WP2
Preparation of campaign

Salvatore Sabina (Ansaldo STS)

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 687414

WP2 – Preparation of campaign

Why these test campaigns?

- Many R&D Projects related to the application of GNSS into the railway environments were executed in the past and roughly all of them did test campaigns. Example of these projects are GRAIL 1, GRAIL 2, 3InSat and ERSAT-EAV.

- The STARS WP 2 aims at defining an **agreed methodology among the UNISIG members** to carry out test campaigns for evaluating the use of GNSS in the **SIL 4** Signalling **Train Position** Function. The **main objectives** of these test campaigns are the collections of the **measurement information** required for the **characterization of the railway environments with regards to GNSS signal reception** and the **achievable quantitative predictions of GNSS performances**.

WP2 – Preparation of campaign (cont.)

This **methodology** covers:

- Identification of the **GNSS SIS** and **SBAS data** to be **measured** to characterize GNSS with respect to system and local feared events in the railways environments;
- Identification of the **railway signalling information** to be **measured** for building the true position references (i.e. **Ground Truth**) to quantitatively assess GNSS in the railways environments;
- Definition and description of the **measurement procedures** and the related **setup environments** to perform test campaigns;
- The description of the **criteria** to be used for **selecting both a line and a type of test train** so as the test campaigns can be considered **suitable for** the **GNSS characterization** and **performance assessment**.

Specification of the Measurement Information

In order to identify the GNSS SIS and SBAS data to be measured, the starting point was the **RTCA DO-229D** with regard to the system feared events. Then, special focus was put on the **local feared events** that are the main peculiarities of the railways environments. Example of these local feared events are:

- Multipath both from trackside permanent objects, on-board permanent objects and temporarily objects due to the dynamic train movements.

- Radio Frequency Interferences (unintentional and intentional, internal or external to the locomotive).

- Sky visibility and NLOS.

Specification of the Measurement Information (cont.)

To identify the GNSS data to be measured to cope with local phenomena, a preliminary analysis of the possible monitoring techniques was done. Examples are:

- Code Minus Carrier (CMC);
- Multipath Mitigation Algorithm embedded in professional receivers;
- GNSS Post-processing techniques of GNSS RF samples;
- Analysis of signal quality indicatorss such as C/N0, SNR, I&Q correlator outputs,, …);
- ……

Local phenomenon	Technique and Measurement	Technique description	Notes (~) Pros (+) Cons (-)
2.1.3 GNSS Signal attenuation, sky visibility	2.1.3.1 Analysis of signal quality indicator(s) in raw data (C/N0, SNR)	Signal attenuation due to shadowing demonstrates as lowering of signal quality indicator(s) (C/N0, SNR). Signal blockage, or also strong signal attenuation, is expressed as synchronization loss, so the receiver doesn't provide measurements (raw data) to blocked satellite(s). These have to be compared with satellite elevations (e.g. computed from ephemeris). First, a satellite ca[illegible] be below the horizon (this is a natural signal blockage by t[illegible] Earth, and not an objective of this analysis). Secon[illegible] sig[illegible] can be tracked with lower C/N0 due to lower gain o[illegible]enn[illegible] radiation pattern (this is a consequence of the utilized a[illegible]na and also not an objective of this analysis). The technique itself has not potential to distin[illegible]caus[illegible] i.e. among the signal attenuation/blockage[illegible]ltipath [illegible]d RF interferences.	~ evaluates sky visibility/signal attenuation only in directions (azimuths/elevations) of actually processed satellite signals; "evaluation" means to assign GNSS signal attenuation to particular direction [illegible]nal quality indicator as C/N0 and SNR ar[illegible]ommonly available in raw data or even [illegible]NM[illegible] messages [illegible] de[illegible]dation of quality indicator can have [illegible] other reasons then signal attenuation due to shadowing (RF interference, lower antenna gain for low elevations, etc.)
	2.1.3.2 Utilization of 360° camera	Panoramic pictures taken from the G[illegible]nte[illegible]n can be used for determination of sky v[illegible]d id[illegible]cation of obstacles which can cause sig[illegible]enuat[illegible] In pr[illegible]le, the identification of clear sky di[illegible] (in az[illegible]th x elevation coordinates) is straightf[illegible]d. A[illegible]sue could be the assessment of obstacles [illegible] GN[illegible] signal attenuation perspective (assig[illegible] the [illegible]nuation in directions of identified obstacle[illegible] fig[illegible] Pr[illegible]bly, a dedicated study with calibratio[illegible] measu[illegible]e[illegible]s [illegible]eeded to determine the lens disto[illegible]rther, an [illegible]pro[illegible]te algorithm has to be proposed an[illegible]plemen[illegible] for [illegible]mous image processing (note that sat[illegible]ngle identification from image processing has [illegible] been [illegible]formed in [12]).	~ evaluates sky visibility/signal attenuation in all directions (360°/180°); "evaluation" means to assign GNSS signal attenuation to particular direction ~ the size of data volume depends on picture quality ~ camera should be regularly checked and cleaned within WP3 + simple requirements of device capabilities (360° camera) + in principle, straightforward identification of directions with clear sky - the assignment of attenuations to identified obstacles (e.g. vegetation with different mass) is feasible but can be challenging, and requires a dedicated study for specific image processing - for autonomous processing of figures the appropriate algorithm has to be proposed and implemented [13]

