TRENI

Train Receiver for Navigation & Integrity

The TRENI Project

Development of a Galileo-based GNSS Receiver and Antenna for Railway Safety-Related Applications

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Context & Needs

Context

ERTMS does not envisage GNSS for for **safety** relevant train applications

Dynamic scenario characterized by different environments (from **rural** to **urban**) and highly variable GNSS SiS **visibility**

Rail application criticality requires robustness to **RF environment threats** that may occur during operation

Threats

Space Segment issues
(SiS & NAV msg level)

Ephemeris Errors
(Orbit & Clock)

Atmospheric Propagation
(Troposphere, Ionosphere)

Local RF Environment
(SiS obscuration, multipath, interference/spoofing)

Key Drivers

Robust solution capable to identify failures & mitigate feared events

Use of Integrity information provided by SBAS (and Galileo) signals over **L1** and **L5** bands

Integration with **PNT sensors**, complementing GNSS Signals

Reduce overall signaling system **costs**

Use Cases & Target Applications

Primary Safety Systems Applications

- **Train control** (virtual balises, absolute positioning, guidance and navigation)
- **Traffic control** (e.g. trains spacing over the lines)
- **Train integrity** (e.g. train length monitoring)

Overlaid Safety Systems Applications

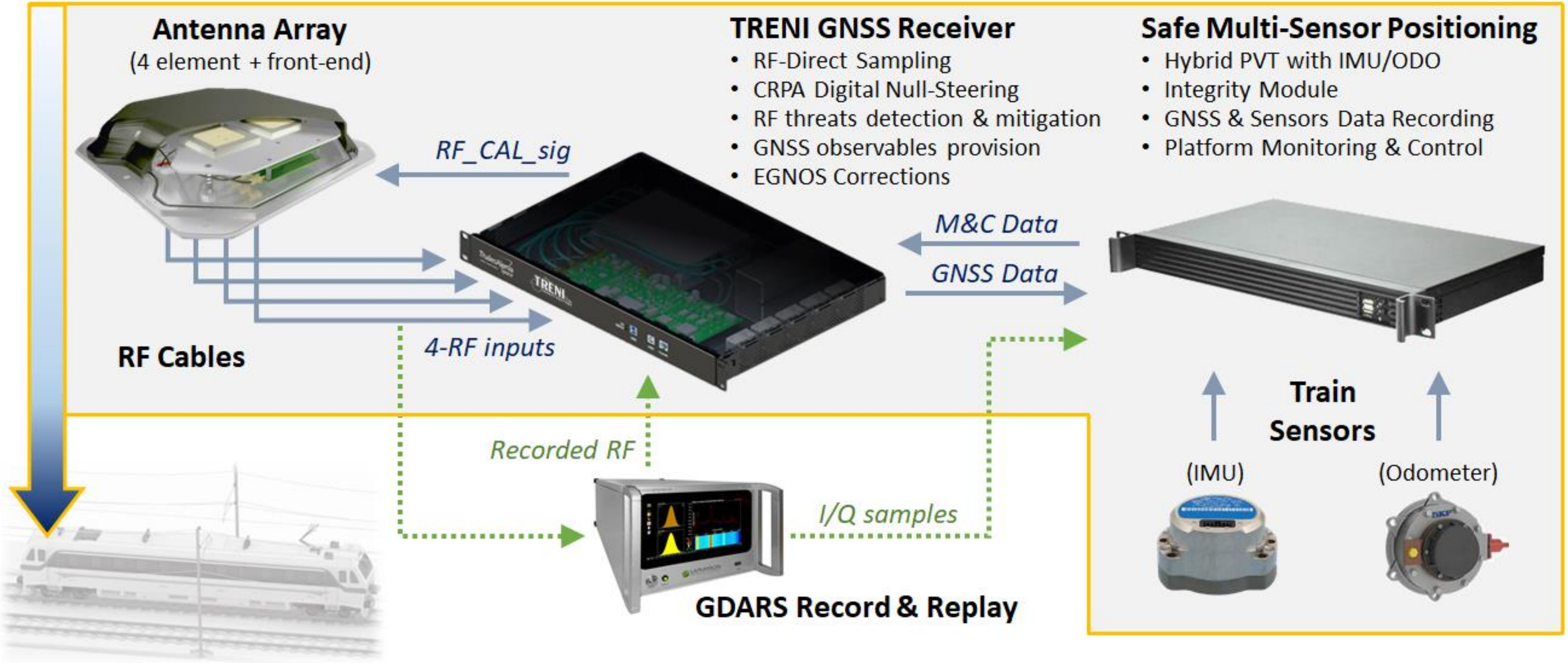
- **Simplified signalling** (back-up) systems providing safety in operational conditions
- **Level-crossing** protection
- **Cold movement** detectors
- **Driving** intelligent **assistance** (e.g. alarms to train driver)

Non-Safety Applications

- **Fixed asset management** (e.g. infrastructure surveying and monitoring)
- **Rolling stock management** (e.g. fleet management, cargo monitoring, energy charging)
- **Passenger Information** (e.g. journey assistant, customer information, on-train reservations)

