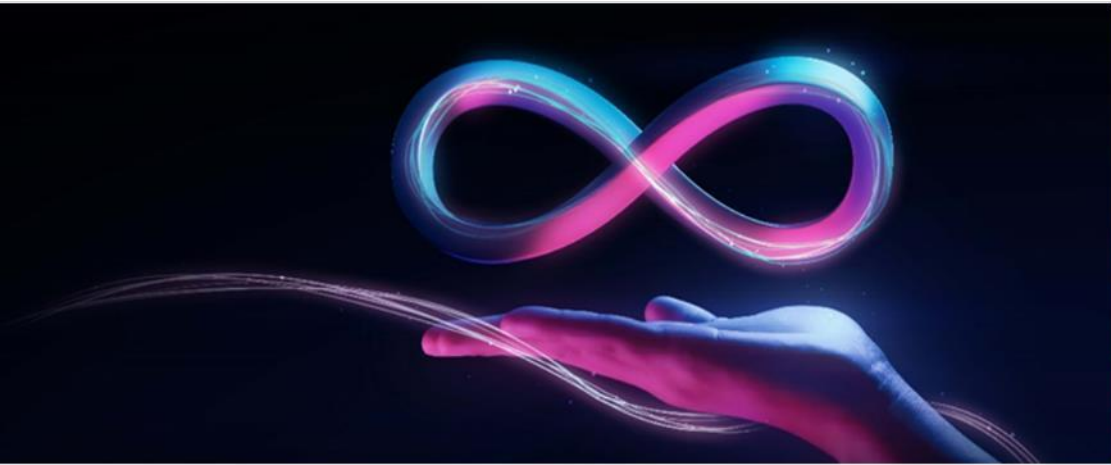


Universität Stuttgart

Institute of Industrial Automation and Software Engineering

Prof. Dr.-Ing. Dr. h. c. M. Weyrich



Picture: SofDCar-Project Consortium, 2023



Software-defined Car

Pathways and challenges
towards IT for future
automotive applications

30.06.2023

Prof. Dr.-Ing. Dr. h.c.
Michael Weyrich





What is a Software-defined Cars / Vehicle?

“A Software-Defined Vehicle is any vehicle that manages its operations, adds functionality, and **enables new features primarily or entirely through software.**”)¹

“(Software- defined Vehicles are) the gradual **transformation** of automobiles from highly electromechanical terminals **to intelligent, expandable mobile electronic that can be continuously upgraded.**”)²

“In 2018 Software-defined vehicles become an **industry hot topic**, 2019 Volkswagen CEO Herbert Diess said that Volkswagen would become a software-driven car company”)²

)¹ according to QNX: <https://blackberry.qnx.com/en/ultimate-guides/software-defined-vehicle>

)² according to Deloitte <https://www2.deloitte.com/cn/en/pages/consumer-business/articles/software-defined-cars-industrial-revolution-on-the-arrow.html>

Where are we positioned in our German Automotive Industry?

Memo: Annual sales of the German automotive industry of around **411 billion euros**)*

Restructuring and new alliances ...

Handelsblatt
CHIPHERSTELLER
Nvidia-Chef: „Mercedes wird die wertvollste Luxusmarke des Planeten werden“

Die Partnerschaft zwischen Nvidia und Mercedes-Benz ist in Stuttgart umstritten. Nvidia-Chef Jensen Huang setzt nun auf eine Charmeoﬀensive.

Felix Kobermann

27.03.2022 07:39 Uhr • 8 x geteilt



Nvidia-Chef Jensen Huang
(Der Konzernsitzler ist das Gesicht des Chipherstellers.
(Foto: Reuters))



BMW verschmilzt iDrive mit Android

CES BMW bringt ein umfangreiches Update des Bediensystems iDrive mit vereinfachter Menüstruktur. In Zukunft wird Android Automotive OS in dafür taugliche BMW-Fahrzeuge integriert.

Torsten Gahr • 09.03.2022

Handelsblatt
VOLKSWAGEN
VW-Chef Oliver Blume beginnt mit der Umstrukturierung von Cariad

Neuer Chef der Volkswagen-Tochter wird ein Bentley-Vorstand. VW muss schneller in der Softwareentwicklung werden, weitere Verzögerungen würden Milliarden kosten.

Martin Murty, Işınar Başkovic, Roman Tyborski

10.05.2023 - 07:53 Uhr • 7 x geteilt



Oliver Blume
Der VW-Chef versucht, das Management der Software-Elitetruppe Cariad aus.
(Foto: wmg/7aktuell)

AV winter is coming ...

Mobileye beantragt keine Zulassung für autonomes Fahren

In Darmstadt und Offenbach wollte Verkehrsminister Wissing Autos fördern, die ohne Fahrer Menschen transportieren. Nun winken die Unternehmen ab.