Specification of the Measurement Information (cont.)

The measurement information to be acquired to enable the GNSS characterization and the related achievable performance on the railways environments were classified into four types of measurements.

- ***THE GNSS/SBAS SIGNALS, PSEUDO RANGE AND PHASE MEASUREMENTS, NAVIGATION MESSAGE***
- ***THE GNSS RF SAMPLES***
- ***THE RAILWAYS ENVIRONMENT***
- ***THE TRAIN ENVIRONMENT***

Specification of the Measurement Information (cont.)

THE GNSS/SBAS SIGNALS, PSEUDO RANGE AND PHASE MEASUREMENTS, NAVIGATION MESSAGE

- Constellation and Frequencies;
- Satellite Elevation Angle;
- Pseudo range and Phase Measurements in RINEX 3.x Format, possibly without any iono or tropo model corrections;
- Navigation Data GPS and SBAS Messages to Record in RINEX 3.x Format;
- Auxiliary Receiver information

  GNSS receivers' flags should also be recorded for supporting in-depth analysis of receiver behavior in some specific points. Examples are:
  - ✓ RX-Status;
  - ✓ User Range accuracy;
  - ✓ Validity of measurement;
  - ✓ Clock update indicator (optional).
- ....

Specification of the Measurement Information (cont.)

THE GNSS RF SAMPLES

These are samples of the GNSS signal down-converted either at baseband or to IF (frequency in MHz).

