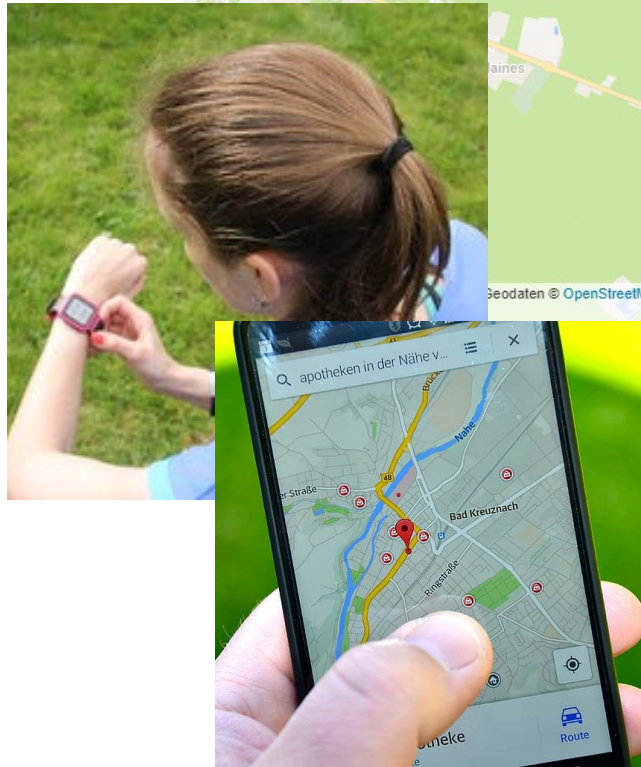
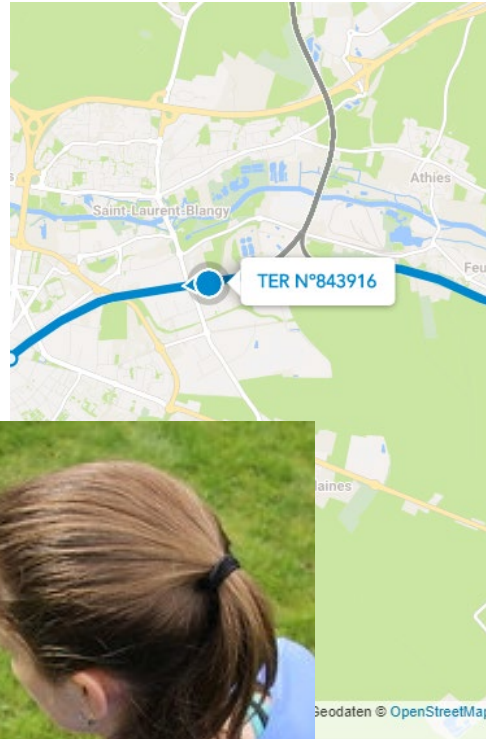


Juliette Marais
29/09/2022

*Enjeux des technologies de
communication, localisation
et perception pour le Train
Autonome*

Quelles avancées en Europe pour les applications ferroviaires du positionnement satellitaire ?

GNSS in every day's life vs Railway applications



AVAILABILITY?



RAILWAY REQUIREMENTS FOR LOCALISATION

Non-safety vs safety

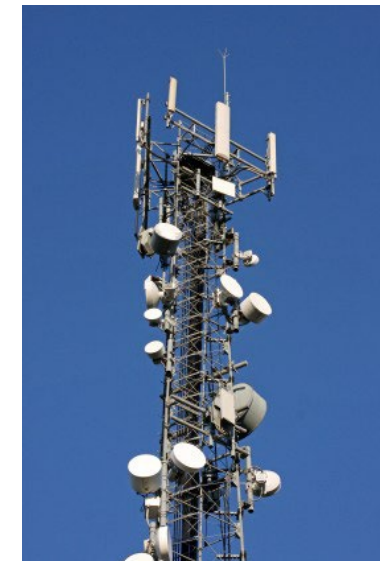
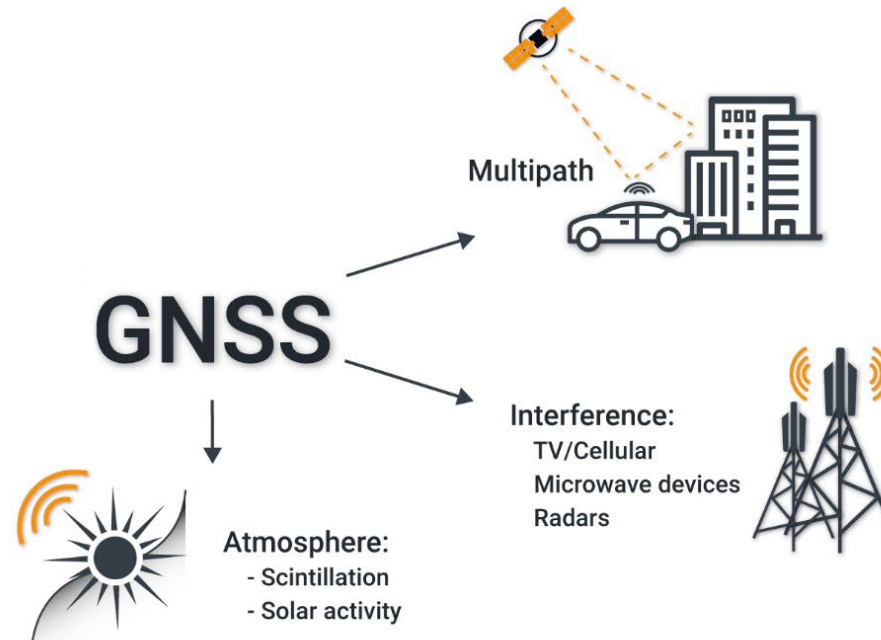
Applications	Non safety-critical applications			Safety-critical applications
	Asset management	Passenger Information	Trackside personnel protection	Signalling and train control applications
Key GNSS requirements	Accuracy (10 metres) Availability (High)	Accuracy (5 to 100 metres) Availability (95%)	Accuracy (1 to 10 metres and track discrimination) Availability (95%)	Accuracy (1 to 20 metres) Availability (High) Integrity Robustness
Other requirements	Connectivity Power Consumption	Connectivity (communication link)	Connectivity (communication link)	Interoperability



https://www.gsc-europa.eu/sites/default/files/sites/all/files/Report_on_User_Needs_and_Requirements_Rail.pdf



