European Global Navigation Satellite Systems Agency

ERSAT GGC

WP4 - Track Survey and Track Classification

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Participants: DLR, Hitachi Rail STS, Radiolabs, RFI, IFSTTAR, INECO, CEDEX, ADIF, SNCF, Trenitalia, RINA

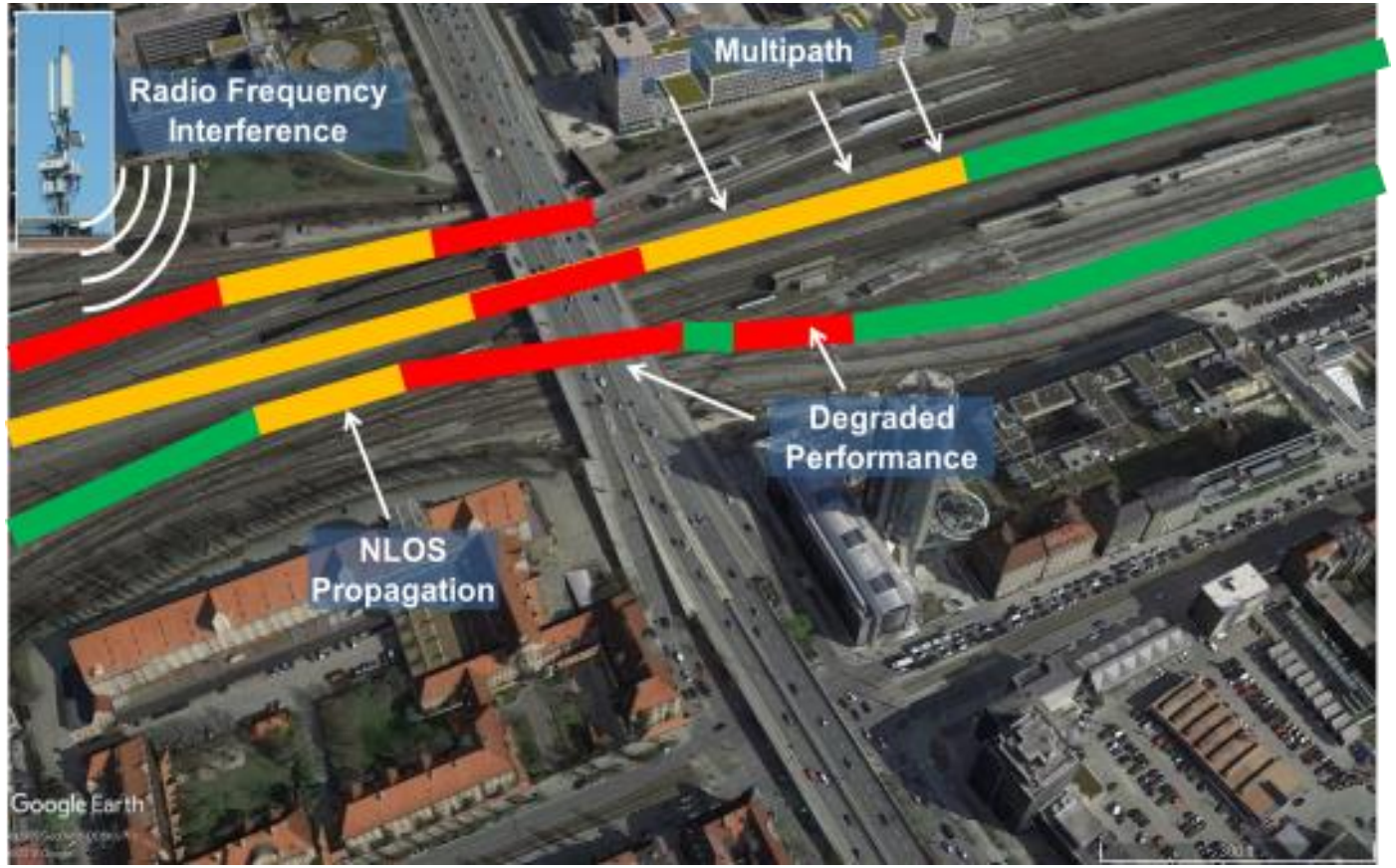
ERSAT GGC Final Event, 26.11.2019

Main Objective

The goal is to eliminate a priori areas where local feared events can potentially impact safety and availability, so that we bound a priori the risk of presence of these hazard causes at virtual balise level.

- We define therefore a **Process, Methodology** and the **related Toolset** for Classifying Track Areas as Suitable or Not Suitable for locating Virtual Balises based on potential GNSS local feared events

- Target: Interference, Multipath, NLOS and degraded performance



WP4 Overview

WP4 - Track Survey and Track Classification	
Participants: DLR, RFI, STS, RDL, IFSTTAR, INECO, CEDEX, ADIF, Trenitalia, SNCF, RINA	
Tasks	Name
WP 4.1	Definition of the Process for the Survey and the Classification of Track Areas
WP 4.2	Specification and Development of the Toolset for the Survey and Classification of Track Areas
WP 4.3	Execution of the Track Survey and Data Collection
WP 4.4	Evaluation of data and Integration of the Toolset in CEDEX, DLR, RINA and RFI Laboratories

Content

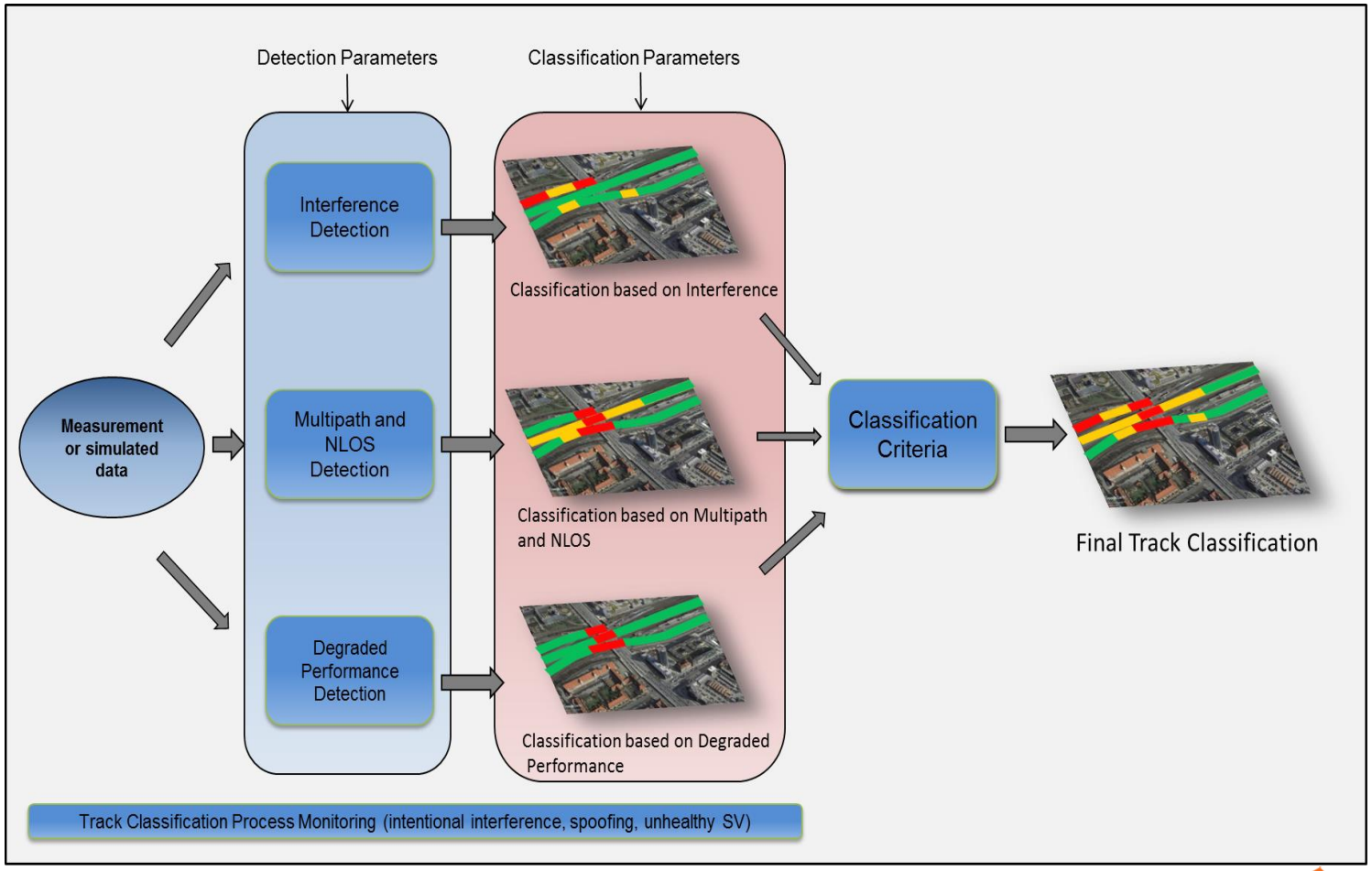
- Classification Process Requirements and Overview
- Campaigns Preparation and Measurement System
- Software Toolset Processing Overview
- Laboratory Testing and Results Evaluation

Track Classification Process

The goal is to build a track area classification process based on the presence of permanent GNSS threats along the railway line.

