INTEGRATION OF TUNNEL SENSORS AND C2X TECHNOLOGY TO ENHANCE TUNNEL SAFETY IN GERMANY

RESEARCH PROJECT KITT

KITT

VI INTERNATIONAL TUNNELLING FORUM

bast Federal Highway Research Institute

Dr.-Ing. Ingo Kaundinya
Federal Highway Research Institute

13th – 15 May, 2024 in Bielsko-Biala, Poland

AGENDA

- Background
- Utilization of C-ITS data
- KITT-Research Project: objective & functional principle
- Artificial Intelligence
- Training data set
- Visualization
- Demonstration
- Outlook

BACKGROUND

WHATS NEW?

Digitisation/ Mobility 4.0

C-ITS

Artificial Intelligence

Cyber Security

➢ **How does this address and change the safety assessment in road tunnels?**

UTILIZATION OF C-ITS DATA

BASIC PRINCIPLES

- **C-ITS** – Cooperative Intelligent Transport Systems
  - › Exchange of digital messages on traffic events and vehicle status between road users and the traffic infrastructure

- **C2X / V2X**
  - Car-2-Infrastructure (C2I) Communication
  - Infrastructure-2-Car (I2C) Communication

UTILIZATION OF C-ITS DATA

IMPORTANT STANDARDIZED C-ITS MESSAGES

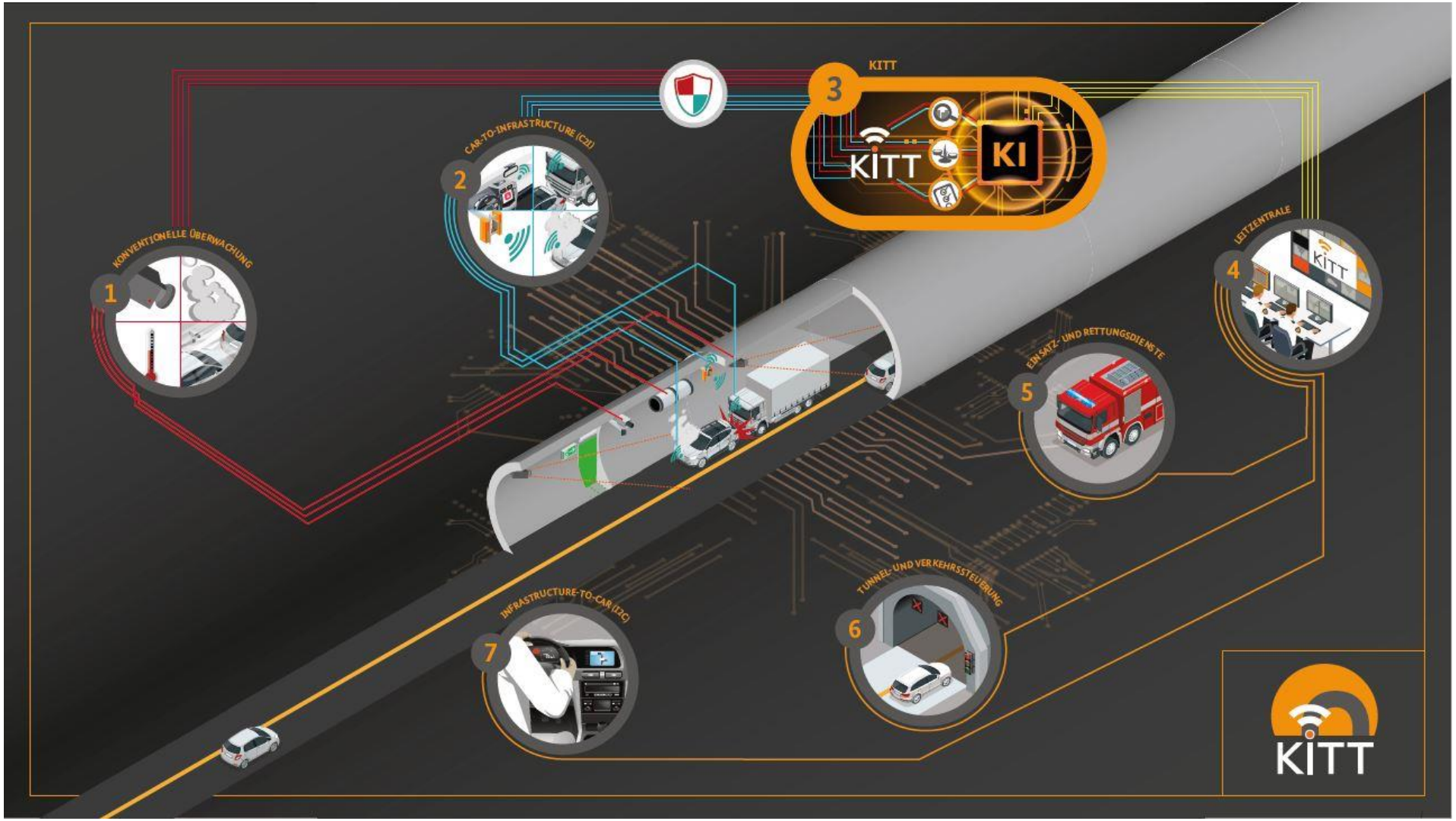
- **CAM** – Cooperative Awareness Messages
  - continuous transmitted (~every second)
  - status of a vehicle: position, direction, speed or vehicle type
- **DENM** – Decentralized Environmental Notification Messages
  - event-based transmission
  - notifications of road users and infrastructure systems in case of safety-critical events with additional event information
- **SPAT** – Signal Phase And Timing
- **IVI** – In-Vehicle Information

