



D2 Regional

What was the initial demand / problem ?

Validation of R2DATO specifications under operational conditions is a key step to reach maturity level for European solution of fully

- **Validate GoA3/GoA4 functions** on the Kopidlno–Dolní Bousov line in Czechia within a common architecture;
- Verify interoperability with ERTMS/ETCS and **interchangeability of modules** from multiple suppliers together with **feedback on interface adequacy and specification elements**;
- Establish a **traceable validation chain** linking use cases, requirements, scenarios and field evidence.

Test scenario families

Routine autonomous operation

Mission loading, start-up, speed supervision, platform stopping and dwell-time management.

Safety-critical response

Obstacle detection, signal recognition, emergency braking and degraded-mode handling.

Remote / fallback operation

Remote takeover, local-to-remote transitions and restoration after failure conditions.

Validation process – How we tested?

Each **operational use case** was translated into **specification sequence diagram** and **test scenarios** defining the expected system behaviour during testing and the **means of verification**.

Preparatory activities progressed through **bench testing**, **vehicle integration**, and **on-track execution** under realistic field conditions.

Validation demonstrated **interoperability/interchangeability** while covering functional performance, safety-relevant behaviour,, and operational feasibility.



Key outputs of the 2026 campaign include **an assessment of cross-supplier module interchangeability** within a **common architecture**

Achievements

Use Cases demonstrated

- ✓ R2DATO **Use Cases** validated in **real-world operational conditions**..

Structured feedback...

- ✓ **Findings** regarding **R2DATO specifications**, providing valuable return of experience, categorised by severity levels with recommendations for further improvements.

Interchangeability validated

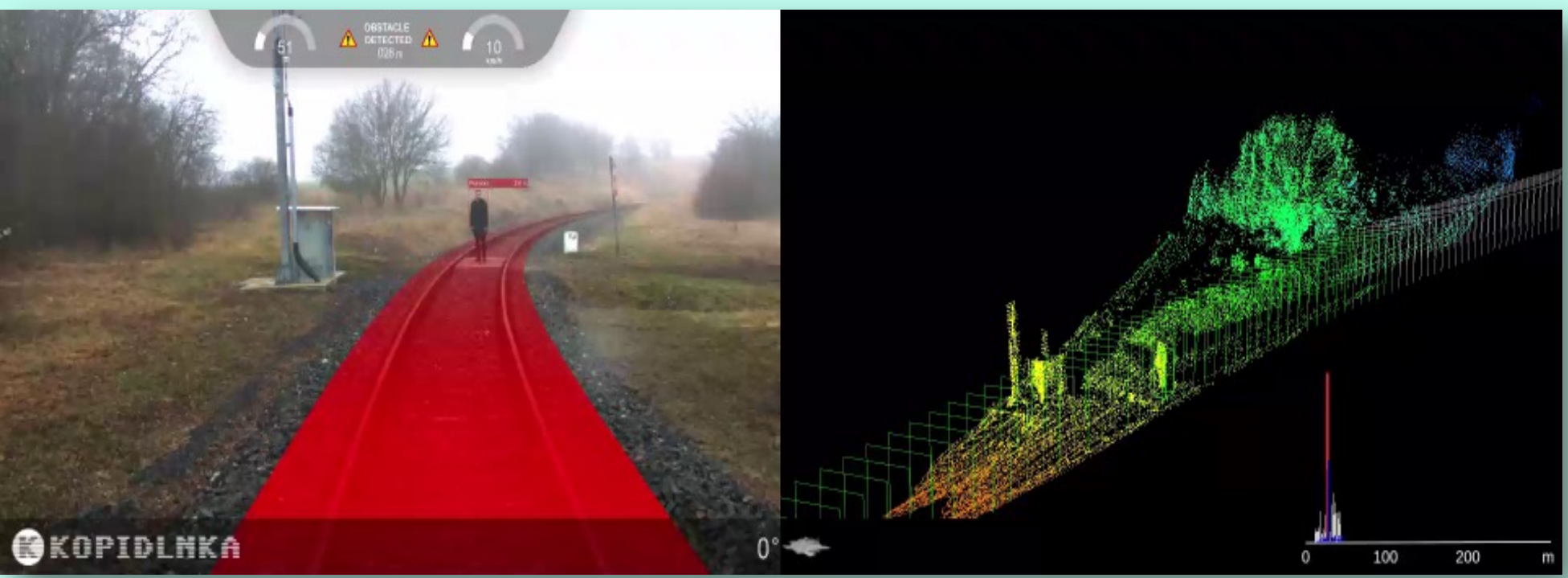
- ✓ Successfull **cooperation** to validate **interchangeability** between multiple suppliers modules

Prototypes for Interchangeability

ADM	PAL	REP	APM	ASTP	PER
AZD, ATSA	AZD, ATSA	AZD, ATSA	AZD, ATSA	AZD, INDRA	AZD, WABTEC

Testing environment

- Regional lines are a **demanding but realistic proving ground** because they combine mixed conditions, open track and legacy infrastructure.
- Equipped with **ETCS Level 2**, **GSM-R** and **5G** connectivity.
- The route includes **unprotected level crossings** and realistic regional operating conditions, making it suitable for **validating perception functions** and **degraded-mode operation**.



Cooperative design and validation lifecycle

Operational specification:

Use Case identification and detail specification

Logical specification:

R2DATO architecture refinement and modules and interface specification

Use Cases & scenarios in real-environment

Interchangeability

On train **Integration test**

Remote interchangeability test

Design and implementation

Lab testing and use cases simulation

Module	Role in the Demonstrator
ADM/APM	Automatic driving and processing functions extending GoA2 toward GoA3/4.
REP-OB	Digital repository for mission, map and infrastructure data needed onboard.
ASTP	Continuous absolute train localisation using GNSS, inertial sensing and data fusion.
PER	Perception of obstacles, signals and track-side situations using onboard sensors.
RC	Remote supervision / control for fallback, degraded modes and special operations.

What was the initial demand / problem?

1.Vision for Autonomous Mobility

2. Understanding Depot Complexity

3. Manual and Staff-Intensive Depot Movements

4. Operational Bottlenecks Revealed

5. Automation Retrofit Challenge



D3 Urban

What are our KPI's?

