Automated Coupling of Freight Wagons using a Road-rail Vehicle and Innovative Communication and Positioning Technologies

Technische Universität Dresden, “Friedrich List” Faculty of Transport and Traffic Sciences, Chair of Transport Systems Information Technology
Dresden, Germany

Robert Richter, Oliver Michler
March, 2025

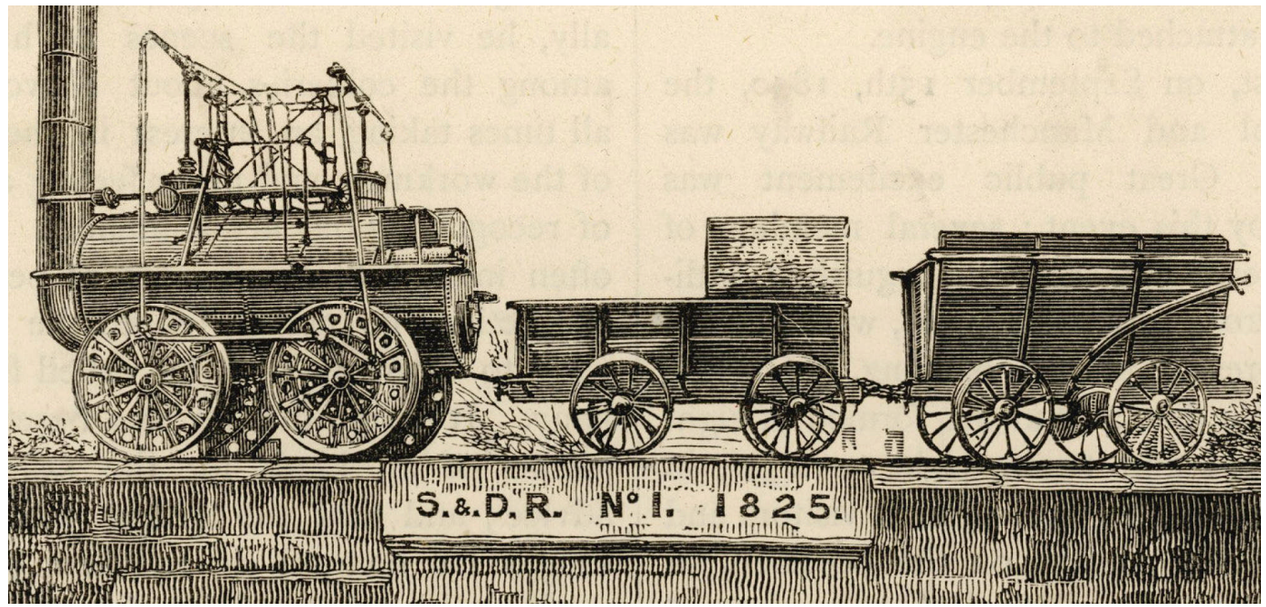
Session 11 [ICAS II]
The Twenty-First International Conference on Autonomic and Autonomous Systems - ICAS 2025

Agenda

- Introduction
- Shunting Concept – Introduction of an ASV
  - Realization, Overview – Autonomous Shunting Vehicle (ASV)
  - Realization, Overview – Infrastructure System
  - ASV - Realization, Stanley Controller
- Special Inside – Time Synchronization Wireless Sensor Network
- Integrity Communication - Investigation Points
- Use of leaky waveguide Cables (LCX) for Shunting Processes
- Experimental Environment
- Conclusion & Future Challenges

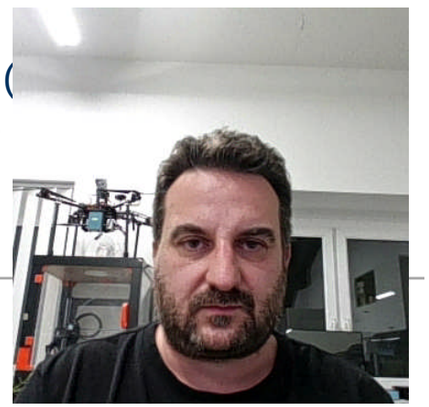
Introduction – History Line

- first railroad with a locomotive by George Stephenson (1781-1848) 1825 in England between Stockton and Darlington over a distance of 9 miles
- Passengers are also transported for the first time; railroads had previously been used in coal mines

