STARS

SATELLITE TECHNOLOGY FOR ADVANCED RAILWAY SIGNALLING

27th of November 2018

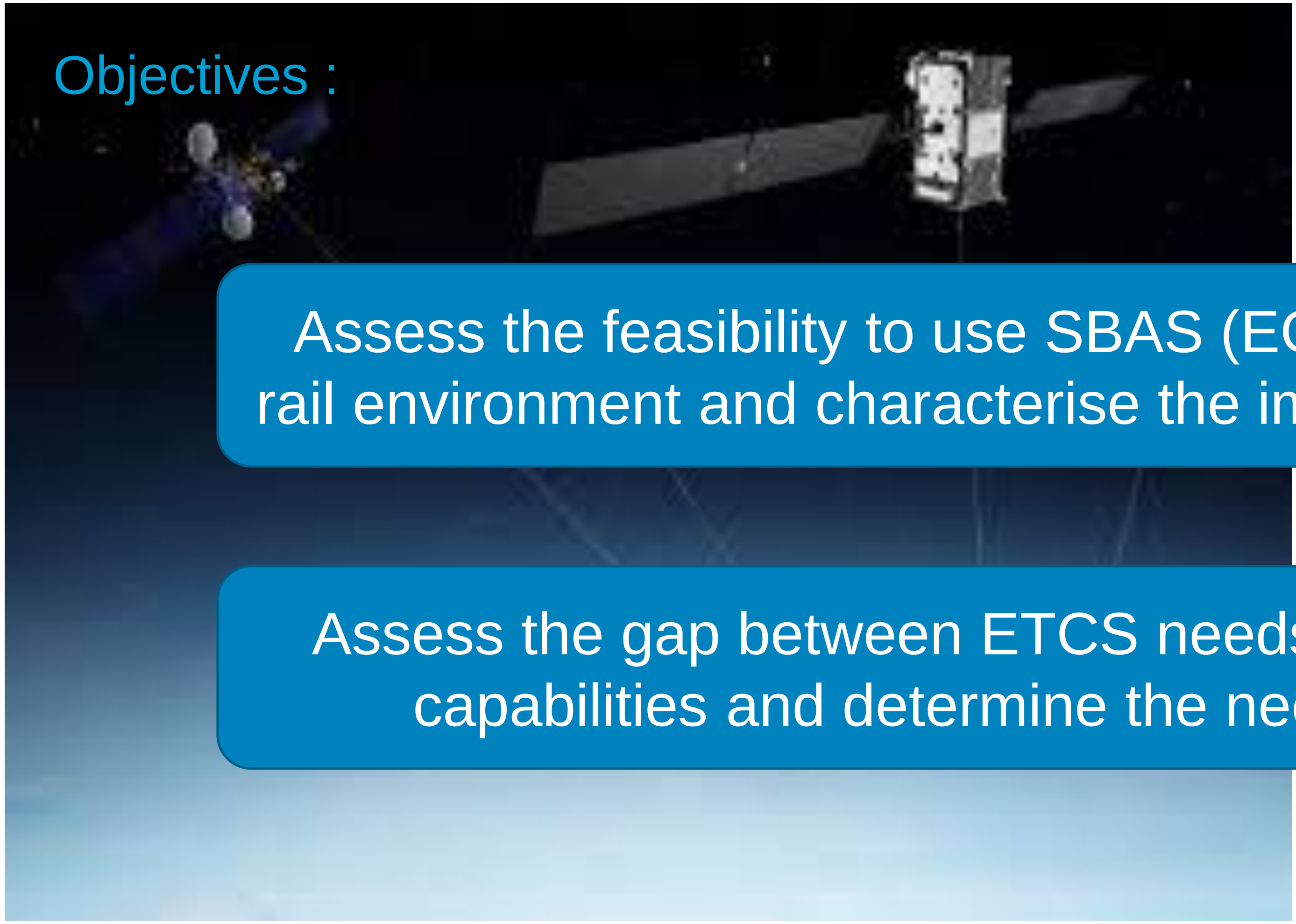
WP-5 EGNOS Technology Feasibility Study

Marc GANDARA (Thales Alenia Space)

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

WP5 :EGNOS Technology Feasibility Study



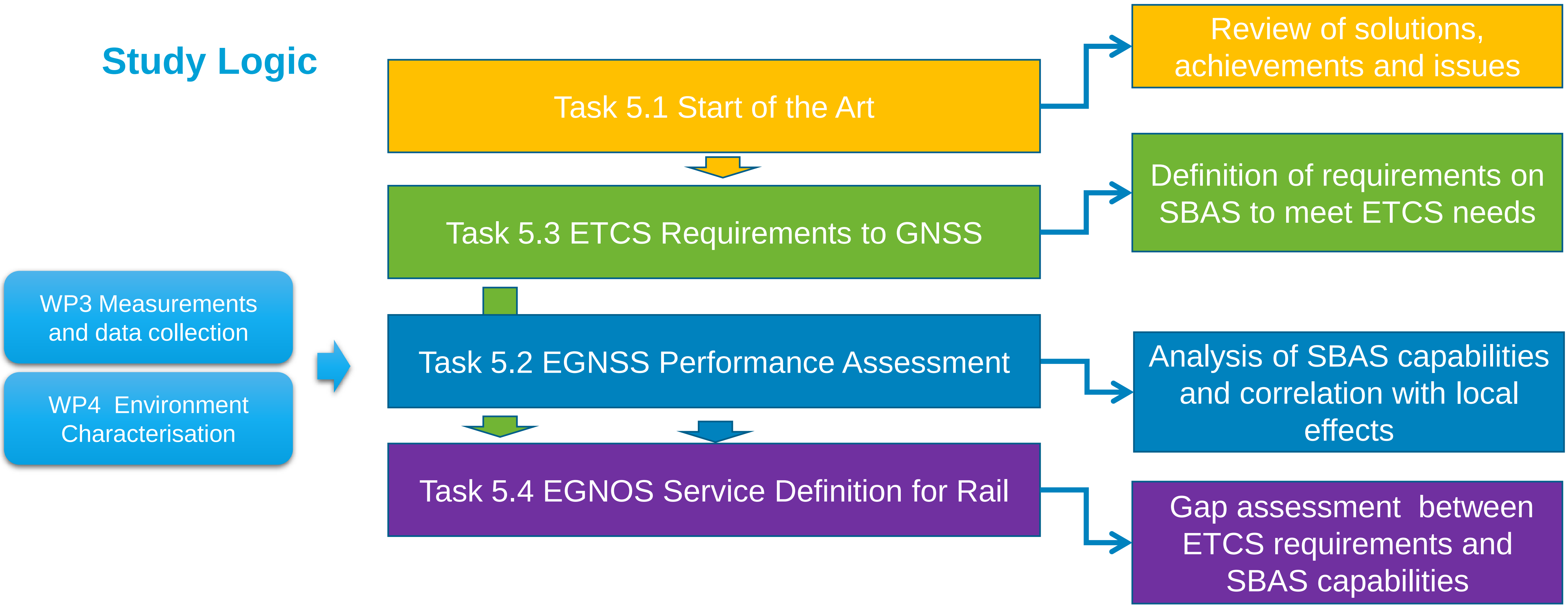
Objectives :

Assess the feasibility to use SBAS (EGNOS) services in the rail environment and characterise the impacts on performances

Assess the gap between ETCS needs and SBAS (EGNOS) capabilities and determine the necessary evolutions

WP5 :EGNOS Technology Feasibility Study

Study Logic



Task 5.1 State of The art

Juliette MARAIS (IFSTTAR)

Main past projects reviewed

Project name	Start	End	Funding program	Solutions
APOLO	1998	2001		GNSS+ODO+GYRO
GADEROS	2001	2004	5th FP	
INTEGRAIL	2001	2004		
LOCOPROL/LOC	2001	2004	5th FP/ESA	1D + Pair of satellites
ECORAIL	2001	2005	ESA	
RUNE	2001	2006		Multi-sensor+Kalman Filter
GIRASOLE	2005	2007	6th FP/GJU	Safety of Life Receiver
GRAIL	2005	2007	6th FP/GJU	Safety of Life Receiver
GRAIL 2	2010	2013	7th FP	Improved ODO based on GNSS
GALOROI	2012	2014	7th FP	GNSS+Eddy Sensors
SATLOC	2012	2014	7th FP	
3inSat		2016	ESA, IAP	Virtual Balise + MC Rx+ODO+IMU
RHINOS	2016	2018	H2020	SBAS + ARAIM
ERSAT EAV	2015	2017	H2020	Virtual Balise + GNSS + GBAS
NGTC	2015	2017	EC	Virtual Balise / ERTMS