The main components of the process are:

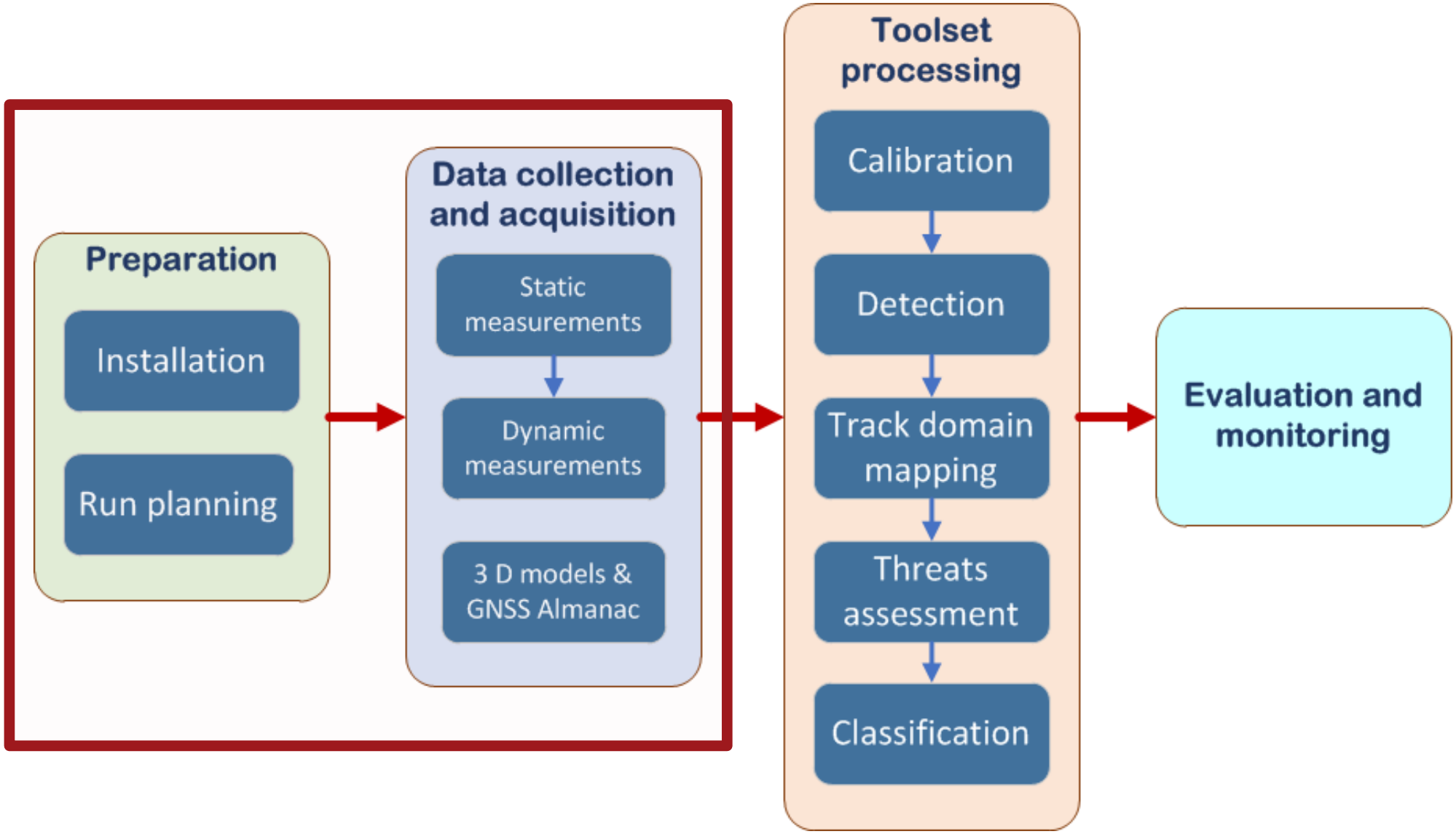
- ✓ A **measurement hardware** system responsible for acquiring the observable signal data
- ✓ Different **detection techniques** targeting the different GNSS threats to be considered
- ✓ A **decision logic** that processes the detection techniques results and generates the area classification.



Main Requirements of the Process

- The measurement system for the classification process shall use **COTS components**.
- Track area classification process should classify track areas for virtual balise placement suitability status in terms of three colours:
  - **Green**: Suitable for placing virtual balise
  - **Red**: Not Suitable for placing virtual balise
  - **Yellow**: Not enough information, further analyses are necessary
- The selected track area classification methodology should also **isolate the single** cause that leads to a **hazard**
- Parameters of the error models and thresholds to classify track areas vulnerability towards each unbounded GNSS local feared event shall be **run time configurable parameters**.
- The classification process shall guarantee the **coverage** of the track areas in terms of **spatial** and **temporal** dynamics.
- The classification process shall use augmentation information to **discard unhealthy satellites** so as to avoid wrong and pessimistic classification results.

Main Steps of the Process



Measurement Campaigns in ERSAT-GGC

- Test Campaigns :
  - **Italy** (Radiolabs, RFI, Trenitalia, Hitachi STS, DLR), **Spain** (ADIF, CEDEX, INECO, IFSTTAR, DLR) and **France** (SNCF)

  - Covering more than 4000 km of GNSS data with different scenarios

Italian Line: Preparation and Data Collection

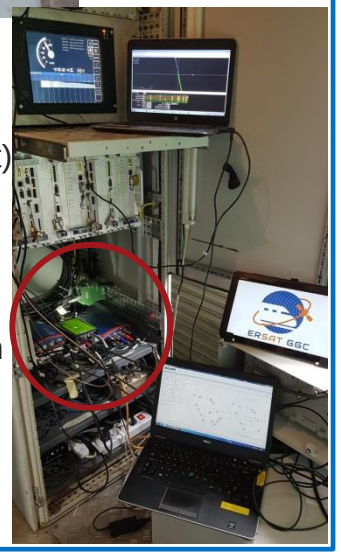
1. Train and Line

Commercial train: ALn668-3136 (Trenitalia)

Cagliari – San Gavino Line:

- Total Length:~ 50 km
- Double Track line
- Maximum speed 150 km/h

2. Measurement Equipment & Installation



Equipment:

- GNSS Antenna(Antcom G5Ant)
- AsteRx4 GNSS Receiver
- Javad Delta-3 Receiver

Installation required:

- Electrical & Mechanical Design
- Construction
- Commissioning & Tests

3. Runs planning

Monday	Standstill train					
08/04/2019	CAGLIARI	Train number	standstill train	-	Train number	-
	09:00 → 17:00	-	8h	-	-	-

Monday	Extra runs during the night					
08/04/2019	CAGLIARI → S.GAVINO (START → STOP)	Train number	standstill train time in the station before next departure	S.GAVINO →CAGLIARI (START → STOP)	Train number	standstill train time in the station before next departure
	23:00 → 23:30		15min	23:45 → 00:16		15min
	00:31 → 01:01		15min	01:16 → 01:47		15min
	02:02 → 02:32		15min	02:47 → 03:18		-

Tuesday	Extra runs during the night					
09/04/2019	CAGLIARI → S.GAVINO (START → STOP)	Train number	standstill train time in the station before next departure	S.GAVINO →CAGLIARI (START → STOP)	Train number	standstill train time in the station before next departure
	23:00 → 23:30		15min	23:45 → 00:16		15min
	00:31 → 01:01		15min	01:16 → 01:47		15min
	02:02 → 02:32		15min	02:47 → 03:18		-

Wednesday	Extra runs during the day (afternoon)					
10/04/2019	CAGLIARI → S.GAVINO (START → STOP)	Train number	standstill train time in the station before next departure	S.GAVINO →CAGLIARI (START → STOP)	Train number	standstill train time in the station before next departure
	17:10 → 17:40		19min	17:59 → 18:30		40min
	19:10 → 19:40		19min	19:59 → 20:30		26min
	20:56 → 21:26		44min	22:10 → 22:41		-

Thursday	Extra runs during the day (morning)					
	CAGLIARI → S.GAVINO	Train number	standstill train time in the	S.GAVINO →CAGLIARI	Train number	standstill train time in the

Static Data Acquisition:

- > 8 hours of data recorded

Dynamic Measurements over **1 week**:

- Different times of the day to **cover 24h diversity**
- > 15 runs per track

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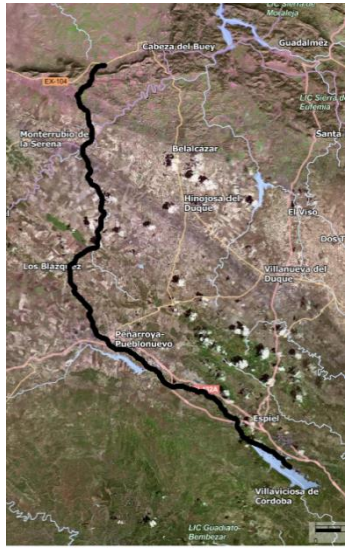
Spanish Line: Preparation and Data Collection

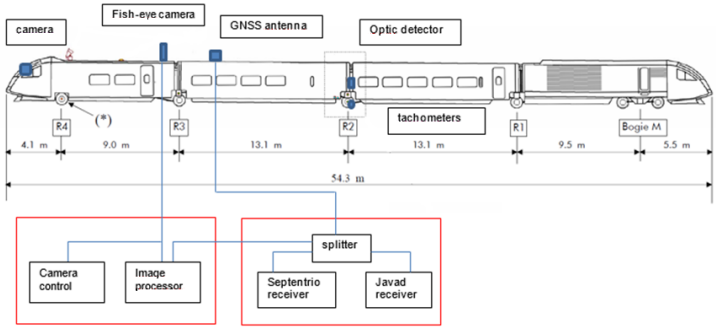
1. Train and Line



Train:
- Laboratory train (unit BT-02) (ADIF)

Almorchon-Alhondiguilla Line:
- Low-traffic Regional line
- Single Track 94 km
- Max. speed 70 kmh

2. Measurement Equipment & Installation



Equipment:
- GNSS Antenna (Antcom G8Ant)
- Javad Delta-3 Receiver
- Septentrio GNSS Receiver
- Fish-eye Camera & Image Processor

3. Runs planning

Dynamic Tests		
Date	**Circulation**	**Scheduled timetable**
20/5/2019	Almorchón-Alhondiguilla-Almorchón	15:00-21:00h
21/5/2019	Almorchón-Alhondiguilla-Almorchón	08:00-14:00h
22/5/2019	Almorchón-Alhondiguilla-Almorchón	08:00-14:00h
23/5/2019	Almorchón-Alhondiguilla-Almorchón	12:00-18:00h
24/5/2019	Almorchón-Alhondiguilla-Almorchón	06:00-12:00h
27/5/2019	Almorchón-Alhondiguilla-Almorchón	18:00-00:00h
28/5/2019	Almorchón-Alhondiguilla-Almorchón	09:00-15:00h
29/5/2019	Almorchón-Alhondiguilla-Almorchón	00:00-06:00h
30/5/2019	Almorchón-Alhondiguilla-Almorchón	15:00-21:00h
31/5/2019	Almorchón-Alhondiguilla-Almorchón	08:00-14:00