TECH. READINESS

- Remote driving: TRL7
- Latency: 340–380 ms (<400 ms)
- Availability: ≈0% failure rate

OPS VALUE

- Operator quality: 4/5
- Image quality: 4/5
- Safer working areas & Reduced time-to-service

STAFF PRODUCTIVITY

- Shunting: +10–15%
- Preparation: +50–70%
- Parking: +10–15%
- Shunting: 20%

Holtet Depot at Oslo

WP41 demonstration at ERJU booth
Innotrans 2024

Project Outputs

- Two Sporveien SL18 units) prepared as tram-labs: mechanical/electrical modifications, enabling technology, monitoring, communications and approvals.
- CERES remote operation centre, onboard/ground VPN communications, video streaming and TCMS/telecommand interfaces integrated for remote driving.
- CAF-STR testing framework defined roles, risk controls, configuration management and reports across auxiliary circuits, static functional and dynamic functional tests.

- Real-environment remote driving, including Oslo–Berlin demonstrations, confirming functional compliance and providing operator/system KPI evidence.
- The autonomous operation centre builds incrementally: missions are commanded from CERES/ground systems and executed by the tram under supervision.
- Result: a scalable depot automation path that reduces staff reaction time and physical intervention while improving safety, availability and productivity.

From Oslo demonstrations to tomorrow's cities: accelerating the journey toward autonomous, efficient, and competitive urban mobility.

What was the initial demand / problem ?

D4 Mainline

What are our KPI's ?

CAPACITY

estimated capacity
improvement
10%-15%

ENERGY

estimated energy
consumption reduction
by 10%-15%

PUNCUALITY

Estimated punctuality
improvement by
10%-15%

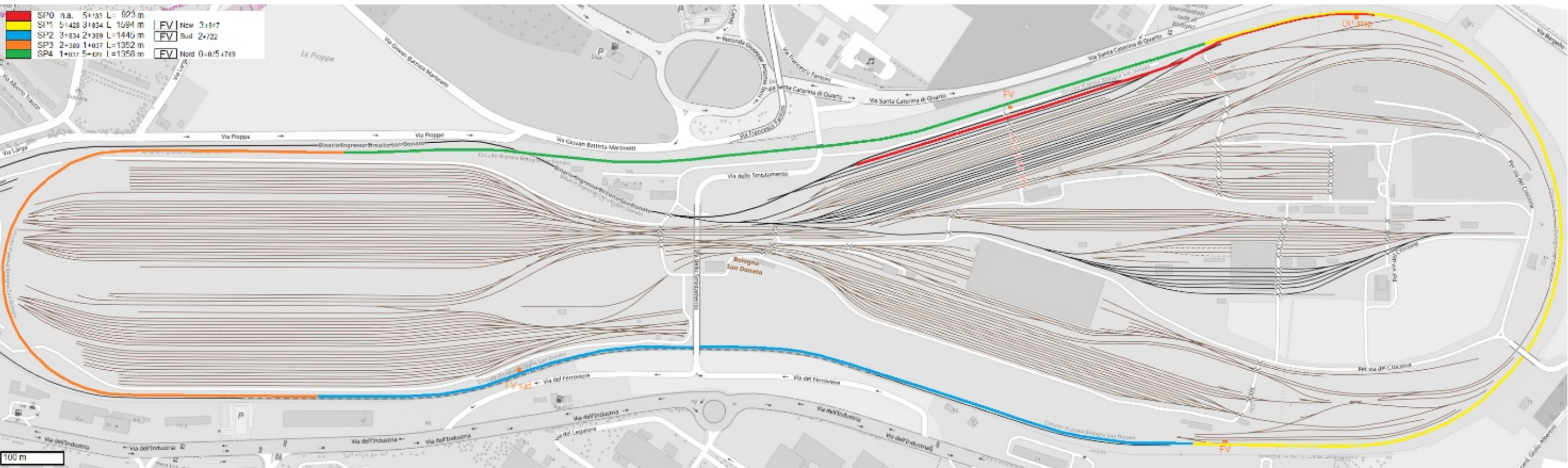
Estimation based on the assumption that the railway service to be performed in a pure ERTMS L2 (or L3) framework by all train (and trackside) equipped by ATO over ERTMS with GoA 3/4

1. The major requirements of infrastructure providers are to increase capacity, lower operational/lifecycle costs

2. Prepare to demonstrate the solutions DATO over ERTMS technology can bring to relieve bottlenecks in main lines in high-density networks with heterogeneous traffic. This complexity is typically present in nodes and junctions.

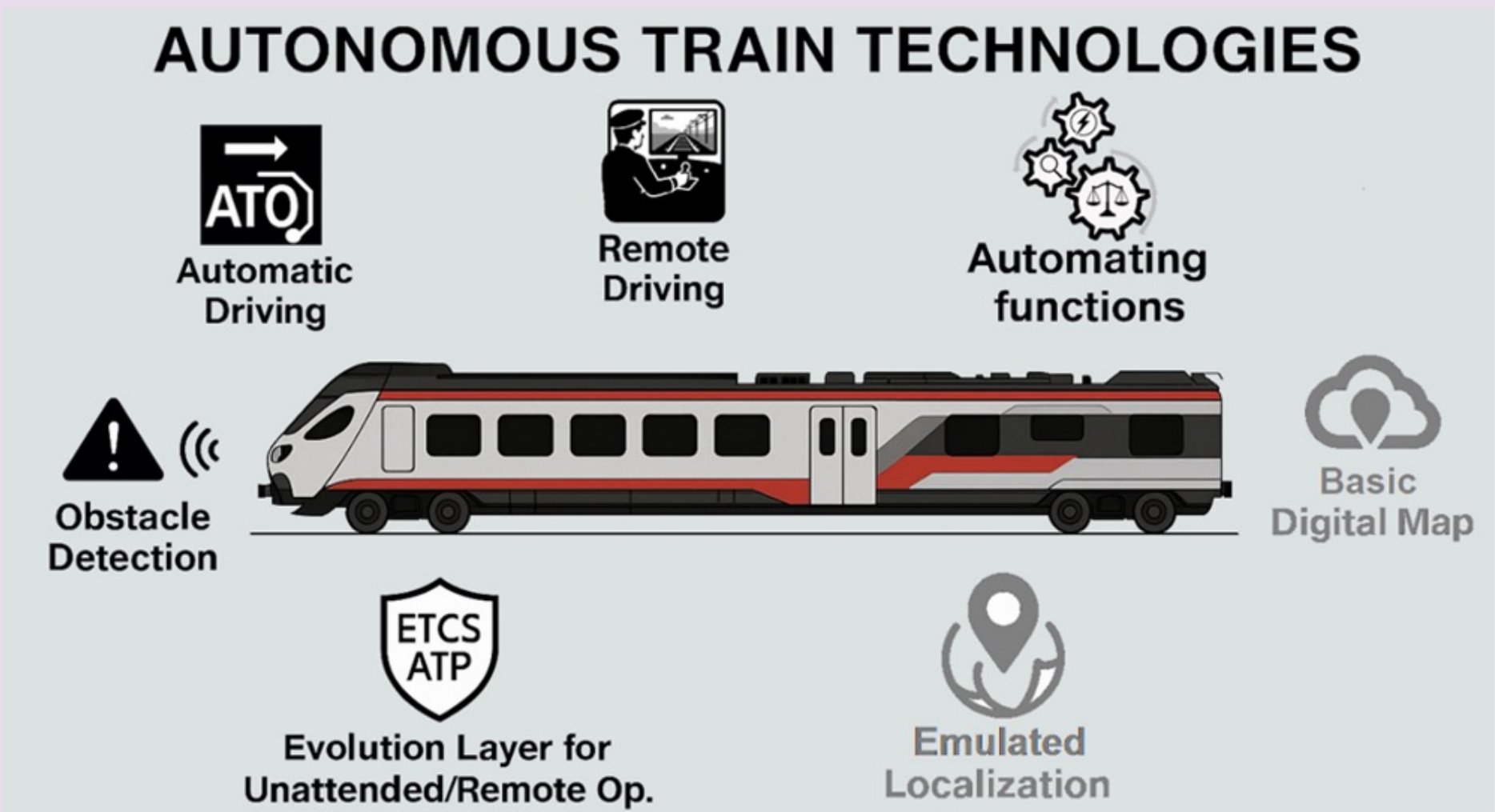
3. elements. Showing the relevant advantages deriving from the synergy between the digital automatic train operation up to GoA 4 and the CCS evolution, increasing the capacity and punctuality of railway lines, with minimum infrastructure

