Ko-HAF –
Cooperative highly automated driving

Contents of the project and focus of research

Status: May 2017

Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

Motivation:
Mobility challenge

People injured and killed in individual mobility:
Reduction of the number of accidents

Economic losses due to traffic obstructions on German roads: **Increased efficiency**

In the future the average age of the population will increase: **Maintaining mobility**

Automation of driving functions is an answer to many issues of future mobility

Motivation

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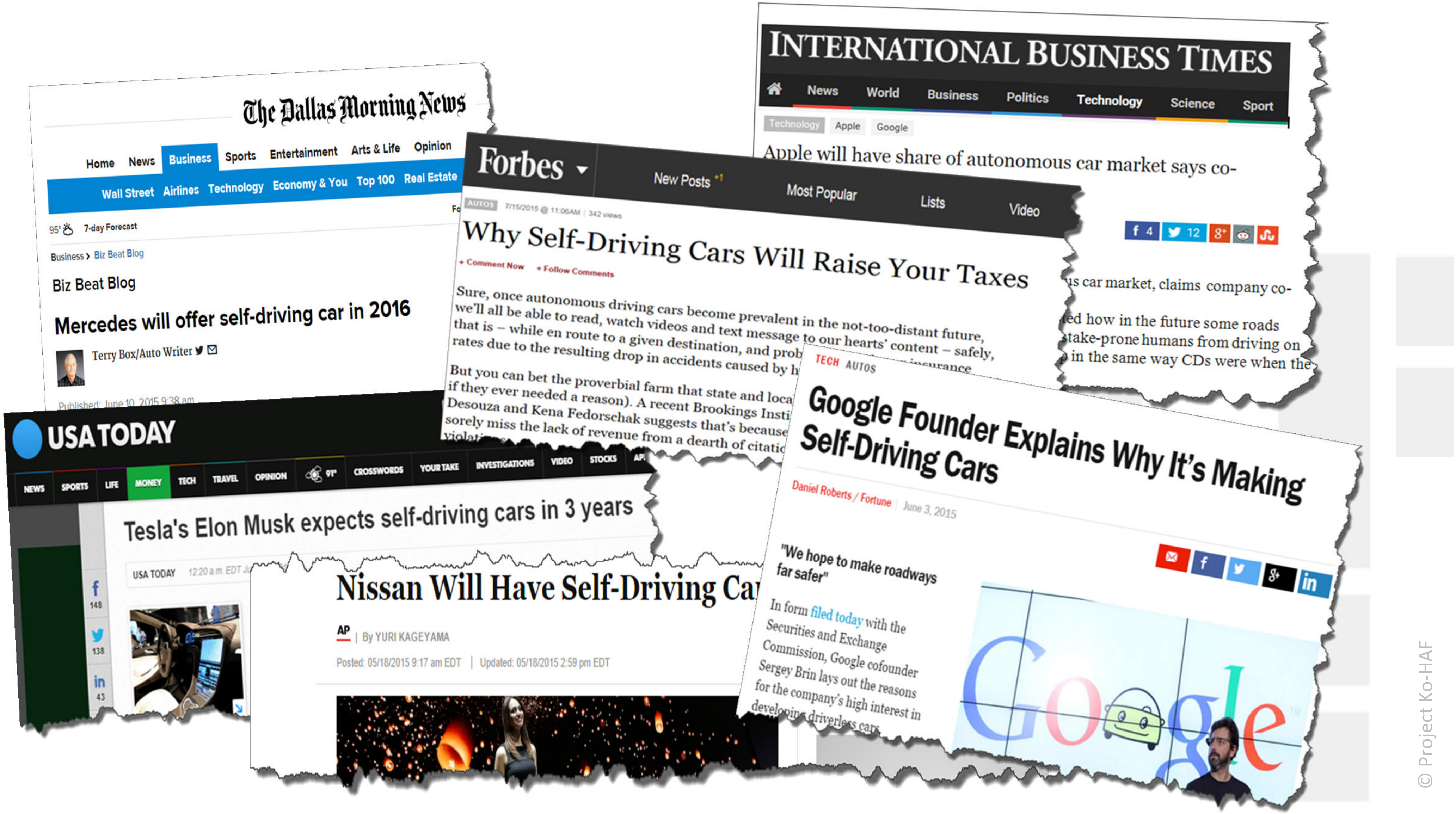

Motivation

- Mobility changes
- Automation of driving functions becomes a key technology
- Two directions of development can be expected
  - **Revolutionary** development approaches for autonomous driving
  - **Evolutionary** development on the basis of today's partly automated driving functions

Project aim

Ko-HAF aims at the **highly automated driving of the second generation**, i.e.

- aversion from the task of driving
- at speeds of up to 130 km/h
- availability in extraordinary situations and in complex highway scenarios
- with a pleasant, anticipating way of driving
- and a further increase of safety and traffic efficiency

Challenges for high automation

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German Law

Road Transport Law
- Section 1 of the German StVG

Liability Law
- Product Liability
- Drivers Liability (§18 StVG)
- Owners Liability (§7 StVG)

Automated driving

International Law

Vienna Convention on Road Traffic 1968
- Article 8 (5)
- Article 13 (1)

Uniform Provision for Type Approval of Vehicles
- ECE R 79 (Steering)

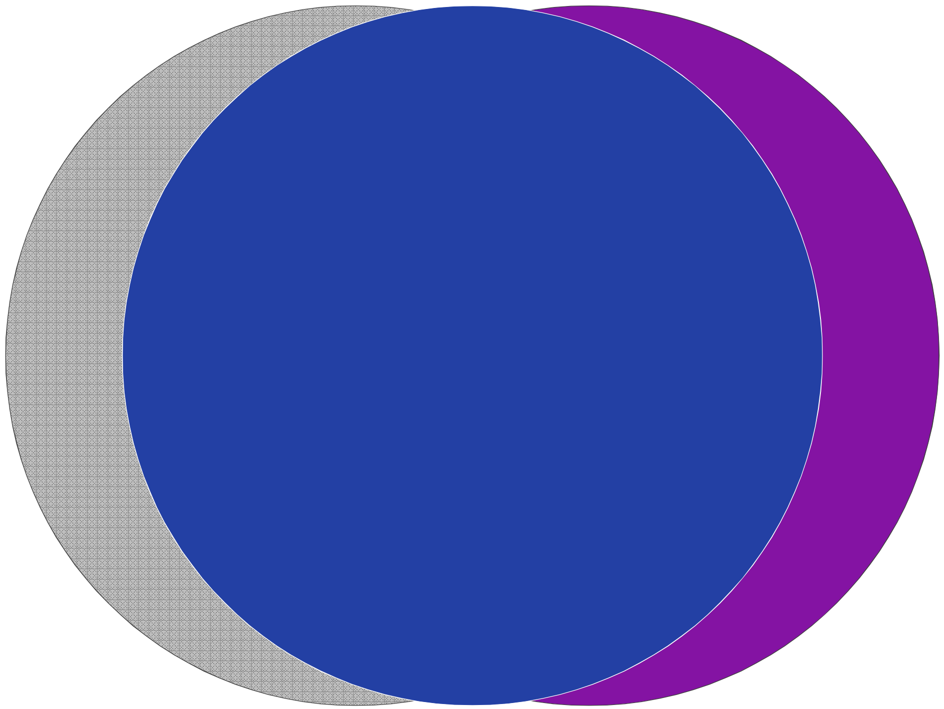
Challenges for high automation

- Sensor technology and environment modelling
  - It suddenly becomes necessary that the driver takes over (e.g. road marking ends, very complex course of the road at construction sites, ...)
  - At 130 km/h and a 10 seconds advance warning, a situation at a distance of over 350 m must be perceived in order to warn the driver that he will have to take over.
  - On-board environment sensors that will be available in the foreseeable future do not provide this capacity!!
- Development of highly automated functions

