

**Automated Vehicles
Controlled by Smart
Infrastructure –
the Architecture of
Managed Automated
Driving (MAD)**

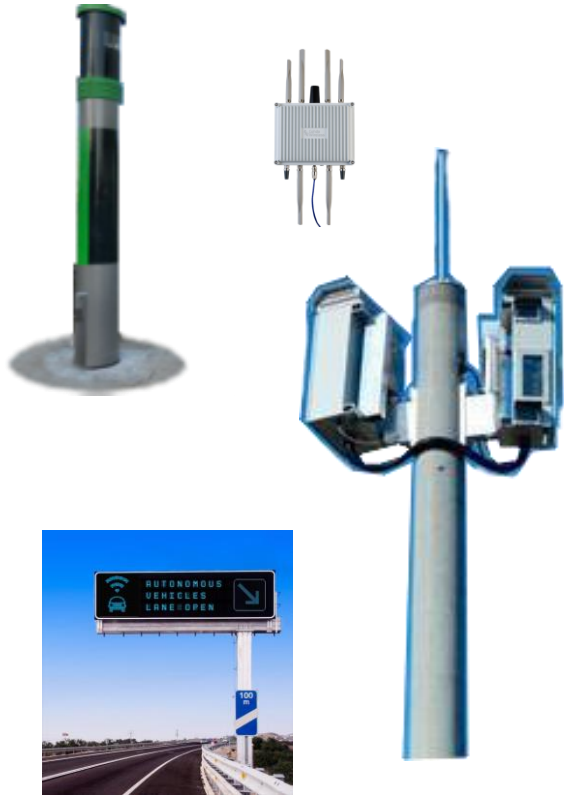
Julian Schindler

**C-ITS Development Manager
German Aerospace Center (DLR)
Germany**

DUBAI 2024

C-ITS Cooperation

Infrastructure



Act (*Prescriptive Cooperation, J3216 Class D, Managed Automated Driving*)

Maneuver command →

Trajectory command →

Vehicle control →

Plan/Think (*Intent-Sharing, J3216 Class B & Agreement Seeking, Class C*)

Maneuver Coordination ↔

Individual speed, lane, distance, etc. advice →

Phase negotiation, prioritization ↔

Sense (*Status-Sharing, J3216 Class A*)

Collective (Object) Perception ↔

Hazard Warning →

Additional Information (Road topology, speed limits, etc.) →

Vehicles on different automation levels



Organised by



Co-organised by



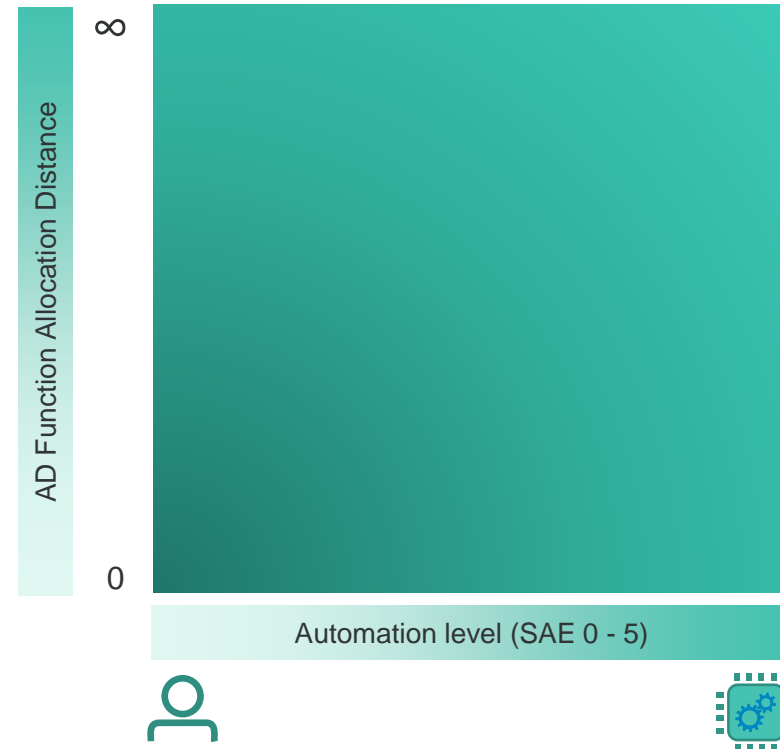
Hosted by



Supported by



From “who is in control”to “who is where in control”



Organised by



Co-organised by



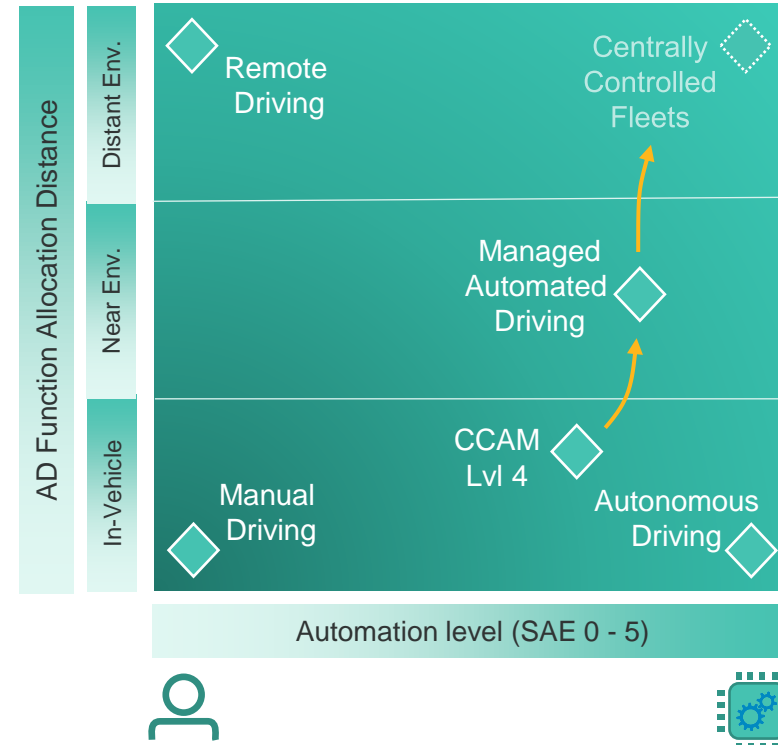
Hosted by



Supported by



From “who is in control”to “who is where in control”