Daniel Dehaes

09.05.2023 - 11:09 Uhr • Kommentieren • 3 x geteilt



Fahrzeug mit Technik von Mobileye

Der Bund hat im vergangenen Jahr insgesamt 55 Millionen Euro bereitgestellt, um „autonomes und vernetztes Fahren in öffentlichen Verkehren“ zu fördern.
(Foto: Deutsche Bahn)



Content

- **State-of-the Art**
- **Research in Software-defined Vehicles**
- **Examples of Research Projects**
- **Conclusion**



Content

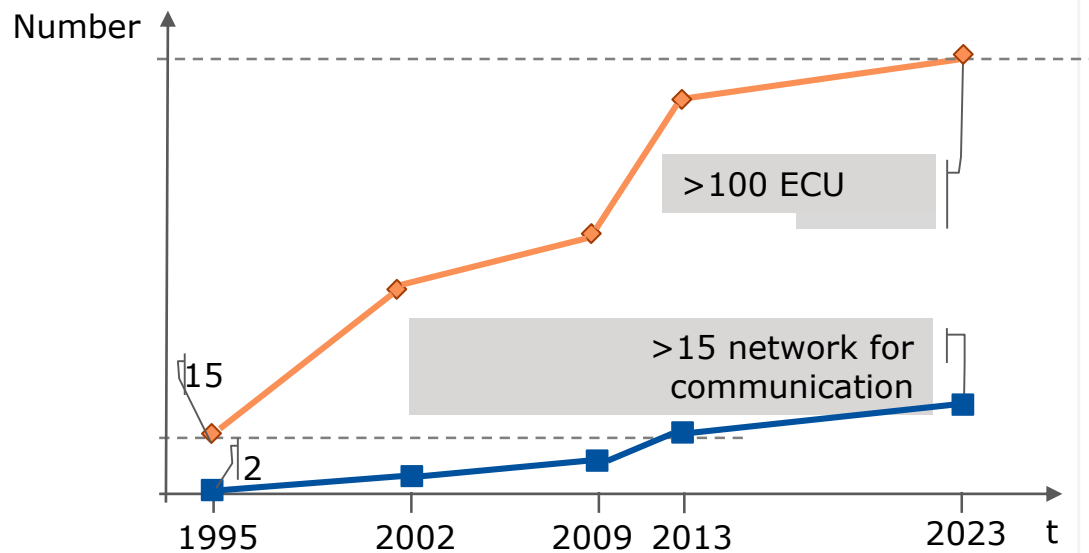


- **State-of-the Art**
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Automotive-IT: State-of-the-Art

It works, but there is an increasing complexity that needs to be managed

Increase of ECUs and network derivatives in a luxury car



AUTomotive Open System Architecture (AUTOSAR) was launched in 2003 has become very complex and needs improvements.



Oct. 2020 Media report on Tesla's advanced architecture.

There are lots of Ideas for IT in Automotive and Mobility



The race for "new smart and connected" functionality in cars and automotive infrastructure is on. Hundreds of Startups are creating innovative ideas about smart future mobility.



For instance: More than 100 Startups and 3600 visitors during the EcoMotion week 2023 in Tel Aviv hunting for innovative ideas in IT, software and services for mobility