UTILIZATION OF C-ITS DATA

REQUIRED EQUIPMENT

- **OBU** – Onboard unit @ vehicle
- **RSU** – Roadside Unit @ tunnel

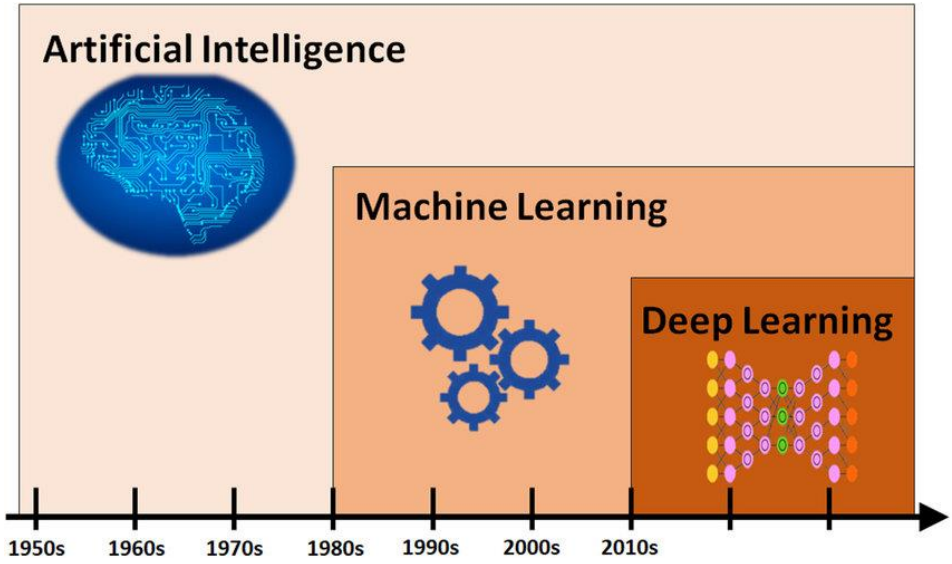
FUNCTIONAL PRINCIPLE OF KITT



ARTIFICIAL INTELLIGENCE

BASIC PRINCIPLES

- **Artificial Intelligence** is used to explain that computers try to perform human activities
- **Machine Learning** can learn from experience to find patterns in a range of data
- **“Weak AI”**:
  - › used for complex but recurring and precisely specified problems
  - › has no creativity and no ability to learn independently
  - › able to complete concrete tasks whose solutions she has previously learned