Organised by



Co-organised by



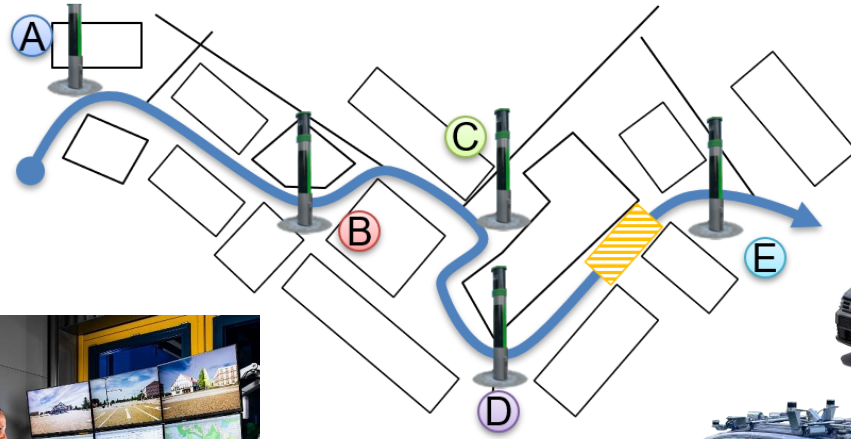
Hosted by



Supported by



Managed Automated Driving



Vision:
Level 4 automated driving with enhanced safety and low unit costs per vehicle, started on dedicated routes.
(Public transport and logistics)

German National Project



Goals:

- Definition of the MAD architecture and communication protocols
- Setting up example implementations at Testbed Lower Saxony and Testbed Autonomous Driving Baden-Württemberg
- Demonstration on public roads

Duration: 07/2022-06/2025

Partners:

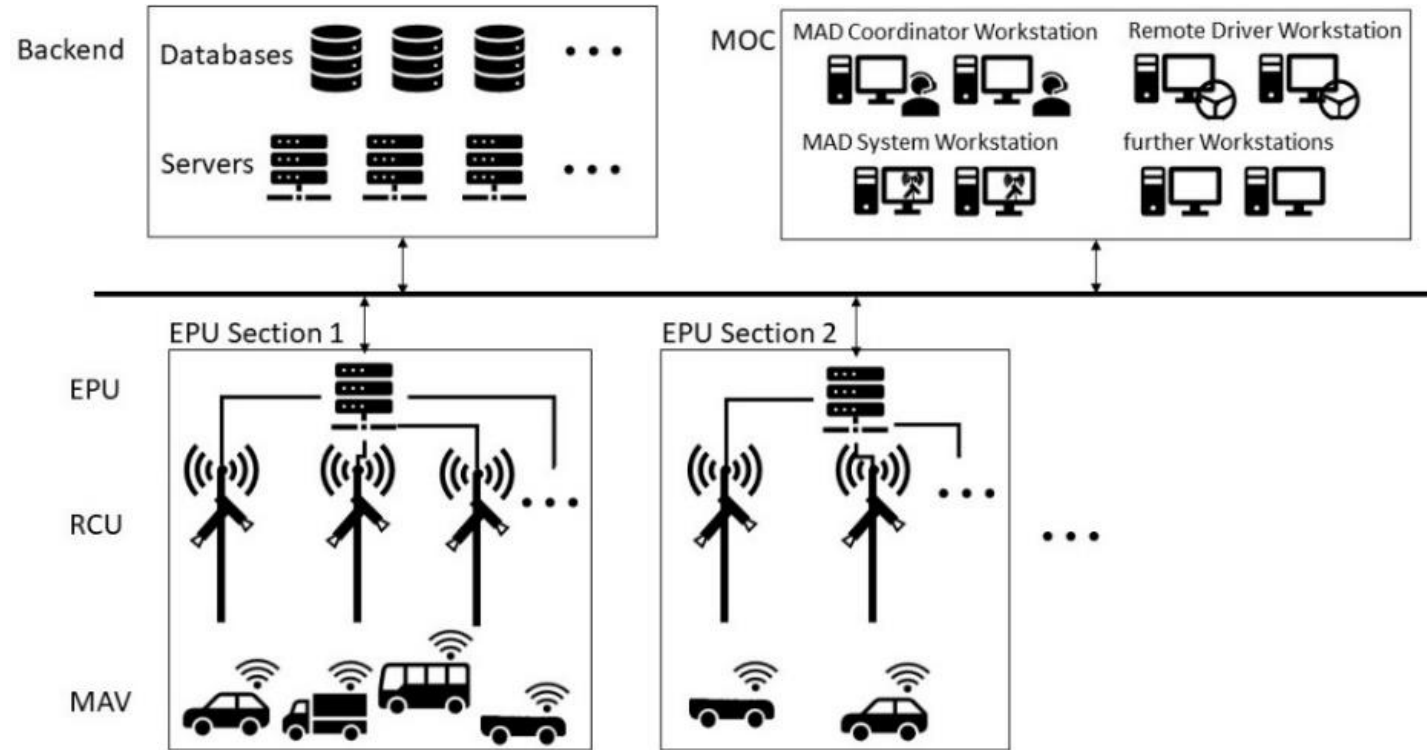







Funded by:  Bundesministerium für Wirtschaft und Klimaschutz

Architecture Overview



Organised by



Co-organised by



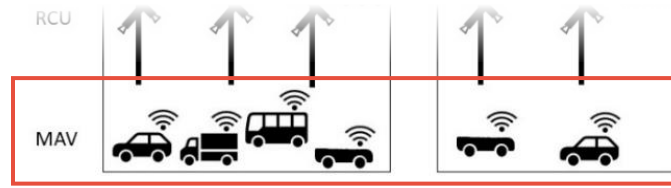
Hosted by



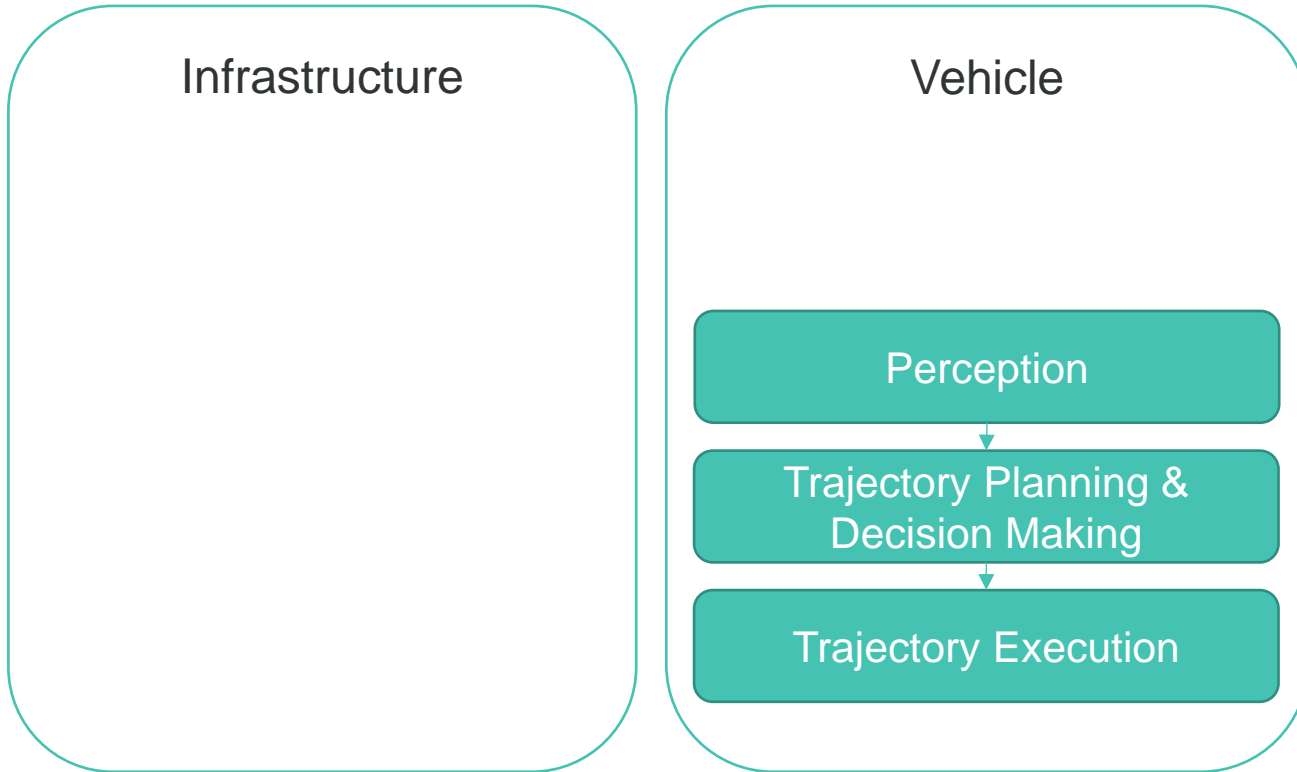
Supported by



The vehicles



Automated Vehicle



Organised by



Co-organised by