Platform Overview

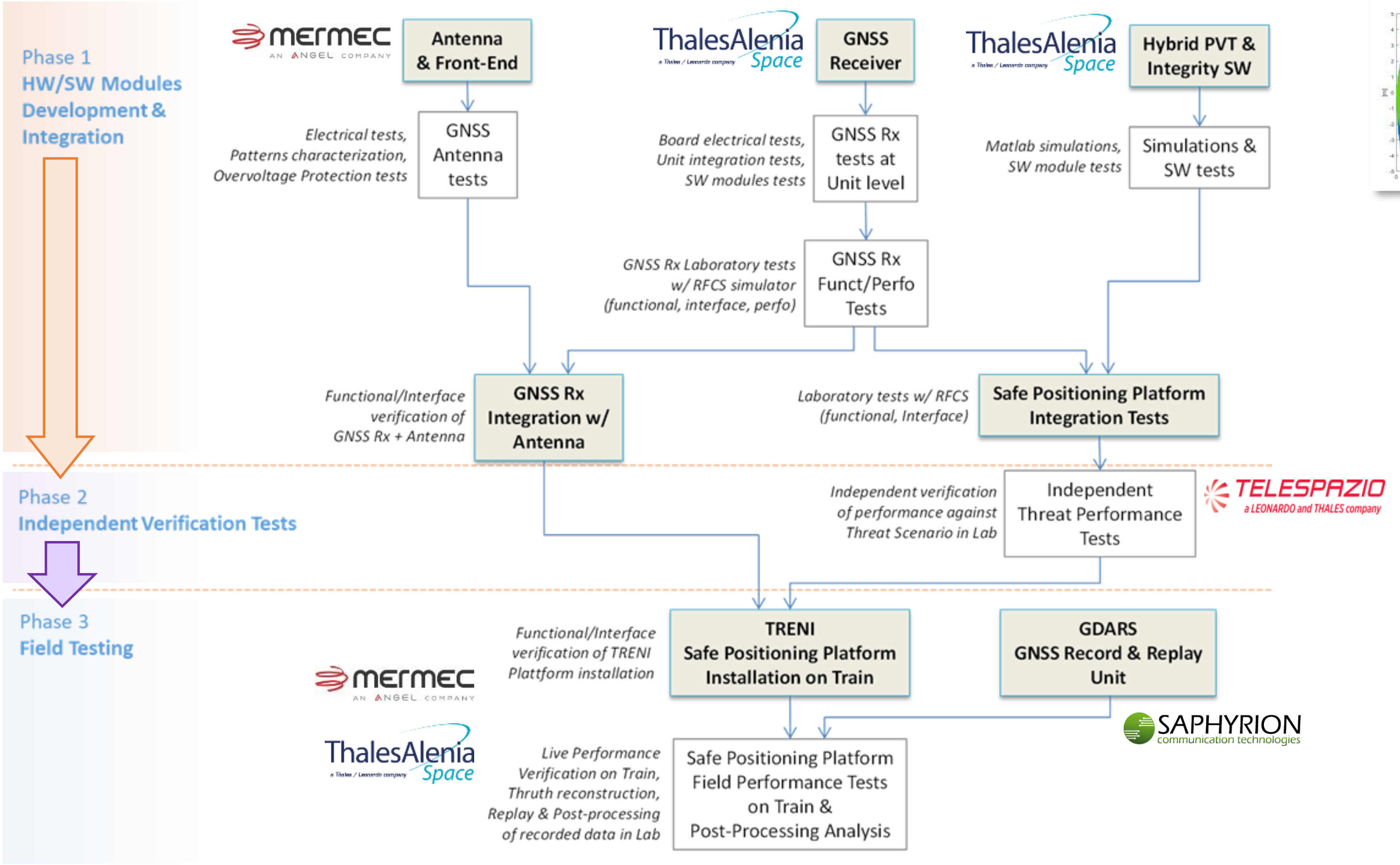
TRENI Railway **Safe Positioning Platform**

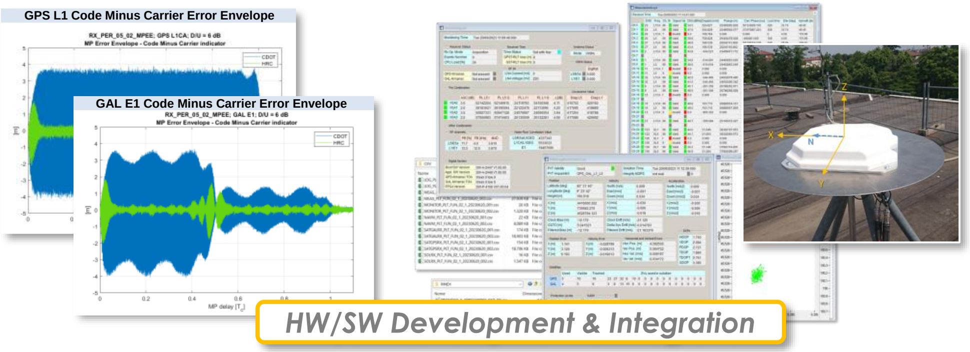


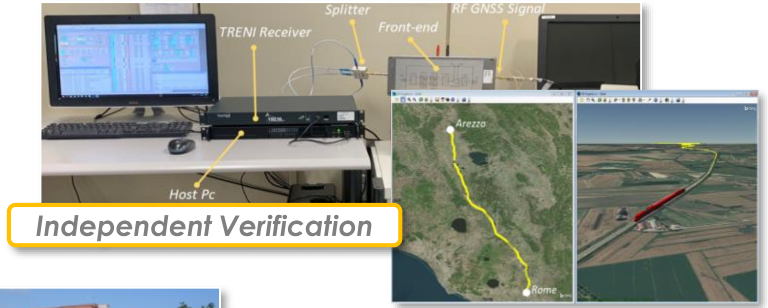
*TRENI is a **TRL7 System Prototype** demonstrator in operational environment*