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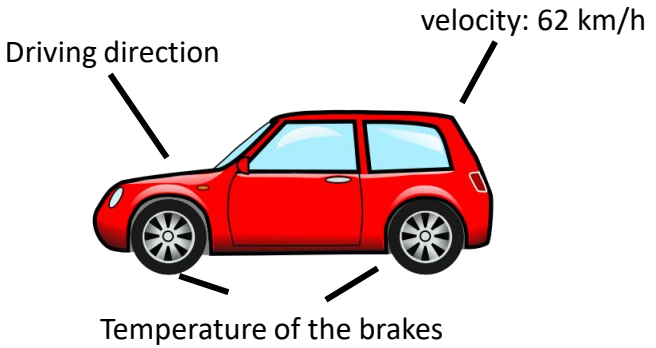
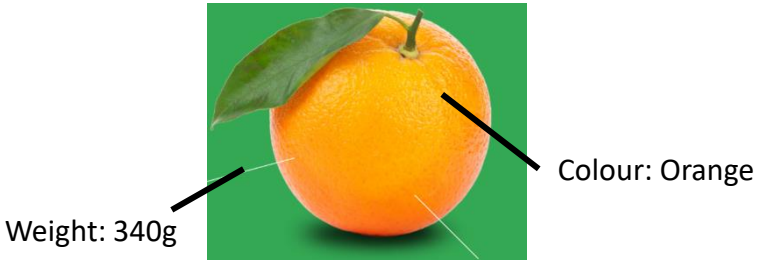
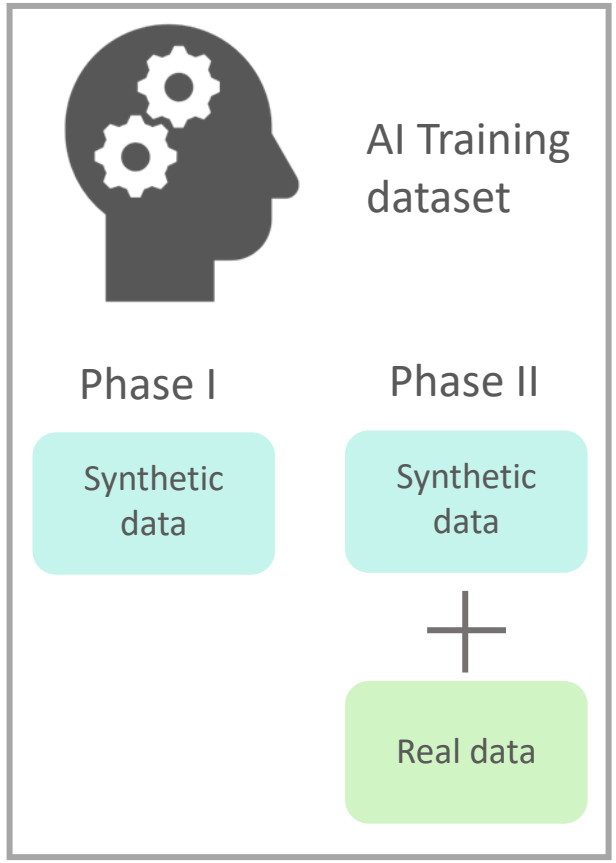




