1st Advisory Board

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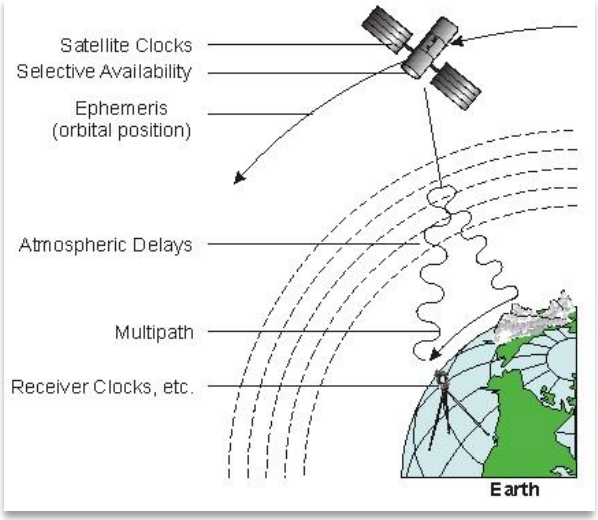
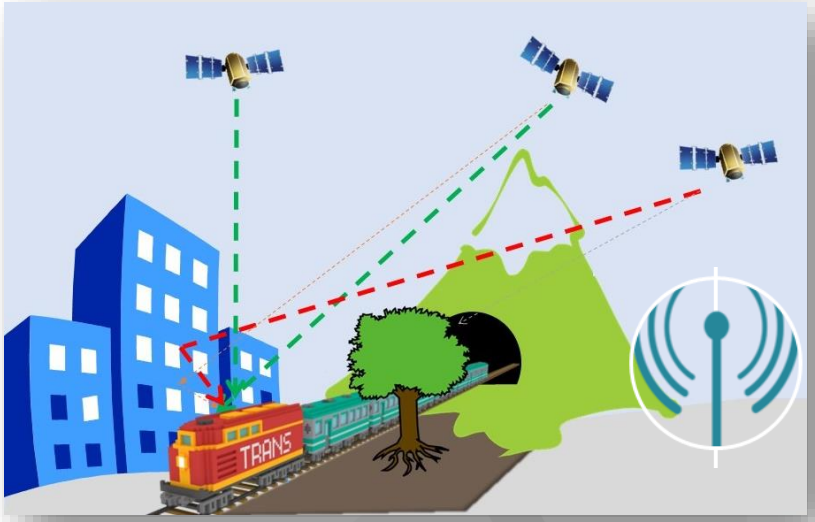
Prepared with GUIDE and M3S

Virtual meeting, 15/10/2020

Methodology for the Characterization of GNSS errors in the Railway environment

CONTEXT – GNSS ERRORS





RISK ASSESSMENT MATRIX

GUIDE		PROBABILITY OF ERRORS (Likelihood)		
		Unlikely	Moderately	Highly likely
IMPACT OF ERRORS (Consequence)	Major (>10m)	• Jamming	• Interference	• Obturation • Multipath
	Significant (<10m)	• Clock		• Diffraction • Unfitted Algorithm (Hybridizations, PPP,...)
	Moderate (<3m)	• Orbit	• Ionosphere	• Attenuation • Sensitivity • Antenna
	Minor (<1m)		• Geometry (DOP)	• Thermal noise