Static Data Acquisition:
- > 8 hours of data recorded

Dynamic Measurements **over 10 days**:
- Different times of the day to cover 24h diversity (GPS) and over 10 days (Galileo)
- 20 runs over the same track

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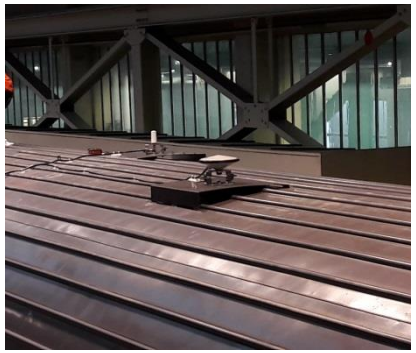
French Line: Preparation and Data Collection

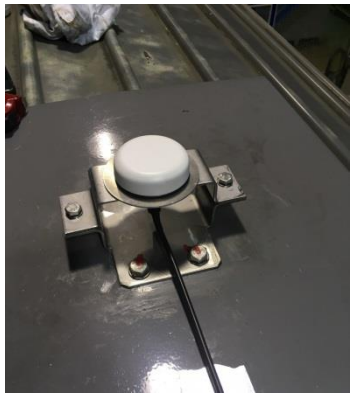
1. Train and Line

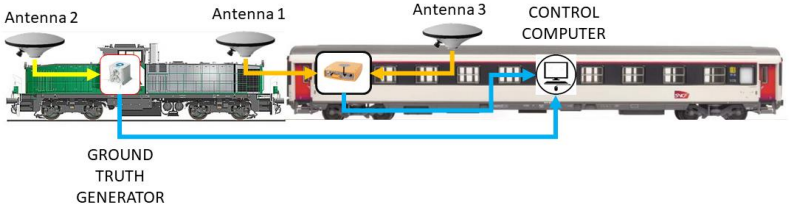
Test Train:
- SNCF class BB 60000 (SNCF)
- Max speed: 100 kmh

Vitry – Montereau Line:
- Over 187 km
- Maximum speed 160 km/h

2. Measurement Equipment & Installation

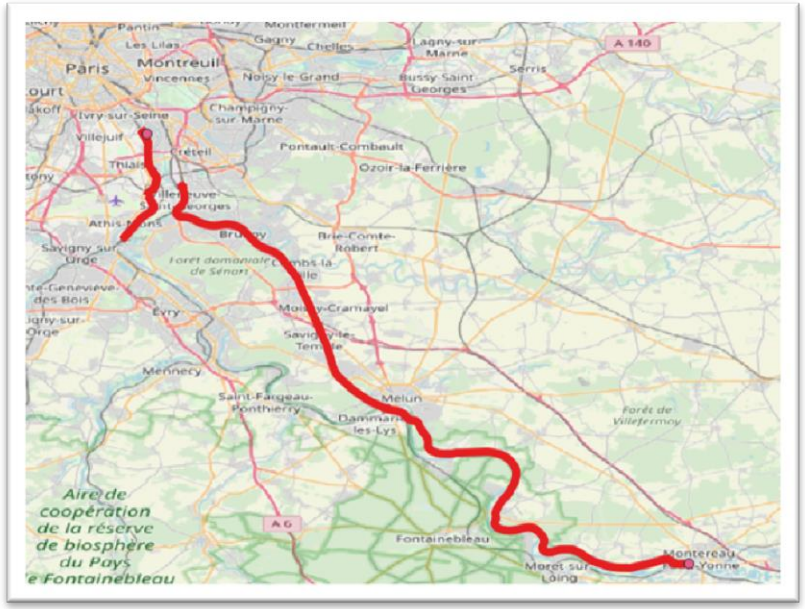






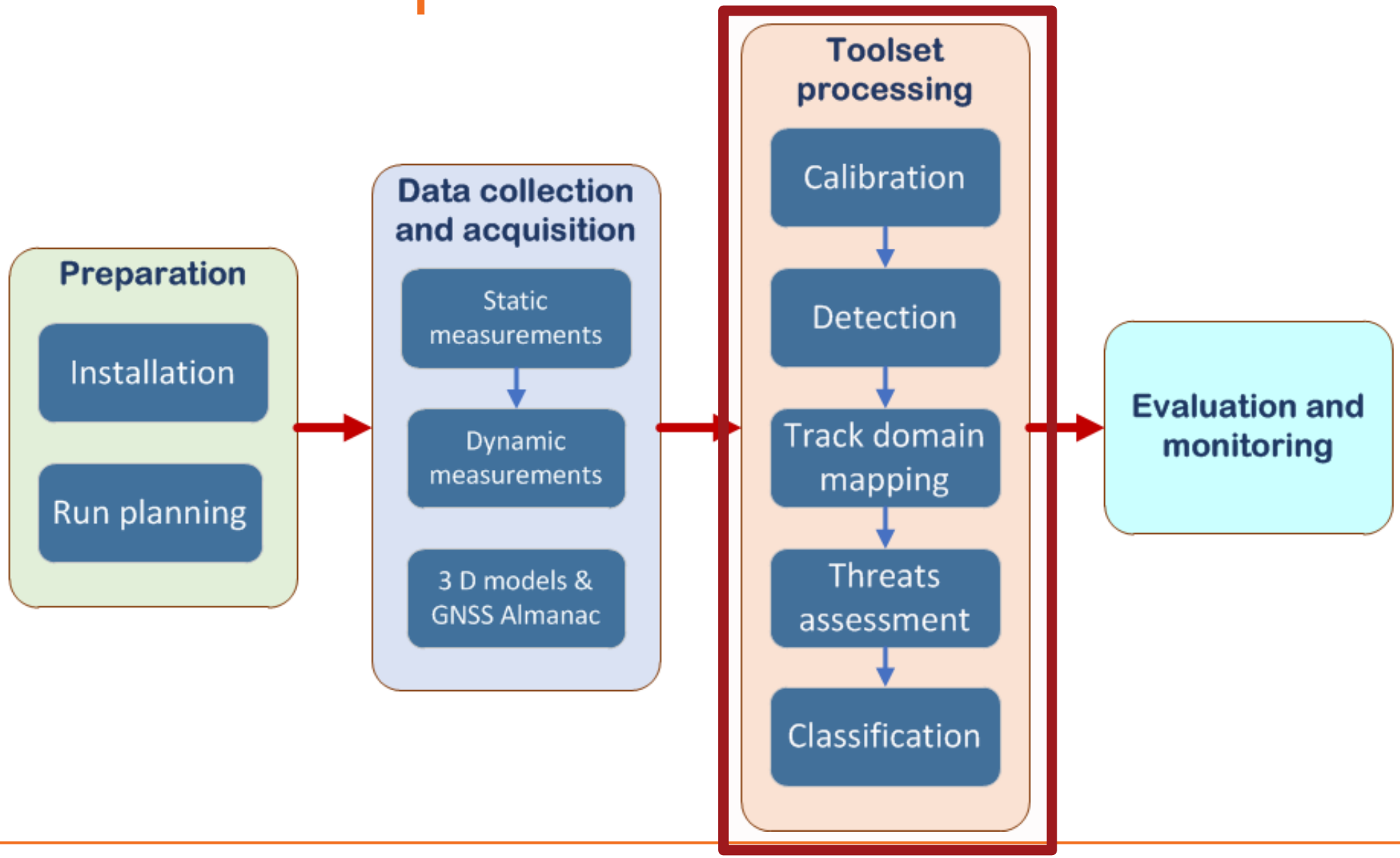
Equipment:
- GNSS Antenna (Septentrio PolAnt NF)
- Septentrio AsterX-4 GNSS Receiver
- High grade FOG IMU