3.1.10 GNSS RF samples

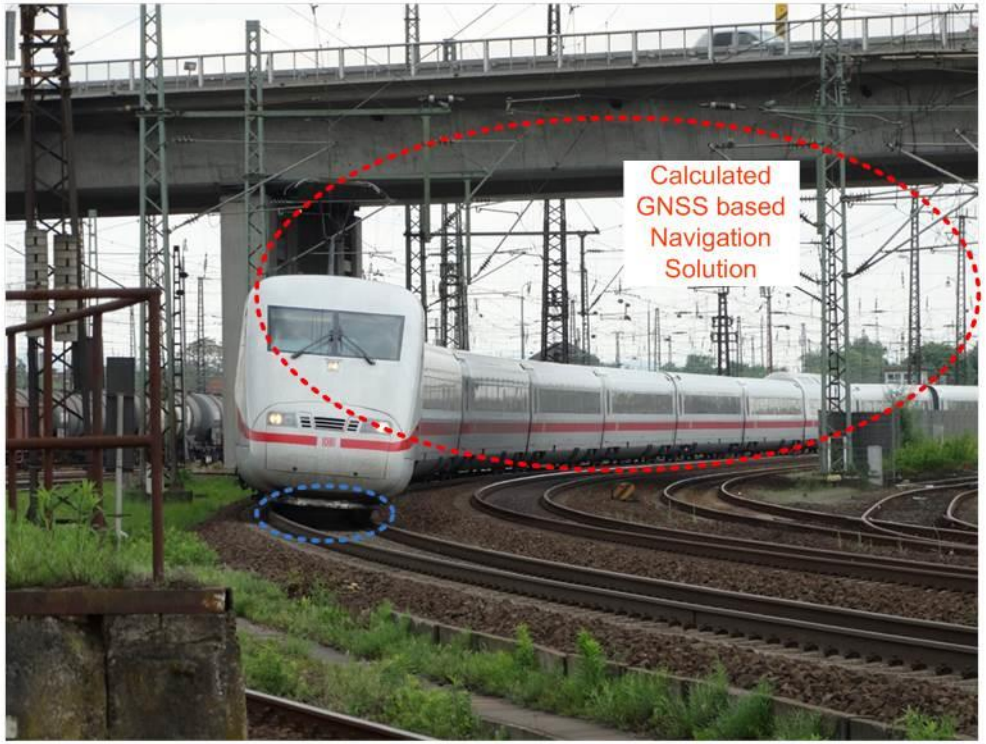
GNSS RF samples shall be recorded with a bandwidth covering the whole frequency plan of the considered GNSS band (of the order of 20 to 24 MHz). The motivation is to consent the experimentation at RF samples level with various algorithms and receivers to characterize interference and multipath affecting GNSS signals in railway environments. If the motivation is to characterize both multipath and interference, there should be at least 16 quantization bits for each sample, on the other hand, if multipath is to be characterized while it is enough that interference be detected from the GNSS RF samples, then 2 quantization bits for each sample should be good enough.

Specification of the Measurement Information (cont.)

THE RAILWAY ENVIRONMENT

N.	Measurement	Frequency/Period	Resolution
1.	Information about obstacles and sources of shading or blockage (such as buildings, foliage, bridges, tunnels) on the railway line	5-10 meters	NA
2.	Minimum satellite elevation for line of sight signal reception with a granularity of a couple of meters	5-10 meters	1 degree
3.	Received GNSS signal power spectral density for all GNSS frequency bands (1140 MHz to 1630 MHz) using a high resolution bandwidth in order to distinguish GNSS signal low power from noise floor density.	1-10 seconds	NA
4.	Received signal power density for frequency bands adjacent to GNSS using a high resolution bandwidth in order to distinguish RFI signal power and GNSS signal power from noise floor density (900-1800 MHz frequency range).	1-10 seconds	NA
…..			

Specification of the Measurement Information (cont.)



GROUND TRUTH AS A POSITION REFERENCE

To allow the quantitative evaluation of the GNSS performance on the railways environments, the along track true train positions for the test campaigns are required.

The estimated along track position is a random process, whose description can be done by using an infinite indexed collection of **random time or space dependent variables**.

Due to the **complexity** of statistically characterizing this random process, it was agreed to compute the true positions to be used as references (i.e. **Ground Truth**) for **each train run** and this Ground Truth has to be computed based on **signalling data <u>contextually</u> measured during the same train run**.

Specification of the Measurement Information (cont.)

GROUND TRUTH AS A POSITION REFERENCE

To allow the off-line computation of the Ground Truth, it was agreed to acquire the following information:

- Track data base (e.g. position coordinates of geo referenced track points, their related position accuracies, track gradient, ...);
- Absolute reference measurements to determine the track on which the train is moving and to recalibrate the relative travelled distance measurements from absolute references;
- Relative travelled distance measurements to determine the position of the train on the track, after it has passed the last absolute reference.

