INFRABEL

Safety-related data collection and manipulation

politics, methods, and rules at Infrabel

Nicolas Gatez

11-13 June 2025

About myself

ing. Nicolas Gatez

Key Data Scientist Signalling

Data acquisition specialist

Constructions engineer, chartered surveyor

27 years at Infrabel

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Who’s Infrabel

Infrabel is the main Infrastructure Manager of Belgium.

9533 employees

6551 km of main tracks

13000 signals

8300 switches

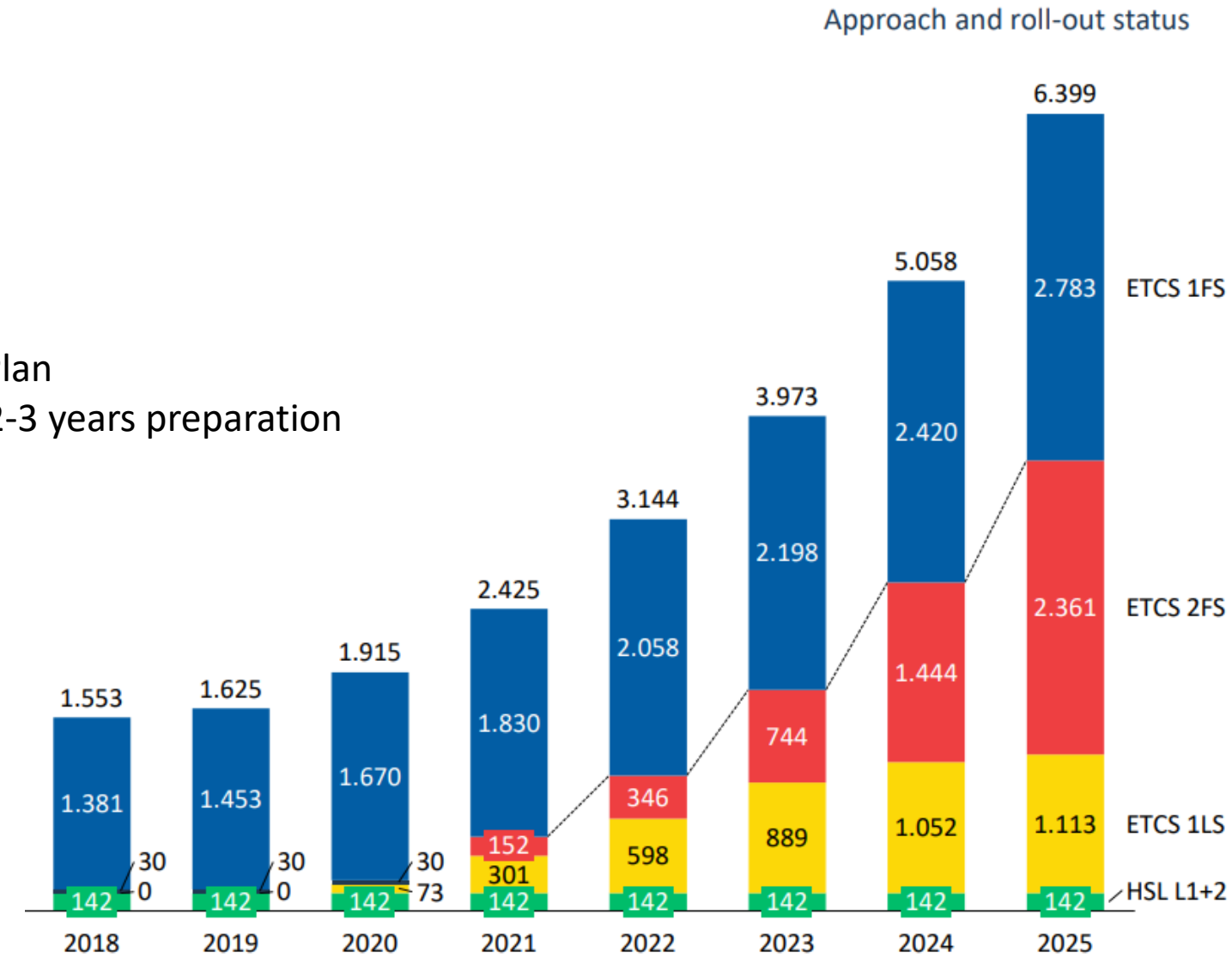
ETCS Deployment

ETCS deployment : motivator

Following a series of deadly accidents,
ETCS expansion was mandated by law,
To cover 99% of the risks for end 2025

ETCS deployment : Roll Out Master Plan

Ambitious Master Plan
Each Project takes 2-3 years preparation



ETCS project : Assessment of the existing situation

ETCS project happens in brown field.