3. Runs planning

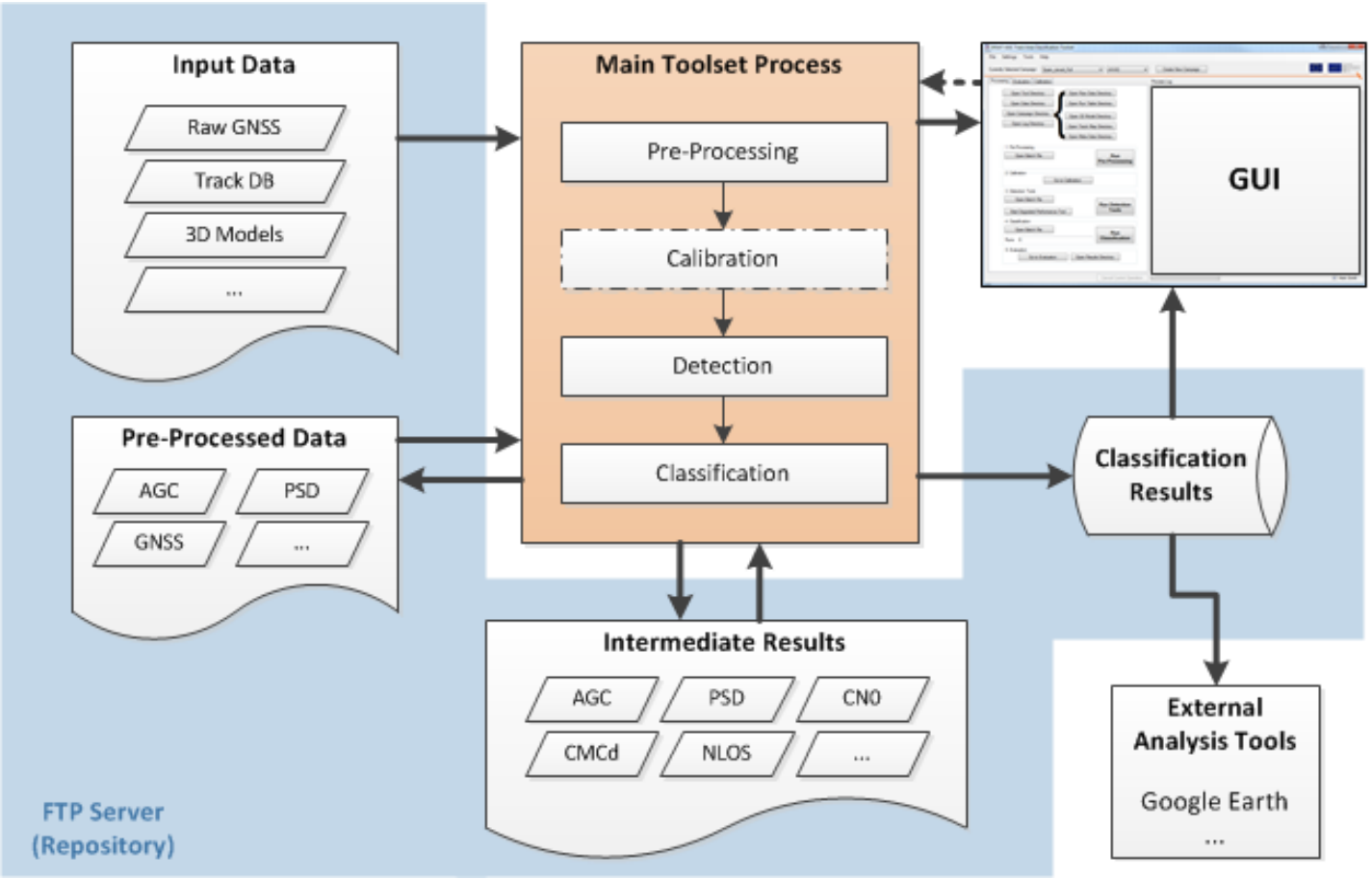


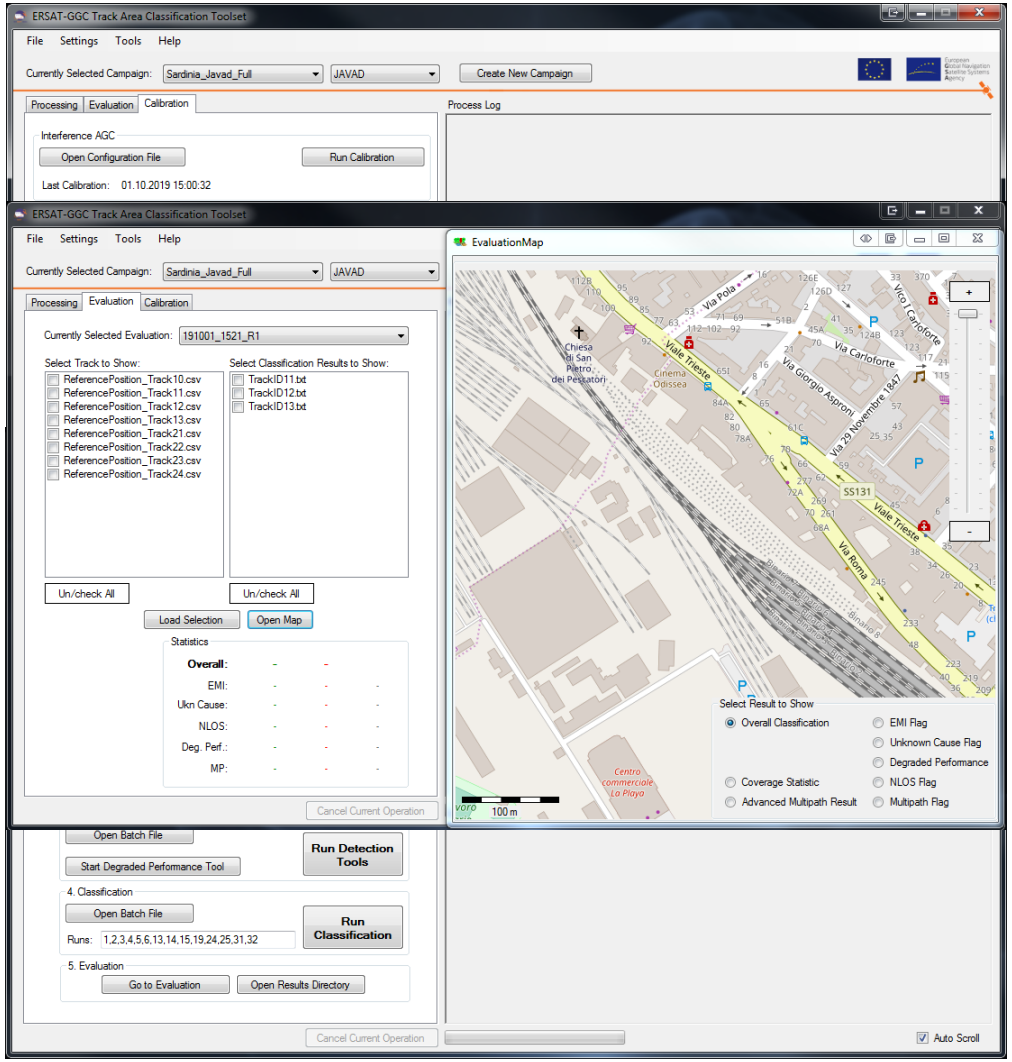
Several round trips along three lines:
- RER C (187 km route)
- RER D
- Paris Lyon Marseille

Main Steps of the Process



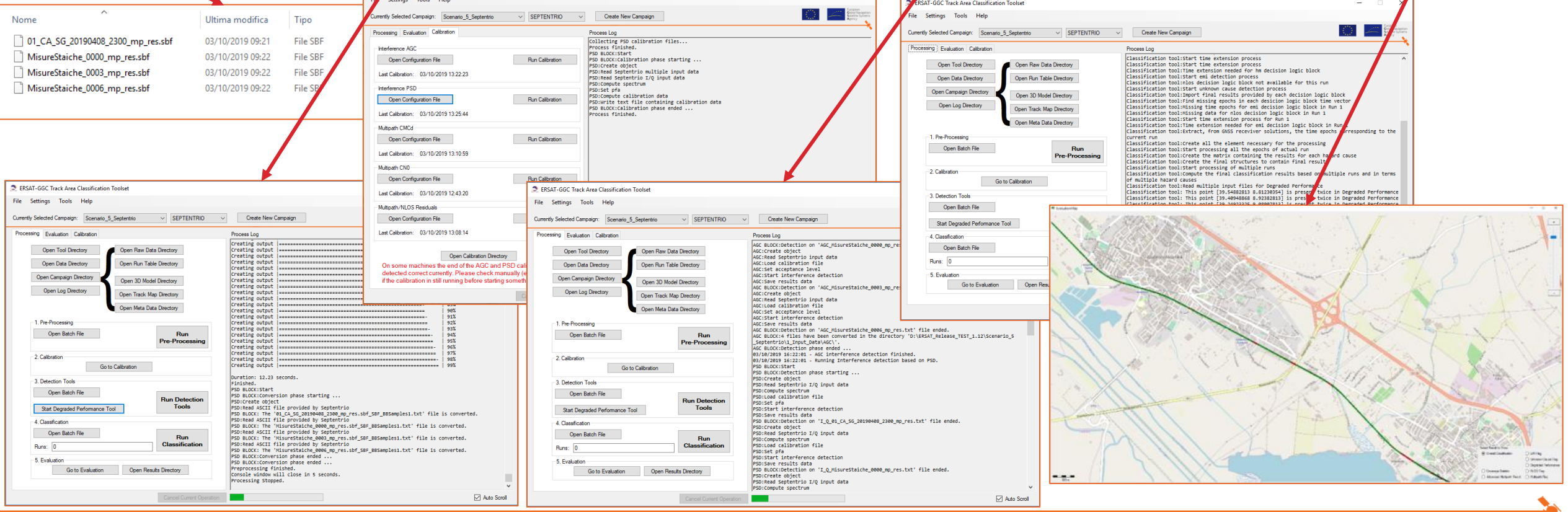
Software Toolset





Toolset Processing

Input Data → Pre-Processing → Calibration → Detection → Classification → Evaluation



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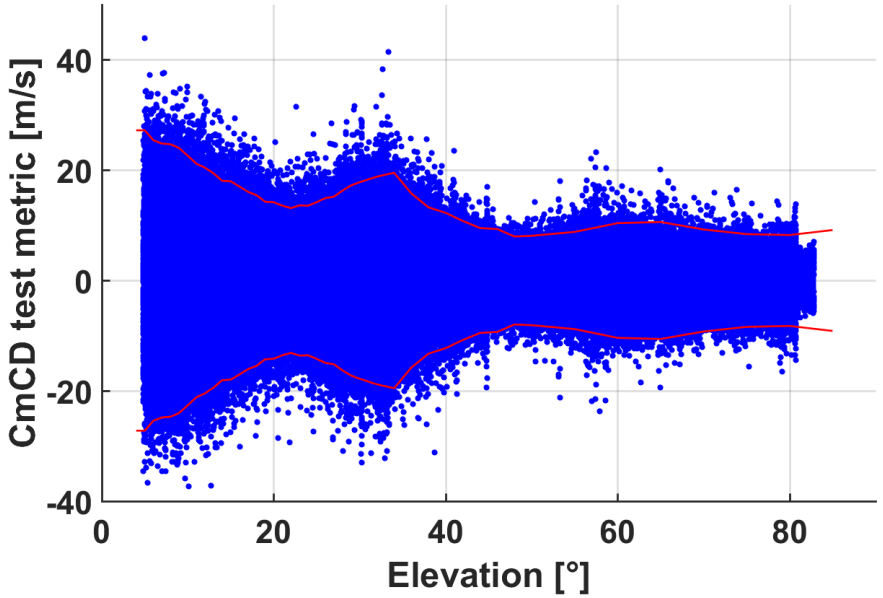
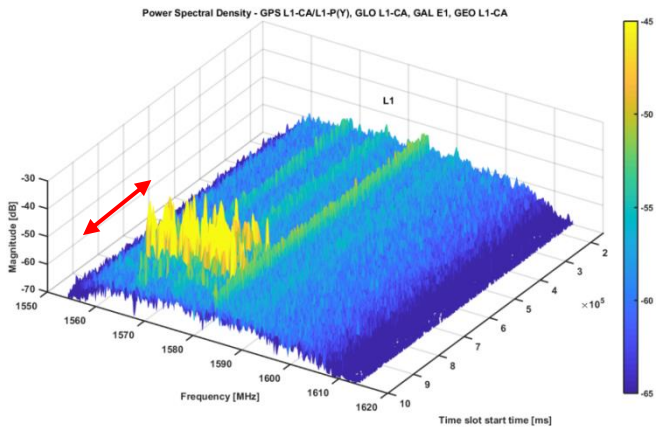
Calibration (Static) Data Processing

