Safety and Comfort of HAD Functions through a Continuous Data Exchange between Vehicle Fleet and Server

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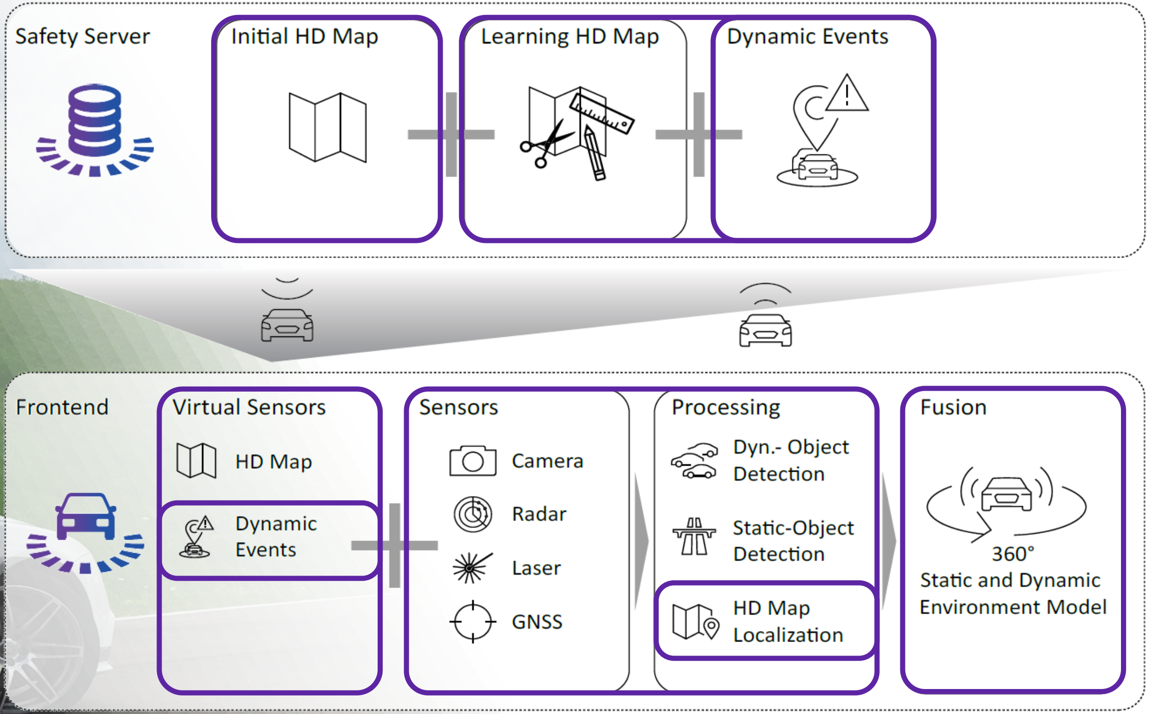
Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

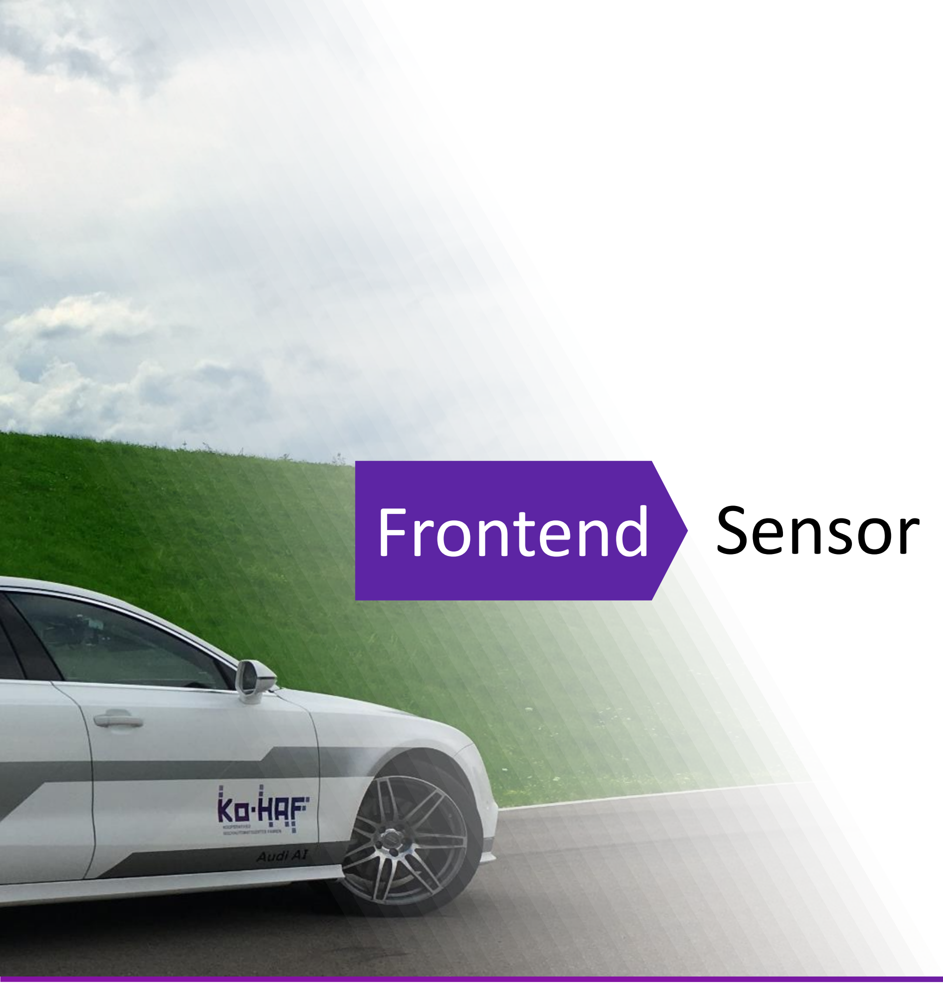
Big Loop

Interplay of Frontend & Safety Server

Big Loop Interplay of Frontend & Safety Server

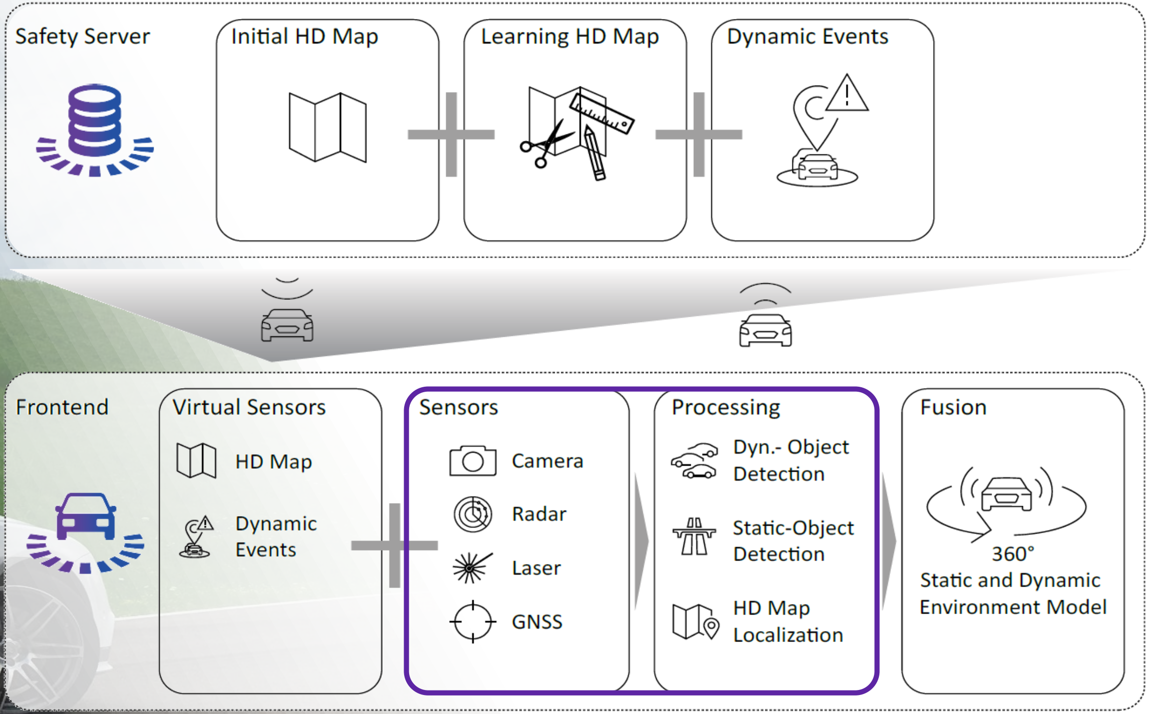


Continuous Data Exchange between Frontend and Safety Server



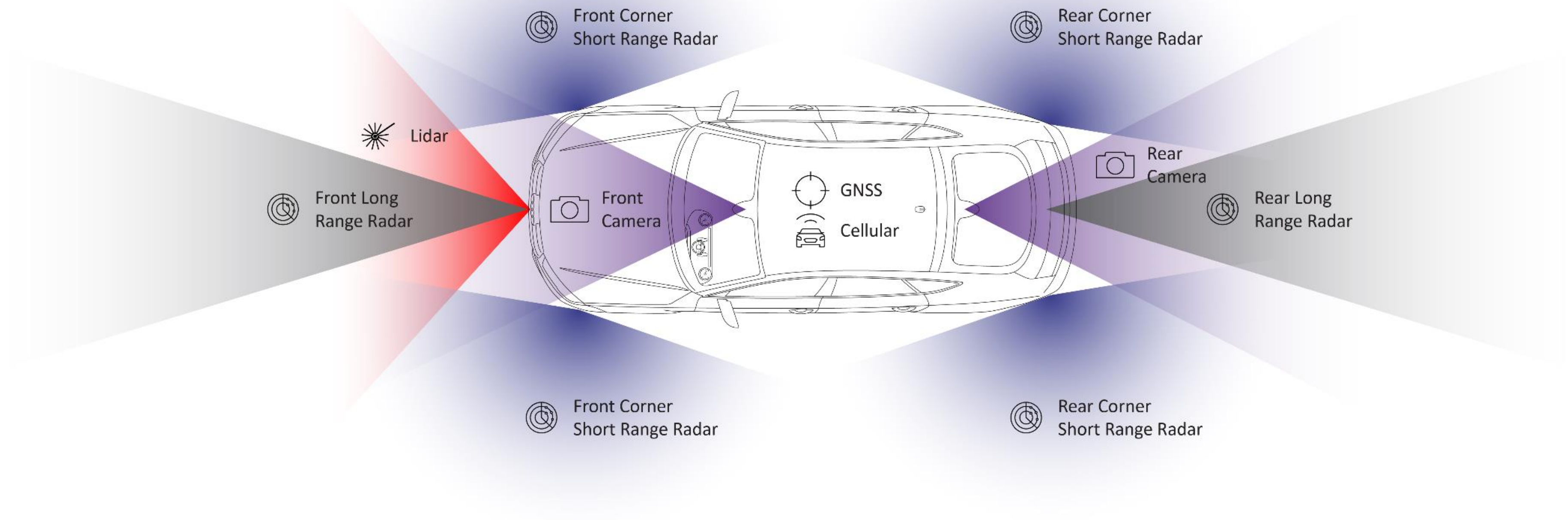
Frontend Sensor Data Upload

Frontend Sensor Data Upload

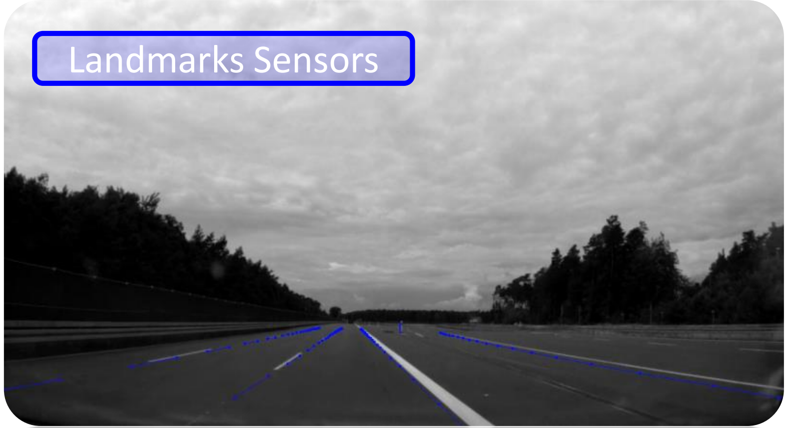


Frontend Sensor Data Upload

Modern vehicles are equipped with manifold types of sensors.
An example …



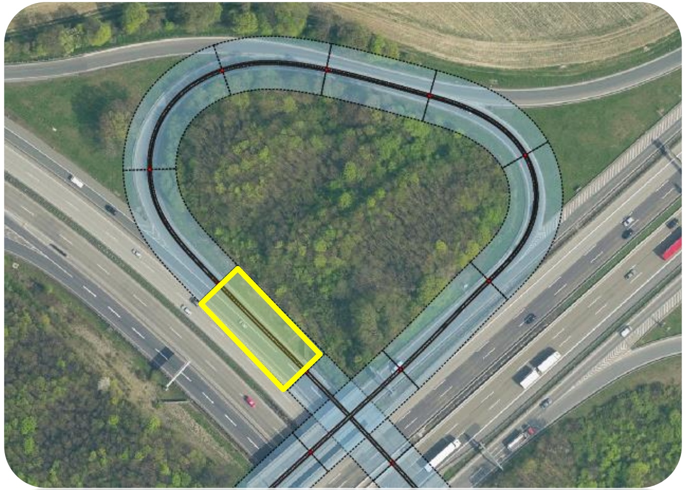
Frontend Sensor Data Upload



Example of Extracted Landmarks

- The data of these sensors can be utilized to map the direct environments of these vehicles
- For example, landmarks, such as **road / lane geometries**, **traffic signs**, **reflector posts**, can be extracted from the sensor data
- These local maps can be propagated to the backend-side for **collaborative fusion**

