



Sara Soltani, SIEMENS

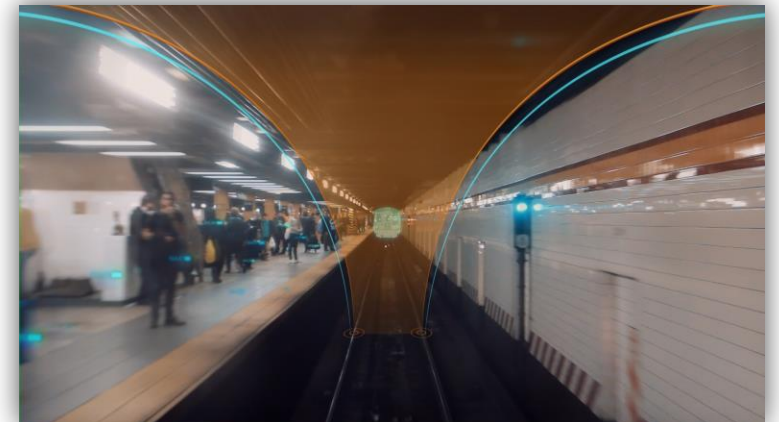
Future Train Control and Automation



Funded by
the European Union



***GoA4 is already the state-of-the-art!
(Nuremberg, Paris, Copenhagen &
many more Urban Metro Operations
are fully automated ...)***



Challenges of the Future:

- *Wireless Communication Infrastructure, e.g., 4G, 5G*
- *Extensive Interfaces & IoT Protocols*
- *Cybersecurity, Safety Compliance & Regulations*
- *Data Management*
- *AI use cases*
- ...



Agenda

- Introduction & Background
- State-of-the-Art, Challenges, and Current Landscape: Key Findings & Results
- Future Metro Control Systems: Architecture For GoA4 Metro Operations
- Future Metro Control Systems: Vision & Path Forward



Introduction & Background

In the Light of NEXUS Objectives

Oct. 24 - Sept. 25

Comprehensive Analysis of Existing and Future Control Systems

- Explore opportunities presented by full automation for improved adaptability and enhanced customer experience [Obj1]
- Optimization of user experience reflecting diverse demographics and travel purposes [Obj3]
- Develop future train control system architecture [Obj5]
- Development of sustainable transport systems [Obj8]

Work Package Leader:

SIEMENS

Participants: AU, STAM, TIS, TUW, UNIGE, VIF, VTU

Feasibility Study

Oct. 24 - Sept. 25

- **Tasks:**

- Analyze current urban train control systems (CBTC, TCMS) & their integration.
- Conduct a feasibility study on automated, fully digital control solutions, focusing on functionality, reliability, maintainability, and availability.
- Develop an architectural framework.
- Assess the feasibility and value of the future control systems by identifying both tangible and intangible benefits.

- **Expected Outcomes:**

- A framework enabling seamless digital train control and operations (Including data communication).
- An evaluation of the feasibility and value of future train control systems based on identified benefits.