ARTIFICIAL INTELLIGENCE

TRAINING CONCEPT

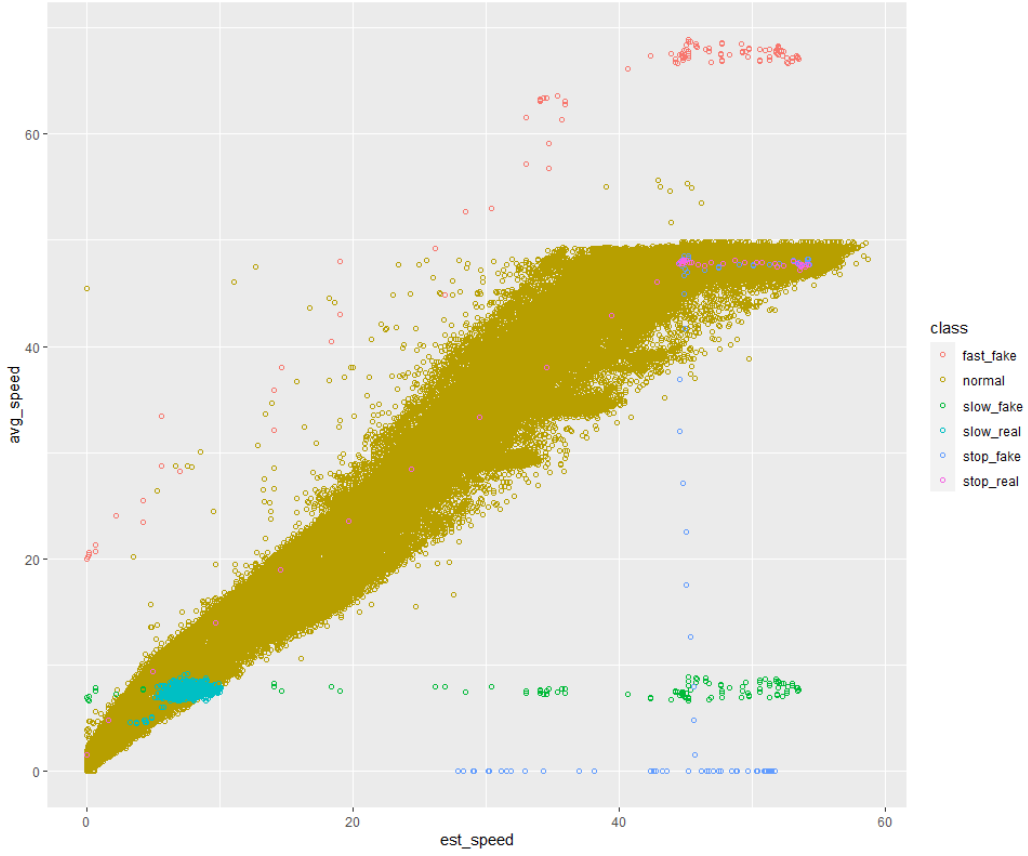
- AI module requires (large) training set with labelled variables and attributes
- Currently a very low rate of C-ITS capable vehicles on the road (<6%); however, numbers are increasing!
- Decision to set-up a training base using synthetic data
  - SUMO: microscopic traffic simulation model
  - ARTERY: C-ITS simulation framework