Challenges for high automation

Validating and securing

Accidents caused by conventional driving



Accidents by new automation risks

Proportion of accidents that can be avoided by automation

Source: T. Gasser, Rechtsfolgen zunehmender Fahrzeugautomatisierung, 5. Tagung Fahrerassistenz, München, 2012

Challenges for high automation

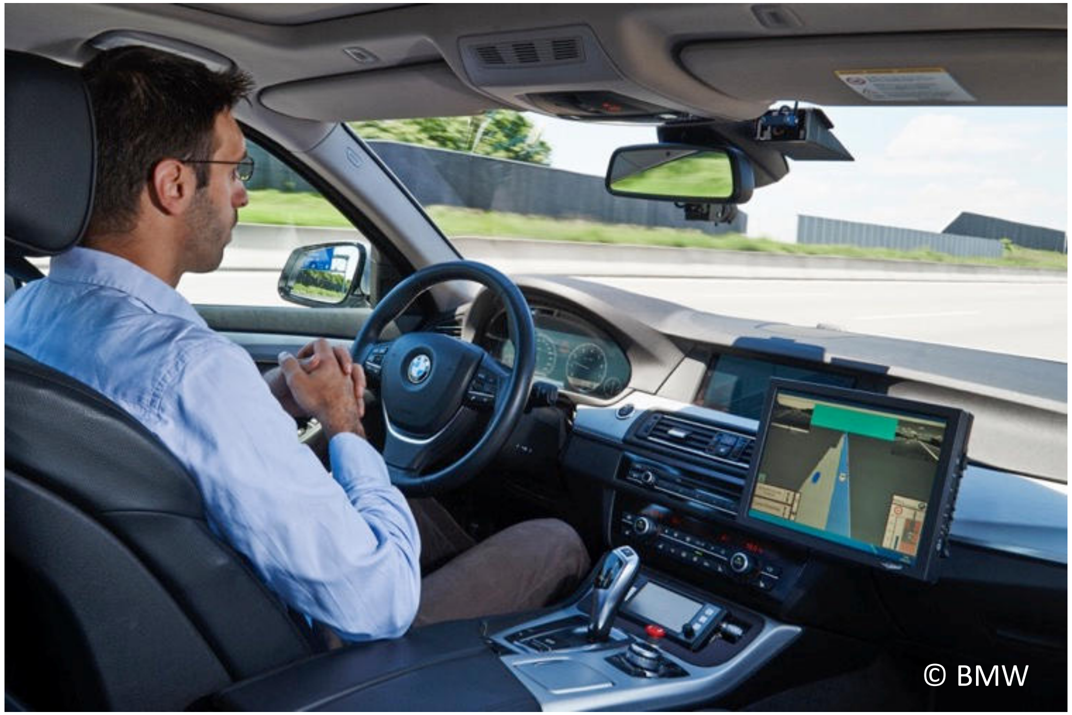
Validating and securing

- How do we test highly automated driving?
- Securing expenses increase with increasing system complexity. Automated vehicles are very complex!
- How do we get a representative overview of possible hazardous situations (field tests, extended accident analyses)?
- How do we test technologies at their limits?

Challenges for high automation

Human

- What is the driver's role?
- Integration and Validation of non driving related activities
- Concept and design of transitions



Underlying data

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Project duration	**06/2015 – 11/2018**
Specification and concept phase	– 05/2016
Development / implementation of the interaction between the safety server (back-end) and the vehicle (front-end)	– 05/2017
Implementation of the Ko-HAF function for normal and emergency operation	– 02/2018
Trial phase	– 11/2018
Overall volume	**36.3M€**
Funds from the German Ministry for Economic Affairs and Energy (BMWi)	**16.9M€**

Gefördert durch:

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aufgrund eines Beschlusses des Deutschen Bundestages

Project partners

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OEM	Suppliers	Small and medium-sized companies	Public institutions	Research organisations
OPEL BMW GROUP DAIMLER	BOSCH Technik fürs Leben Continental Visteon	3D MAPPING	bast HESSEN	IZVW Technische Universität Braunschweig TECHNISCHE UNIVERSITÄT MÜNCHEN FORWISS

Project structure

AP3
Cooperative driving
and controllable automation

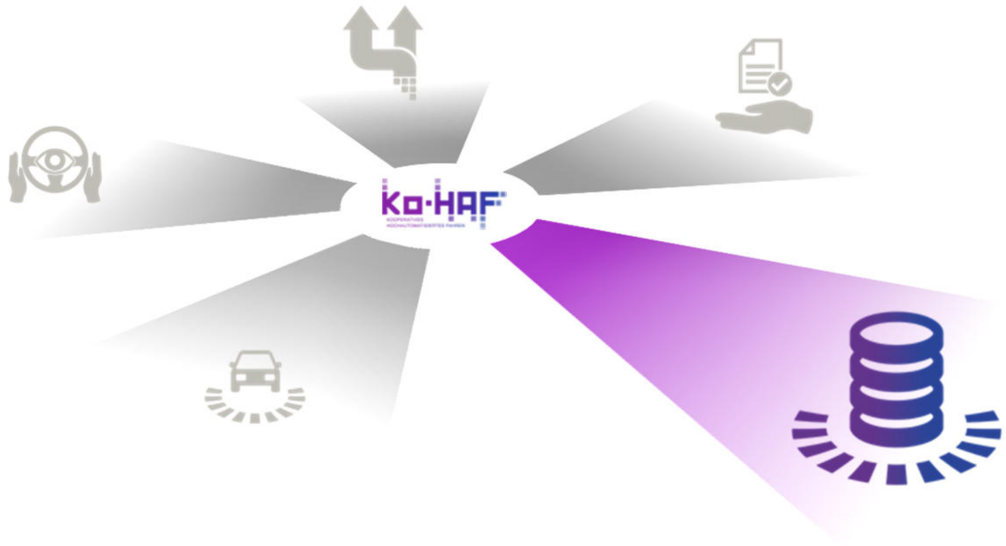
AP2
Localisation and static
environment model