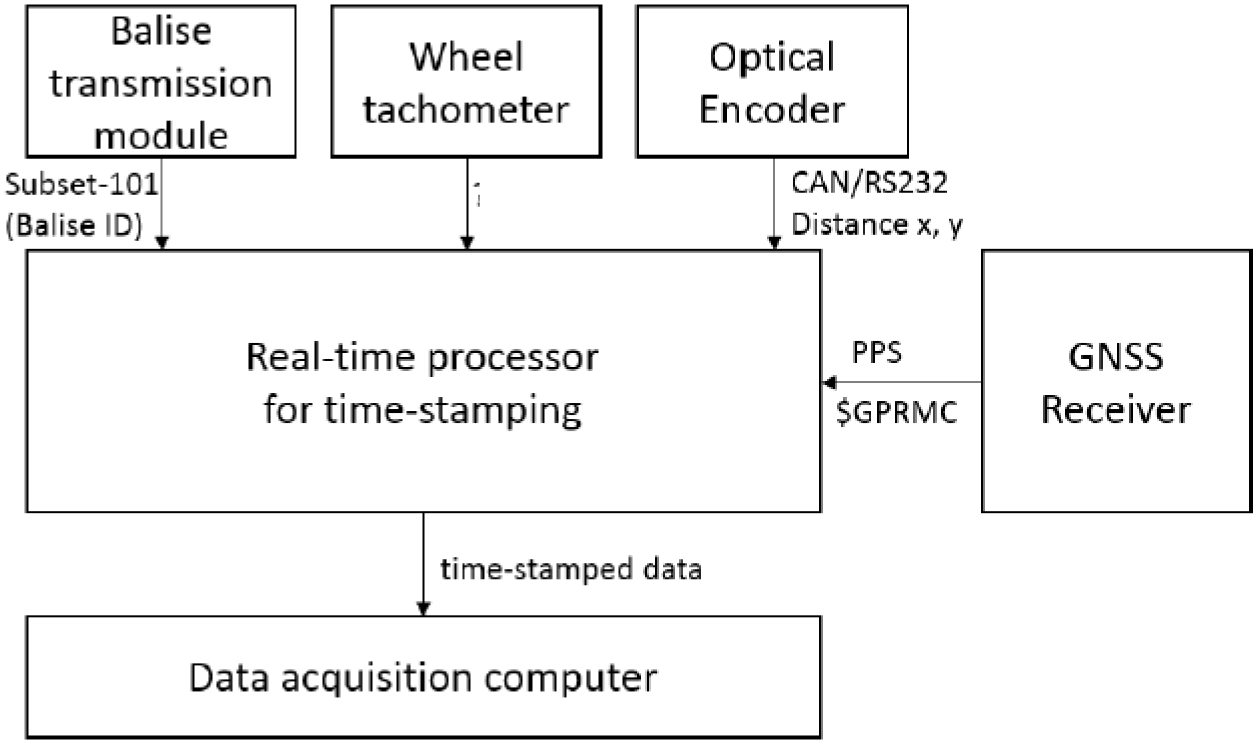
Absolute Reference Points with Eurobalise