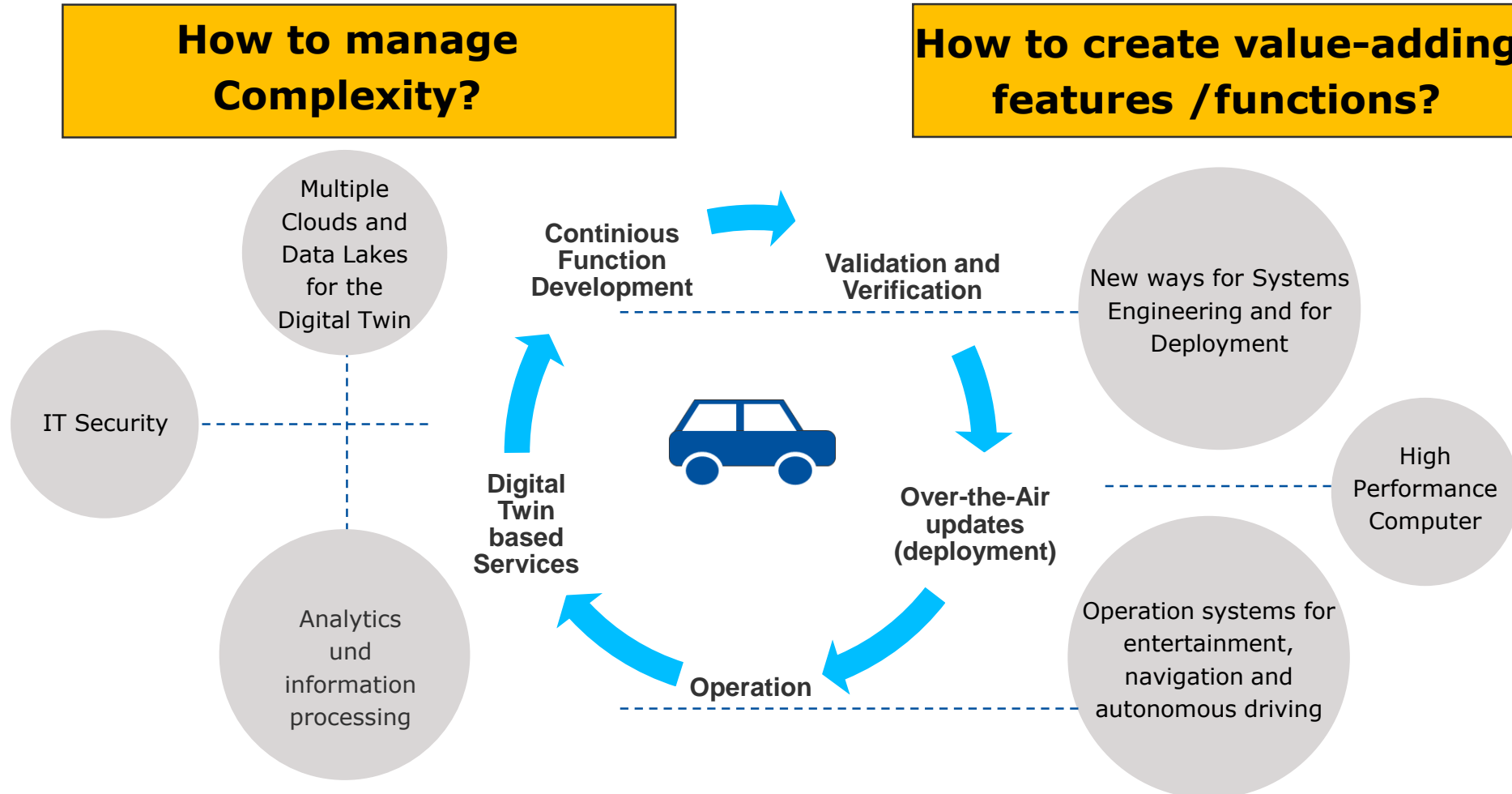


*Jeff Brandes, (ex-) Governor of Florida: „**Only those will achieve who are managing to combine the technological development with a business model**“*

Automotive-IT: It works, but there is an increasing complexity of software and the value add of new functions is unclear




Automotive IT has very specific rules due to many different models, the tier structure of suppliers and the complexity of its "deep tech".





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Software-defined Vehicles (SofDCar lead project)

SofDCar consortium addresses the challenges of future E/E and software architecture in vehicles.

- Vehicles are considered as part of a **network of all vehicles and infrastructure**
- **Digital twins** based on efficient data structures form a virtual image of the physical vehicles
- A **data loop** enables a connection between the vehicle in operation and development, e.g. for the re-deployment of software.

SofDCar Workstreams
The SofDCar consortium has jointly defined four of these focus fields

DATA LOOP

RE-DEPLOYMENT

DIGITAL TWIN

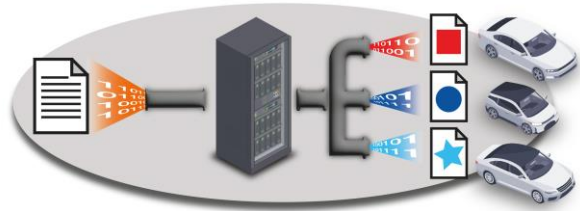
DEMONSTRATOR

21.09.2022 SofDCar Consortium, funded by Federal Ministry for Economic Affairs and Climate Action

5

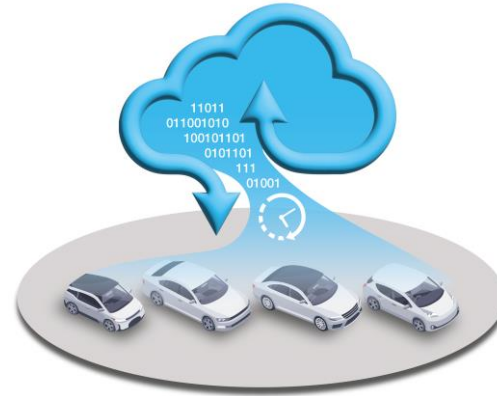
Research Topic: Re-Deployment

How can CI/CD approaches be deployed for the Vehicles?



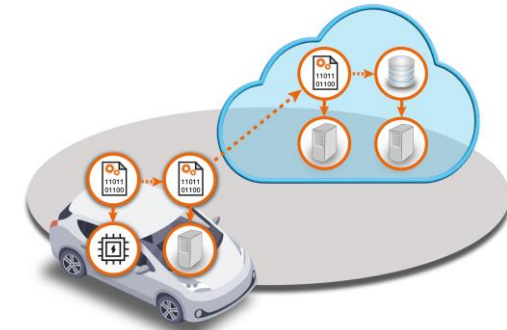
Development of variant-rich software for the software-defined vehicle

Intelligent complexity management of variant-rich software, considering the wide range of customer requirements



Over-the-air update for vehicle fleets

Updating entire fleets of vehicles Over-the-Air while considering the role of cloud elasticity due to different workloads

