High Accuracy and High Integrity GNSS for Multimodal Transport and Public Services

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sogei

High Accuracy and High Integrity Applications: key elements

- Any innovative service is nowadays using high accuracy and high integrity positioning metadata
- Standardisation is the key element for transport and mapping applications
- Wide Spread Test Beds are needed for certification of emerging applications in the autonomous transport sector

Agenda

- High Accuracy and High Integrity Applications Requirements
- RTCM SC-104
- Application Projects
- Conclusions and Recommendations

The RTCM SC-134 Special Committee "Integrity for GNSS-based High Accuracy Applications"

RTCM – the Beacon for Maritime Communications and Navigation

Presented By: Roberto Capua
SC-134 Chairman and BoD Member

Introduction to RTCM

- RTCM (Radio Technical Commission for Maritime Services): an International non-profit organization, founded on 1947 (US Advisory committee), nowadays members from all over the world

- Started as an organization dealing with maritime radionavigation and communication systems standardization, RTCM is currently working with a broad range of applications and services

- Organized by several Special Committees (SC). Some of the SCs are at the base of nowadays GNSS high accuracy positioning and implemented by most of the manufactures

RTCM Special Committees

- Special Committee 101 on Digital Selective Calling (DSC)
- **Special Committee 104 on Differential GNSS Service**
- Special Committee 109 on Electronic Charting Technology
- Special Committee 110 on Emergency Beacons
- Special Committee 112 on Ship Radar
- Special Committee 117 on Maritime VHF Interference
- Special Committee 119 on Maritime Survivor Locating Devices
- Special Committee 121 on Automatic Identification Systems (AIS) and Digital Messaging
- Special Committee 123 on Digital Message Services over Maritime Frequencies
- Special Committee 127 on Enhanced Loran (eLoran)
- Special Committee 128 on Satellite Emergency Notification and Location Devices
- Special Committee 129 on Portrayal of Navigation-Related Information on Shipboard Displays
- Special Committee 130 on Electro-Optical Imaging Systems
- Special Committee 131 on Multi-System Shipborne Navigation Receivers
- Special Committee 132 on Electronic Visual Distress Signals
- Special Committee 133 on Data Exchange for Navigation-Related Applications for Mobile Devices
- **Special Committee 134 on Integrity Monitoring for High Precision Applications**
- Special Committee 135 Radio Layer for Real-Time DGNSS Applications
- Special Committee 136 on Beacon Type Approvals
- Special Committee 137 on Electromagnetic Compatibility Requirements for LED Devices and other Unintentional Emitters Located Near Shipboard Antennas

RTCM SC-134 Objectives

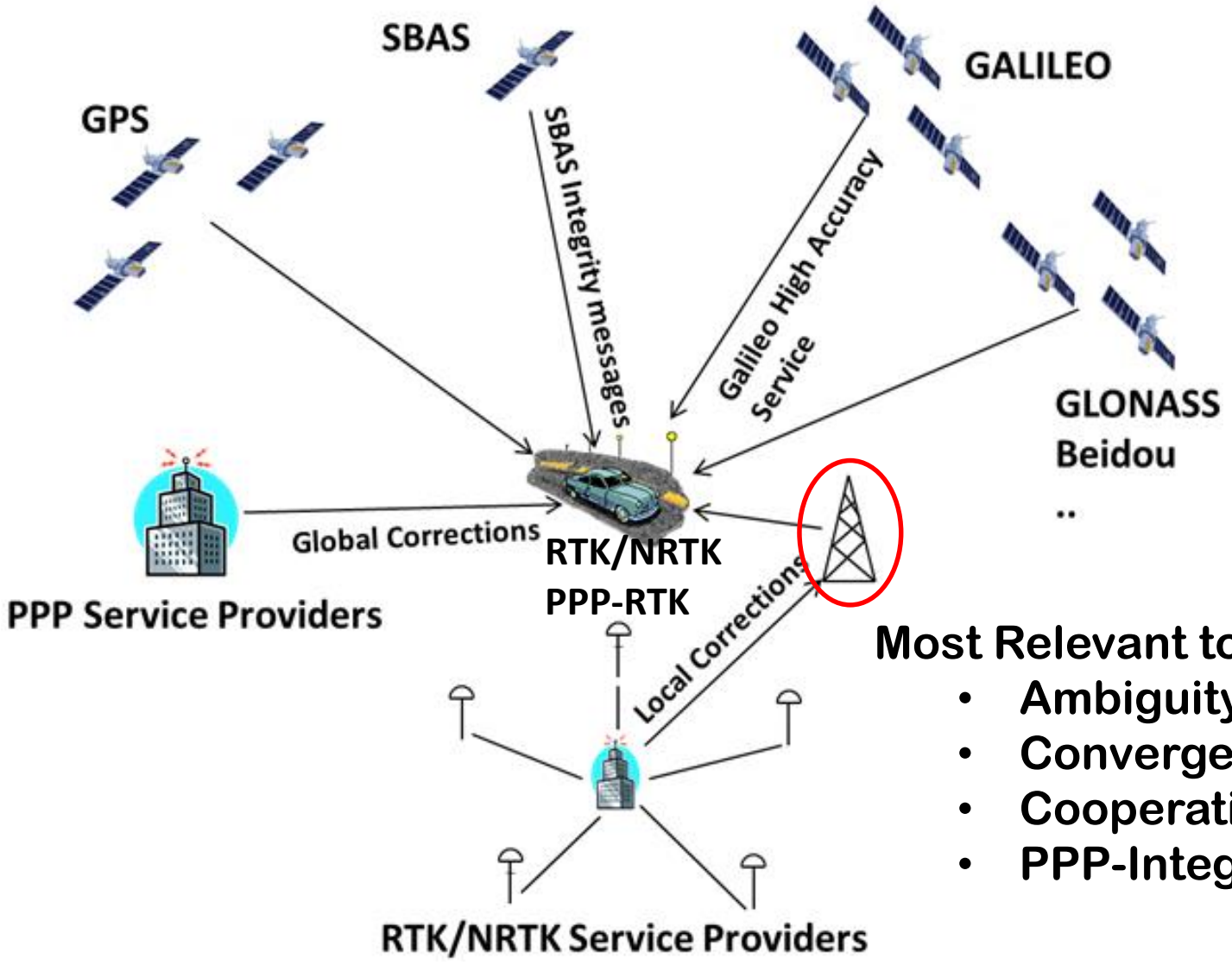
Scopes of the SC-134 Committee:

- **Definition of a Standard Messages formats for GNSS Integrity Augmentation at User and Service Provider Level, with a Multimodal Approach**
- **Continuous review of emerging application requirements and safety metrics**
- **Update of existing single application Fault Models and Integrity Parameters for Integrity Monitoring**
- **Liaison with application domain and other standardization organizations**

RTCM SC-134 Membership:

- **Current number of members: 265**
- **Manufacturers, Service Providers, Universities**