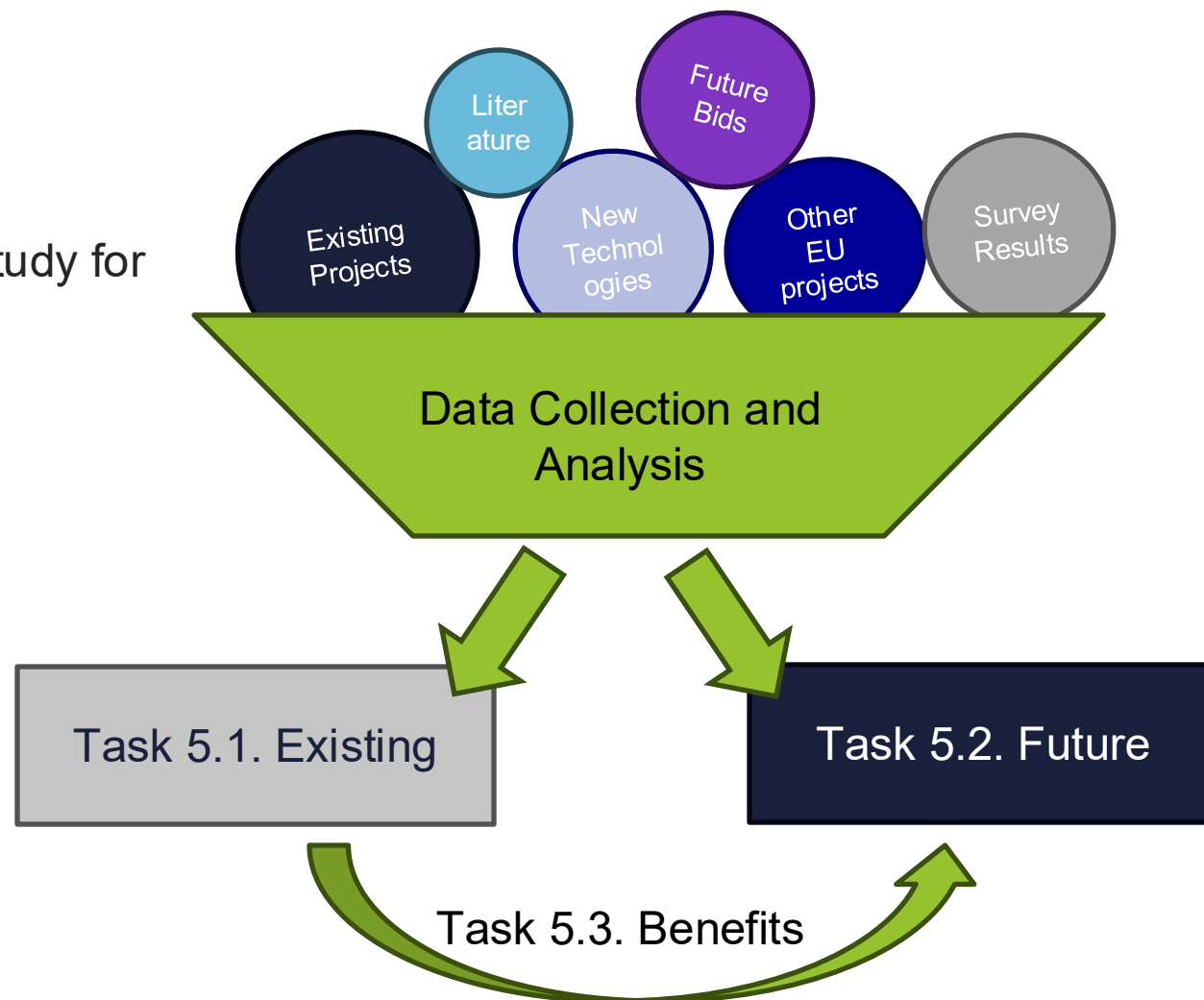
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Methodology

Qualitative Research: *Use Case Study*;

- WP5 delivers a comprehensive feasibility study for next-generation metro control solutions.
- Focusing on
 - Next-generation Technologies,
 - Standardization,
 - Interoperability,
 - Modular architectures,
 - Integration,
 - Communication & Interfaces.
- Final report:

[D5.1 - FUTURE CONTROL SYSTEMS REQUIREMENTS, FRAMEWORK AND BENEFITS.pdf](#)



WP5 – Deliverables, Milestones & KPIs

Future Train Control Feasibility Study

Mil. n.	Title of Milestones	Responsible	Due date	
7	Analysis of <u>Existing</u> Control Systems	SIEM	M08	✓

End of May '25

Del. n.	Title of Deliverables	Responsible	Reviewer n.1	Reviewer n.2	Due date	
5.1	Deliverable D5.1 – Future Control Systems: Requirements, Framework and Benefits	SIEM	UNIGE	UITP	M12	✓

End of Sep '25

Obj. n.	Title of Technical KPI	Criteria
5	Number of key requirements and functional aspects identified for future metro control systems.	≥ 20
5	Number of proposed control systems investigated	≥ 5
8	The assessment of the tangible benefits impacts of NEXUS metro control system.	≥ 7%

The KPIs will be reviewed and adjusted (TIS)



