

HITACHI

Hitachi Rail - Public

Intelligenza Artificiale come abilitatrice di Guida Autonoma
nel Trasporto Tramviario // AI as an enabler of Autonomous
Driving in Tramway

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Hitachi Rail - Autonomous Drive Solutions

Impact of the tramway context on Autonomous Driving

TRAM OR STREETCAR OR LIGHT RAIL TRANSIT

Environment impact:

- Operation: 'Drive on Sight'
- Right of way: 'integrated on-street', 'segregated on-street', 'off-street'
- Vehicles: 10.000+
30-45 m length
70 km/h max. speed
- Space: mostly urban open spaces



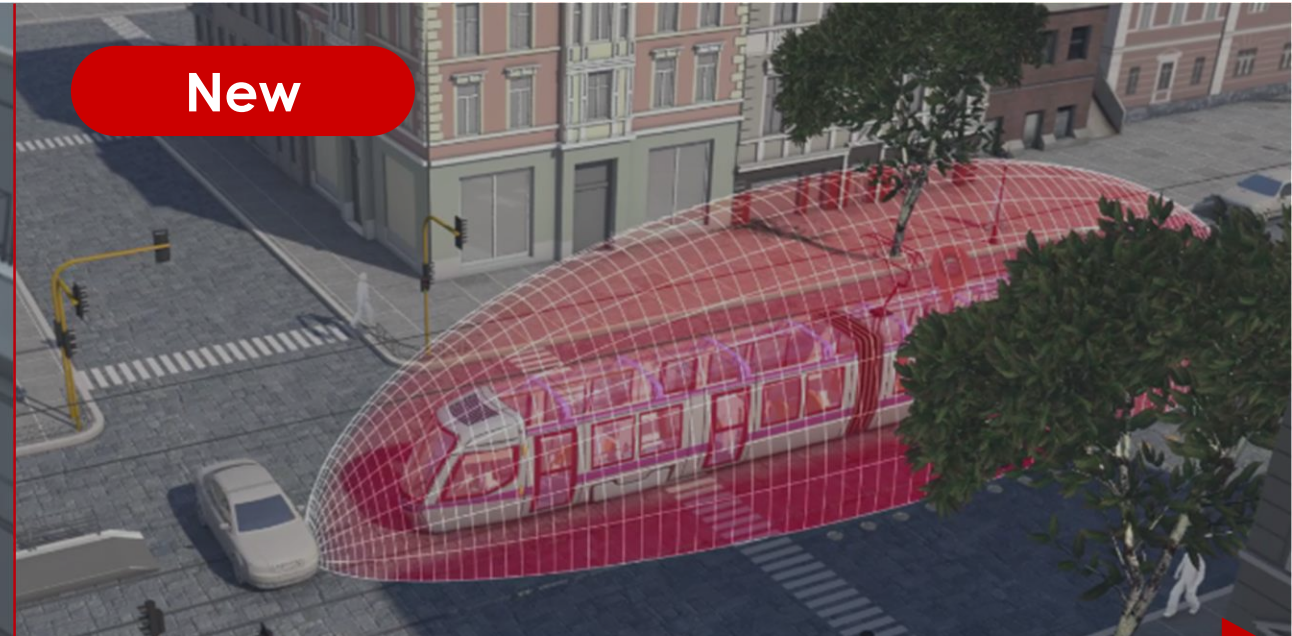
Tram systems are deeply integrated into their surrounding environment

Tram Evolution and Autonomous Driving

Legacy



New

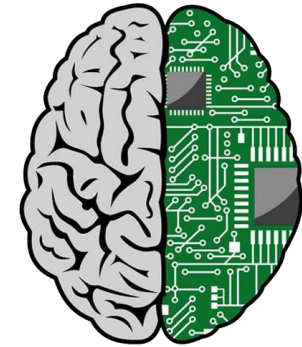


- Line-of-sight driving
- Strongly dependent on wayside infrastructure
- Limited supporting on Safety functions

- Autonomous Driving
- Lightly dependent wayside infrastructure
- Improved situation awareness and Safety

What is Tram Autonomy ?