LOCAL
GLOBAL
Terminal

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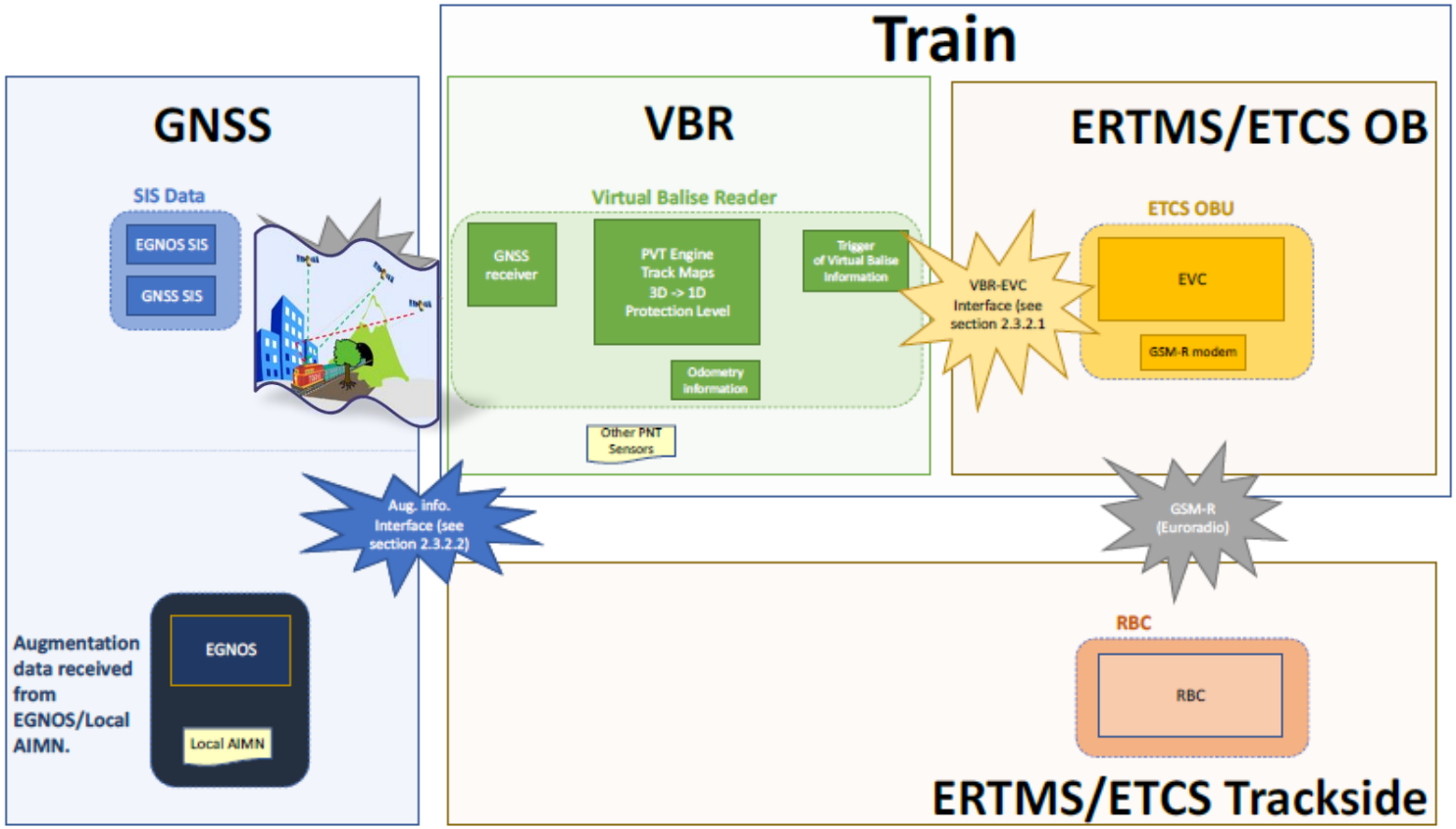
OBJECTIVES

Simulate typical GNSS errors in order to evaluate their impact on the global Gate4Rail simulation chain



