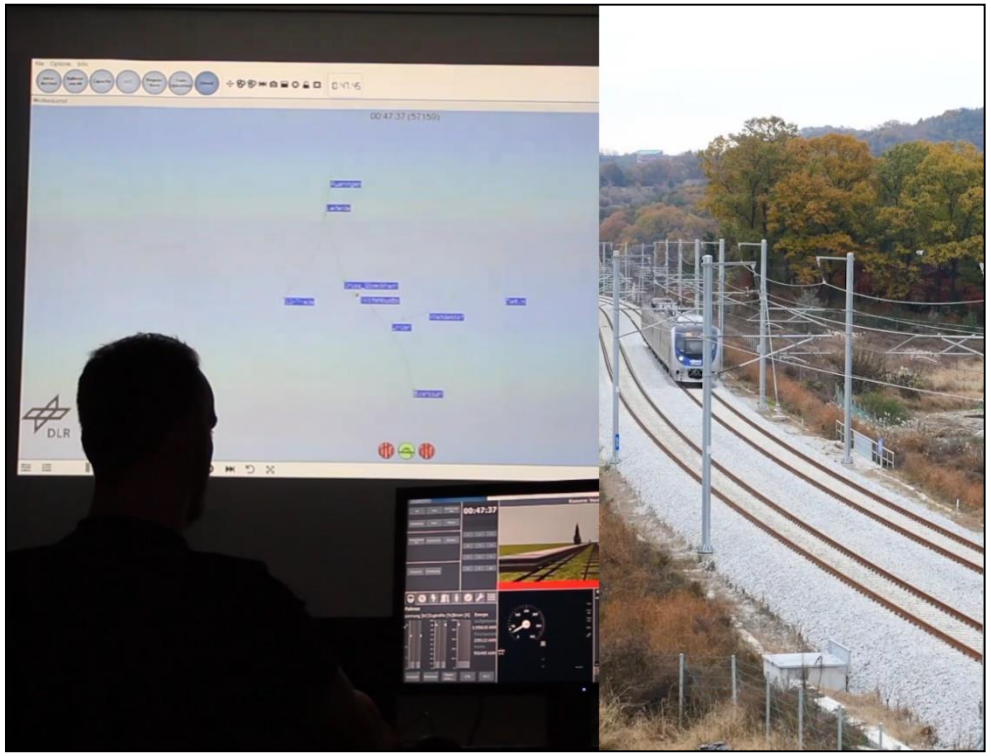
Implementation of a Remote Control Workplace to Realize Remote Train Control over 5G-Network in Real-World Testing

Niels Brandenburger, Friedrich Maximilian Strauß, Igor Bier

Institute for Transportation Systems
German Aerospace Centre

Remote Control via 5G Network – Real World Testing
Agenda

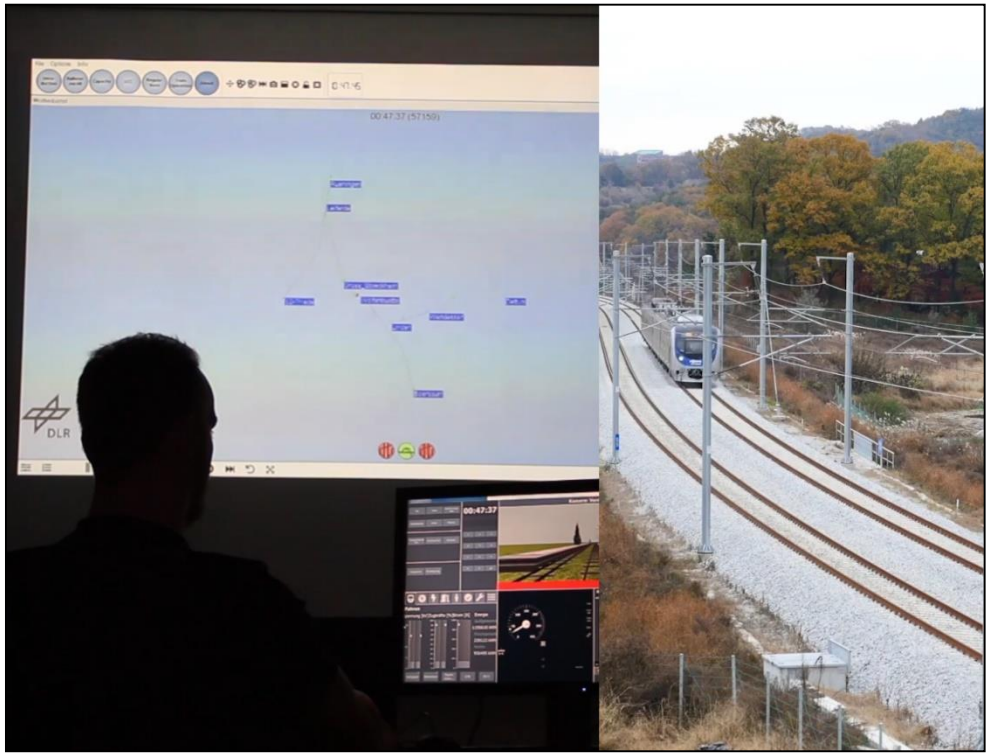
- Subject Rationale
- The 5G-Reallabor Project
  - 5G quality benchmarking and homologation concept
  - Field-Testing
- Scenario-based user requirements
  - Information Requirements
  - Control Requirements
  - Safety requirements (related to mobile network)
- Broaden the horizon - Next steps