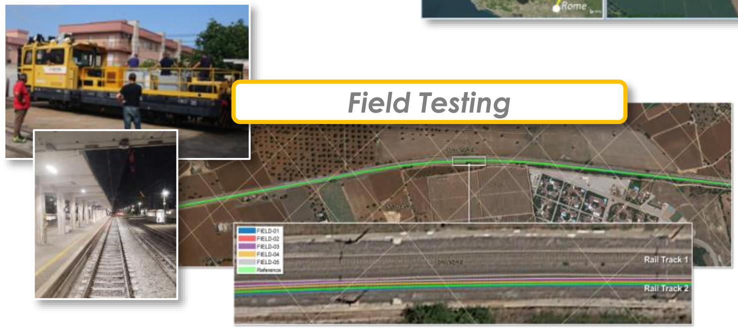
Platform Development

TRENI **Platform Development** & **Verification** Phases









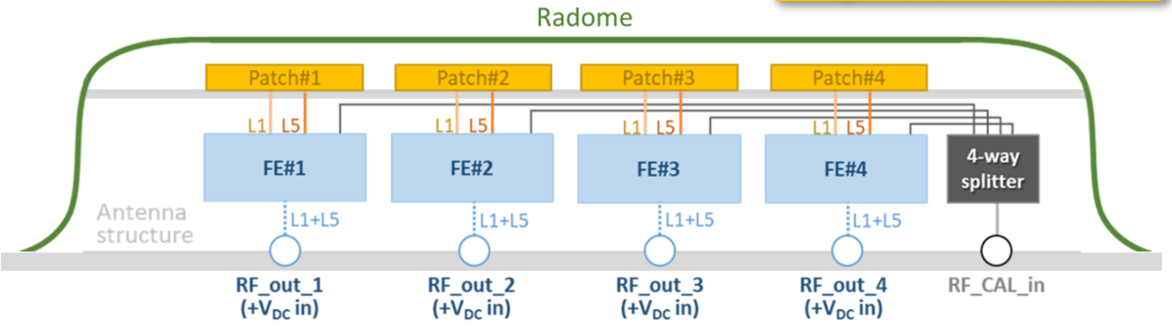
GNSS Antenna Solution

TRENI GNSS **Antenna Architecture**

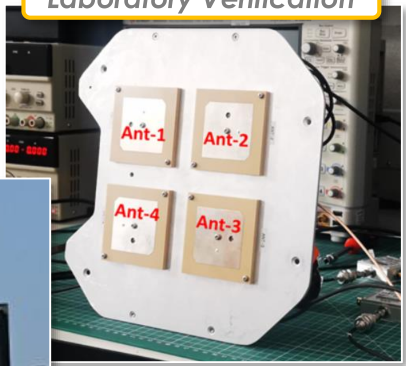
Need to develop a **Dual-Band (L1/L5)** multi-element GNSS **antenna** to:

- Support **advanced interference** mitigation functionality
- Keep **costs** within limits compatible with railway market
- Solution based on **stacked patch** & **self-duplexing** structure
- Comply with applicable railway **EN standards**

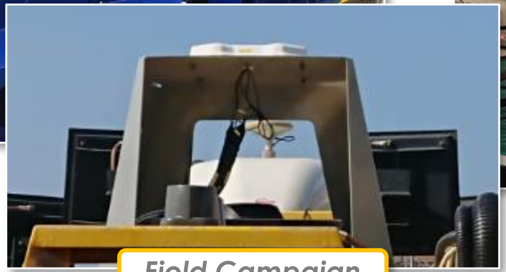
High-Level Architecture



EN certification

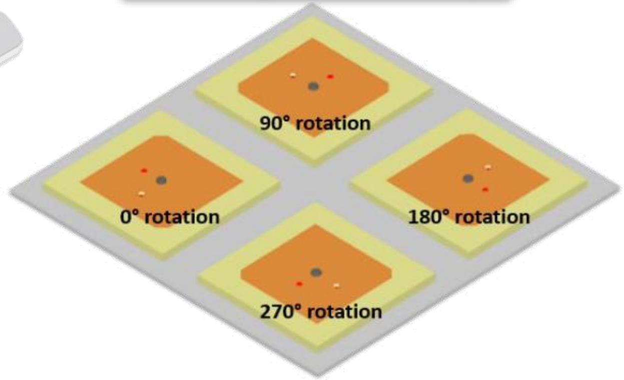


Laboratory Verification



Field Campaign

Antenna Layout



Radiating Elements Array

GNSS Receiver Solution

TRENI GNSS Receiver **Processing Capability**

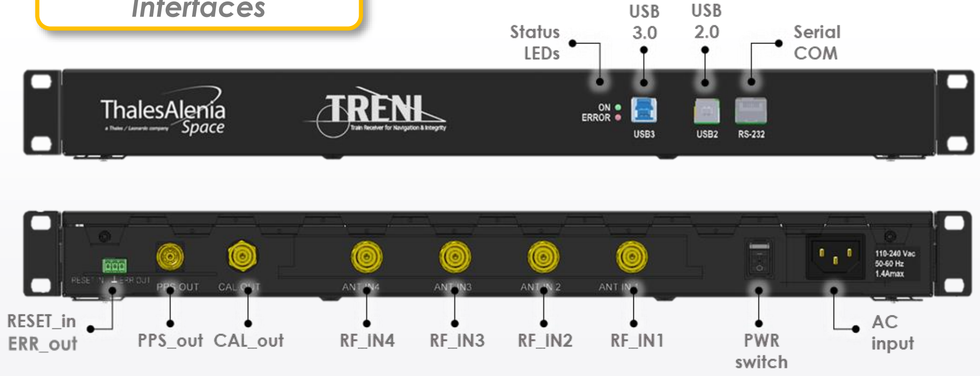
The TRENI GNSS Receiver is based on Thales Alenia Space Test User Receiver (TUR) platform, suitable for **avionic, rail** or **maritime** users:

- Multi-frequency (**L1**/**L5**) & Multi-constellation (**GPS**/**Galileo**/**EGNOS**)
- **SBAS MOPS** and **DFMC** standards compatibility
- **RF Direct-Sampling** with **Digital Down-Conversion**
- Accurate **1PPS signal** for on-board systems synch
- **Active anti-jamming** with **time**, **frequency** and **spatial** mitigation (i.e. **CRPA null-steering** capability)
- Enhanced **Multipath** mitigation
- **RAIM** & **PVT Hybridization** with on-board sensors

TRENI GNSS Receiver

Physical Dimensions
(w × h × d) = 483 × 45 × 310 mm

Front/Back Panel Interfaces



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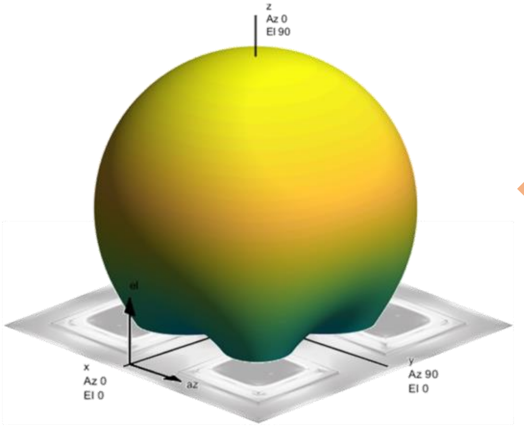
GNSS Receiver Solution

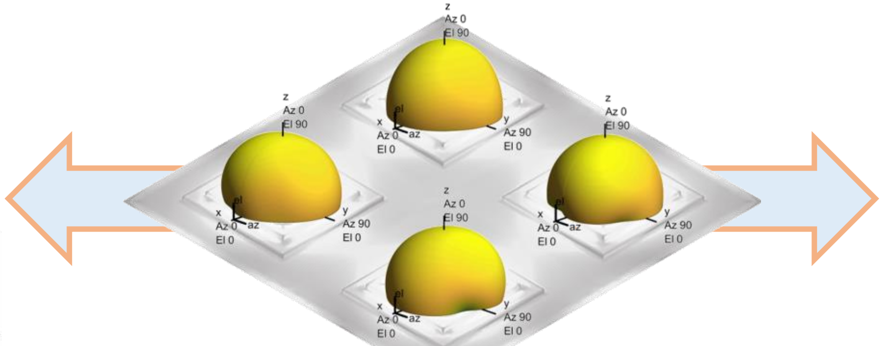
TRENI Rx **Digital Null-Steering** Capability with 4-element antenna

FRPA mode
(Fixed Combined Pattern)

e.g. for Nominal Environment



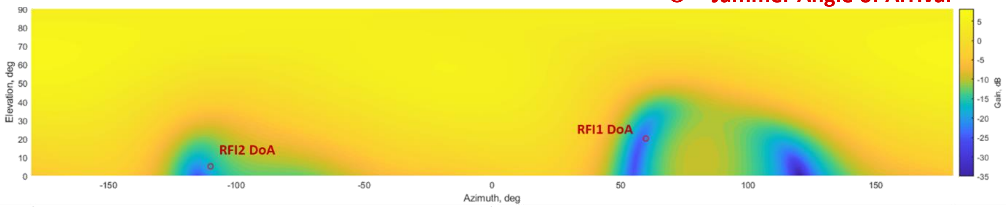
Embedded Radiating Elements RHCP Gain Patterns