GNSS High Accuracy Systems



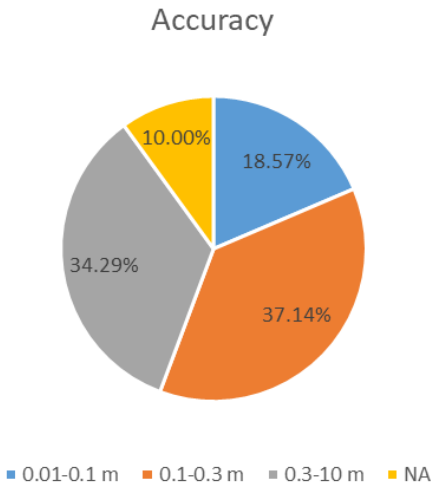
Most Relevant topics:

- **Ambiguity Fixing Integrity**
- **Convergence time**
- **Cooperative approaches**
- **PPP-Integrity**

User Requirements Analysis

- More than 70 application requirements
- Accuracy

Accuracy Classification	% applications
0.01-0.1 m	18.57%
0.1-0.3 m	37.14%
0.3-10 m	34.29%
NA	10.00%

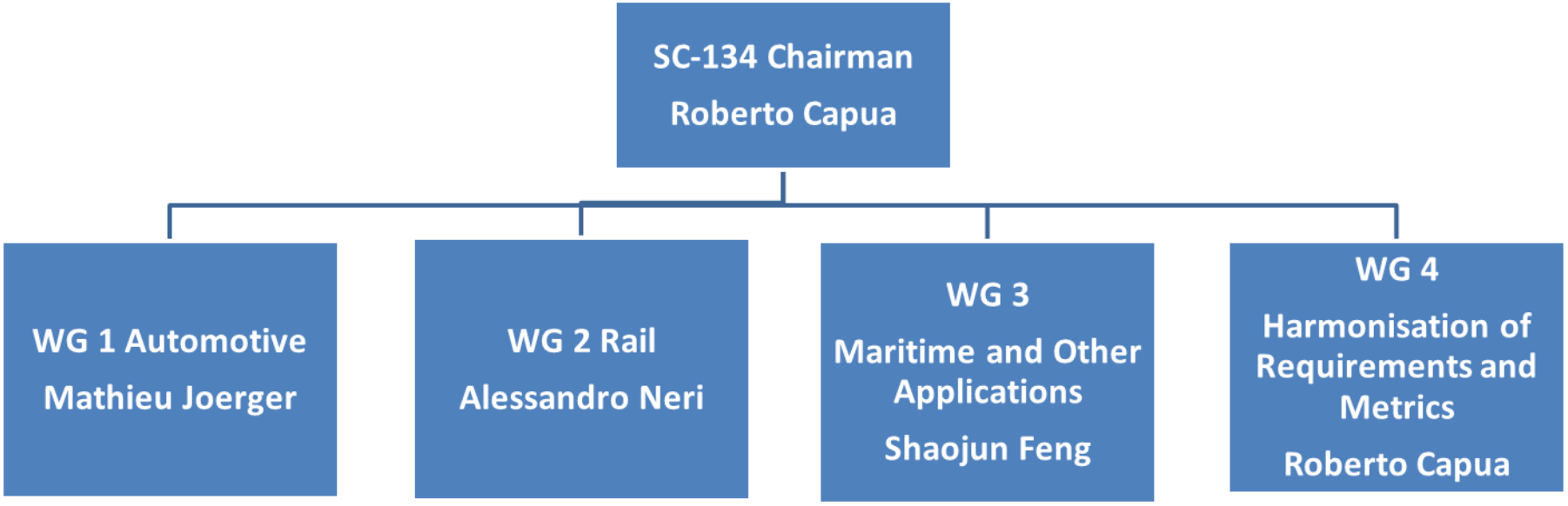


- Integrity (THR/SIL)

General IEC-61508	Dangerous Failure/h	ISO 26262	Rail CENELEC 50126/128/1	% application
SIL-1	10^{-5}-10^{-6}	ASIL-A	SIL-1	50.79%(*)
SIL-2	10^{-6}-10^{-7}	ASIL-B/C	SIL-2	0.00%
SIL-3	10^{-7}-10^{-8}	ASIL-D	SIL-3	9.52%
SIL-4	10^{-8}-10^{-9}	-	SIL-4	4.76%
NA				41.27%

(*) On the boundary of two levels

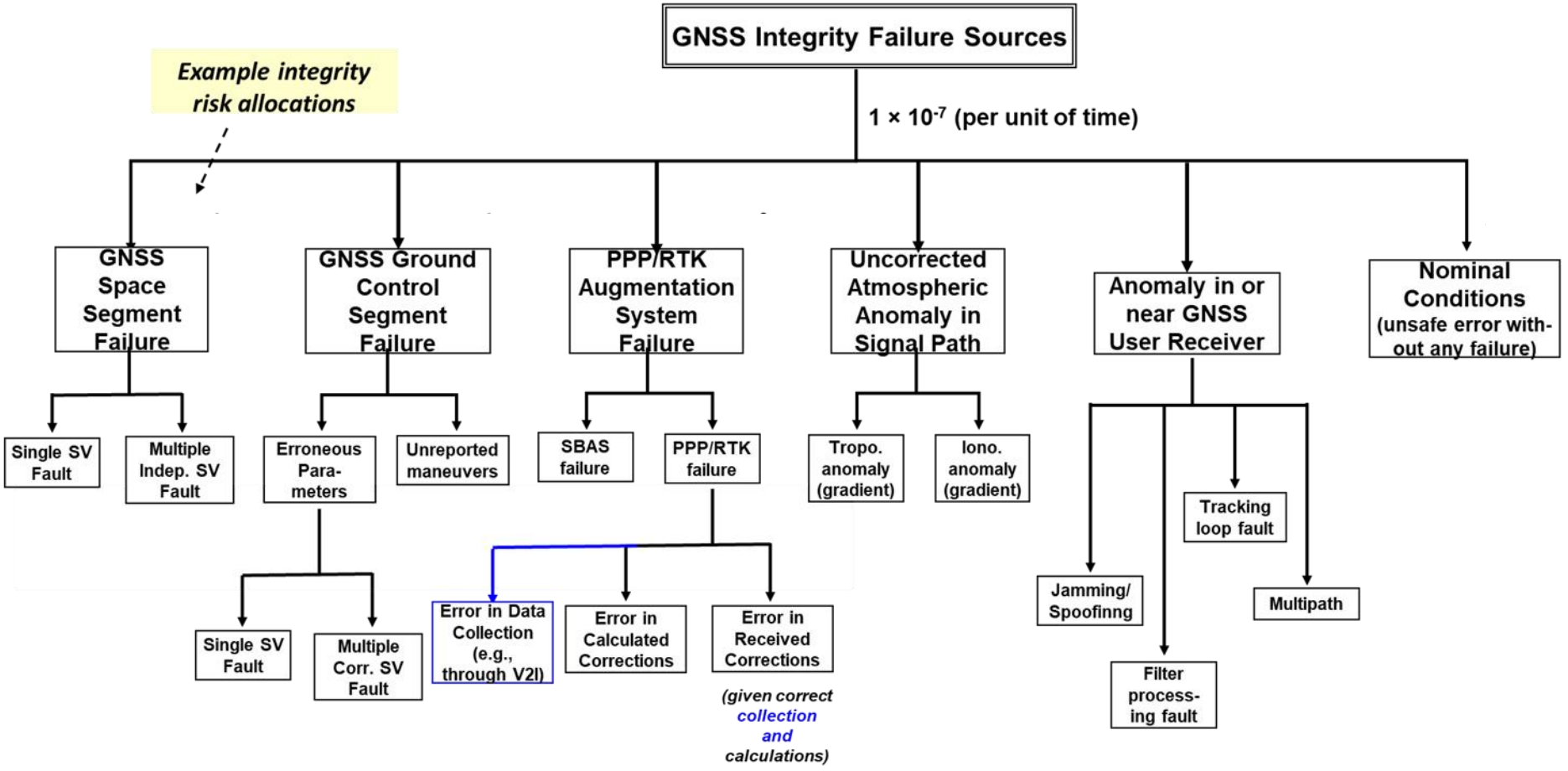
RTCM SC-134 organization



Specific Task Forces are setup:

- Augmentation Transition Mode integrity
- NRTK Integrity
- ….

Example of Automotive Fault Tree



Automotive Service Levels

Application	Description	Accuracy (95%)	Conti-nuity	Integrity, Alert Limit	Integrity, Time to Alert	Integrity Risk / THR	Avail-ability (%)	Max. Age of Integrity Data	Time to Become Available
High-speed maneuvers (autonomous)	(Highway driving) High-speed merging, lane changes, passing maneuvers	0.25 m (Lat); 0.50 m (Long); 0.45 m (Vert) [2]	10^{-6} / 15 sec	0.75 m (lat); 1.5 m (long); 1.4 m(vert)[2]	6 / 1 sec (see notes)	10^{-7} / hr (ASIL C/D) [1-4]	99.9% [1]	~ 30 sec unless alert	~ 1 min (see notes)
Follow temporary traffic control (autonomous)	(General) Detect and respond to police, accidents, detours	0.25 m (Lat); 0.25 m (Long); 0.5 m (Vert) [2]	10^{-6} / 15 sec	0.75 m (lat); 0.75 m (long); 1.5 m(vert)[2]	10 / 2 sec (see notes)	10^{-7} / hr (ASIL C/D) [1-4]	99.9% [1]	~ 30 sec unless alert	~ 1 min (see notes)
Regulatory Enforcement (non-autonomous)	Automatically enforce zone-based road tolls & speed restrictions	5 m (2-D horiz.); 0.5 m/s (2-D horiz.) [1]							

Example Service Levels:

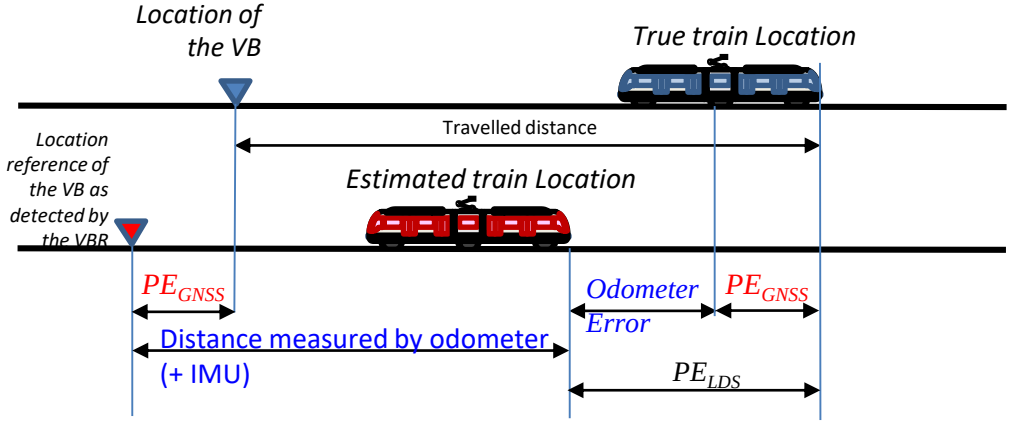
- **~ASIL D**
- **~ASIL C**
- **~ASIL A**

TTA for detection of (but failure to exclude) slowly-growing error or PL / TTA for detection of (but failure to exclude) sudden large or rapidly growing error

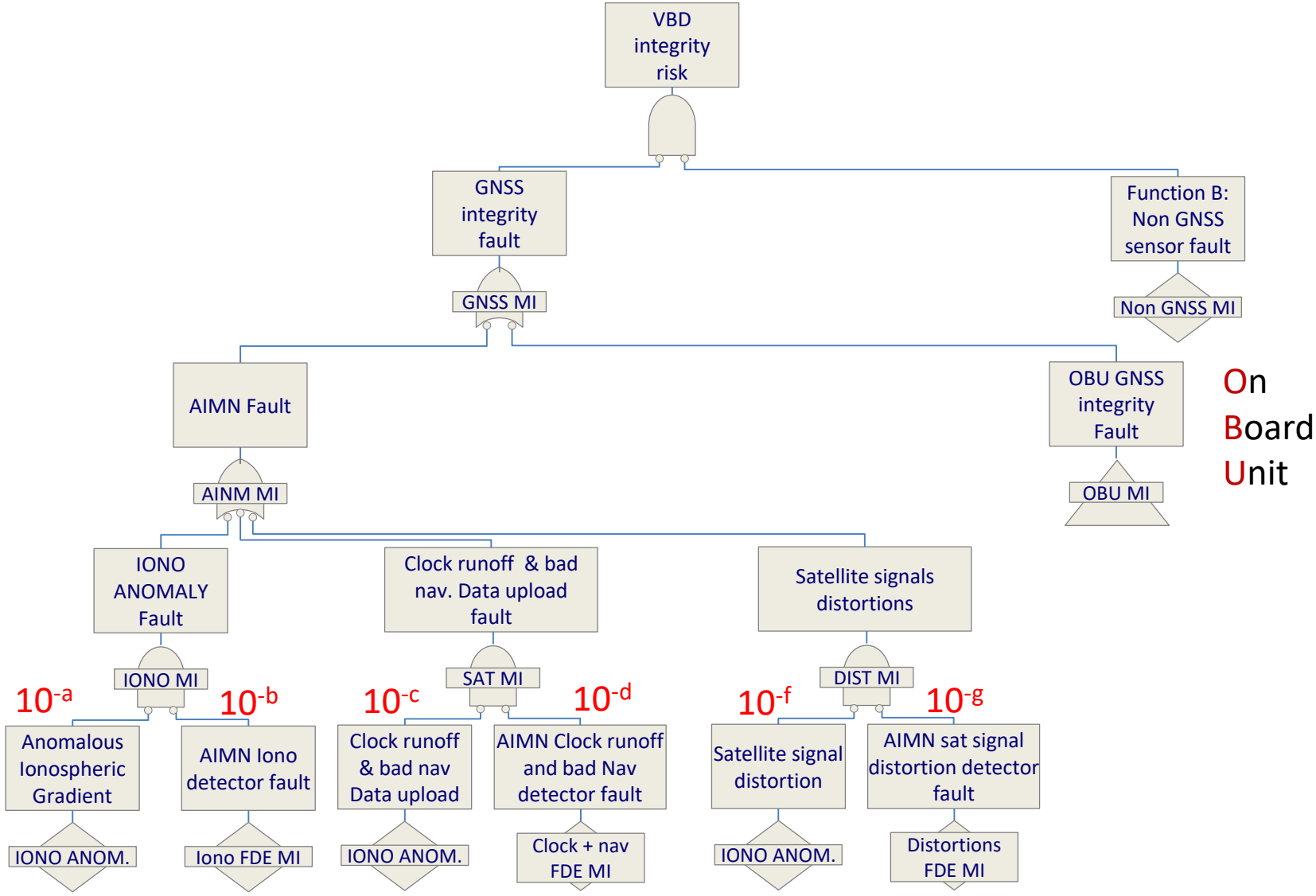
TBA = time at which some probability of service can be provided, but not necessarily meeting the availability requirement.