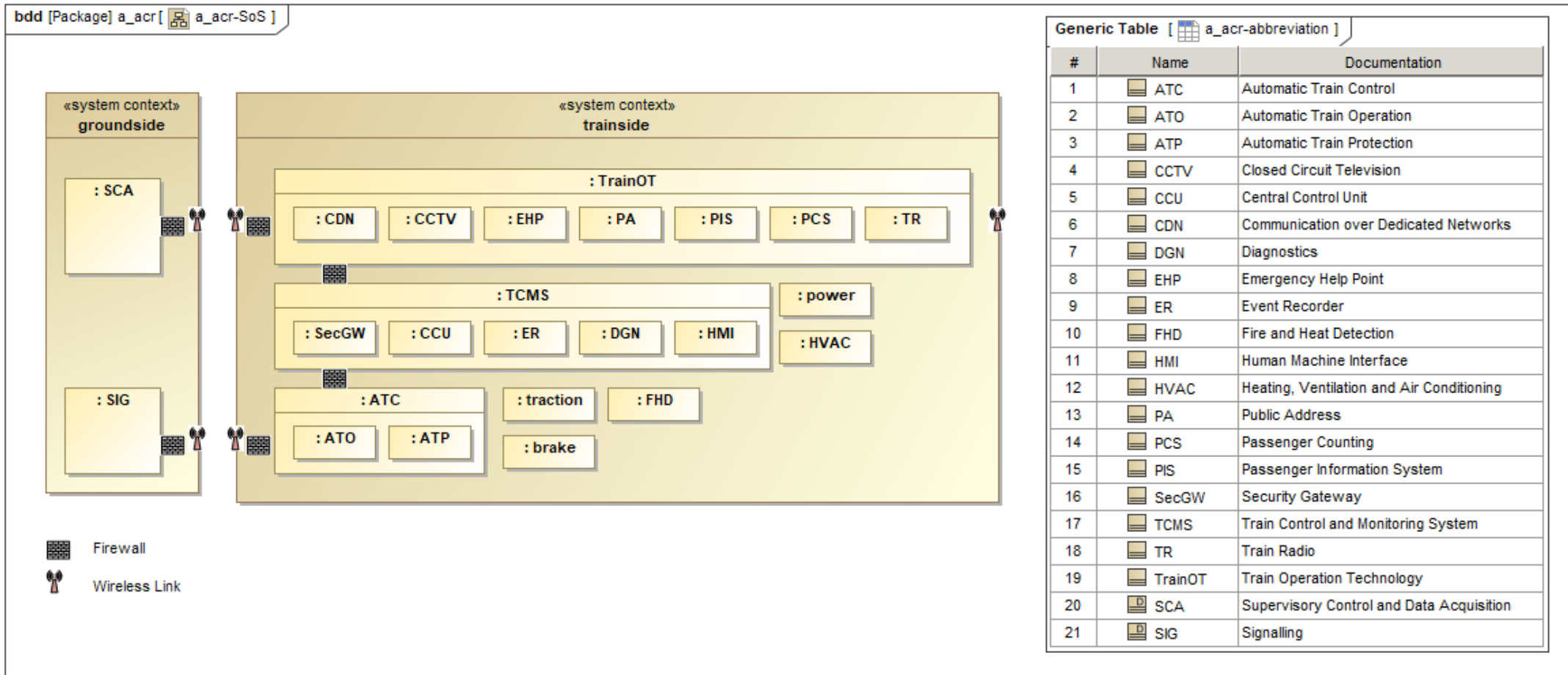
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State-of-the-Art, Challenges, and Current Landscape: Key Findings & Results

Sate-of-the-Art TCMS

- **Centralized Control:** TCMS integrates and coordinates traction, braking, doors, HVAC, and diagnostics.
- **Automation Integration:** Modern TCMS combines Automatic Train Operation (ATO), Protection (ATP), and Control (ATC) with onboard equipment, enabling unattended operation under CBTC supervision.
- **Network Separation:**
 - Vital (Safety-Critical): Deterministic, wired networks (MVB, Ethernet) for emergency stop, train integrity, etc.
 - Non-Vital: Separate Train Operation Network (TON) for CCTV, PIS, Wi-Fi; isolated via secure gateways (SecGW) to mitigate cyber risks.
- **Open Standards:** Interfaces based on IEC-61375-2-3 (2015) ensure interoperability.