Frontend Sensor Data Upload



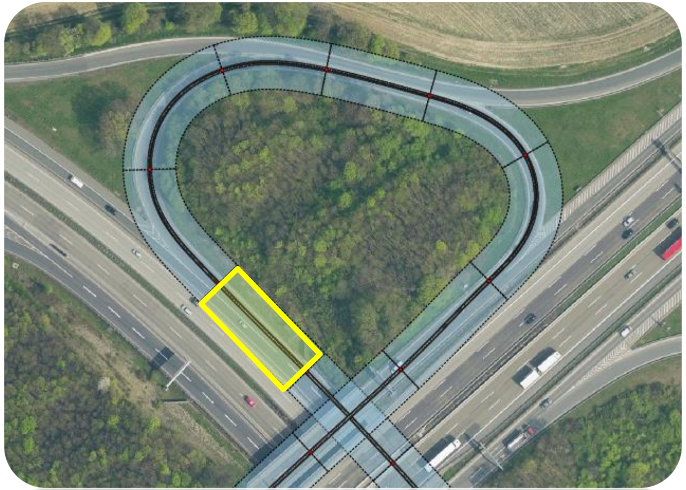
Example of Sensor Data
Preaggregation to Maplets

Distinction in Ko-HAF between …

1. **Static Sensor Data**
   > Road infrastructure information
   > Preaggregated to maplets
   > Normally prioritized upload

2. **Dynamic Sensor Data**
   > Potential hazard information
   > Not preaggregated to maplets
   > Direct and highly prioritized Upload

Frontend Sensor Data Upload



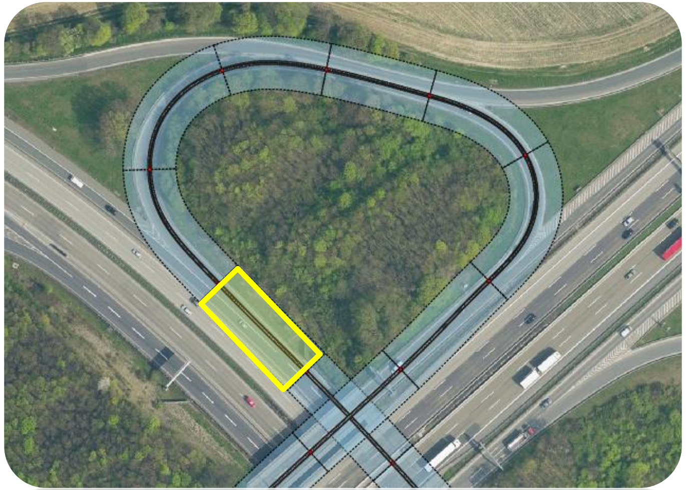
Example of Sensor Data Preaggregation to Maplets

The **preaggregation** of static sensor data to maplets **means that the amount of** required

> **cellular traffic** and
> **computational resources** at the backend-side

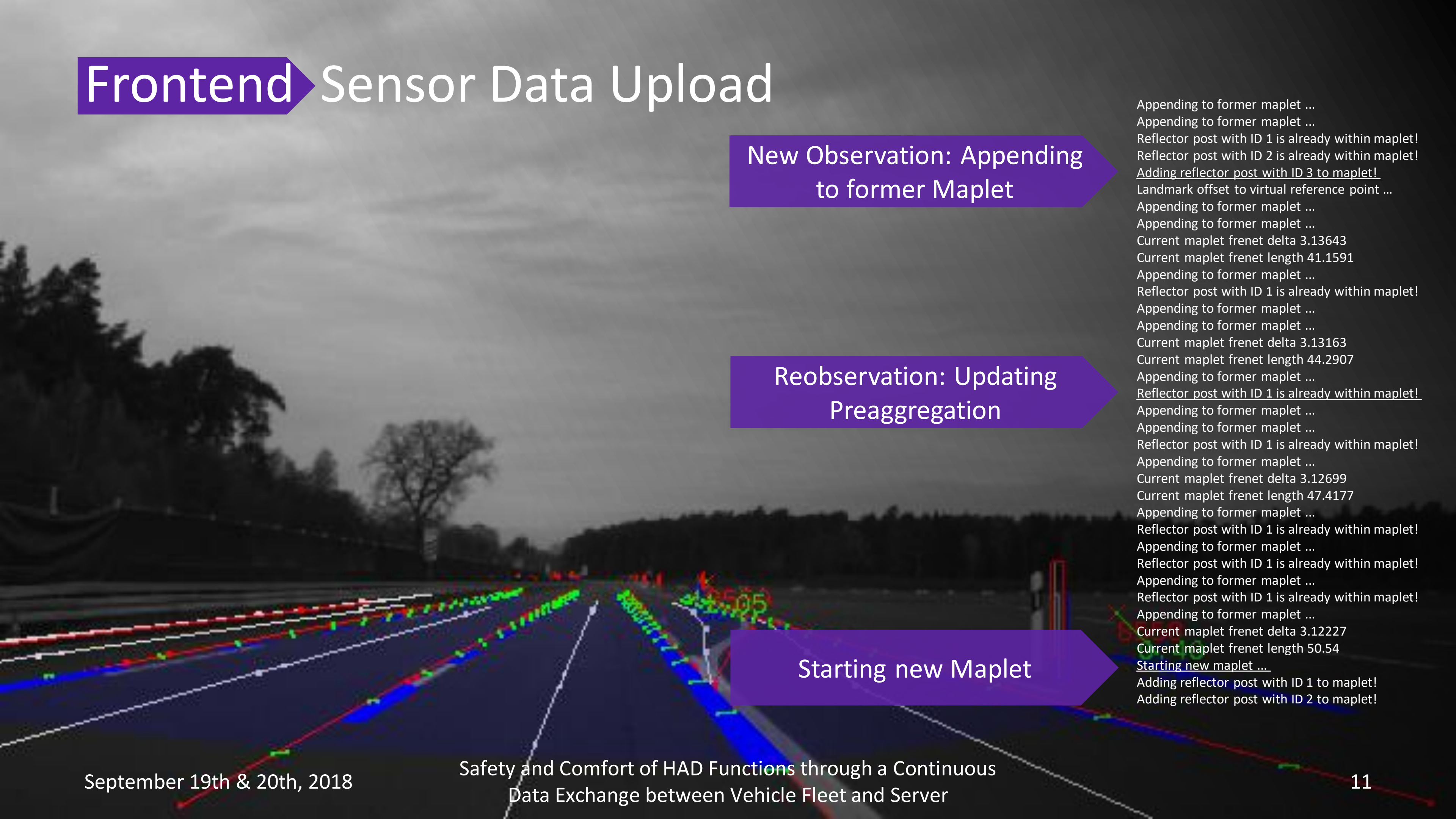
is significantly **reduced**.

Frontend Sensor Data Upload



Example of Sensor Data Preaggregation to Maplets

- In Ko-HAF the SENSORIS format has been **significantly extended** to match the needs of the project
- The changes are intended to be part of the next format version



Frontend Sensor Data Upload

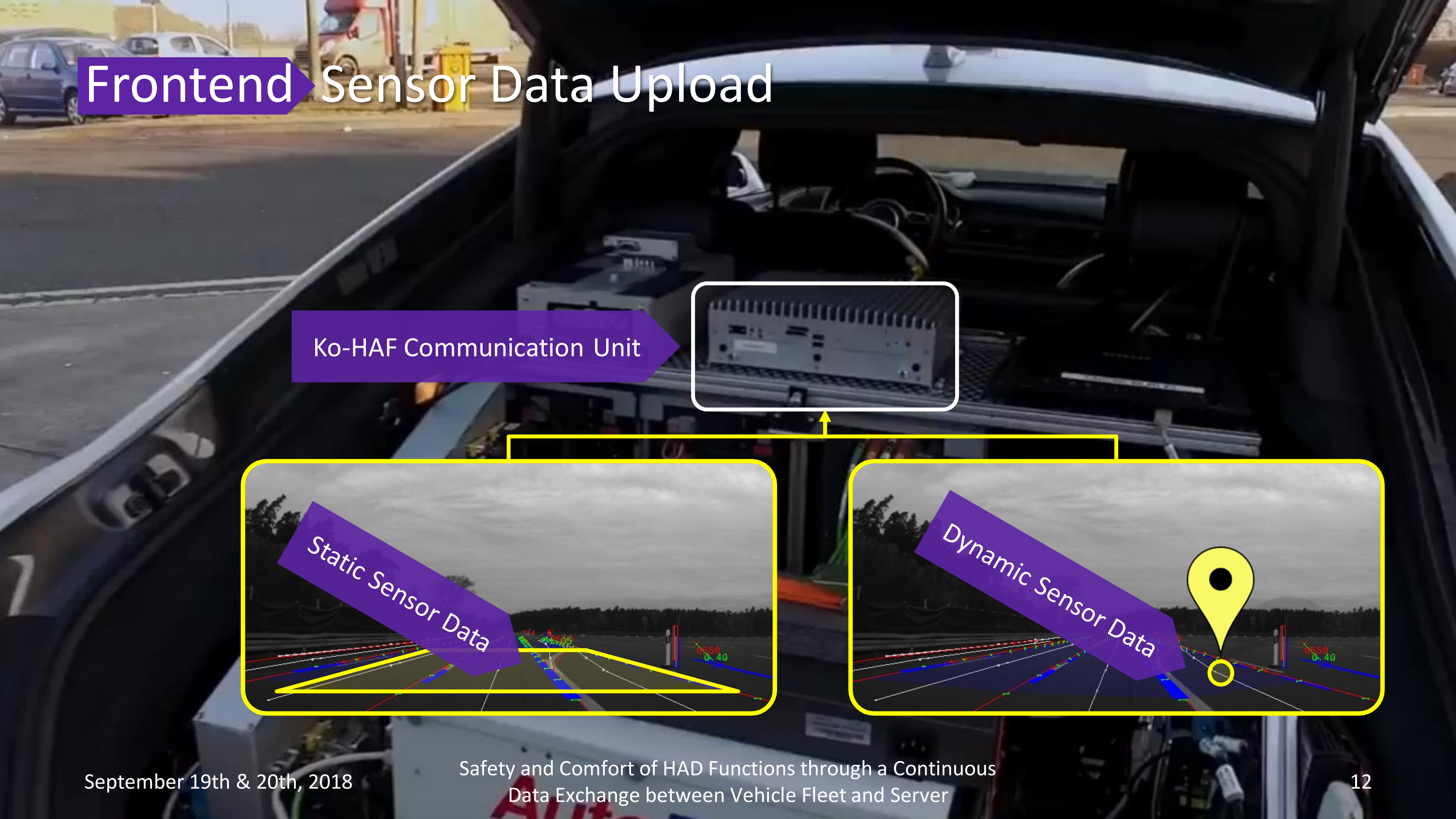
New Observation: Appending to former Maplet