- Missing documentation
- Inaccurate plans
- Situation changed
- …

Measurement needed

Constraints and requirements

Constraints and requirements

SAFETY

SPEED

SCALE

COST

No COTS available : we had to design new processes and tools

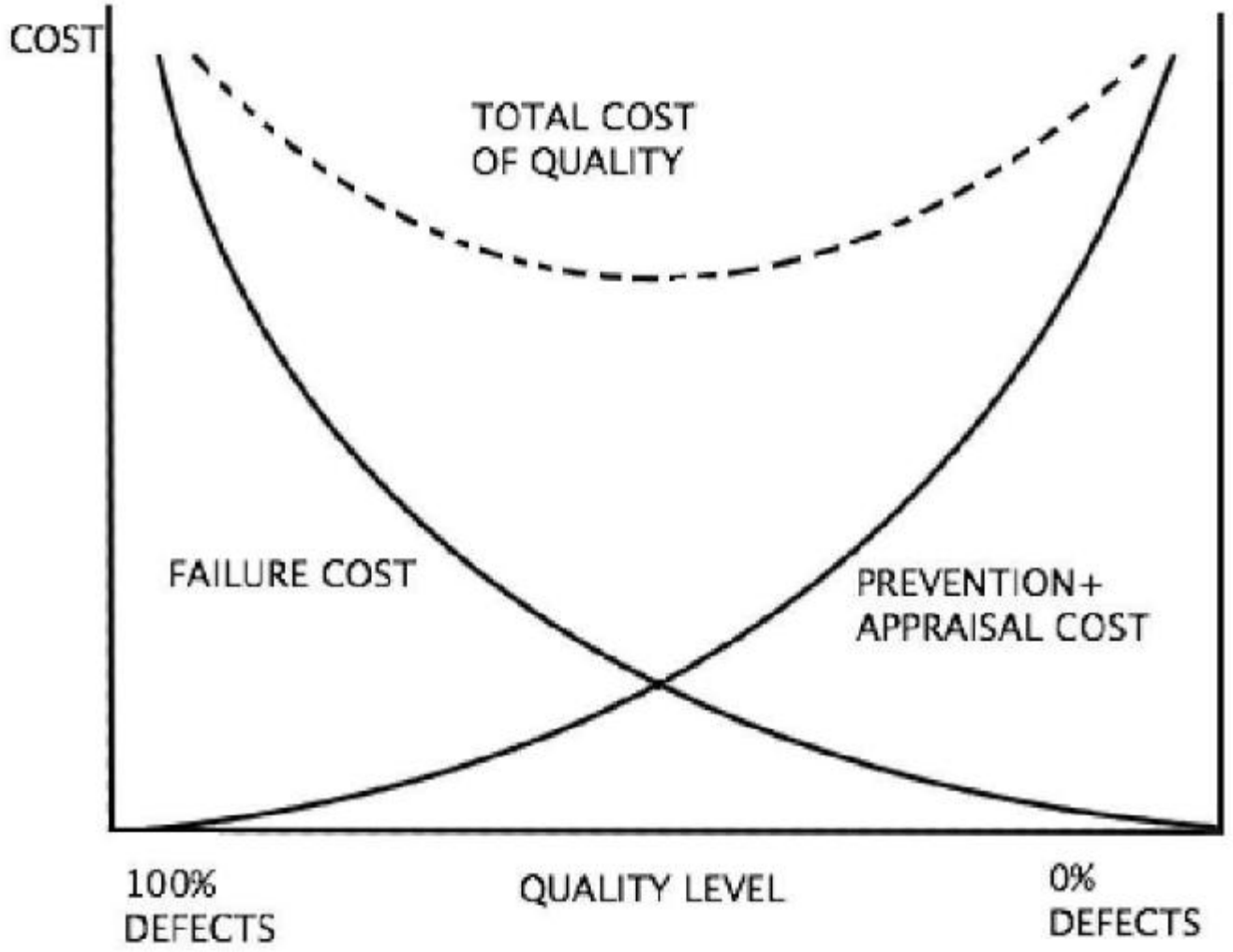
How to measure :

Cost of quality :

The importance of defining your quality goals.