	ID	Begin	End	Length	Stopping Points
	SP0	n.a.	5+133	923 m	
	SP1	5+428	3+834	1594 m	OP-stop 5+158; FV (New) 3+847
	SP2	3+834	2+389	1445 m	FV (Sud) 2+722
	SP3	2+389	1+037	1352 m	
	SP4	1+037	5+428	1358 m	FV (Nord) 0+0/5+749



What is our solution ?


- S.Donato test ring and Blues hybrid train have been equipped according to the R2DATO reference architecture with the following Technical Enablers:
 - TE1 – Automatic functions,
 - TE4 – ATO technology,
 - TE6 – Perception,
 - TE7 – Remote driving.
- Integration Laboratories integration activities mainly performed in the lab allowing to dedicate train and railway asset only for evaluating DATO functions and the related operational impact.
 - ATO up to GoA4 –CCS
 - Remote Driving –CCS
 - ATO up to GoA4 –TCMS
 - Remote Driving –TCMS
 - Deployment in the hardware platform





- Testing TE vs Train operation:
 - train preparation
 - leaving the depot to reach the first station.
 - ending train service: service retention/energy saving/shutdown
- Monitoring of Commercial Service for Energy Saving
 - acquisition campaign was carried out to analyse driving styles during commercial service operations on a Blues train-CCS
 - Estimation of Automatic Driving benefit.
- Test specification definition of DATO and TMS interface for mainline operations and the corresponding best practices development of mainline capacity assessment, including the testing Operational Concept, based on demonstration results together with FP1.


What was the initial demand / problem ?


- European railways face increasing pressure to modernise signalling.
- The challenge is to increase capacity while maintaining safety and avoiding costly investments in new infrastructure.
- The technology has been demonstrated since 2016. However, it is not deployed yet to a lack of a clear and structured deployment strategy.


**Increase capacity**
More trains, same infrastructure

**Integrate innovation**
Smooth upgrade & simplified rules

**Lower costs**
Reduce operational & lifecycle spend

**Reduce development efforts**
Simplify development & migration complexity

**Optimise deployment strategy**
Faster planning & deployment


**Guarantee safety**
Maintain & enhance safety


D5 ETCS Hybrid Train Detection

What is the impact ?






- Accelerated Deployment: Reduced time-to-market for digital signalling through standardised migration strategies.
- Cost Efficiency: Reduced physical trackside infrastructure costs.
- Justified Benefits: Capacity and Robustness gains with specific design configurations.
- Operational Readiness: Roadmaps and deployment strategies for 5 market segments.

What are our KPI's ?

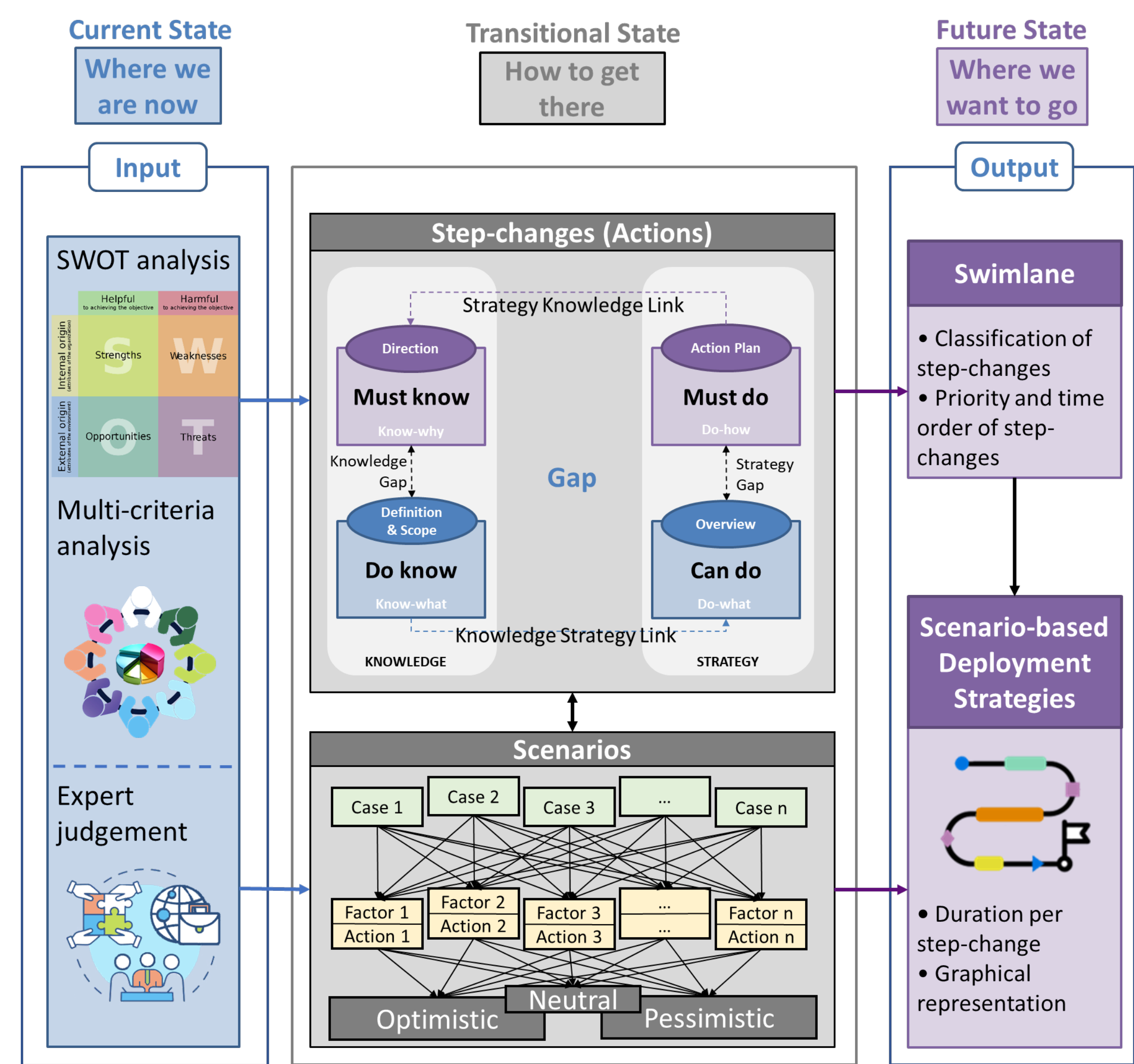
**★ MAJOR KPI**
Capacity
Increased line throughput without full infrastructure overhaul, represented by the relative available capacity utilisation.