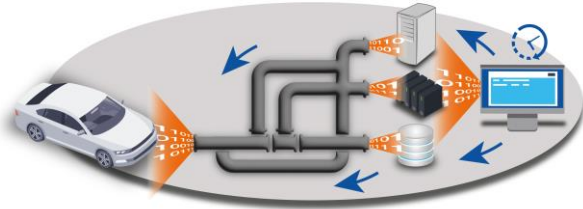


Orchestration of vehicle components

Variant modeling of deployment models with the goal of orchestrating software and hardware in the vehicle and the cloud (install, configure, and update)

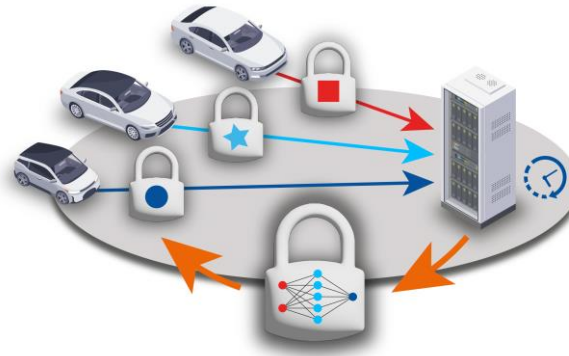
Research Topic: Data Loop

How can Data be exchanged and stored?



Data stream and update analysis

Continuous analysis of the 5G architecture for a dynamic error management and as feedback for future software updates



Federated learning for improved connectivity and privacy

Training of machine learning models with decentralized data in vehicles by avoiding the disclosure of personal information and improving connectivity

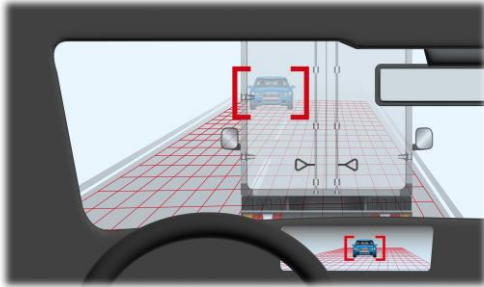
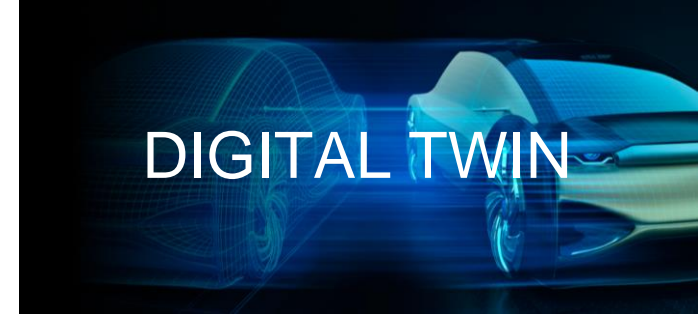


Privacy

Anonymization and policies to protect the privacy of the drivers, which is guaranteed by the operation of the pipelines.

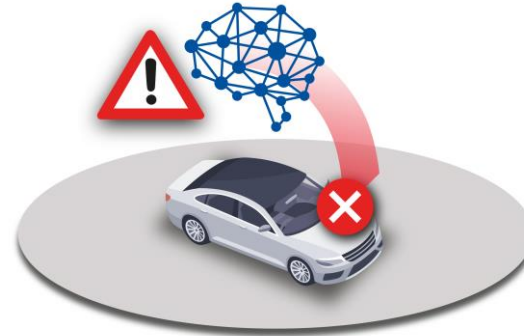
Research Topic: Digital Twin

How to build and deploy a Digital Twin?



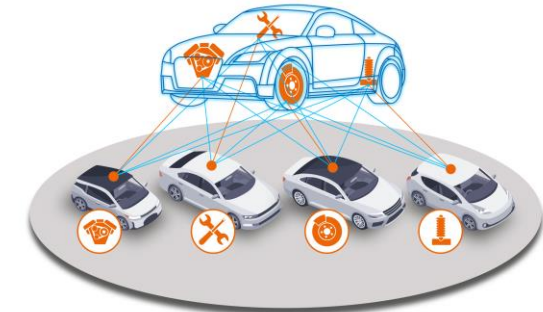
Improved environmental detection

Extension of the sensor acquisition range through data exchange



Anomaly detection

Configuring the most appropriate AI-based anomaly detection methods depending on the context.

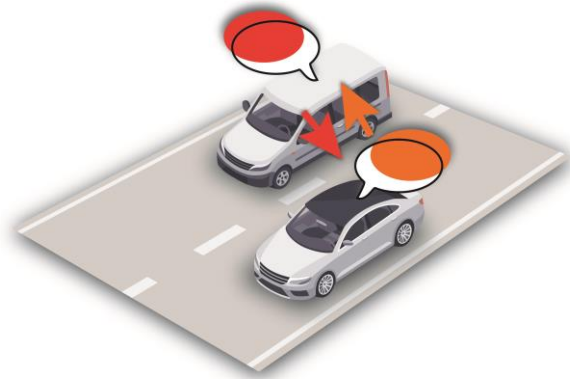


Semantic integration of digital twins

Linking of different models for different aspects of a digital twin of an automobile and exchange of information between these different models

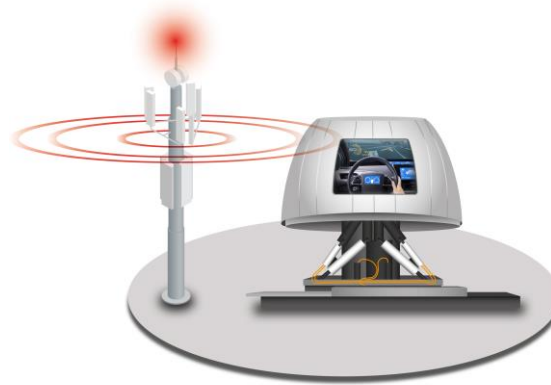
Research Topic: Demonstrator

How to investigate on real world scenarios?