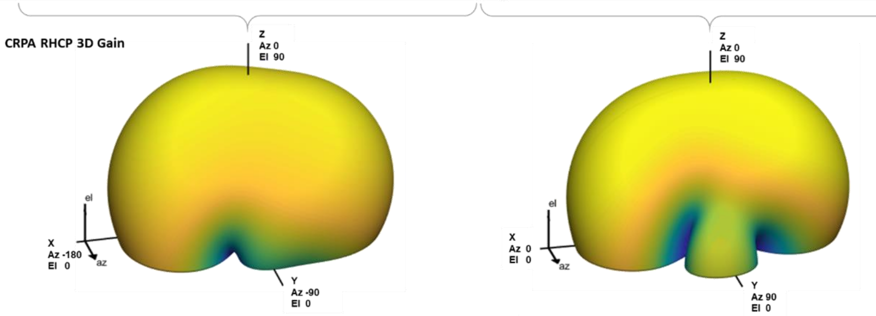


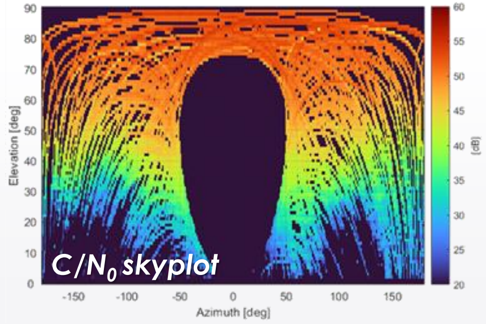
CRPA mode *(Digital Null-steering)*

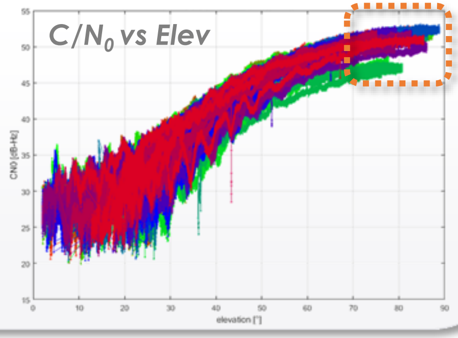
e.g. in presence of RF Interference

○ = Jammer Angle of Arrival





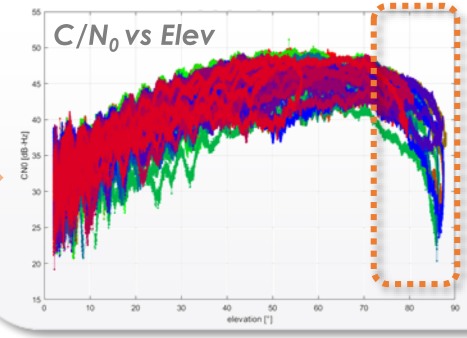


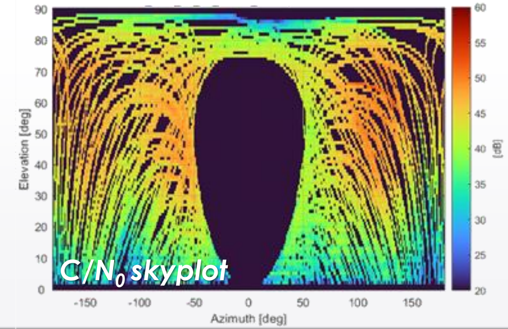


CRPA mode examples
with live GNSS SiS

Max RHCP Gain @ Zenith

Pattern Null @ Zenith

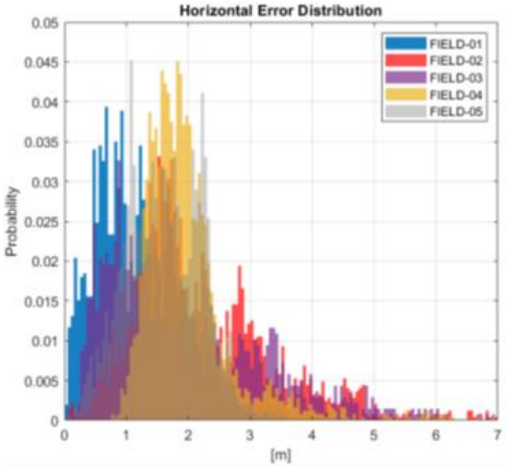


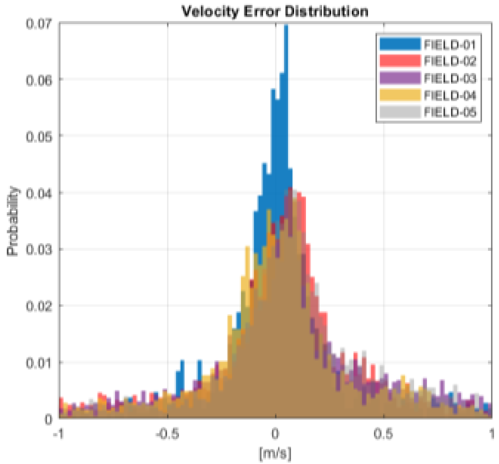


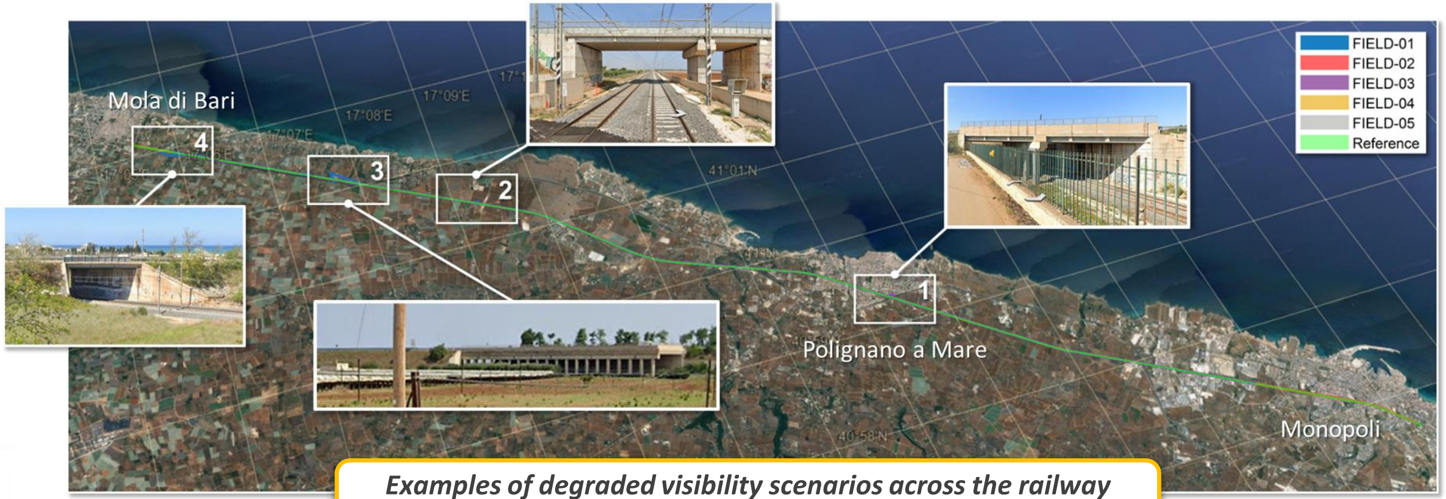
TRENI Platform Verification

Field Test Campaign in harsh Railway Environments

✓ ***Good fitting of Rx solution w.r.t. true trajectory*** *(green line)*







Examples of degraded visibility scenarios across the railway
(severe multipath or partial / complete SiS loss events)

- **Horizontal** (2D) absolute **errors** 1-sigma in the order of **1 m**
- **Velocity** estimates **errors** (1-sigma) ~**1.8 km/h**
- **HRC DLL** configurations (**FIELD-01**, **FIELD-03** and **FIELD-05**) confirm an **increased robustness against multipath** biases, but more susceptible to tracking loss @ low SNR
- **CRPA** performance (**FIELD-03**) show no regression w.r.t. **FRPA** based configuration (**FIELD-01**) in AWGN conditions, with significant benefits in presence of RF interference

Note: FIELD-01/-02/-03 = DFMC based cfg. , FIELD-04/-05 = MOPS based cfg.