TRAM AUTONOMY is more a technological journey than a one-shot enhancement



Localization and Mapping

Cloud - Edge

Perception & Environment analysis

Middleware and OS

Generative AI

Decision making

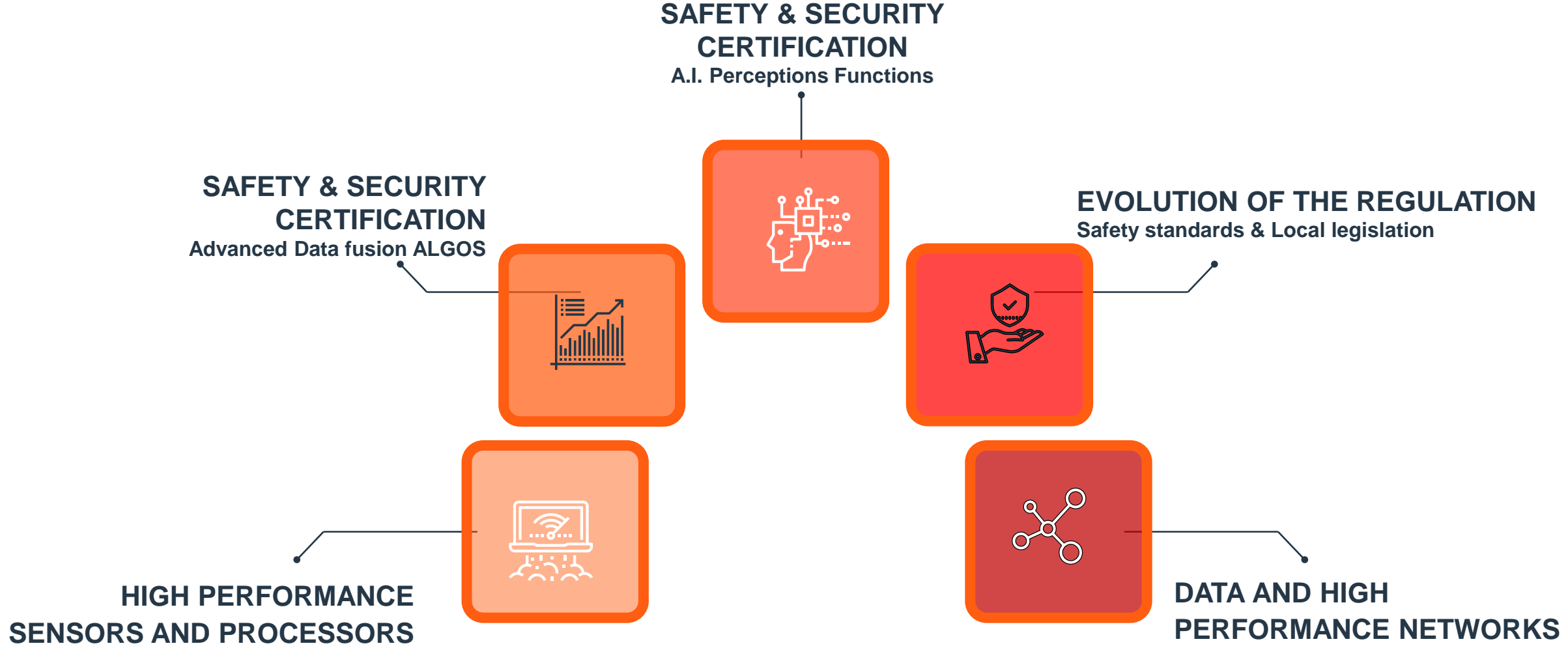
Actuation

High Performance Computing

Driver control

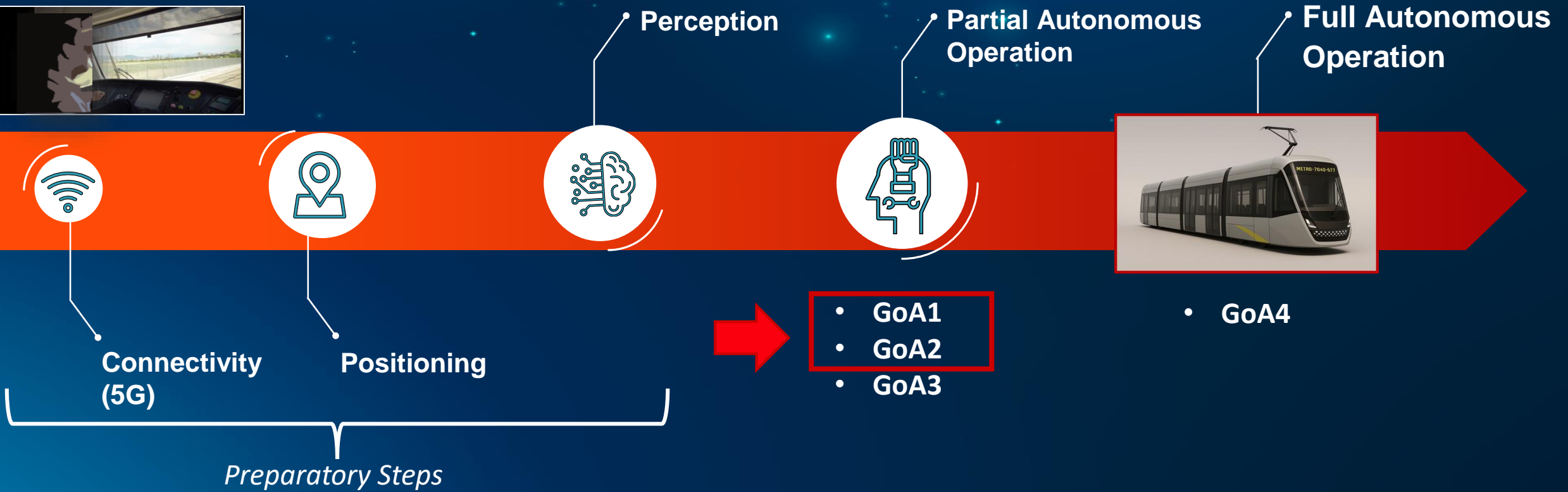
Sensors

Key Challenges



AI as an enabler of Autonomous Driving in Tramway

Urban Transit Evolution ...is built on Autonomy



AI as an enabler of Autonomous Driving in Tramway

Uses Cases for Autonomy: Current top priorities (1, 2, 3)

Use Cases Analysis

- A set of **use cases for autonomous tram operations has been identified**, each with different levels of priority based on technical feasibility and market relevance.
- Additional use cases may be added over time, and **their implementation will follow a gradual, phased approach aligned with evolving market demands** and stakeholder input.

 ENV. MONITORING	 TRAIN WAKEUP	 MISSION CONTROL	 TRACK WORK	 TRAIN INTEGRITY
 DANGER AVOIDANCE	 TRAIN POSITIONING	 TRAIN COUPLING	 VIRTUAL COUPLING	 AUTO TURN BACK
 ZERO HEADWAY	 SIGNAL DETECTION	 DEPOT OPERATION	 OBSTACLE DETECTION	 AUTO LOADING

Market-Driven Priorities

- **Remote Driving**

Centralized control of trams in specific scenarios, such as emergencies or complex intersections. Already requested by operators for increased safety and flexibility.