Sate-of-the-Art TCMS



Communication & Data Exchange

CBTC & TCMS Connectivity:

- Ethernet and hard-wired connections in the train for critical signaling;
- WLAN (IEEE-802.11) for continuous, bi-directional train-to-wayside communication.

GoA4 Requirements (Expectations):

- Near 100% real-time data availability
- Utilizing both WLAN and mobile networks (4G/LTE, FRMCS).

Reliability Challenges:

- Limited real-time visibility into onboard conditions, despite trains remaining in a safe state.
- Unstable wireless links can degrade performance;
- Cellular technologies (4G/LTE) improve coverage and latency.

T2G Communication:

- Enables remote supervision, diagnostics, and high-bandwidth services (PIS, CCTV).
- Critical signaling (movement, telemetry) remains on CBTC for safety.

Key Results & Insights:

Modernization & Integration:

- TCMS and CBTC integration is essential for automation, safety, and operational efficiency.
- Modern TCMS must support mobile and reliable radio communication for seamless data transfer and interoperability.

Architectural Evolution:

- Modular, scalable TCMS architectures and functional abstraction layers to support flexible train configurations and incremental upgrades
- Open standards (e.g., IEC-61375, OPC UA, MQTT, REST) for interoperability and integration with legacy infrastructure.

Technological Advances:

- Adoption of wireless technologies (WLAN, LTE, 5G), new Ethernet protocols, e.g., TRDP, & Time-Triggered Ethernet (TTE), to enhance performance, stability, and data efficiency.
- Real-time monitoring and diagnostics.



System Complexity & Fragmentation

- Highly customized, operator-specific solutions
- Integration costs and increased system complexity.
- Diverse fleet configurations and legacy systems hinder harmonization and scalability.
- Vendor-specific implementations complicate upgrades and interoperability.



Technical Evolution & Cybersecurity

- Transition to cellular networks (5G/LTE, FRMCS)
- Certification, safety assurance, and compliance with EU regulations.
- Persistent cybersecurity risks.



Standardization & Lifecycle Management

- Modular, standardized architectures remain an active research area.
- Balancing customization with scalability.
- Lifecycle complexity due to fragmented IT systems and evolving technology.



Operational Demands & Automation

- Increased automation (GoA3/GoA4) requires robust, real-time communication and monitoring.
- Cost optimization and migration challenges across heterogeneous fleets.
- Enhanced passenger experience expectations: real-time information, safety, and service continuity.