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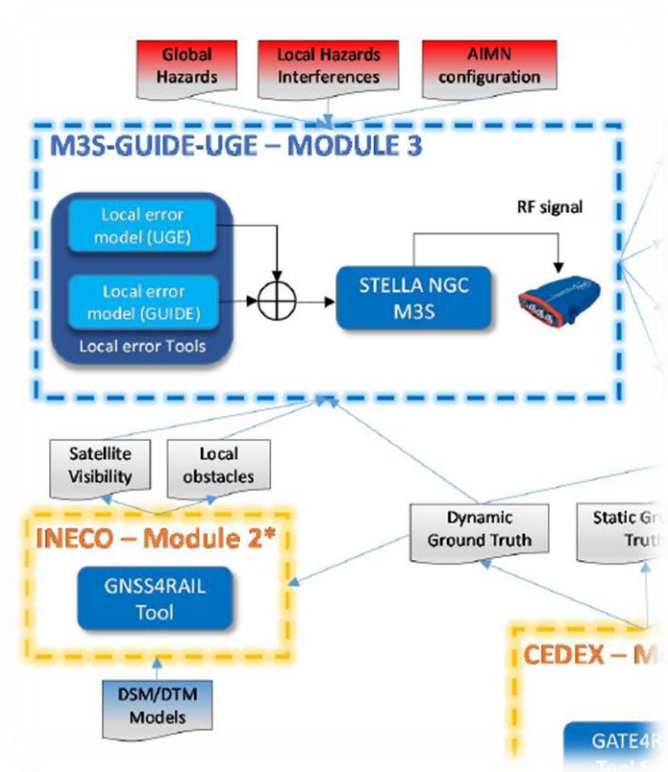
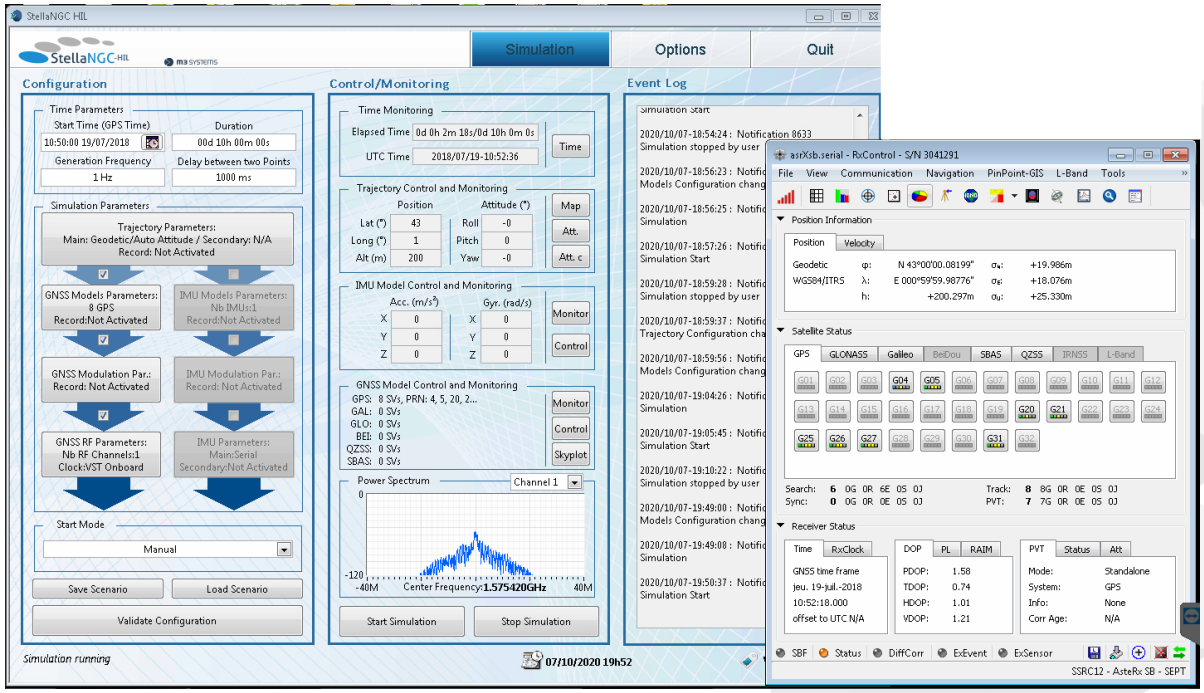


Cf. Past presentation

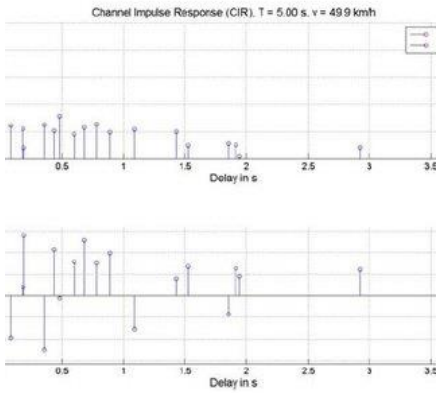
OVERVIEW ON ERROR MODELS

Global errors	Local effects	
	Interferences	Obstacle effects
• Simulated by STELLA NGC	• Implemented in STELLA NGC	No existing models



HOW TO SIMULATE MULTIPATH?

Statistical models
(ex. DLR Land Mobile
Multipath Channel Model)



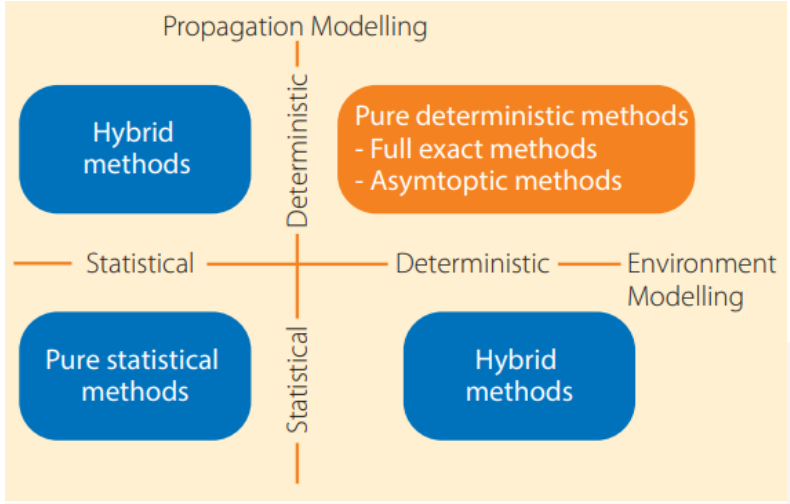


FIGURE 1 Methods of computing GNSS signal propagation in constrained environments, sorted according to how the environment and signal propagation are modeled