**★ MAJOR KPI**
Cost
Reduced Lifecycle costs of railway signalling assets : Capital Expenditure (CAPEX) and Operational Expenditure (OPEX).

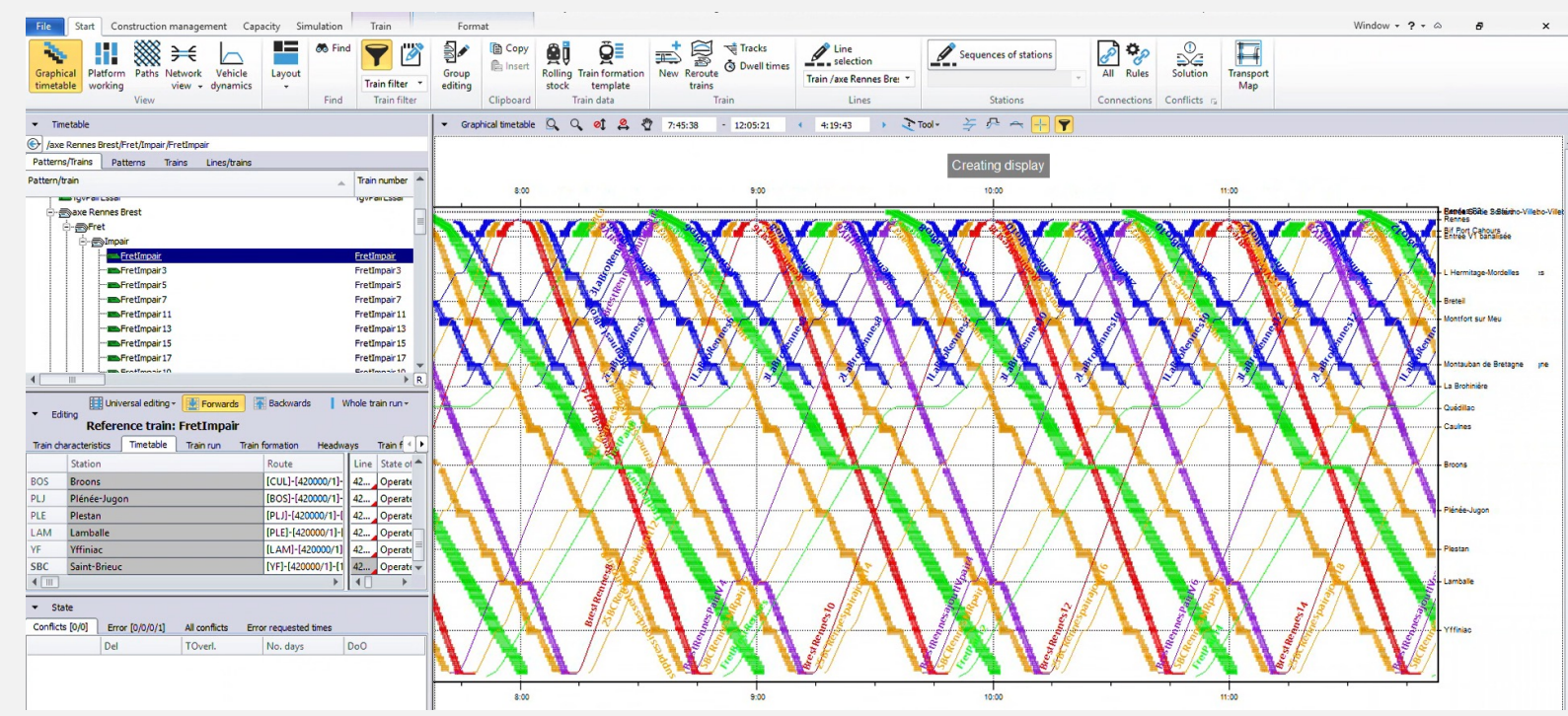
SUPPORTING

-  Robustness
-  Reliability
-  Safety
-  Energy consumption
-  Standardisation / Harmonisation

Results based on 48 Railway Experts and Decision Makers from 16 Countries.



EXAMPLE OUTPUT



Criteria Weights	
Cost	21%
Capacity	25%
Robustness	15%
Reliability	16%
Energy consump.	7%
Safety	11%
Standardisation	5%



5 RAIL MARKET SEGMENTS



14 CASE STUDIES (55+ SIMULATED SCENARIOS)



What is our solution ?