- **Depot Operations**

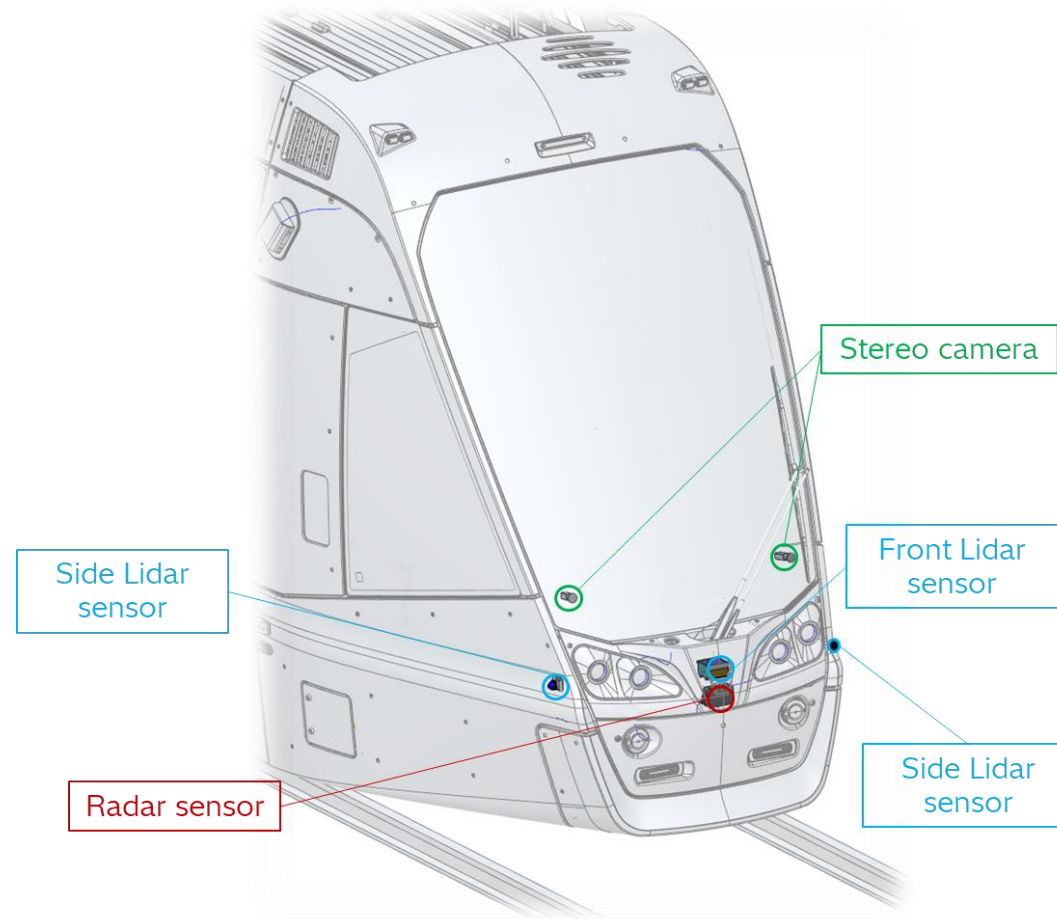
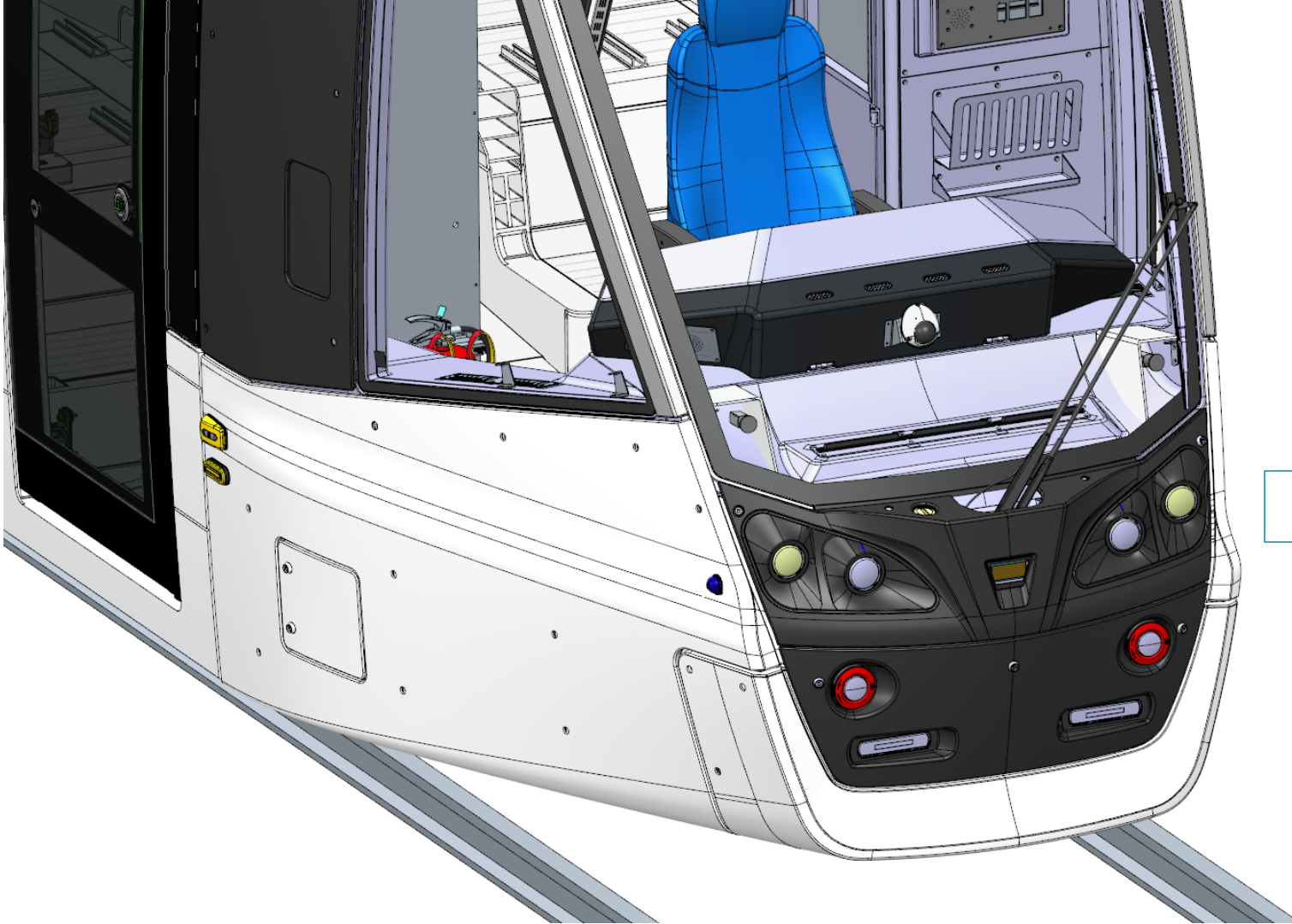
Automation of tram movements within depots for parking and maintenance. Strong market interest due to efficiency and safety benefits.