Absolute Reference Points with MIB

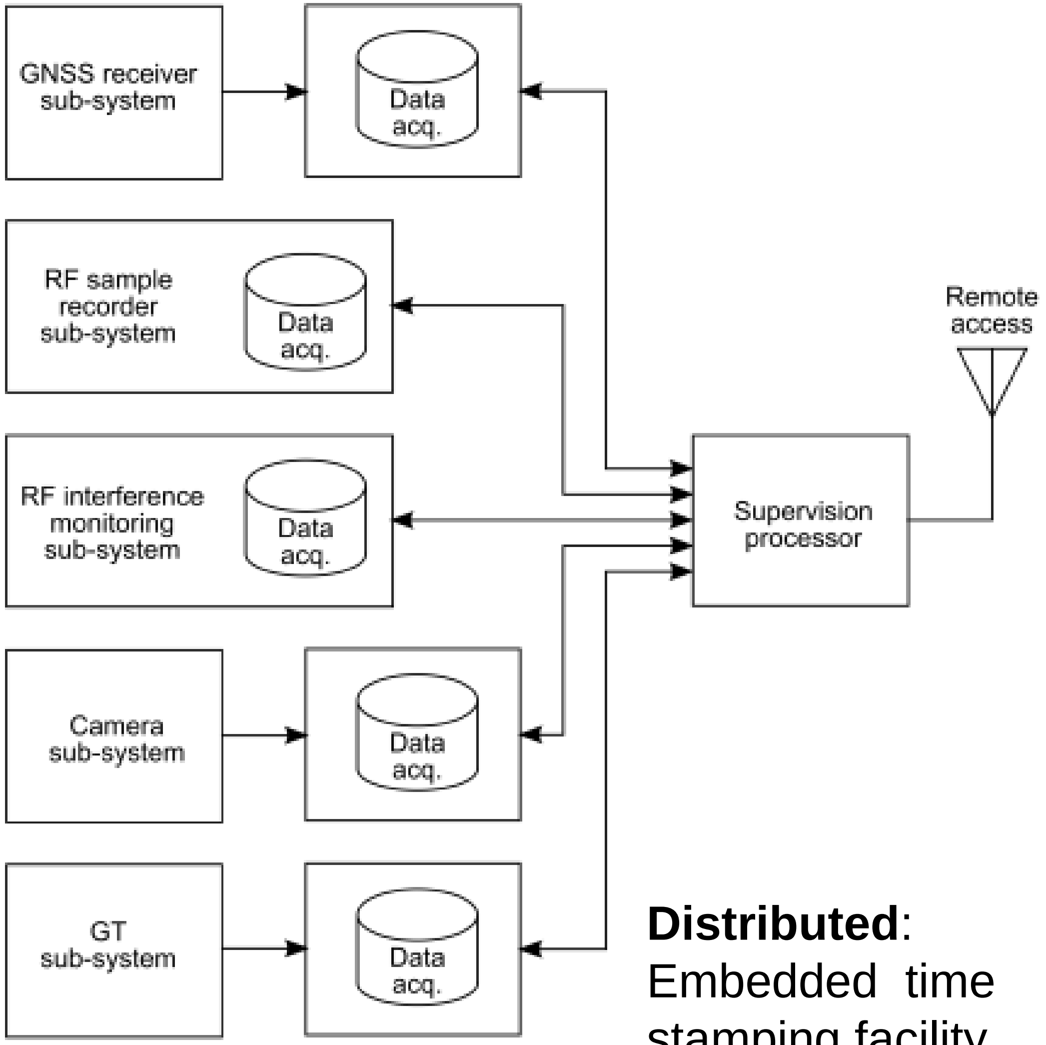
Absolute Reference Points with Track Markers

Measurement Procedures Specification

Measurement Infrastrutture Architectures



Centralised: The real time processor provides a unique time reference for all measurements and data storage



Distributed: Embedded time stamping facility

Measurement Procedures Specification (cont.)

Set of Measurements	Equipment
GNSS Raw Data, GNSS PVT Output, GNSS PVT by using RTK	GNSS Receiver: Septentrio AsteRx3 or AsteRx4, Ublox EVK-M8T, Javad TRE-G3T, GNSS Antenna Antonics OmPlecs-TOP 200 AMR 1500 B, Antcom G8Ant-3A4T21-RL-RoHS, Huber&Suhner SWA - 0825/360/5/30/V
GNSS RF Samples	GNSS Spirent GSS6425 or GSS6450, TeleOrbit GTEC
In-Band/Out-Band Interference	Spectrum Analyzer (Spectran HF-8060 V5 RSA)
Environment Related	Viovotek FE8174V, GoPro, 360° Camera
Train Estimated Position	Magnetic Identification Balise; Eurobalise, RFID RF-R300, Tachometer, Optical Correlation Sensor, AVV&CRV System




Measurement Procedures Specification (cont.)

The Measurement Procedures Specification includes:

- Procedures related to:
  - ✓ Time Synchronization;
  - ✓ Data Acquisition Computer;
  - ✓ Test Specific Data;
  - ✓ Common Measurement infrastructure composed of GNSS Antennas, GNSS Splitters, GNSS Receivers, GNSS Recorder Playback System, Spectrum Analyzer;
  - ✓ EGNOS Data (e.g. EDAS Service, the broadcasted information, web servers);
- The description of the agreed common data format;
- The description of the naming conventions to enable the exchange and the use of the measured information by each STARS participants;

Identification of the Representative Railways Lines / Sites

Requirements for selecting Railway Lines and Types of Engines

- Geographic Track Data:
  - ✓ Availability of track data information;
  - ✓ Accuracy of the track position data;
  - ✓ Freshness of the track data information;
  - ✓ ...
- Absolute Reference Points (Eurobalise, MIB, RF-TAG, ...)
- Vehicle Data:
  - ✓ Engine Type (AC/DC or Mixed Power Supply or Diesel)
  - ✓ Maximum Acceleration / Deceleration;
  - ✓ Maximum Speed;
- ...