- Accelerated HTD deployment to unlock benefits earlier and reduce infrastructure costs.
- Detailed capacity and cost evaluation across 14 European case studies.
- Wholistic multi-disciplinary analysis for 5 rail market segments.
- Scenario-based deployment strategies using SWOT, Multi-Criteria Analysis and expert input through a survey and multiple workshops.
- Five strategic dimensions (Why, What, Who, Where, When) mapped to concrete step-changes across operational, technological and business domains.
- Phased implementation with optimistic, neutral and pessimistic timelines.

Moving Block Project in a Nutshell

Moving Block Demonstrator

Comprises three integrated subsystems:

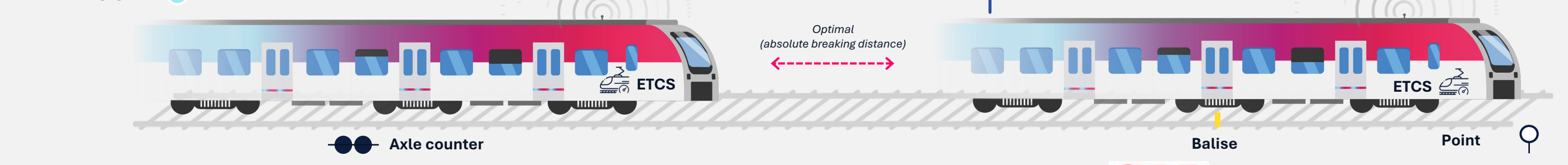
- PES: Submits requests to the ETPS
- ETPS: Processes requests, controls field elements, and ensures train protection
- DR: Provides PES and ETPS with the required topology data
- Communication: In the test field via 5G / FRMCS

Test Environment

- Laboratory environment in Berlin
- Test site in the Erzgebirge region, including:
 - Field elements / EULYNX OCs
 - Two trains w ETCS OBUS
 - Balises

Releases:

- R1: Control and supervise point in the field
- R2: Handling of trains and authorise train movements
- R3: Moving Block & Train manoeuvres
- R4: Restriction Areas & Degraded Situations
- R5: Shunting

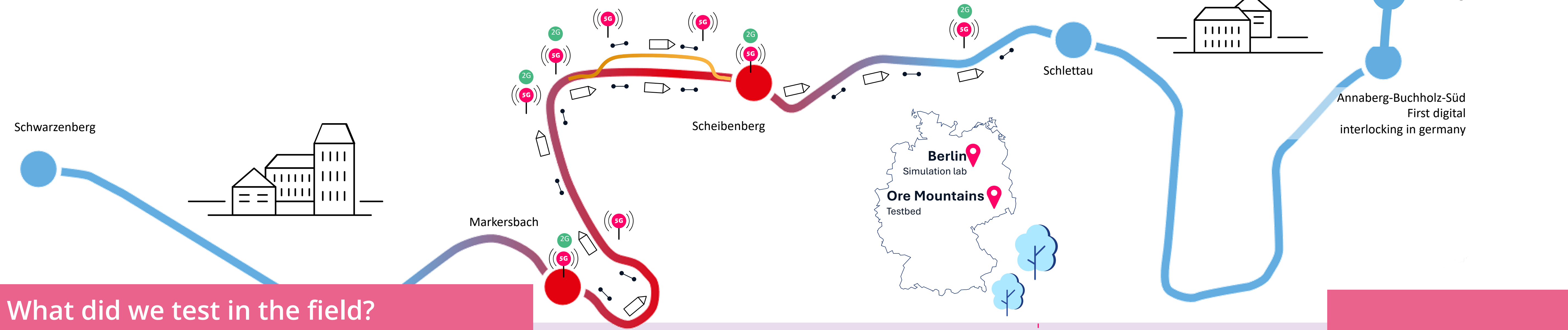


Project Team **DB InfraGO** **SBB CFF FFS** **ÖBB INFRA** **HITACHI**

D6 Moving block

Benefits + Features of Demonstrator

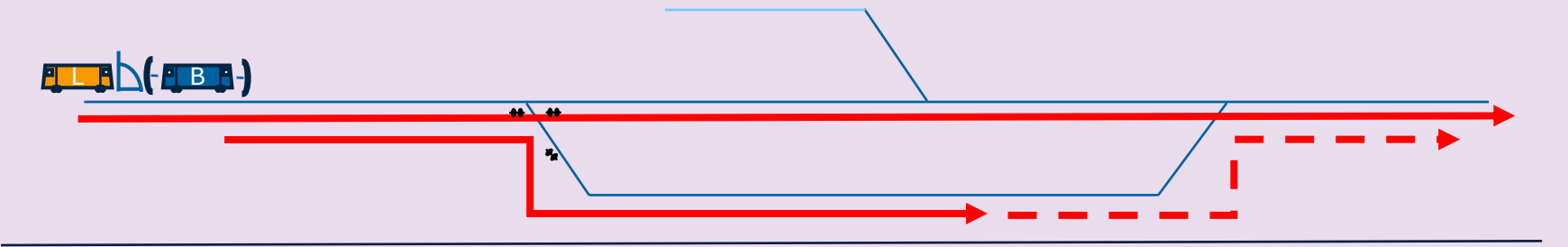
- Optimized **mix of train capabilities** (integrity monitoring and safe train length) and **trackside equipment to provide desired line capacity**.
- The Moving Block Demonstrator validates the adoption of new technologies and concepts, such as **the generic safety logic** leading to a **reduced data preparation** effort and enabling **track reconfigurability**
- The work is highly **aligned with System Pillar Architecture** and **validates the harmonized railway operation concept and system architecture**



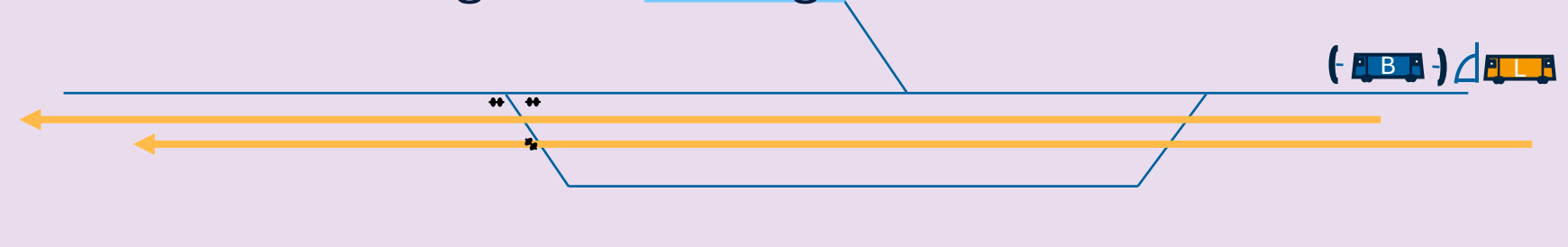
SCAN ME FOR PROJECT VIDEO

What did we test in the field?