AP4
Function development
for normal and
emergency operation

AP1
Detection & representation of the
environment in the safety server

AP5
Securing and trial
testing

AP1 – Objective



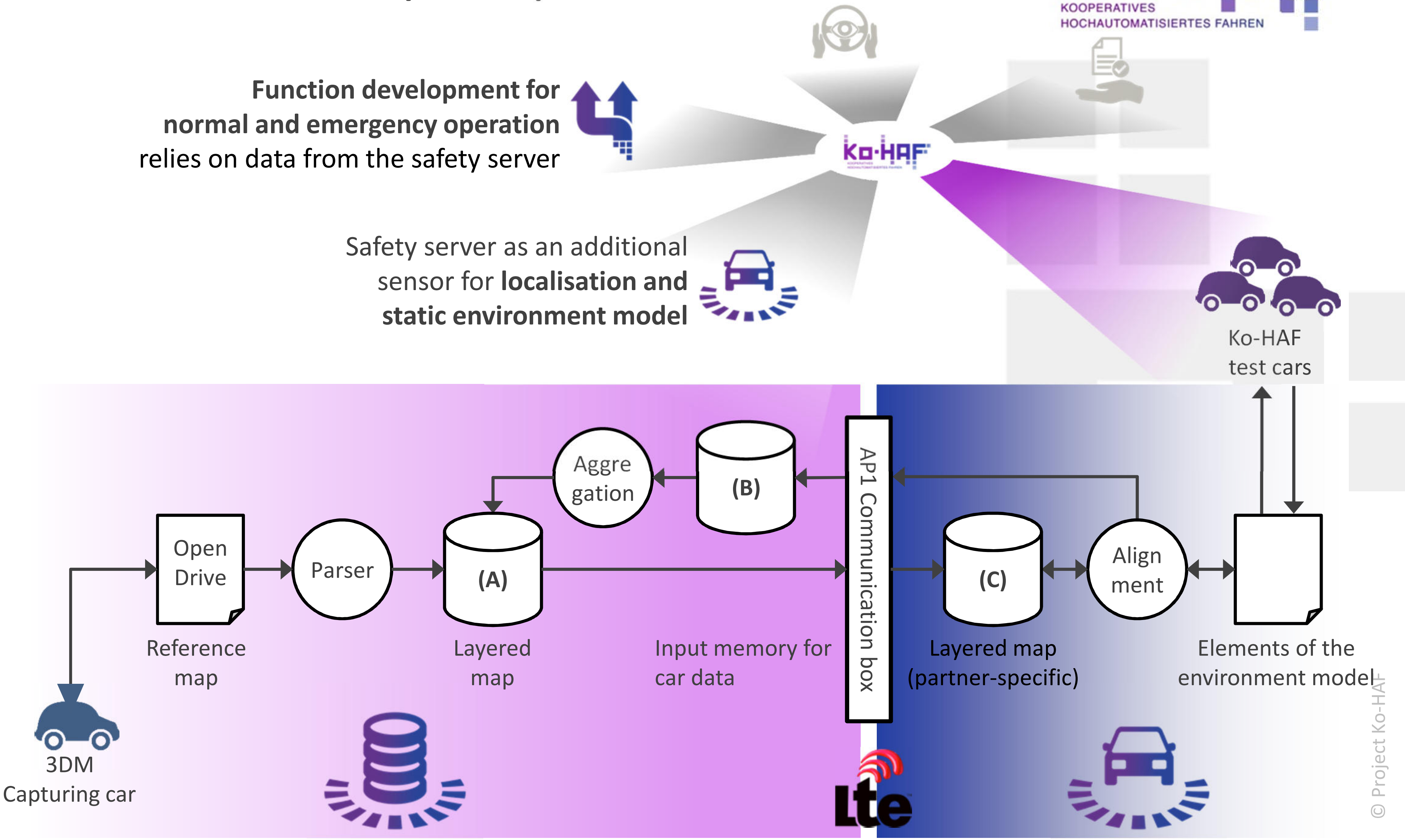
AP1
Detection & representation of the environment in the safety server

- Increase of the anticipation exceeding the range of sensors existing today by collective perception
- The prototypical back-end service “Safety Server” combines the heterogenous landscape of the test cars.
- Cars and external data sources provide more up-to-date data than ever before
- Precise maps thus become up-to-date maps

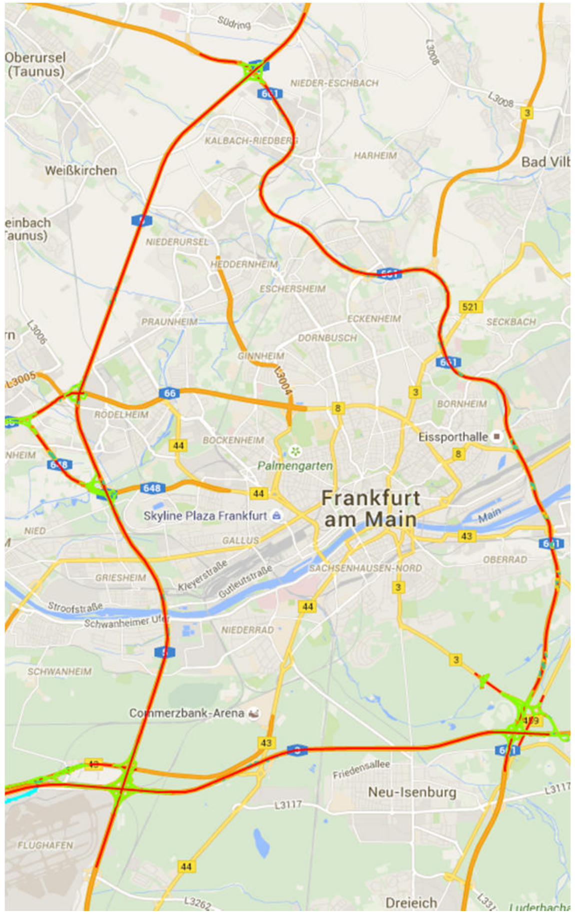
AP1 – Collective perception

Function development for normal and emergency operation relies on data from the safety server

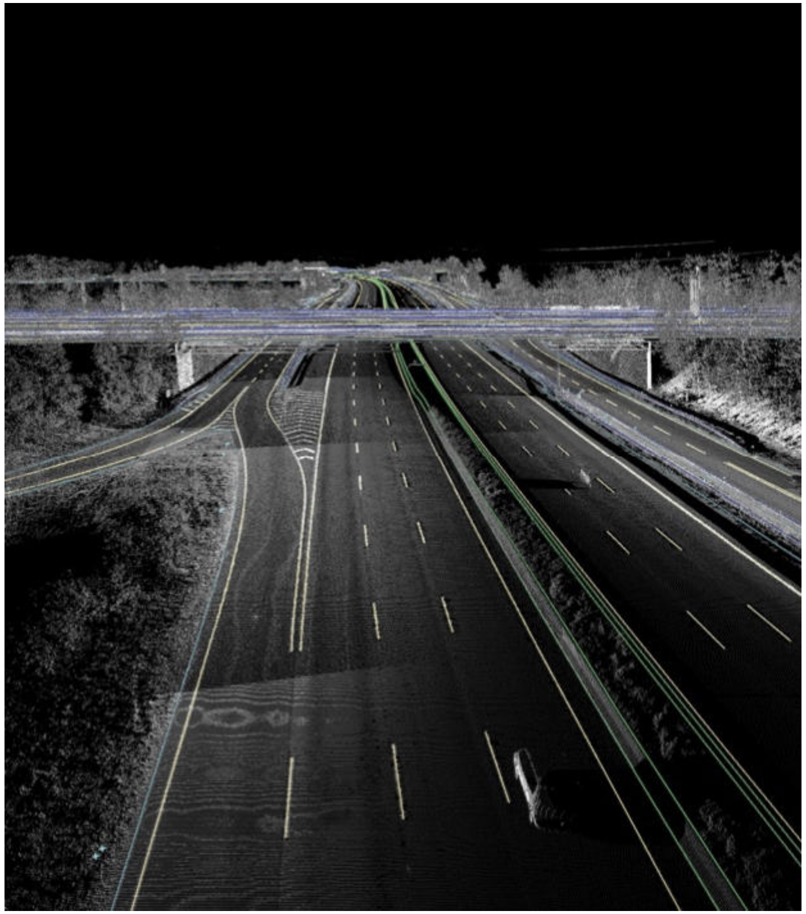
Safety server as an additional sensor for **localisation and static environment model**