Reobservation: Updating Preaggregation

Starting new Maplet

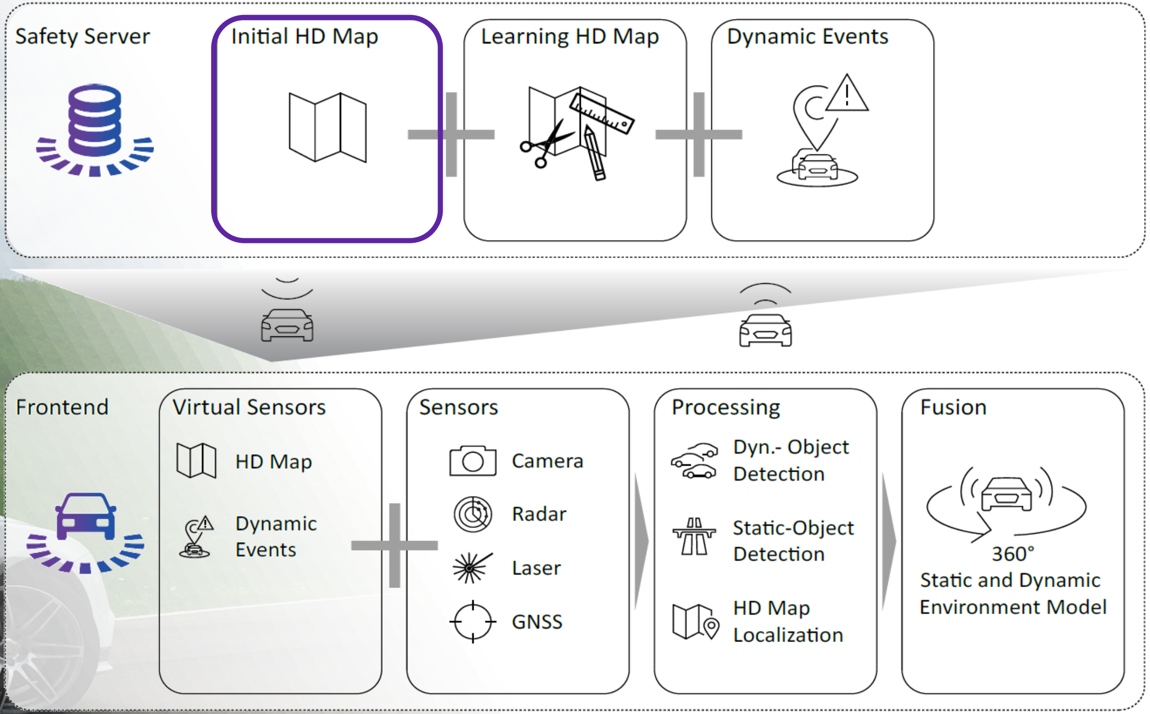
Appending to former maplet ...
Appending to former maplet ...
Reflector post with ID 1 is already within maplet!
Reflector post with ID 2 is already within maplet!
Adding reflector post with ID 3 to maplet!
Landmark offset to virtual reference point ...
Appending to former maplet ...
Appending to former maplet ...
Current maplet frenet delta 3.13643
Current maplet frenet length 41.1591
Appending to former maplet ...
Reflector post with ID 1 is already within maplet!
Appending to former maplet ...
Appending to former maplet ...
Current maplet frenet delta 3.13163
Current maplet frenet length 44.2907
Appending to former maplet ...
Reflector post with ID 1 is already within maplet!
Appending to former maplet ...
Appending to former maplet ...
Reflector post with ID 1 is already within maplet!
Appending to former maplet ...
Current maplet frenet delta 3.12699
Current maplet frenet length 47.4177
Appending to former maplet ...
Reflector post with ID 1 is already within maplet!
Appending to former maplet ...
Reflector post with ID 1 is already within maplet!
Appending to former maplet ...
Reflector post with ID 1 is already within maplet!
Appending to former maplet ...
Current maplet frenet delta 3.12227
Current maplet frenet length 50.54
Starting new maplet ...
Adding reflector post with ID 1 to maplet!
Adding reflector post with ID 2 to maplet!

Frontend Sensor Data Upload

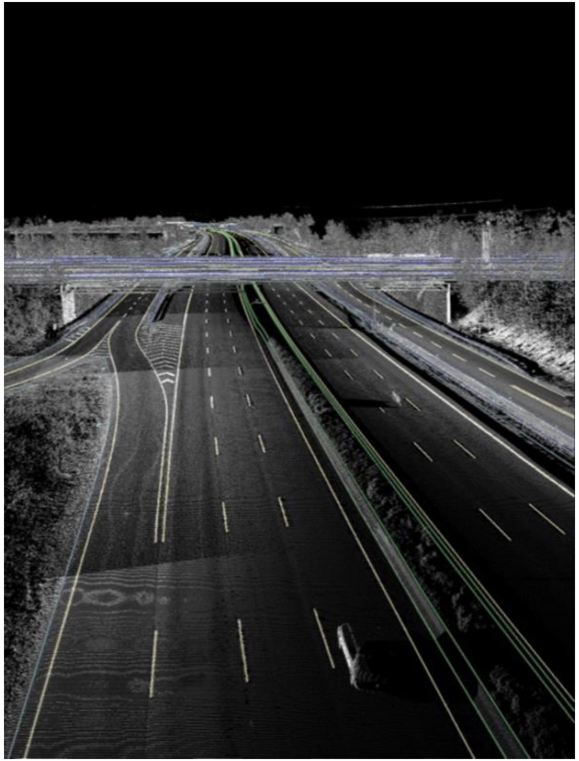


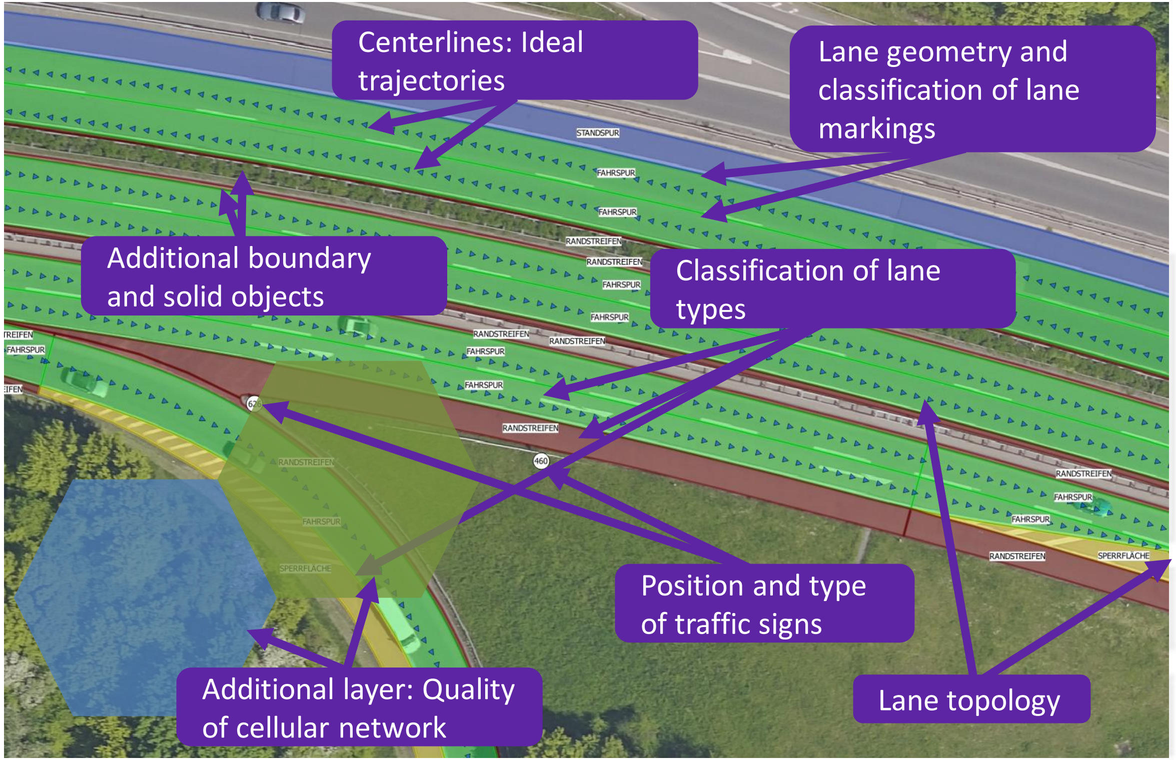
Safety Server — Continuous Update of HD Map