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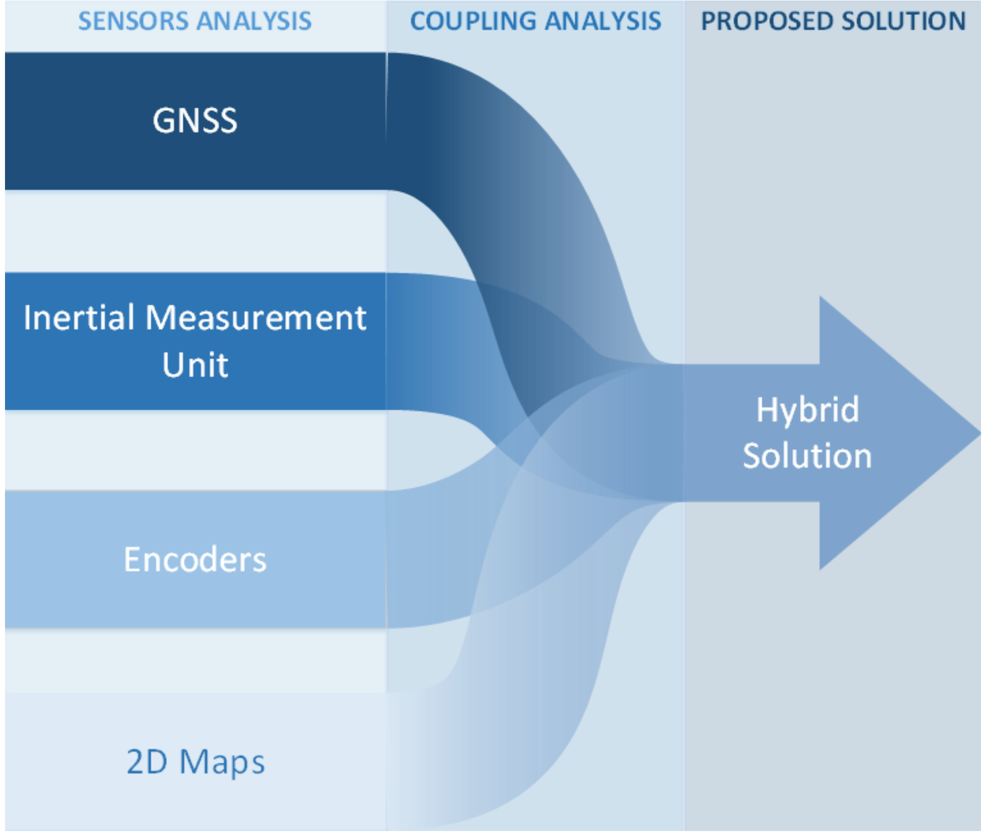
PVT Hybridization & Integrity

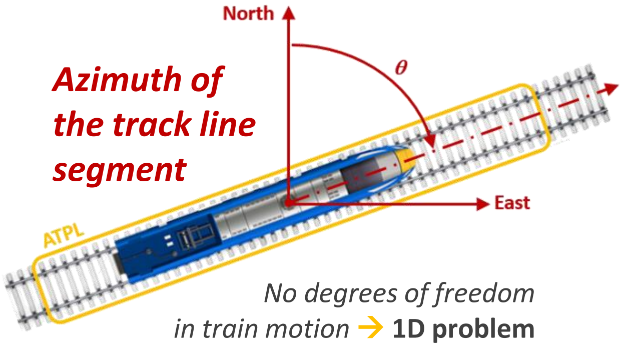
TRENI **Hybrid-PVT & Integrity** Concepts



GNSS alone is not self-sufficient in ERTMS/ETCS domain …

… **Hybridized PVT** solutions evaluated in order to assess enhancements brought by **GNSS data fusion**

- **FDE** capability to remove faulty ranges
- **Accurate positioning** even in GNSS **NLOS** signal conditions
- **Along Track Position** (ATP), speed and associated **Protection Level** (ATPL)



$$ATPL = K_{PMI} \cdot \sigma_{along}$$

- K_{PMI} = *protection coefficient*
- P_{MI} = *integrity risk probability*
- $\sigma_{along} = \sigma_E \cdot \sin(\theta) + \sigma_N \cdot \cos(\theta)$

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PVT Hybridization & Integrity