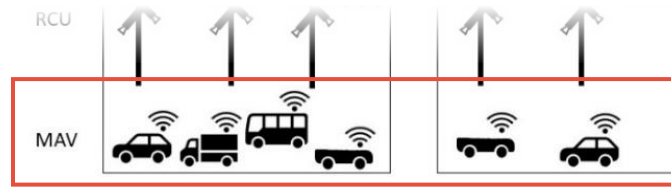
Hosted by



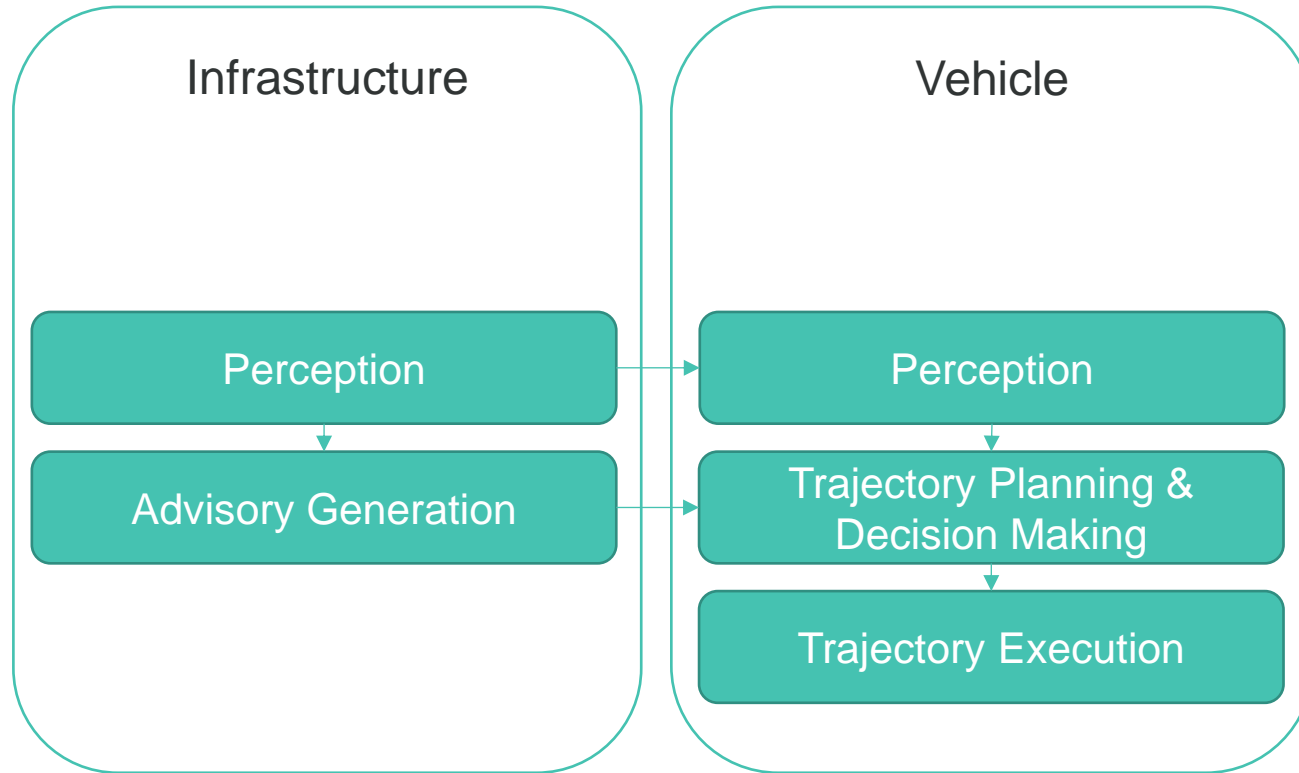
Supported by



The vehicles



Automated Vehicle Connected Automated Vehicle



Organised by



Co-organised by



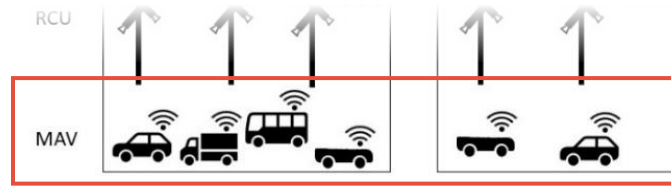
Hosted by



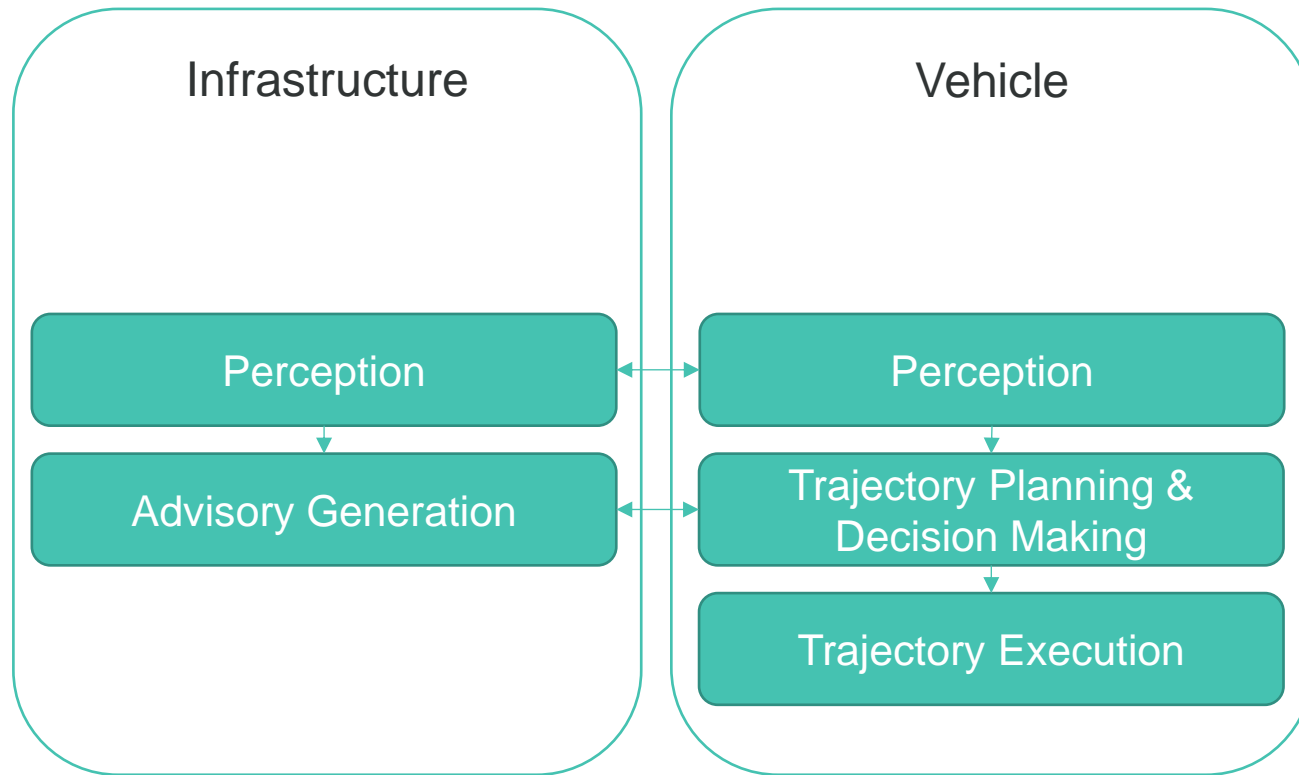
Supported by



The vehicles



Automated Vehicle