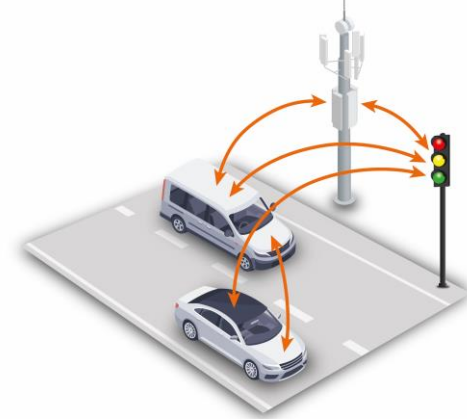
Event-based communication of vehicles

Exchange of information between vehicles in order to coordinate an overtaking process (cooperative overtaking) and carry it out autonomously



Test bench integration

Integration of the vehicle dynamics test bench and the Stuttgart driving simulator into a 5G environment



Multi-agent systems smart infrastructure

A highly connected smart infrastructure with vehicles that communicate with the infrastructure to use location-based and decentralized services while respecting privacy requirements

More Projectes of the Innovation Campus Mobility

Projects are dedicated to utilize distributed data and update software over-the air


- Over the Air Communication for sustainable Energy Management of Fleets (Otrace/INDU2)**
Objective: increase the range of electric vehicles by sharing data from the fleet of city buses.
- Integrated approaches for the software development of upgradeable vehicles (SWUpCar / SdMobi2)**
Objective: possible enhancement to the vehicle in operation with additional hardware and software components should be considered at in the design phase.
- Standardized Test Procedure for Highly Configurable Software Defined Mobility Systems in Operation (TESSOF / SdMobi5)**
Objective: development of a new generation of test methods for the validation of highly configurable mobility software systems in time and space.
- Improvement of product creation and operation by identification of fault and abnormal situations in the powertrain and vehicle dynamics (Networked e cars / SdMobi1)**
Objective: Vehicles and their components are connected using 5G and a digital twin, to then make assessments and derive improvements both "online" and in the simulation.



Bild: Univ. of Stuttgart, IAS



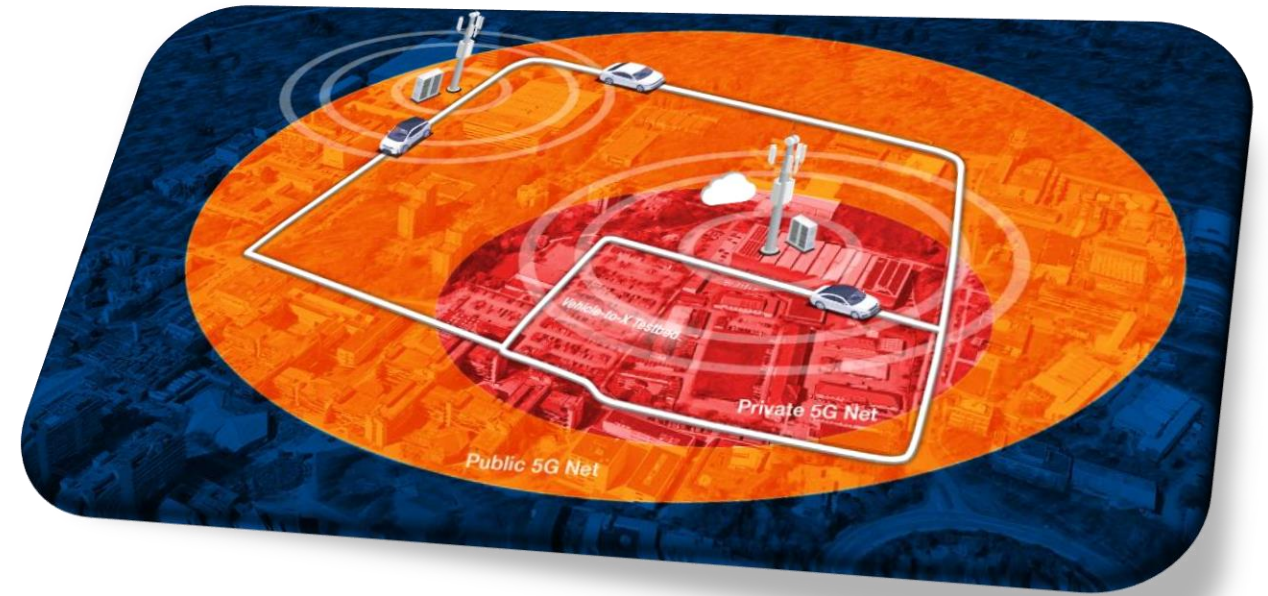
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Testbed 1: 5G for networked Vehicles

During operation in the field vehicles and their components can communicate with each other, the infrastructure and the development departments.