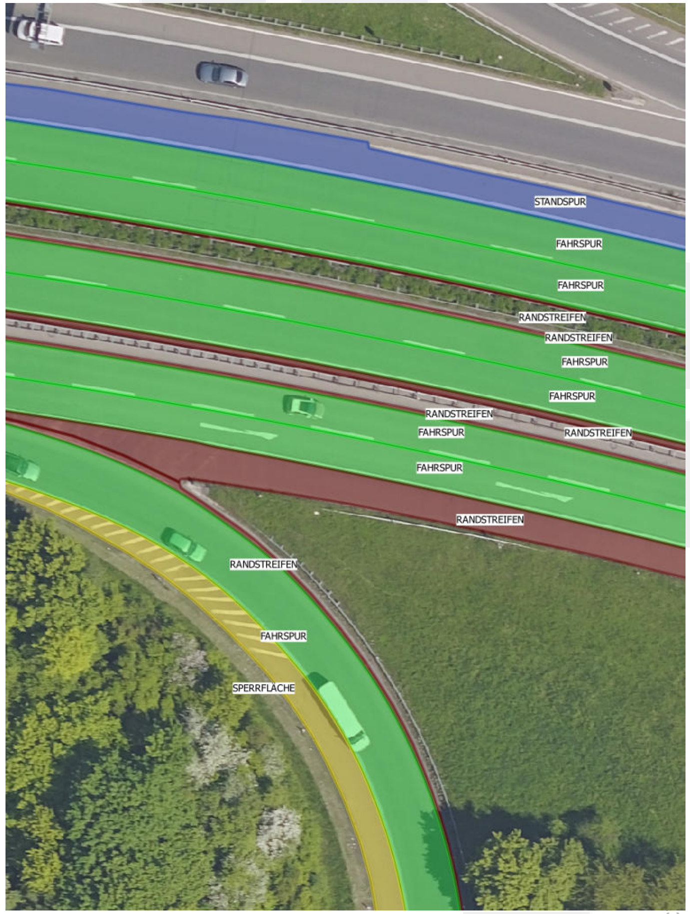
AP1 – Interim results: Test area defined, surveyed and Map created



Test track around Frankfurt



Reference Map XML / OpenDrive

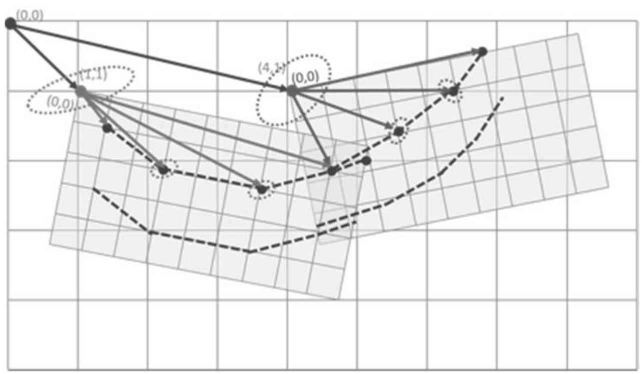


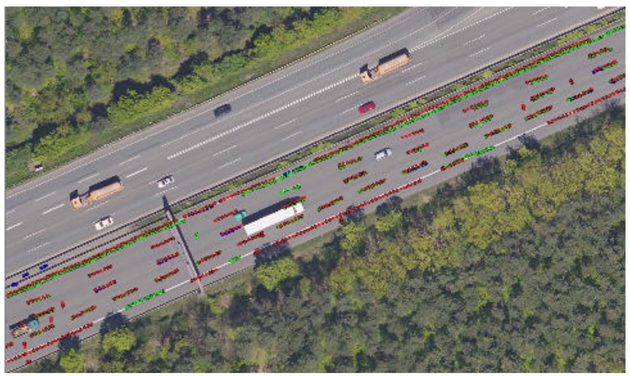
Map elements

Map visualization created with QGIS: *http://qgis.o*

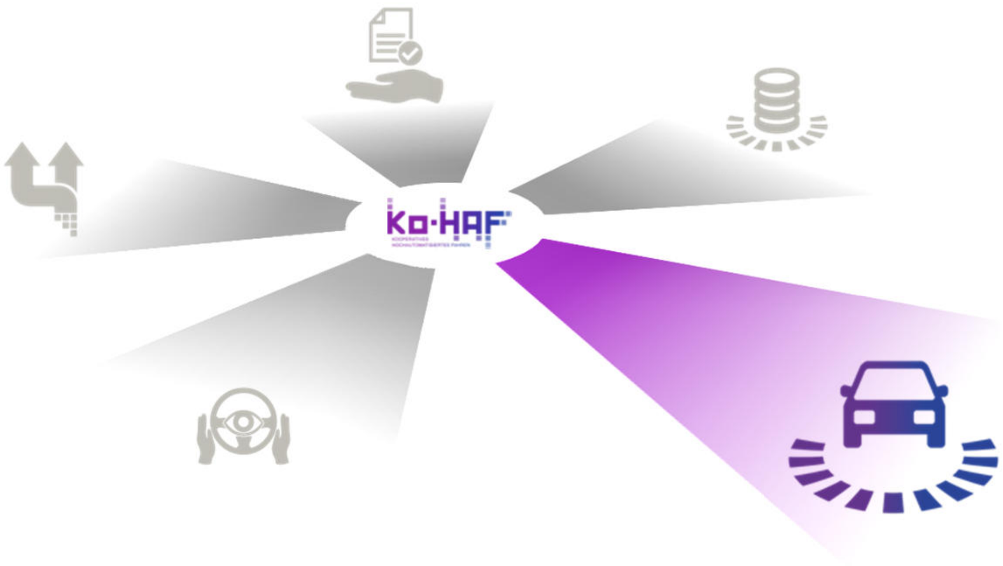
AP1 – Interim results

- Specification of an exchange system independent from maps for a high-resolution geometry made
- Adequate message formats for transmission is available
- Specification of the data format in the server is available
- Implementation of the basic software in basic version available
- First test runs done and data processed in specified format
- First results of aggregators are available
- AP1 communication box built into vehicles and basic functionality implemented