In terms of :

- Accuracy
- Precision
- Completeness
- Timeliness



Cost versus Quality Level according to the PAF Model (adapted from Kazaz et al., 2005)

ETCS critical dependencies

Measure what?

Everything that can impact the braking distances!

- Positions and curvilinear distances between signalling objects.
  - Tolerance ±50 cm
- Gradient of the track.
  - Tolerance ±1 ‰
- Absolute position (X,Y,Z)
  - Tolerance ±1.8m2
- **Undetected error rate : less than 1/100.000.000**

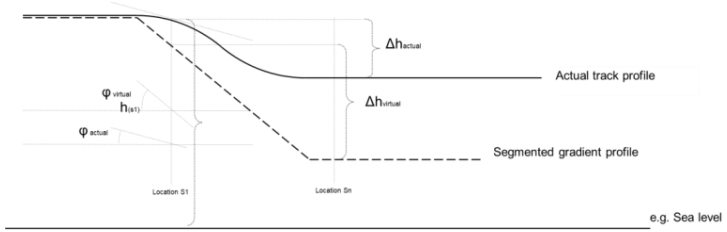


Figure 2: Actual track profile versus segmented gradient profile

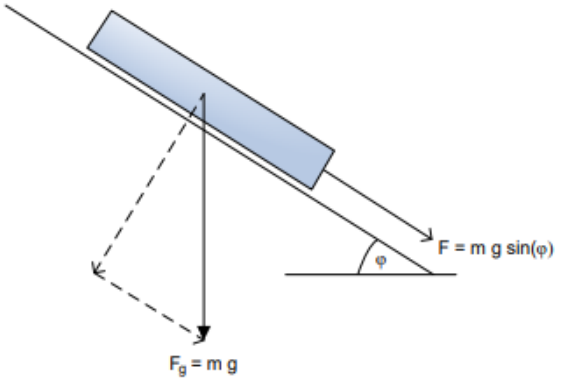


Figure 3: Influence gravity on a train

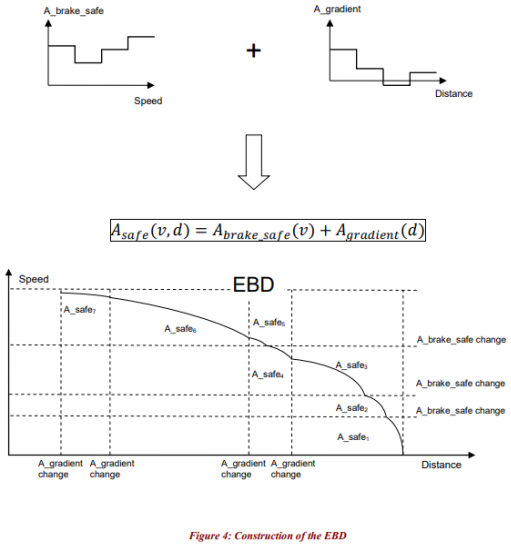


Figure 4: Construction of the EBD

Images : EEIG ERTMS Users Group, ERA

Independent safety assessment (ISA)

belgorail
Railway Certification Body
Notified Body 1615

File: 121005IN
Document: 121005IN_MSR-CMP_RAP-EVAD-ISA-3X 28/09/2021
Assessment plan: 121005IN_MSR-CMP_PLAN-EVA-ISA_5X 11/05/2021
Client: Infrabel Camp-Mesure - Marché TR330389 30/11/2015

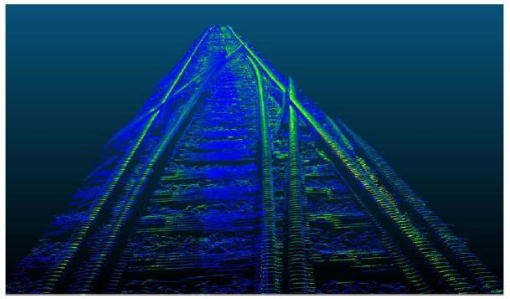
MEASUREMENT CAMPAIGN - GENERIC PROCESS

INDEPENDENT SAFETY ASSESSMENT (ISA)