Remote Control via 5G Network – Real World Testing
Subject Rationale

- Assuming Grade of Automation (GoA; IEC 62267) 3-4 in mainline service, a fall-back solution for unattended rolling stock malfunction is vital
- Basically, two options exist:
  - Get expertise to the site physically
  - Get expertise there virtually
- Since, virtual expertise seems more feasible (time, available resources, etc.), we focus on the virtual approach, keeping the other as a further fall-back layer

- Thus, remote diagnosis, recovery and control provided by centralised experts out of an operational centre emerged as a research topic*. “The Train Operator” was born…

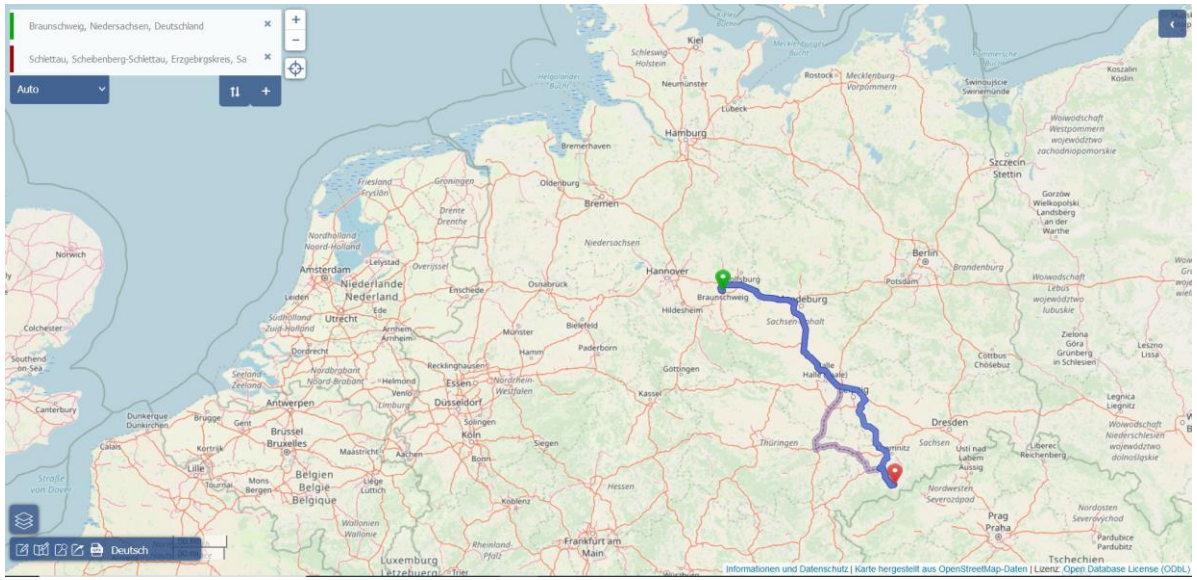


*e.g. Brandenburger, N., & Naumann, A. (2018). Towards remote supervision and recovery of automated railway systems: The staff´s changing contribution to system resilience. In Proceedings of the International Conference on Intelligent Rail Transportation (pp. 1-5). IEEE.