Safety Server Initial HD Map

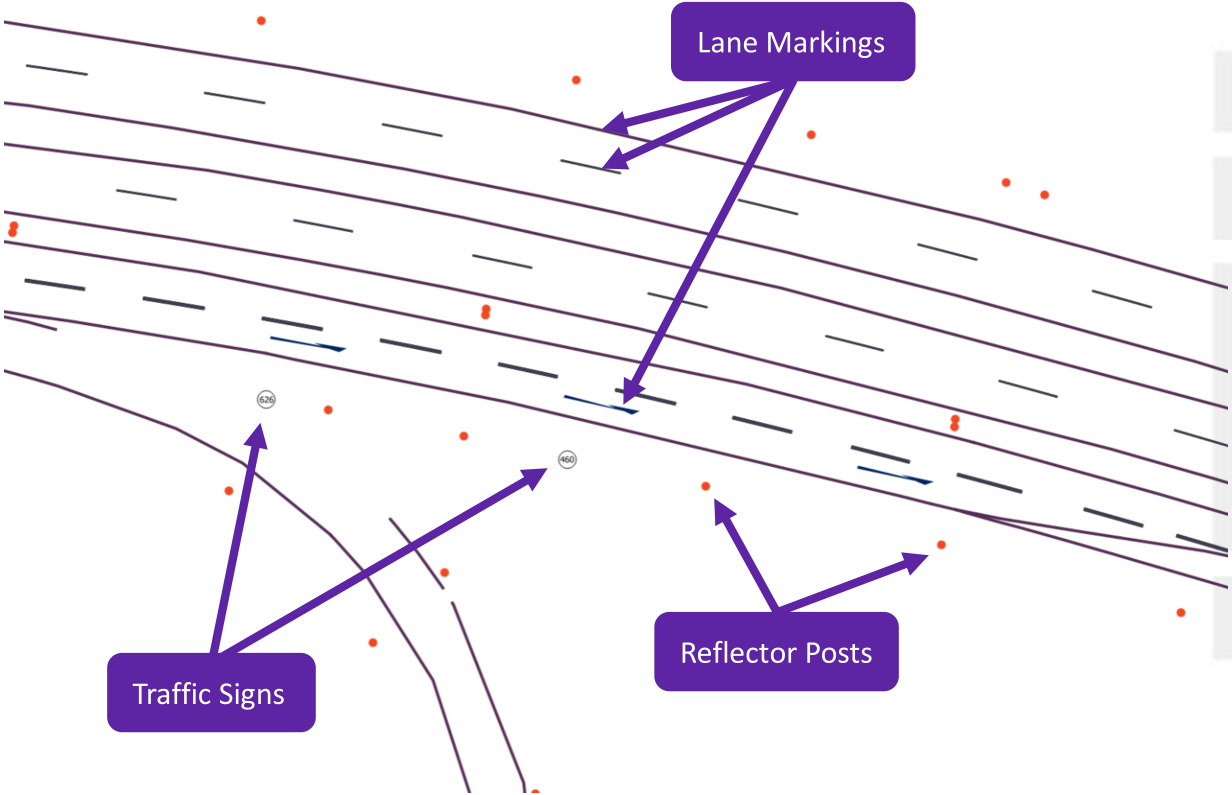


Safety Server Initial HD Map

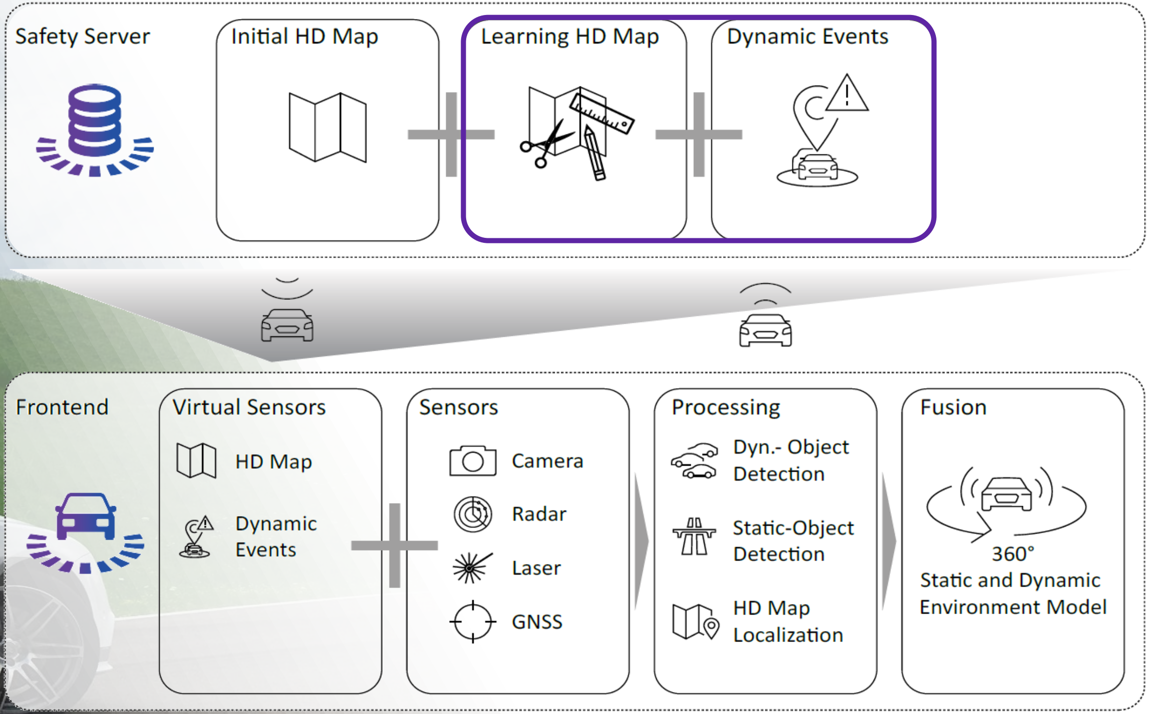




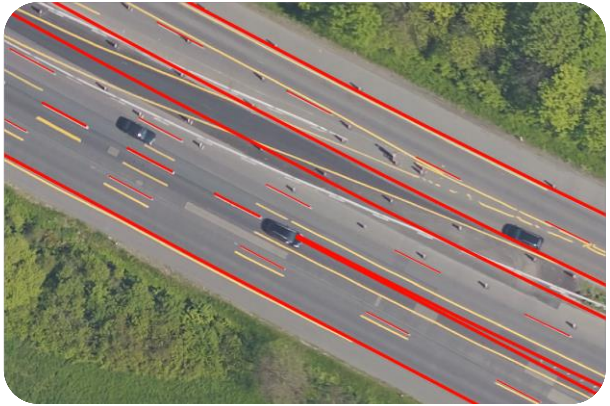
Safety Server Initial HD Map: Landmarks

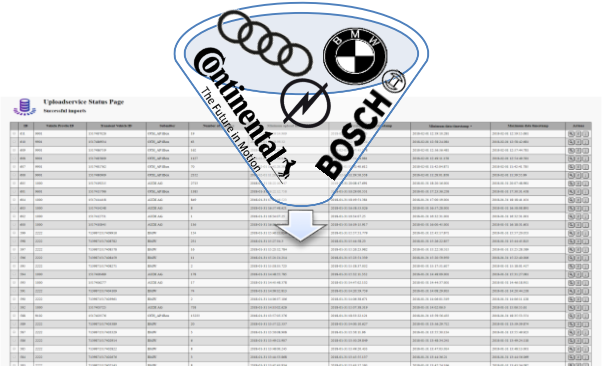


Safety Server Continuous Update of HD Map



Safety Server HD Map Change Detection



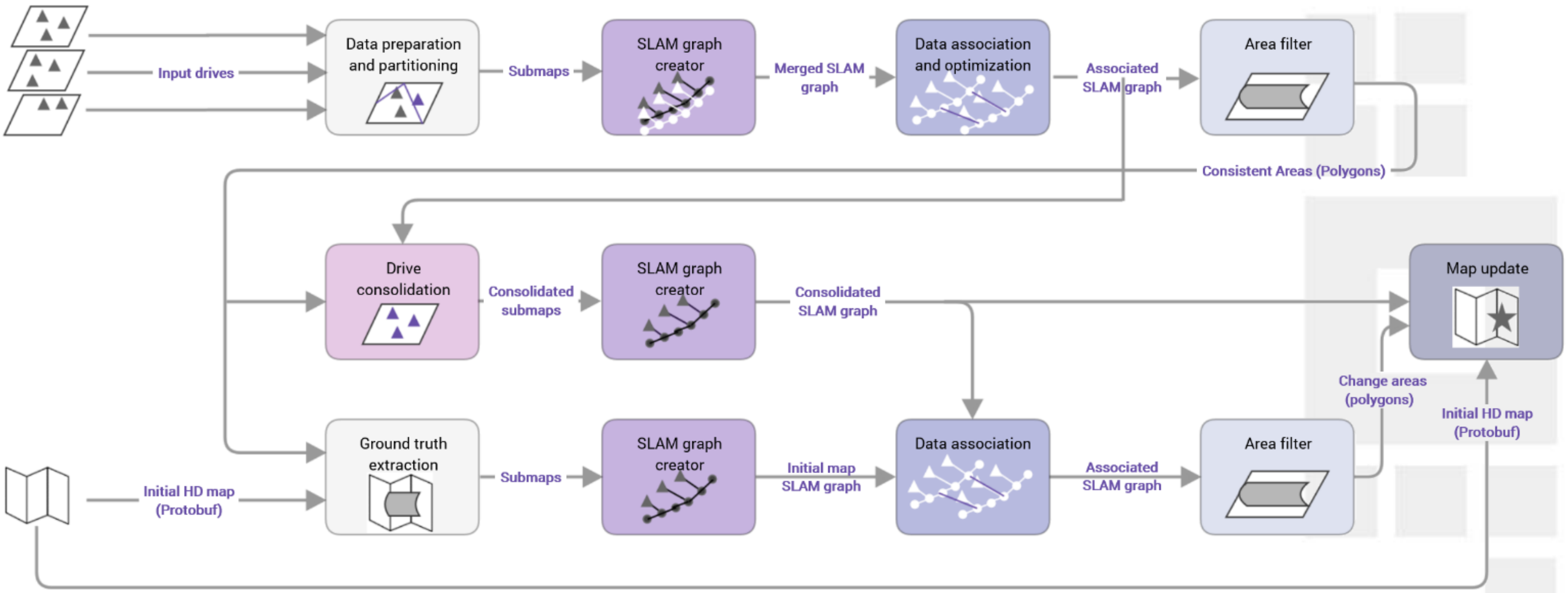


> **Maps become outdated due to road network changes**, such as construction sites, new lanes, lane marking changes, new/removed/ changed traffic signs

> **Modern vehicles** are equipped with **manifold sensors**

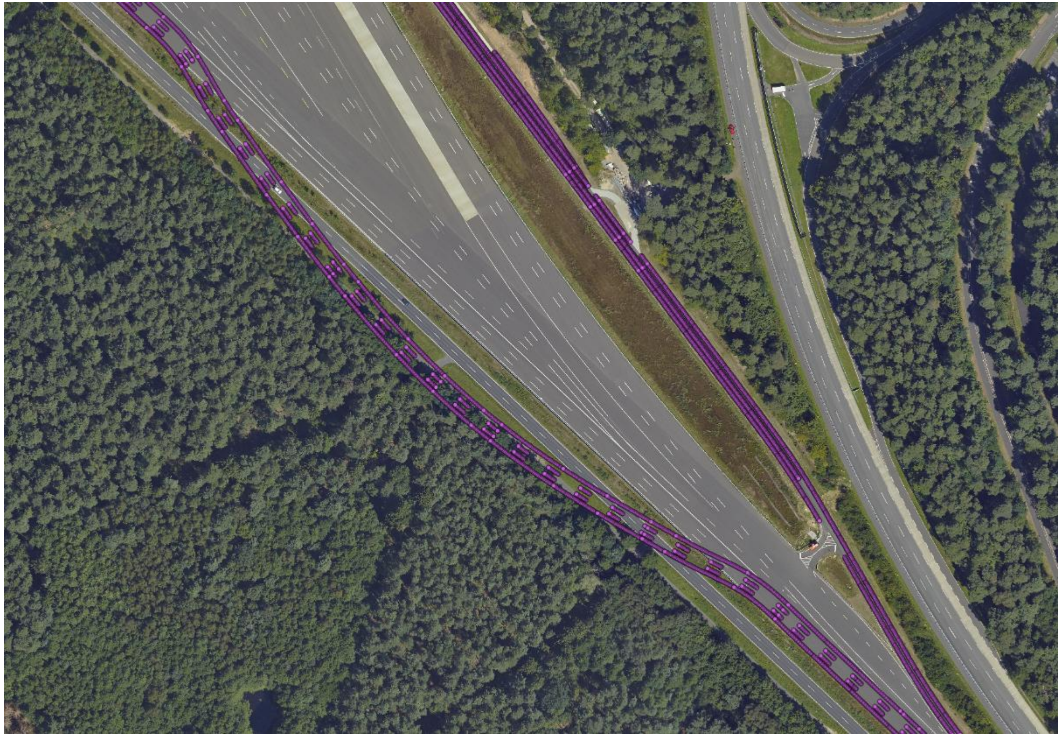
> The data from the vehicle fleet is propagated to the Safety Server and can be utilized for **change detection and** if required **for map updating**

Safety Server HD Map Update Pipeline



Safety Server

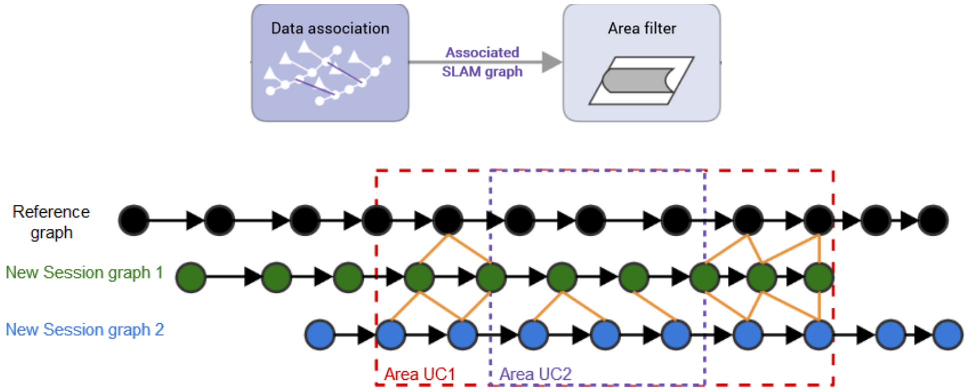
HD Map Update Pipeline
Case Study "Dudenhofen Detour"



- **Detour part on the straight (= geometry affected)**
- Same number of lanes (= topology not affected)
- **Lane markings shifted**
- As vehicles continue to drive straight, their **data should indicate a change of the road geometry**

Safety Server

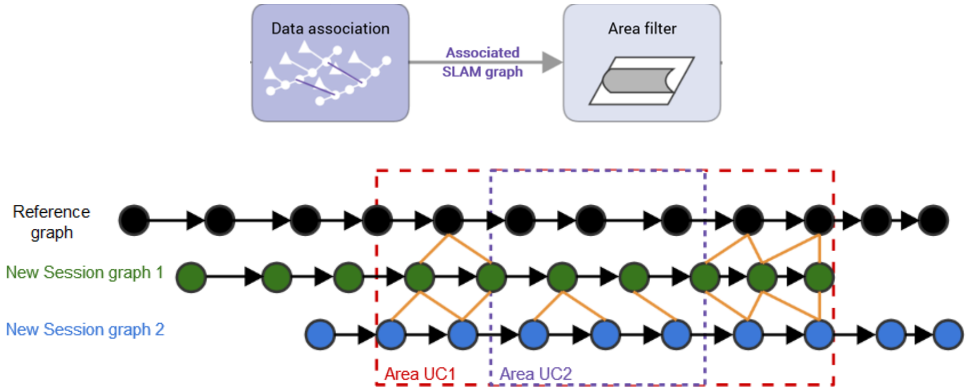
HD Map Update Pipeline Key Steps



The pipeline contains a number of preprocessing operations, such as

- > **Filtering** of fleet and map data
- > **Transformation** of fleet and map data **into mathematical models**
- > **Optimization of the data** based on observed features and models
- > **Change Detection**

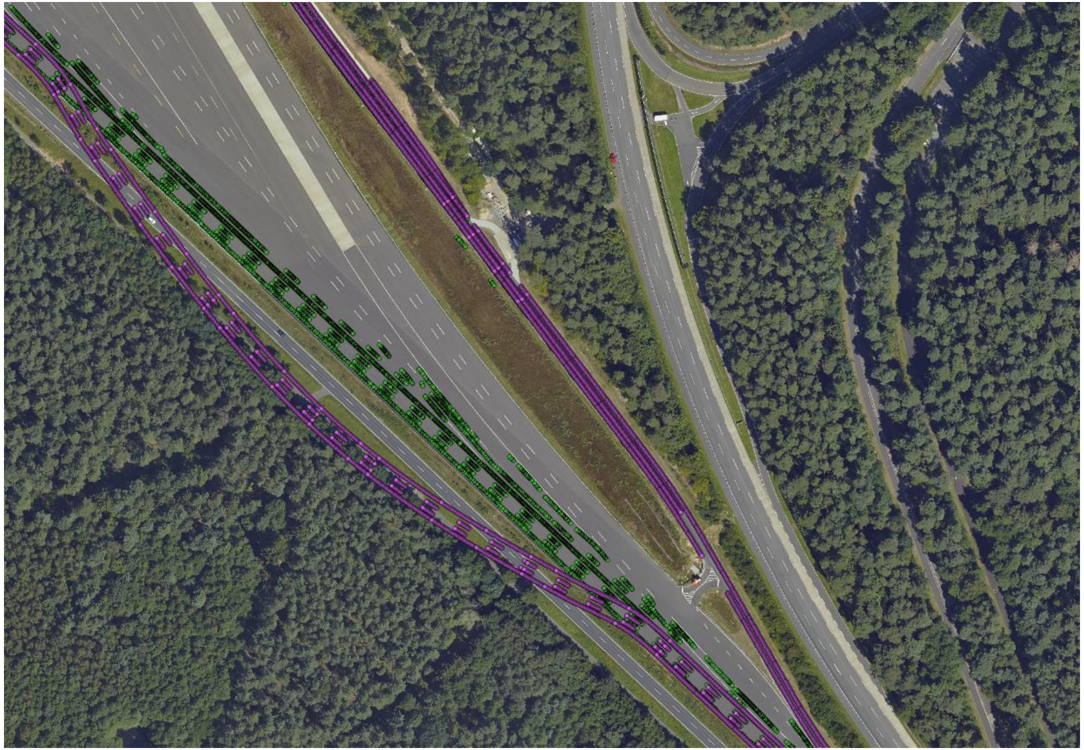
Safety Server HD Map Update Pipeline Key Steps



- The **change detection** mainly consists of the association of the initial HD map graph with the graph of the consolidated drives
- Assumption: At by change **affected areas**, drives are consistent to each other and **inconsistent to the initial HD Map**
- These areas are **of special interest** as they **indicate** that the initial HD **map** is **outdated**