Scenario 1: Overtaking with TIMs, less Axle Counter



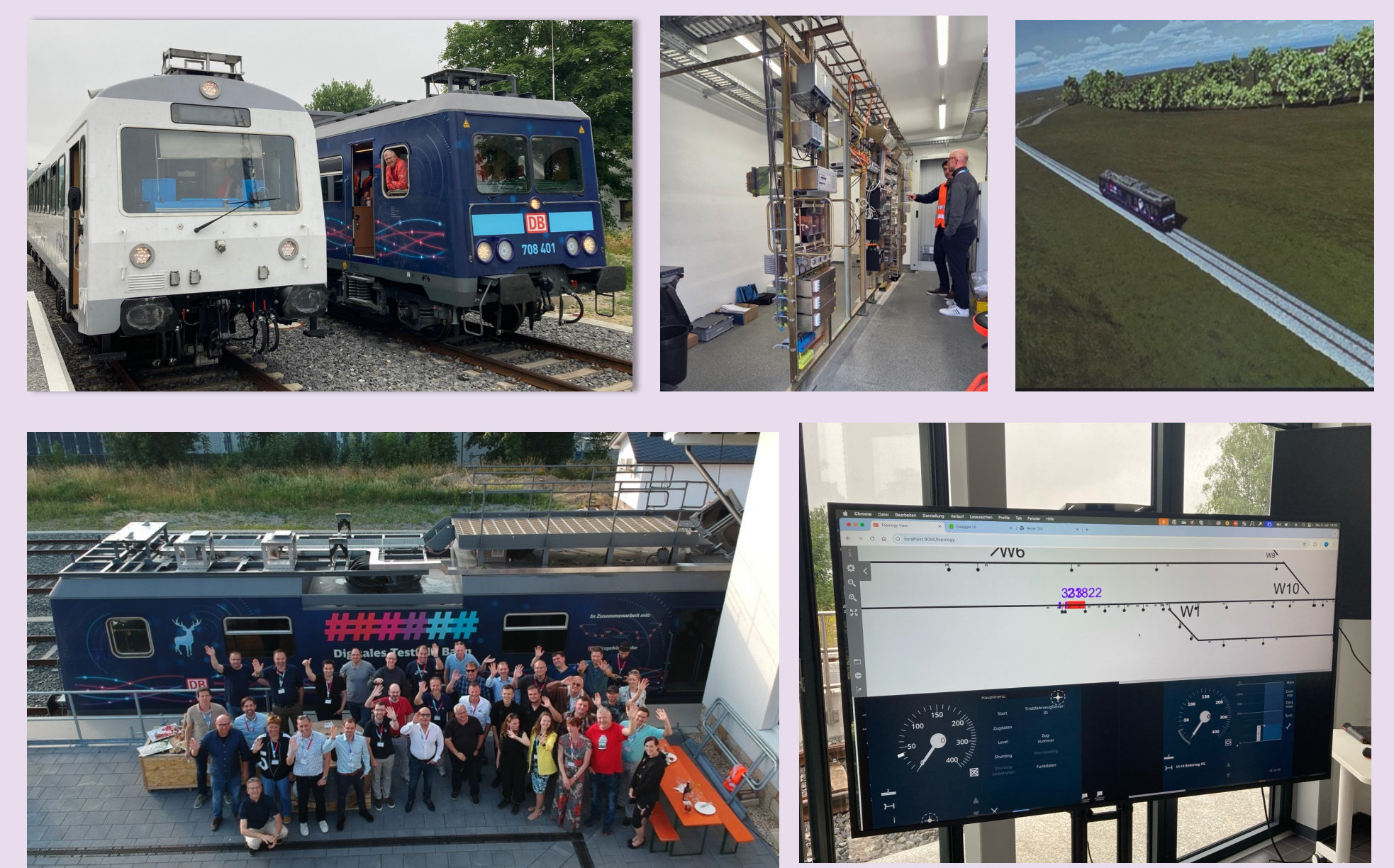
Scenario 2: Moving Block Driving



Scenario 3: Overtaking without TIMs, more Axle Counter

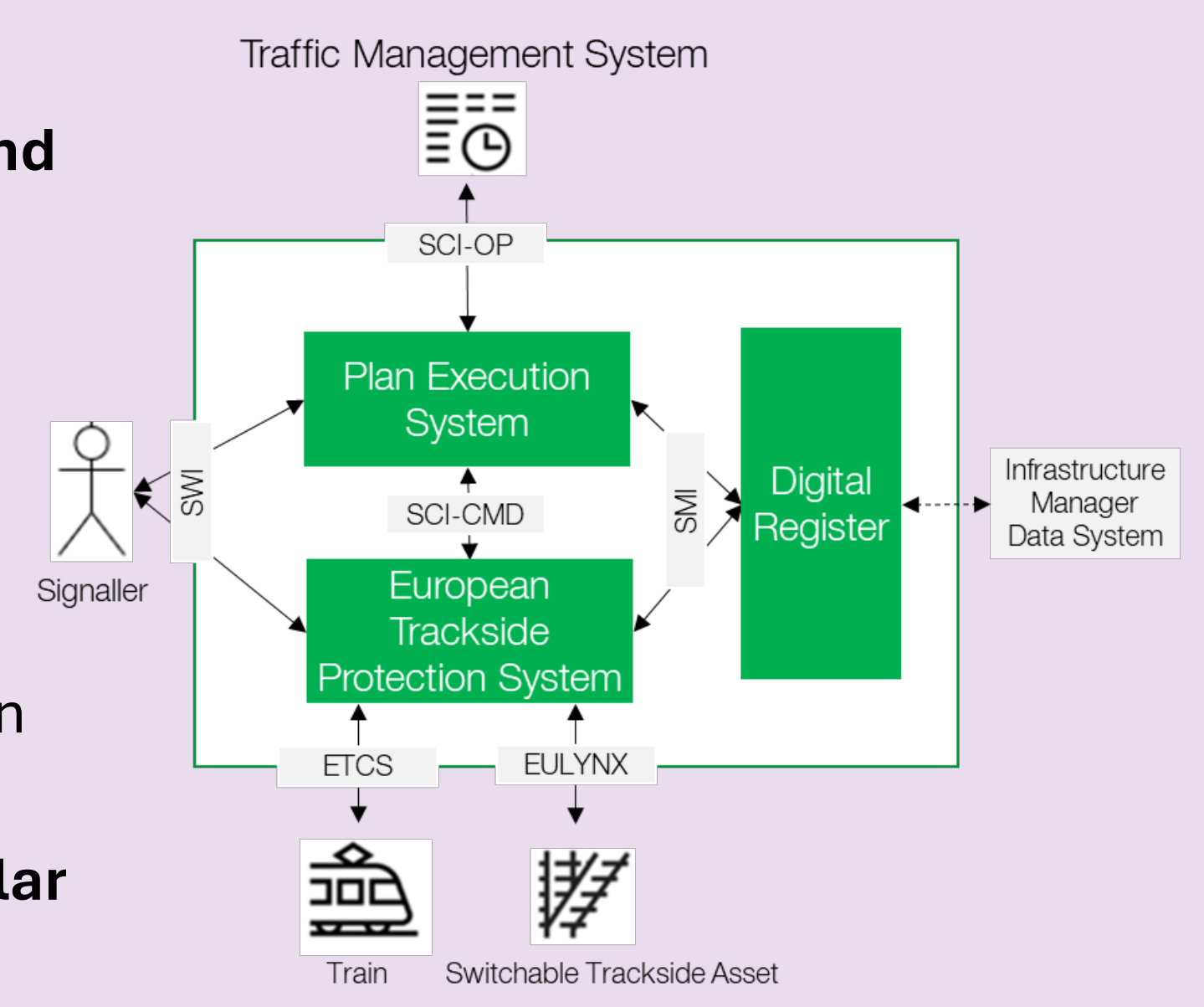


BR708
Lucy
Breaking Distance
Vehicle with TIMs



What did we achieve?

- Deployed prototype wayside safety systems for **ETCS Level 2 Moving Block (w/o TIMS) in lab and test field (TRL 6)**
- Realised the **System Pillar's agreed system architecture** and **ERA aligned TMS/CCS data model**
- Implemented **geometric safety logic** (reduced engineering effort, generic safety approval, and increased capacity while reducing trackside train detection)
- Provided **system specifications for System Pillar standardisation**

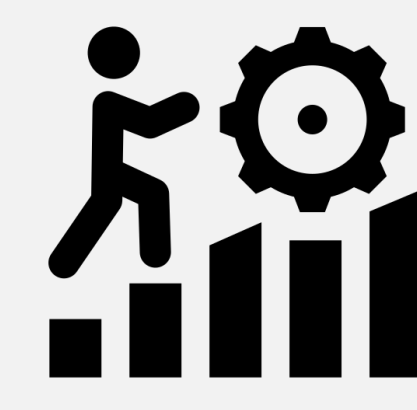


What was the initial demand / problem?



Repositioning

Significant time is required for repositioning staff by walking/traveling between tasks.



Operational Resilience

Last minute changes to asset deployment (e.g. replacing a faulty train) are difficult under the current shunting process.



Technical Maturity

Applying new technologies in real-world operational environments is essential to improve technical standards and prepare for future deployments of RTO, remote fallback solutions and GoA4.

D7 Stabling / Shunting



What did we deliver?

KPI Input

D38.9 investigates the potential benefits of staff productivity that remote driving can bring as a stand-alone concept. This is done using simulations of RTO in real-world scenarios.

Test Results

Five deliverables covering operational lessons, technology performance, and human-factors findings from RTO and ATO field tests.

Training Materials

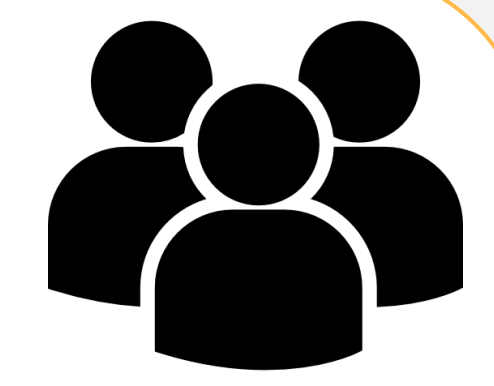
D38.1 provides training materials for remote drivers and provides feedback from applying the training to regular train drivers.