Rail Safety Aportionement (ERTMS)

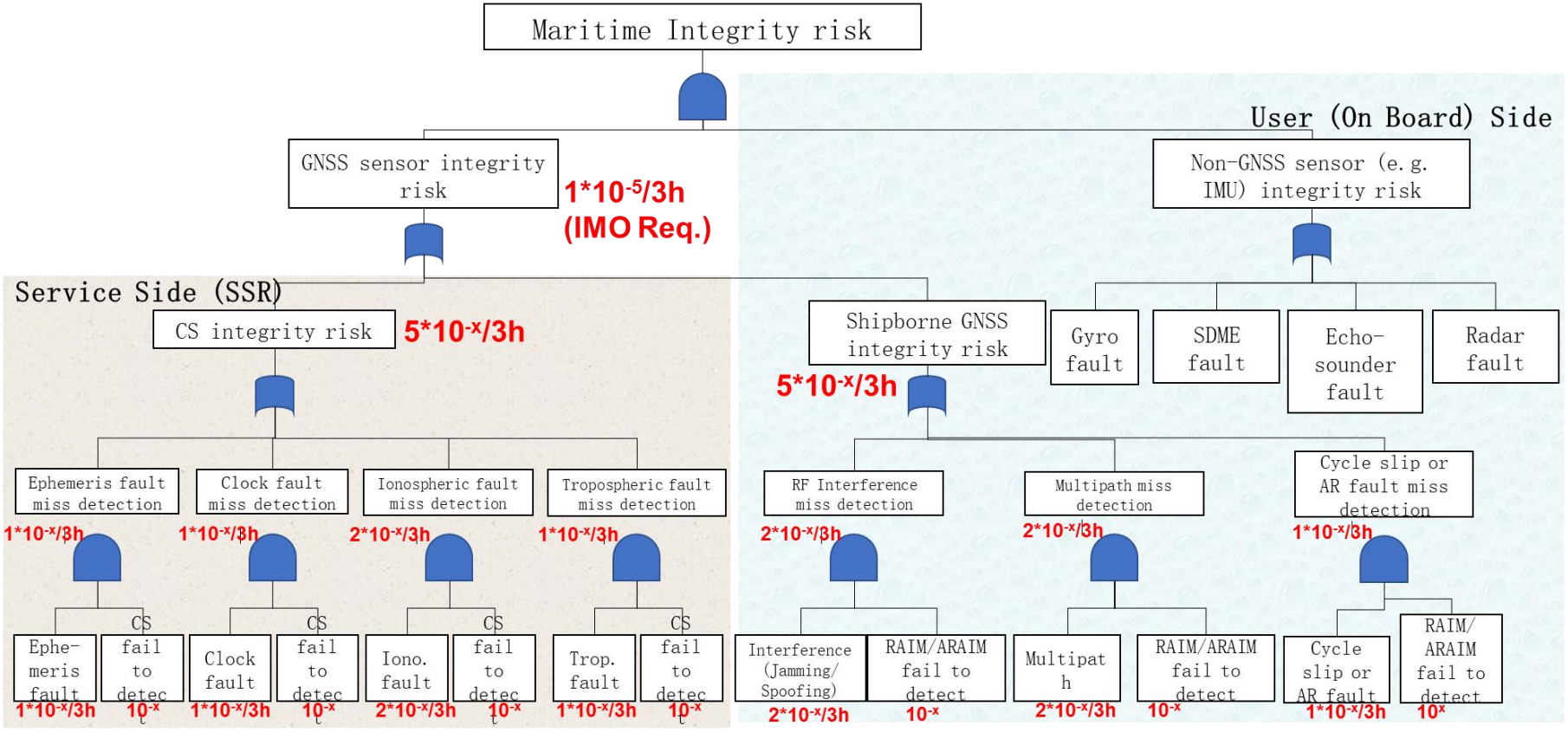
- The core THR parameter with reference to subsystems functions shall be the “exceedance of safe speed or distance as advised to ETCS” and shall be equal to 2.0*e-9 / hour (see UNISIG Subset 088).
- The total THR shall be equally apportioned between
  - ONBOARD,
  - TRACKSIDE
  - TRANSMISSION (components or “gates”)



Example of Rail Fault Tree



Example of Maritime Fault Tree



PPP Integrity Messages

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Message Definition Process

Application Group	Application	Description	Accuracy (95%)	Continuity	Integrity Alert Limit (PNT)	Integrity-Time to Alert	Integrity Risk THR	Average THR/group	Availability (%)	Fu S
Automotive	Obey Rules of the Road (autonomous)	(General) Detect and respond to traffic signs and signals, determine right-of-way, etc.	0.25	10^{-5} / 15 sec	0.75 m (Lat); 0.75 m (Long); 1.5 m (Vert) [2]	10 / 2 sec (see notes)	1.00E-07	1.51E-06	99.5 [1]	T <
	High mani (auto									
	Low- mani (auto									
	Navi inter (auto									
	Follow temporary	(General) Detect and respond to		10^{-5} / 15	0.75 m (Lat);	10 / 2				T

DF #	DF Name	DF Range	DF Resolution	Data Type	Data Field Notes
DF908	Satellite Health Mask	0-1	1	bit(64)	1 bit for each satellite (64 at maximum) describe the health status: '0' do not use, '1' use This message is transmitted together with the DF909
DF909	Satellite Monitoring Status	0-1	1	bit(64)	1 bit for each satellite (64 at maximum) describe the Monitoring status: '0' not monitored, '1' monitored; for not monitored state, the respective Satellite Health in DF908 (in the same position) is set by default to 1; the use of such satellite is under the responsibility of the user

DATA FIELD	DF NUMBER	DATA TYPE	NO. OF BITS
Satellite Monitoring Status			
Satellites Integrity Mask			
TOTAL			