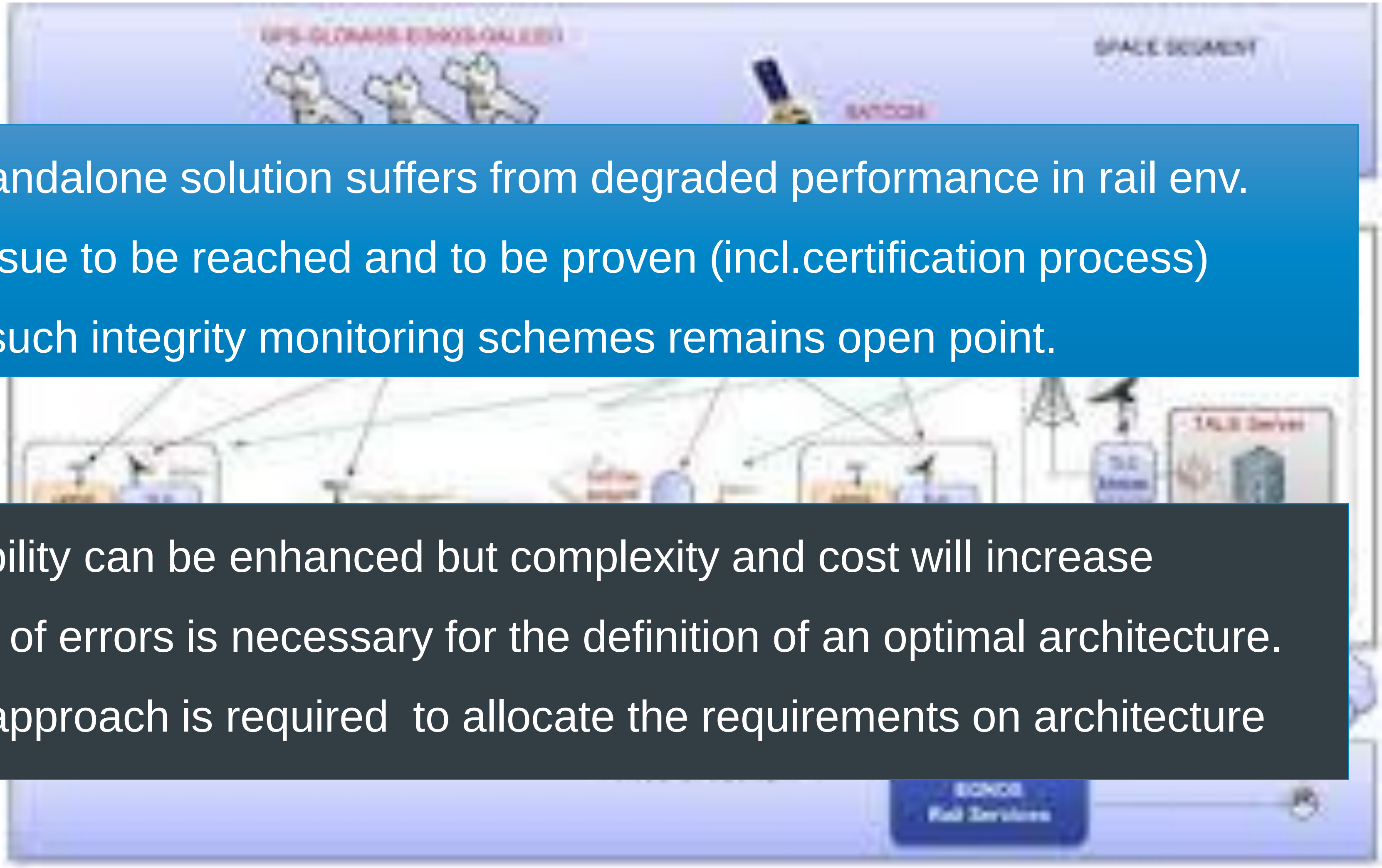
European Global Navigation Satellite Systems Ag

esa

More than 15 years of studies exploring the feasibility to use GNSS for RAIL in Europe

Several approach combining different solutions have been experimented **but no one has been qualified and deployed operationally in Europe**

Main Oucomes of the state of the art



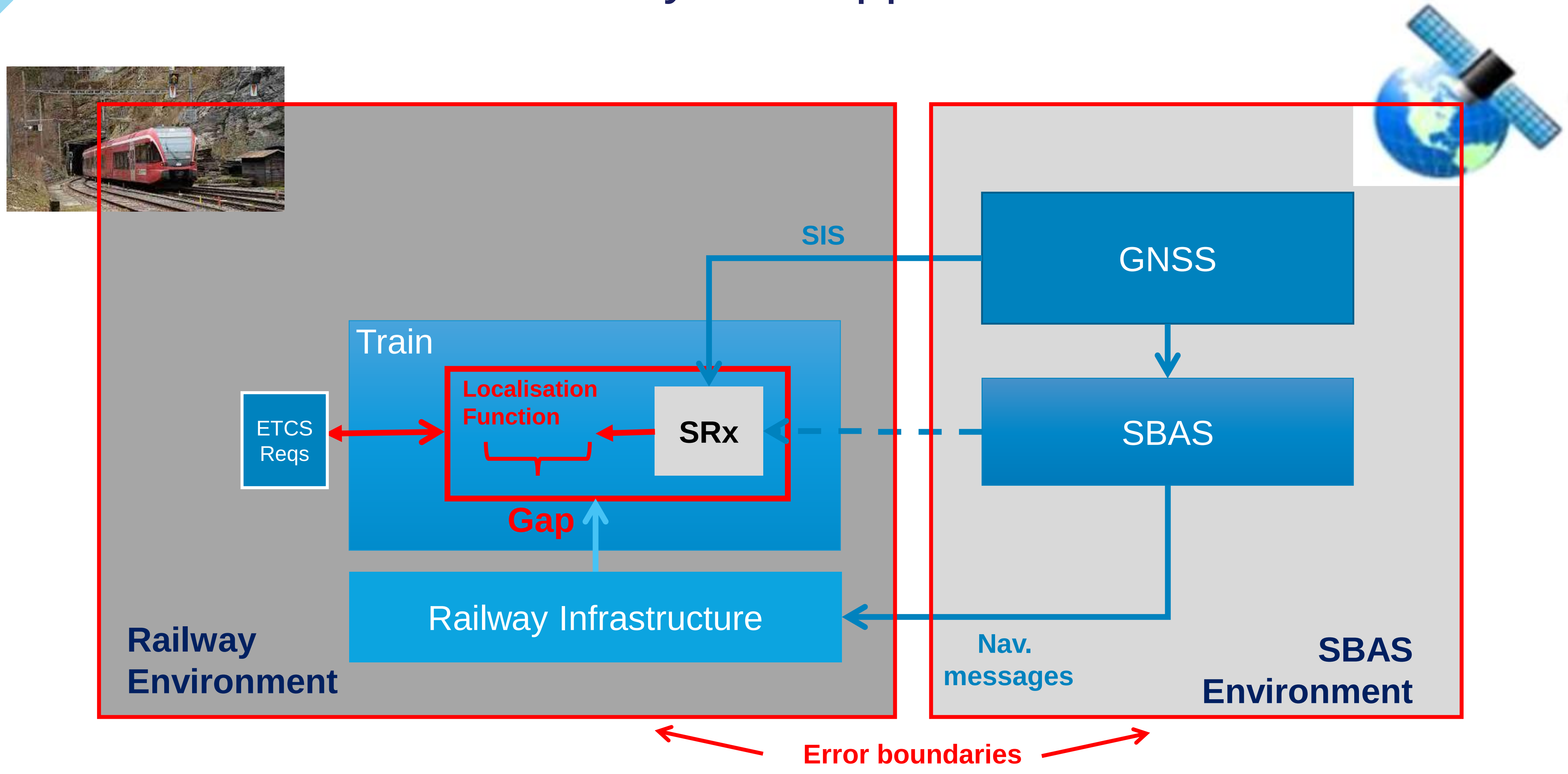
Issues and open points

- GNSS/SBAS as a standalone solution suffers from degraded performance in rail env.
- Safety is the major issue to be reached and to be proven (incl.certification process)
- Safety mechanisms such integrity monitoring schemes remains open point.

Lessons Learned

- Accuracy and availability can be enhanced but complexity and cost will increase
- Fine characterization of errors is necessary for the definition of an optimal architecture.
- A system top-down approach is required to allocate the requirements on architecture

System Approach



Task 5.3

Barbara BRUNETTI (ANSALDO)

Main Signalling Safety and Operational Requirements related to some key signalling functions

- Track Discrimination;
- Train Position.