Connected Automated Vehicle
Cooperative Automated Vehicle



Organised by



Co-organised by



Hosted by

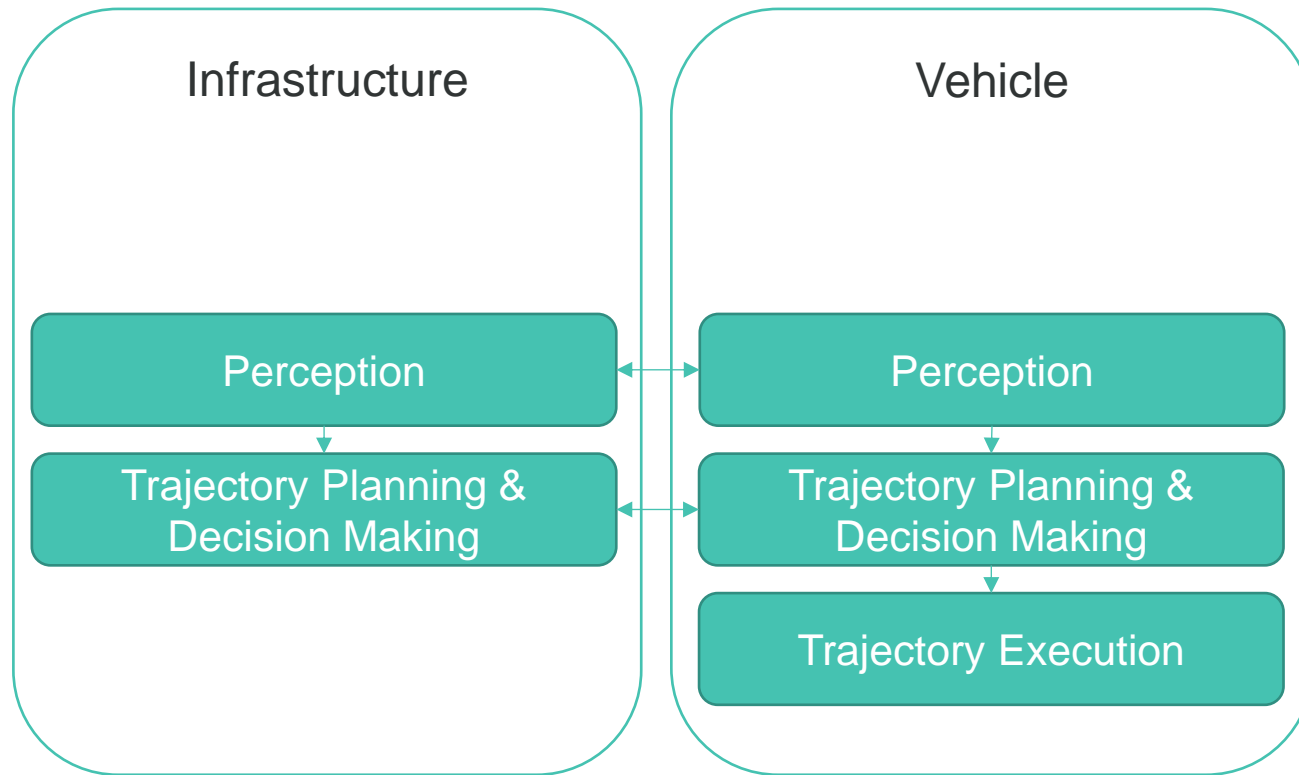
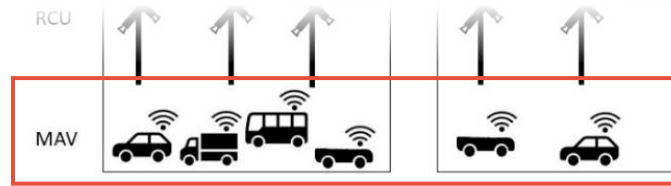


Supported by



The vehicles

- Automated Vehicle
- Connected Automated Vehicle
- Cooperative Automated Vehicle
- Managed Automated Vehicle (Research)**