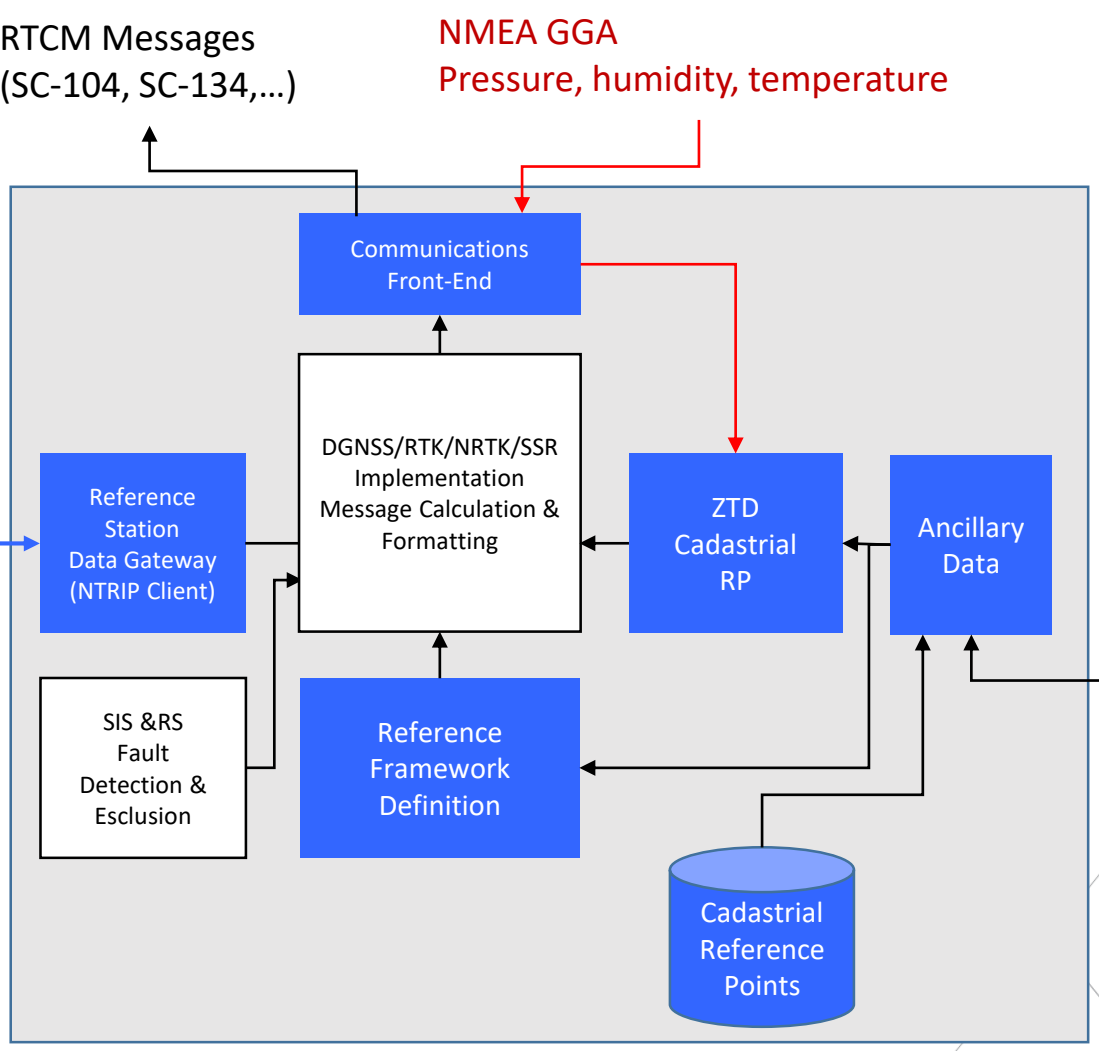
DATA FIELD
Message Number
GPS Epoch Time (TOW)
Reference Station ID
Reference Station Monitoring Status
Reference Station Integrity Flag
TOTAL

1. Requirements definition
2. Fault Analysis and models
3. Message Definition
4. Interoperability Test
5. Standard Update

Application	Operational scenario	Safety Integrity	Accuracy (2*sigma)	Alert Limit (AL)	Time to Alert (TTA)	Availability	Security	Notes
RAIL	Track identification	Very high (SIL 4)	generally < 1 m across track; more precise estimate 0.7 m	1.785 m across track	from 10 s to 30 s	High	Very high	Integrity of vertical position not required
	Odometry calibration	Very high (SIL 4)	generally < 1 m along track; more precise estimate 0.7 m	1.7 m along track	< 1 s	High	Very high	
	Cold Movement Detection	Very high (SIL 4)	< 2 m along track	5 m along track	< 10 s	High	Very high	
AUTO	Automated driving on highway; velocity 80-130 km/hr	Very high (ASIL D)	< 34 cm lateral	< 75 cm lateral	< 1 s	High	Very high	Integrity of vertical position required to confirm road level on multi- level crossing
	Automated driving on local roads; velocity 60-90 km/ hr	Very high (ASIL D)	< 20 cm lateral	< 45 cm lateral	< 1 s	High	Very high	
	Automated driving on narrow and curved roads; velocity 20-60 km/ hr	Very high (ASIL D)	< 9 cm lateral	< 20 cm lateral	< 1 s	High	Very high	