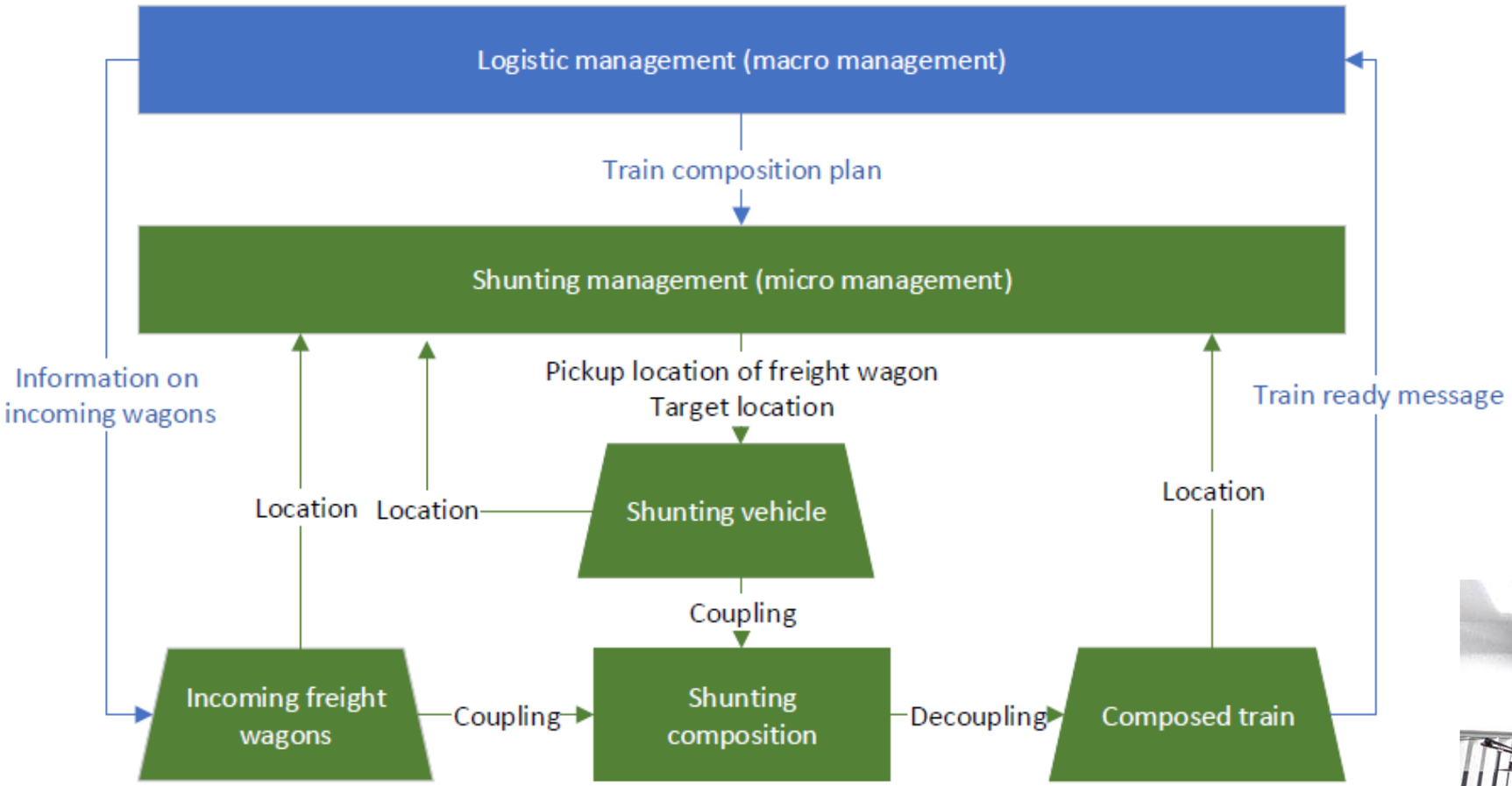


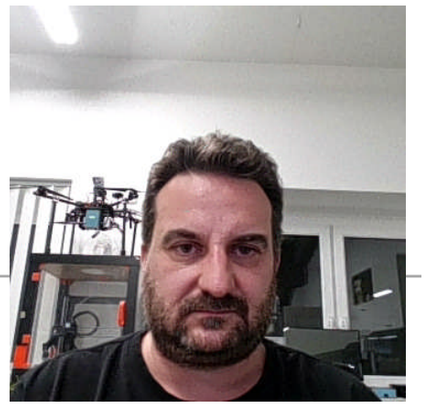
picture-alliance / Mary Evans Pi/Mary Evans Picture Library

While innovative and disruptive technologies, such as the use of Unmanned Aerial Vehicles (transportation, are opening up new opportunities, **historically evolved transport infrastructures to be of central importance.**

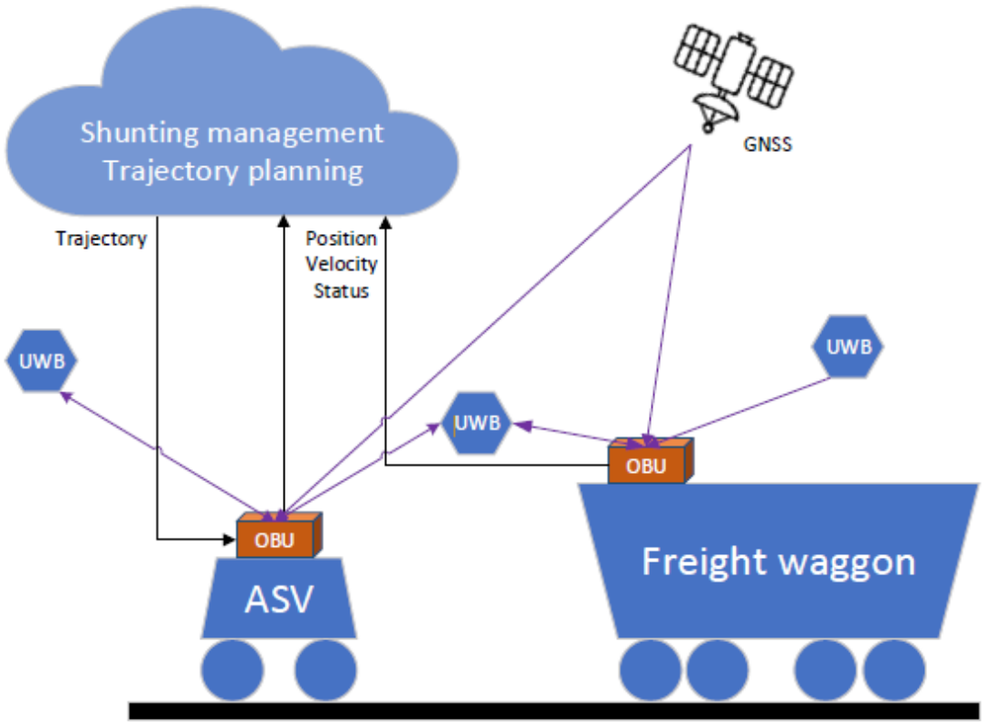


Introduction – Shunting Process





Shunting Concept – Introduction of an ASV



Approaches to solutions:

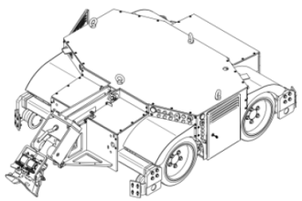
- Wireless Sensor Network (WSN) is adapted for positioning in combination with RTK GNSS and an IMU combined in an Onboard Unit (OBU)
- WSN is self-configuring based on Ultrawideband (UWB)

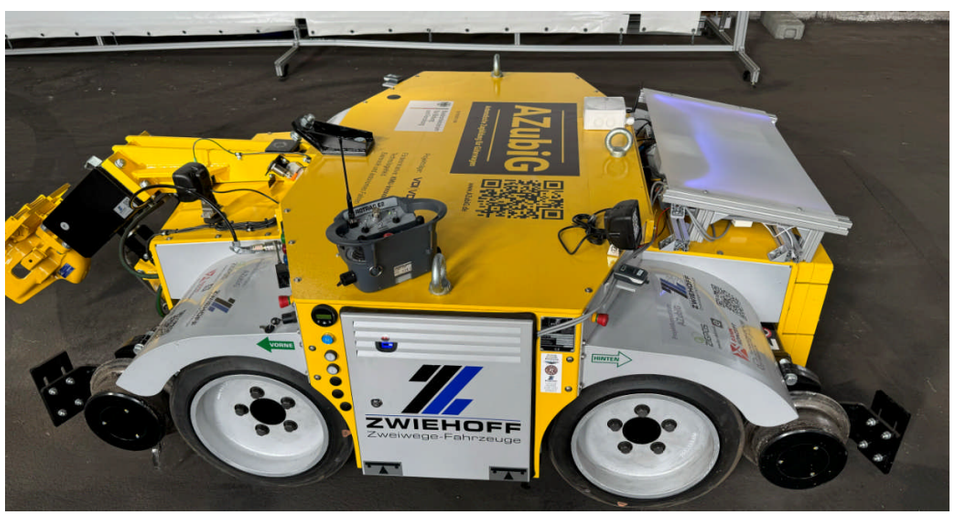
One goal - realization of seamless indoor and outdoor localization