- **Perception - Forward Collision Warning (FCW)**

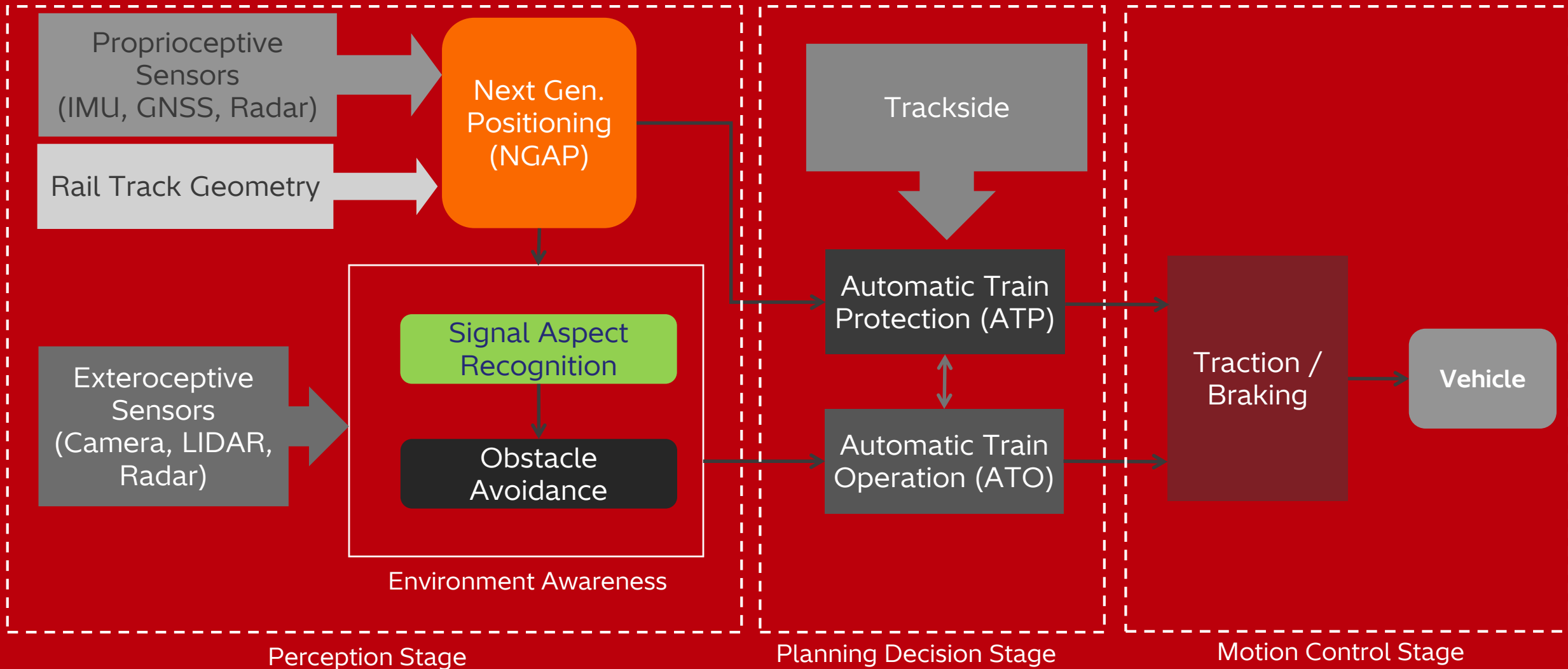
Detection of obstacles with early warnings to prevent collisions. A key safety feature and essential step toward higher automation levels.