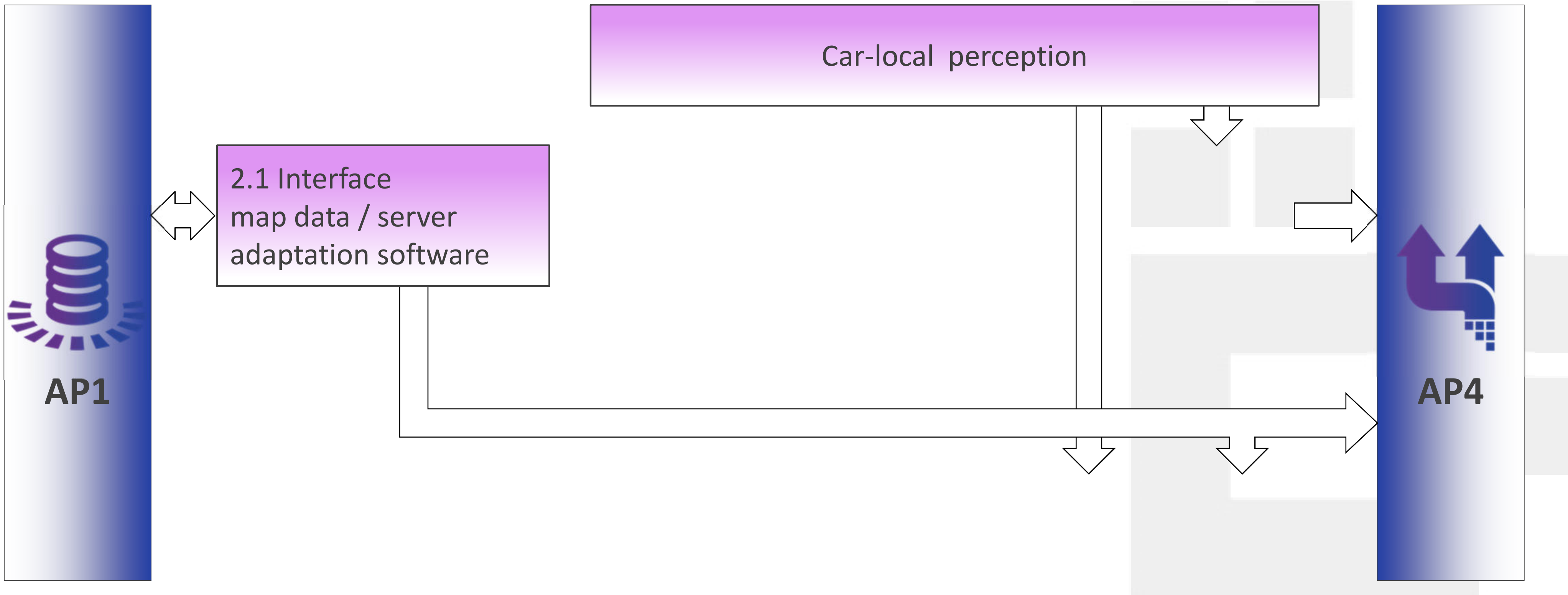
AP2 – Objective



AP2
Localisation and static environment model

- Transmission of environment data to a central back-end
- High-precision localisation with a robust availability
- Fusion of the sensor-based environment model with back-end data

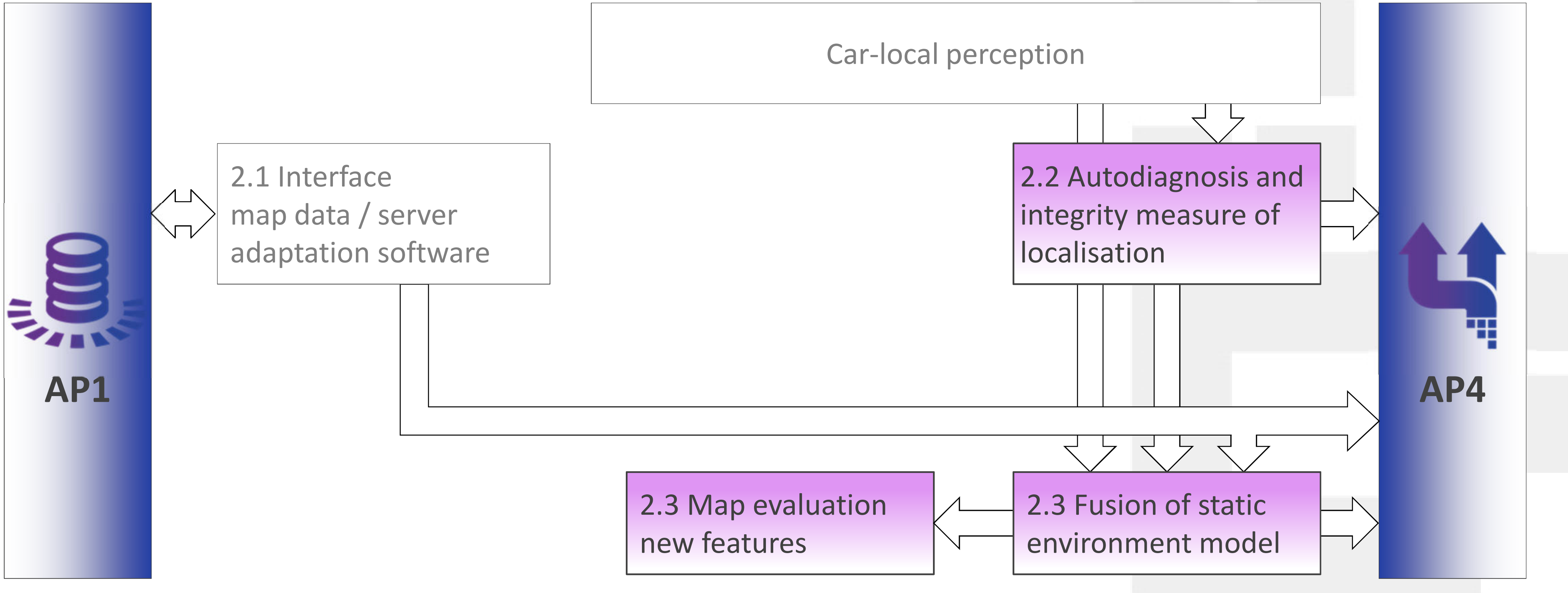
AP2 – Architecture



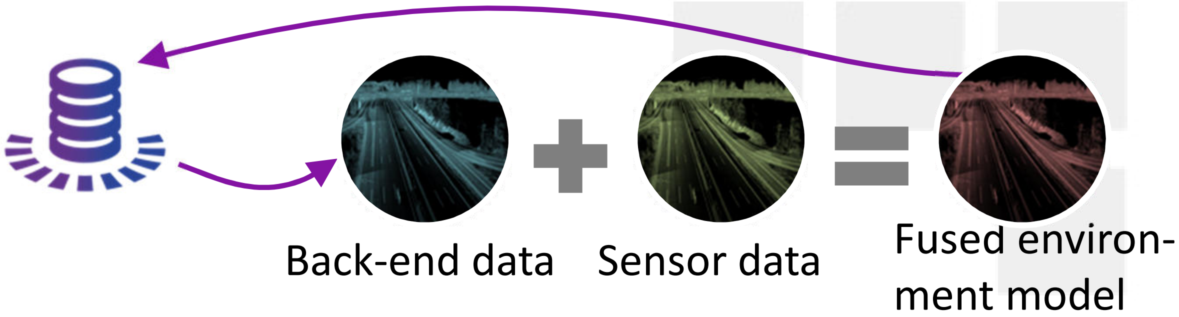
Back-end | Data interface | AP1 communication box | Data interface | Front-end