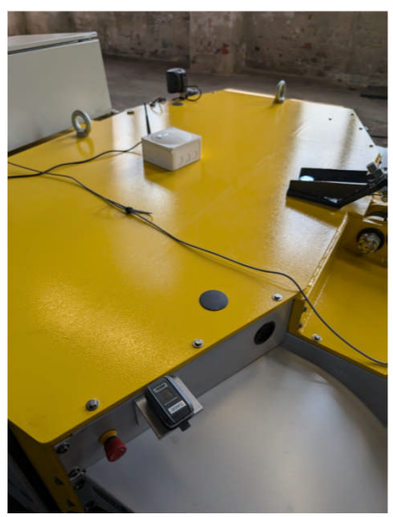
Realization, Overview– Autonomous Shunting Vehicle (ASV)

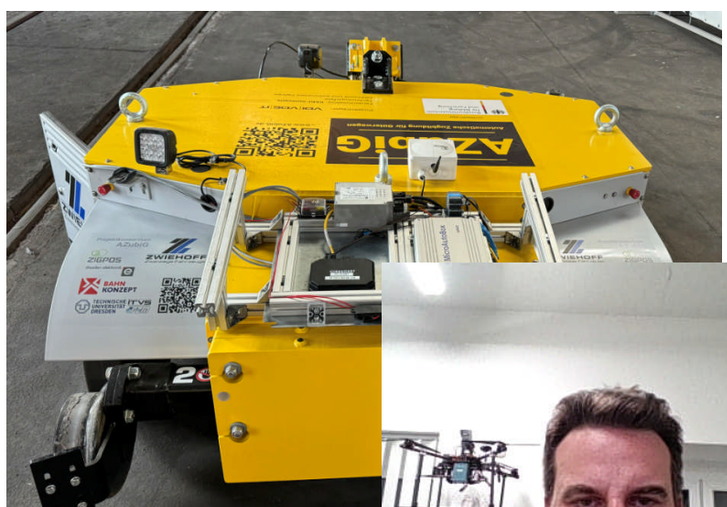
The ASV is equipped with:

- UWB Tags
- IMU, Central
- AI Camera
- Realtime Computing System (dspace)
- CAN-bus Controller





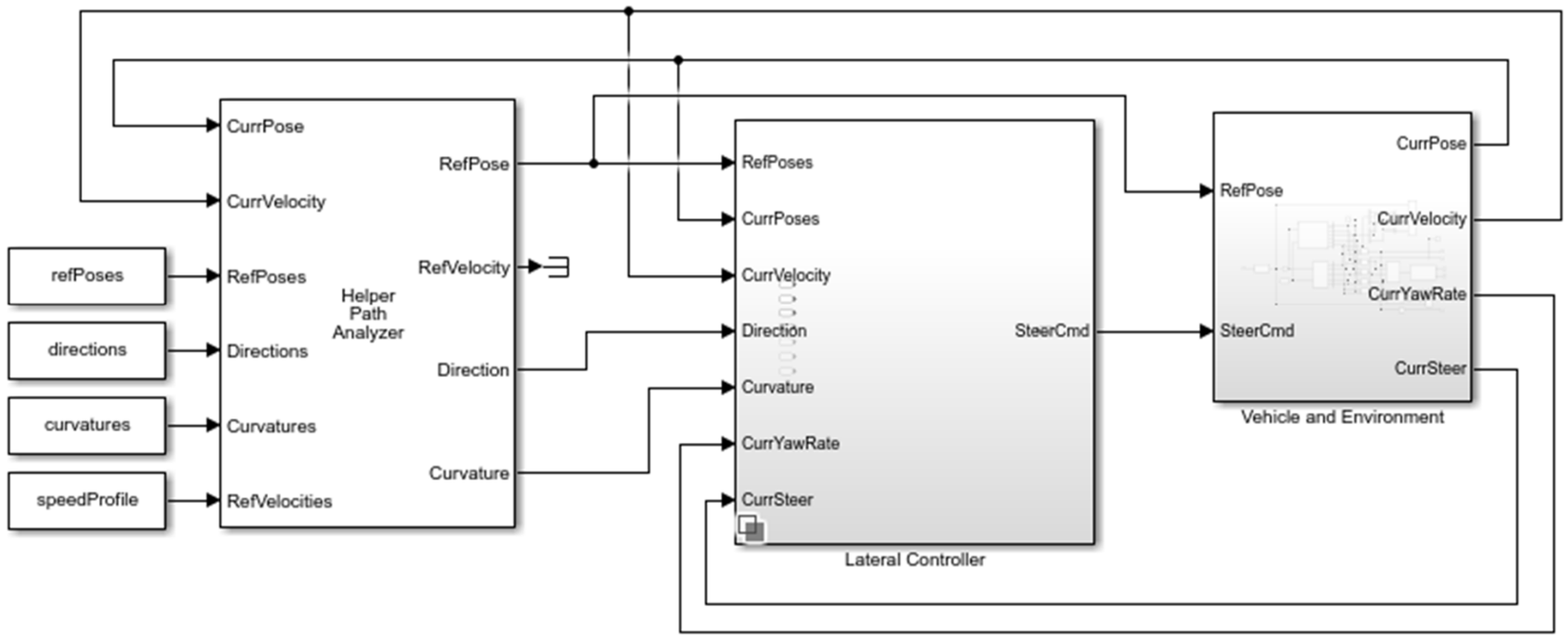




ASV - Realization, Stanley Controller

The two-way vehicle used is a vehicle with so-called tank steering, i.e., no axle is steered. Steering movements are achieved by speed differences between the left and right wheels, which also enables the vehicle to turn on the vertical axis.