AI as an enabler of Autonomous Driving in Tramway

Sensors Installation Studies



Hierarchical Functional Architecture

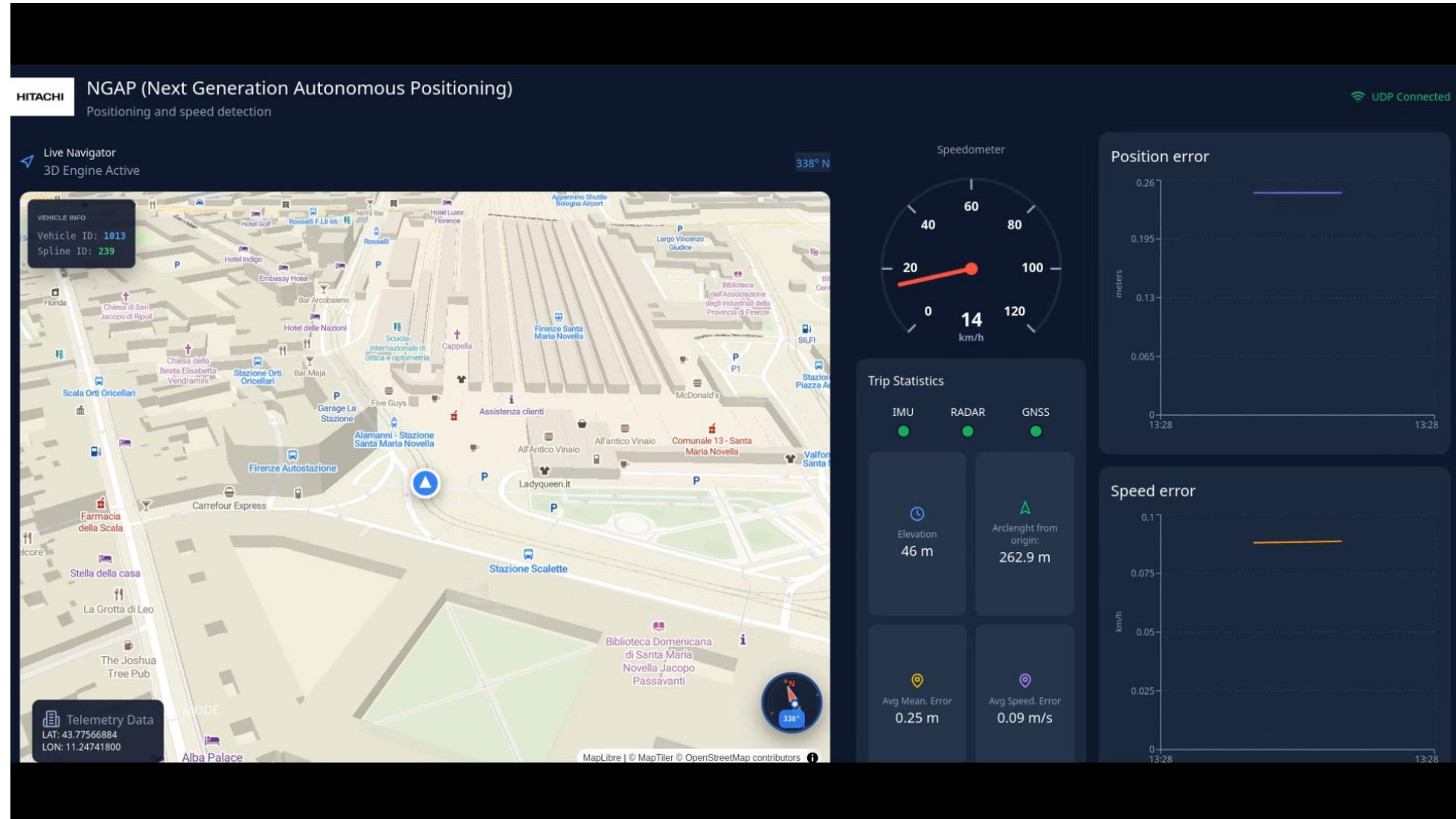


AI as an enabler of Autonomous Driving in Tramway

Next Generation Autonomous Positioning (NGAP)

Accuracy and Safety in Positioning

- Integrates sensors (IMU, radar, and GNSS) with the digital map
- Cutting-edge sensor fusion algorithm to provide highly accurate positioning
- **All processing is done directly on edge (on-board)**, enhancing responsiveness and minimizing dependence on remote connections.