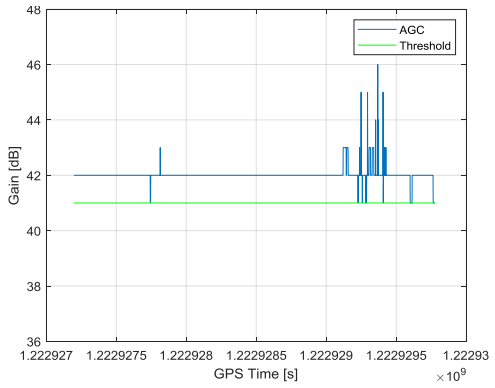
- A calibration process is required for several detection techniques to adapt them to the performance of every unique installation of the GNSS antenna on a train
- It consists in the acquisition of measurement data with standstill train in a location with nominal conditions:
- The duration of such acquisition shall have a duration to capture the behaviour of the GNSS signal and other data in all the conditions



Detection Tools

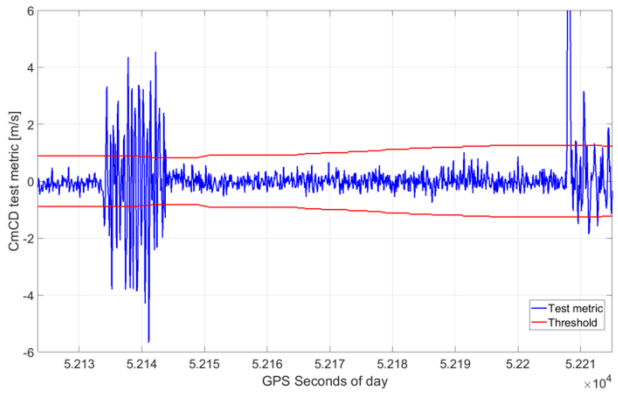
Interferences

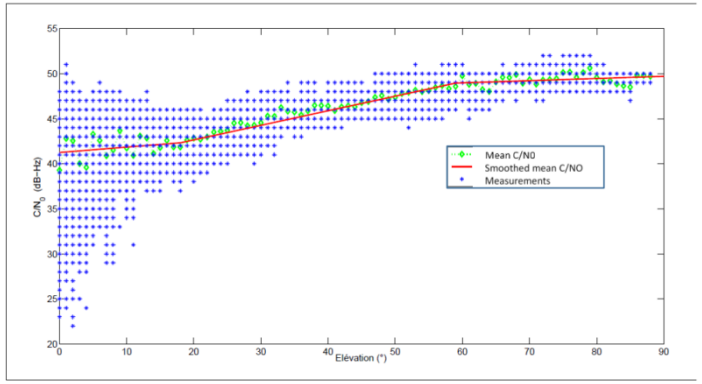




EMI detection with Power Spectrum Density (**PSD**) and Automatic Gain Control (**AGC**)

Multipath

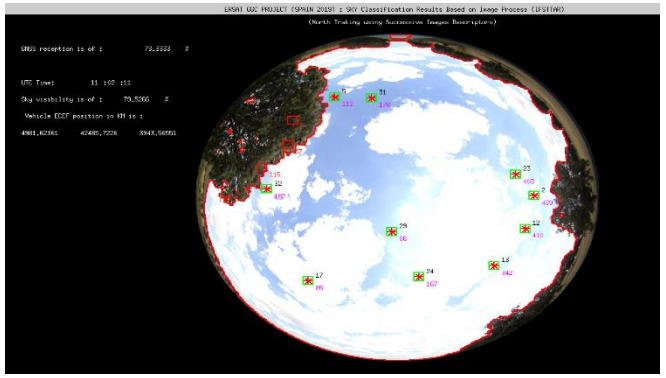




Multipath detection with Code-minus-Carrier Delta (**CmCD**) and Combination of **CN0** levels in different frequencies

NLOS

1. Detection with PVT Residual Test



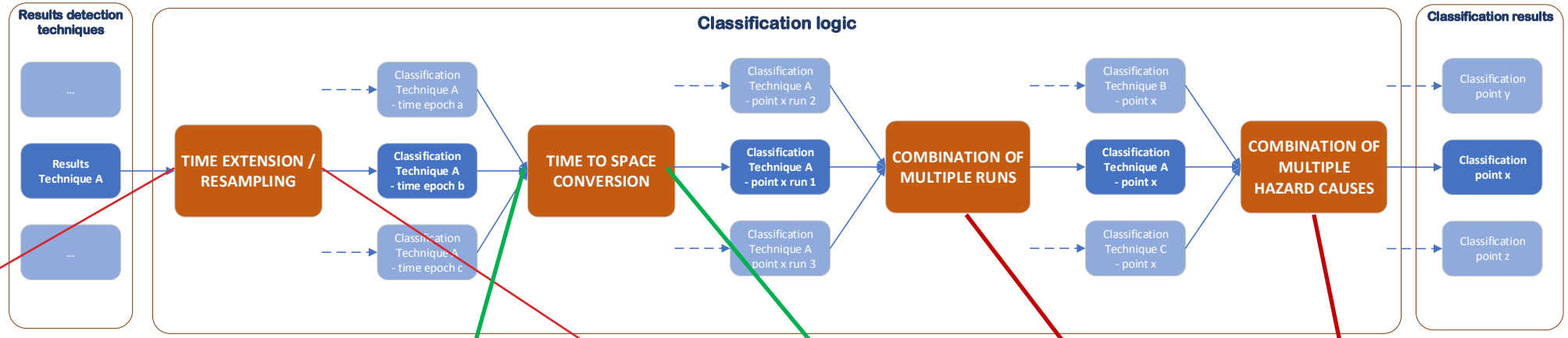
2. NLOS satellite detection with camera

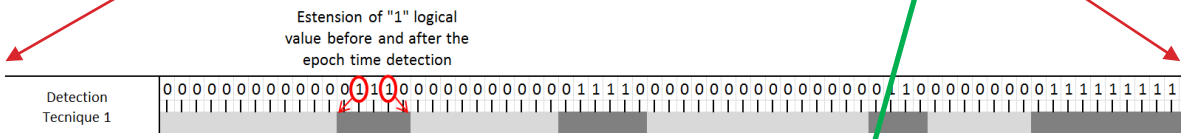
Degraded Performance

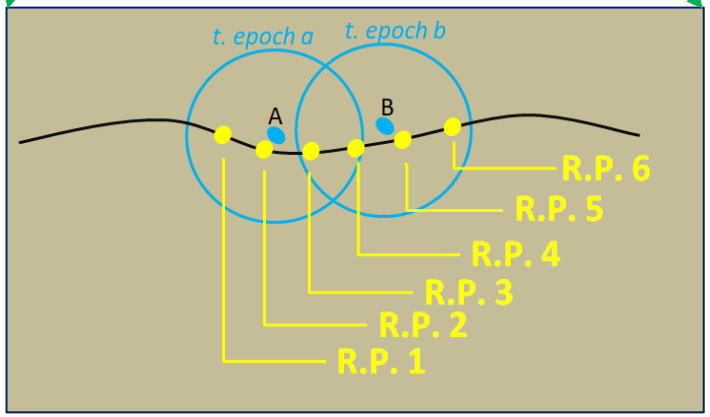
Satellite visibility based on 3D models and constellation **simulations**:

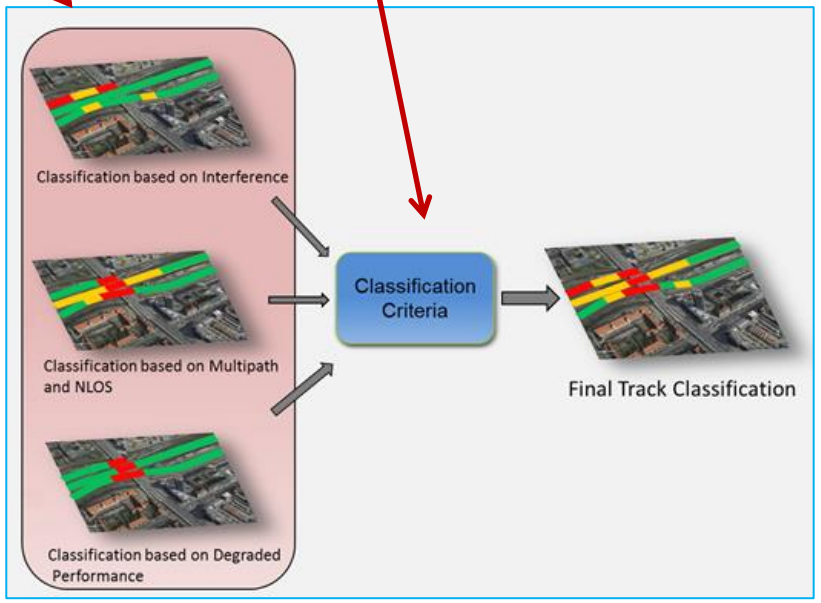
- DOP
- # Satellites
- …

Classification Logic





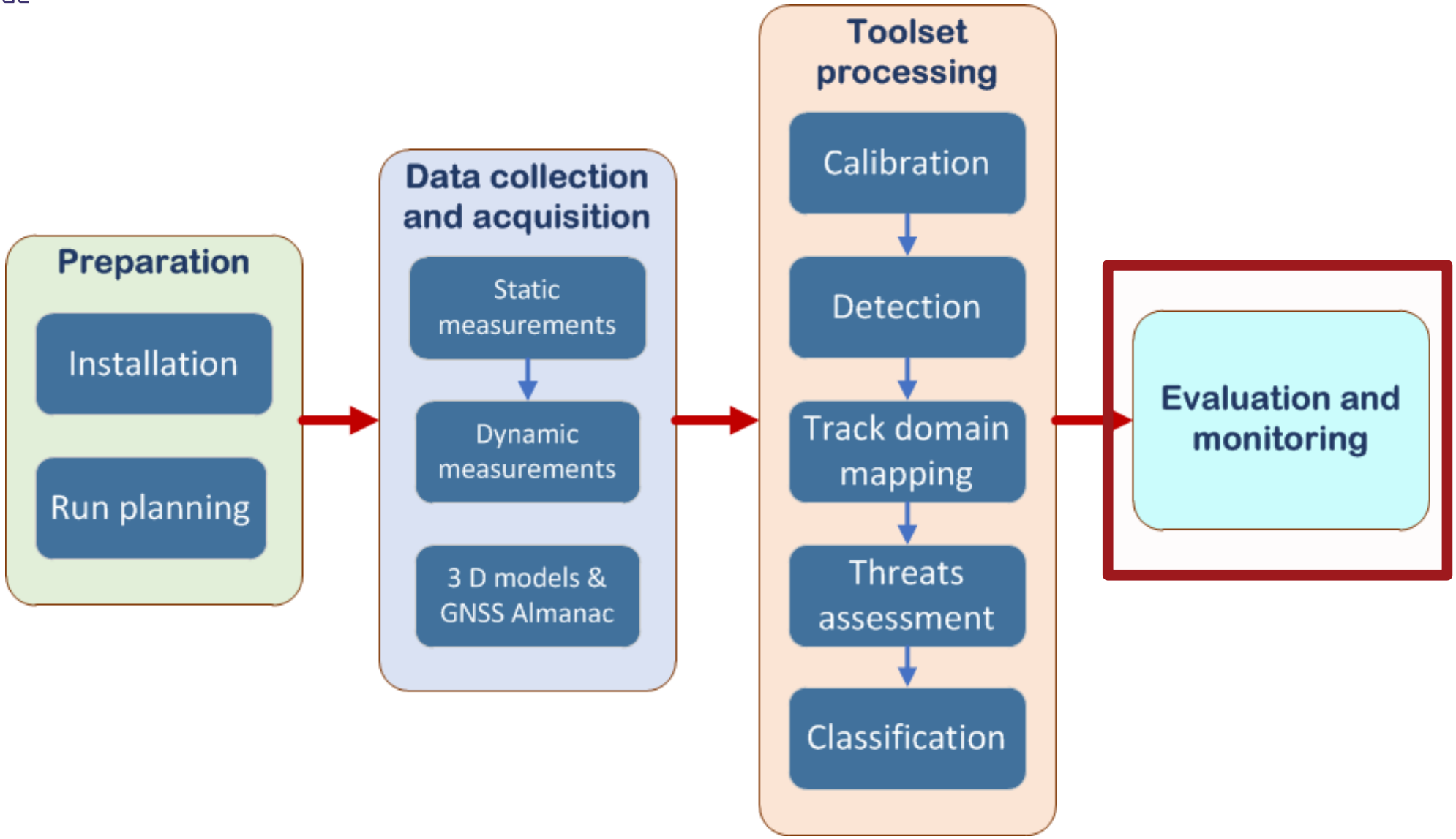




Important aspects for the classification logic:

- Availability of a **track reference coordinates** (DB)
- **Reference position** per detection technique epoch
- Information about the tracks covered by each of the measurement collections (**Runs Tables**)

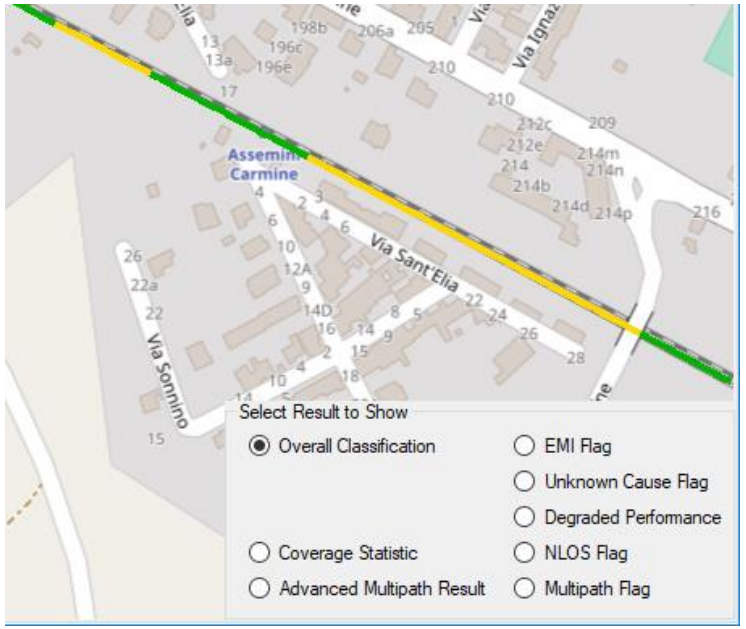
Main Steps of the Process



Results Evaluation

- Evaluation of the measurement data collected in Italy and Spain in order to allow:
  - Laboratory integration
  - Validation of the software Toolset
  - Validation of the classification process
- Evaluations:
  - Classification results with only one or several runs
  - Classification of expected multipath and NLOS areas
  - Classification results with different receivers
  - Overall classification results

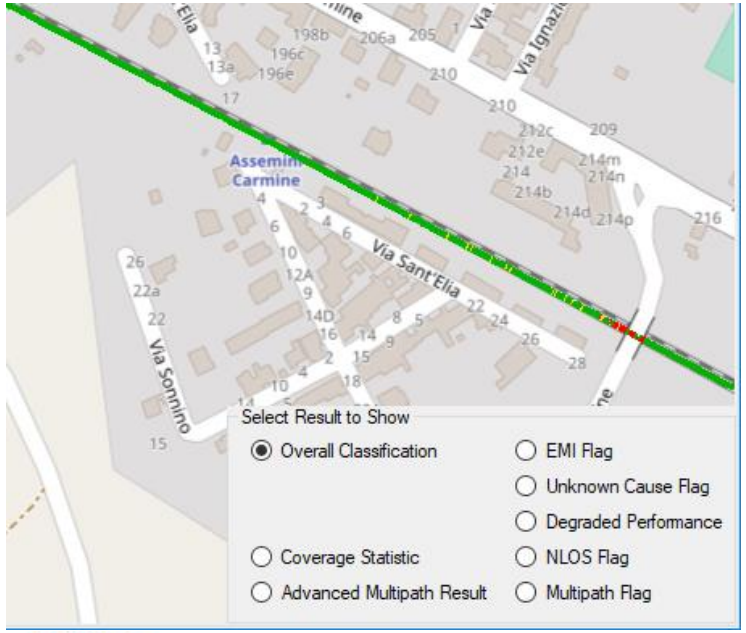
Single Run vs Multiple Runs (Italy)



Statistics

Overall:	62,8 %	2,3 %	34,9 %
EMI:	99,1 %	0,9 %	0,1 %
Ukn Cause:	99,9 %	0,0 %	0,1 %
NLOS:	0,0 %	0,0 %	100,0 %
Deg. Perf.:	94,0 %	1,0 %	5,0 %
MP:	66,8 %	0,5 %	32,7 %

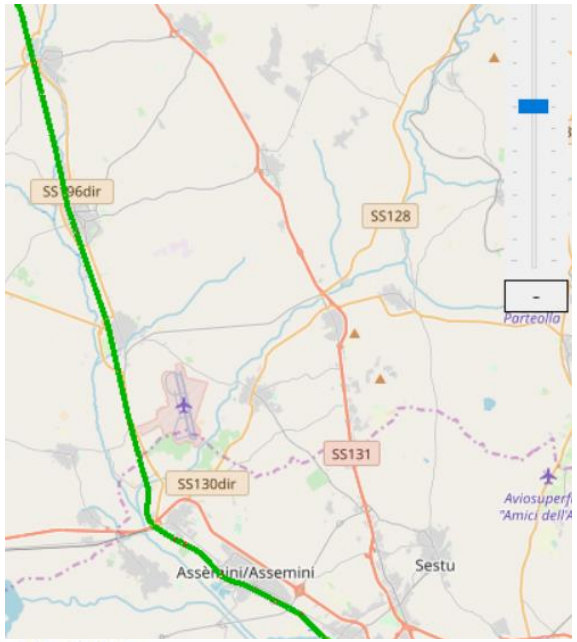
1 single Run



Statistics

Overall:	85,5 %	3,6 %	10,9 %
EMI:	98,8 %	1,2 %	0,1 %
Ukn Cause:	99,9 %	0,0 %	0,1 %
NLOS:	0,0 %	0,0 %	100,0 %
Deg. Perf.:	94,0 %	1,1 %	4,9 %
MP:	91,6 %	1,6 %	6,8 %

5 Runs

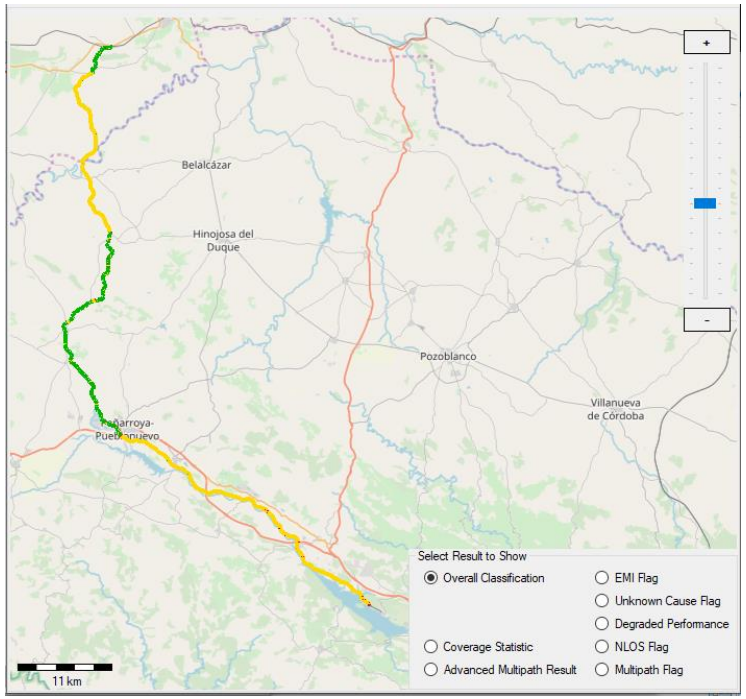


Statistics

Overall:	90,5 %	3,4 %	6,1 %
EMI:	98,6 %	1,4 %	0,0 %
Ukn Cause:	100,0 %	0,0 %	0,0 %
NLOS:	0,0 %	0,0 %	100,0 %
Deg. Perf.:	94,2 %	0,9 %	4,9 %
MP:	97,1 %	1,3 %	1,6 %