Safety Server

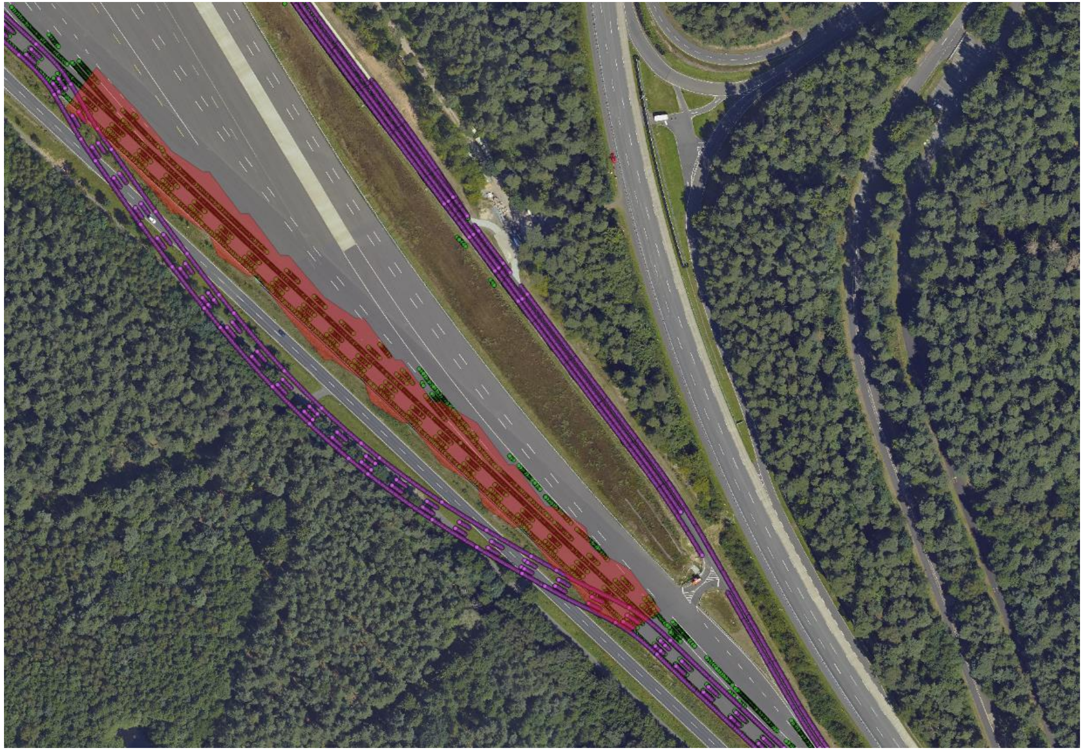
HD Map Update Pipeline Case Study „Dudenhofen Detour“



- At the HD map update pipeline, consistent parts of the fleet data are consolidated
- For each by change affected area, the consolidated drives are merged into the initial HD map

Safety Server

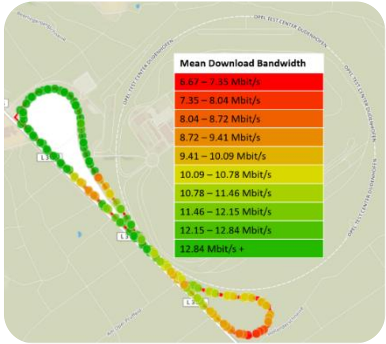
HD Map Update Pipeline Case Study „Dudenhofen Detour“

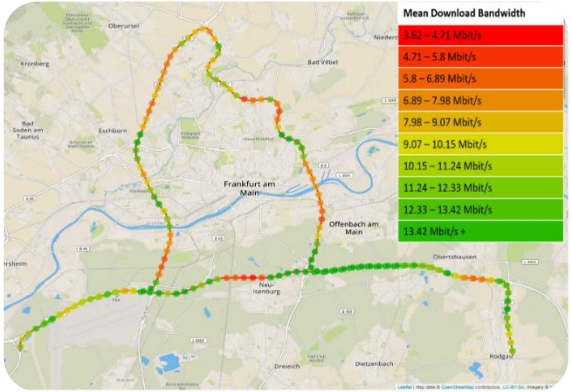


Change types evaluated at Ko-HAF

- Detours (changed geometry, same topology)
- Lane marking type changes
- Point-object type changes (reflector posts and traffic signs)

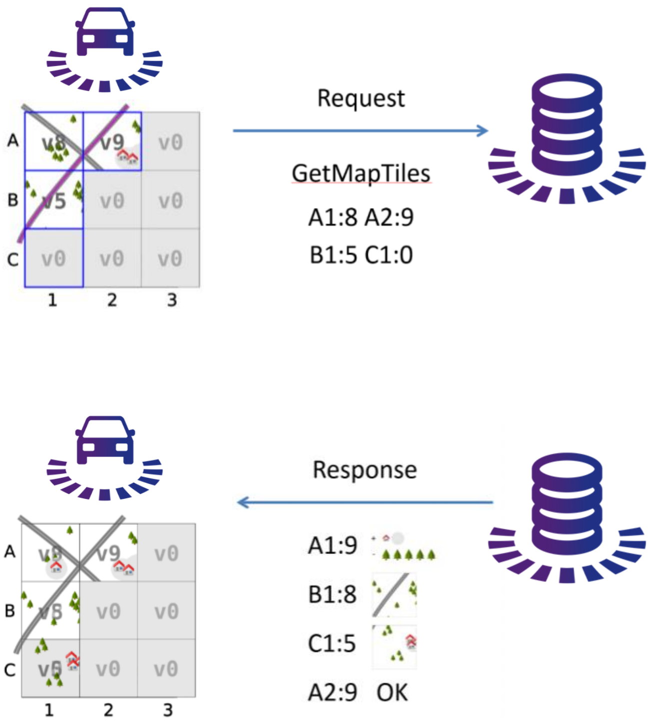
Safety Server HD Map Update Pipeline Additional Information Layers



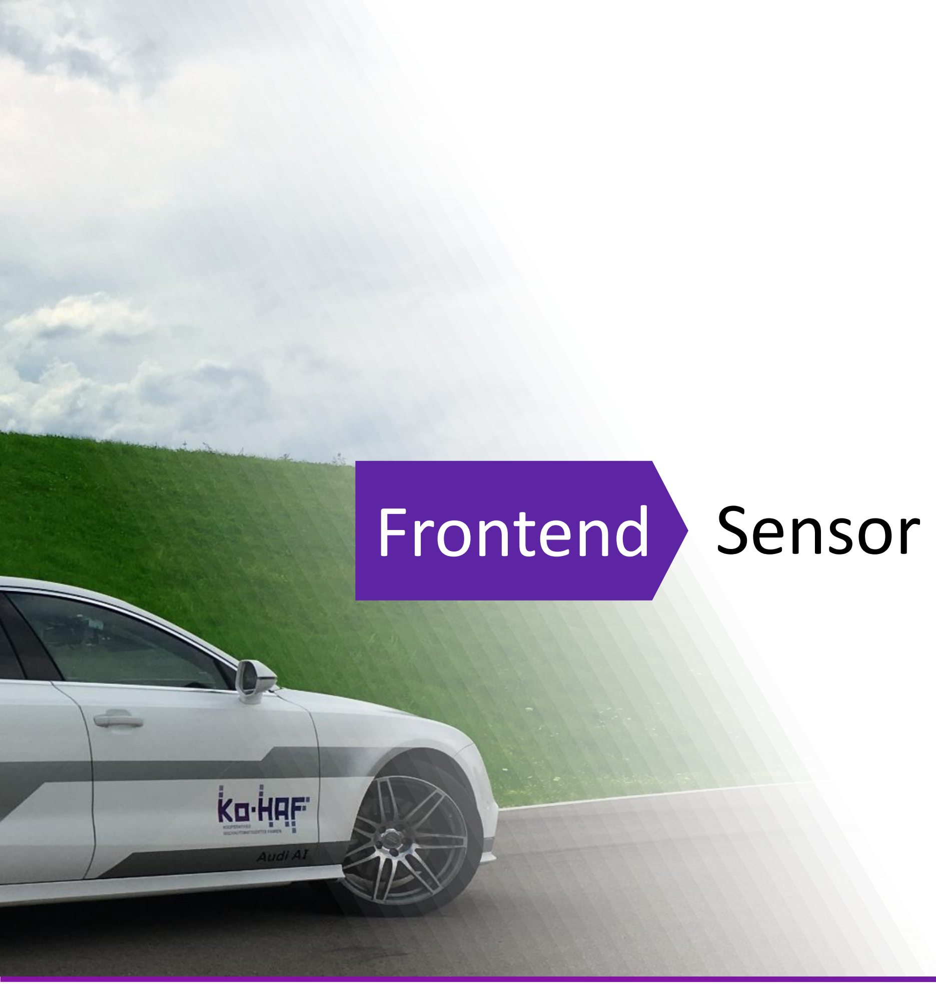


- Additionally to static road network features the vehicles also collect **information** about the **measured cellular network quality**
- The onboard communication module provides all necessary quality parameters
- Similar to the road network information, this data is also **aggregated at the Safety Server**
- The key performance indicators are:
  - **Data Throughput** (Upload and Download)
  - **Latency**

Safety Server Frontend Download Interface

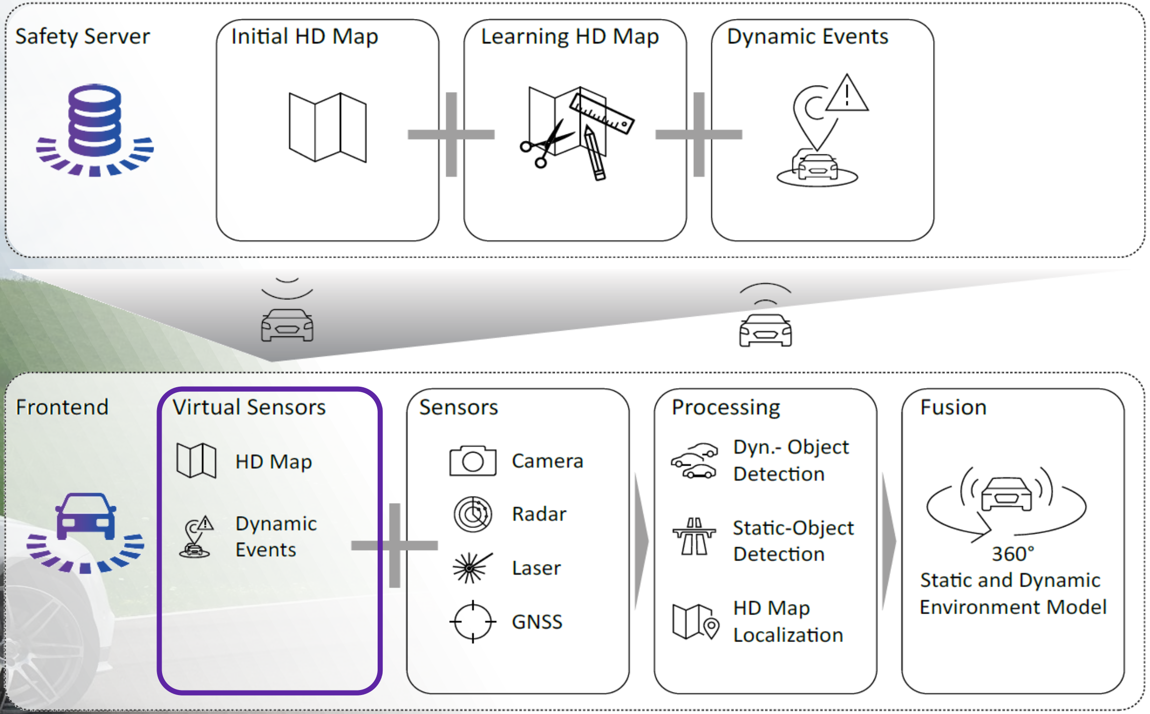


- > **Safety Server stores the HD map tile-based** and offers their **download** to the vehicles **on demand**
- > Vehicles inform the Safety Server which version of a tile they already have cached
- > **Only newer tiles are distributed** to the vehicles
- > **Safety Server allows the vehicles to subscribes for dynamic events**
- > Vehicles are informed regarding **potential hazard information**, such as obstacles, broken-down vehicles, or road closures