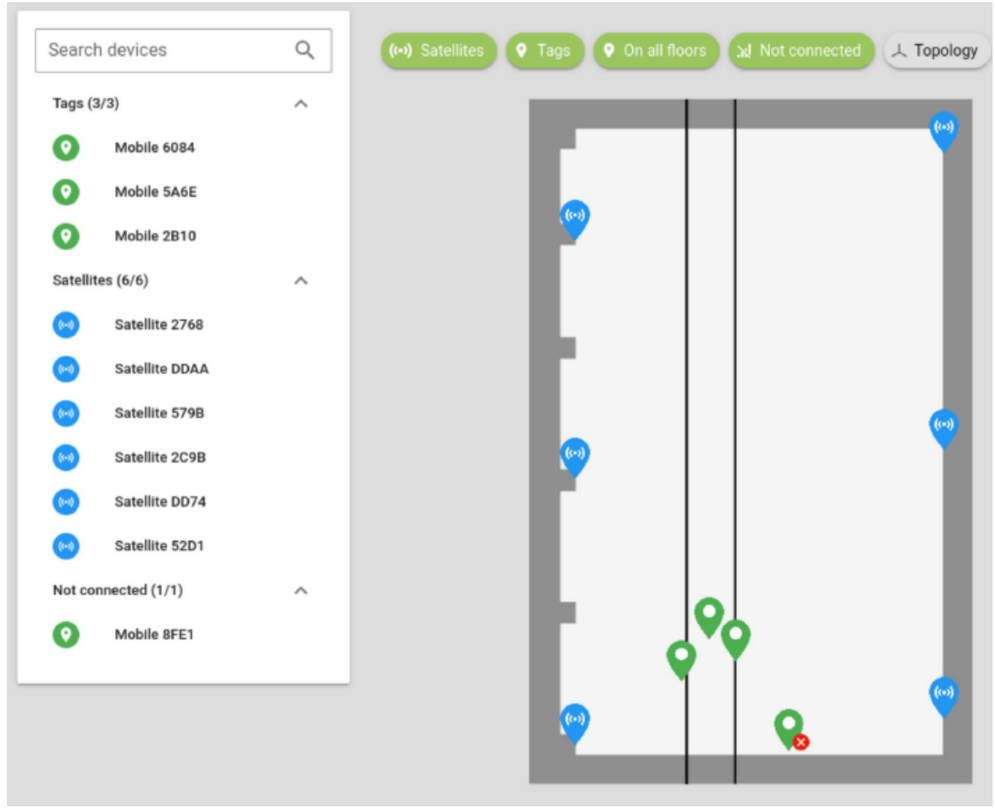
- Stanley Controller is realized for used ASV



Realization, Overview Infrastructure System

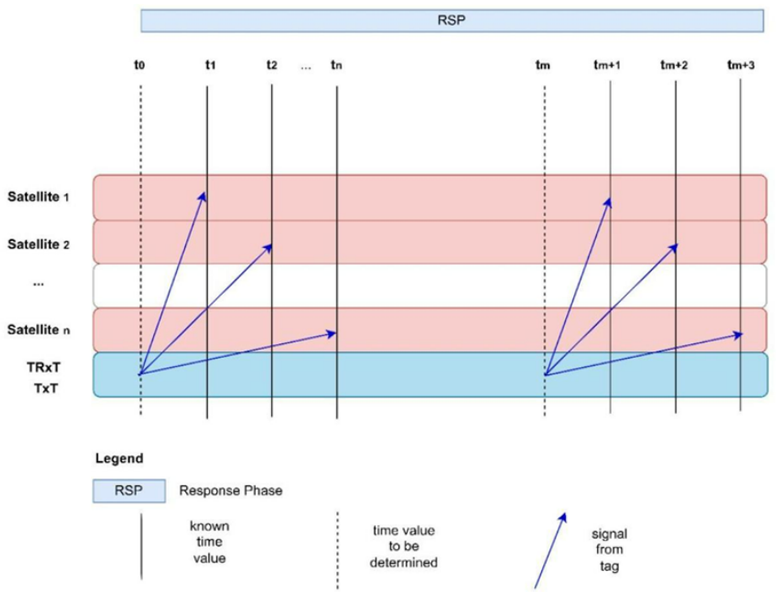
The infrastructure is equipped with:

- UWB Satellites
- LCX-Cables
- Control center
- Automatic networked roller shutters
- …



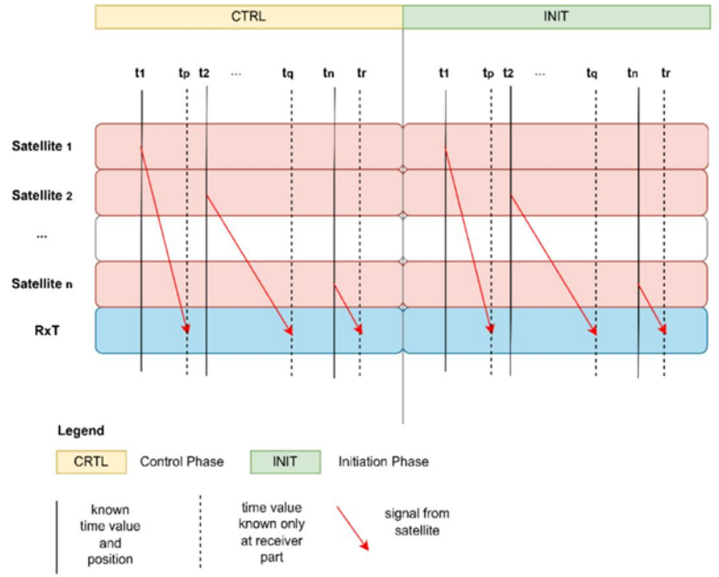
ASV - Special Inside – Time Synchronization of used Wireless Sensor Network

The aim of the processes - faster, more accurate and more energy-efficient localization



Transactions	Interface to upper layer
t0: TxT / TRxT sends message. t1: Satellite 1 (noted S1) receives message. t2: Satellite 2 (noted S2) receives message. tn: Satellite n (noted Sn) receives message.	S1: I received the message back from tag at t1. S2: I received it at t2. Sn: I received it at tn.

Downlink TdoA for ASV



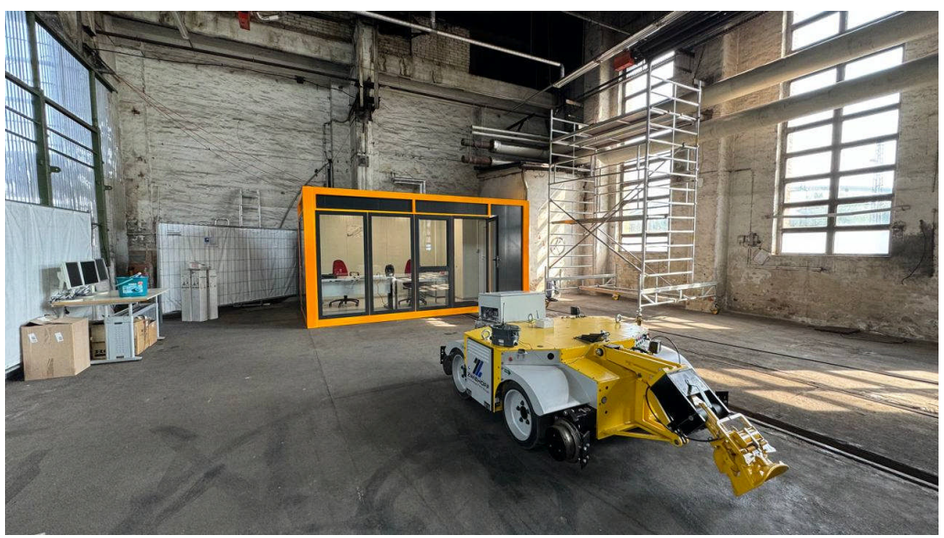
Transactions	Interface to upper layer
t1: Satellite 1 (noted S1) sends message tp: RxT receives message t2: Satellite 2 (noted S2) sends message tq: RxT receives message tn: Satellite n (noted Sn) sends message tr: RxT receives message	none