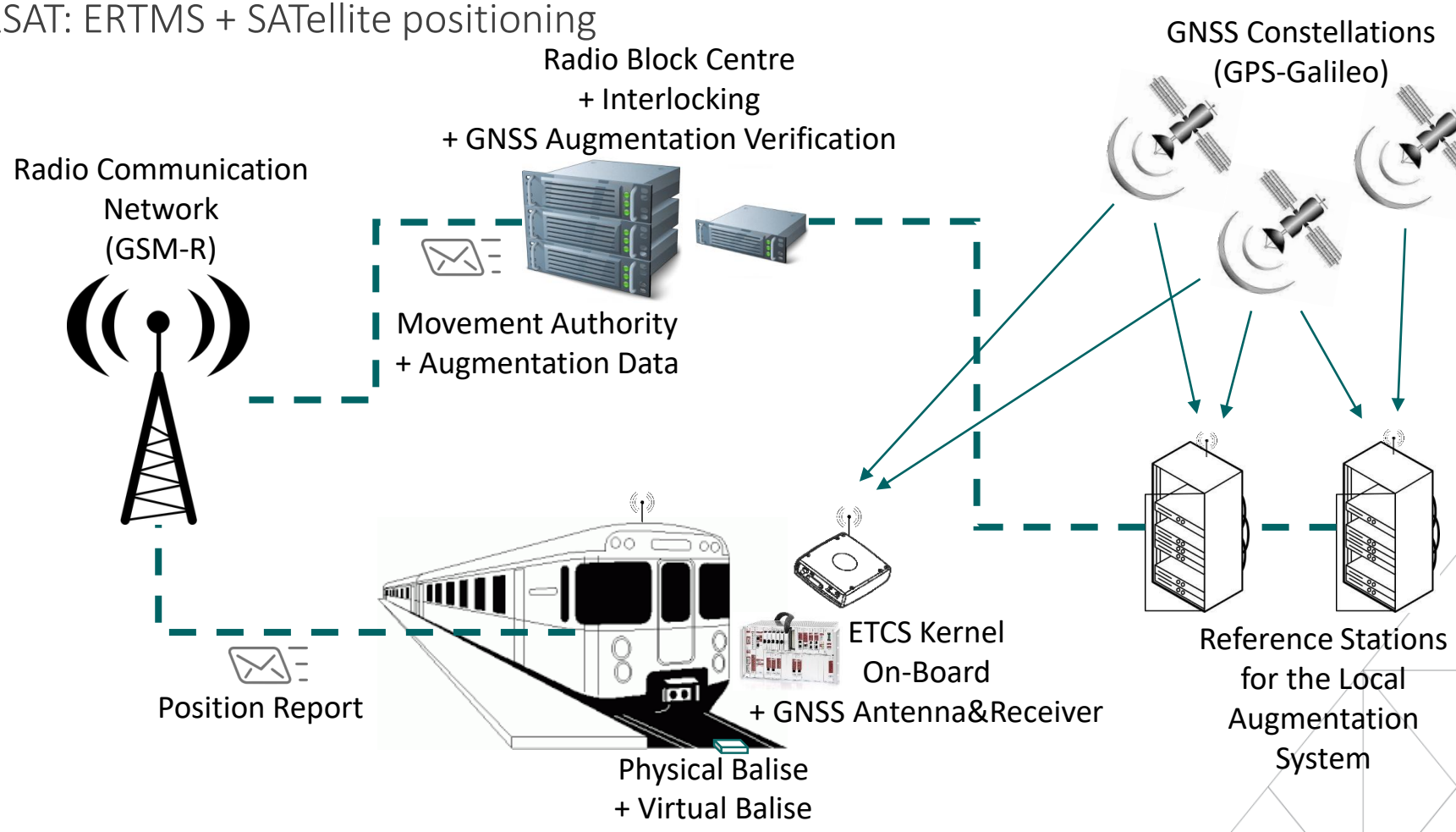
Features

- Several service classes
  DGNSS, RTK, NRTK, SSR, PPP
- On demand services
  Possibility to switch among services on the fly
- Compliance of I/F to international standards for High Accuracy High Integrity