(121005IN_MSR-CMP)

ASSESSMENT REPORT

☑ **FINAL ASSESSMENT**



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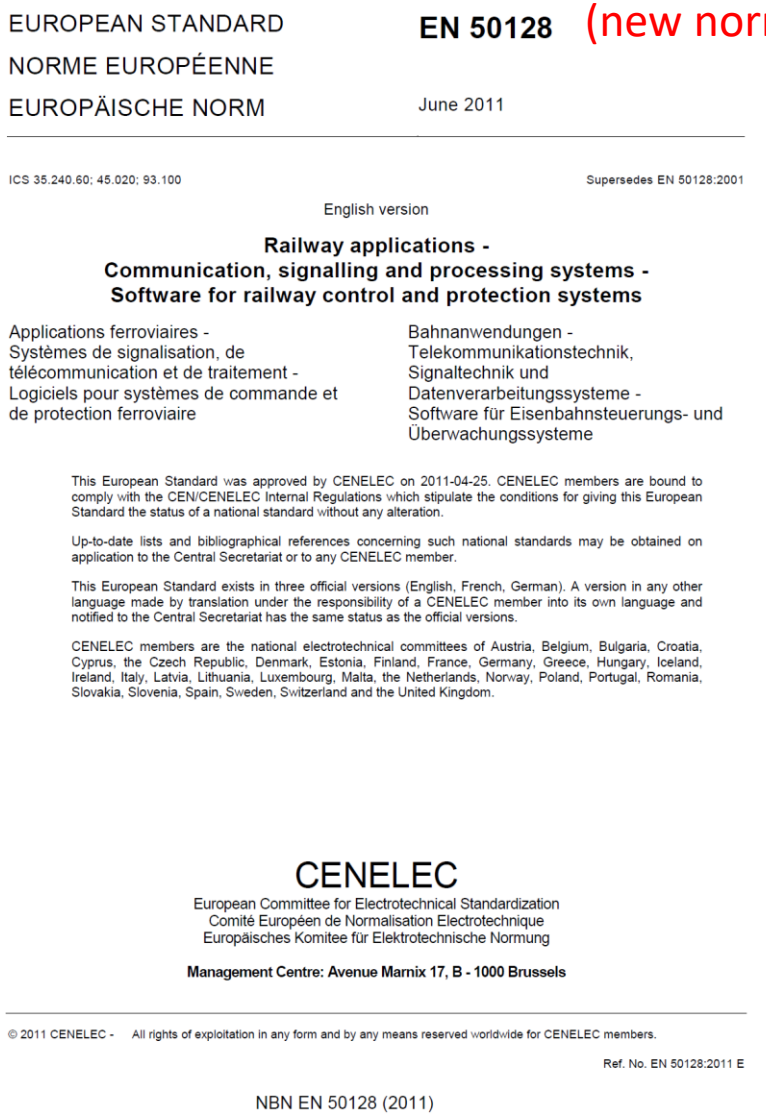
2.2 System under assessment

The object under assessment is the Measurement Campaign Process introduced in § 2.1, which aims at acquiring topographical data to be used for a safe configuration of the CCT components of the Infrabel network.

2.3 Safety requirements

The Measurement Campaign Process shall be SIL 4.

Normative constraints



EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 50128

June 2011

ICS 35.240.60; 45.020; 93.100

Supersedes EN 50128:2001

English version

Railway applications -
Communication, signalling and processing systems -
Software for railway control and protection systems

Applications ferroviaires - Systèmes de signalisation, de télécommunication et de traitement - Logiciels pour systèmes de commande et de protection ferroviaire

Bahnanwendungen - Telekommunikationstechnik, Signaltechnik und Datenverarbeitungssysteme - Software für Eisenbahnsteuerungs- und Überwachungssysteme

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CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

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Comité Européen de Normalisation Electrotechnique
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Management Centre: Avenue Marnix 17, B - 1000 Brussels

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Ref. No. EN 50128:2011 E

NBN EN 50128 (2011)

(new norm 50716 – with unchanged requirements)

measurement tools

f) application data tools that produce or maintain data which are required to define parameters and to instantiate system functions e.g. function parameters,[…],alarm and trip levels, […], geographical layout.