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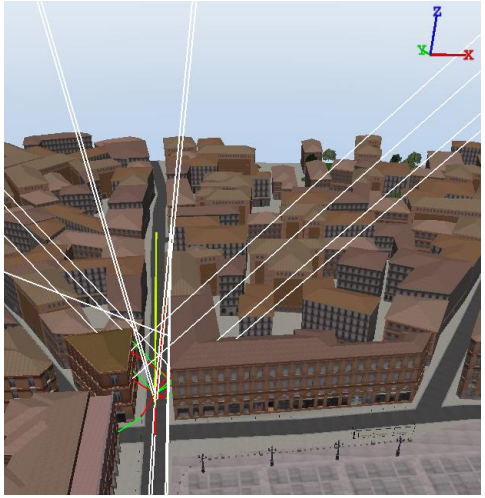
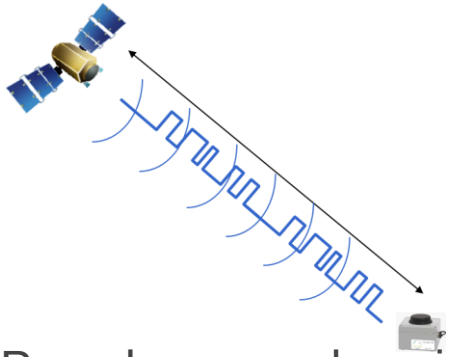


Deterministic models
(Ray tracing tools)

Require an accurate 3D model of the environment

Generic model – not « railway » (artificial scenario based on statistical distribution of obstacles)
Realistic if reception conditions are similar to the acquisition conditions

In Position domain?



In Pseudo-range domain?

From real datasets

- Knowledge of reference track coordinates/Ground truth
- Possibility to compute position error and model them as distributions