Findings

Human Factors

Human-factors insights on the challenges of remote train driving.

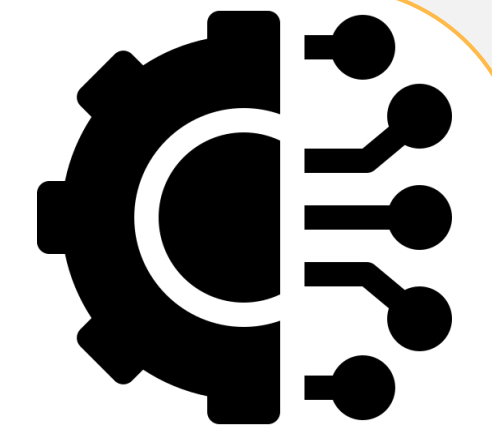


Key topics to address in future projects include:

- Workload and fatigue
- Motion sickness
- Perception of speed, acceleration and distance
- Situational awareness

Technical Readiness

Demonstration of technical functionality in real-world shunting and stabling scenarios.



Demonstrating the feasibility of various remote shunting and stabling functions at TRL 6 in nominal operating conditions.

Test scope

Key use cases	RTO	RTO-GoA2	ATO-GoA4	RTO
Preparation				
Shunting				
Mainline stabling				
Station halting				
Obstacle detection				
(Un)coupling				



1. Generic introduction (WP, Shunting/Stabling, applied technologies, two demonstrators, deliverables). ~5 min
2. Explanation of SBB demonstrator (Scope (shunting), Technical implementation (RTO, retrofit), Test approach / goals, Results
3. Explanation of NS demonstrator (Scope stabling/shunting), Technical Implementation (ATO-GoA4 + RTO), Test approach/goals. Results

- In summary
- Across both NS and SBB demonstrators, the picture is consistent:
- Technically, remote operation works in real mixed-traffic environments and shunting yards with manageable latency.
- Human-factor wise, the main challenges are:
 - increased mental workload,
 - distance and speed estimation,
 - signal recognition and colour fidelity,
 - lack of physical feedback and altered fatigue patterns,
 - and the need for specific, structured training.
- Both projects provide converging recommendations:
 - improve cameras and HMIs (especially speed, distance, and signal visibility),
 - consider adding audio/haptic feedback,
 - design remote-specific training and procedures,
 - and further research human performance and fatigue for longer-term, large-scale deployment.