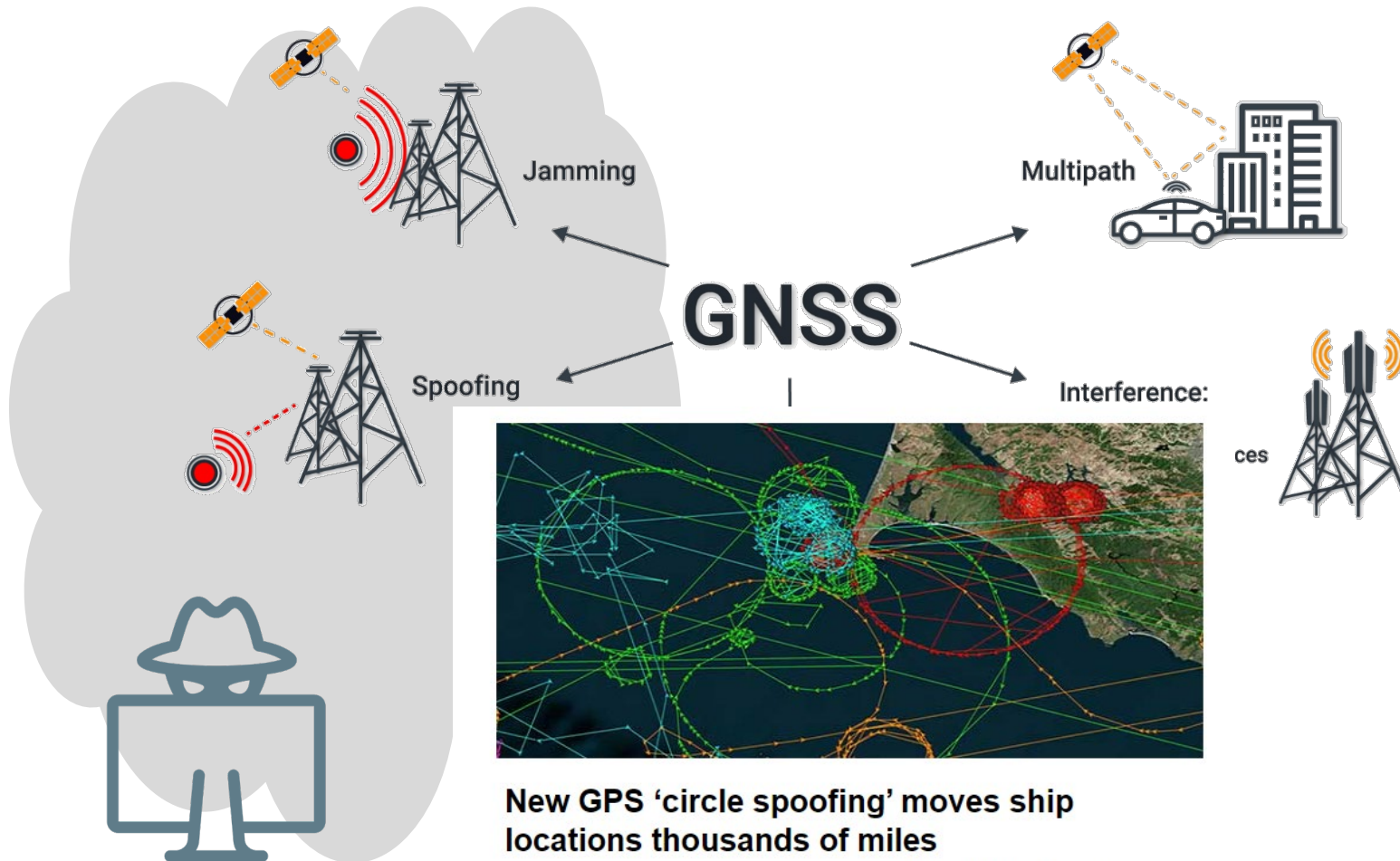
GNSS PERFORMANCE – IT IS ABOUT SURROUNDINGS



IT IS ABOUT SURROUNDINGS

Russia is jamming GPS satellite signals in Ukraine, US Space Force says

By Elizabeth Howell published 14 days ago



New GPS 'circle spoofing' moves ship locations thousands of miles

May 26, 2020 - By Dana Goward

Est. reading time: 2 minutes



IT IS ABOUT TIME TOO...

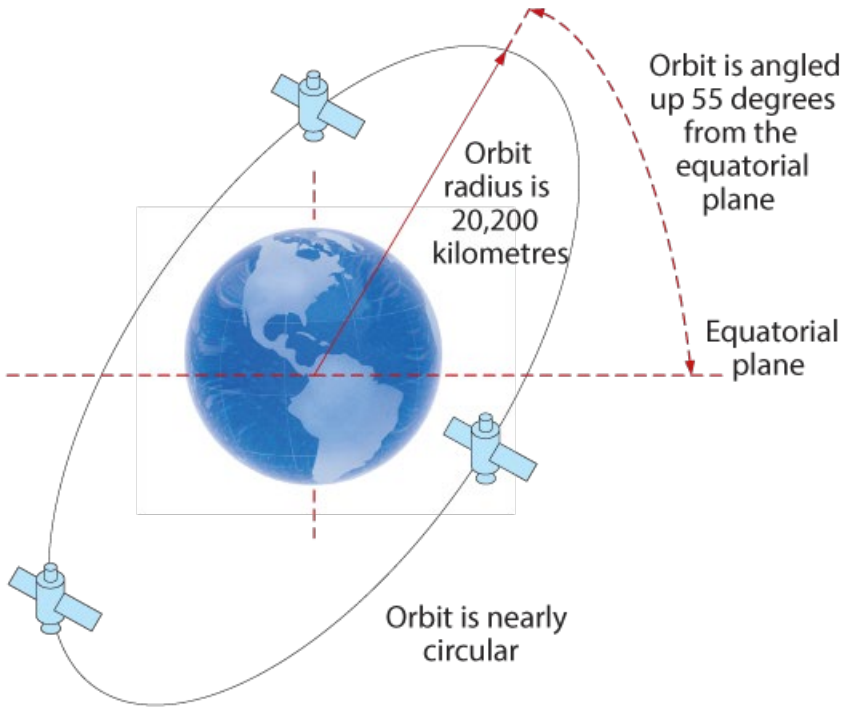
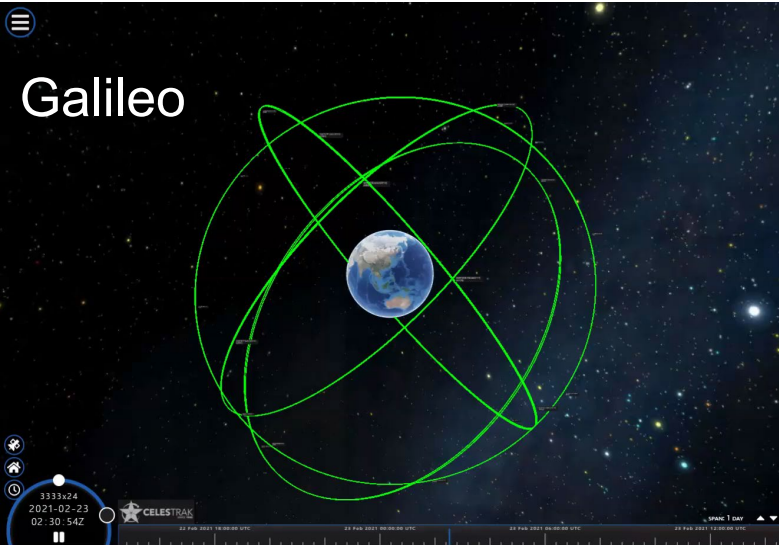
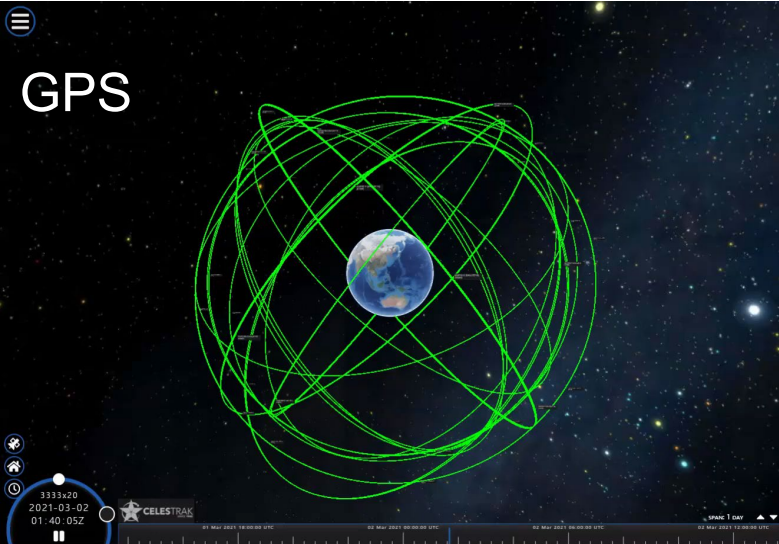


Figure 28 GPS Satellite Orbit

SO... DO WE REALLY WANT TO USE GNSS???

POURQUOI,
POURQUOI,
POURQUOI ?



- ✓ Continuous absolute position, 24h/24h, 7/7
- ✓ No borders
- ✓ « Cheap » chips
- ✓ On-board equipment (no infra)
- ✓ No fees
- ✓ New services (i.e. signal authentication, High accuracy...)

EU Parliament calls for fast adoption of satellite-based train localization in railway signaling

Adoption of the own-initiative procedure 2019/2191 (INI) in July 2021, the European Parliament highlights the need to take advantage of the **potential cost savings that GNSS offers in railway signalling.**

GNSS FOR RAIL

What will be facilitated with GNSS for rail?



Attractiveness

New services for clients

- Passengers,
- Freight customers



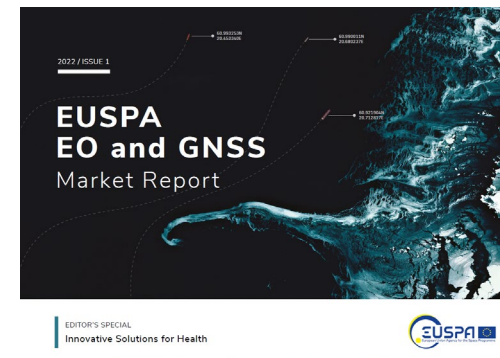
Efficiency

Improve maintenance

- Real-time diagnostic
- Anomaly detection and localisation
- Predictive maintenance



©Traxens/SNCF Logistics



https://www.euspa.europa.eu/sites/default/files/uploads/euspa_market_report_2022.pdf





Safety

POSITIVE TRAIN CONTROL & SAFETY

Amtrak Accident Renews Push for PTC

The fatal derailment of an Amtrak passenger train in Washington state has, once again, prompted calls for installation of GPS-aided positive train control (PTC) systems on board American trains.

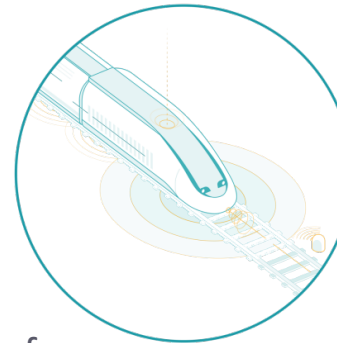
On December 18, 2017, passenger train 501 — a Talgo Incorporated locomotive on its inaugural passenger service trip — went off the tracks at an estimated 78 mph in a 30-mph speed zone near Dupont, Washington, a small community between Tacoma and Olympia.



Autonomy

+ **ecology** thanks to optimal energy consumption.

+ **rolling stock fleet rotation**: no timeout for the drivers



+ **regularity** thanks to the reactivity and robustness of the system to rail feared events.

+ **capacity** thanks to speed and position optimisation of each train, to increase the train line frequency.