DB

gradients, distances between objects,…

tool class T3

generates outputs which can directly or indirectly contribute to the executable code (including data) of the safety related system.

Normative constraints

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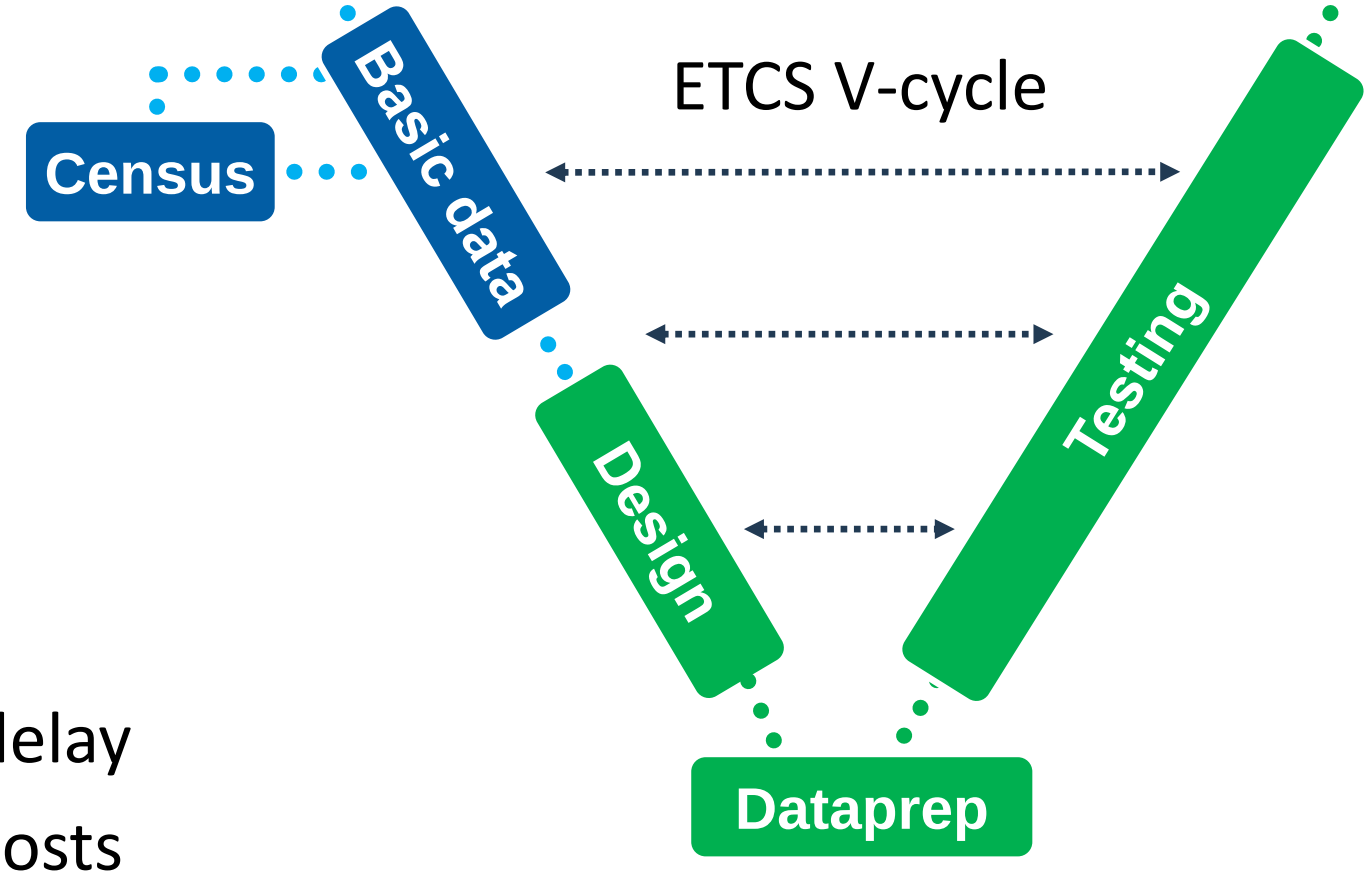
NBN EN 50128 (2011)

geographical data

The objective for the development of application data is the correct deriving of the data from the given installation and the check of the intended behaviour, followed by an assessment of the used development process for that application data