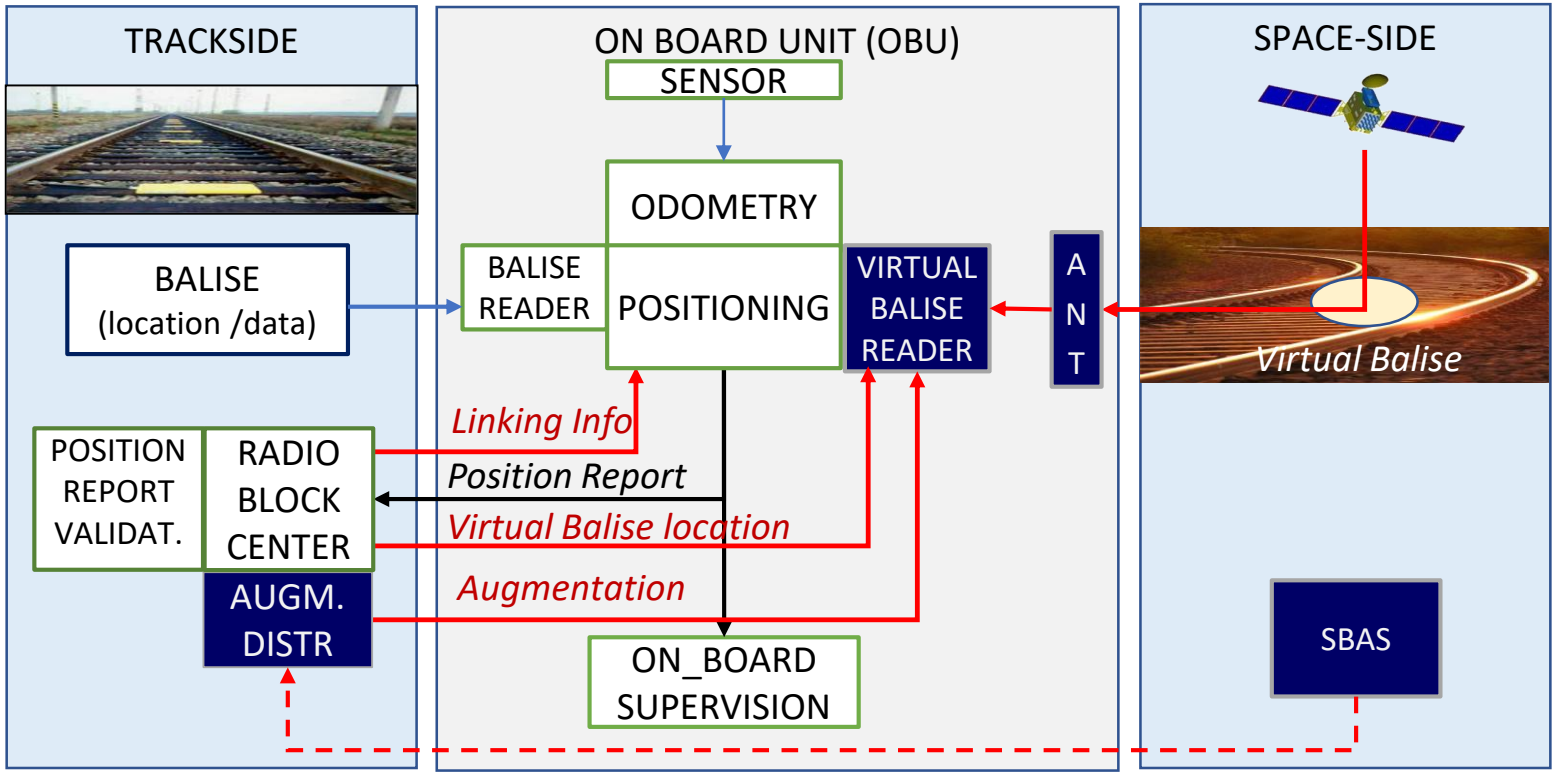


GNSS positioning in the ERTMS

- ERSAT: ERTMS + SATellite positioning

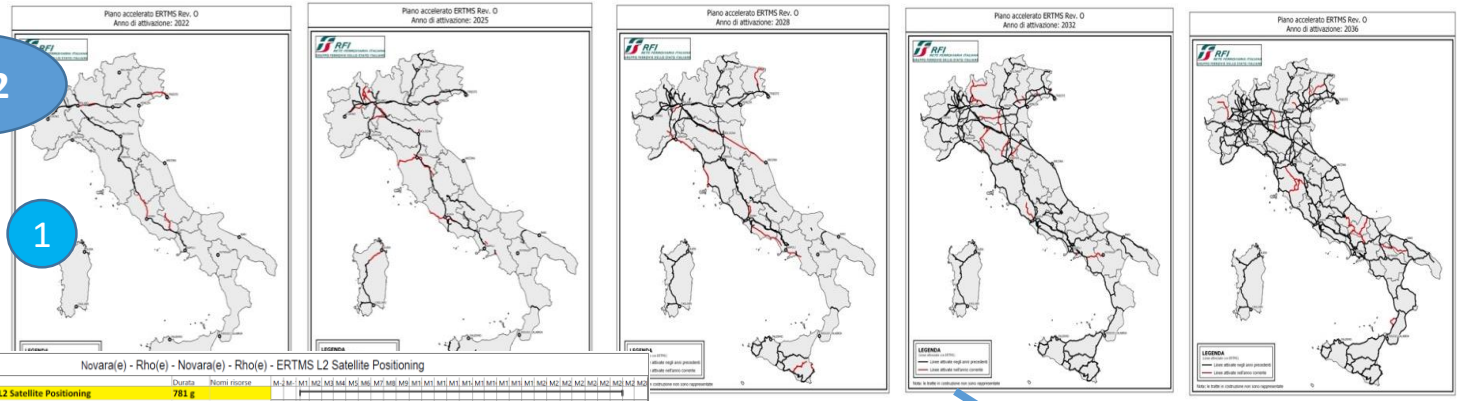


ERTMS/ETCS Train Localization



The GNSS Location Determination System generates the same signals produced by a Balise Reader detecting a physical Balise, through the same logical and physical interface, then emulating the Balise reader behavior with respect to the train equipment. In this way the On Board ERTMS/ETCS location determination functions do not need to be changed.

Il Piano ERTMS nazionale



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Novara(e) - Rho(e) - Novara(e) - Rho(e) - ERTMS L2 Satellite Positioning

ID	Nome attività	Durata	Nomi risorse
1	**Novara(e) - Rho(e) - ERTMS L2 Satellite Positioning**	**781 g**	
2	**Milestone**	**567 g**	
3	Rilascio ISA Report Fase 1 Corridoio ERTMS - Lotto 1	0 g	RFI
4	Disponibilità Loco 668	0 g	RFI
5	Adeguamenti TLC collegamenti PC-PP	0 g	RFI
6	Conferma della disponibilità interruzioni per test in campo	0 g	RFI
7	Alimentazioni PP SAT	0 g	RFI
8	APC con funzioni SAT	0 g	RFI
9	**Realizzazione**	**781 g**	
10	Completamento SRS ed Hazard Analysis	80 g	HSTS
11	Sviluppo GA ERTMS/GAD/TV	275 g	HSTS
12	Sviluppo GA VBR e integrazione SSB BL3	275 g	HSTS
13	V&V GA ERTMS/GAD/TV	151 g	HSTS
14	V&V GA VBR e integrazione SSB BL3	151 g	HSTS
15			
16			

In field test, safety case, ISA Report

12/2/2023

3

RFI supported projects

- GNSS Receiver → ESA - EUSPA
- Telecom → FRMCS readiness
- GNSS Laboratory → Simulation tools ERTMS Laboratory
- «Testa di Serie» → Migration from Novara-Rho
  Standard AU-network, pre-operational fleet

1 + 2 + 3

A joint effort: industry – RFI – Space Agencies

For all their potential synergies, industrial investments and coordinated actions towards Space Agencies is possible to define a master plan including technological developments, validations and certifications to allow RFI to procure satellite-based ERTMS solutions.

European Global Navigation Satellite Systems Agency

Co-funded by the Horizon 2020 programme of the European Union

The GISCAD-OV Project: Innovative GNSS High Accuracy Services for Cadastral Surveying

"This project has received funding from the European GNSS Agency under the European Union's Horizon 2020 research and innovation programme under grant agreement No 870231"

Project Organisation

- Horizon 2020 Project
- Started on December 2019
- Project Duration: 36 months
- Project Coordinator: Geoweb

- Project Members:
  - International Organisation of Surveyors
  - Local and PPP Service Providers
  - Service Providers
  - PPP and NRTK Software Company
  - NMCAs
  - Surveyors Service Providers
  - Receiver Manufacturers
  - Universities
  - RTCM and ISO Standardisation Chairmen
  - Advisory Board, including NMCAs

Organization	Type
GEOWEB SpA	Industry
EXAGONE	Industry
IGN-CNIG	Public Body
SOGEI SpA	Industry
UNIPD	University
GEO++ MbH	Industry
NOVATEL Inc	Industry
YORK University	University
GEOFLEX	Industry
TU Delft	University
TELESPAZIO	Industry
VUGTK	Public Body
CLGE	Public Body
UNIROMATRE	University

European Global Navigation Satellite Systems Agency
Co-funded by the Horizon 2020 programme of the European Union

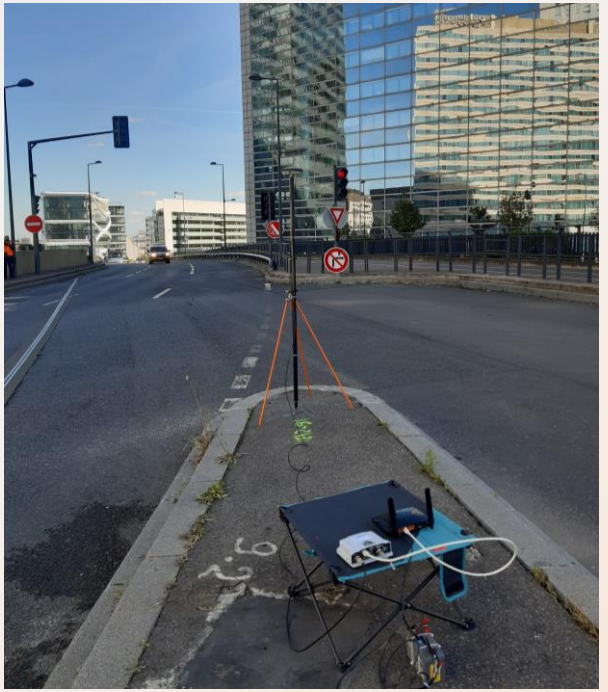
Project objectives

- **Objective**: design, development and validation of **reduced cost GNSS High Accuracy Services** for Cadastral Surveying and **Infrastructural Monitoring** applications through **Galileo HAS services, PPP and PPP-RTK**
- Expected impacts:
  - Service Providers: reduced infrastructure and maintenance costs
  - Cadastral Professional users: reduced HA service costs
  - Receivers manufacturers: market uptake due to lower barrier to entry
  - NMCAs: Harmonized GNSS service levels over a wide area, improved efficiency