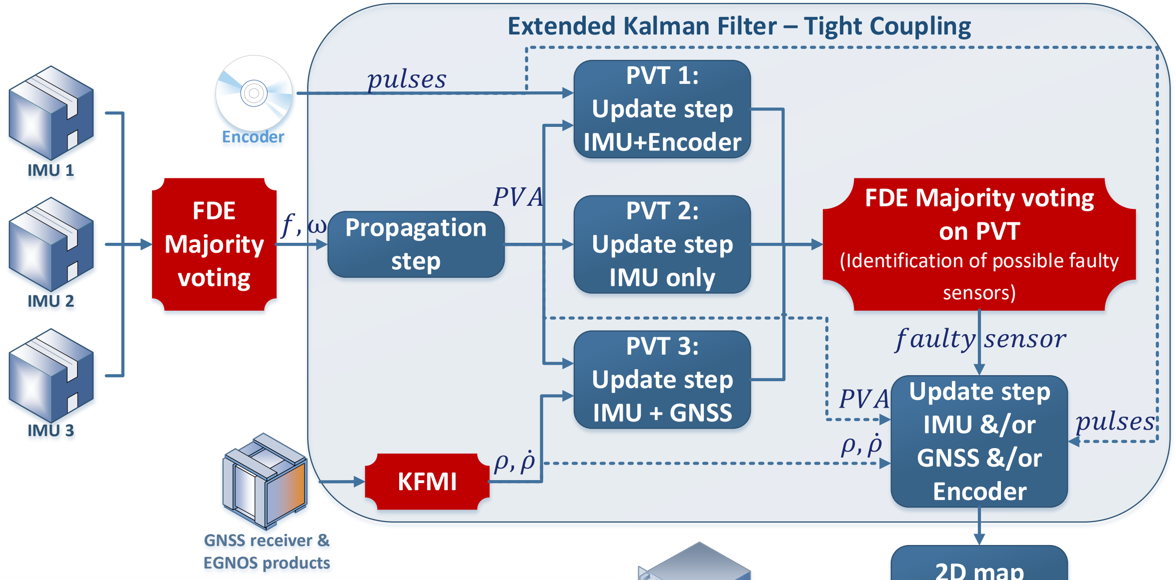
TRENI **Integrity** Architecture

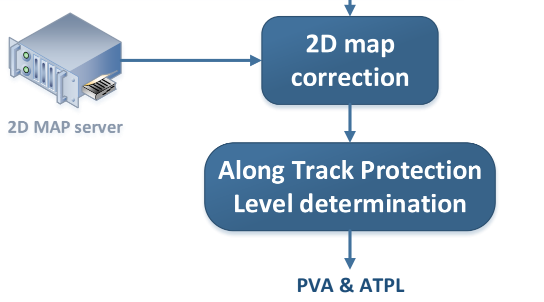
Integrity concept is designed in order to meet integrity requirements and user KPIs.

Proposed Integrity solution leverages on:

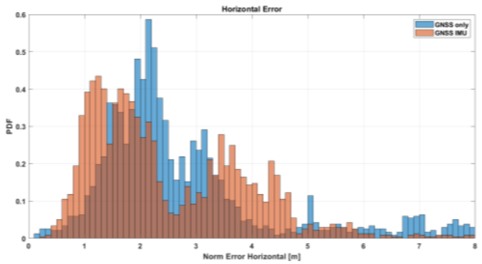
- mixed use of **Kalman Filter Measurement Innovation** (KFMI)
- **Majority vote** redundancy scheme

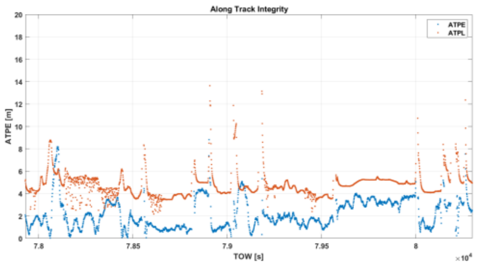
FDE methods are applied both in the "pre-processing" and in the "update" step.





Majority voting method is applied in the pre-processing step to ensure validity of IMU measurements.





The **combination** of **KFMI based solution** with **majority vote solution** is used to identify and reject potential faulty sensors.

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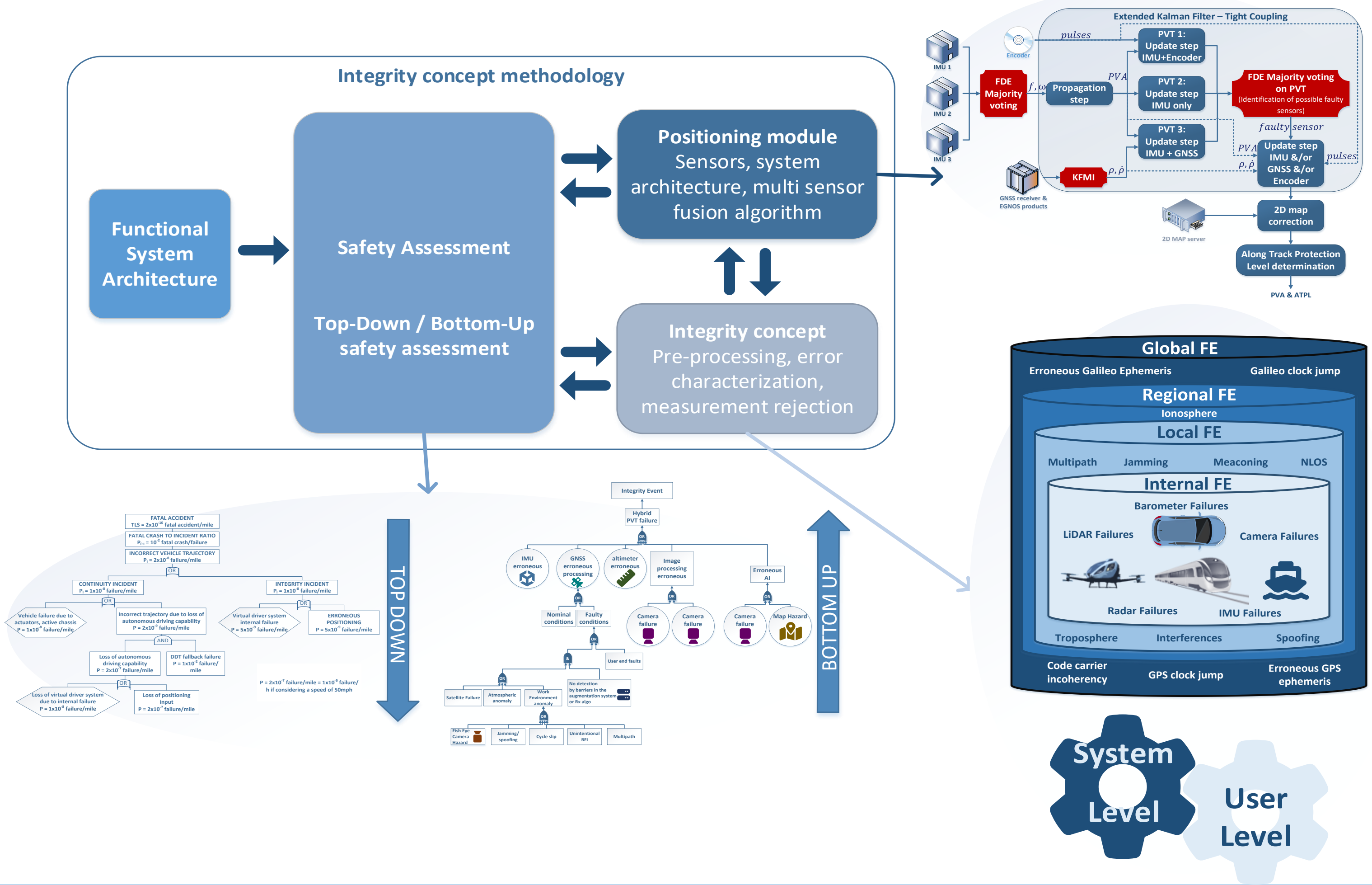
Beyond TRENI Project…