Uplink TdoA for freight wagons

Seamless Localization and Transition Indoor ←→Outdoor

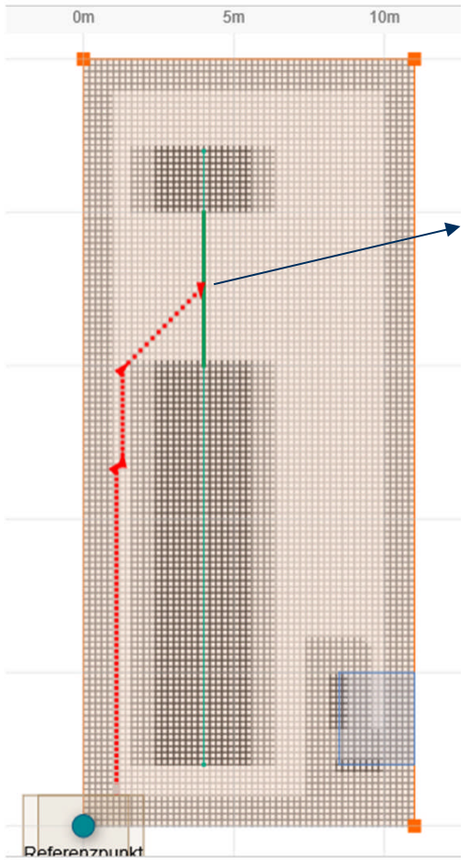
Challenge for the localization concept:

- simultaneous calculation of the position based on distances and angles of different physical positioning systems
- no switching of the algorithm!
- UWB and BLE (WSN, LCX), RTK-GNSS, IMU
- work in progress

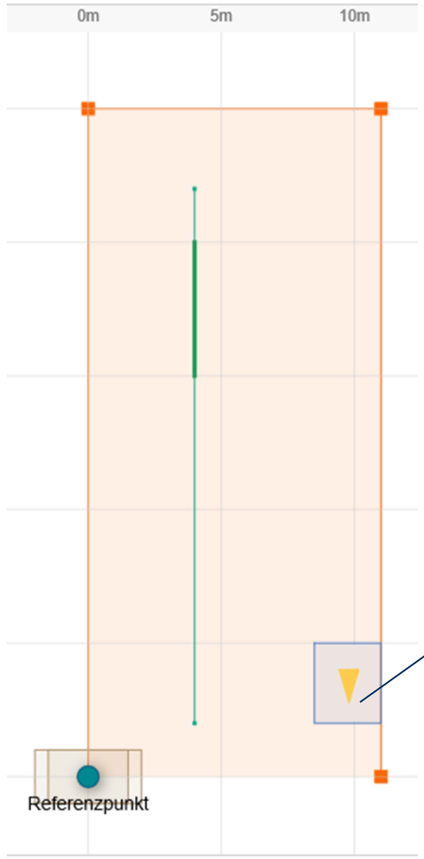


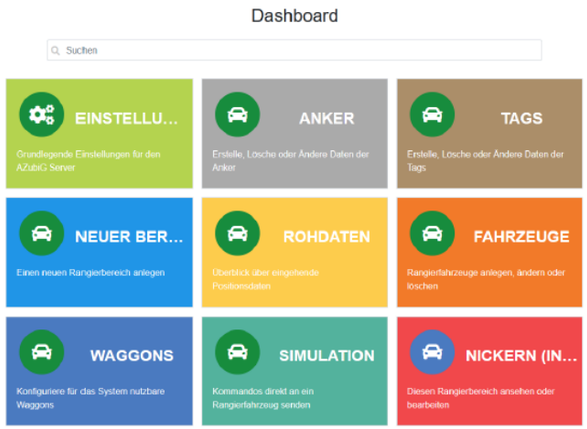
Trajectory Planning

- control center for ASV configuration, wagon composition, trajectory planning, map overview, live tracking of the ASV and many more.



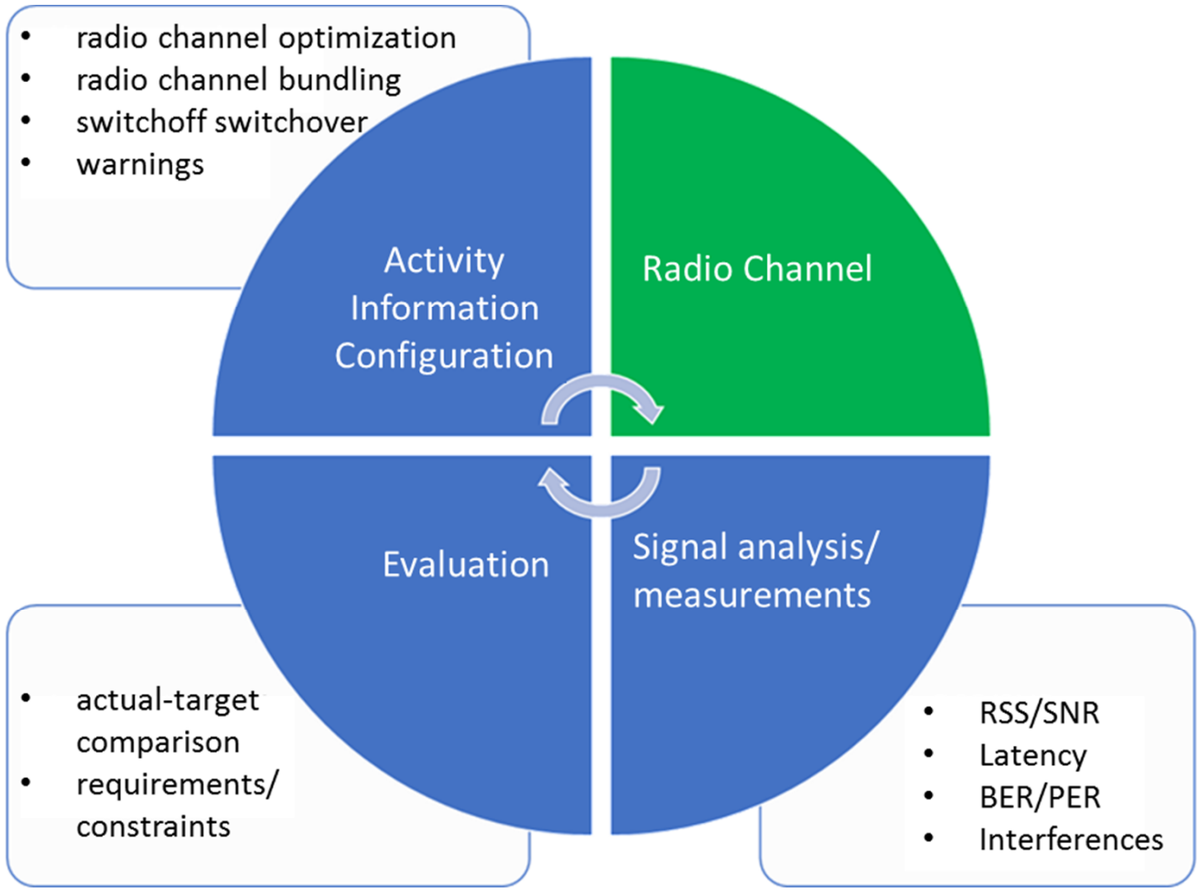
Control Center dashboard with trajectory computing