- **Secure networking:** Edge and cloud communication on Internet protocols between vehicles, and traffic infrastructure
- **Management and reliable (re-)deployment** for variant-rich software with software product lines
- **Analysis and reliable synchronization of data** and information with the digital twin
- **Remote function provision (with Collective Perception)** for the vehicle from the back-end



5G test site (network: private and public) with edge and cloud at the Uni of Stuttgart, Paffenwaldring campus.

Testbed 2: Advanced Cockpit for new Features and Functions



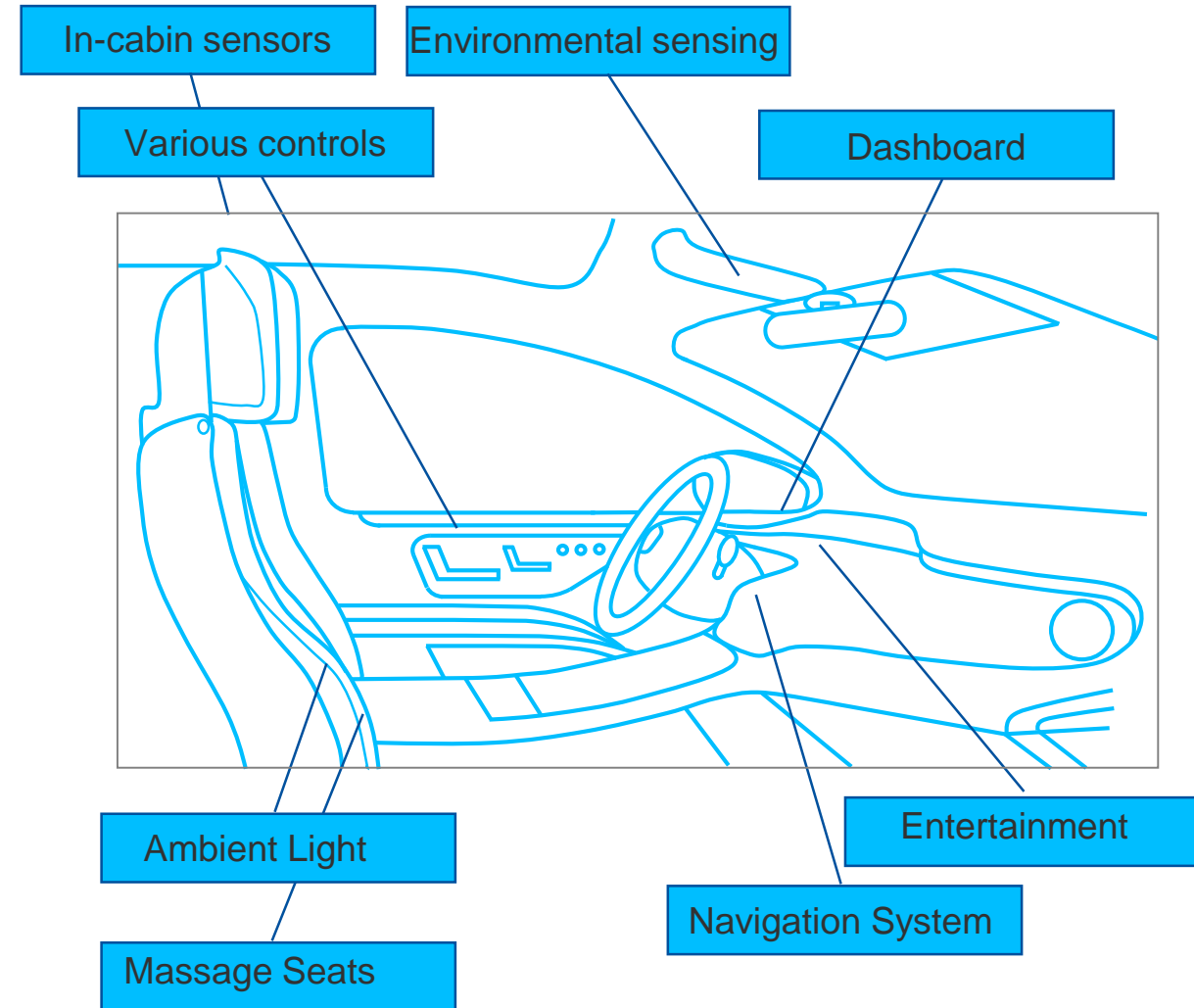
The testbed enable the development of innovative features / functions for the user based on sensorical information of the car and of other cars.