From real datasets

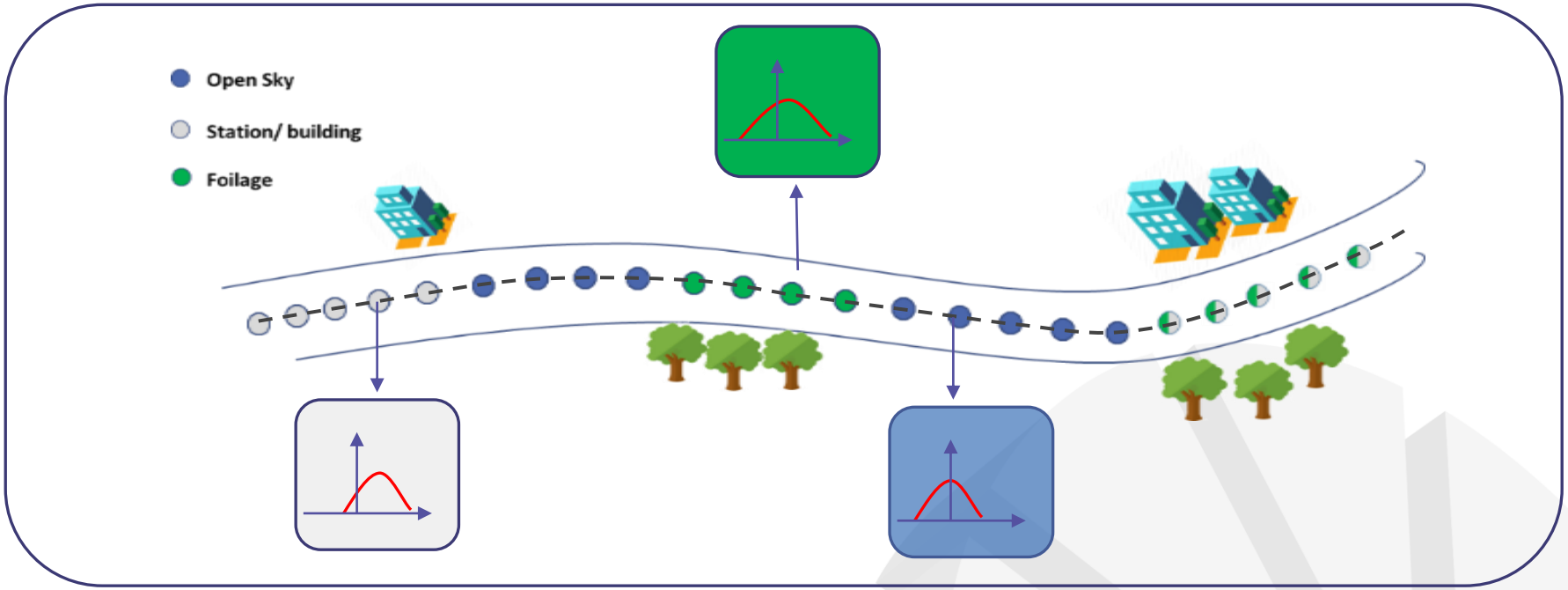
- No ground truth

From simulation tools

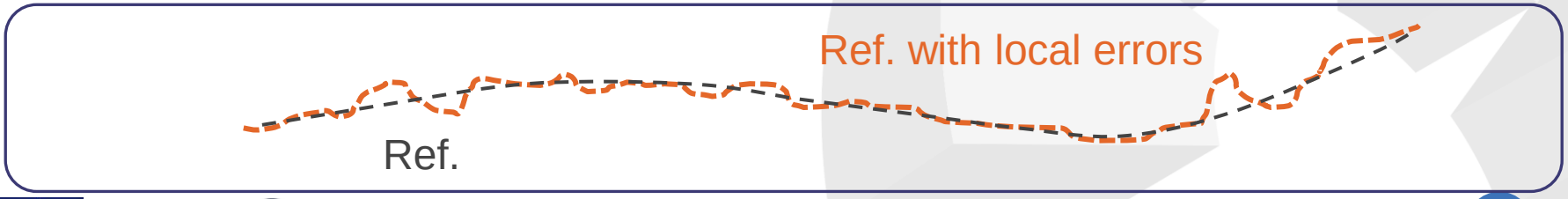
- No specific railway channel model

OUR APPROACH FOR RAIL

1. DEFINE LOCAL ERROR MODELS

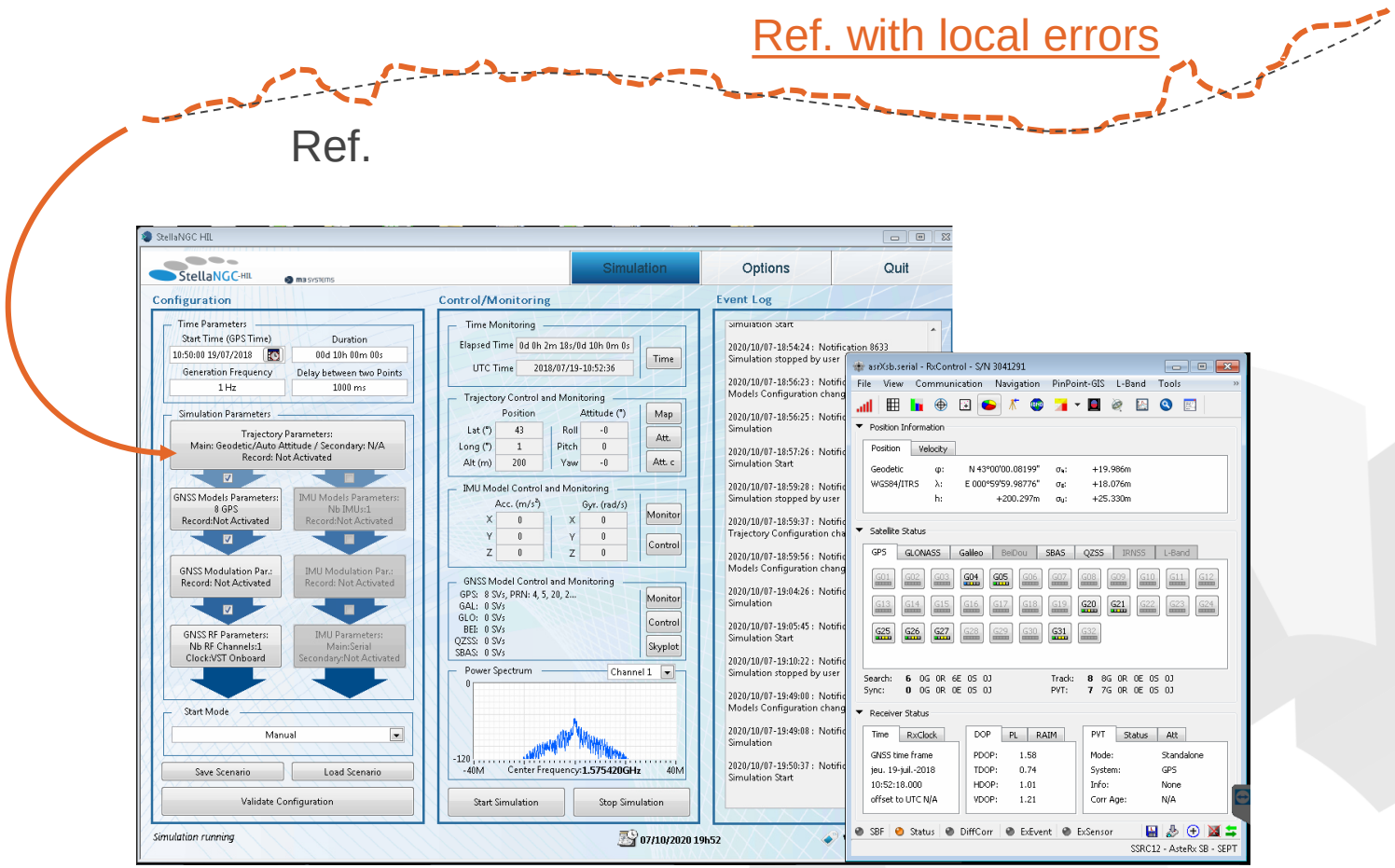


2. ESTIMATE LOCAL ERRORS



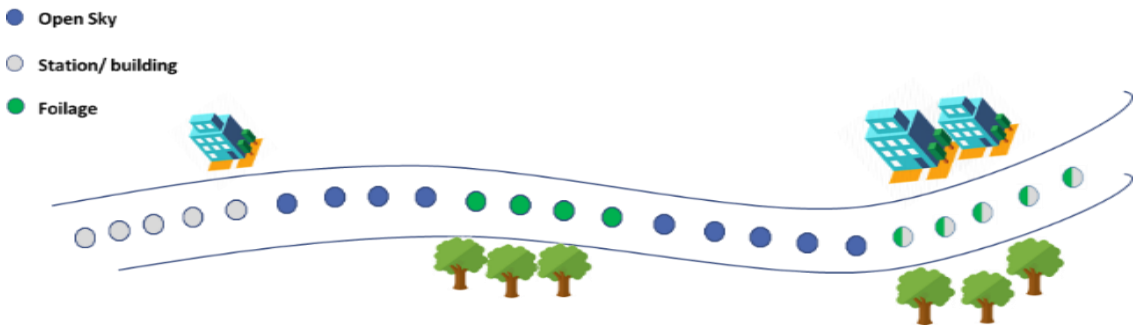