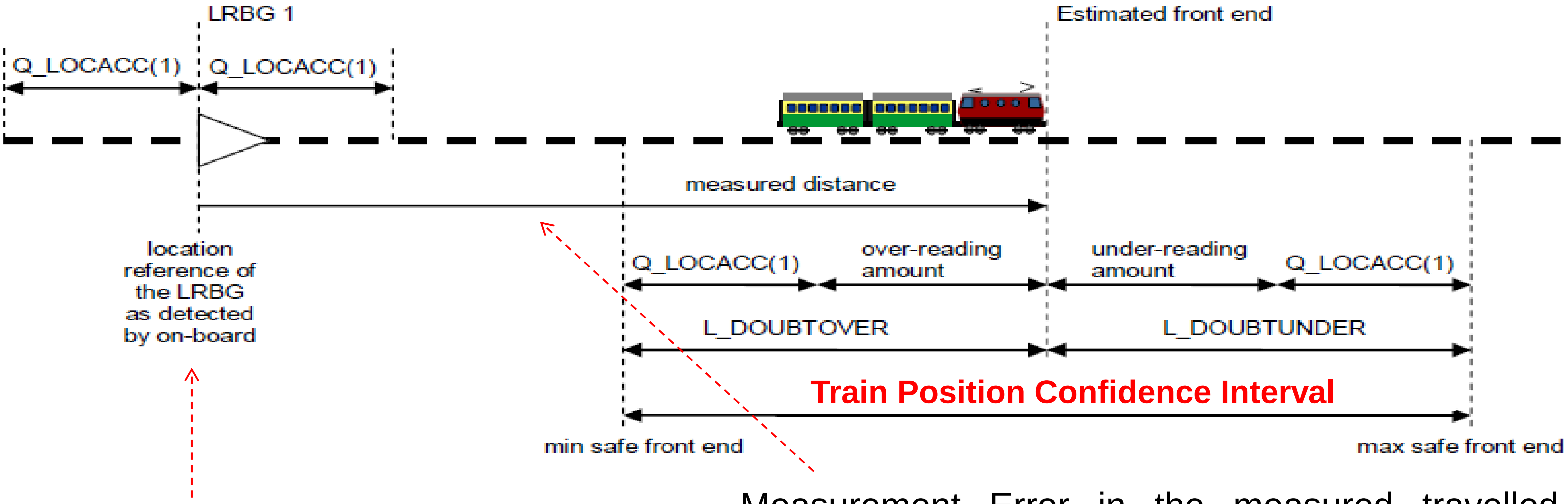
Track Discrimination

Minimum nominal horizontal distance between track centres [Regulation (EU) No 1299/2014, e.g. Table 4]

Maximum allowed speed [km/h]	Minimum nominal horizontal distance between track centres [m]
160 < v ≤ 200	3,80
200 < v ≤ 250	4,00
250 < v ≤ 300	4,20
v > 300	4,50

Track Discrimination, SIL 4 Function (THR = 1E-9/h) implies a maximum lateral position error less than 3,80 / 2 m = 1,9 m in all railways conditions.

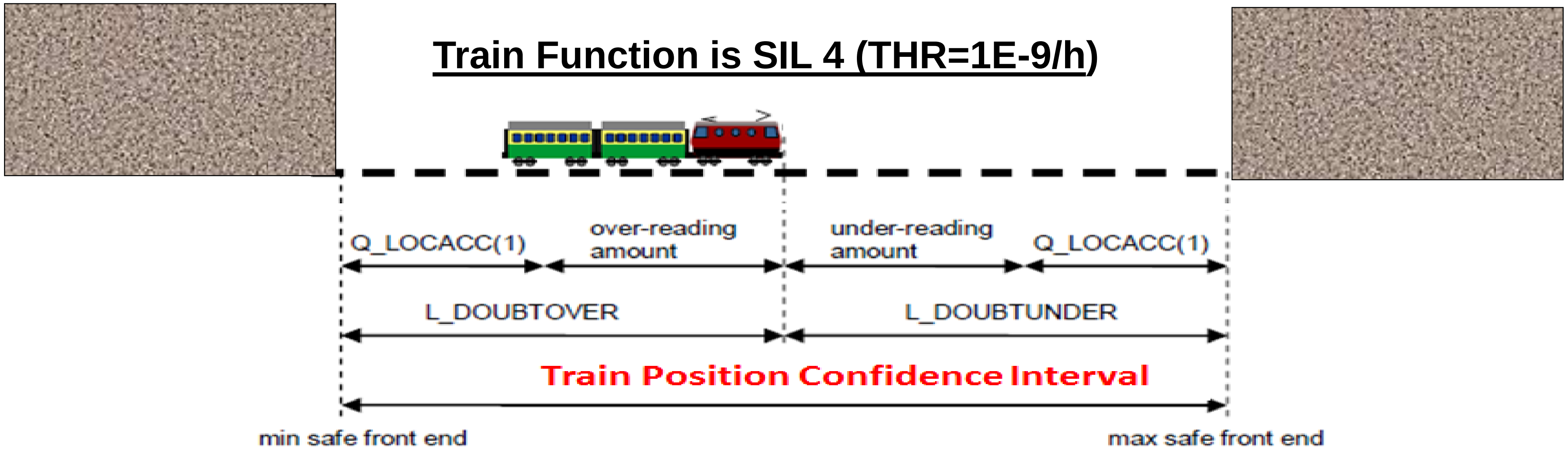
Train Position



Measurement Error in the Location of the Reference Balise ≤ ±1 m (in all conditions) [Subset 036]

Measurement Error in the measured travelled distance *s* (on-board fault-free conditions) due to odometry and the location reference error [Subset 041] ≤ ± (5 m + 5% * *s*)

Train Position



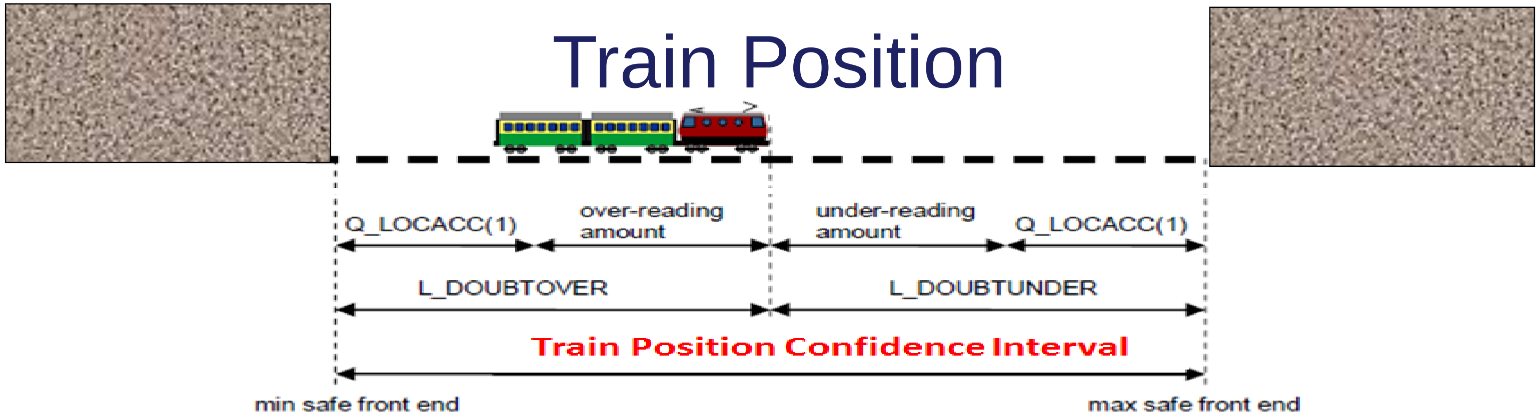
The Train Confidence Interval is normally periodically computed on-board.

Safety Requirement:

Train Position Function is a SIL 4 function (THR=1E-9/h). The True Train Position must always be within the Train Position Confidence Interval. It can be temporarily large for meeting the safety requirement.

In addition, see the note of the Subset 041, Req. 5.3.1.1 , "**Also in case of malfunctioning the on-board equipment shall evaluate a safe confidence interval.** "

Train Position



Operational Functional Requirements:

Train Position Confidence Interval <= 2* [Q_LOCACC + (5m+5%*d)]

where d is the measured travelled distance and Q_LOCACC depends on the Infrastructure Manager needs

Maximum Distance (m) Between Consecutive Balises (Subset 091)	2500	
	Distance (m)	%error (m)
Example of an average Maximum Distance (m) Between Consecutive Balises in LINE	1200	60
Example of an average Maximum Distance (m) Between Consecutive Balises close to Stations	80	4
Typical Q_LOCACC values are 4, 5, or 6 m. Special scenario may require 1 m. For example, assuming Q_LOCACC = 6 m		
Example of a Minimum Train Confidence Interval (m) at the Reference Balise Detection	**22**	
Example of a Maximum Train Confidence Interval (m) in LINE (1200 m)	**142**	
Example of a Maximum Train Confidence Interval (m) close to Stations (80 m)	**30**	

Task 5.2 : EGNSS Performance Assessment in Rail Environment

Damien JOLY (Thales Alenia Space)

WP 5.2 general presentation

- Objectives of STARS WP 5.2 study: Characterise current E-GNSS performances
- Based on available train receiver captures performed in three European countries.