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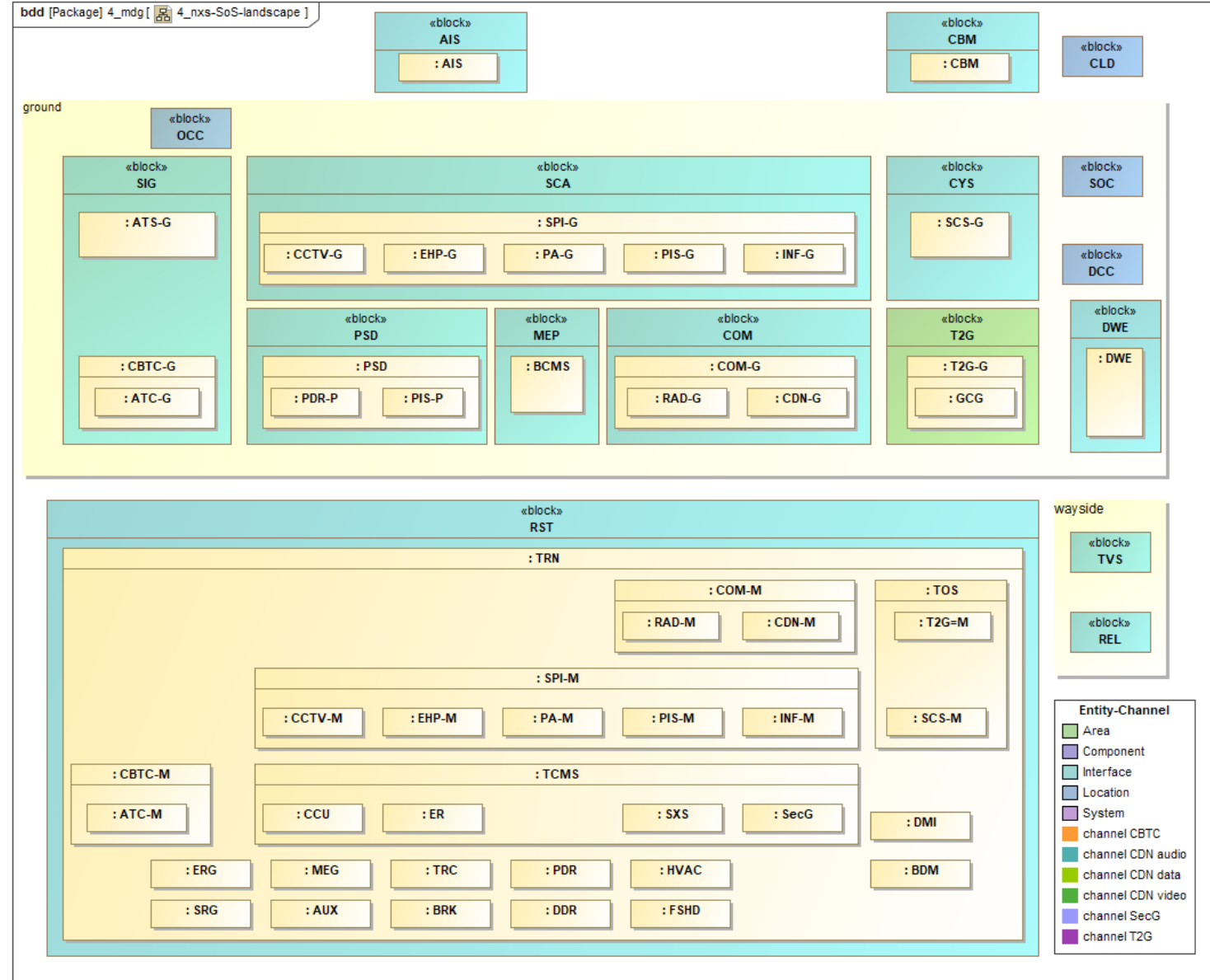
Future Metro Control Systems: Architecture For GoA4 Metro Operations

Core domains:

- **Groundside:** Signaling, SCADA, Cybersecurity, Condition-Based Maintenance, Communication.
- **Rolling Stock (RST):** Train Operation Technology (TrainOT), TCMS, Mobile Communication (CDN-M).

Subsystems include:

- CCTV, Emergency Help Points, Public Address, Passenger Information System (PIS), Human-Machine Interfaces (HMI), Diagnostics (DGN), ATC connectivity.