+ **benefits** : system less costly thanks to the removal of trackside signalling equipment

GNSS IS PART OF THE EU R&D PROGRAMS

EU-Rail Multi-Annual Work Programme



Network management planning and control & Mobility Management in a multimodal environment

Network management planning and control (new processes and automation for decision support) & rail management in a multimodal environment (real-time demand-driven operations, including demand from other transport modes)

Digital & Automated up to Autonomous Train Operations

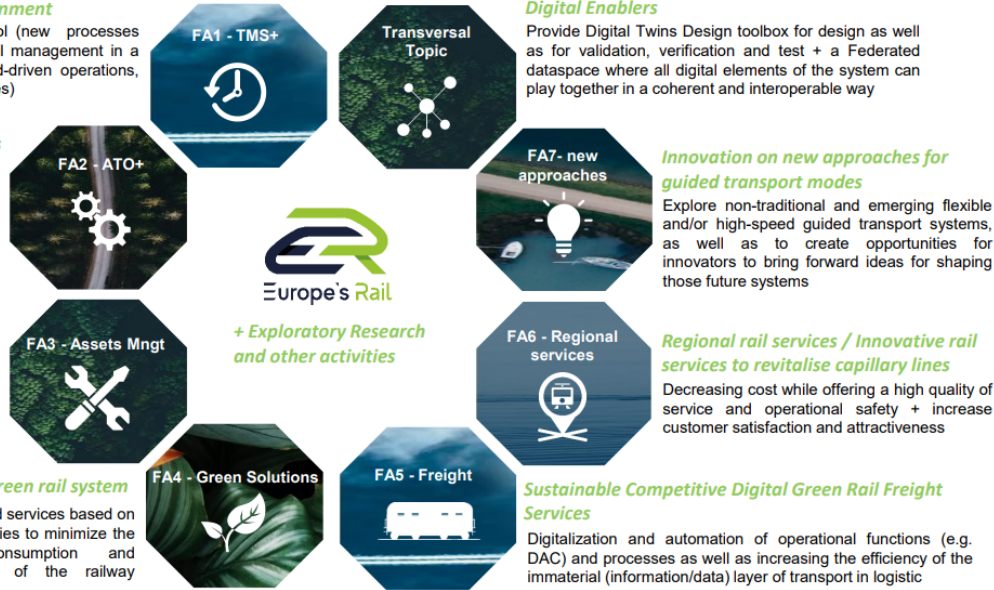
Digital "Automated & Autonomous" Train Operations building upon the next gen Automatic Train Control based on ERTMS + enhancements on TCMS for integration at the on-board level

Intelligent & Integrated asset management

Knowledge from the digital transformation will feed back into the design, construction, manufacturing as well as into operation and maintenance processes.

A sustainable and green rail system

Innovative solutions and services based on leading edge technologies to minimize the overall energy consumption and environmental impact of the railway system



<https://space4rail.esa.int/opportunities/ba-s4r>

E-GNSS IN RAIL SIGNALLING

ROADMAP

EUSPA

EUSPA- FUNDAMENTAL ELEMENTS

INDUSTRY & USER DRIVEN INITIATIVES

EUSPA R&D ACTIVITIES

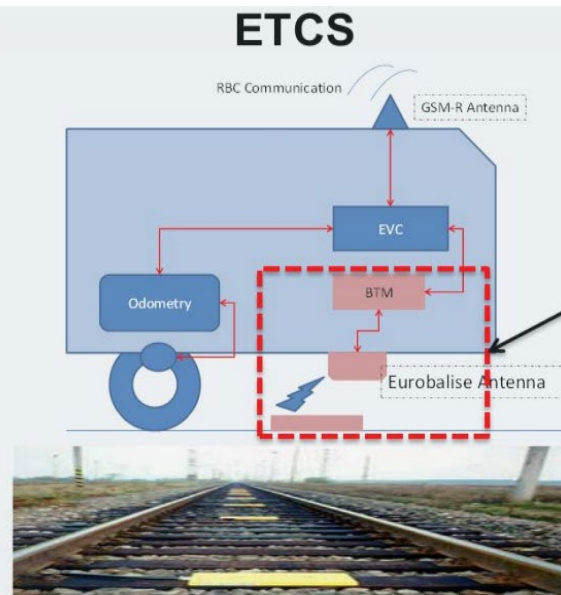
ESA ACTIVITIES

ERA & RAIL STAKEHOLDERS WITH
EXTERNAL EUSPA AND ESA SUPPORT

https://www.euspa.europa.eu/sites/default/files/roadmap_2021.pdf

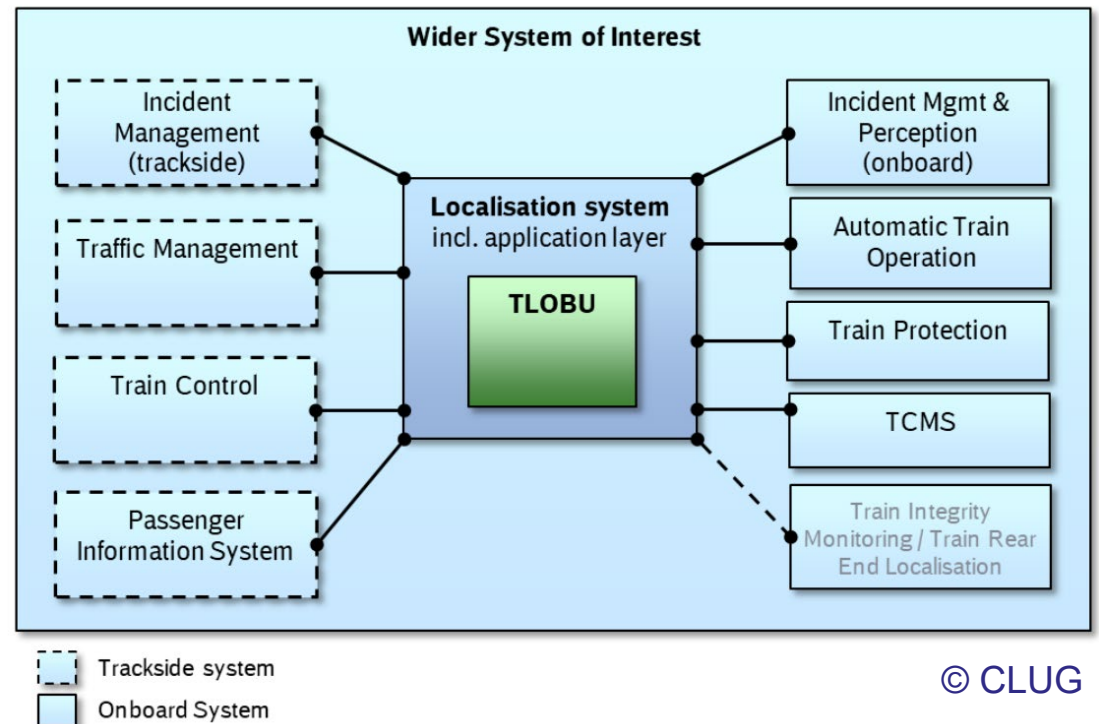
TWO // APPROACHES AND PROGRESSES

The use of GNSS for Virtual Balise



© Hitachi Rail STS 2019

A continuous localisation of the train



© CLUG



**What are the challenges...
...in particular with local effects?**

A 1st LEVEL OF ANSWER: EGNOS, for global errors

Satellite Based augmentation System (SBAS)

→ in Europe : EGNOS

+ More accuracy (correct iono, orbits...)
EGNOS improves the accuracy and reliability of GNSS positioning information