Utilize networked information for:

- **New features/ functions** based on in-cabin sensors and the fleet
- Enhancement of **safety and security**
- Assisted control of the interior („**autonomous comfort**“)

Also:

- **integration of multiple controls** utilizing Dev Ops in real car set-ups and automotive tier-organizations



Source: Univ. Stuttgart, IAS

Status of the Testbeds 1 and 2 (as per June 2023)

About 60% of the allocated budget is freed, call for tender process about to be started:

- **Public 5G net of German telecoms** along with advance functionality (e.g. positioning, edge services) to be available autumn / winter 2023
- **Cockpit installation** about to be purchased but require significant **E/E integration** effort to be ready for tests
- **Private 5G net** with edge core and mobile test installations are still stuck in release processes of funding organization



Cooperative perception for connected vehicles

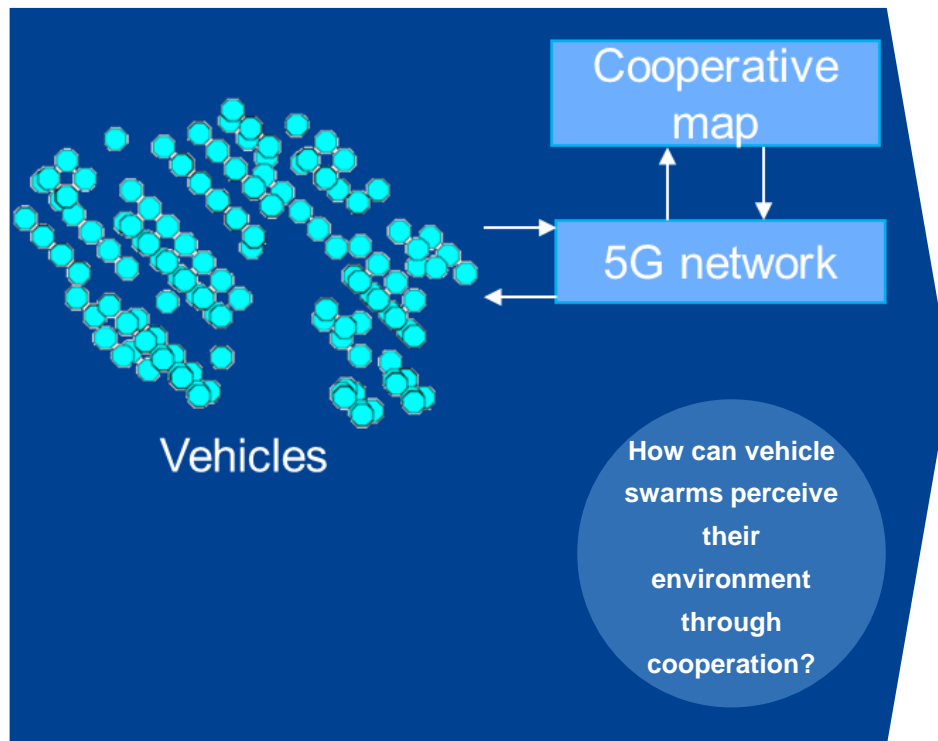
Cooperative map generation for swarms of vehicles

Requirements:

- Improve incomplete sensor data by combining data from multiple perspectives
- Bandwidth optimized data transmission

Core technologies:

- 5G communication network
- Object detection and tracking
- Micro map generation



Motivation

- Vehicles can manoeuvre in dynamic situations, but environmental perception is limited due to occlusion, which limits the performance

Approach

- Enabling cooperative environmental perception via 5G with optimized bandwidth usage
- Definition of transport mechanisms to distribute data and obstacles based on detection confidence
- Intelligent cooperative perception

Personal autonomous comfort with Federated Learning

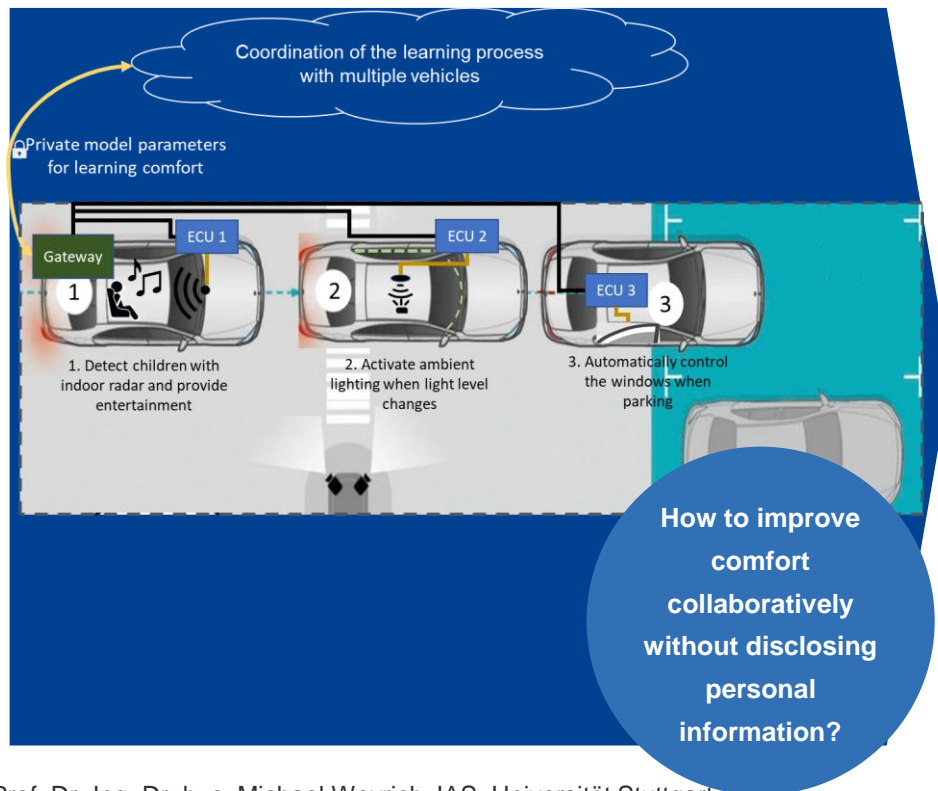
Secure and personal enhanced driving experience through collaborative sensing