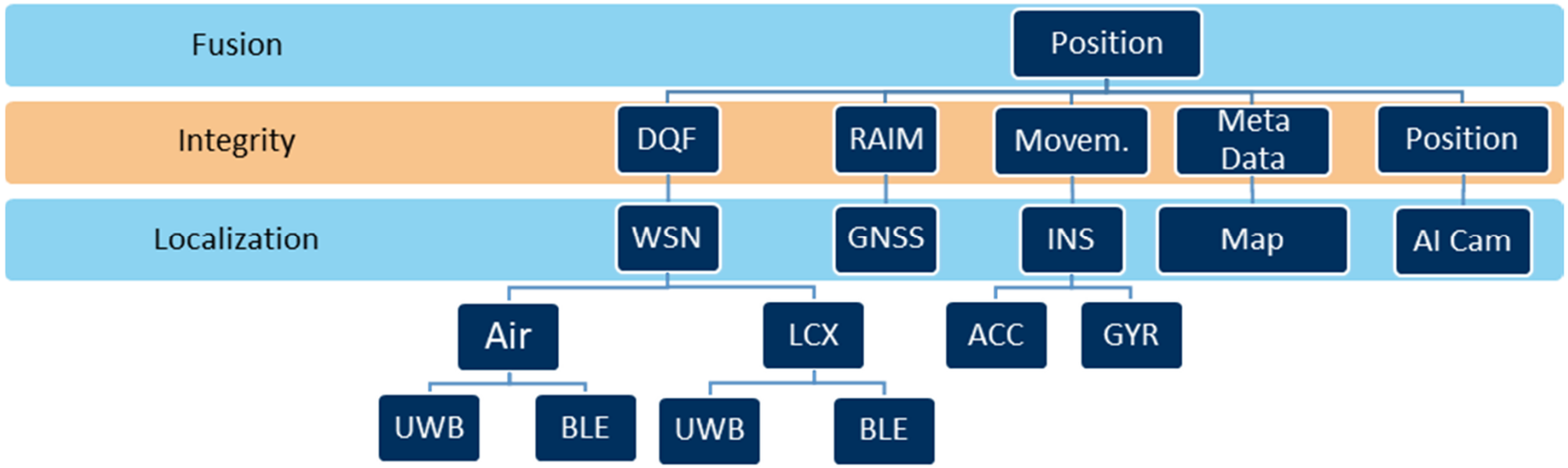


Control Center dashboard with ASV position and heading (MAP view)

Integrity Communication - Investigation Points



Integrity Localization - Investigation Points



Statistical integrity
Integrity estimation by analyzing the underlying sensor readings

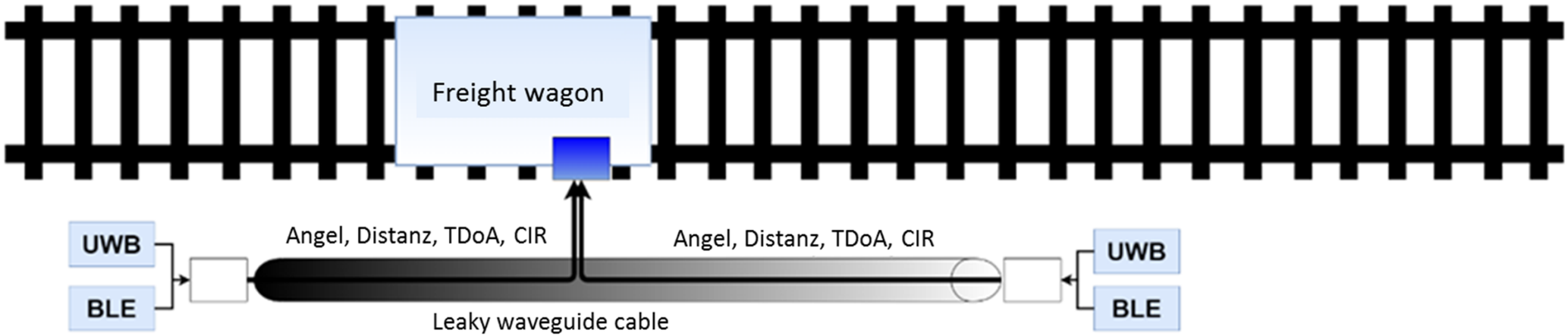
- Distance Quality Factor (UWB, BLE)
- Receiver Autonomous Integrity Monitoring (GNSS)

Systemic integrity approach
Use of all available information for integrity estimation

- Intersection of data from different positioning systems
- Fault Detection and Exclusion → Detection of the cause of the fault