+ Error bounds

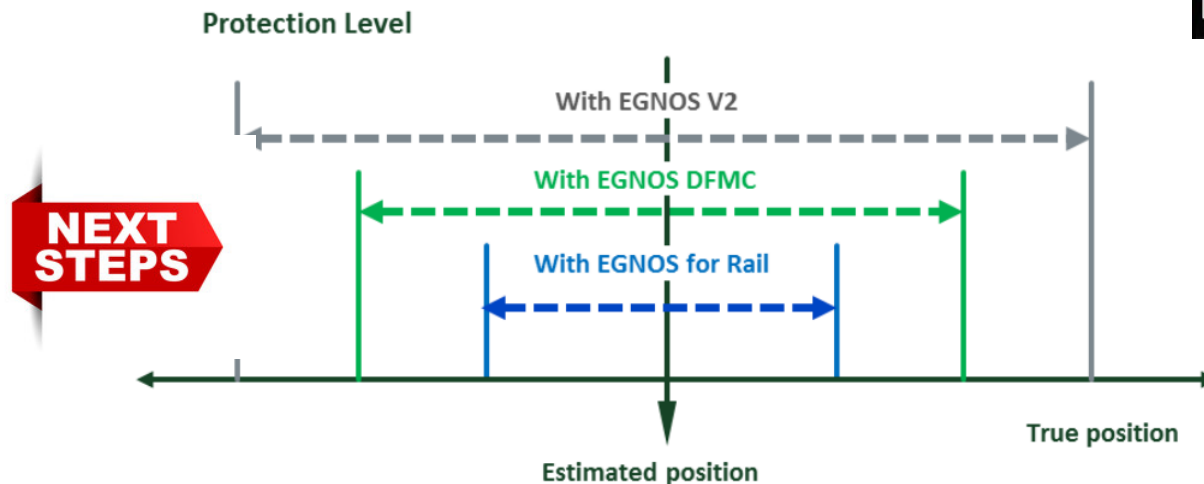
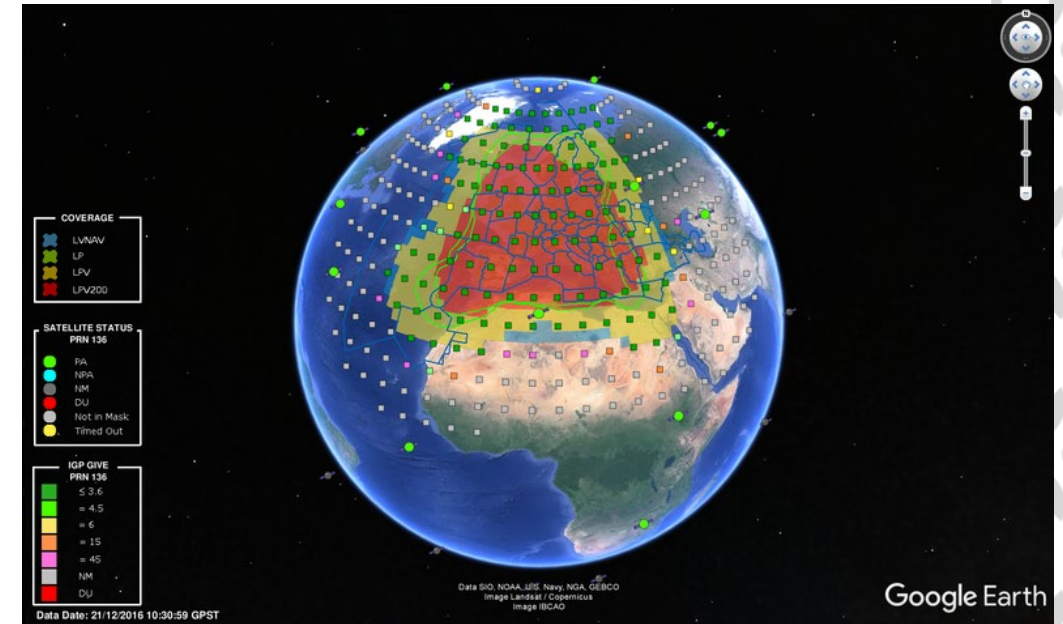


Figure 13: Qualitative train protection levels versus EGNOS versions ©CLUG

A 1st LEVEL OF ANSWER: EGNOS, for global errors

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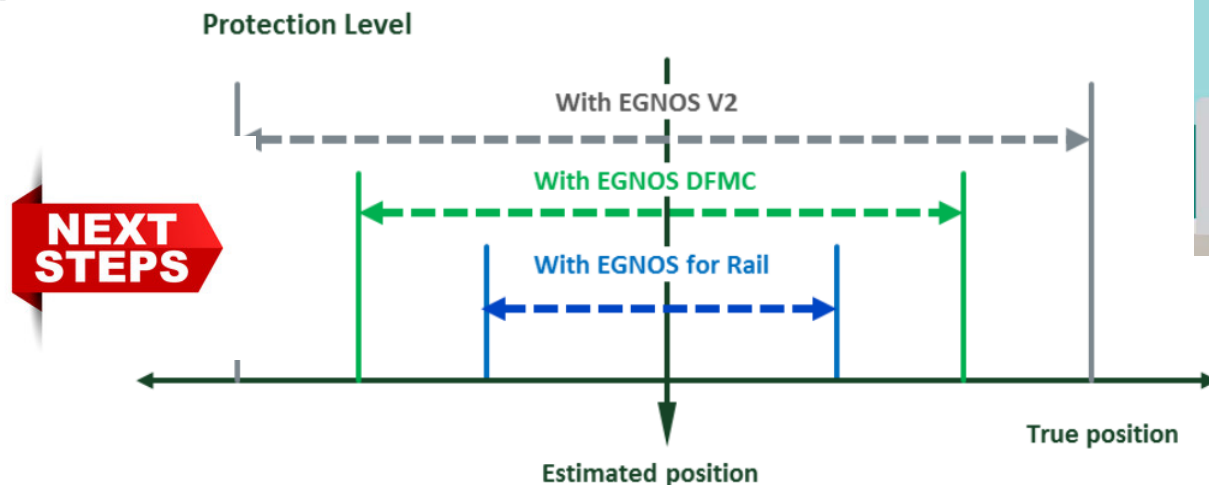
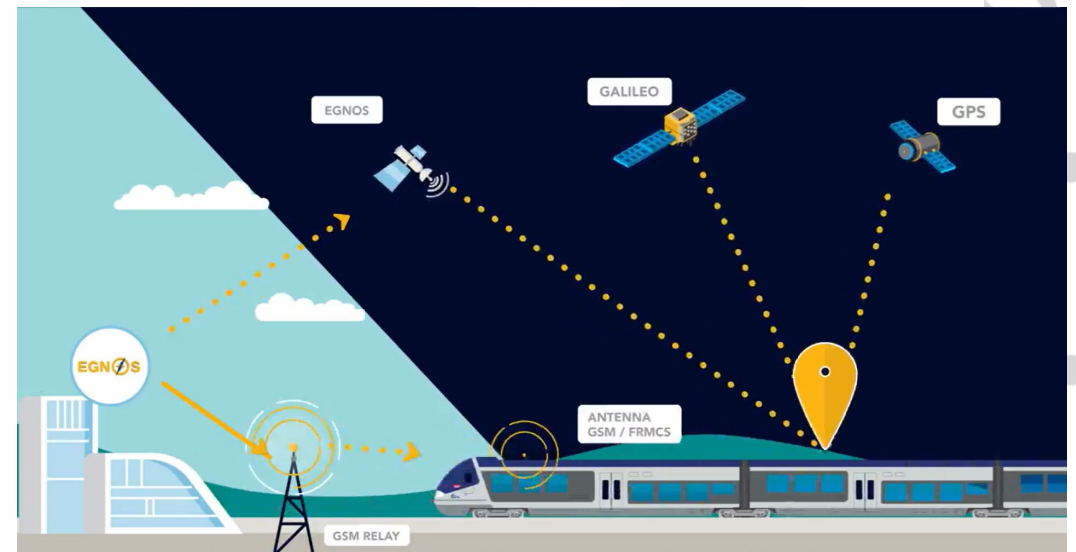


Figure 13: Qualitative train protection levels versus EGNOS versions ©CLUG

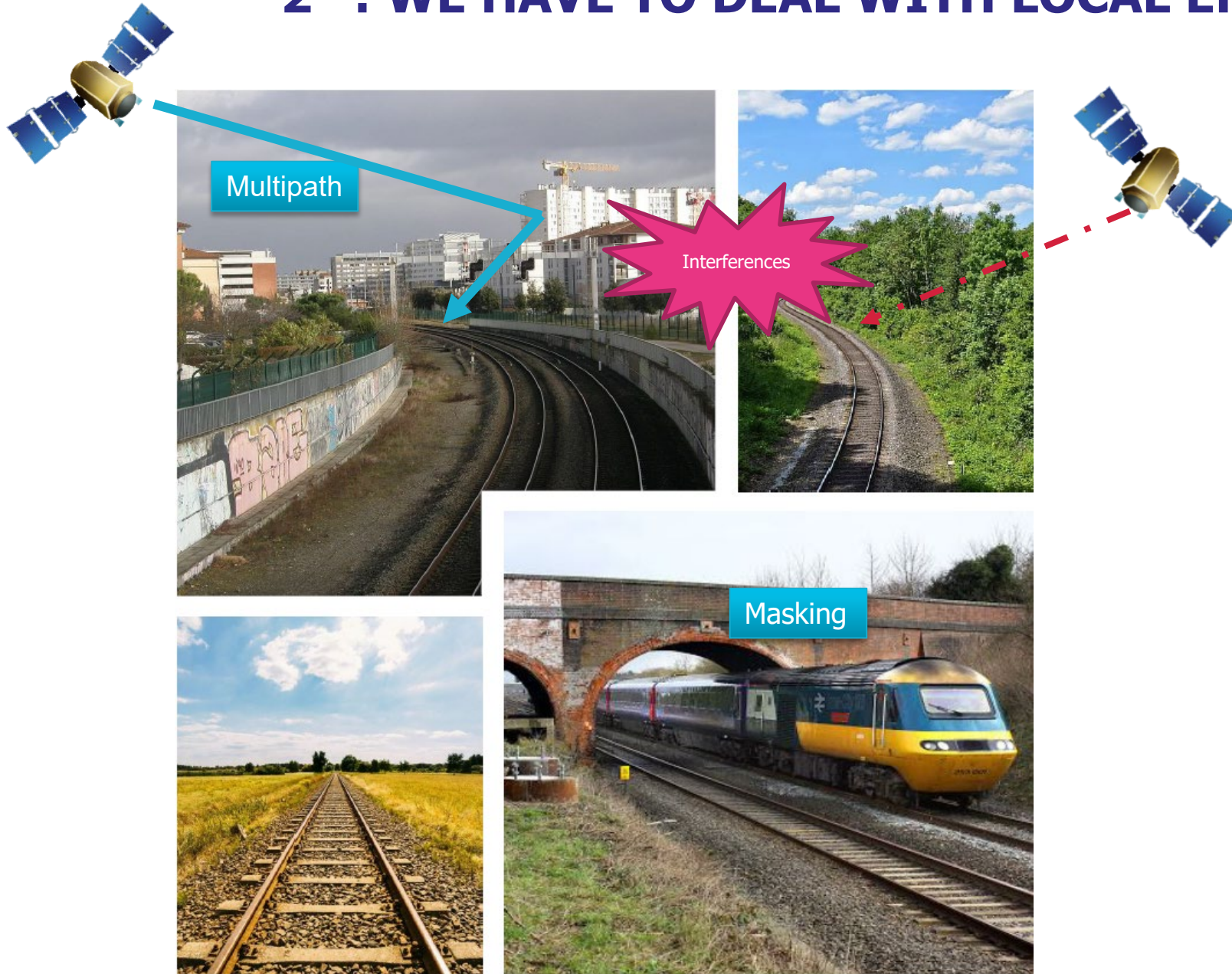
Processing...