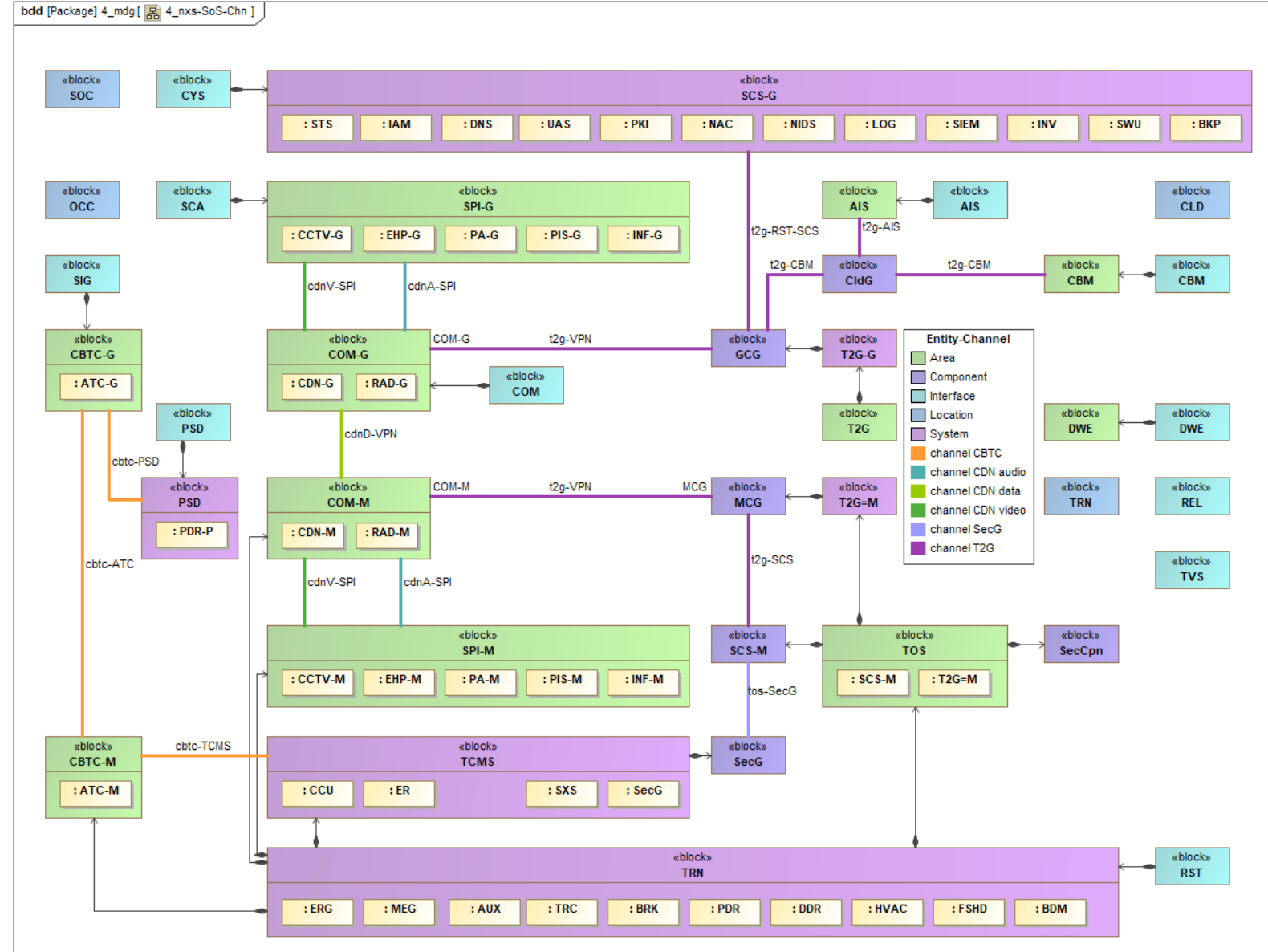


Communication & Integration:

- Data flow via CBTC, CDN (audio/video/VPN), & T2G
- Shared Cybersecurity Services (SCS) and DMZ zones

Cybersecurity & Compliance:

- SL-T per IEC-62443-3-3, & IEC-63452.A
- EU Cyber Resilience Act
- and EU-Rail 2025
- Defense-in-Depth strategy



Protocol Landscape: Use Cases

MQTT:

- Lightweight publish/subscribe protocol for non-critical diagnostics and cloud/IoT data exchange.
- Efficient for low-bandwidth environments and remote monitoring.
- Mentioned in IEC-61375-2-6 (2018).

OPC UA:

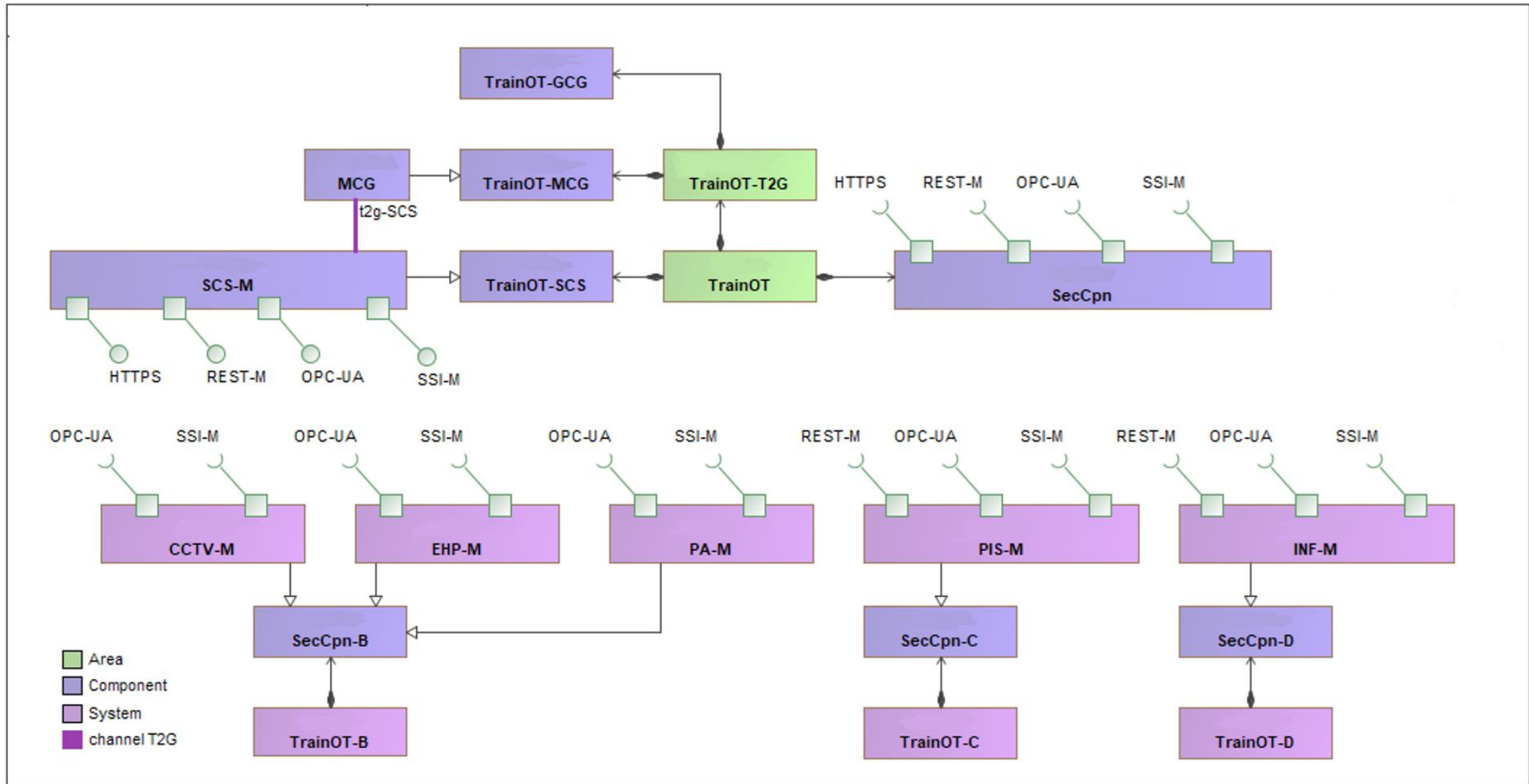
- Enables secure, service-oriented integration between train and groundside systems.
- Ideal for telemetry, SCADA interfaces, and third-party system integration.
- Supports modular architectures and interoperability across vendors.

TRDP:

- Ethernet-based protocol optimized for deterministic, real-time control.
- Used in safety-critical subsystems, e.g., braking, traction, and BCU.
- Supports cycle times as low as 10 ms, modular train configurations, and redundant, secure operation

RESTful:

- Open protocol based on REST principles for web-based communication.
- Facilitates secure transmission of commands and parameters from groundside to train.
- Useful for state-of-the-art system integration and flexible API-based architectures.





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Future Metro Control Systems: Vision & Path Forward