Identification of the Representative Railways Lines / Sites (cont.)

Requirements for selecting Railway Lines and Types of Engines

- Diverse Railway Environments

Open Sky Environment

Restricted Environment

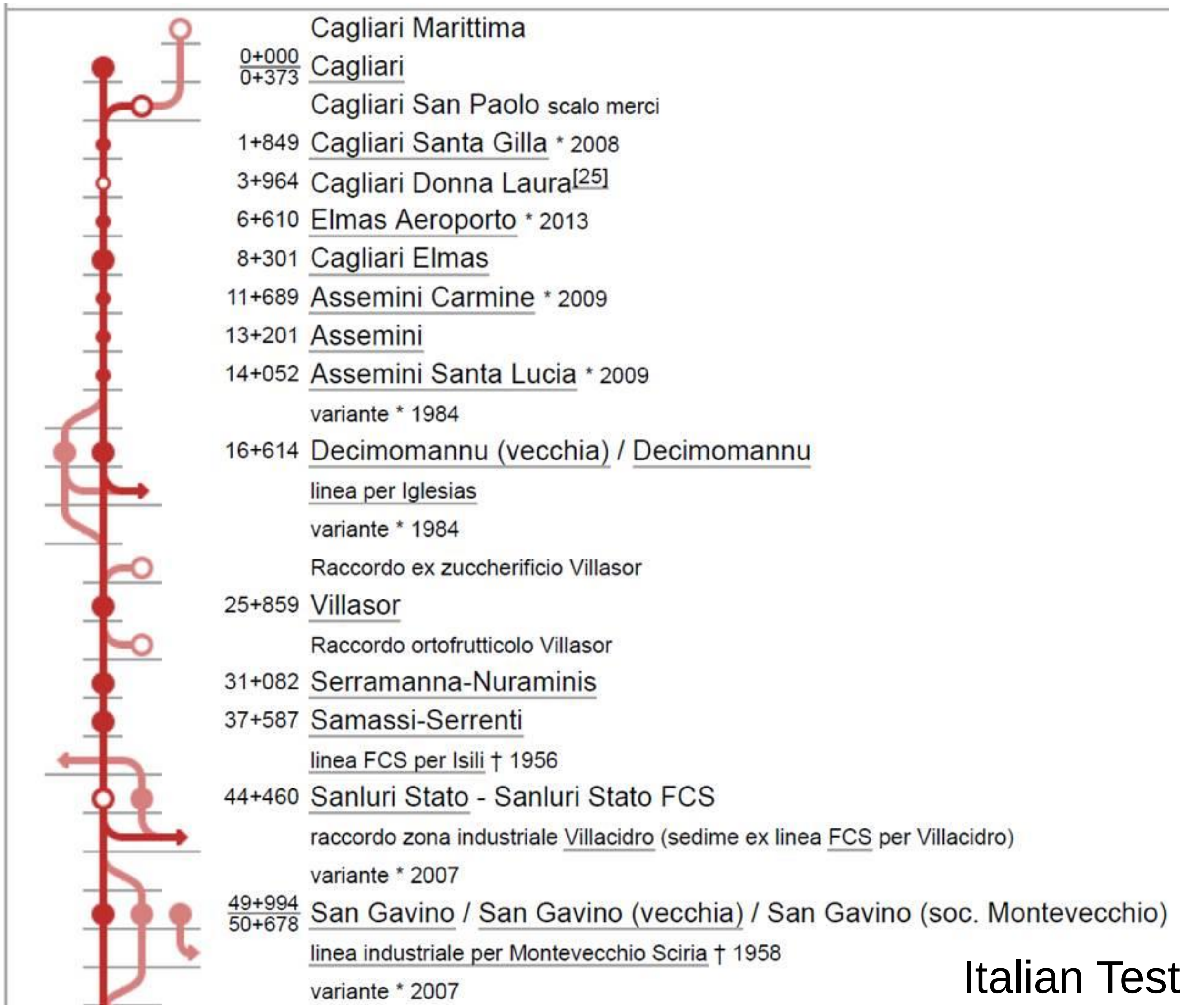
Urban Environment

Identification of the Representative Railways Lines / Sites (cont.)