Cf. CLUG Recommendation (D3.4)
Cf EGNSS-R project



©EGNSS-R SNCF Airbus

2nd: WE HAVE TO DEAL WITH LOCAL EFFECTS

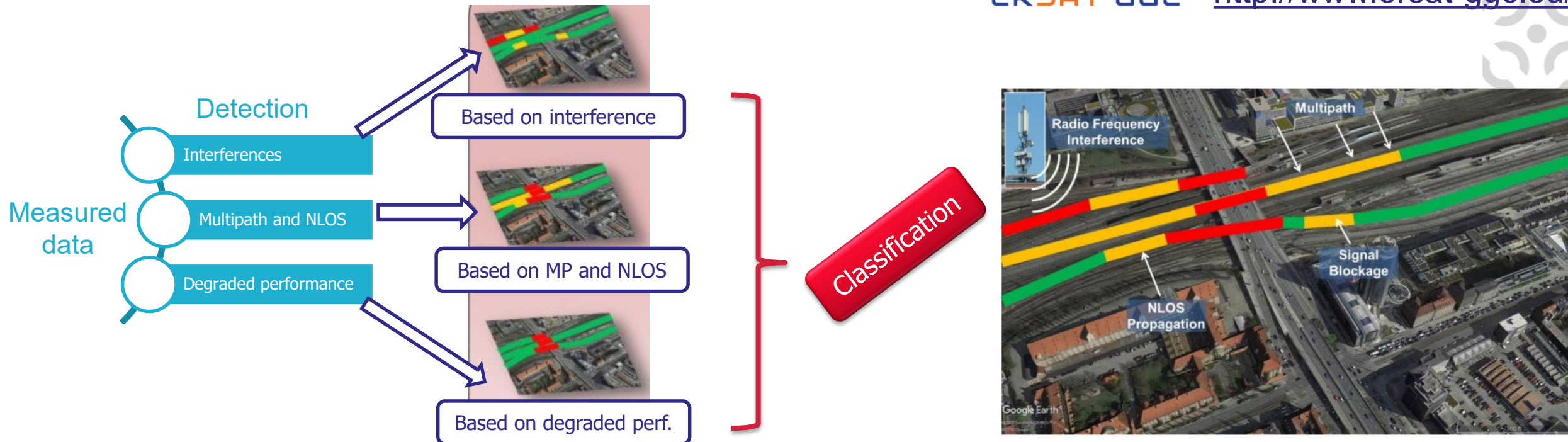


HOW DO WE DEAL WITH LOCAL EFFECTS?

1. IDENTIFY, CHARACTERIZE, MAP, LOCALISE THEM...



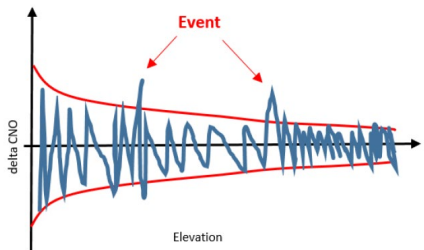
ERSAT GGC <http://www.ersat-ggc.eu/>



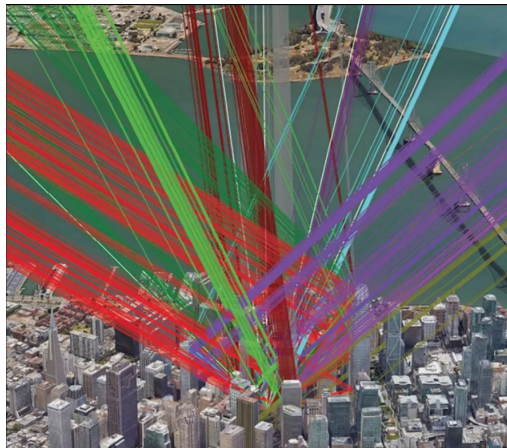
HOW DO WE DEAL WITH LOCAL EFFECTS?

2. MITIGATE MULTIPATH

Multipath and NLOS detection and mitigation is highly investigated!

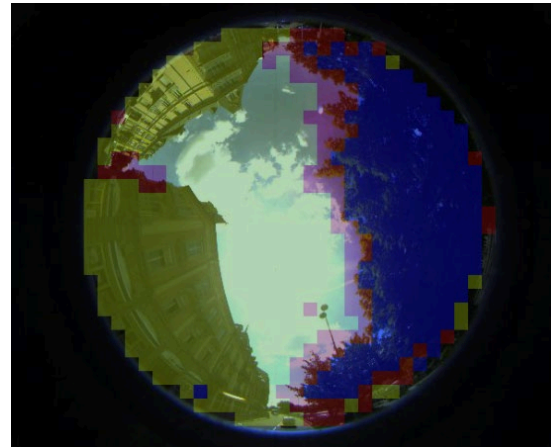


From raw
measurements



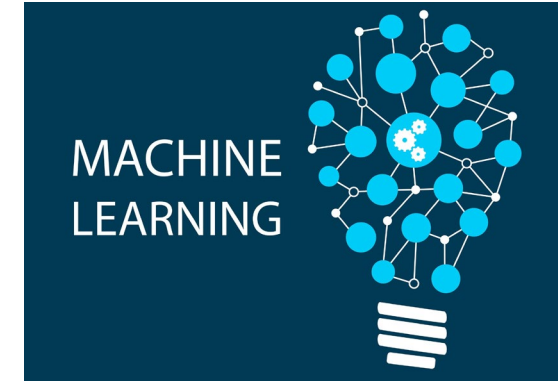
©Frank van Diggelen, Google

With 3D maps



©Cyril Meurie, Uni. Eiffel

With cameras



With ML



With FDE, RAIM

HOW DO WE DEAL WITH LOCAL EFFECTS?