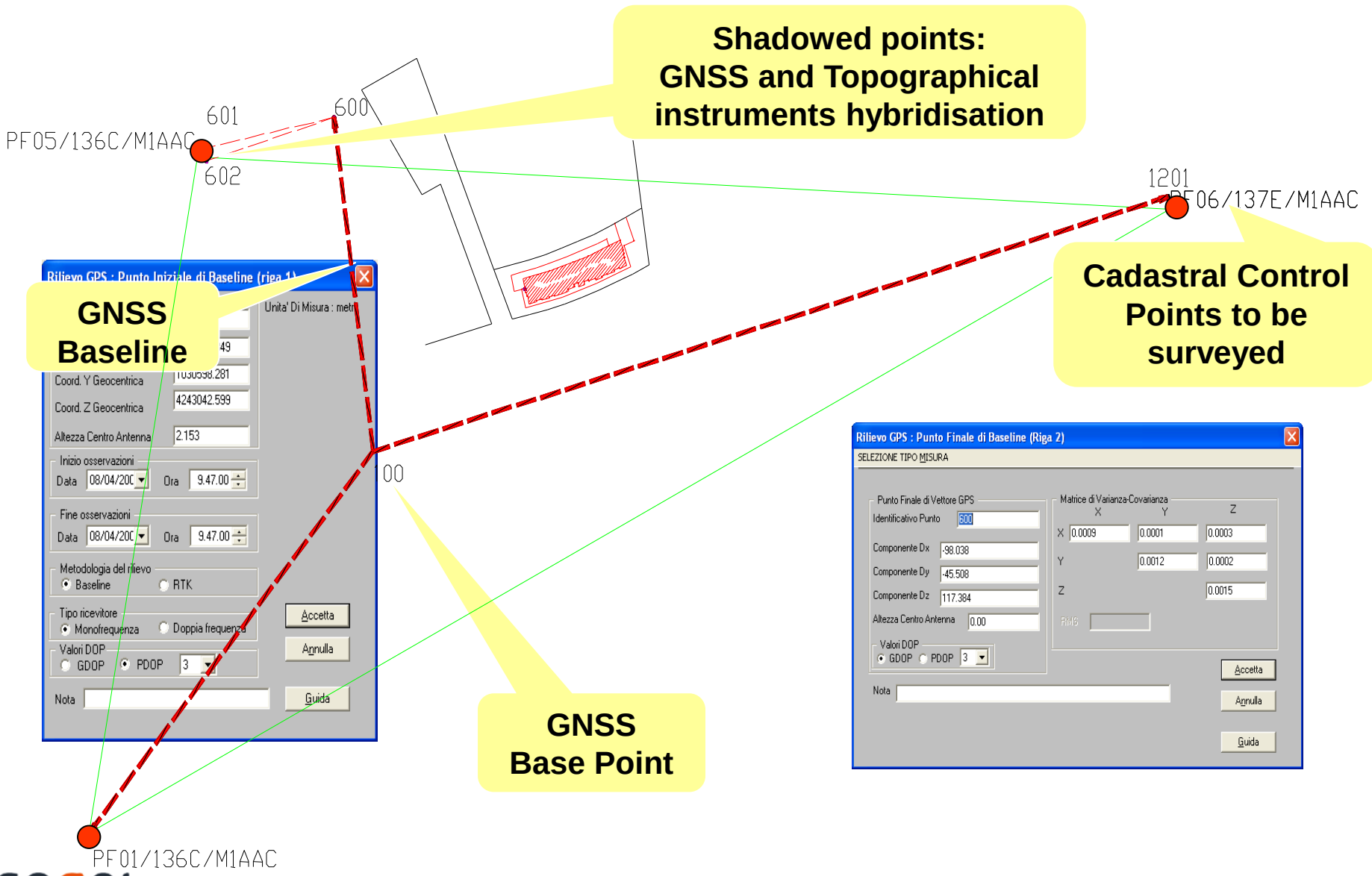
Co-funded by the Horizon 2020 programme of the European Union

Pilot Project activities

- Carried out Pilot activities: three Real Cadastral surveys in Italy (Rome, Nepi) and France (Paris, Montlherey)
- Galileo High Accuracy Services:
  - PPP-RTK
  - Galileo HAS
  - RTK
- On-field performances:
  - PPP-RTK: 1 cm, istantaneous fixing
  - Galileo HAS: nominal performances
- Infrastructure Monitoring Test on Buildings and Critical infrastructures (ponte di Orte)

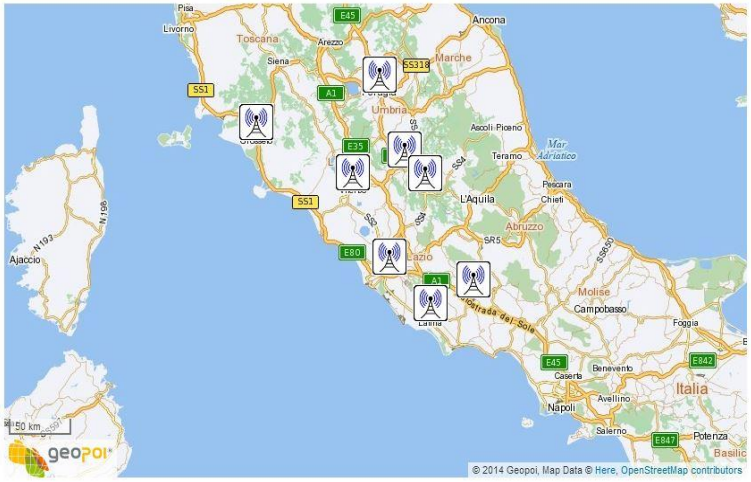


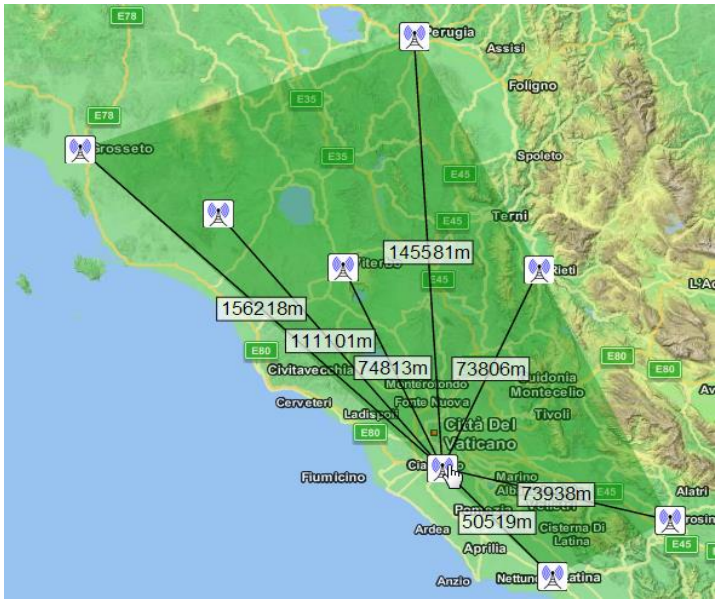
Cadastral applications in Italy



GRDNet (GNSS R&D Network) Network

- Deployed in 2003 by Sogei for providing institutional Real-Time high accuracy positioning services
- Currently covering the central area of Italy
- **Single Station, Nearest and VRS Services**
- **Fully Standard compliant** (NTRIP protocol, RTCM v3.x data format)
- **Open and Scalar** Architecture, **any kind of GNSS Reference Station**
- **Internally developed GNSS Control Centre Software**
- **Web Network Performances Monitoring and Control**
- **All Reference Stations are Galileo Ready**





Conclusions and recommendations

- A unique Augmentation Network is needed for autonomous and multimodal transport implementation and surveying/mapping applications
- A Cost Sharing among the trasport applications can be used for the High Accuracy and High Intgrity Augmentation System Development
- Integration of Global (PPP, Galileo HAS) and Local Augmentation can lead to service differentiation and Infrastructure cost reduction for several applications
- Italy, through EC funded projects and Next Generation EU funds, can become a pioneer for the development of autonomous transport and public administration services