Remote Control via 5G Network – Real World Testing
The 5G-Reallabor Project

- Overarching Project Rationale
  - Demonstrate 5G capabilities in real-world applications
- Signalling and remote control in automated rail as one possible application of 5G technology
  - Remotely controlling a train in Saxony from Brunswick
    - Remote Recovery
    - Remote Shunting
  - By now, note the developments around FMRCS (!)
- In 2020, we presented the project goals at RHF BS 2020
  - 5G network quality benchmarking
  - homologation concept
  - Deriving user requirements for the workplace
  - Field-Testing remote control

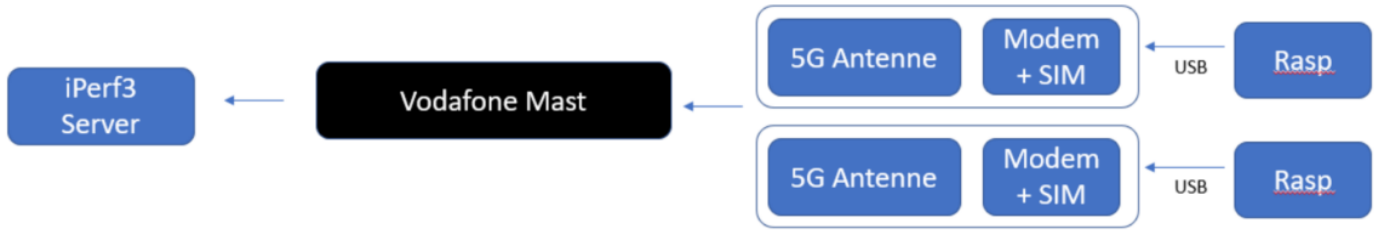
- Two years later, most results are available now



Remote Control via 5G Network – Real World Testing

5G Network Quality Benchmarking/ Homologation Concept

- 5G Network Quality Benchmarking (ongoing untill 06/2023)
  - Set-up of communication infrastructure in Saxony and Brunswick, GER
  - Skripting the testcases (uplink, downlink, interaction)
  - Since 04/2022 we are continuously sending and receiving various package sizes
  - Logging vital parameters such as latency, bandwidth, paket loss
- Homologation concept (finished)
  - Based on EN 50126 (RAMS) and EN 50128 (safety-critical software developement) a safety assessment for remote control via (public) mobile network has been delivered



Remote Control via 5G Network – Real World Testing

Field-Testing Remote Control (ongoing)

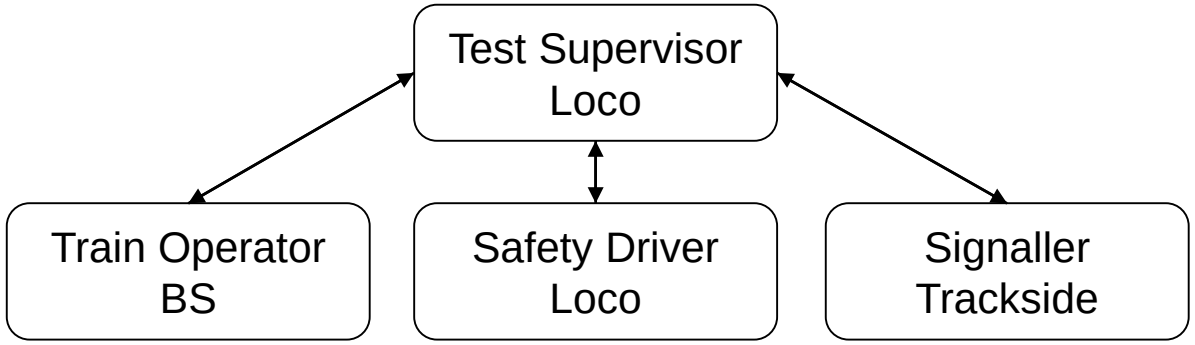
- (Quite some) Preparations, such as
  - Defining operational scenarios and compile test cases to test catalogue
  - Defining system architecture and functionality
  - Contracting industry partners (Thales, Railergy, YASC)
  - System refinement and developement
  - Pre-Release Testing
    - Software only
    - Physical safety feature test
    - Single location testing according to test catalogue
- Initial Field-Testing in Elmstein (August 2022)
  - Video shared on my LinkedIn profile
- Major Field-Testing Event in Brunswick/Saxony (22-23.11.2022)