3. HYBRIDIZE WITH OTHER SENSORS



THE CLUG PROJECT

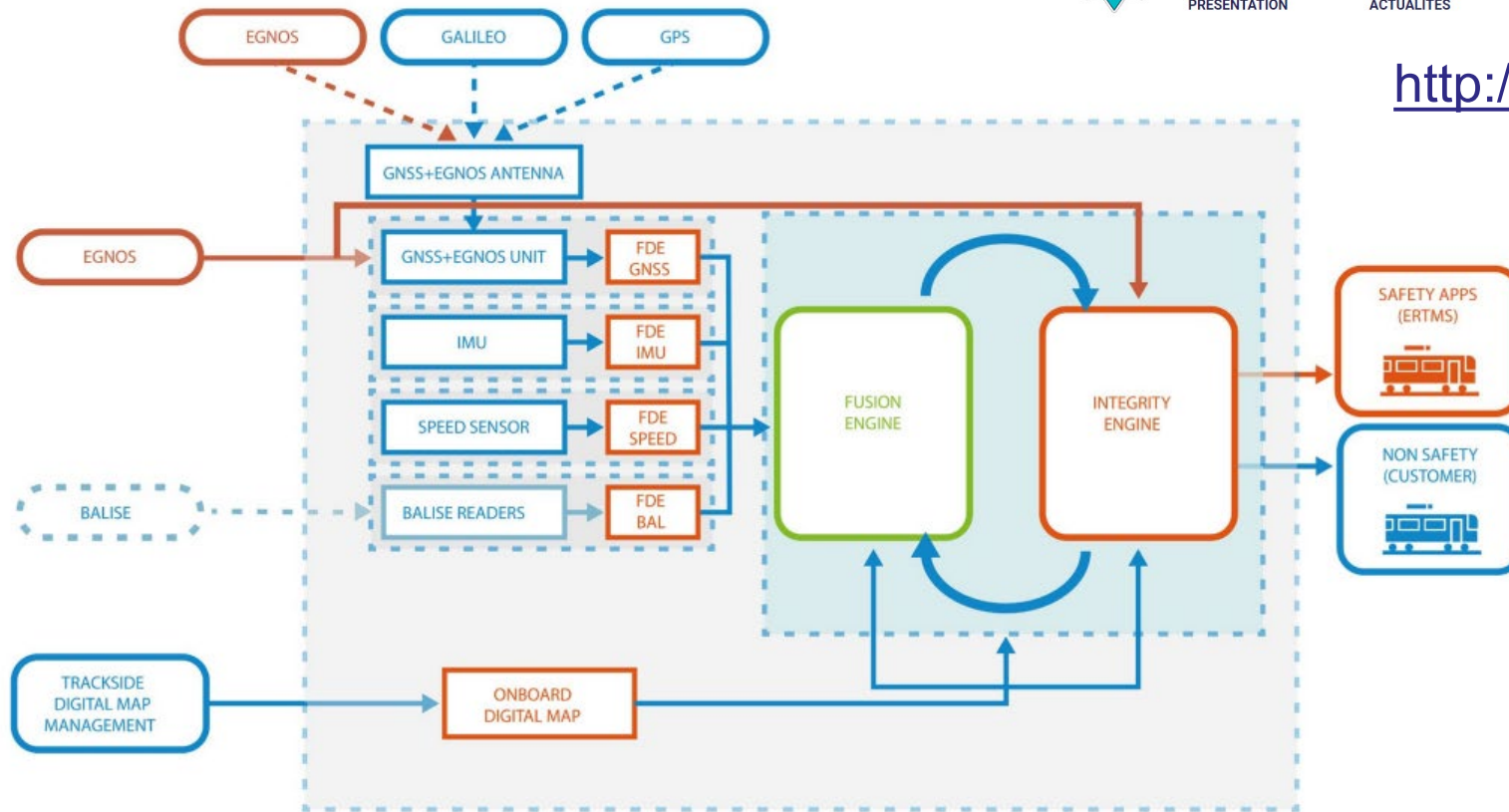
PRÉSENTATION

ACTUALITÉS

PARTENAIRES

LIVRABLES

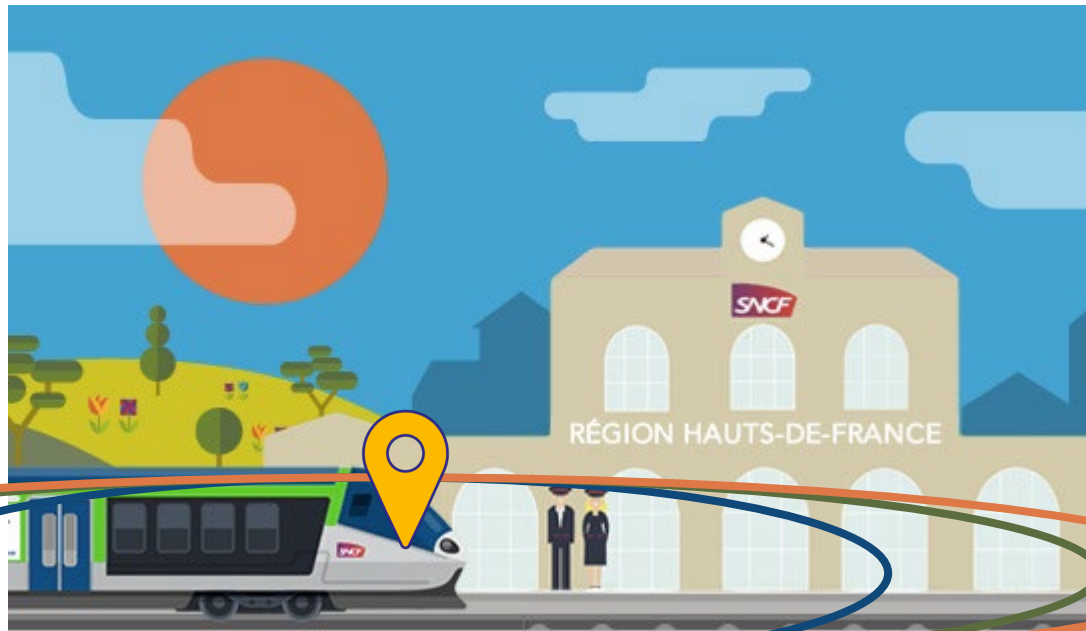
<http://www.clugproject.eu/fr>



* EGNOS v3 DFMC service : EGNOS service on L1/L5 GPS, E1/E5 GALILEO

HOW DO WE DEAL WITH LOCAL EFFECTS?

4. CHARACTERIZE UNCERTAINTY – THE CONCEPT OF INTEGRITY



$RE < PL < AL$



$RE > PL$

Alert limit_(defined)

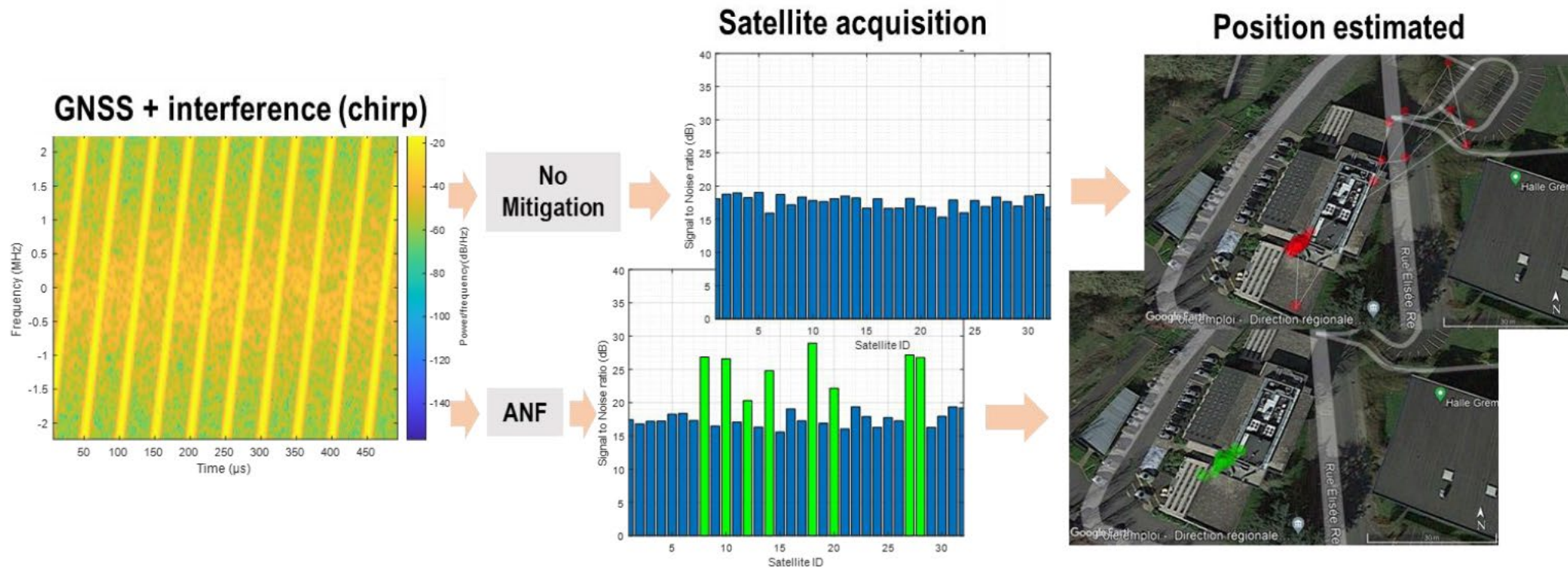
Protection level_(estimated)

(Real) Error_(unknown)

In short: what is difficult?
→ Protection level computation (modelling errors)

HOW DO WE DEAL WITH LOCAL EFFECTS?

5. MITIGATE INTERFERENCES



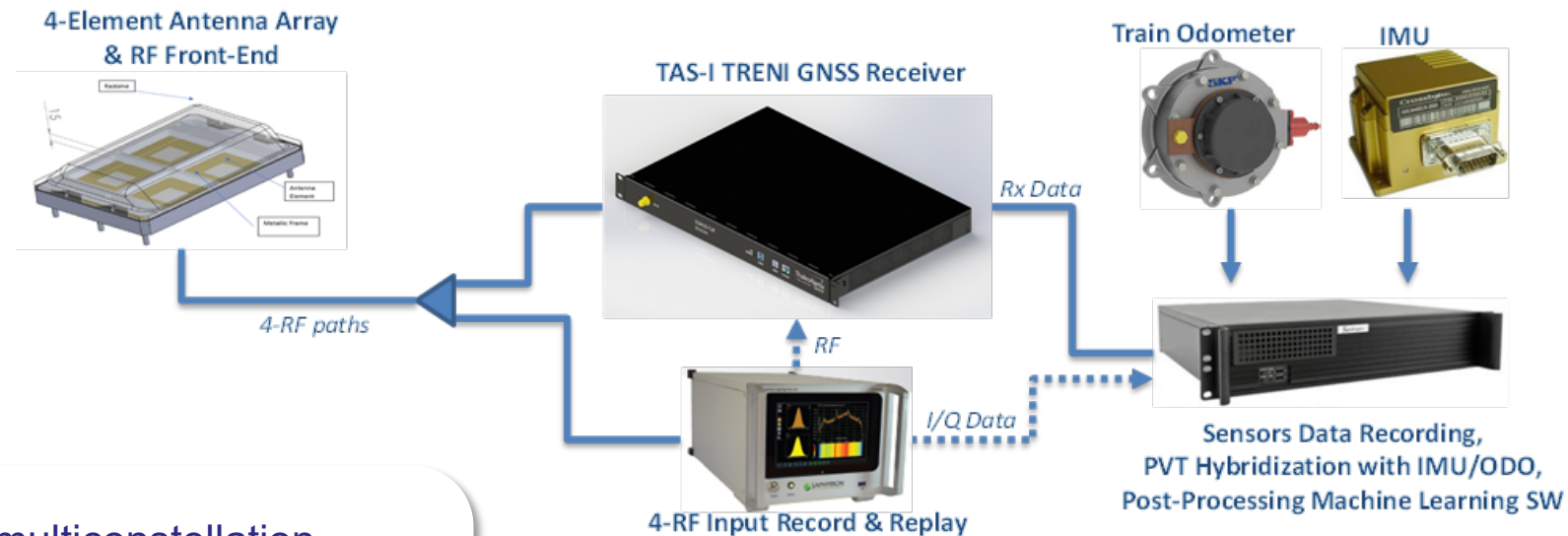
Juliette Marais, Syed Ali Kazim, Zaynab El Mawas, Maan El Badaoui El Najjar, Jeremy Skelton, Contributions to the development of safe and accurate localisation solutions: The LOCSP project, Accepted to TRA 2022, Lisbon