cross-AP and **independent** from partner-specific map formats

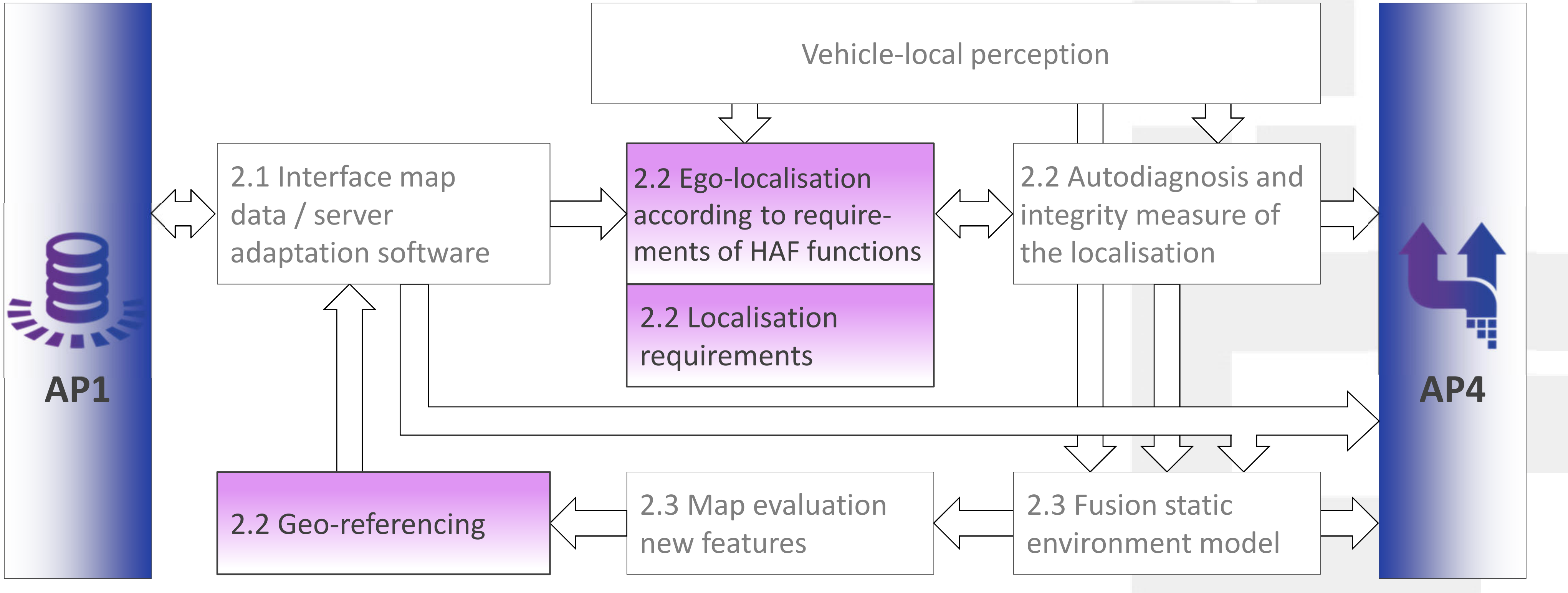
AP2 – Architecture



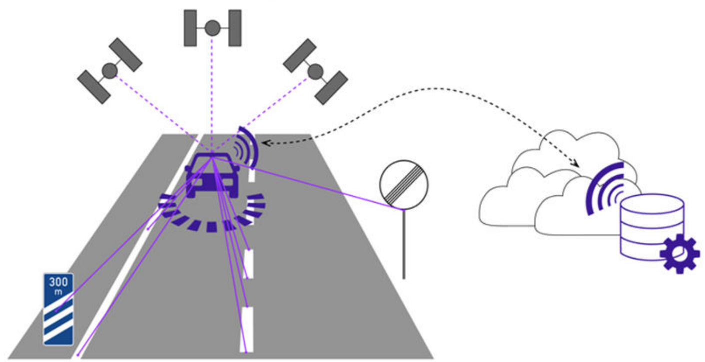
- Plausibility check of the back-end data with the vehicle sensor data
- Geo-referencing of the environment features and the back-end in case of deviations



AP2 – Architecture



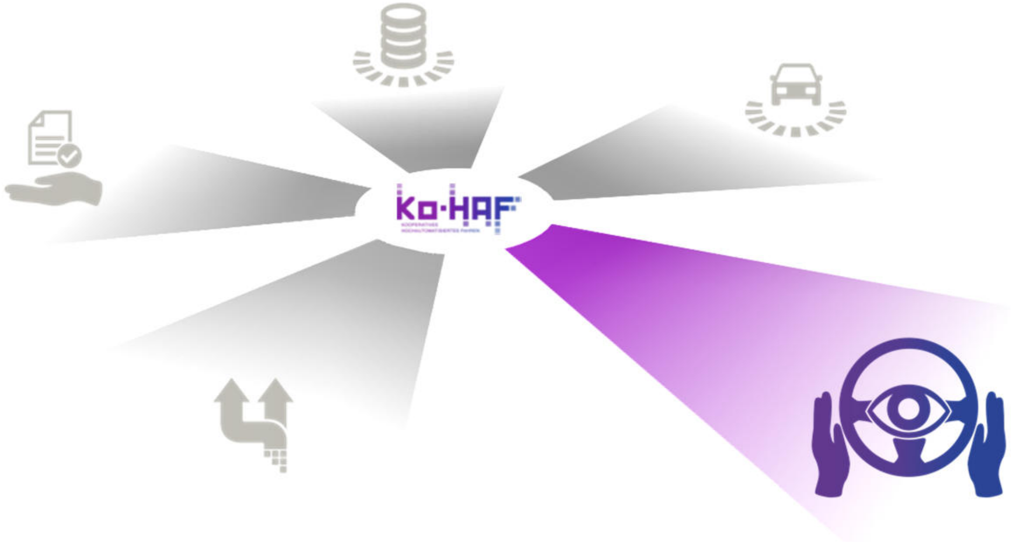
- Support of the localisation through geo-referenced landmarks from the back-end
- Geo-referencing of the extracted environment features
- Autodiagnosis and integrity measure of the localisation



AP2 – Interim results

- Data exchange
  - First data exchange between front end (AP2) and back end (AP1) has taken place
- Localisation
  - First round of referencing landmarks took place
  - First landmark-based localization has taken place
- Fusion
  - First fusion of digital card data and sensory perception has taken place

AP3 – Objective



AP3
Cooperative driving
and controllable automation

- Specifications of the test scenarios and aspects of the man-machine interaction
- Modelling the driver availability and vigilance
- Investigation of automation effects
- Transition concepts optimised for HAD
- Recommendations for methods and interaction concepts

AP3 – Central questions

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- What is the driver's role?
- For how long can the driver attend to non driving related activities?
- How long does it take until the driver can take over the driving in case of a sudden disturbance?
- The heterogeneity of the transitions is increasing – Does the system remain operable?

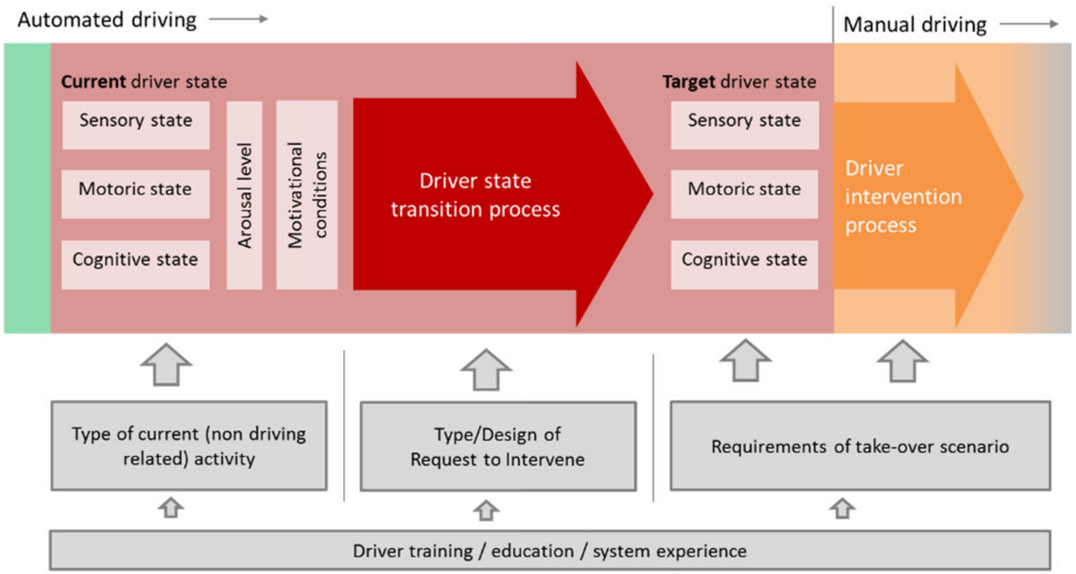
Ironies of automation

"Automated systems still are man-machine systems, for which both technical and human factors are important."
(Bainbridge, 1983)