Requirements:

- Consideration of various data that contribute to driving comfort
- Ensuring the privacy of personal data
- Timely reaction to changing conditions

Core technologies:

- ML Methods (e.g. Reinforcement Learning)
- Cryptographic methods (e.g. Homomorphic Encryption)



Motivation

- Modern vehicles promise a high level of comfort, but collect and process a lot of personal data.

Approach

- Collection of individual sensor data, local training of ML models, and protection of model updates.
- Jointly build a better-performing global model
- Private and proactive comfort learned from individual experiences

Distributed Integration of ECUs

Remote physical testing of geographically distributed Automotive Electronic Control Units (ECUs)

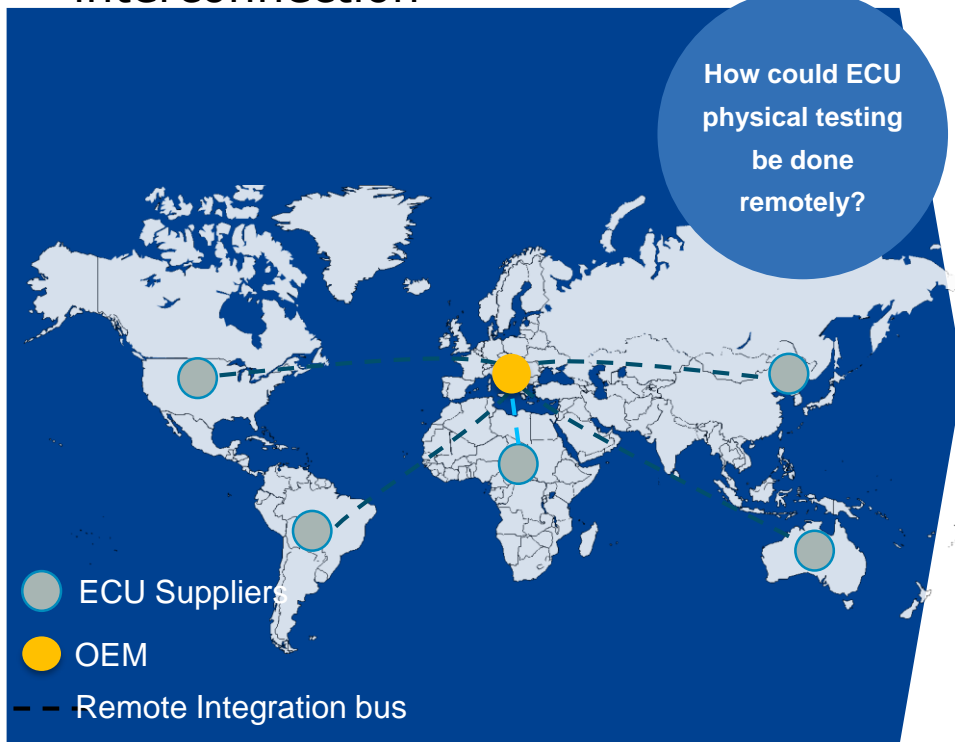


Requirements:

- Analysis of the network implications of a distributed test environment
- Analysis of technical requirements for an external gateway that enables remote interconnection

Core technologies:

- Time Sensitive Networking
- Communication bus Analysis
- Hardware in the Loop (HiL), Software in the loop (SiL)



Motivation

- Long delays in shipping ECU devices from external Suppliers to the OEM for integration testing
- Late development errors during physical testing

Approach

- Remote testing via external gateways over the Internet
- Long distance latency correction



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Conclusion: There are many questions ...

Here are some examples, but there are many more facets with lots of depth.



DATA LOOP

- How can topics of cooperative perception of connected vehicles be utilized?



RE-DEPLOYMENT

- What are the issues of software product lines and software erosion in the upcoming software systems, which rely on CI/CD toolchain?



DIGITAL TWIN

- How can future function be based on a Digital Twin and deploy techniques of modelling, synchronization, real-time processing etc.?



DEMONSTRATOR

- What are the “real world” problems and issues such as latencies, different formats, open source framework limitations etc.?