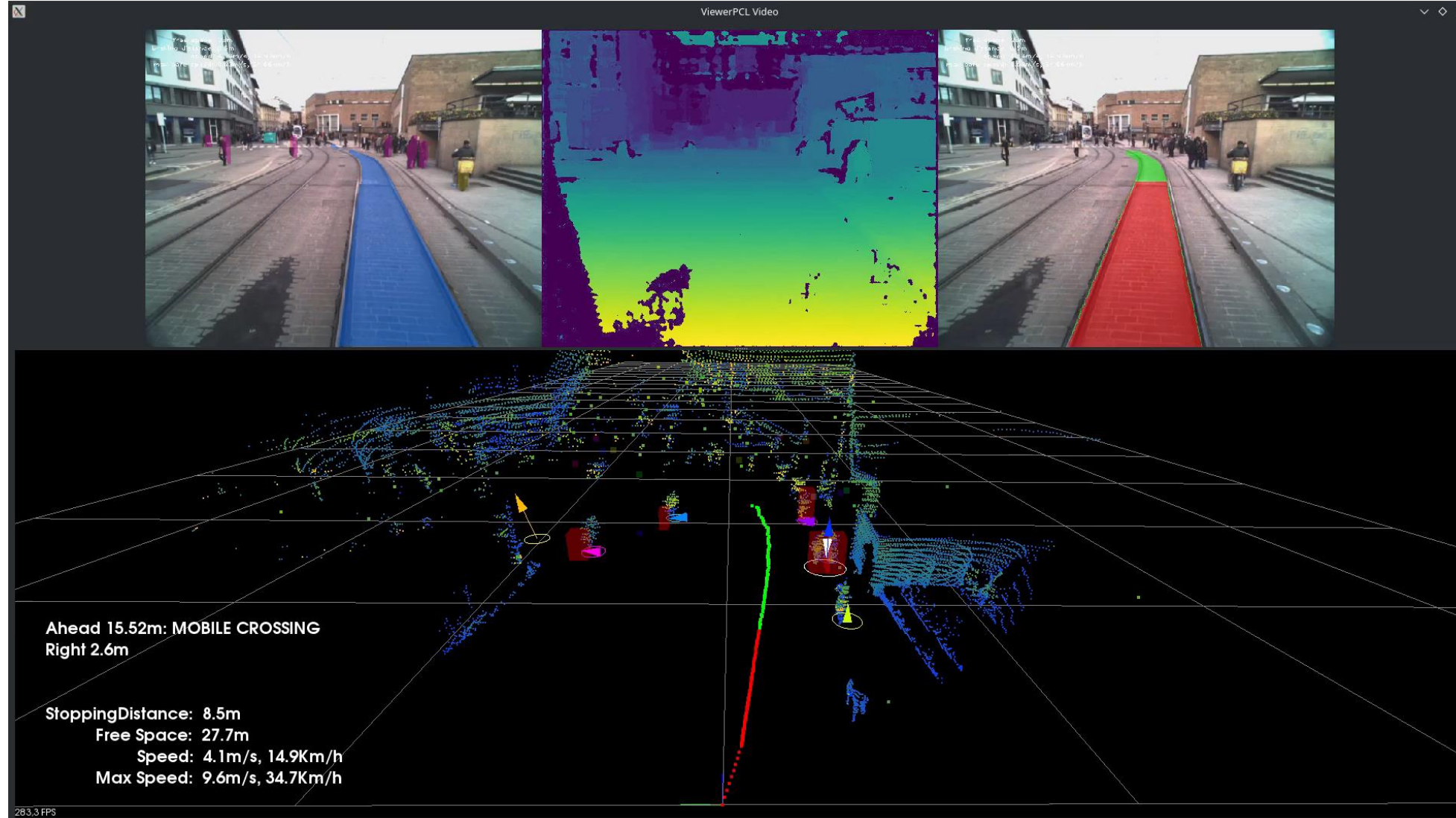


AI as an enabler of Autonomous Driving in Tramway

Obstacle Detection and Tracking

Real-time Environment Awareness

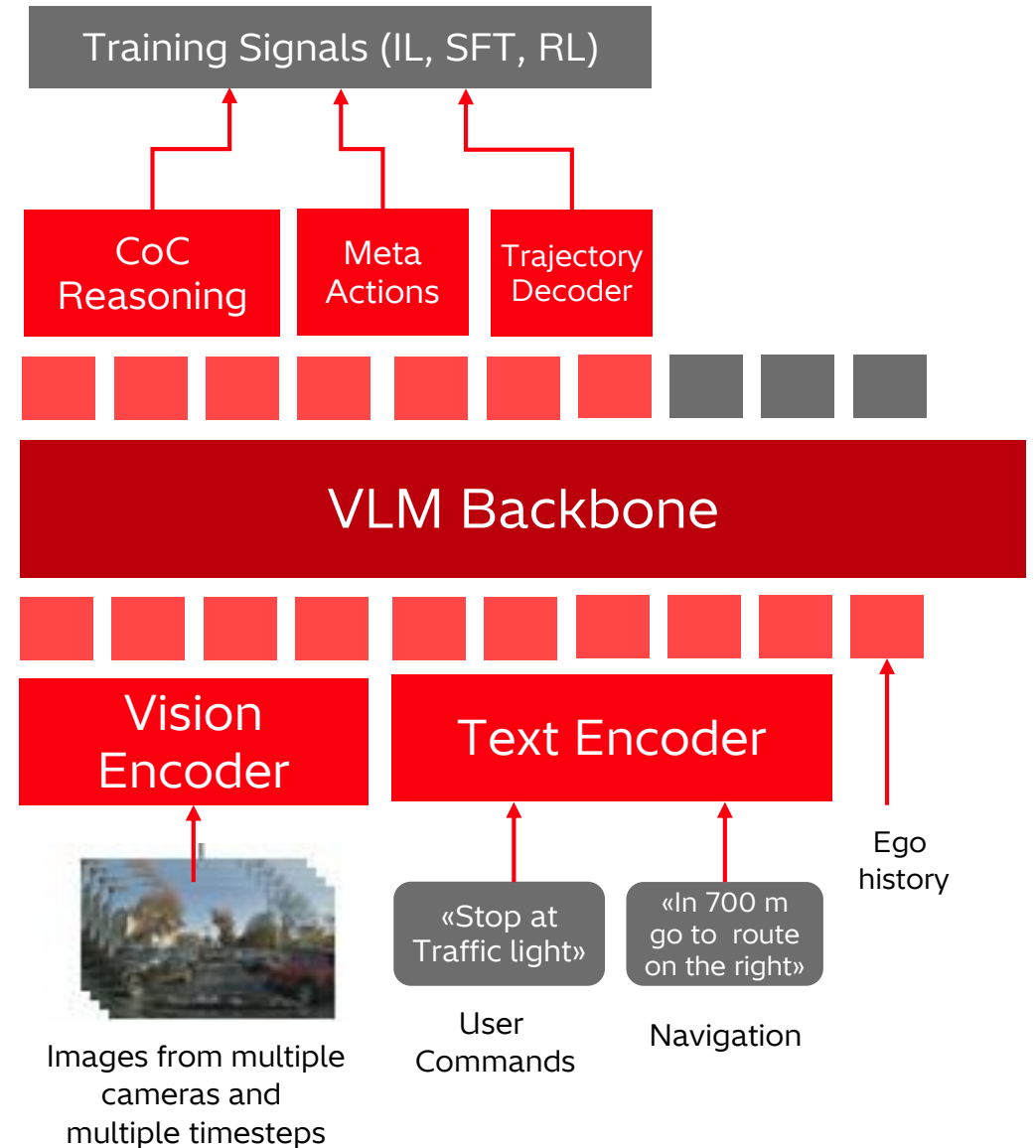
- **ADAS** provides warning and suggestions regarding obstacles to the driver
- Sensors (**LiDAR, radar, cameras**) data are processed by an **Association and Tracking Algorithm** for rapid decision-making
- The **on-board Edge processing significantly decreases the response time** required to avoid collisions



End-to-End Architecture

Overview

- A **Vision Language Model (VLM)** is an AI model that jointly understands visual data and natural language, enabling it to interpret images or videos and reason about them to describe scenes
- Multi-camera images and ego-motion are processed by a **vision encoder** to produce visual tokens, which are fed into a **VLM backbone** along with textual inputs
- The **model autoregressively generates chain-of-thought reasoning** and discrete trajectory tokens
- **At inference**, an action-expert decoder using flow matching converts the discrete trajectory tokens into continuous, kinematically feasible waypoints conditioned on the reasoning output