Organised by



Co-organised by



Hosted by

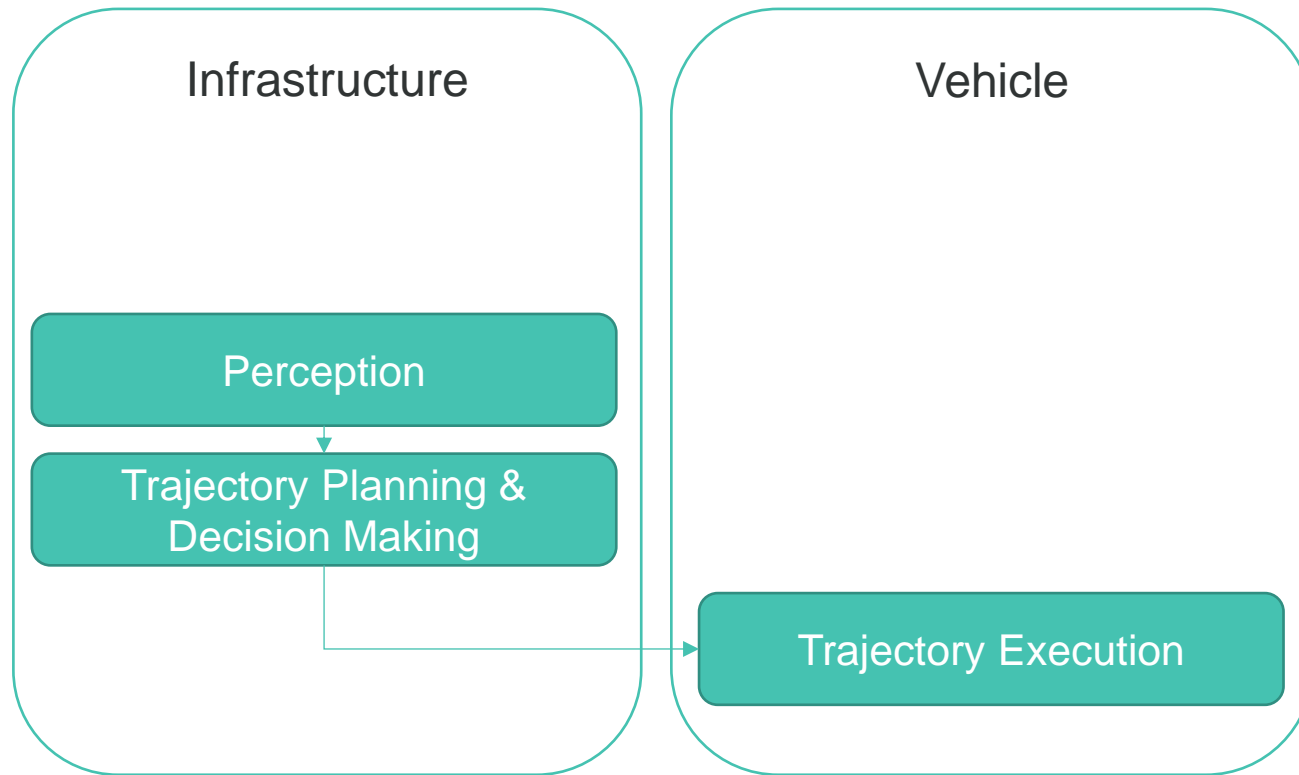
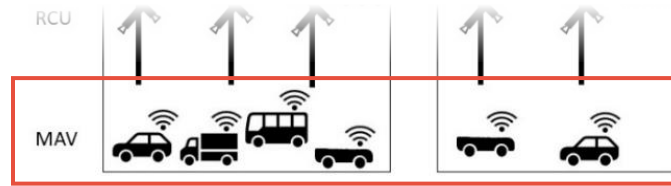


Supported by



The vehicles

- Automated Vehicle
- Connected Automated Vehicle
- Cooperative Automated Vehicle
- Managed Automated Vehicle (Research + Full)**



Organised by



Co-organised by



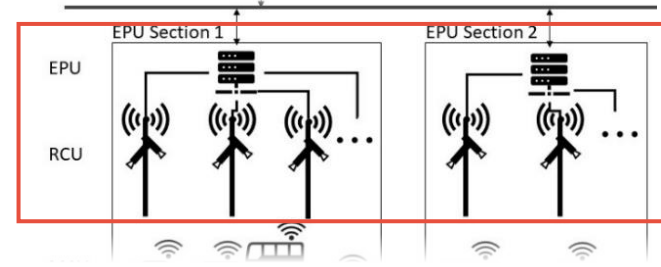
Hosted by



Supported by



The local infrastructure



Edge Processing Units (EPU)



Components

- Computer cluster
- Network components

Tasks

- High level sensor fusion of attached RCUs
- Overall situation assessment
- Behaviour calculation for all managed entities
- Backend communication

Road Capturing Units (RCU)



Components

- Sensors tailored to the requirements at the specific location, e.g. 4D LIDARs, RADARs, (Stereo-) Cameras
- Communication hardware (e.g. V2X-RSU) where required

Tasks

- Detection of objects
- Optionally: pre-calculations, low level sensor fusion
- Local communication