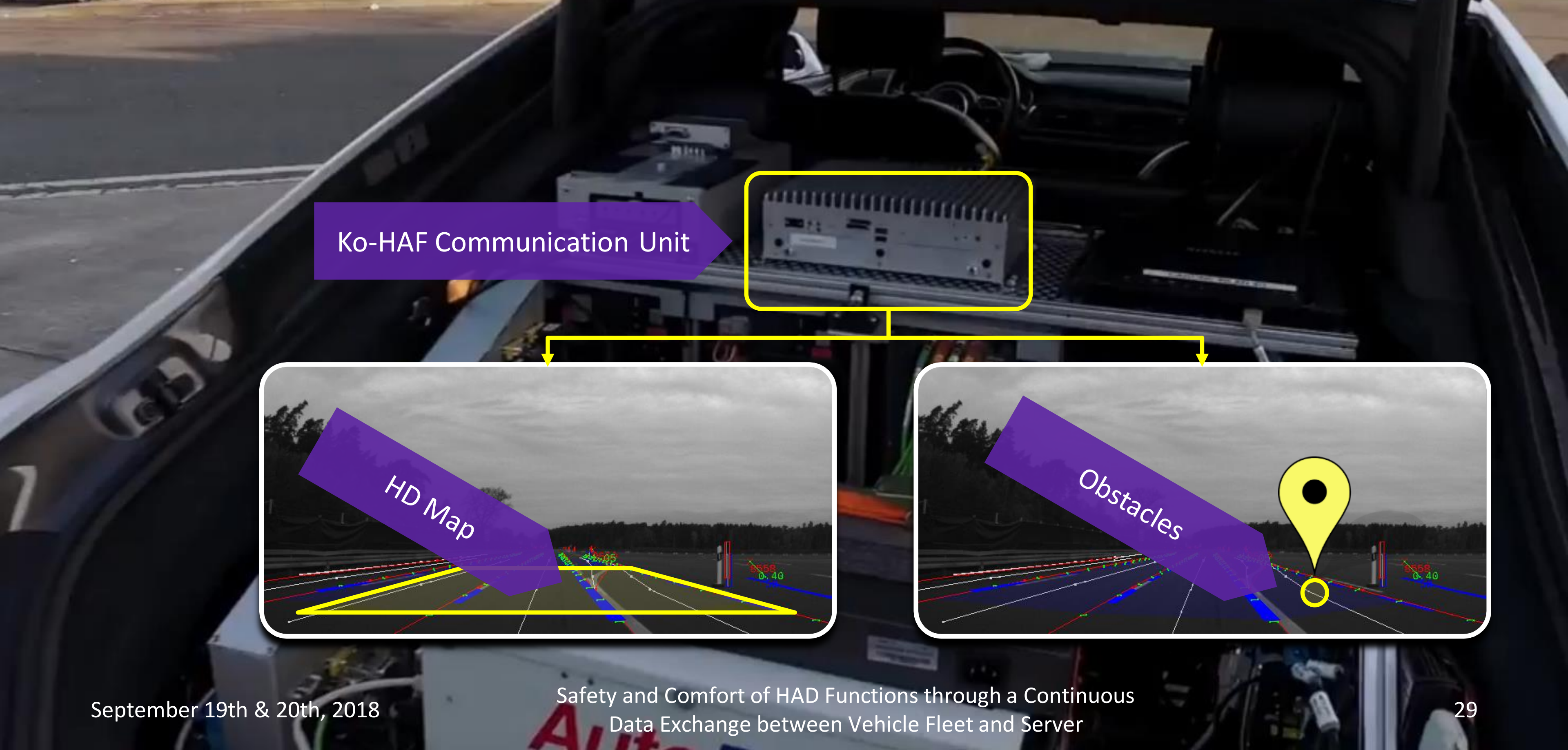


Frontend Sensor Data Download

Frontend Sensor Data Download

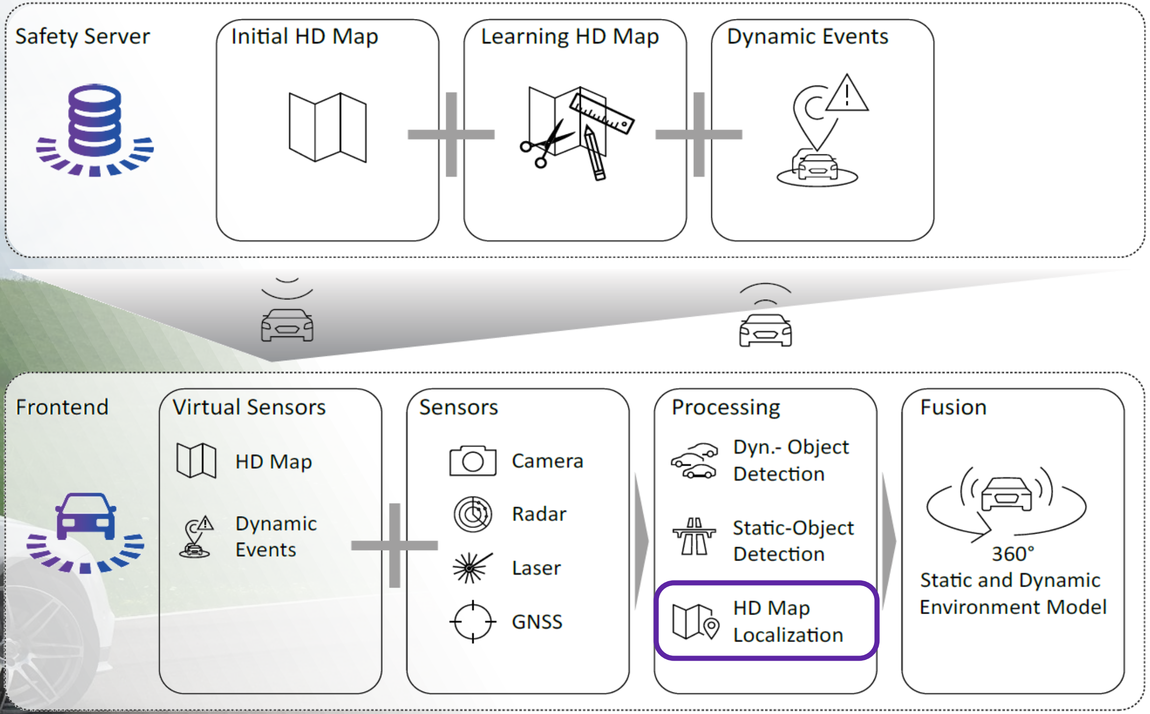


Frontend Sensor Data Download

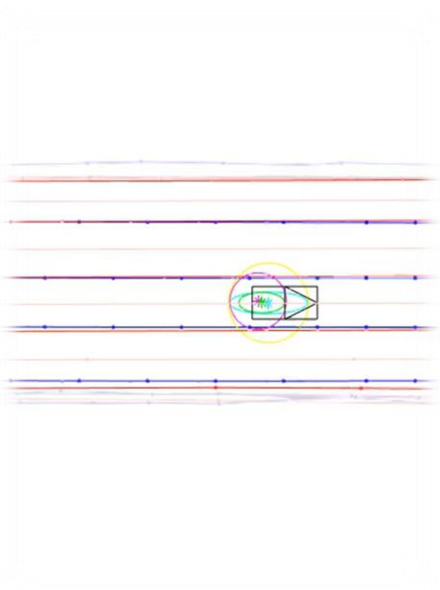


Frontend HD Map Localization

Frontend HD Map Localization



Frontend HD Map Localization



GNSS Localization

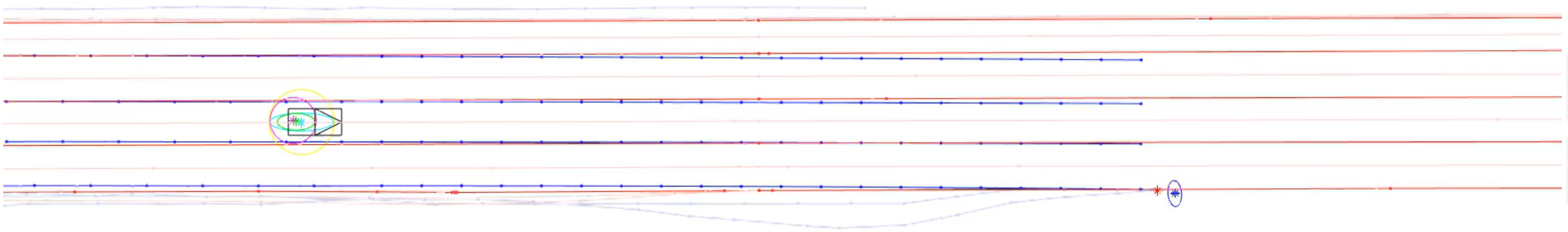
HD Map Localization

Motivation:
Improving the GNSS-localization by means of HD Map data

Input:
GNSS, IMU, Odometry, Landmarks from Sensors, Landmarks from HD Map

Output:
Improved global and relative position

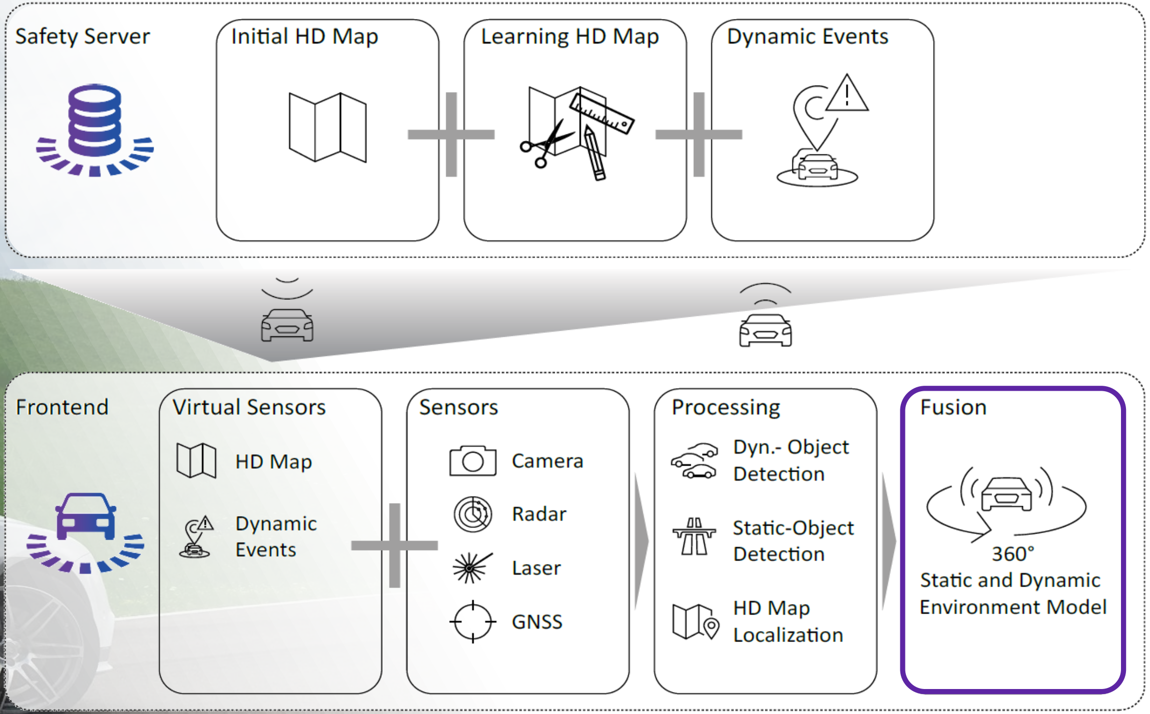
Frontend HD Map Localization



Landmarks HD Map | Landmarks Sensors | Pure GNSS Localization | HD Map Localization