OUR APPROACH

A NEW REFERENCE USED FOR SIMULATION



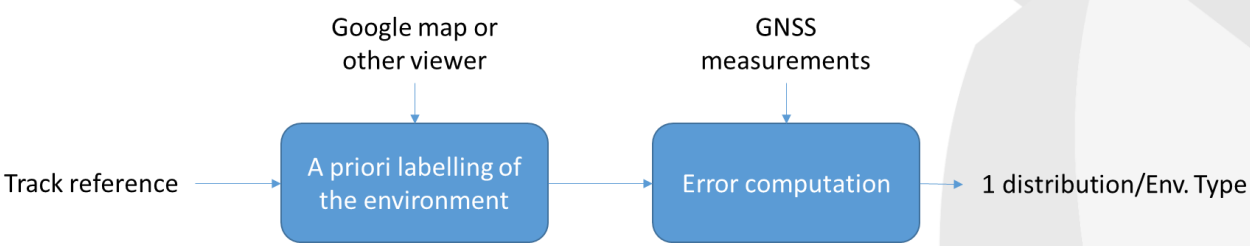
WORK DONE – 1st tool

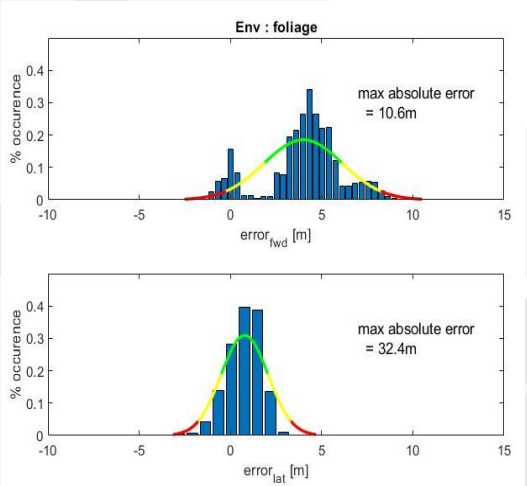
1. Typical environments: forest, urban, open sky



a. a priori classification of the environment of the track
b. Computation of error distribution from exp. DB