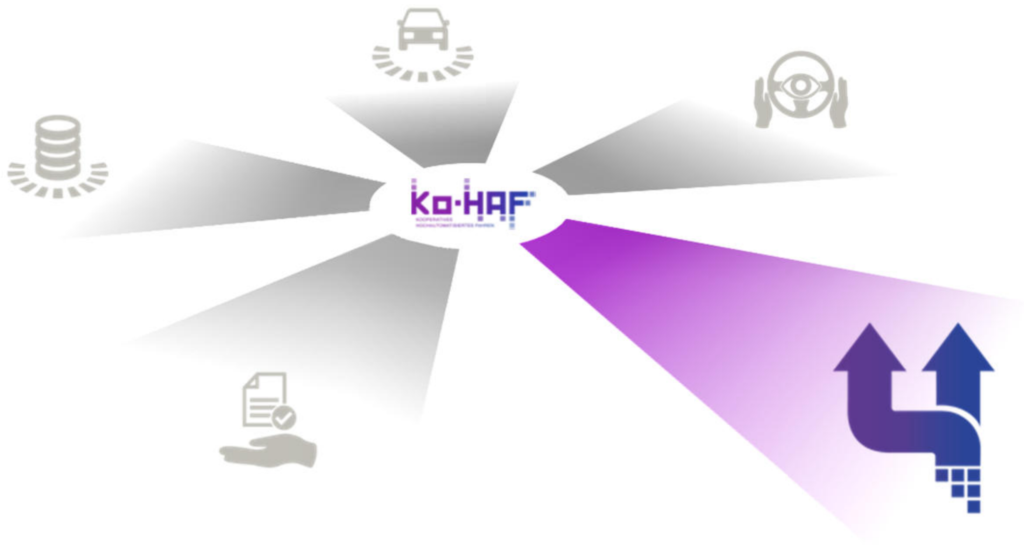
"… the irony that the more advanced a control system is, so the more crucial may be the contribution of the human operator."

AP3 – Interim results

- Test scenarios, metrics and requirements for take-over concept defined
- Studies to non driving related activities and tired drivers largely completed (10+ simulator and real vehicle studies)
- Modeling of driver availability is currently the focus



AP4 – Objective



AP4
Function development for normal and emergency operation

- Environment modelling and situation analysis
- Development of highly automated driving functions
- Anticipatory reaction to danger points
- Transition into a minimal risk state

AP4 – Function development

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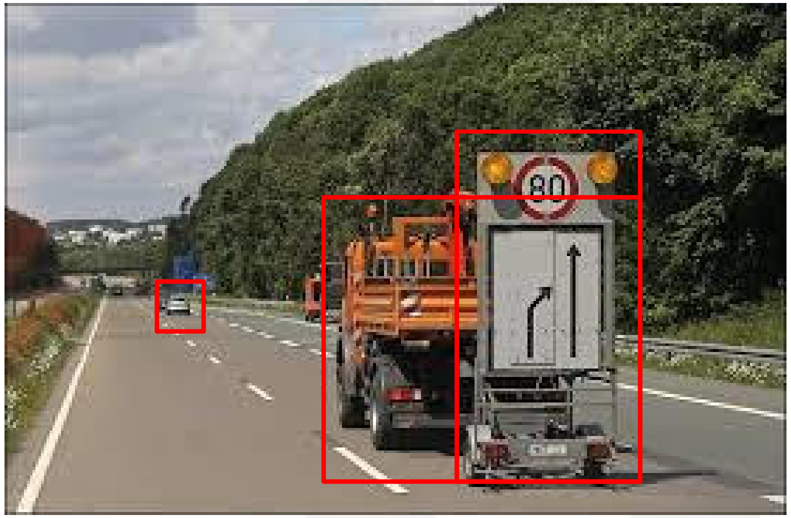
- Developing and testing HAD functions for normal operation

Functions	Project partners					
	Audi	BMW	BOSCH Technik fürs Leben	Continental	Opel	Technische Universität Braunschweig
Exit automation	✔		✔	✔	✔	
Highway intersections		✔				✔
Highway access and merging	✔		✔	✔	✔	
Roadworks		✔				
Adjustable driving behaviour				✔		

- Interim results:
  - A catalogue of scenarios defined
  - Vehicle setup and function development started

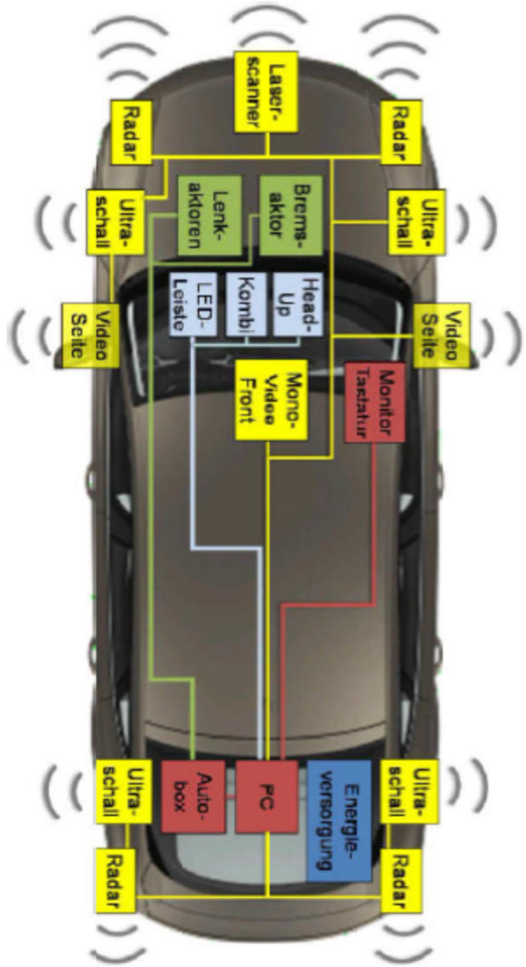
AP4 – Danger points

- Tactical / immediate approach
  → safety manoeuver
  - Braking
  - Steering
- Strategic reaction on the basis of server data → anticipatory manoeuver
  - Reducing speed
  - Changing lanes
  - Increasing distance
  - Informing the driver



AP4 – Vehicle setup and safe operation

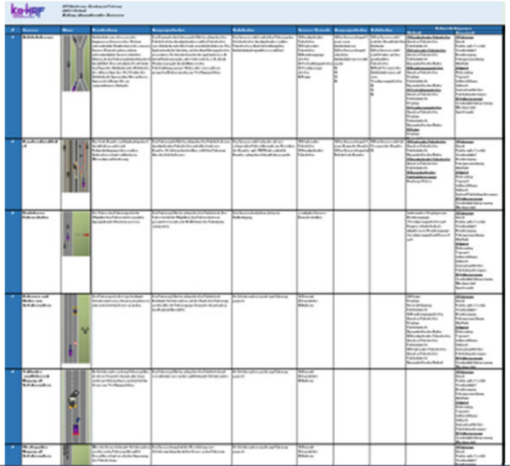
- Conversion of serial cars to HAD cars
- Concepts for measures for attaining the risk-minimal state in your own car
  - What is a risk-minimal state?
  - How do I attain the risk-minimal state?
- Cooperative measures on the basis of server data
  - Notifying other vehicles of a take-over command
- Safety concept for test operation on public roads
  - Emergency off in case of malfunctions
  - Overriding of the system by the driver