Frontend Static Environment Fusion

Frontend Static Environment Fusion



Frontend Static Environment Fusion

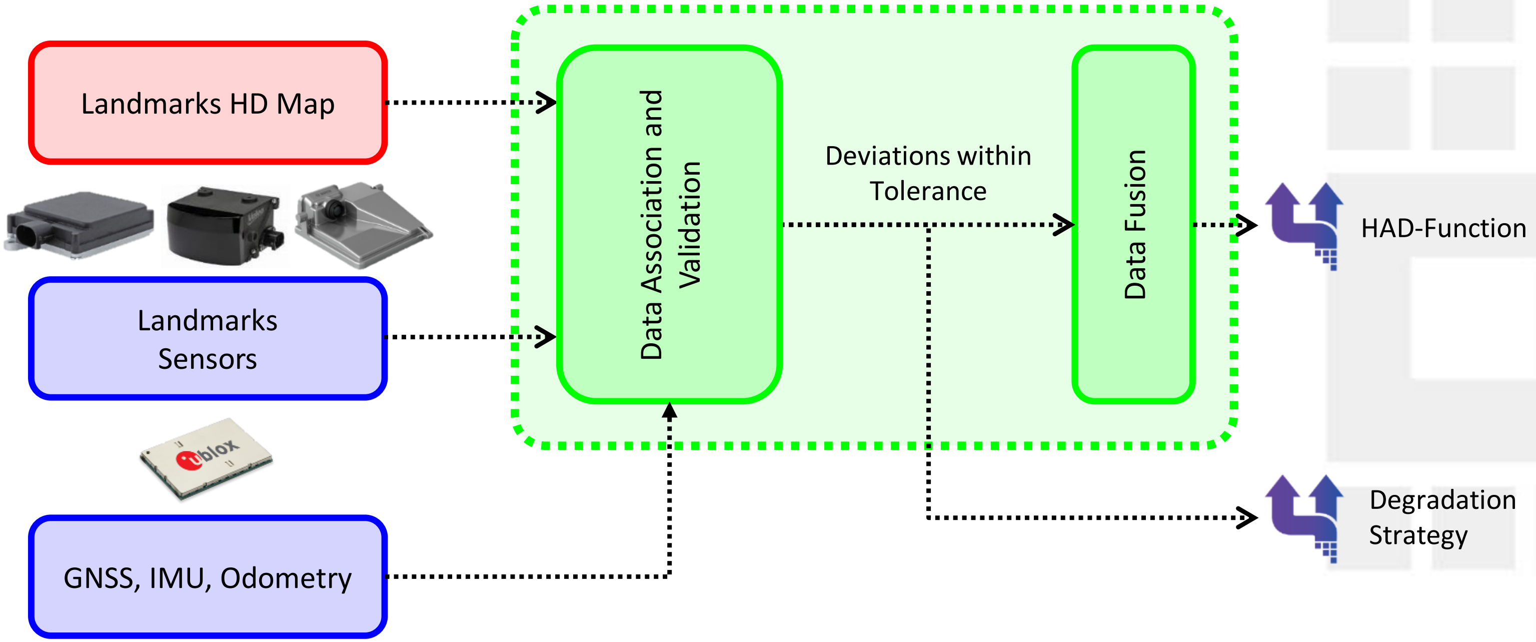
Landmarks HD Map

Landmarks Sensors

+ Additional Sensor Redundancy
+ Increased Sensoric Foresight

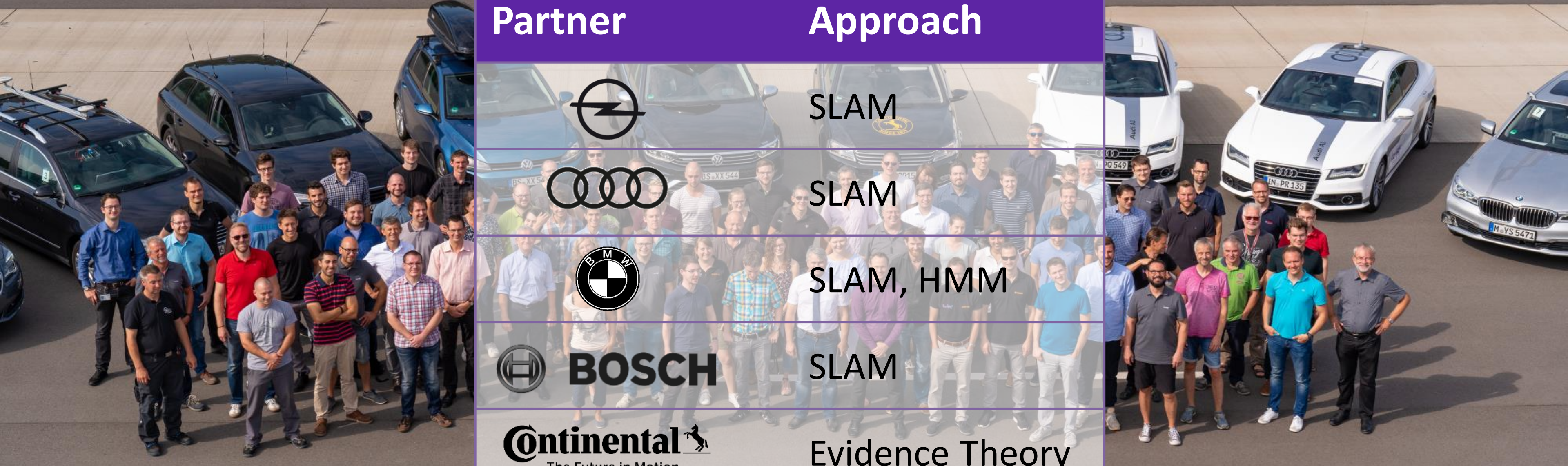
Frontend Static Environment Fusion

One common cross-partner concept …



Frontend Static Environment Fusion

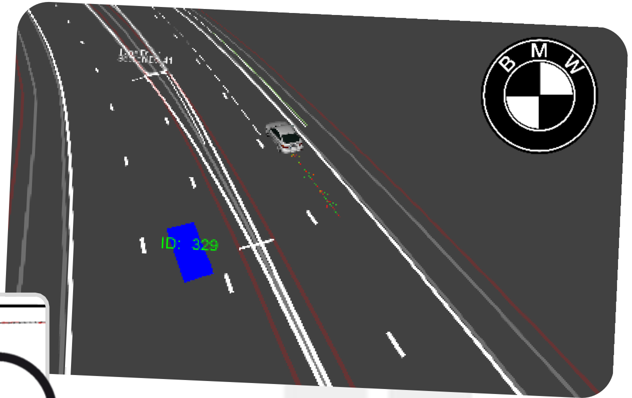
… distinct partner-individual realizations

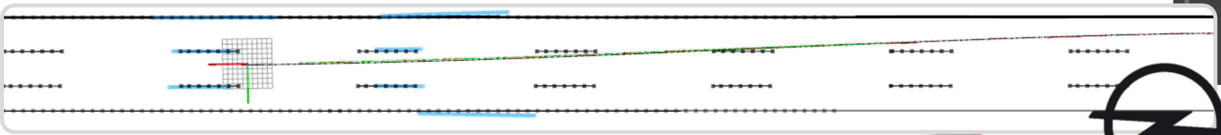


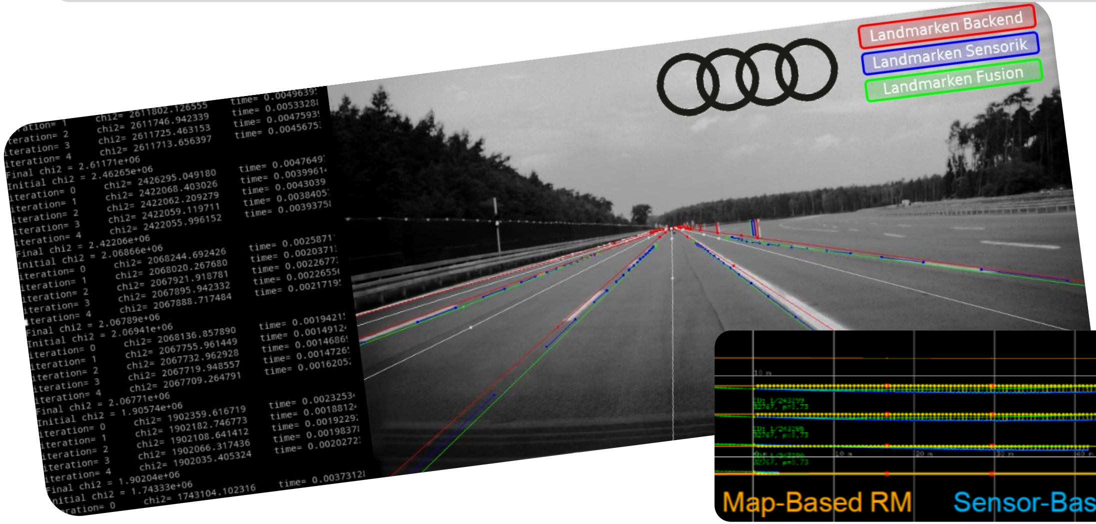
Partner	Approach
	SLAM
	SLAM
BMW	SLAM, HMM
BOSCH	SLAM
Continental The Future in Motion	Evidence Theory

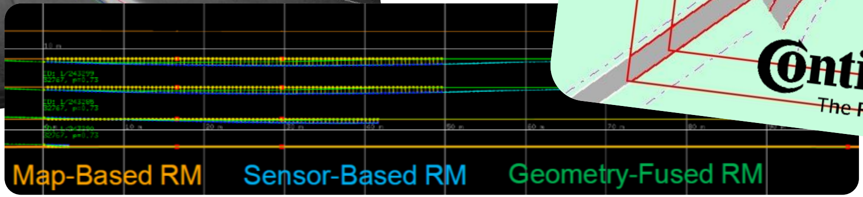
Frontend Static Environment Fusion

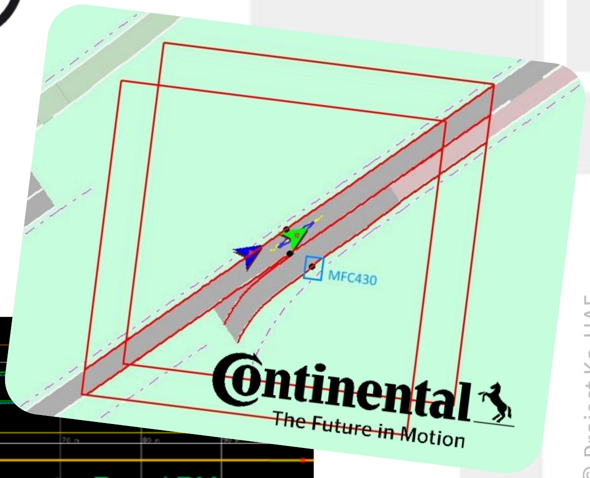
… distinct partner-individual realizations