$$E = Pos_{meas} - Pos_{True}$$

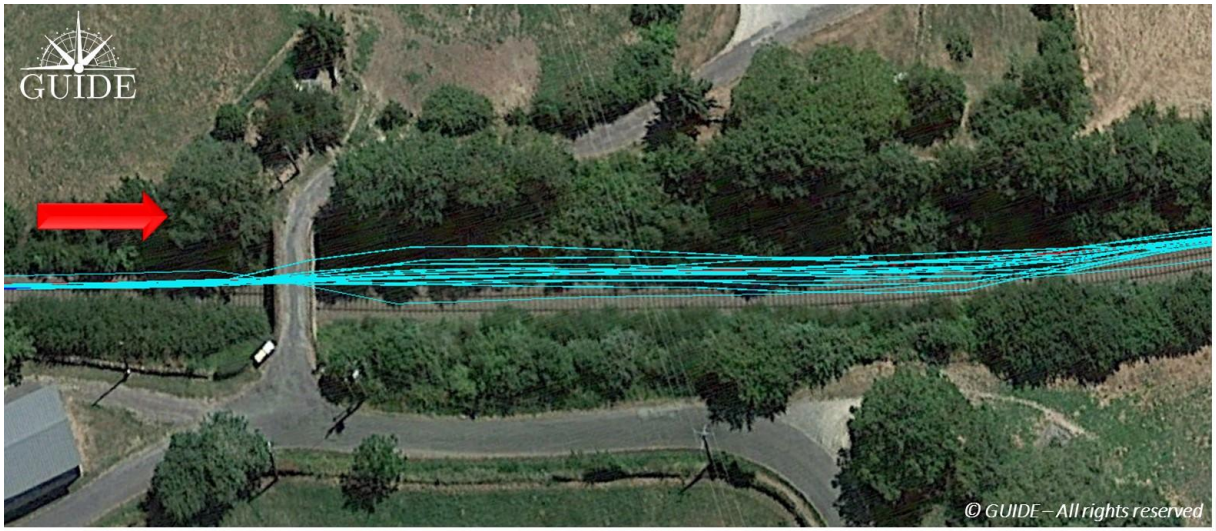




WORK DONE – 2nd tool

2. Typical Obstacles: Tunnel and Bridges

a) Example of errors for bridge crossing *Record&Replay Technique*



b) Modelling of the errors profile

$$s(t) = \begin{cases} p, & t = t_{bridge} + 1 \\ \frac{p}{3}, & t = t_{bridge} + 2 \; ; \qquad p = 7 \\ 0 & elsewhere \end{cases}$$

Data used for modelling

1st tool

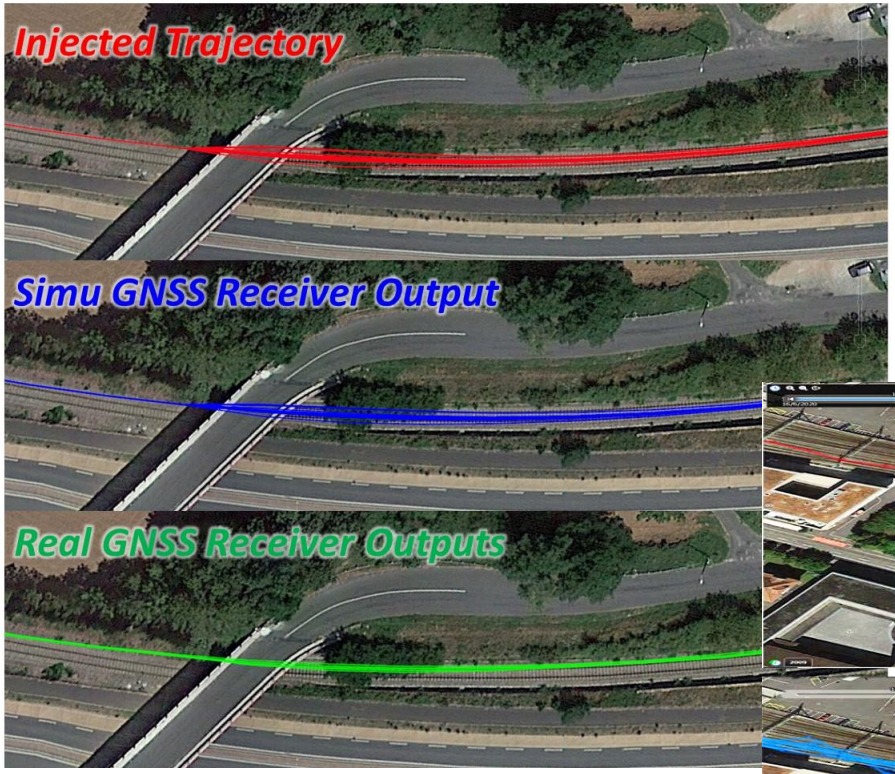
- STARS project data for typical environments
  - Multi-constellation, multi-frequency Rx
  - Data collected in Switzerland, Rotkreuz - Berne - Yverdon-les-Bains (RBY)
  - All three environments (foliage, urban and opensky) are taken from the same campaign.
  - The position is obtained after the conversion of .sbf > Rinex and processed with RTLlib.

2nd tool

- I&Q records from rural line in France for R&R (punctual obstacles)
  - Data digitized on Rodez-Toulouse line, Occitanie, France.
  - GNSS Multi-constellation, multi-frequency signals (L1, L2, L5)
  - GNSS signals replayed on two types of GNSS receiver.
  - Several bridges and two tunnels present.
  - Model developed analyzing errors for all of them.