Selection Criteria for Test Sites and Vehicles were defined

Criteria	Applicability	Characteristic	Relevance	Description
Track type diversity	Track	mountainous tracks, secondary lines, urban tracks, high speed lines and others	High	
Environment diversity	Track	Open sky, restricted and urban environment	High	
Operated track	Track	Length	Low	It should be ensured that the track used is sufficiently long to provide diversity, and to avoid that measurements are only performed in an area which might be uniformly impacted by a single parameter
Geographical track data	Track	Availability, accuracy	Low to High (depends on the available Ground Truth measurement system capability)	Data analysis will depend heavily on accurate ground truth information and digital track data; although a good ground truth measurement system can make track data information obsolete. The absolute train position reference will have to be compared with the position determined by GNSS. Track data must be track selective, providing separate data for each track on a line.

Identification of the Representative Railways Lines / Sites (cont.)



Aln 668 - Diesel, 130 km/h, Test Line Length 50 km, Ground Truth based on Eurobalise and Odometry

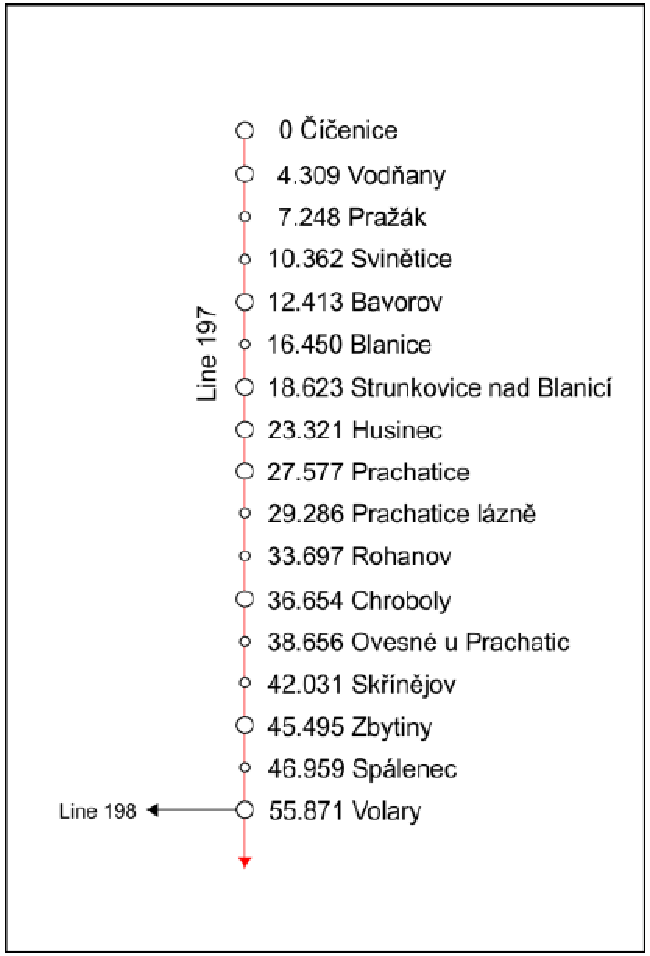
Italian Test Site

Identification of the Representative Railways Lines / Sites (cont.)

RBDe 560, 15KV 16.7 Hz, 140 km/h, Test Line Length >1000 km, Ground Truth based on Eurobalise and Odometry

Switzerland Test Site

Identification of the Representative Railways Lines / Sites (cont.)



Diesel Multiple Unit, 80 km/h, Test Line Length 56 km, Ground Truth based on RF-RID

Czech Test Site

THANK YOU

STARS

SATELLITE TECHNOLOGY FOR ADVANCED RAILWAY SIGNALLING

SALVATORE SABINA
Vice President Innovation & Satellite Projects

ANSALDO STS
Via Paolo Mantovani 3/5, 16151
Genova

+39 010 655 2400

salvatore.sabina@ansaldo-sts.com

www.ansaldo-sts.com

European Global Navigation Satellite Systems Agency

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 687414