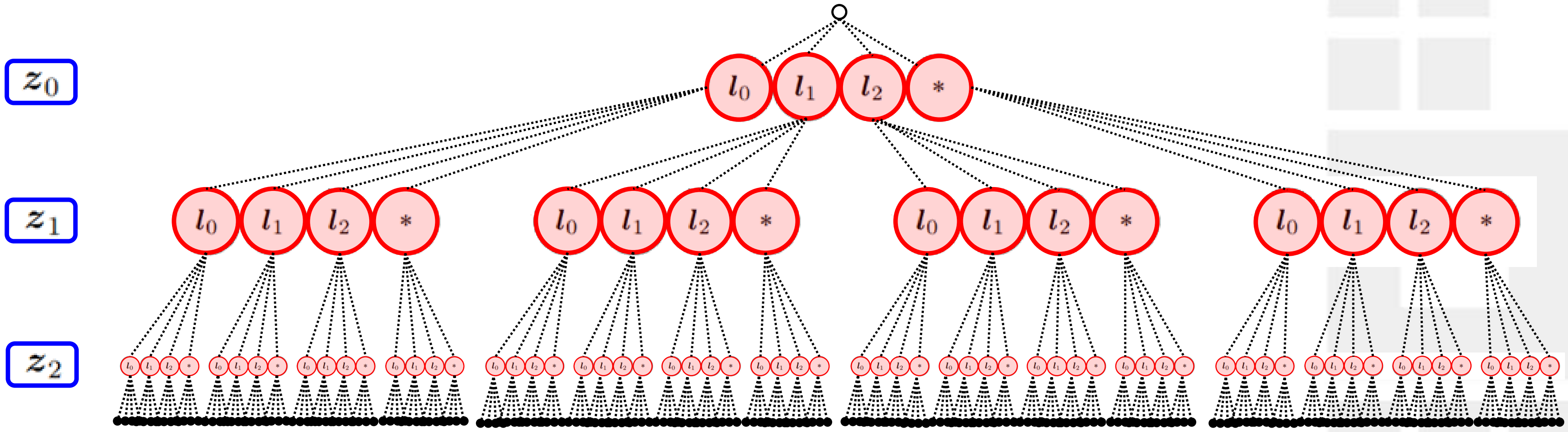






Frontend Static Environment Fusion

Optimal data association is a hard problem due to its exponential nature …

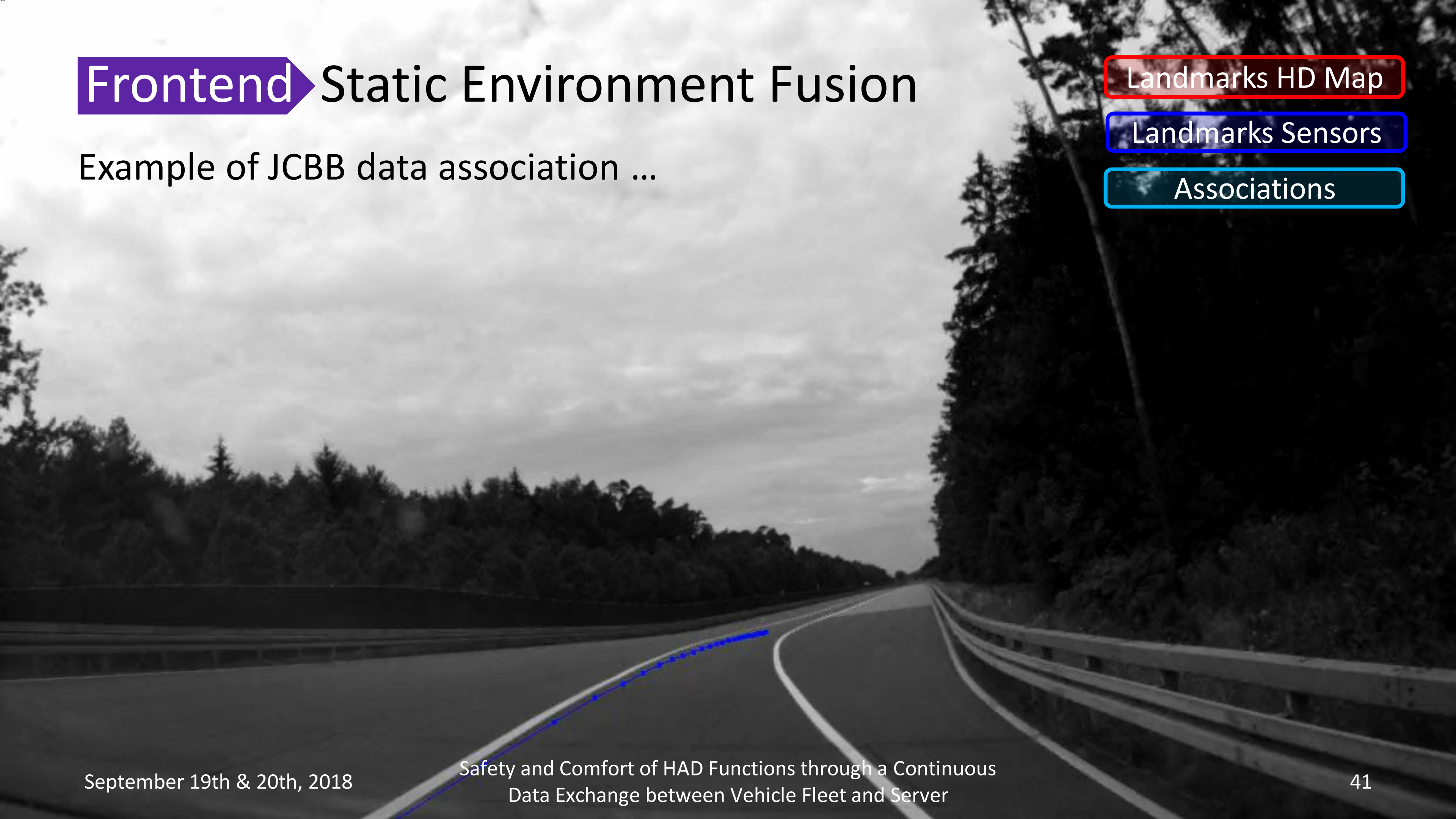


Landmarks HD Map

Landmarks Sensors

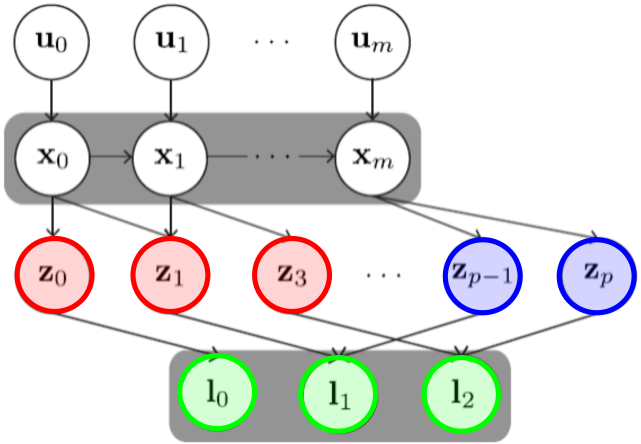
Frontend Static Environment Fusion

Example of JCBB data association …



Frontend Static Environment Fusion

Static environment fusion by means of Bundle-Adjustment based Full-SLAM



Input:

Motion Increments **u**, Landmark Observations from Sensors / HD Map **z** plus Associations

Output:

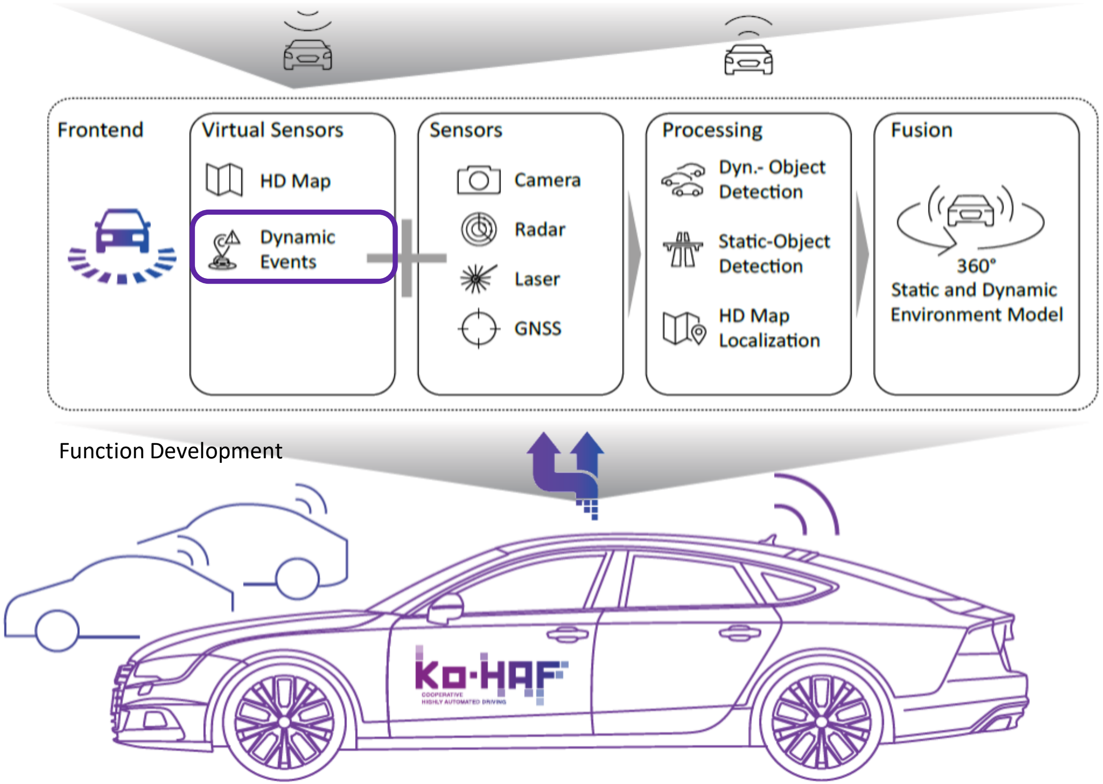
Landmark Estimates from Sensor Data Fusion **l**, Global and Relative Vehicle Localization **x**

Landmarks HD Map | Landmarks Sensors | Landmarks Fusion

Frontend Static Environment Fusion

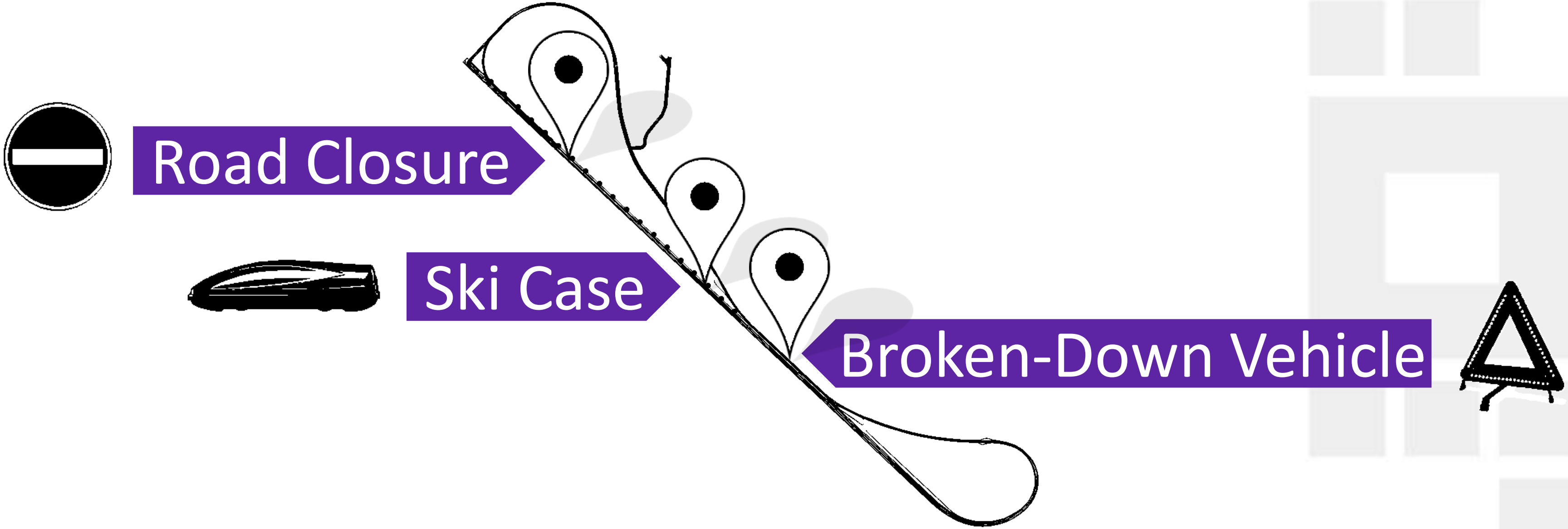
Big Loop Dynamic Events

Big Loop Dynamic Events



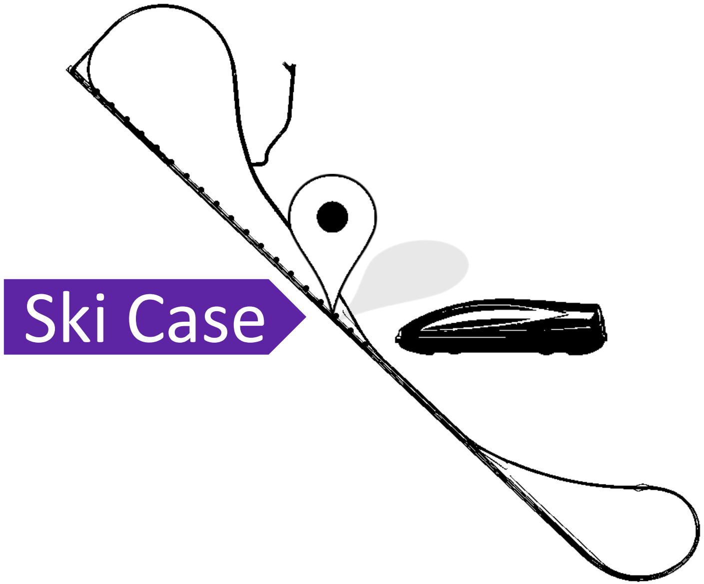
Big Loop Dynamic Events

Dynamic events considered by the Ko-HAF partners



Big Loop Dynamic Events

Dynamic Ski Case Observation Scenario

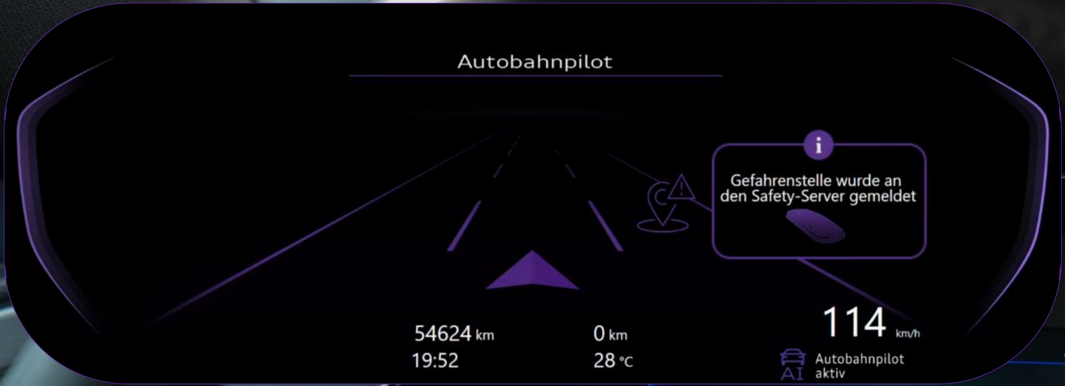


1. Upload of **lost ski case observation** to the backend-side
2. Propagation of the **hazard warning** by the backend-side to the subsequent vehicle
3. **Automatic lane change maneuver** by the cooperative HAD function

→ **Increased safety and comfort**

Big Loop Dynamic Events

Dynamic Ski Case Observation Scenario



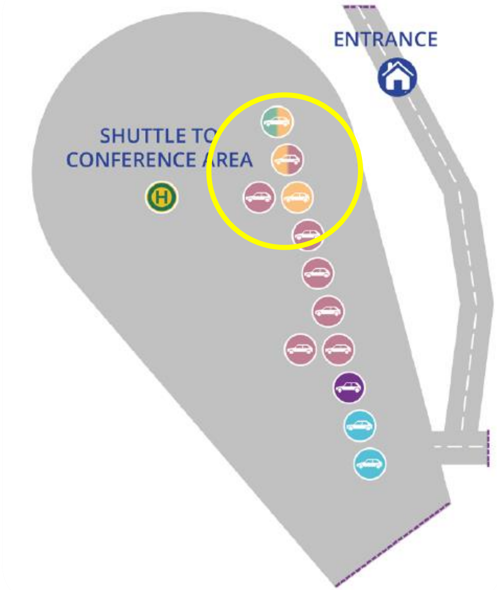
Big Loop Dynamic Events

Dynamic Ski Case Observation Scenario

Big Loop Related Demonstrations & Talks

Big Loop Related Demonstrations & Talks

Ko-HAF
KOOPERATIVES HOCHAUTOMATISIERTES FAHREN



Creation and Deployment of HD Map Data
Dr. Gunnar Gräfe, *3D Mapping GmbH*
Tobias Knerr, *University Passau – FORWISS*
Josef Schmid, *Technical University of Applied Sciences Amberg-Weiden*

Continuous Updating of Backend HD Map Data Based on Vehicle Fleet Data
Florian Jomrich, *Opel Automobile GmbH*
Dr. Lukas Klejnowski, *Robert Bosch GmbH*

Online Localization and Fusion via Vehicle Sensor and Backend HD Map Data
Maximilian Harr, *Opel Automobile GmbH*
Dr. Matthias Schreier, *Continental Teves AG & Co. oHG*

KOOPERATIVES
HOCHAUTOMATISIERTES FAHREN

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for your attention!

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aufgrund eines Beschlusses
des Deutschen Bundestages