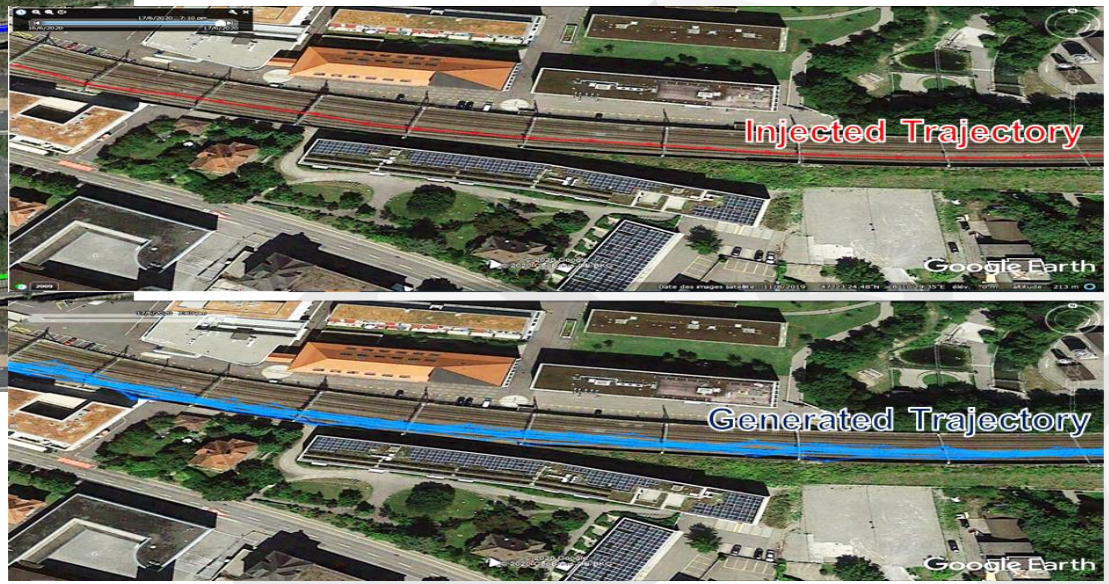
RESULTS

- Examples



Tools are ready for PoC!

Presented in D3.1 and D3.2
(Public deliverables)



EVOLUTION. FUTURE WORK. EXPORTED ISSUES

Existing tools & some models

EVOLUTION. FUTURE WORK. EXPORTED ISSUES

	Has been done	Future works / Evolutions
Error models/Classes	Errors models proposed for some typical environments and obstacles	Improve current models (more data -> more representative distributions)
	5 classes of environments or models	Extend the number of environments to have a more exhaustive coverage of a line
	“Typical” environments with a short description	Quantification or better qualification of the environment types
	Manual labelling of classes	Machine Learning for automatic context detection

EVOLUTION. FUTURE WORK. EXPORTED ISSUES

GNSS technologies are evolving continuously
⇨ Models need to evolve too

Existing tools & some models

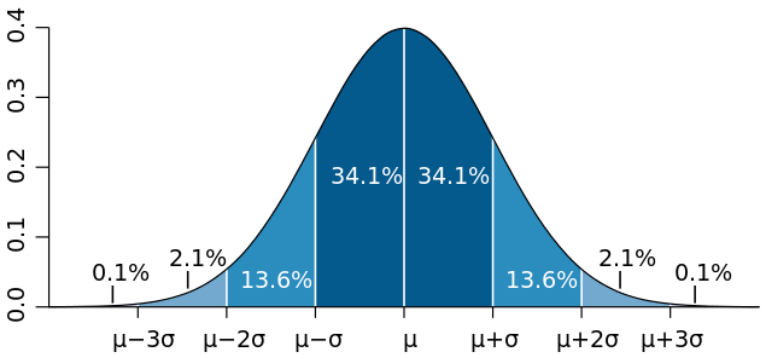
	Has been done	Future works / Evolutions
Techno	Current models based on standalone GNSS	Estimation of new models for high accuracy correction services (NRTK/PPP)

EVOLUTION. FUTURE WORK. EXPORTED ISSUES

Existing tools & some models

« Worst cases » to be developed to push limits?

EVOLUTION. FUTURE WORK. EXPORTED ISSUES 2/2

	Has been done	Future works / Evolutions
Gaussian shape	Gaussian distributions “hide” worst cases ▪ For typical environments, the Gaussian shape of the distribution will mostly represent “typical errors” and tends to minimize the occurrence of large errors. ▪ To “push” the limits of the simulation and simulate in particular these faults, it may be necessary to force their occurrence.	Analysis of the occurrences of worst cases and new modelling for their simulation 
Domain	All models have been developed in the position domain	Modelling of errors on measurements domain

QUESTIONS/DISCUSSION

- What kind of local error or location could be implemented in the future?
- What would be the limits to be pushed? (for safety demo)
- Which of the systems do we need to model?
  Different GNSS Receiver (mono-frequency/multi-frequency)/grades, Future signals, Multi-constellation...
  High accuracy correction services (NRTK/PPP)