What was the initial demand / problem ?

- CCS-on-board systems are traditionally monolithic and vendor-specific
- Evolution, integration, and migration require high engineering and certification effort
- Limited reuse of software and hardware across fleets
- Rising complexity driven by digitalisation, FRMCS, automation and future operations
- Resulting in high lifecycle cost (CAPEX & OPEX) and slow innovation cycles

➔ **The railway sector requires modular, interoperable and evolvable onboard architectures**



What is our solution ?

WP36 demonstrates a modular, multi-vendor onboard platform architecture that:

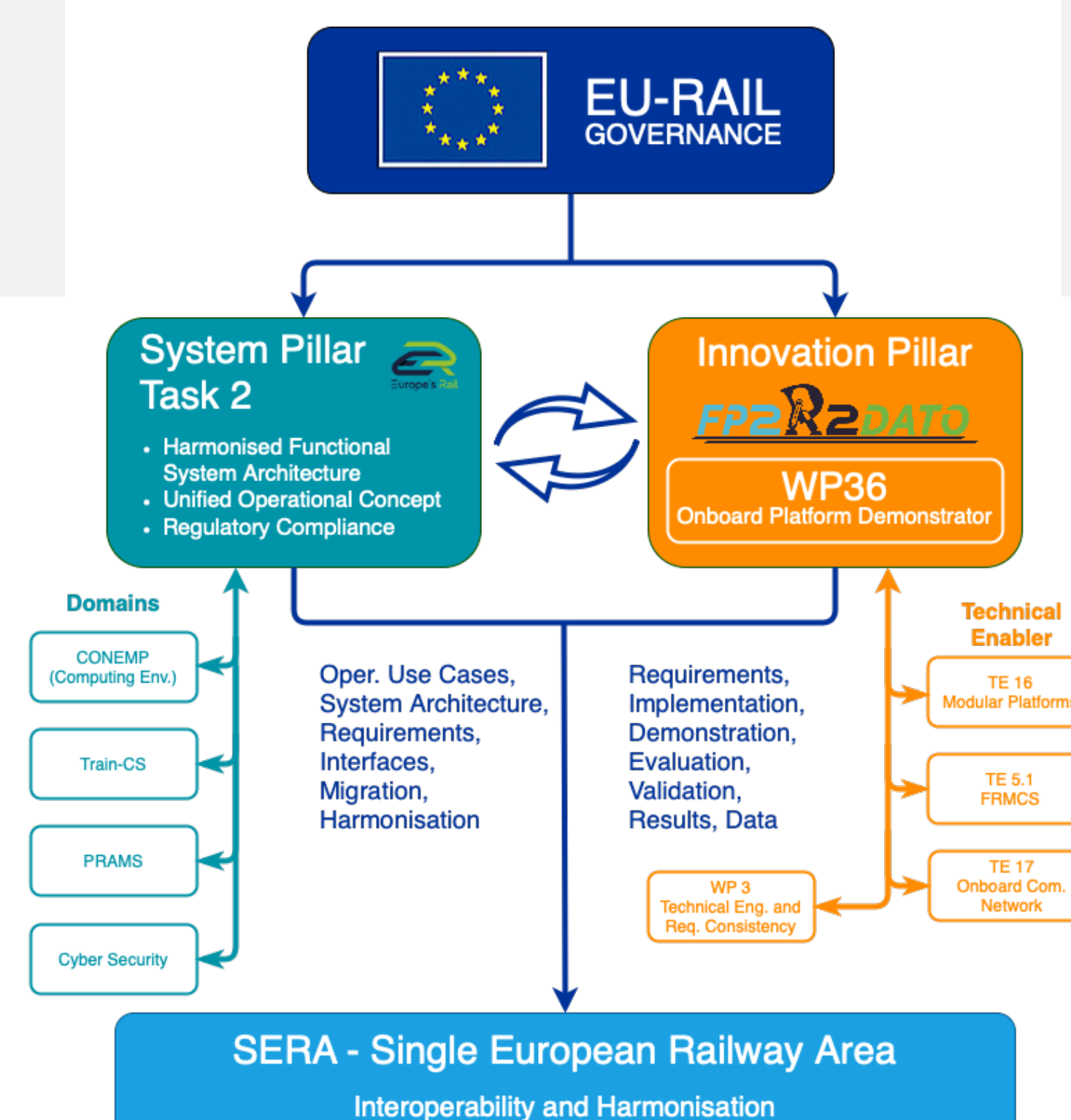
- Hosts mixed-criticality applications (up to SIL 4) on COTS-based computing platforms
- Enables supplier-independent integration and migration of onboard functions
- Integrates FRMCS-based onboard-trackside communication with platform-managed redundancy
- Provides harmonised diagnostics and TCMS data services
- Is aligned with R2DATO WP3 architecture and ERJU System Pillar concepts

➔ **Results consolidated into the first Onboard Platform Blueprint for future EU-RAIL phases**

Key Take-Away

WP36 proves that modular, multi-vendor onboard platforms are technically feasible, system-compatible and a key enabler for reducing CAPEX/OPEX while evolving CCS-on-board towards future European railway needs.

D8 Onboard Platform



What are our KPI's ?

Staff Productivity

WP36 contributes qualitatively and structurally to:

- Reduced engineering and system integration effort
- Reduced maintenance effort
- Reduced product development and certification costs
- Increased reuse and standardisation of onboard solutions
- ➔ **CAPEX reduction** (reuse, modular design, simpler certification)
- ➔ **OPEX reduction** (maintenance, updates, evolution over lifecycle)

Impact for the sector

- Clear migration path for CCS-on-board evolution
- Improved maintainability, availability and lifecycle efficiency
- Reduced dependency on vendor-specific solutions
- Decoupling of applications from hardware
- Lower entry barriers and reduced certification overlap
- Support for interoperable European CCS ecosystems

Key technical achievements

- Modular Platform validated (TRL 5–6)
- Deterministic execution, replication (2oo3), robust failover
- Multi-vendor hosting including third-party ETCS application
- FRMCS integrated end-to-end
- OB-App interface abstracts radio specifics from applications
- Transparent recovery without interruption of ETCS communication
- Diagnostics & Train Integration
- SOVD-based diagnostics architecture
- TCMS Data Services enabling condition-based maintenance
- Resilient onboard communication network
- Ethernet-based CCS Consist Network with redundancy
- Stable operation in degraded and failure conditions