Accuracy

Reference position

Processed position

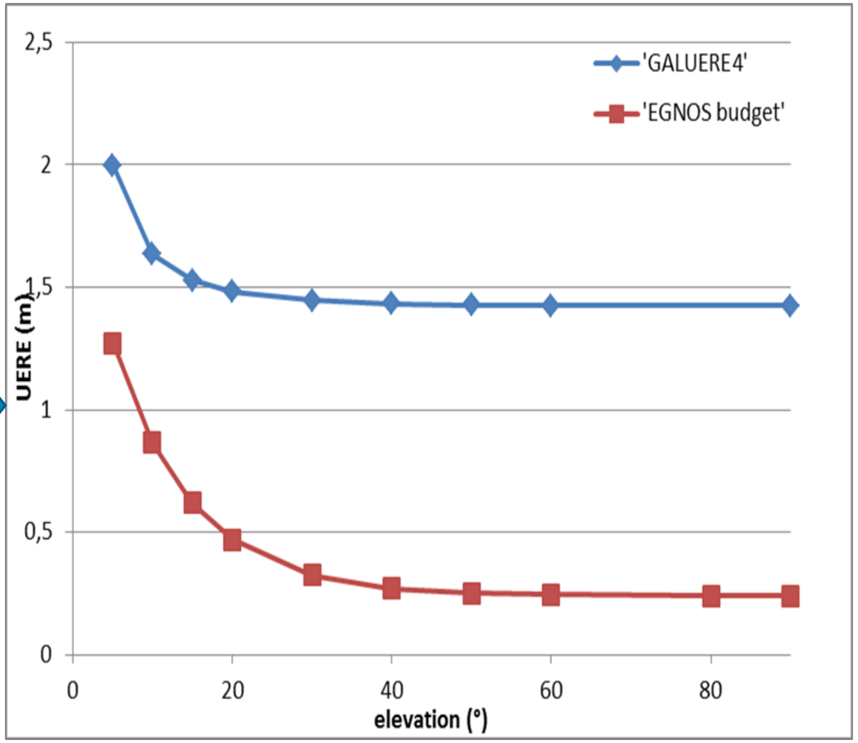
Navigation error

Availability

Receiver information

User error budget hypothesis

HPL



Integrity

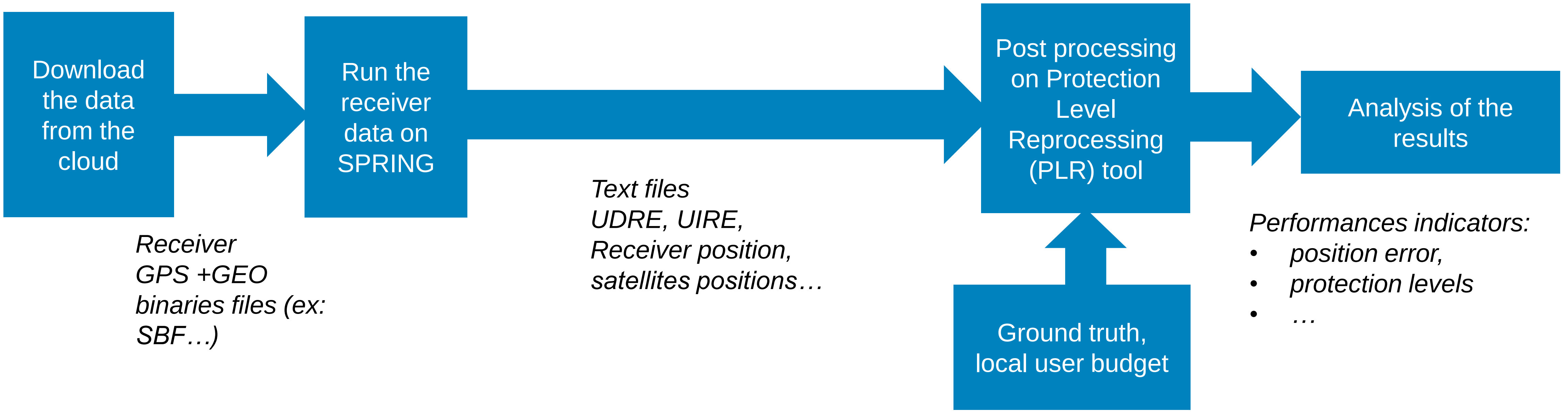
Navigation error

HPL

Integrity

WP5.2 Methodology

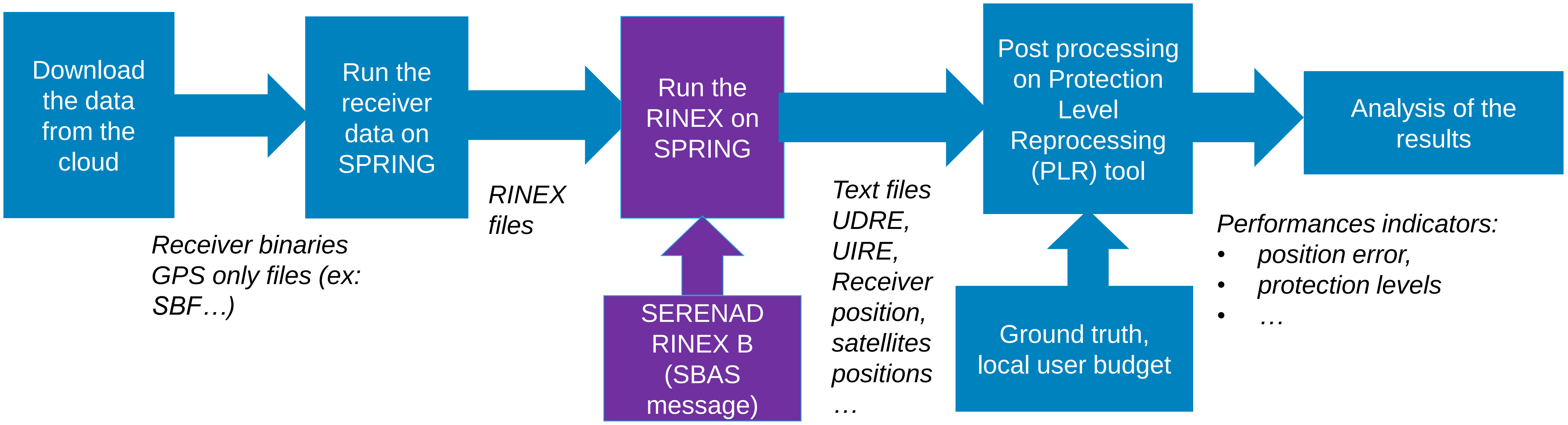
For surveys where EGNOS GEO data are available



SPRING tool limited to MOPS (civil aviation) models for the user local errors budgets.

WP5.2 Methodology

For survey where EGNOS GEO data is of poor quality or not available



SBAS corrections (RINEX B) are obtained from CNES SERENAD server

WP5.2 Open Sky results

Conditions: Open Sky (Sardinia campaign results)

- Good level of EGNOS GEO reception
- Low masking angles
- Very low local errors levels except on few spots.

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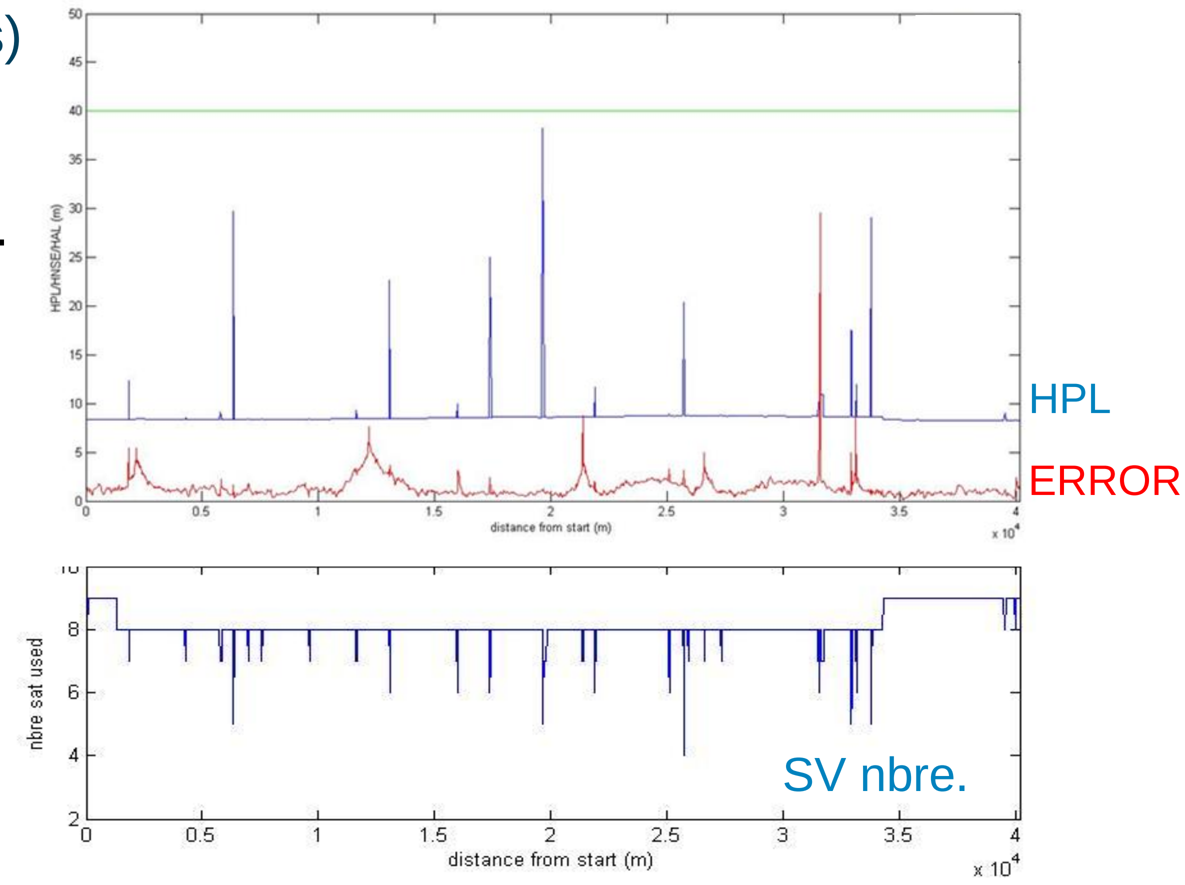
Observations:

- Used number of SV around 8
- Most of the time the error is very good (1m)
- HPL around 10m with MOPS budget
- 6 events of position error above 5m
- 2 events of non-integrity events

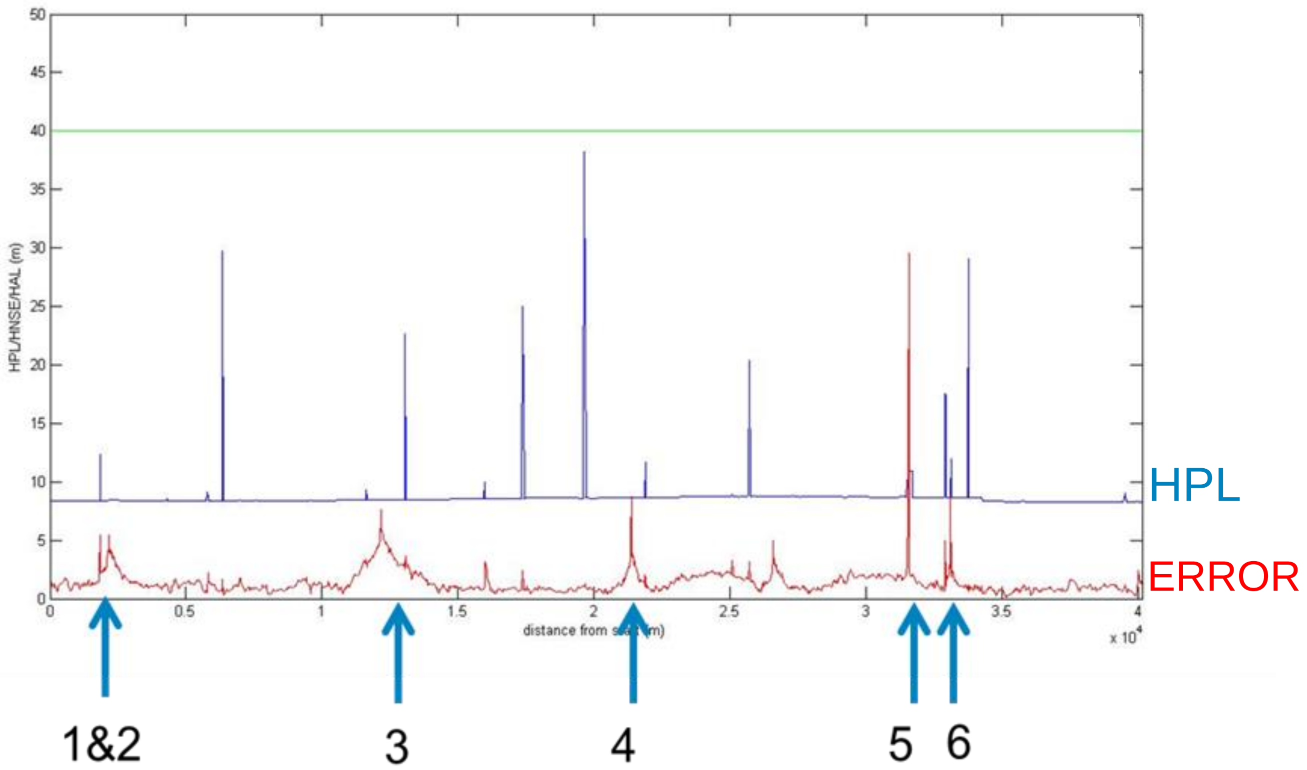


WP5.2 Open Sky Environment

Exceptions: Points with high position

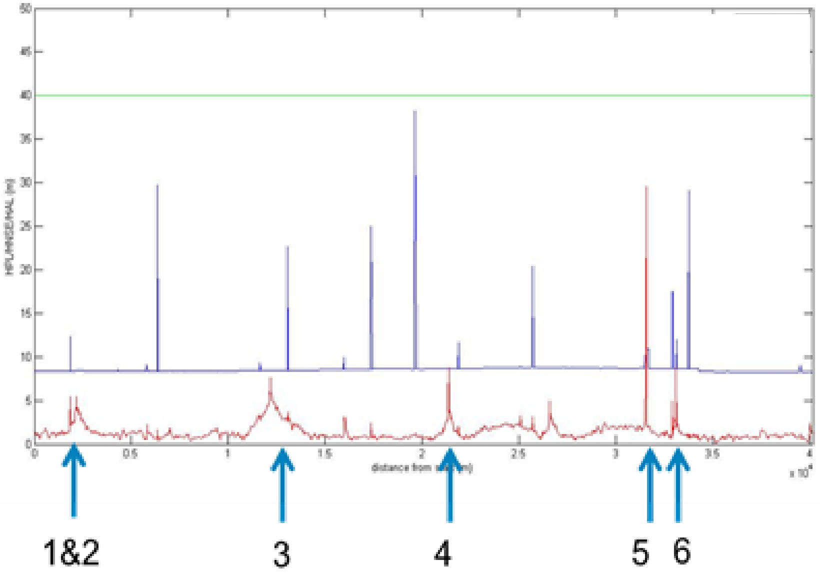
HPL	ERROR
Satellites geometry	Satellites geometry
EGNOS information	Iono, Orbit and Synchro. Error
User error budget hypothesis	True local error (unknown to users)

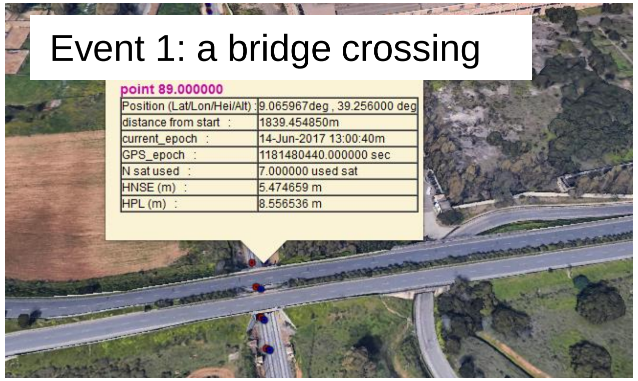
- High Position ERROR are due to outliers in encountered local error (Multipath…)

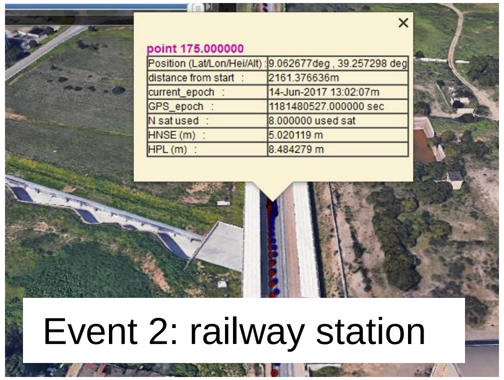


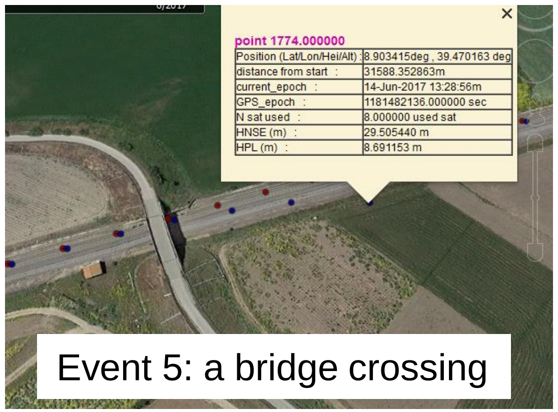
WP5.2 Open Sky Environment

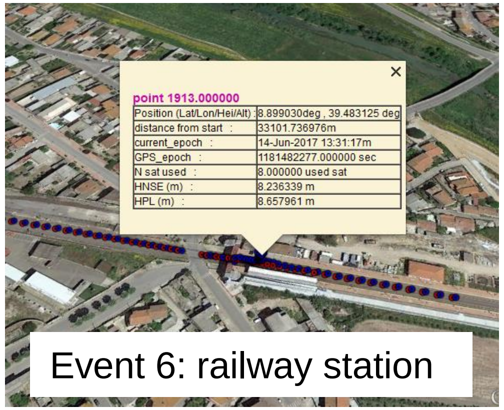
Geographical identification of the position error exceptions











Each of the High position error events can be linked to obstacles pointing towards multipath outliers.