All (16) Runs

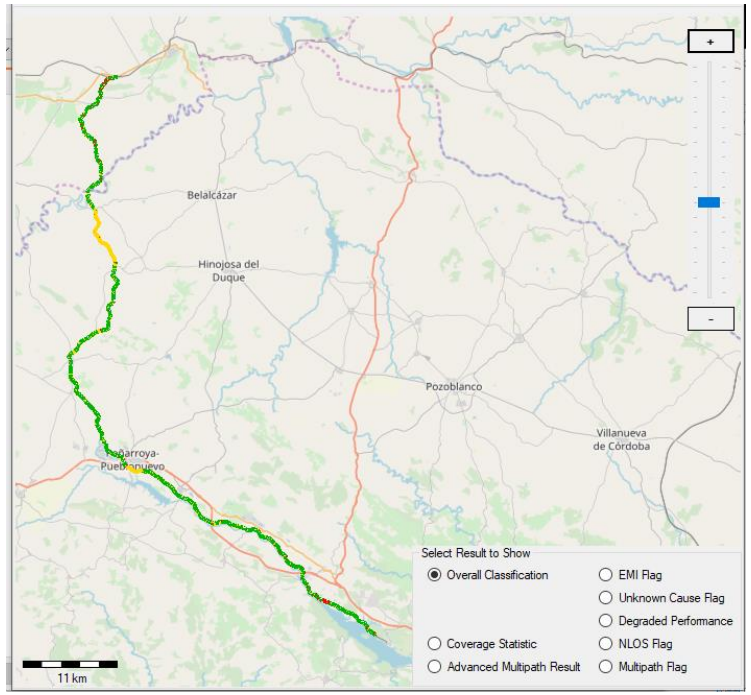
Single Runs vs Multiple Runs (Spain)



Statistics

Overall:	33,7 %	1,1 %	65,2 %
EMI:	76,8 %	0,0 %	23,2 %
Ukn Cause:	99,8 %	0,0 %	0,2 %
NLOS:	0,0 %	0,0 %	100,0 %
Deg. Perf.:	94,9 %	0,1 %	4,9 %
MP:	35,5 %	0,2 %	64,4 %

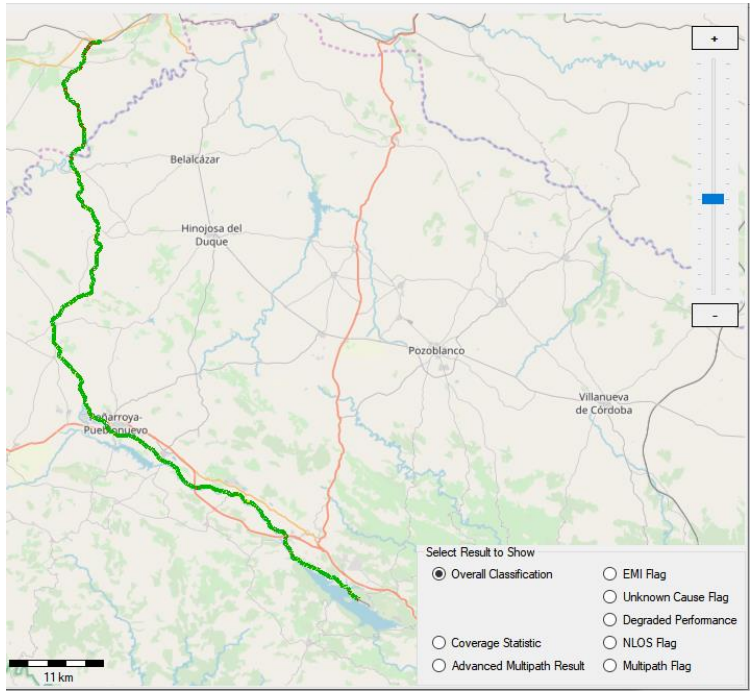
1 single Run



Statistics

Overall:	76,2 %	3,9 %	20,0 %
EMI:	96,7 %	1,8 %	1,5 %
Ukn Cause:	100,0 %	0,0 %	0,0 %
NLOS:	0,0 %	0,0 %	100,0 %
Deg. Perf.:	94,9 %	0,2 %	5,0 %
MP:	82,0 %	0,5 %	17,5 %

5 Runs



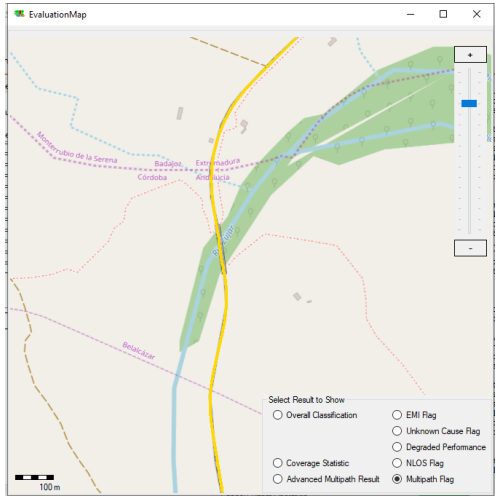
Statistics

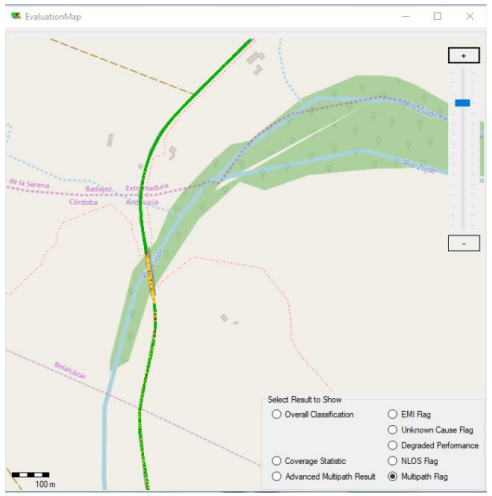
Overall:	92,2 %	2,8 %	4,9 %
EMI:	97,5 %	2,3 %	0,2 %
Ukn Cause:	100,0 %	0,0 %	0,0 %
NLOS:	0,0 %	0,0 %	100,0 %
Deg. Perf.:	94,9 %	0,2 %	4,9 %
MP:	99,4 %	0,3 %	0,3 %

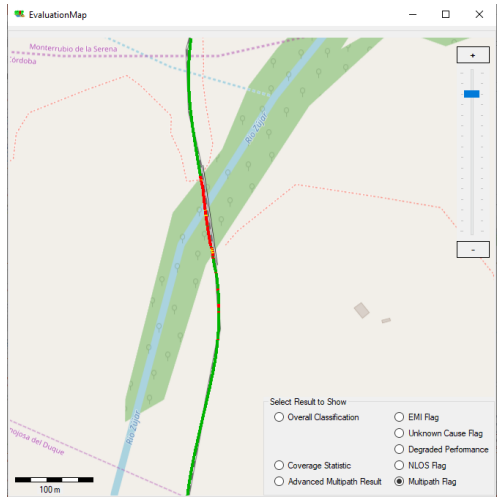
All (20) Runs

Evaluation Multipath and NLOS

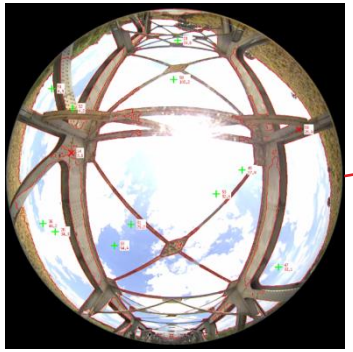
- Example: Bridge in Spanish line

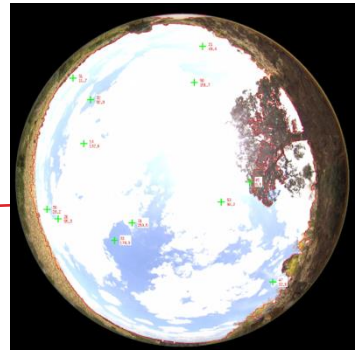






Classification results according to **multipath** with 1, 5 and all runs





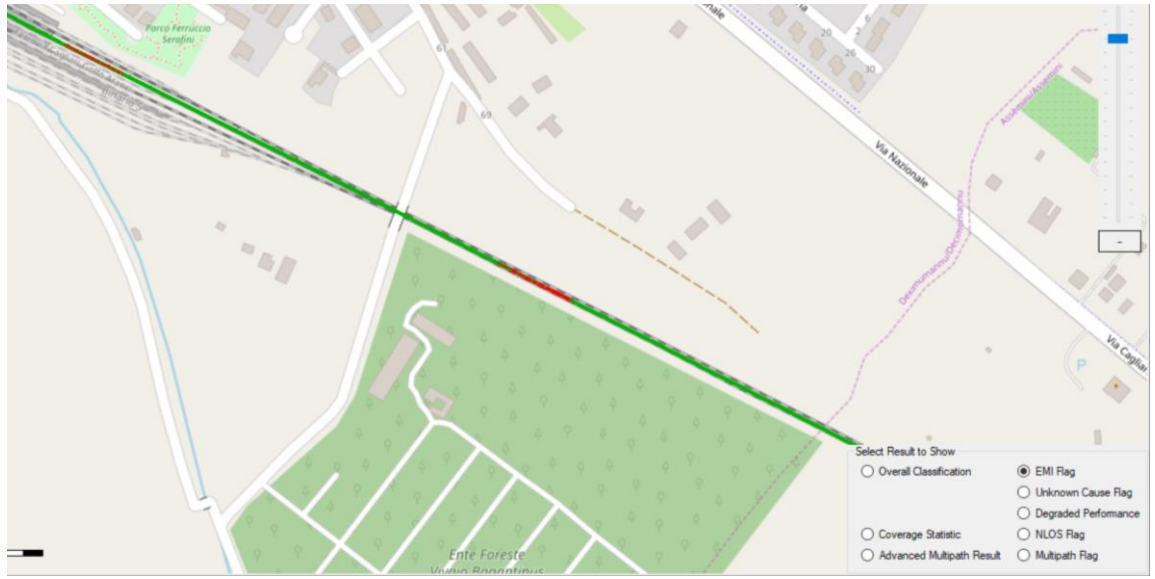
Classification results according to **NLOS**