Control Center Hardware	Control Center Software	Software Interface	In- Vehicle RTO Software	Conventional Vehicle Software

Remote Control via 5G Network – Real World Testing

Field-Testing Remote Control (ongoing)

- Field-Testing roles and setup



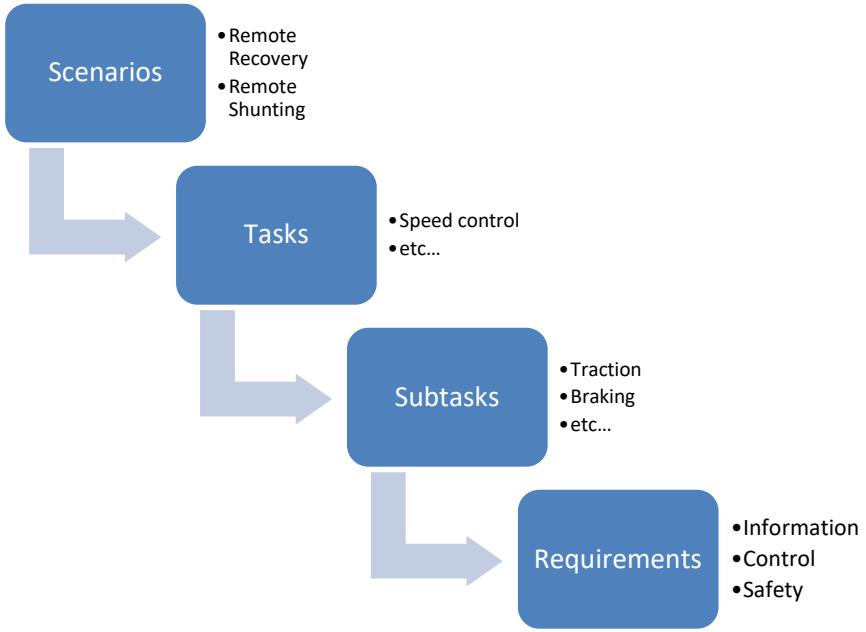
Control Center Hardware	Control Center Software	Software Interface	In- Vehicle RTO Software	Conventional Vehicle Software

Remote Control via 5G Network – Real World Testing

Scenario-based user requirements

- Turning to the heavy part of it…
  - the train operator and it´s workplace!

- Research question: What does the operator need to remotely control the train safely and correctly during the scenarios?
- Method:



Remote Control via 5G Network – Real World Testing

Scenario-based user requirements

- Systematic aggregation of functional requirements for each subtask in three categories (information, control, safety)

User Requirements 5G-Reallabor

ID	Scenario	Task	Subtask	Category	Requirement	Safety Impact	Functional Priori	Information Source
12	Remote Recovery	Take over	Request Take over	Control	The operator can request control from remote workplace	10	8	Not applicable
13	Remote Recovery	Take over	Request Take over	Safety	The operator´s request for control is granted only if video feed available	10	8	Network status data
14	Remote Recovery	Take over	Request Take over	Safety	The operator´s request for control is granted only if parking brake is on hold	10	8	Vehicle data
15	Remote Recovery	Take over	Request Take over	Safety	The operator´s request for control is granted only if VoIP connection is on	8	6	Network status data
16	Remote Recovery	Take over	Request Take over	Safety	The operator´s request for control is granted only if test supervisor approves	10	3	Procedure
17	Remote Recovery	Take over	Request Take over	Information	The operator´s request for control and the status of control is displayed at the remote workplace and inside the locomotive	10	8	In-vehicle RTO Software