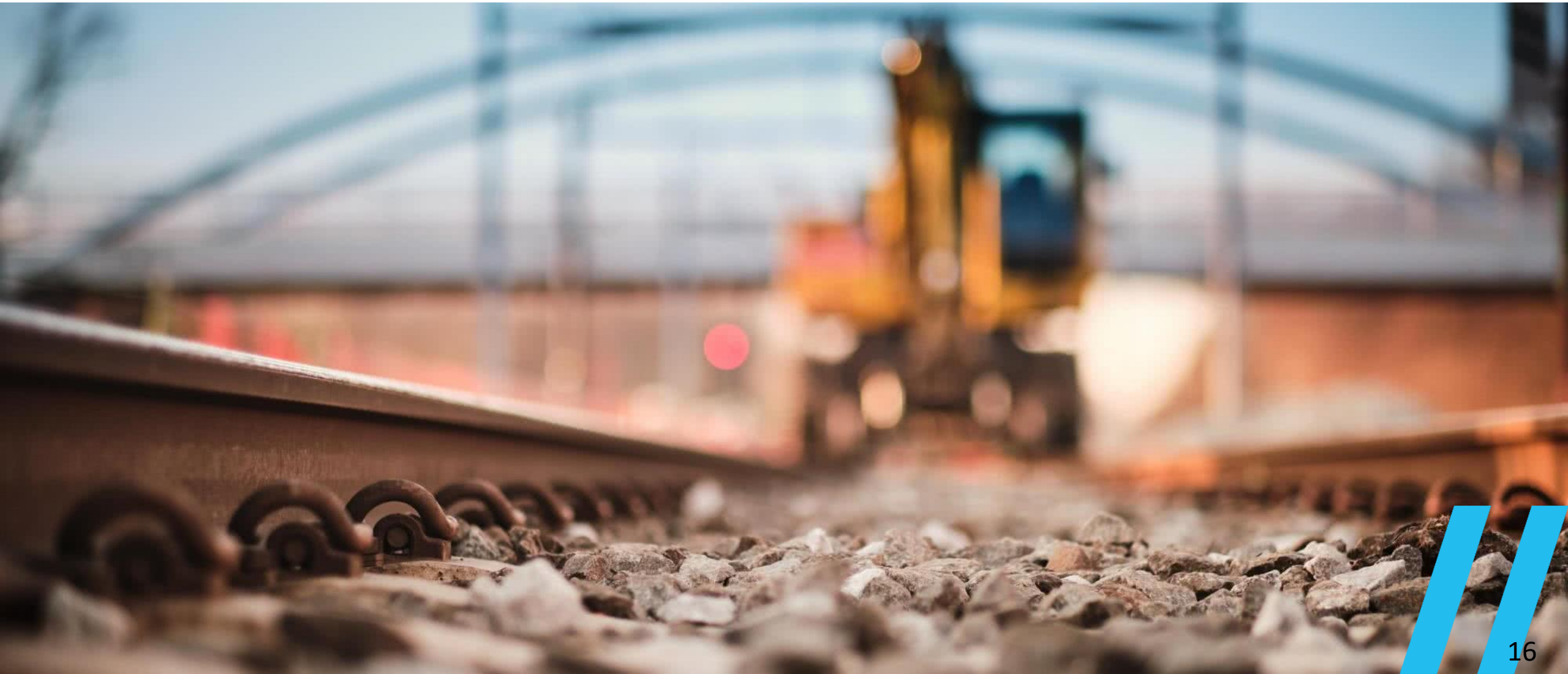
measurement campaign process

Continuously validate data during the project



- Avoid delay
- Avoid costs

Our data acquisition tools



Most important : People

Dedicated team

- 4 Engineers
- 4-6 Operators
- 2 Surveyors (part time subcontractors)

Support :

Safety, quality, drivers, mechanics, …


GEISMAR
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Right On Track
ETCS
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EXT 2
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Sensors