DEVELOPMENT OF A SPECIFIC GNSS RECEIVER FOR RAIL



(Train REceiver for Navigation and Integrity)

A solution at Technology Readiness Level 7 (TRL7) providing PVT that will fulfill the accuracy and robustness requirements of several rail applications.



Multi-frequency, multiconstellation

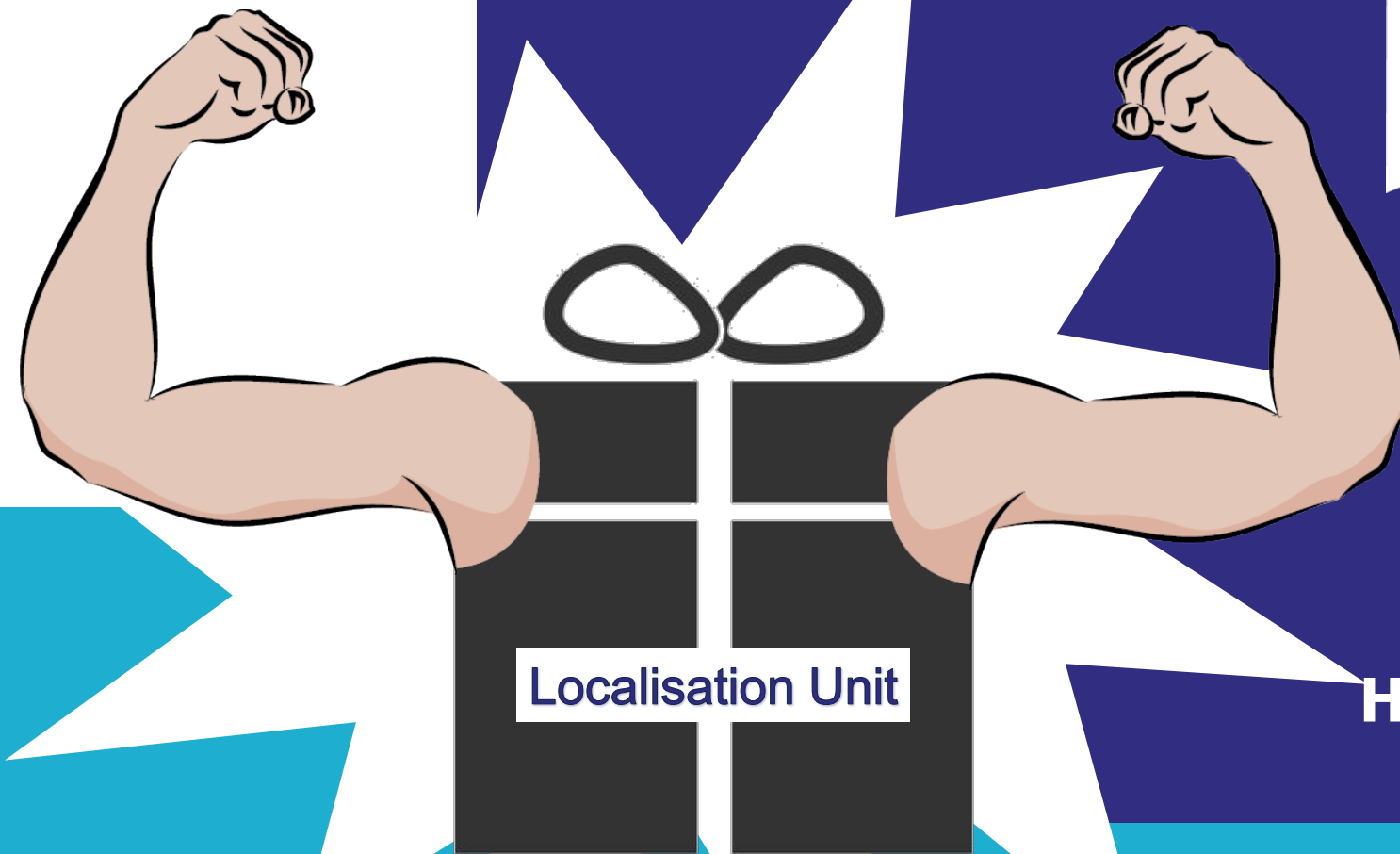


Robust to jamming, spoofing, Multipath



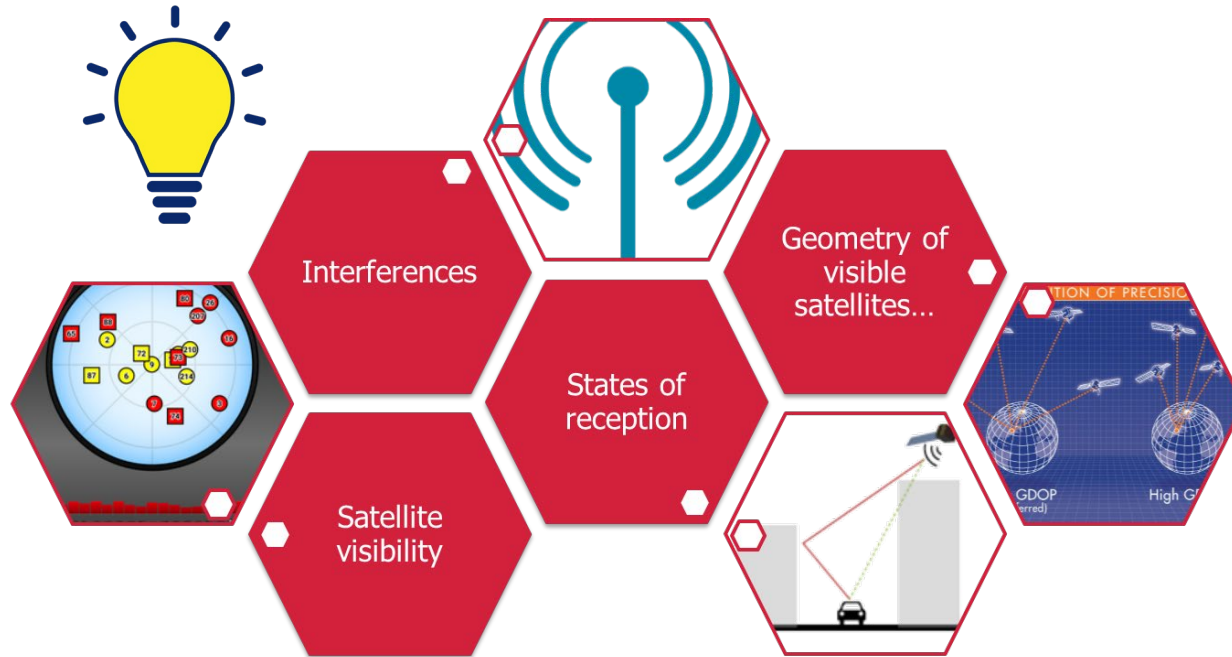
Answering Railway safety standards

<https://www.treniproject.eu/>



**And next?
How to demonstrate?**

WE NEED TO QUANTIFY PERFORMANCE OF NEW SOLUTIONS



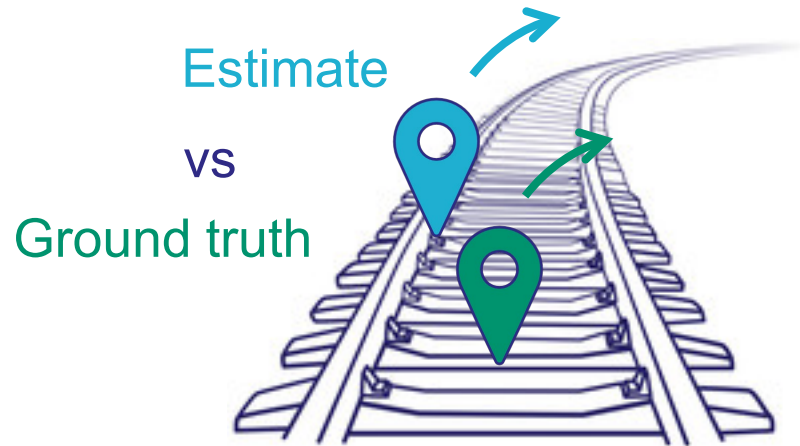
In real life?