ARTIFICIAL INTELLIGENCE

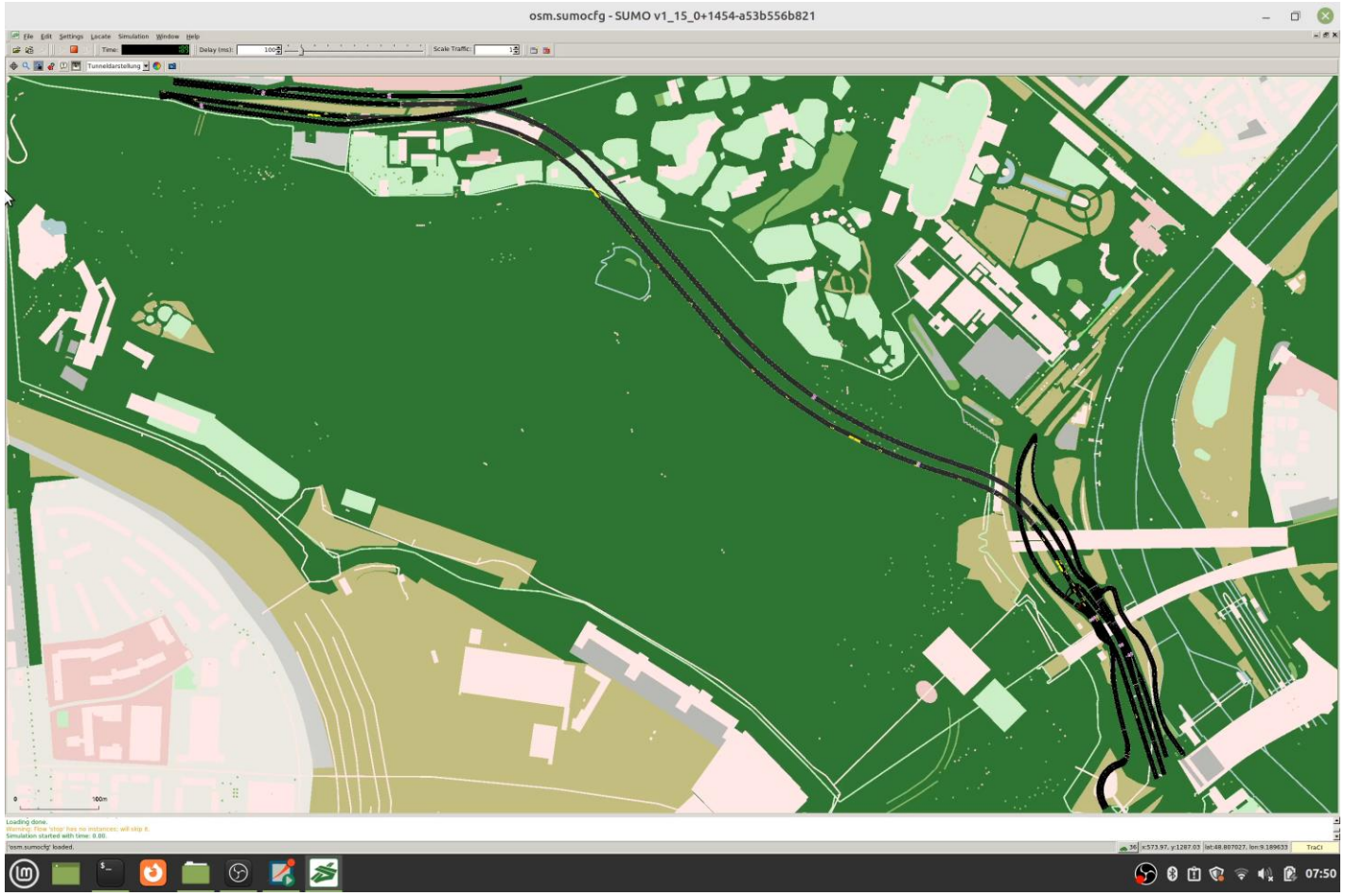
THE ROLE OF AI IN THE PROJECT

- Cope with the big amount of data transmitted by vehicles via C-ITS and sensor technology
- Detect anomalies in the data
  - **C-ITS-AI**: improve the detection of (potential) critical traffic situations at an early stage
  - **Tunnel sensor-AI**: additional analysis of tunnel sensor data
  - **IT-Security-AI**: detect security-relevant events, e.g. Denial-of-Service, spoofing of C-ITS data
- Future: On-the-job learning – learn from the reactions of the operators



TRAINING DATA SET

SUMO FOR TRAFFIC FLOW SIMULATION



- GUI for Simulation - SUMO
- Yellow Vehicle – normal Vehicle
- Red Vehicle – event-vehicle (e.g. collision, wrong-way driver)

TRAINING DATA SET

EXAMPLE OF CAM OUTPUT VIA SIMULATION

```
ITS PDU Header:
 Protocol Version: 2
 Message ID: 2
 Station ID: 2372
CoopAwarensess:
 Generation Delta Time: 10696
 Basic Container:
  Station Type: 5
  Reference Position:
   Longitude: 92089680
   Latitude: 488002490
   Semi Major Orientation: 3601
   Semi Major Confidence: 4095
   Semi Minor Confidence: 4095
   Altitude [Confidence]: 800001 [15]
 High Frequency Container [Basic Vehicle]:
  Heading [Confidence]: 1623 [10]
  Speed [Confidence]: 825 [3]
  Drive Direction: 0
  Longitudinal Acceleration: 0
  Vehicle Length [Confidence Indication]: 1023 [0]
Msg stats: 126 scheduled / 114811 existing / 485322 created
```