The 3 Computers Model

Training Computer

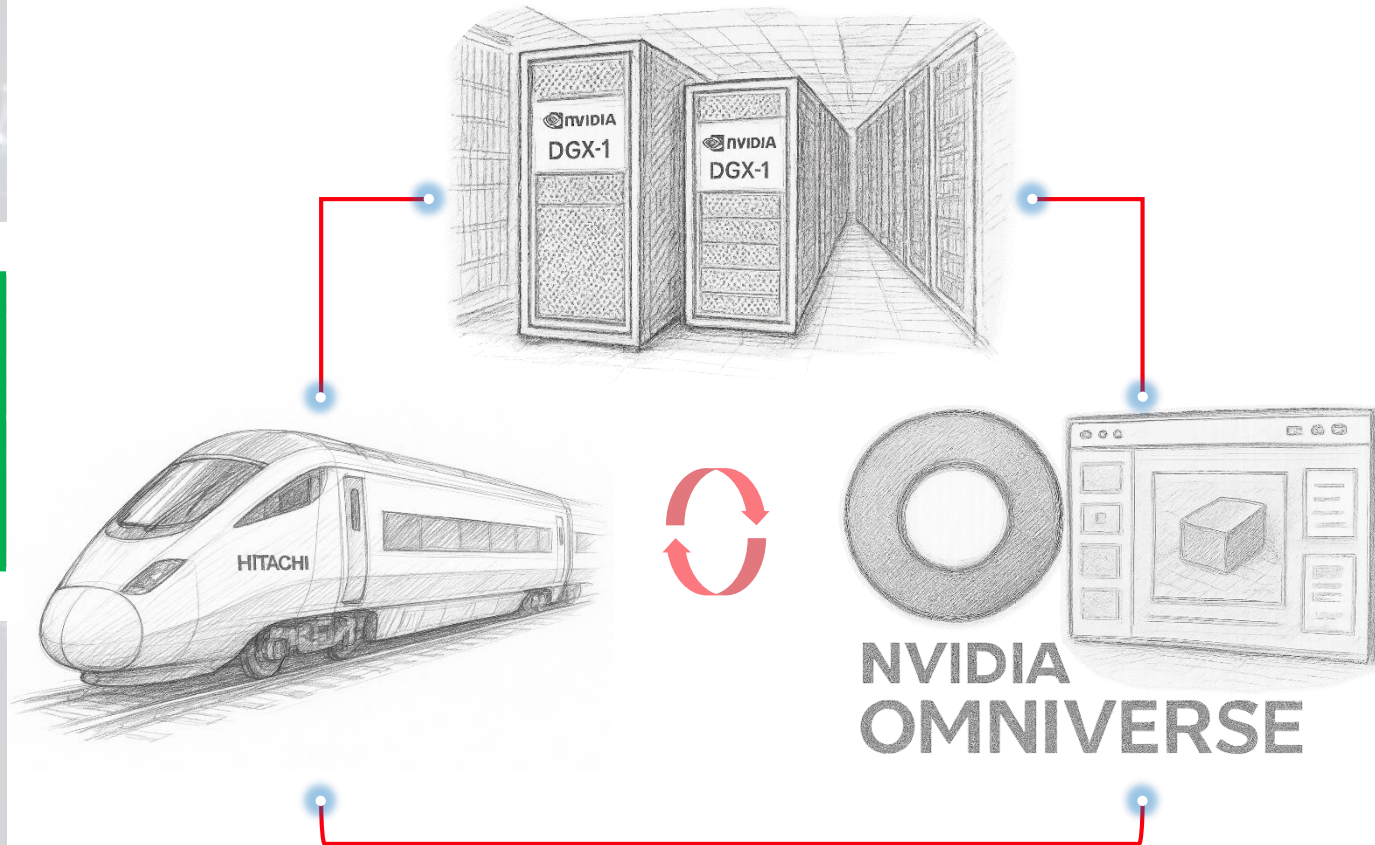
High-powered computers like the NVIDIA DGX AI supercomputers to train large AI models for tasks like perception, planning, and multi-modal behaviour.

Simulation Computer

Real-world data can be limited, costly, and difficult to collect, particularly when preparing for edge cases. NVIDIA Omniverse is used for simulation and synthetic data generation, creating digital twins for testing.

Inference Computer

While leveraging on the train equipped sensors and data foundation, we are using NVIDIA AGX for on-robot inference, providing real-time processing on the edge and reducing the amount of data transferred.



Scalable 3D Scene recreation

When all above steps are done in the 3D design tool, the scene is exported to **NVIDIA Omniverse** and ready for simulation in **IsaacSim**.

This video represents the current progress on the 3D representation of the entire Florence T1 tram line within **NVIDIA Omniverse** and **IsaacSim**.

Activities are ongoing to further enhance the photorealistic representation of the T1 line.



Validation of AI Models using Synthetic Data

Concept

Full 3D digital twin representation in IsaacSim of Florence T1 tram line from Talenti to Piazza Unita' Italiana (after S. Maria Novella station).

Architecture

IsaacSim to run on a dedicated computer, while ADAS to run on IGX Thor DevKit. ADAS to send in real-time messages (Start / Stop) to IsaacSim.

Scenarios

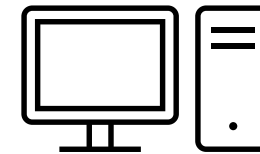
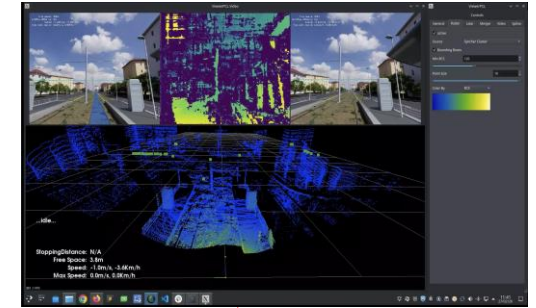
Scripted scenario simulation on the selected route, including pedestrian crossing, car crossing, falling object/vegetation.