Tangible Benefits

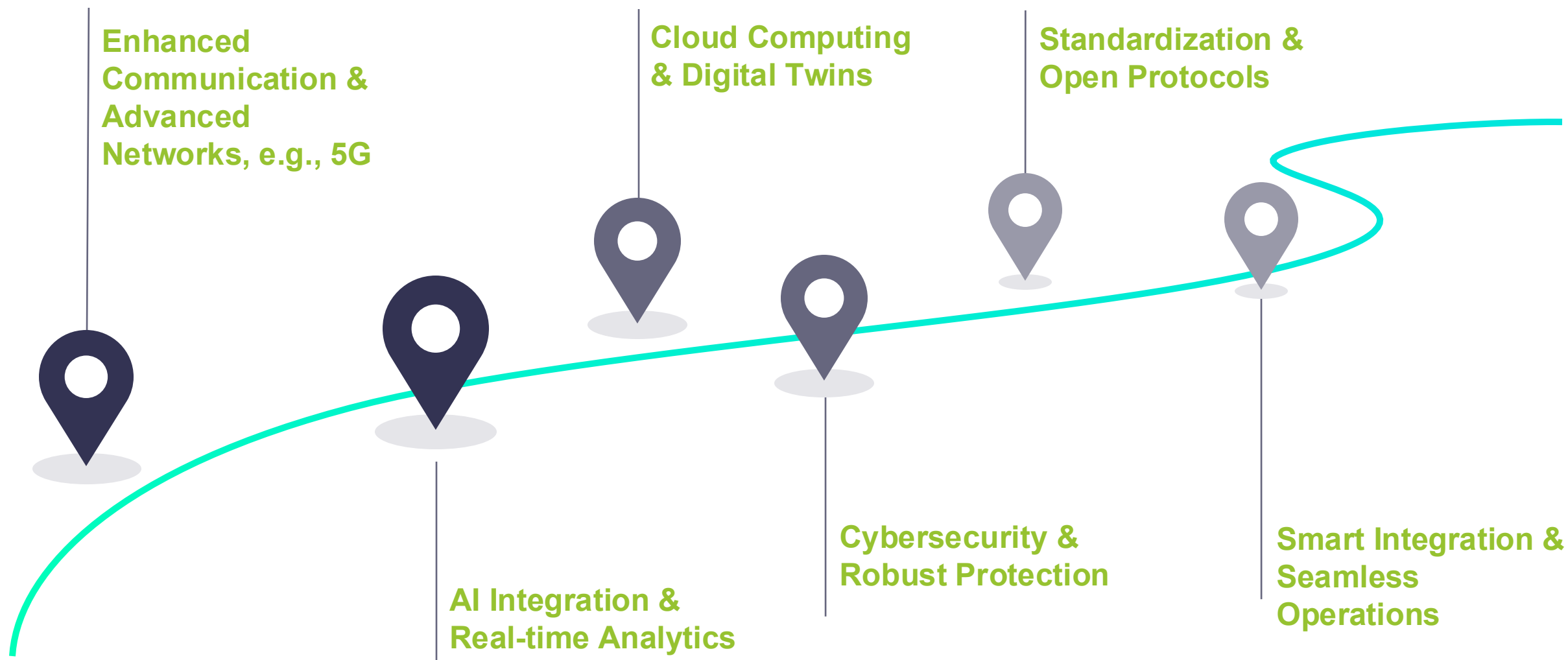
- Enhanced Operational Efficiency
- Smart Diagnostics & Predictive Maintenance
- Energy Consumption Optimization
- Improved Operation & Cybersecurity
- KPI Impact e.g., lifecycle costs

Intangible Benefits

- Passenger-Centric Experience
- Sustainability through efficient resource use & reduced emissions.
- Scalability & Interoperability
- Innovation Enablement: AI, digital twins, and cloud computing

Strategic Recommendations

- **Standardization:** Authorities and suppliers should actively engage in consortia to define open interfaces and common data formats, easing 3rd party integration and aligning metro systems with mainline rail innovations.
- **Invest in robust communication infrastructure:** Plan for future-ready communication infrastructure upgrades to support automation and emerging services when network enhancements are feasible.
- **Leverage data and AI for efficiency:** Metro operators and maintainers should pilot predictive maintenance and smart operational tools, supported by strong data governance.
- **Ensure cybersecurity and safety certification:** A defense-in-depth strategy and early collaboration with certifying bodies are essential for secure, approved innovation.
- **Modular implementation and incremental rollout:** Enables phased transition from GoA2 to GoA4 and supports feature upgrades within GoA4, reducing operational and reliability risks.





The future of metro control systems lies in embracing innovations such as artificial intelligence, big data analytics, and enhanced connectivity while ensuring effective integration into existing systems.

THANK YOU!

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 NEXUS Project

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