Multimodal End-to-End Integrity Concept

Many projects with a common objective to ensure **end-to-end integrity** of **PNT solutions** for various transportation applications, amongst others:

- **ICHASE** (Autonomous Driving)
- **SAMVA** (UAS / VCA)
- **EGNOS-NEXT** (multi-applications)



Beyond TRENI Project…

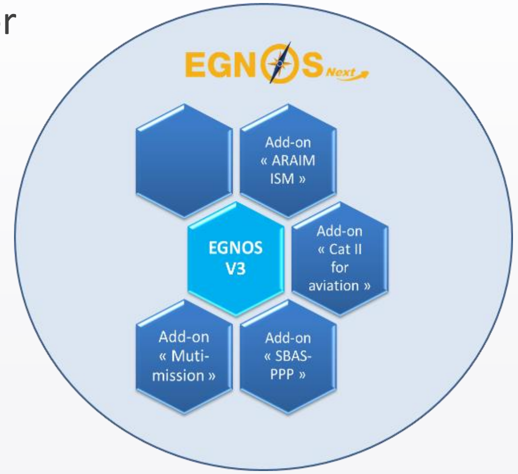
TRENI Follow-up and further TAS developments in **EGNOS rail roadmap**

EGNOS Next

EGNOS-NEXT, building on EGNOS V3 as a first brick of a **system of systems**, and targeting a wide range of **new safety critical applications**.

Phase 0/A proposed an integrity concept:

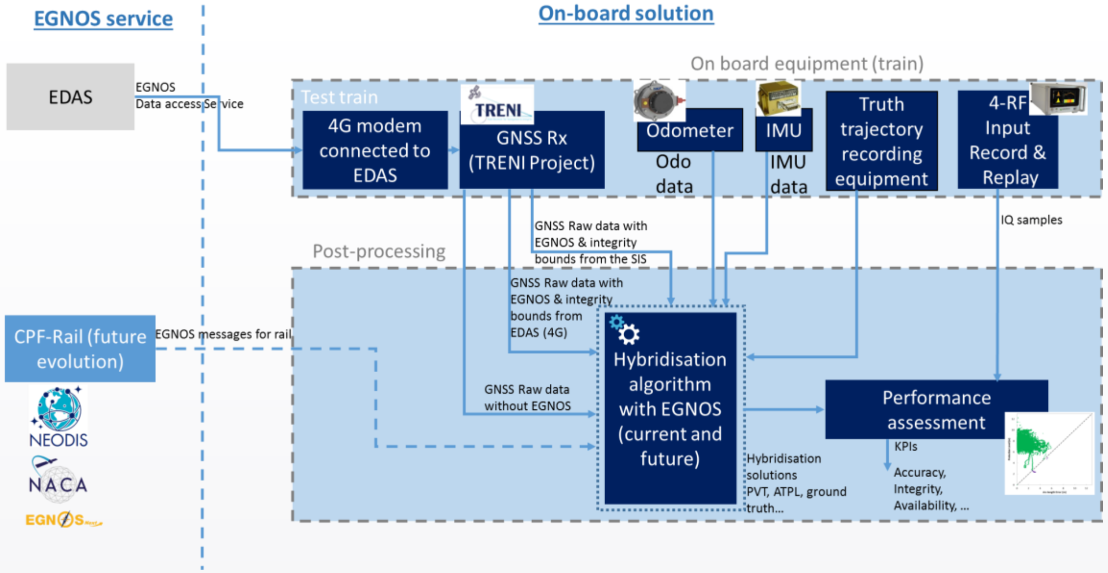
- allowing integrity monitoring for **Kalman filter users**
- able to cover users with very **different integrity risk**
- Covering SBAS-PPP users to get the **highest accuracy with integrity** (covering residual errors time correlation)



Experimentations results in **representative railway environment**

Status: ***Completed***

EGNOS Adoption In Rail *(EGNOS AIR)*



Further **experimentations** in representative railway environments planned from mid-may benefiting from both **EGNOS-NEXT** and **TRENI**

Status: ***Ongoing***

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Acknowldegments

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https://it.linkedin.com/in/**treni-project**

Leading consortium partner with strong experience in Navigation system/sub-system design & development for both space and ground segment infrastructures, navigation payloads, high-end GNSS receivers, user terminals and tools for environment characterization.

Develops a wide range of applications based on Galileo as well as EGNOS for Safety of life and regulated/liability-critical domains.
Telespazio is Galileo System Operator Prime through its subsidiary Spaceopal and EGNOS System Operator in partnership with ESSP

Provides the knowledge on the railway signalling world, with heritage and experience in railway surveying, train tracking and field testing operations.

Experienced in space borne electronics for GNSS, has developed a family of novel instruments for RF environment characterization, record and replay equipment for GNSS receiver development.