AP5 – Objective

- Test methods for testing automated driving functions
- Setup of virtual trial test environment (HW/SW)
- Setup of test tools for reality trials
- Trial testing new highly automated driving functions

AP5 – Procedure



- Test process and specification
- Methods for generating safety statements

Interface between the virtual and the real test

Virtual tests and trials

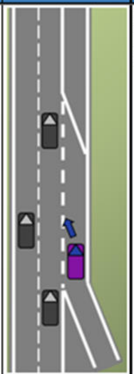
Joint trial testing in a secluded test area

Joint trial testing in a public test area

Setup test equipment and facilities in test area

AP5 – Interim results

- Initial catalogue of scenarios and tests completed
- Initial testing methods developed
  - Approach: minimization of driving tests in public environment
  - Strategy: combination of virtual and real testing
  - Goal: High level of automation by XiL
- Requirements for the test track and test devices defined
- The preparation of a public test field completed

#	Szenario	Skizze	Beschreibung	Ausgangssituation	Endsituation	Szenerie Elemente	Ausgangssituation	Endsituation
1	**Hochautomatisiertes Auffahren und Einfädeln**		Das Fahrzeug fährt auf einer Solltrajektorie von einer Rampe über einen Beschleunigungsstreifen auf die rechte Fahrspur der Autobahn	Das Szenario beginnt mit Befahren der Rampe/des Auffädelungsstreifens. Dies ist im manuellen als auch im automatisierten Fahrbetrieb (im Rahmen von Autobahnkreuzen) möglich.	Das Szenario endet, sobald das Fahrzeug den Zielfahrstreifen (durchgehender rechter Fahrstreifen) erreicht hat. Für den Fall, dass das Auffahren fehlgeschlagen ist, wir das Fahrzeug am Ende des Einfädelungsstreifens zum Stehen kommen (MRM).	1) Rampe 2) Beschleunigungs-streifen 3) Durchgehender Fahrstreifen	1) Das HAF Fahrzeug befährt einen AB-Zubringer und nähert sich der Rampe. Bei Befahren der Rampe beginnt das Szenario. 2) Sobald das Fahrzeug die Rampe verlassen hat und den Beschleunigungs-streifen erreicht, beginnt das Szenario. 3) Nach dem Beschleunigen und dem Einfädeln in den fließenden Verkehr beginnt das Szenario auf dem durchgehenden Fahrstreifen.	1) Das Szenario endet mit Erreichen des Beschleunigungs-streifens. 3) Das Szenario endet, sobald das Fahrzeug den Zielfahrstreifen (durchgehender rechter Fahrstreifen) erreicht hat.

Conclusion / Expected innovations

- Collective perception by means of a communication among the vehicles and the safety server (back-end)
  → extended perception of the environment
- Collection of data in the vehicle including auto-localisation and interaction with the safety server
- Gapless transition between normal operation and active safety functions and between different automation levels
- Transfer into the safe state (emergency operation), e.g. in case of a driver blackout (no reaction to the take-over command)
- Experimental joint trial testing of the HAD functions on highways in mixed public traffic
- Development of test and evaluation methods for highly automated systems

Contact

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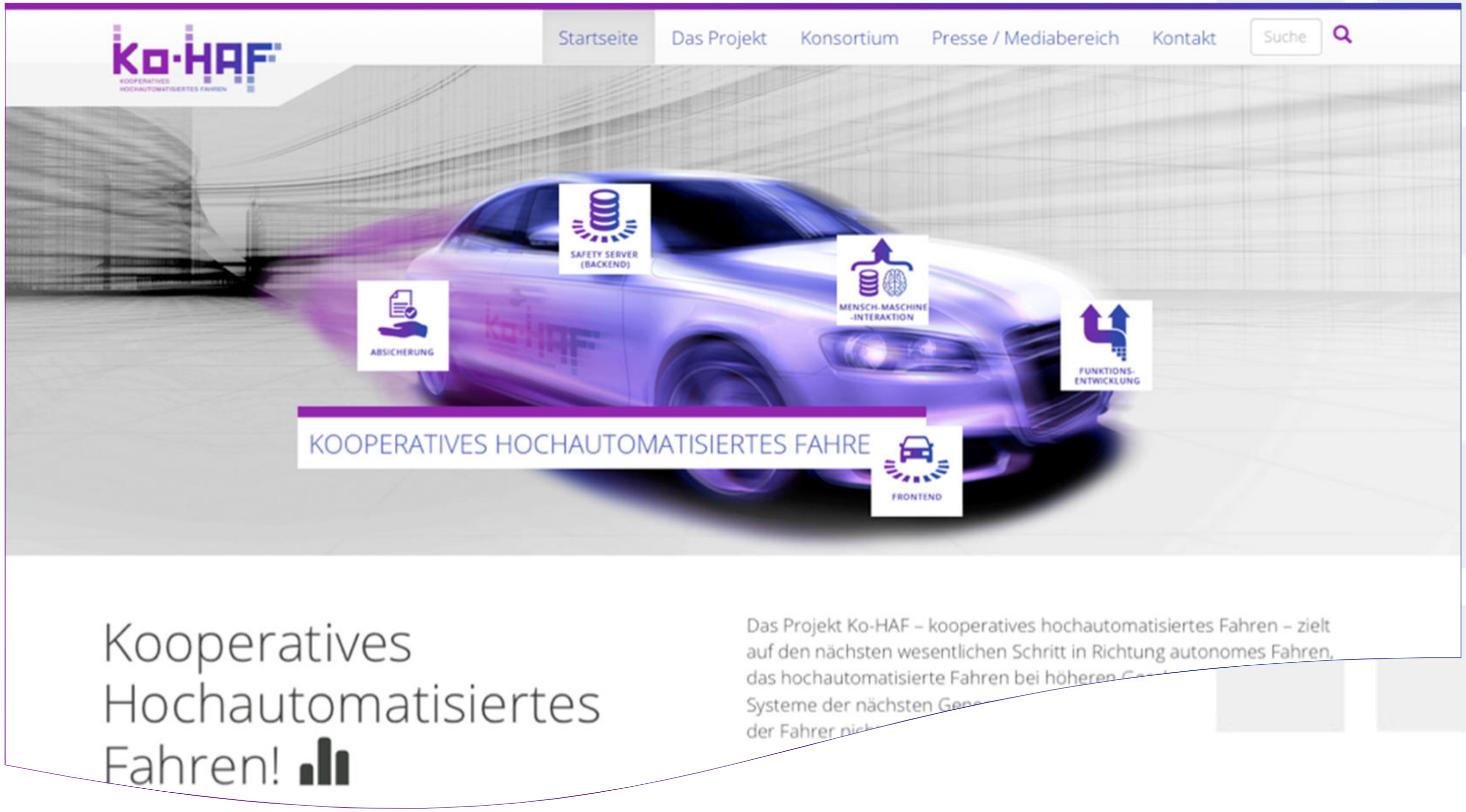
http://www.ko-haf.de



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