Remote Control via 5G Network – Real World Testing

Scenario-based user requirements

- Information Requirements (excerpt)
  - Video footage
  - Vehicle status data
    - Including traction/ braking
  - ATP data (ETCS)
  - Network status data
  - VoIP
  - Checklists
- Control Requirements (excerpt)
  - Modus of control
  - Speed control
  - Direction of Travel
  - Choosing Camera
  - Vehicle functions
    - Horn, Light, Door
- Safety Requirements related to mobile network connection loss

Remote Control via 5G Network – Real World Testing

Scenario-based user requirements

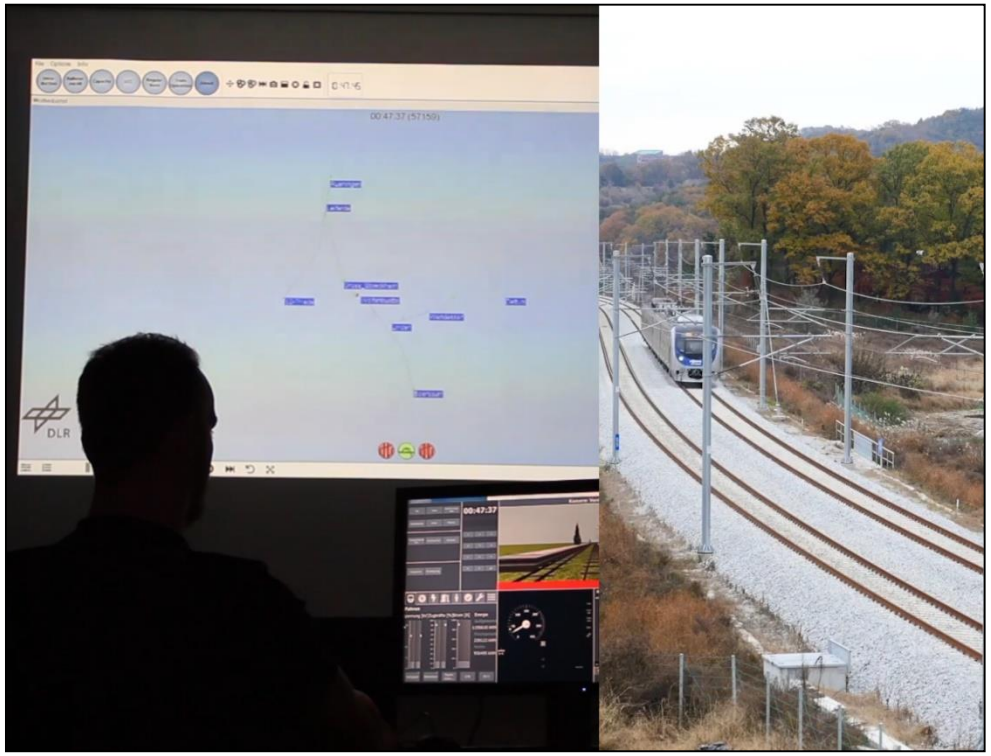
- Concerning the desirable video quality (information requirements) there is still an online choice- reaction time study going on
  - https://ts.dlr.de/survey/5greallabor/
  - Feel free to participate

- Aim is to establish the effect on bitrate and frames per second in railway video footage on human perception qualtiy

Remote Control via 5G Network – Real World Testing

Broaden the horizon – Some next Steps

- Project ATO-Cargo
  - One year trial phase of ATO and remote control fall-back layer in 2025 sidelining regular freight service on Betuwe route (NL)
  - Industry Partners: DB Cargo, ProRail, (.. tba)
  - After very elaborated requirement derivation, procurement processes conclude end of Nov 2023
- Project TRACO (DLR internal)
  - Substancial simulator study on shift- length and operator workload, fatigue, performance
- Project ARTE
  - Real-world testing with main focus on operational roles and procedures for ATO
  - Industry partner: ALSTOM
  - Please direct further questions to Anja Naumann
- Basically, the fun has just started…



Implementation of a Remote Control Workplace to Realize Remote Train Control over 5G-Network in Real-World Testing

Thank you for your questions/ feedback/ criticism!

More research on ResearchGate…

Niels.Brandenburger@dlr.de