WP5.2 Open Sky Environment

Summary

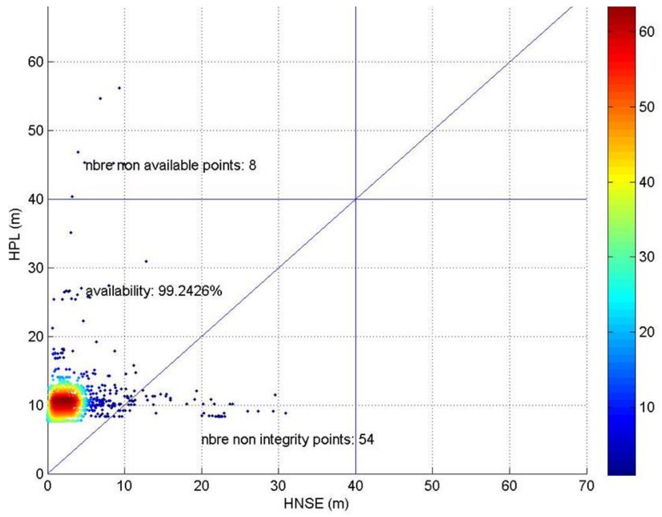
- In Open sky conditions the error values are low (~1m)
- HPL are around 10 meters (MOPS local error budget)
- HPL are around 15 meters (UERE-4 local error budget)
- High Position Error and even non-integrity events exist…
- …they can easily be related to environments events such as bridge crossing, railway station stop etc…

WP5.2 Forest Environment

Condition: Forest effect (AZD Czech republic)

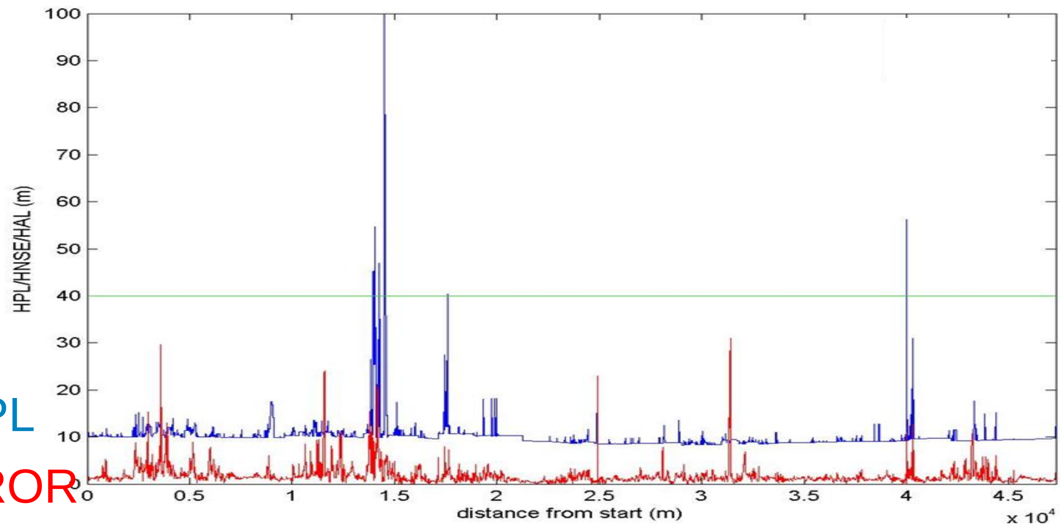
1. HPL variation very important
2. Linked to variation in the number of used satellites
3. Results of Sardinia campaign are confirmed in open sky
4. …but integrity events (HPL<Error) presents.

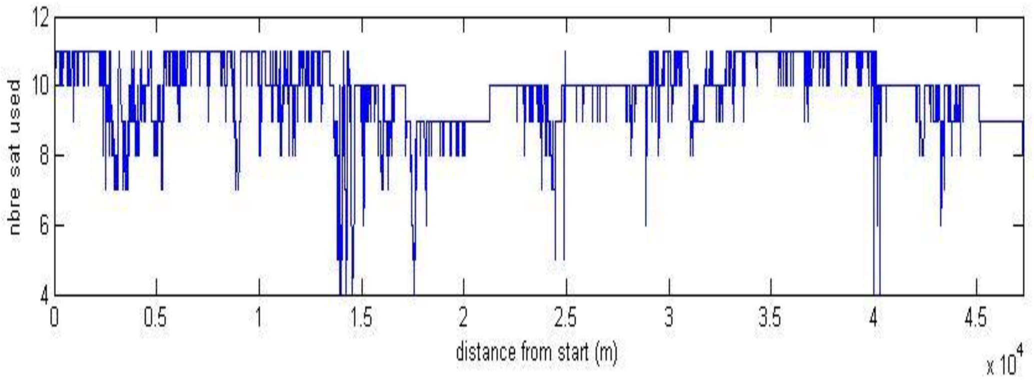
54 non-integrity/8186 samples



HPL

ERROR





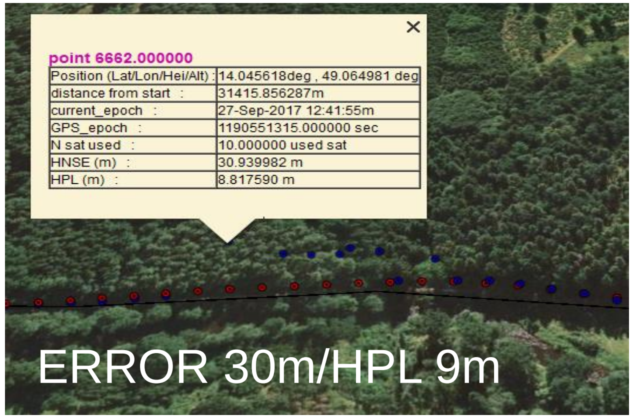
WP5.2 Forest Environment

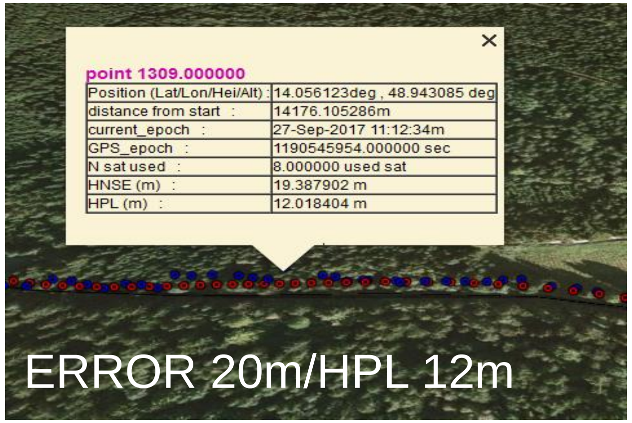
Forest effect on navigation performance

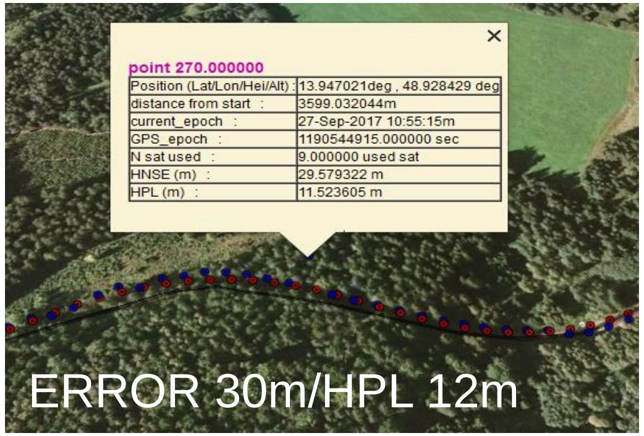
Degraded accuracy in the tree with several occurrence of important errors.

Trees attenuate the GPS signals => increase of potential multipath, or false locks errors

- Generate a lot of non-integrity events.
- Observed position errors in forest up to 5m and 50m.