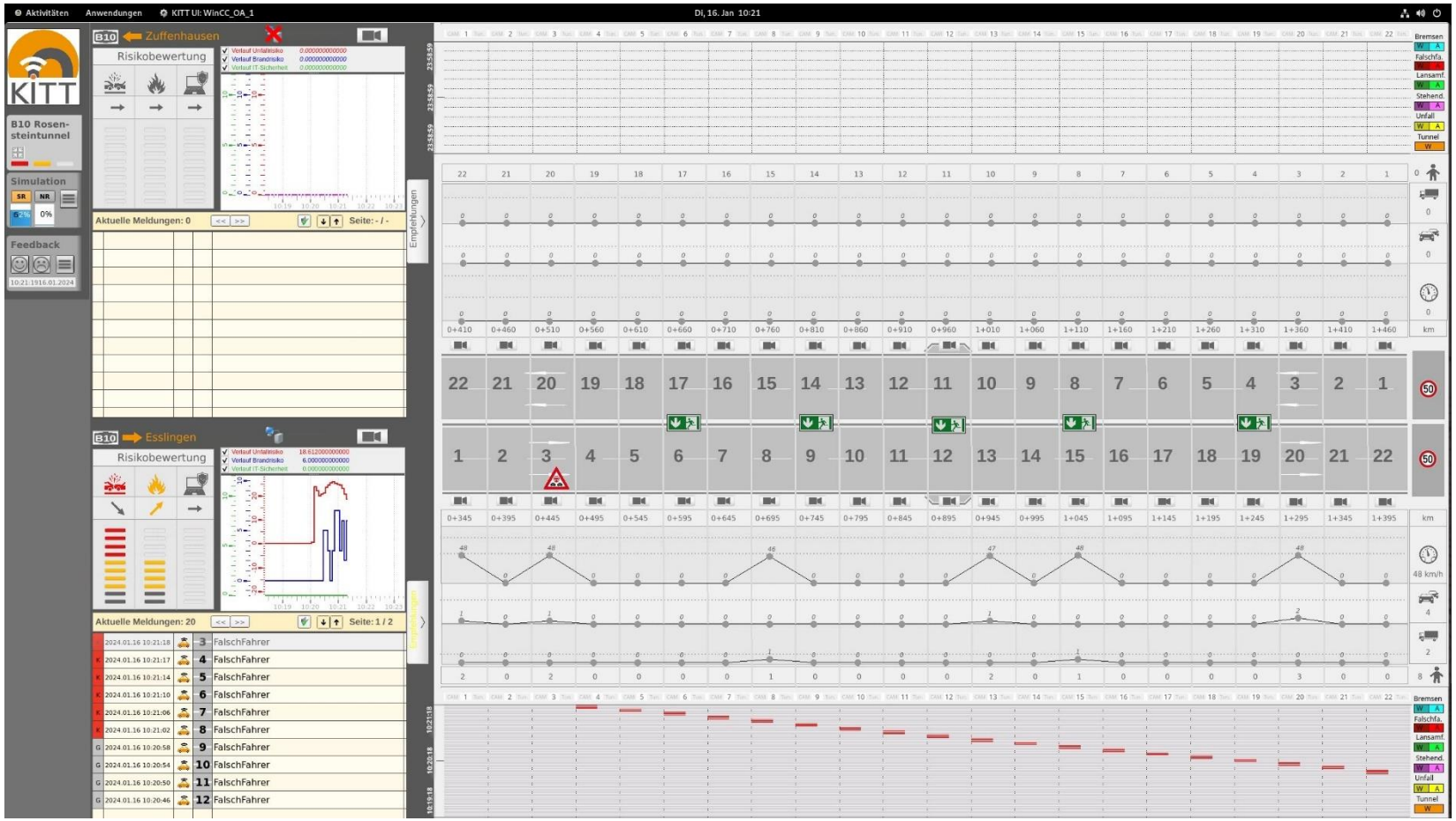
Vehicle before breakdown

```
ITS PDU Header:
 Protocol Version: 2
 Message ID: 2                          type of the C-ITS message
 Station ID: 4147                       ID of the vehicle
CoopAwarensess:
 Generation Delta Time: 32624
 Basic Container:
  Station Type: 5                       type of the vehicle
  Reference Position:
   Longitude: 92010090                  position of the vehicle
   Latitude: 488049440
   Semi Major Orientation: 3601         orientation of the vehicle
   Semi Major Confidence: 4095
   Semi Minor Confidence: 4095
   Altitude [Confidence]: 800001 [15]
 High Frequency Container [Basic Vehicle]:
  Heading [Confidence]: 1391 [10]
  Speed [Confidence]: 0 [3]             speed of the vehicle
  Drive Direction: 0
  Longitudinal Acceleration: 0
  Vehicle Length [Confidence Indication]: 1023 [0]
Msg stats: 160 scheduled / 970959 existing / 4070362 created
```