Traffic simulation

Leverage on a traffic simulator integration for traffic and pedestrian simulation.

Train Dynamic

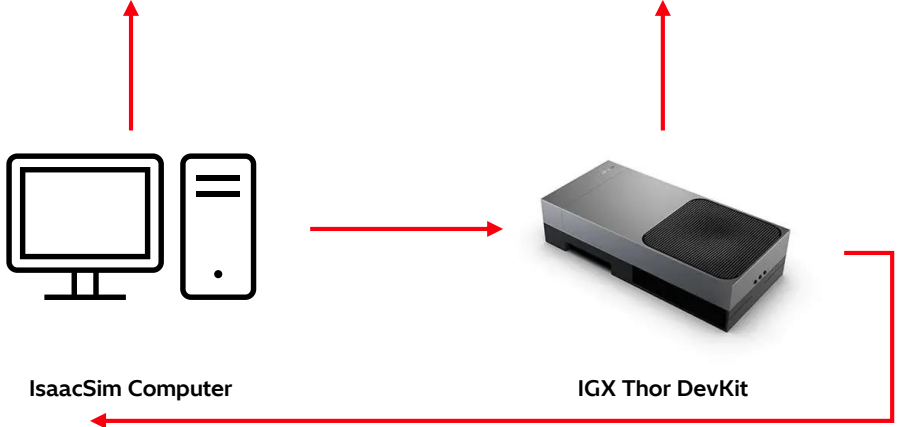
Implement a train dynamic solution, leveraging on NVIDIA Newton physics model.



IsaacSim Computer



IGX Thor DevKit

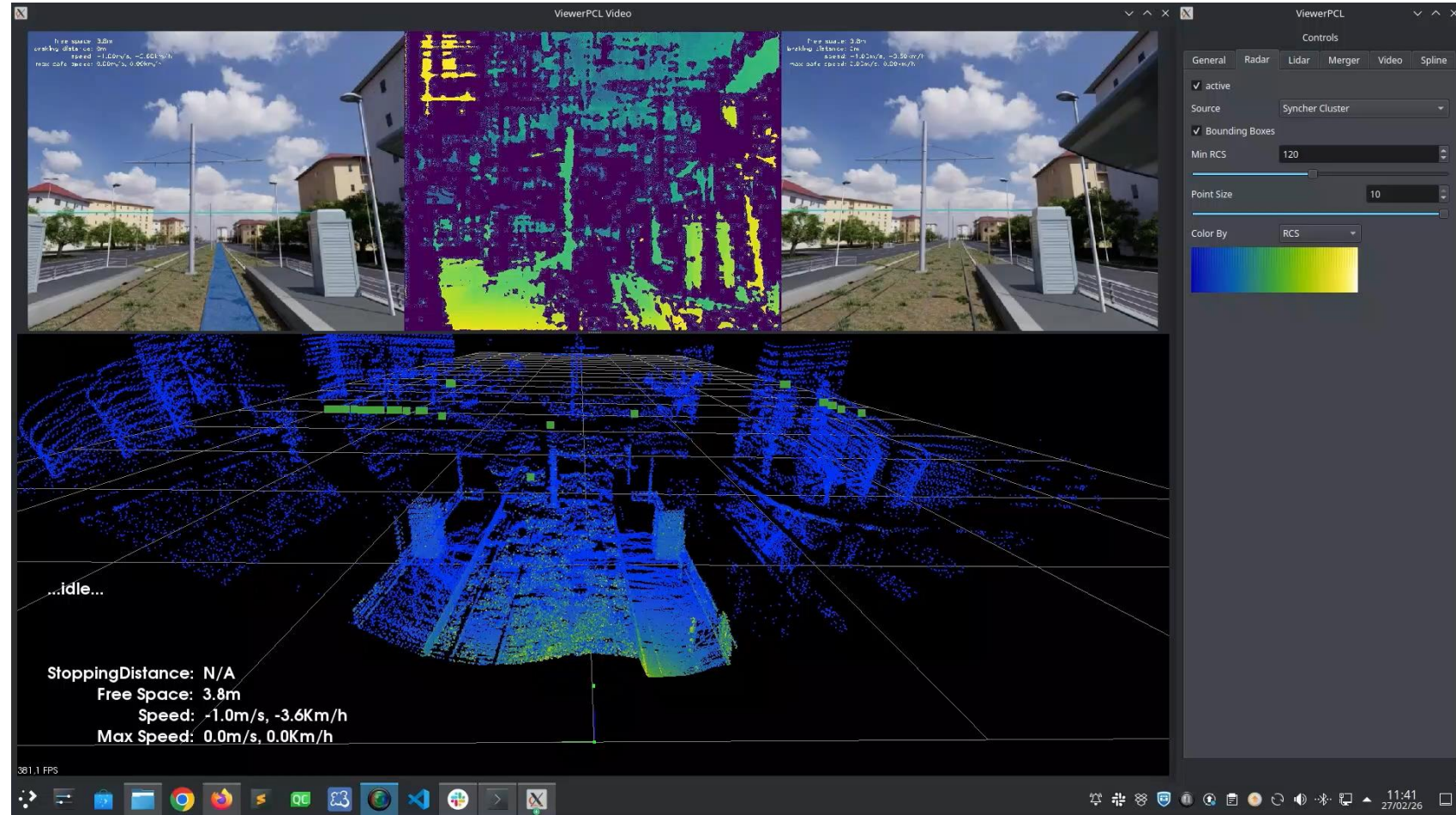


Implement a 3D digital twin leveraging NVIDIA IsaacSim and integrating it with Hitachi Rail ADAS.

Validation of AI Models using Synthetic Data

To validate the synthetic data generated:

- We execute synthetic data files by Obstacle Detection algorithm
- The video depicts what the Obstacle Detection is able to "see" receiving the synthetic data
- We have confirmed with Rail SME accuracy of the synthetic data that has been generated through this method



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