WP5.2 Forest Environment

Summary

- New environment encountered in AZD campaign is forest.
- This new environment strongly disturb the GNSS measurements
  - High position errors in forest are important. Observed events show errors up to 50m
  - Most of these events lead to Miss integrity as the HPL is unable to cope with local environments threats
- On all the campaign forest is the WORST observed environment.
- These results are valid for both tested user local error budgets (MOPS and UERE-4)

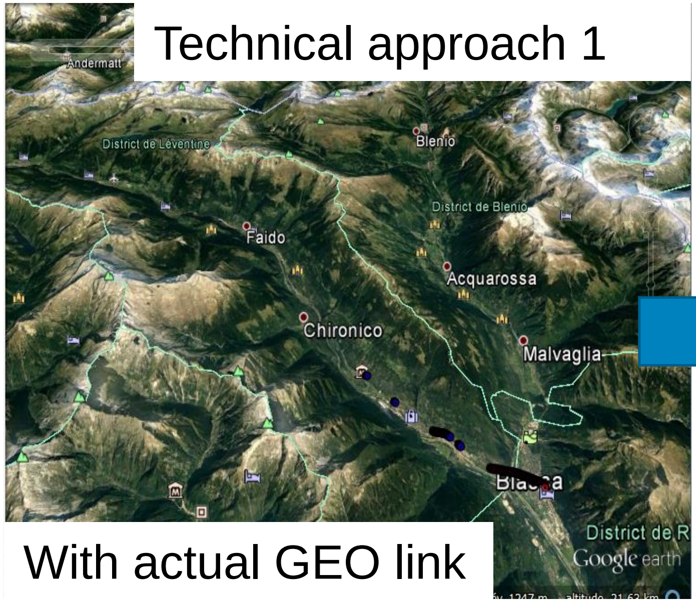
WP5.2 Mountain Environment

Conditions: Mountains (Siemens Switzerland)

1. Disturb the EGNOS GEO reception to the point it disturb position availability.
2. High masking angle (lot of GPS masked).
3. Both HPL and Position Error are disturbed.

9 non integrity events reported!! (over 1716 points).

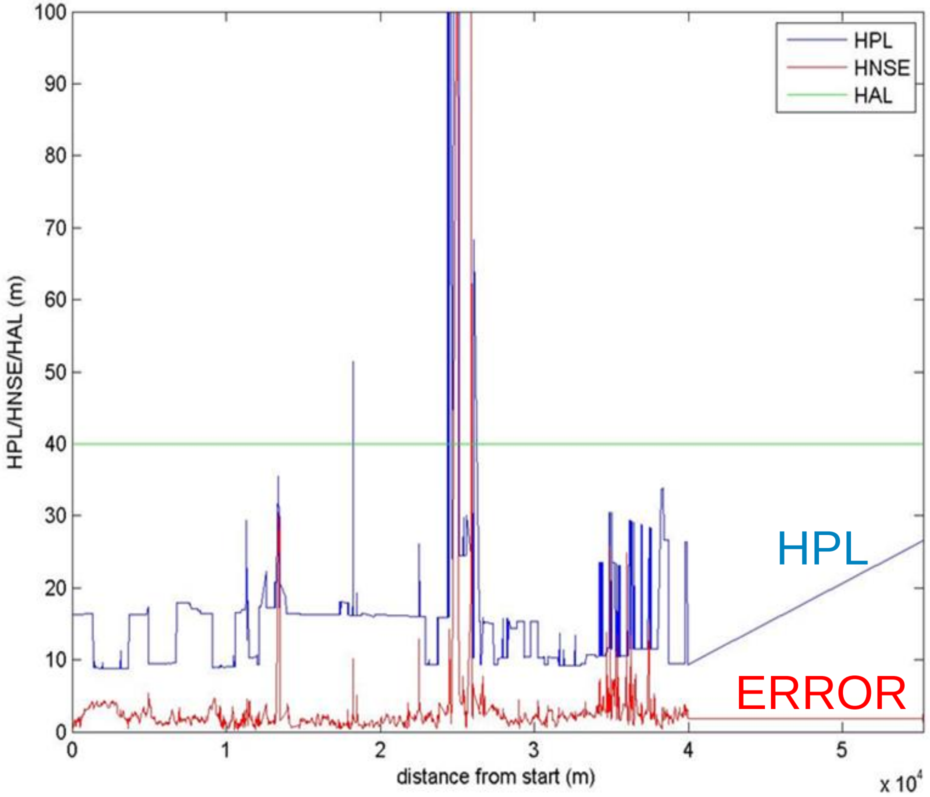
Technical approach 1



With actual GEO link

Technical approach 2

With perfect GEO link



WP5.2 Mountain Environment

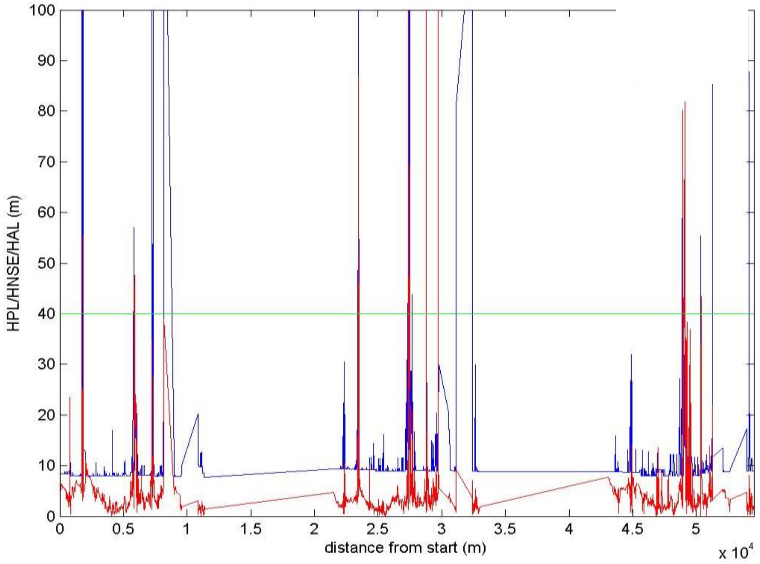
Summary

- As expected the mountain degrade the available GNSS performance.
- The degradation are mainly due to satellites masking.
- GEO transmission of EGNOS data is not usable (confirmed by other environment survey results).
- This degradation impact availability as HPL are degraded due to low satellites number.
- Some Miss integrity also appear but the number seems limited.

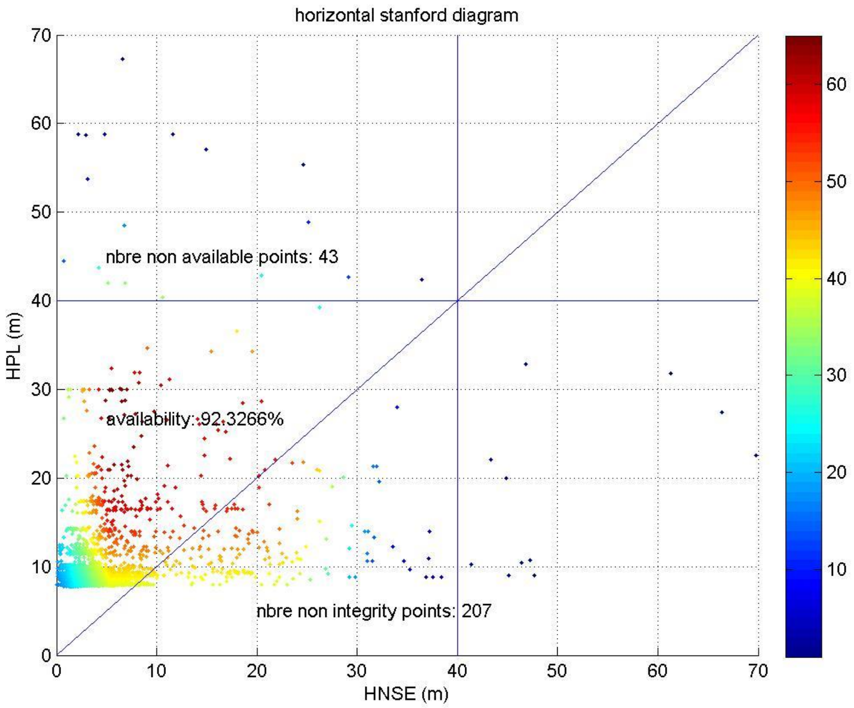
WP5.2 Urban Environment

Conditions: urban environment (Siemens Switzerland)

1. Some masking due to building. GEO/GPS reception impacted=> impact on HPL & Position Error
2. Some occurrence of high multipath/interference occurs
3. High level of non-integrity (HPL<Position error)