Evaluation of Degraded Performance

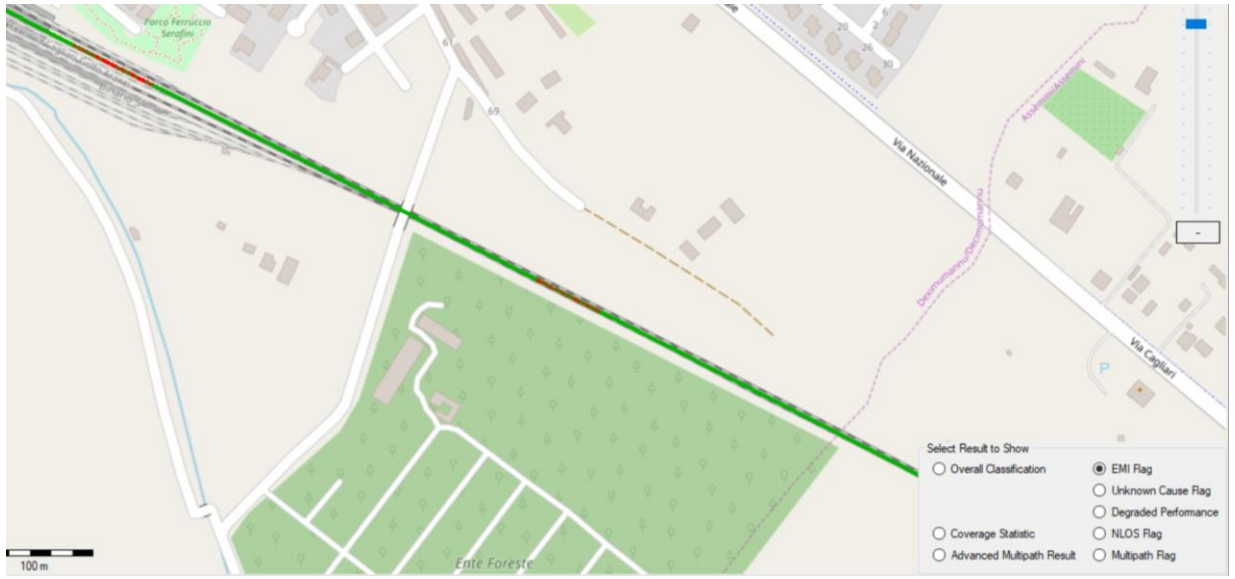
- Example: Spanish line

Evaluation of Interference with different receivers

- Example: Italian line with Septentrio and Javad (PSD, AGC)



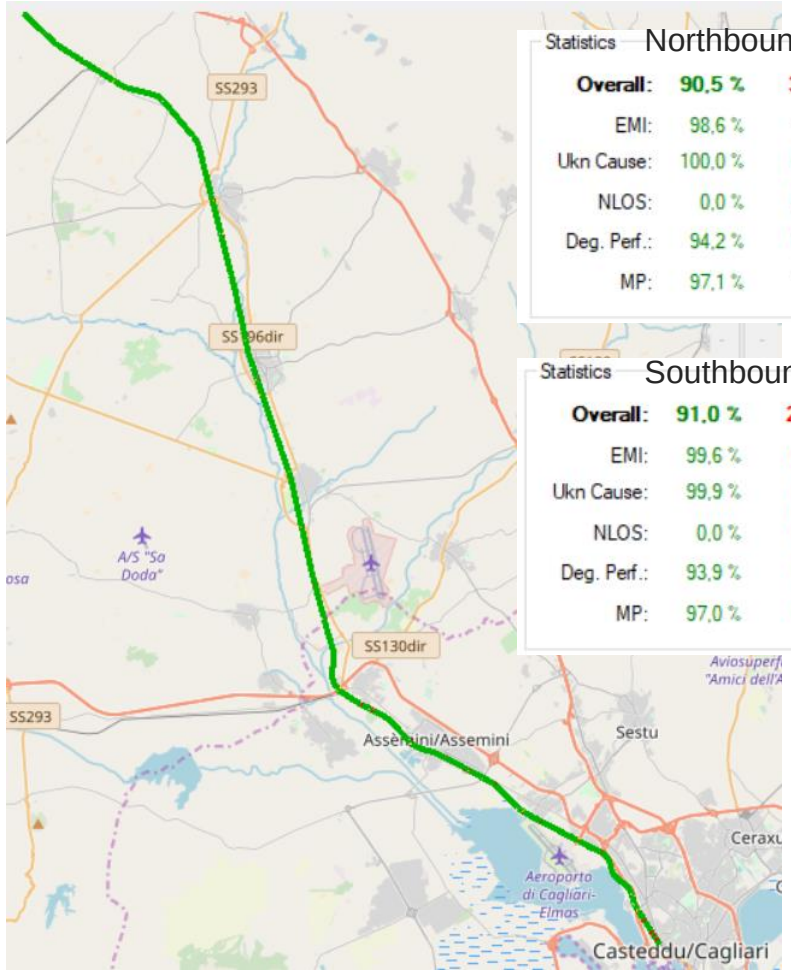
Septentrio



Javad

Overall Classification

Italian Line



Statistics — Northbound Track

Overall:	90,5 %	3,4 %	6,1 %
EMI:	98,6 %	1,4 %	0,0 %
Ukn Cause:	100,0 %	0,0 %	0,0 %
NLOS:	0,0 %	0,0 %	100,0 %
Deg. Perf.:	94,2 %	0,9 %	4,9 %
MP:	97,1 %	1,3 %	1,6 %

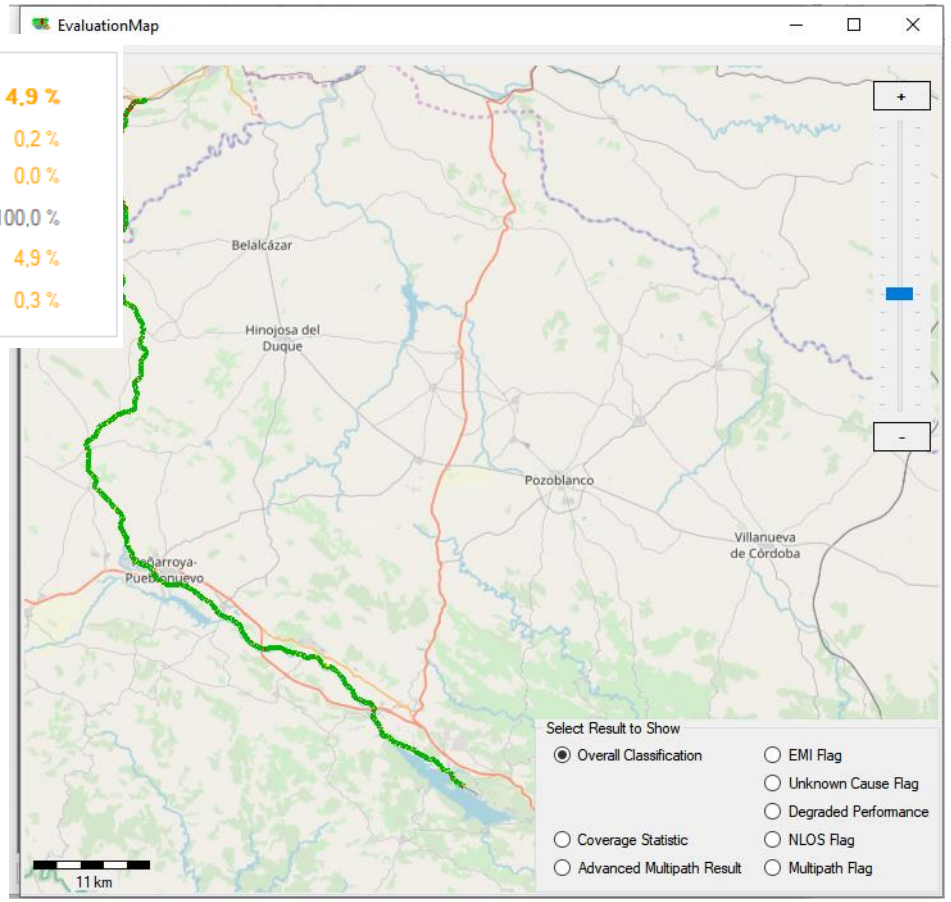
Statistics — Southbound Track

Overall:	91,0 %	2,6 %	6,4 %
EMI:	99,6 %	0,4 %	0,0 %
Ukn Cause:	99,9 %	0,0 %	0,0 %
NLOS:	0,0 %	0,0 %	100,0 %
Deg. Perf.:	93,9 %	1,1 %	5,0 %
MP:	97,0 %	1,3 %	1,7 %

Spanish Line

Statistics

Overall:	92,2 %	2,8 %	4,9 %
EMI:	97,5 %	2,3 %	0,2 %
Ukn Cause:	100,0 %	0,0 %	0,0 %
NLOS:	0,0 %	0,0 %	100,0 %
Deg. Perf.:	94,9 %	0,2 %	4,9 %
MP:	99,4 %	0,3 %	0,3 %



Conclusions

- The process provides a deep insight into the local threats along the line
- The process is modular and extendable based on defined interfaces (Hardware and Software)
- Multiple Campaigns in different countries during the project. Applicability to different scenarios and equipment was shown.
- Toolset validated by independent Lab users. Message on the operability by railway users.
- Starting point is VB, but the process and results have a wider significance to other use cases.
- Results show in general a high percentage of availability (green areas) along the scenarios tested

ERSAT GGC

Thank you!

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