Use of leaky waveguide Cables (LCX) for Shunting Processes

Transmission and localization medium for various radio technologies

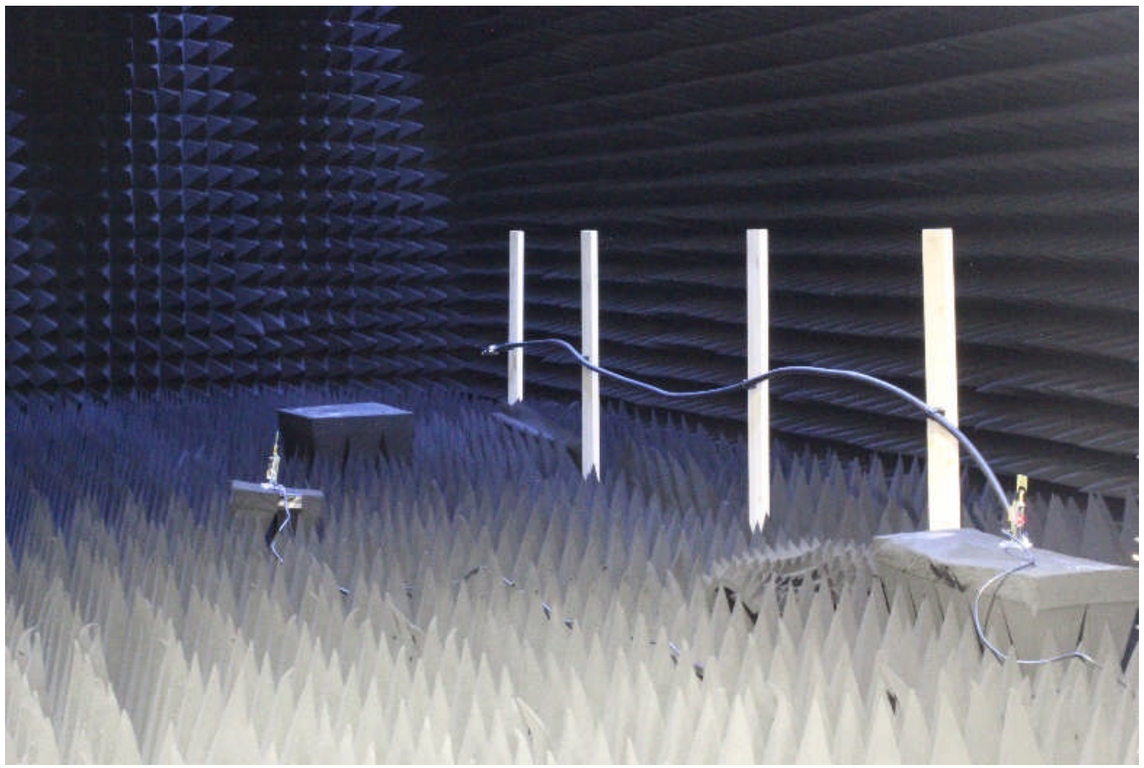


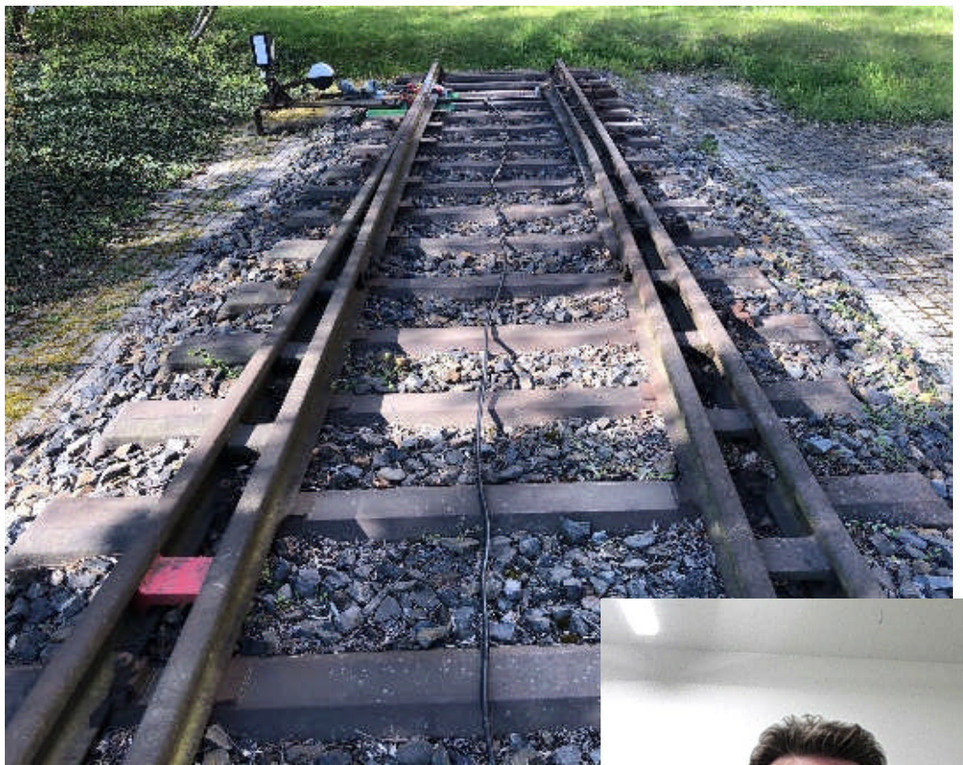
Redundant transmission medium

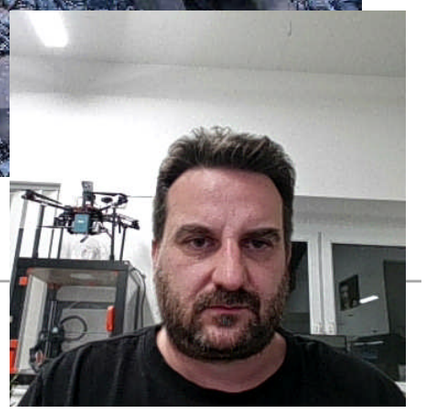
- Infrastructure device requires external antenna connections for each radio technology
- Transmission signals from infrastructure components are fed in from the right and left (e.g. UWB and BLE signal)
- Installation possible on both sides of the track