Vehicle after breakdown

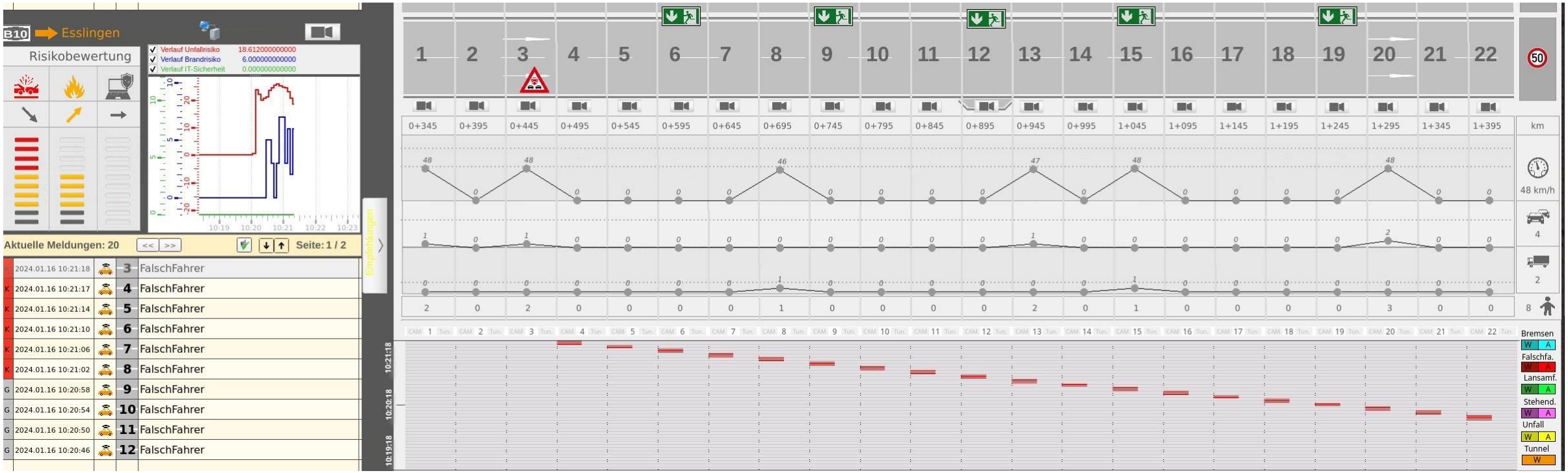
VISUALIZATION

GRAPHICAL USER INTERFACE



VISUALIZATION

GRAPHICAL USER INTERFACE - DETAIL



DEMONSTRATION

Rosensteintunnel Stuttgart

- Lenght 1300 meter
- Twin-tube tunnel
- Opening: March 2022
- Costs: 456 Mio. €

DEMONSTRATION

ROSENSTEINTUNNEL

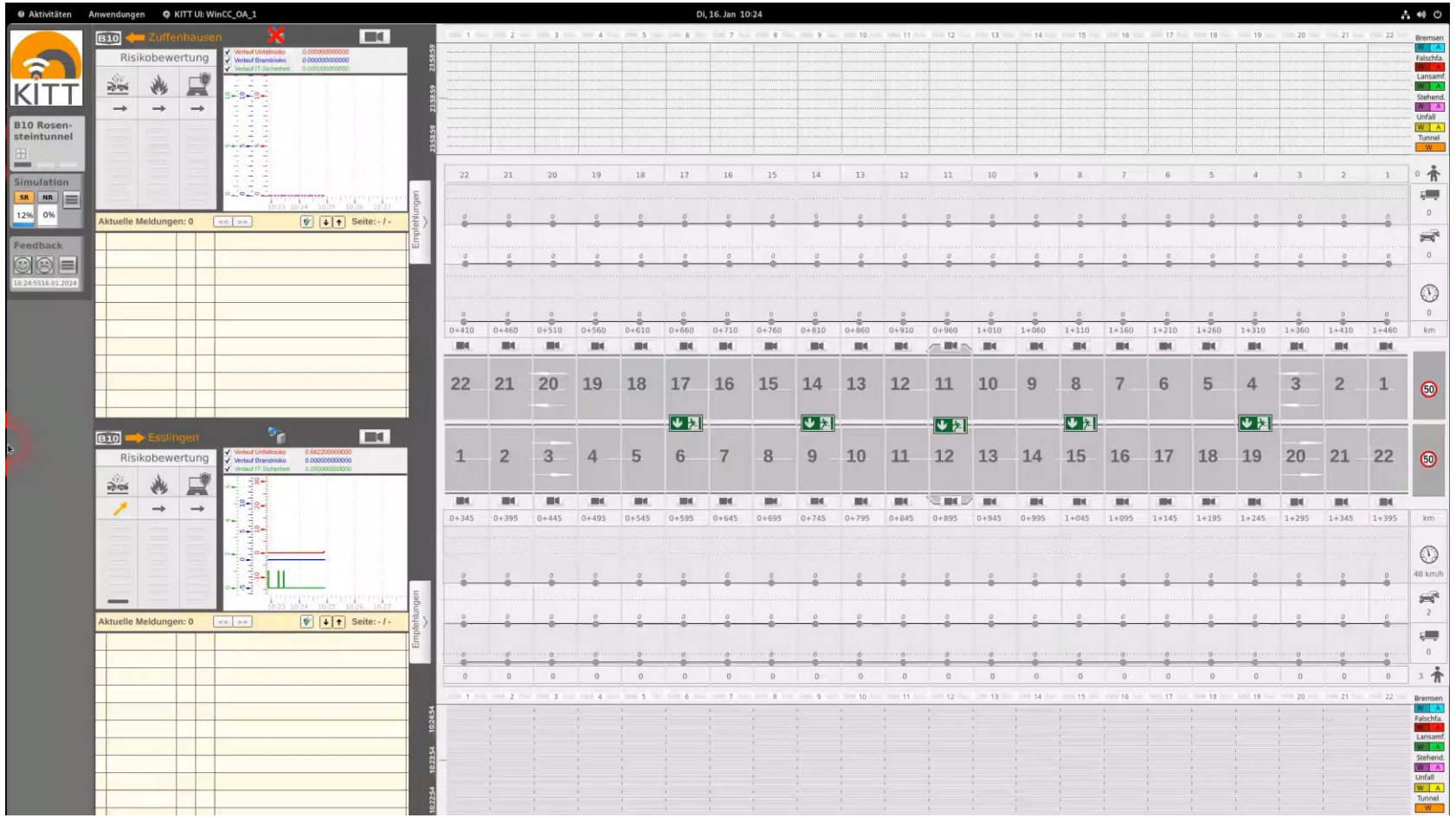
- Equipment of tunnel tube with 3 RSUs at both tunnel portals as well as in tunnel center
- Implementation of RSUs and other KITT modules into tunnel control and monitoring system
- Proof-of-concept planned with real-life test vehicles and also synthetic data for scenarios like „vehicle fire“

➢ Missing GNSS reception: functional verification mainly based on synthetic data

➢ Individual scenarios such as wrong-way drivers with vehicle VW ID.7

DEMONSTRATION

FUNCTIONAL VERIFICATION



CONCLUSION

LESSONS LEARNED, OUTLOOK

- Number of C-ITS vehicles at the moment is small, but steadily increasing. C-ITS data is already existing, but not (yet) used in tunnels.
- KITT showed great potential for C-ITS in tunnel safety
- For the future realization of autonomous driving on roads and highways it is necessary to ensure the functioning of C-ITS in tunnels
- Standardization & Harmonization

THANK YOU FOR YOUR ATTENTION!

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