QUANTIFY WITH MEASUREMENTS



<https://railgap.eu/>



1. development of innovative and advanced methodology and related tools for designing accurate and reliable references (**i.e. a Ground Truth for position and odometer information such as travelled distance, speed as well as accelerations and heading**)
2. The definition of high integrity and accuracy ground truth and digital trackside map with integrity requirements



Location
dependent



Time
dependent

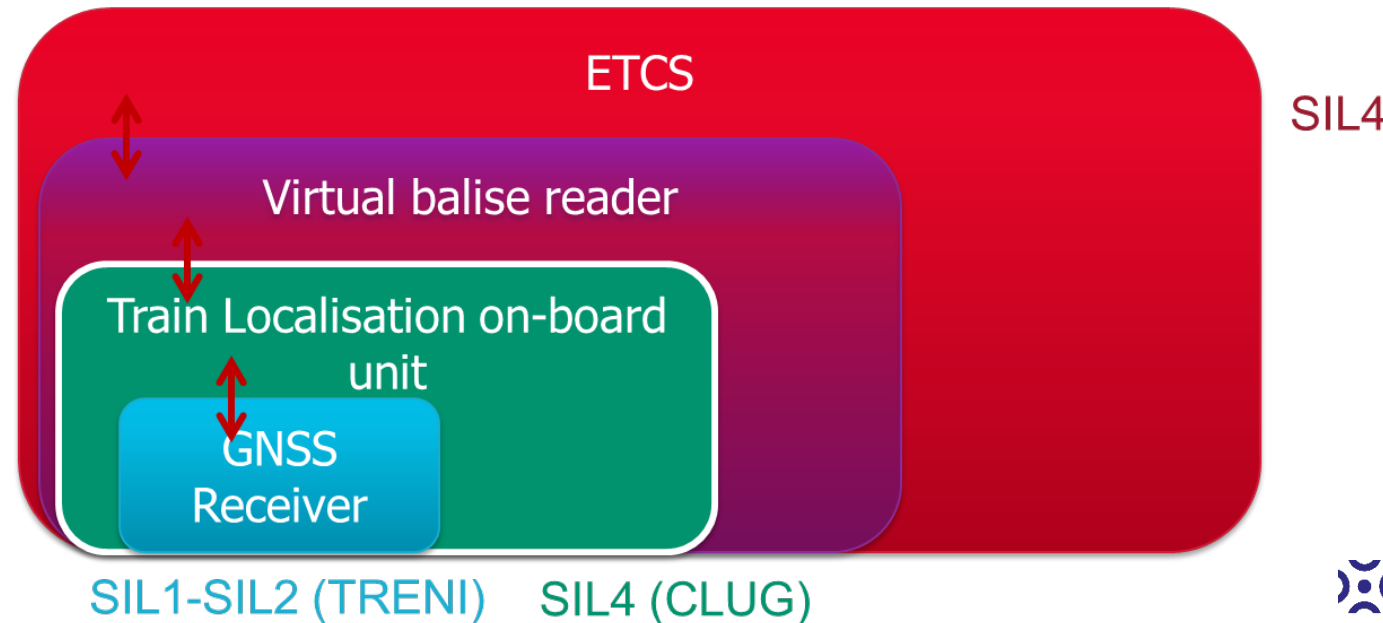
HOW TO CONSIDER GNSS-BASED SOLUTION IN A CERTIFICATION CONTEXT?

“A certifiable product in a railway system suitable for use as a component of a SIL4 system” (CLUG)

There are not yet requirements included in the TSIs for GNSS positioning unit or locator, but there will be in the future (TSI 2027?).

Functional performances and RAMS requirements shall be defined.
Different options:

What will be the module?



CONCLUSIONS

Development of GNSS-based applications

In good progress: Development of solutions that can reach requirements in terms of accuracy, availability, ...safety

Performance
Certification **Safety**
Robustness
detection Fault mitigation
Testbeds
Evaluation
Analysis
Standardization



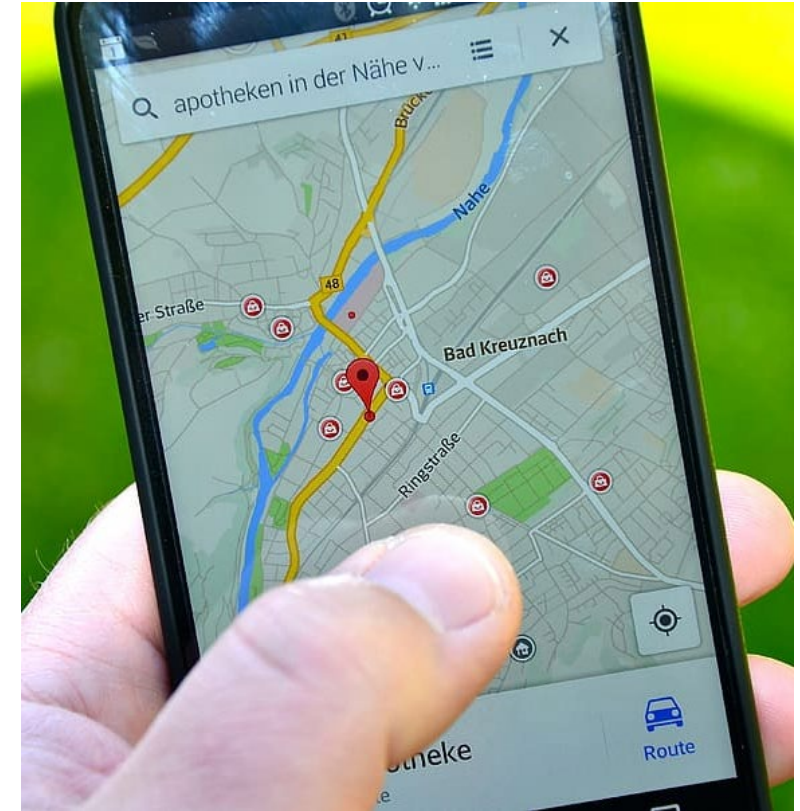
Juliette Marais

juliette.marais@univ-eiffel.fr
Université Gustave Eiffel, Campus de Lille



GNSS Uses & performance

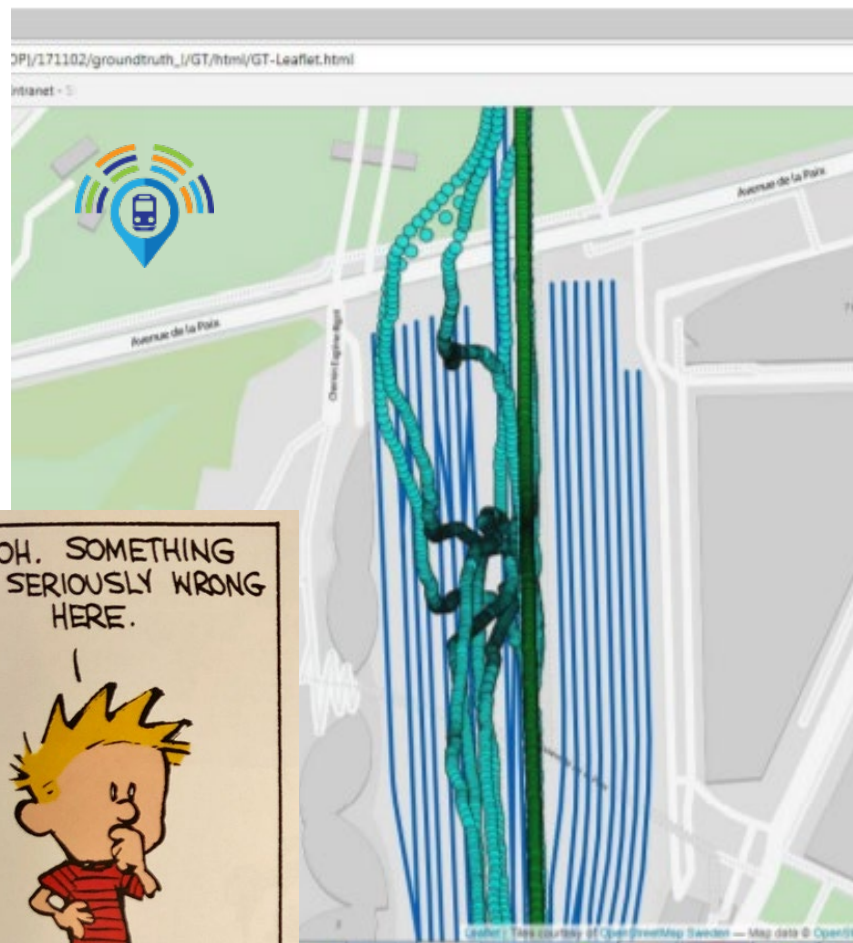
Good! For most of our applications!



And in railway environments?



ACCURACY?



AVAILABILITY?

INTEGRITY?