Use of leaky waveguide Cables (LCX) for Shunting Processes

Laboratory tests and field tests in a railroad environment

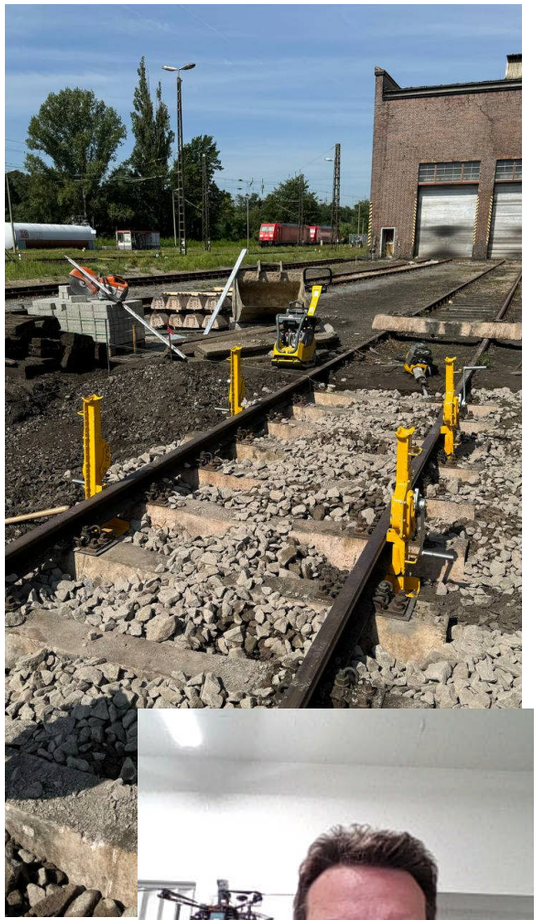






Experimental environment with single track

- Test Site with experimental building and outdoor area in Dresden, Germany
- Special feature, a single-track station equipped with LCX for rerailing
- will continue to be built up

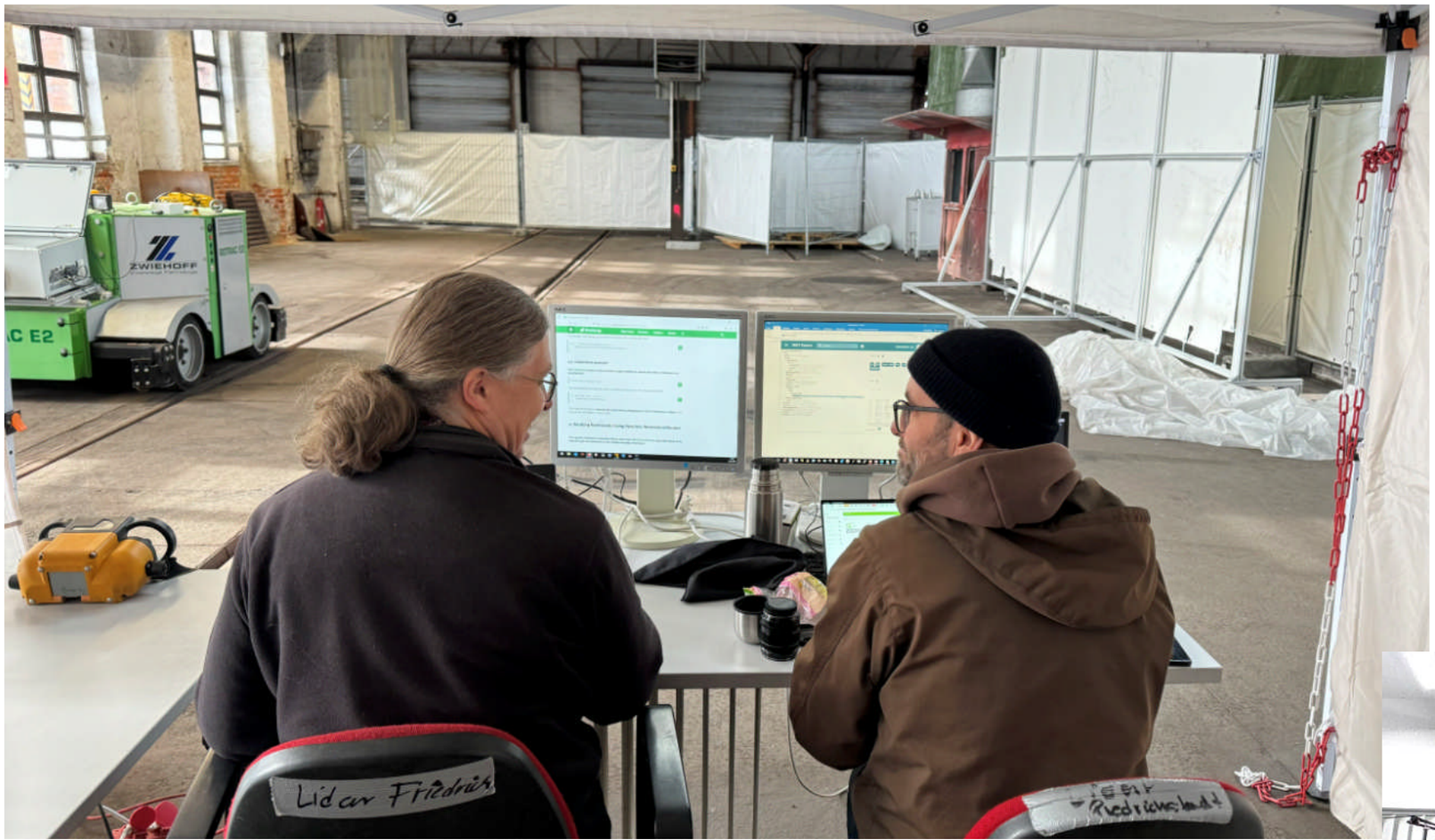


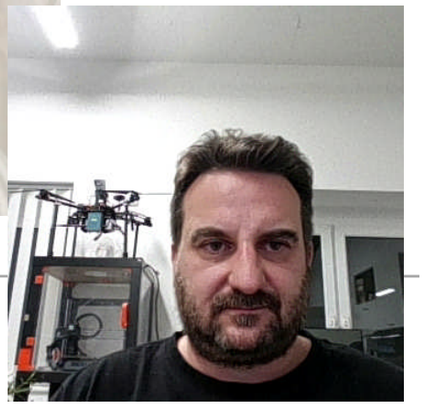
Conclusion & Future Challenges

- Introduction to the world of shunting processes in the railway sector
- Introduction of an autonomous shunting vehicle
- Problem descriptions and their solutions for autonomous operations
- Specifically, the use of ASV localization using radio sensor networks and leakage waveguide cables
- Introduction of integrity concepts for localization and communication
- Introduction and presentation of the various test areas for autonomous shunting

The Work is still in progress!

Thank you for your Attention!





Robert Richter, Oliver Michler
Fakultät für Verkehrswissenschaften "Friedrich List"
Institut für Verkehrstelematik

Contact & Special Thanks to all Partner

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

This work was partially funded by the Federal Ministry of Education and Research (BMBF, FKZ: 16ME0054, AZubiG). The work on the research project was carried out jointly within various chairs of Technische Universität Dresden (ITVS, FZM, EB) and by the project partners Zigpos GmbH, Bahnkonzept GmbH Deutschland, Dresden Elektronik Ingenieurtechnik GmbH and G. Zwiehoff GmbH