Organised by



Co-organised by



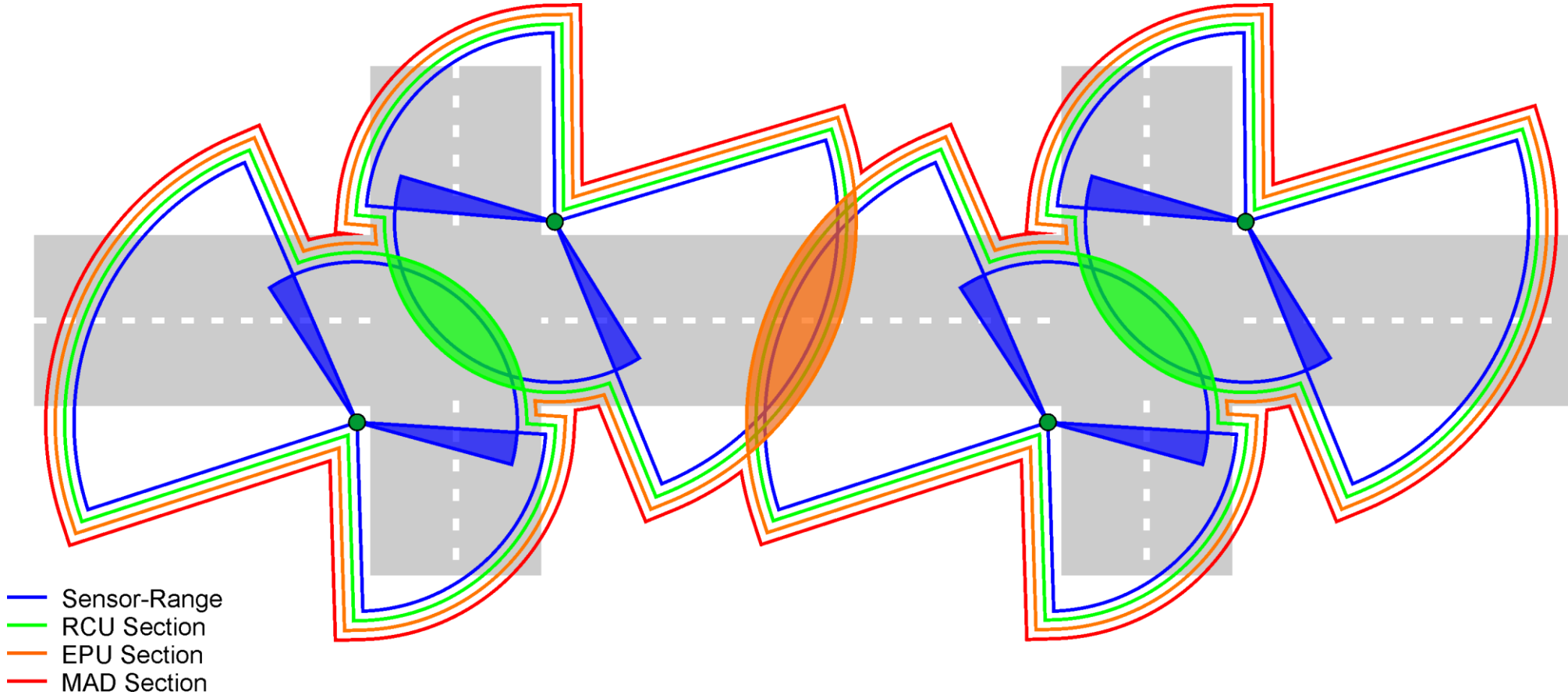
Hosted by



Supported by



Topological mapping of infrastructure components



Organised by



Co-organised by



Hosted by

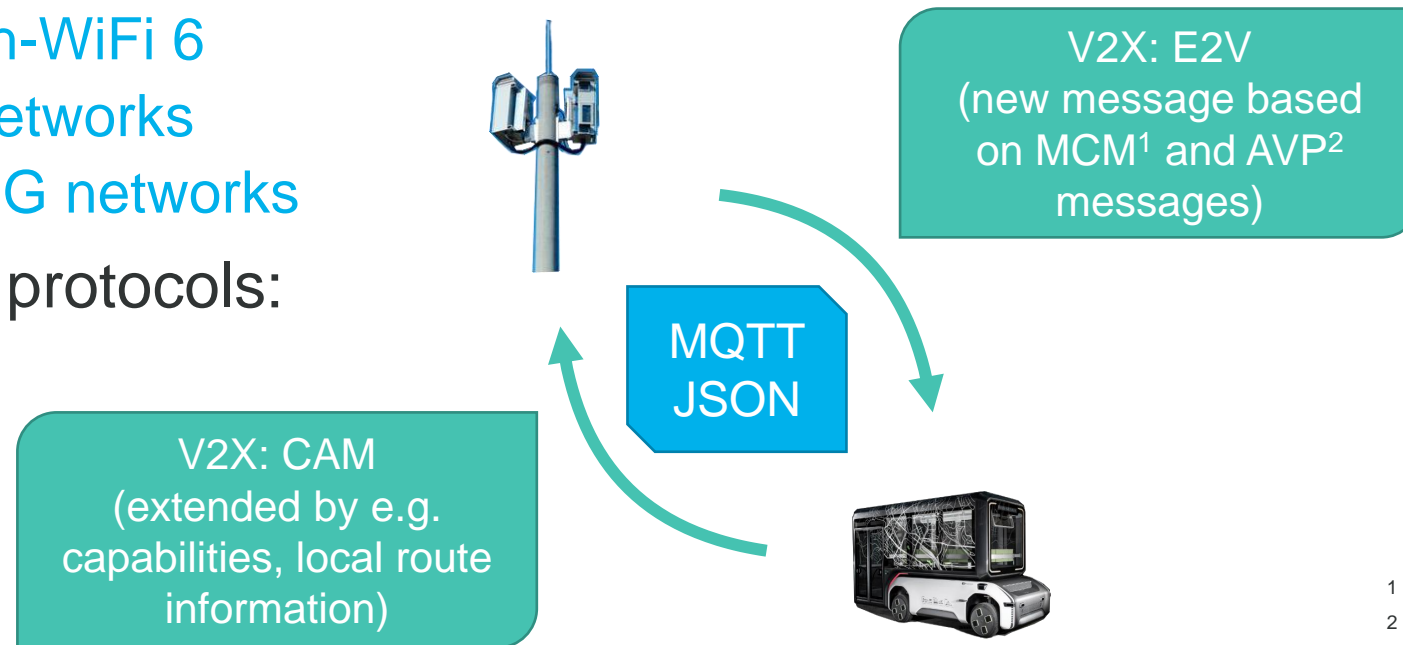


Supported by



Communication

- Goal: Redundant communication using standardized messages
- Current approach: Concurrent testing of different communication channels
 - ITS-G5 V2X / DSRC
 - Standard Mesh-WiFi 6
 - 5G Campus Networks
 - Standard 4G/5G networks
- Currently used protocols:



¹ Maneuver Coordination Message
² Automated Valet Parking

Organised by



Co-organised by



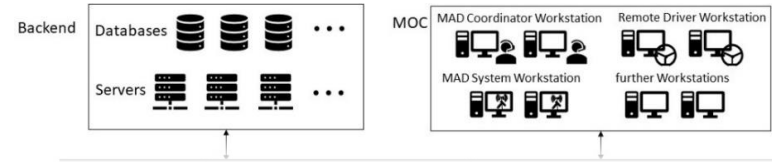
Hosted by



Supported by



Technical Assistance & Remote Operation



- Monitoring of vehicle functions and Operating Domains
 - Higher complexity: must include monitoring of additional infrastructure components
 - But:
 - Offers use of additional data sources, like infrastructure cameras/sensors to gain overview
 - Allows problem solving for fleets rather than individual vehicles
 - Offers modification of e.g. signal plans



Organised by



Co-organised by



Hosted by



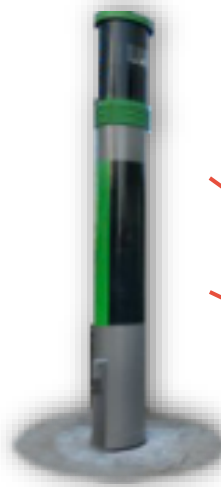
Supported by



Specific implementations by (set up currently in progress, done in October '24)



- Research roadside equipment on Tostmannplatz, Braunschweig, Germany
 - 2x VITRONIC sensor poles equipped with (total)
 - 4x Stereo camera pairs (Balluff MV)
 - 2x 4D Radars (Smartmicro)
 - 1x 4D Lidar (Aeva)
 - Additionally 2x hemispheric cameras (Axis)
- Computing on three performance levels
 - High-Definition: 4x Apple Mac Pro
 - Medium-Definition: 2x Jetson Orin AGX and 2x Nuvo CarPC
 - Low-Definition: 1x Jetson Orin NX
- Communication: 1x V2X-RSU (Cohda), 2x WiFi6 (Rukkus)



Organised by



Co-organised by



Hosted by



Supported by

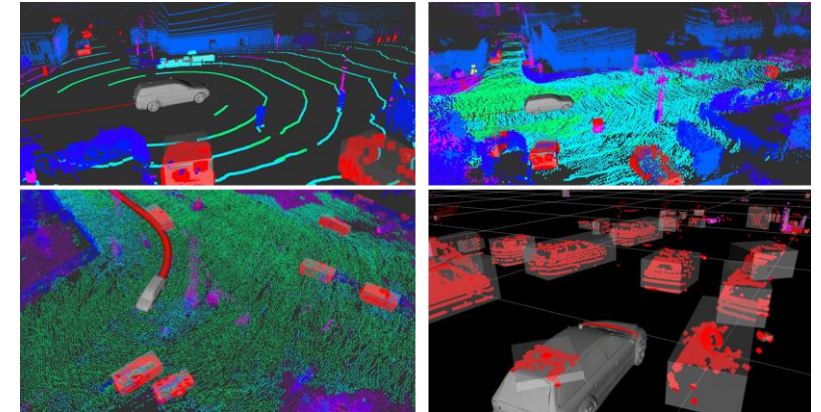


Tostmannplatz Research Goals

(campaigns performed 11/24 - 05/25)



- Comparison of sensor capabilities, e.g.
 - Range, field-of-view, accuracy, latency, (raw) data availability, stability
- Fusion of different data sources, also including collective perception and vehicle positions received via V2X
- Usability for automated driving regarding
 - Sense (collective perception)
 - plan/think (maneuver and speed advisory)
 - and ACT (maneuver/trajectory control)
- Remote Operation on public roads



Organised by



Co-organised by



Hosted by

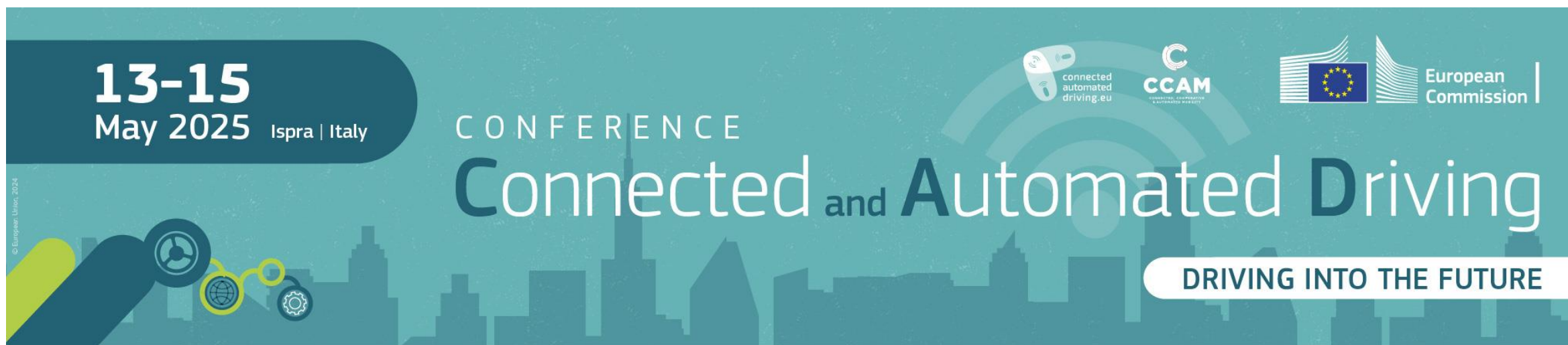


Supported by



Stay tuned!

Life demonstration of the full system planned at the EUCAD Conference 2025!



13-15
May 2025 | Ispra | Italy

CONFERENCE
Connected and Automated Driving

DRIVING INTO THE FUTURE

connected automated driving.eu
CCAM
European Commission

Organised by



Co-organised by



Hosted by



Supported by





DUBAI

ITS World Congress

16 -20 September 2024

Mobility Driven by ITS

Organised by



Hosted by



**Thank
you!**