HPL
ERROR

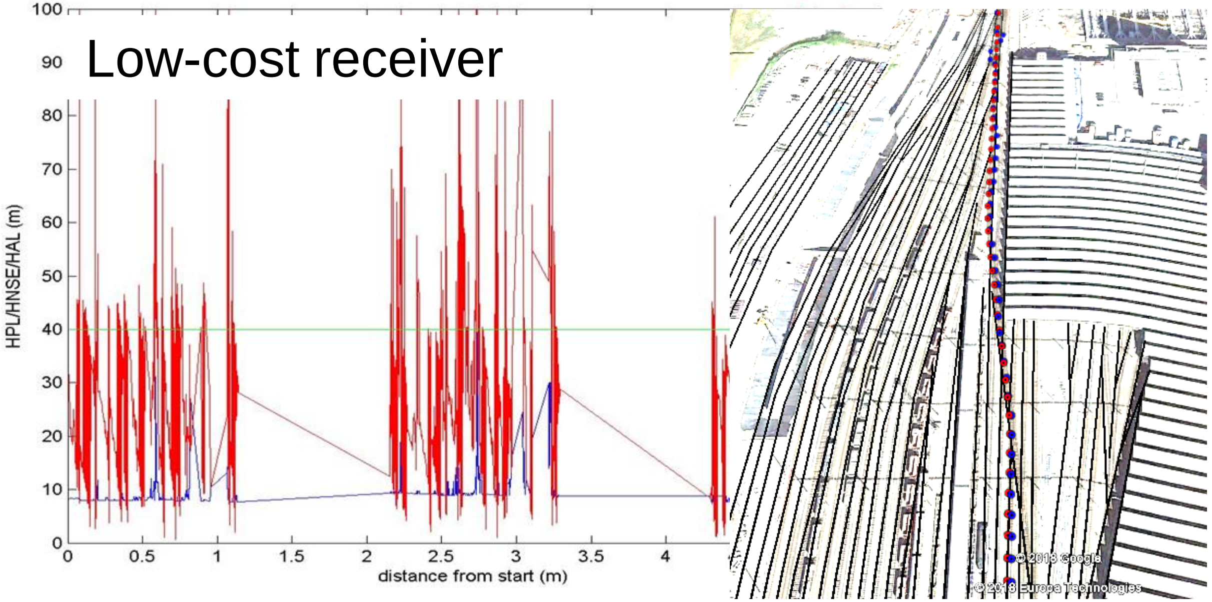


207 non integrity events reported!! (over 3258 points).

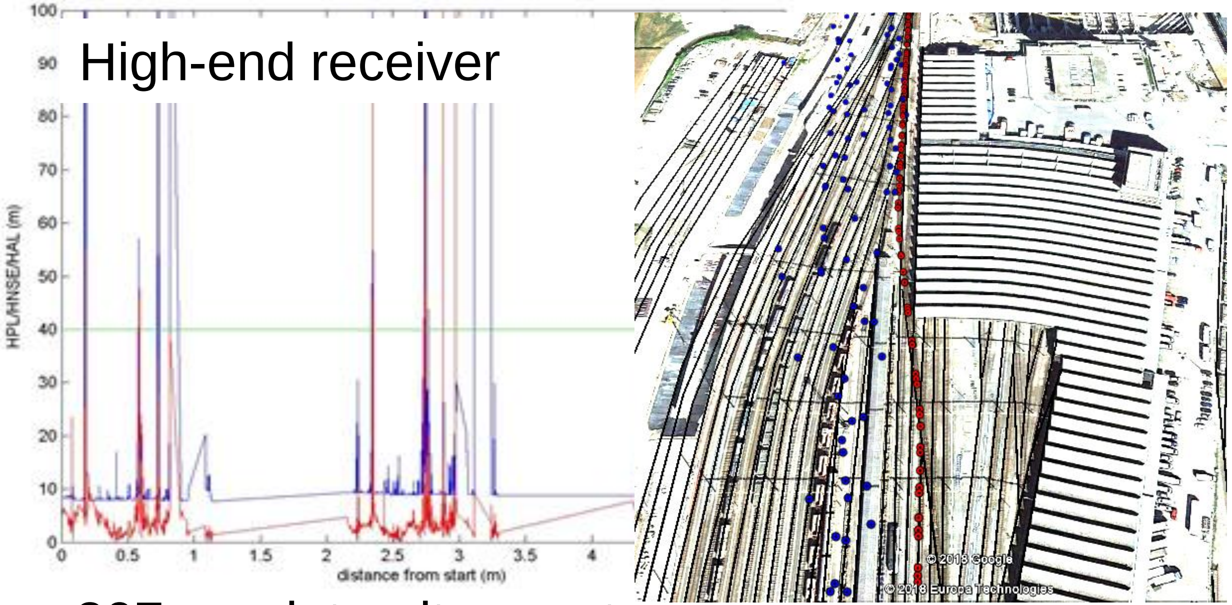
WP5.2 Urban Environment

Urban environment comparison of performances by two different receivers

- Two receivers used for several surveys



1937 non-integrity events



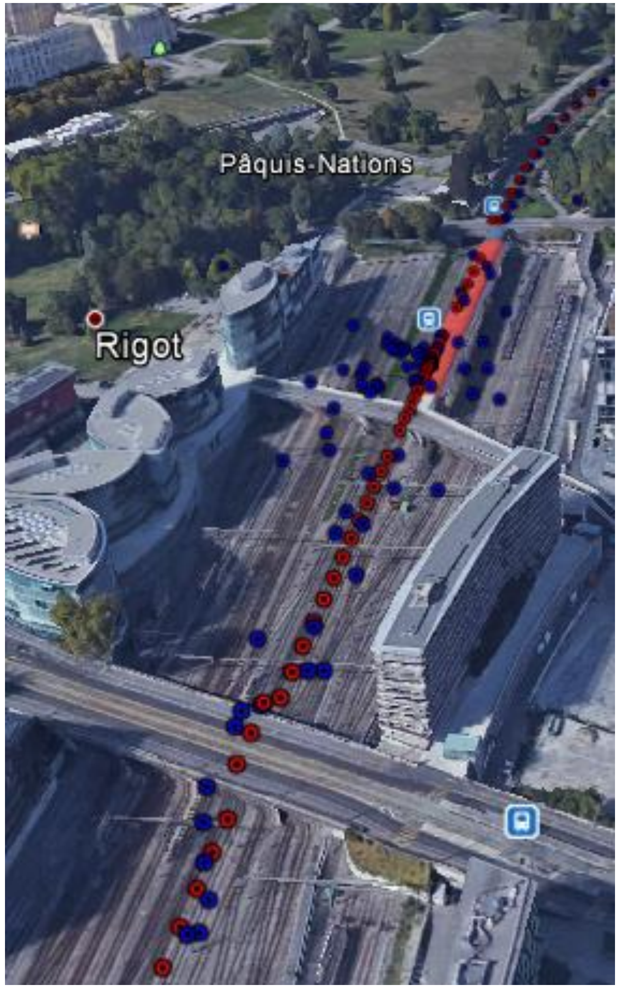
207 non-integrity events

- As a conclusion: necessity to specify user receivers Technology in future Rail standard.

WP5.2 Urban Environment

Summary

- As expected the buildings degrade the available GNSS performance.
- The degradation are mainly due to satellites masking.
- This degradation impact availability due to low satellite number.
- Some miss integrity also appear but they seems to be linked to railway stations stops.



Task 5.4 : EGNOS Preliminary Service Definition

Jean POUMAILLOUX (Thales Alenia Space)

Filippo RODRIGUEZ (Telespazio),

WP5.4 EGNOS Service Definition

GEO satellites are not a convenient mean of dissemination of EGNOS corrections

- Another distribution mean needs to be analysed, defined and standardised
- This could be transmission of EGNOS corrections toward the railway domain through commercial telecom services with committed transmission delays, performances and security.
- This subject should be analysed and trade-off made between potential solution
- One or several potential solutions should be tested in realistic situation

WP5.4 EGNOS Service Definition

Local multipath error cannot be bounded without severe impact on service availability without use of additional sensors.

- **Large outliers leading to non-integrity have been experienced using both** multipath over bounding formulas tried:
  - MOPS formula designed for in flight airplanes
  - Galileo formula intended to be convenient for ground users
- **Need to develop a mean to exclude wrong measurement impacted by important environment effect.**
  - Virtual balise location could be selected where measurement shows low level of local errors
- **But there is no guarantee that this low local error will be maintained over time**
  - New buildings or new bridges could one day be constructed along the line
- **Viable solution could be to require, by standard, that the train capable positioning function is able to detect and reject lines of sight that suffers from multipath value above the threshold of the standardised bounding formula**.

WP5.4 EGNOS Service Definition

SBAS alone cannot provide the required level of performances

- **Hybridisation with other sensors is mandatory (IMU can be the first one)**
  - To be able to meet the required integrity level
  - To improve accuracy so that track selectivity may be obtained
- **If deemed necessary, hybridisation with other sensors may be thought**
  - Map-Matching using a track position database is a good candidate
- Experiment in real environment should be done to demonstrate that an on board positioning function using a GNSS (GPS + Galileo) receiver and an EGNOS corrections receiver (may be GSM-R), hybridised with IMU and may be with other sensors is able to reach the required level of performances, including integrity.

WP5.4 EGNOS Impacted Architecture