1 INS-GNSS

2 DMI

3 Profil (2D lidar)

4 Left + right + center: Topographic cameras

5 '3D' lidar

6 link to OBMT

Fast, inserts in traffic, mass acquisition. Great for main lines

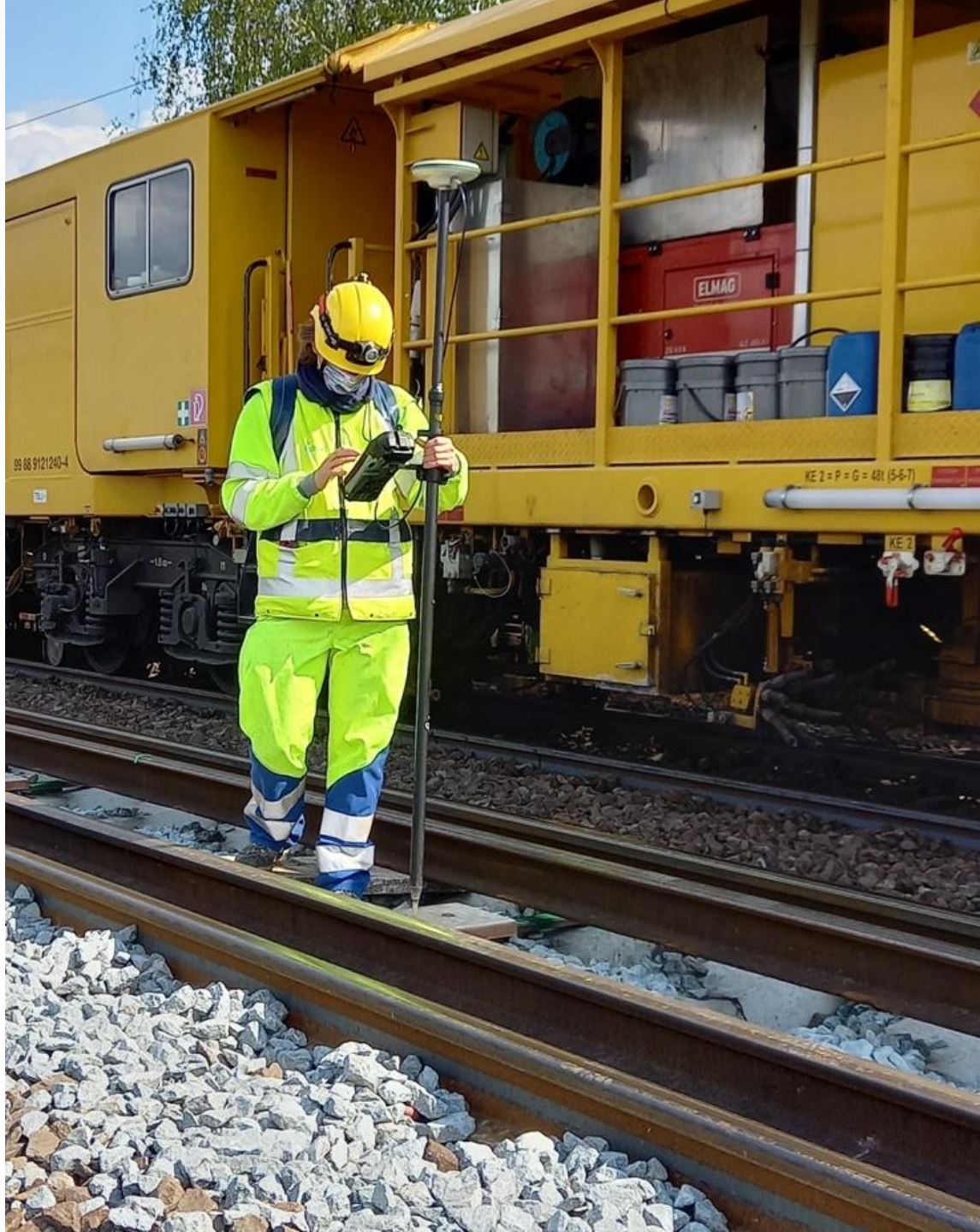
Depends on free tracks, Not great in yards (shunting process)

Handheld GNSS

- measure known points before/ after
- issues at borders and with config RTK

Very accurate, independent from shunting

Slow, needs protection



Measurement wheel

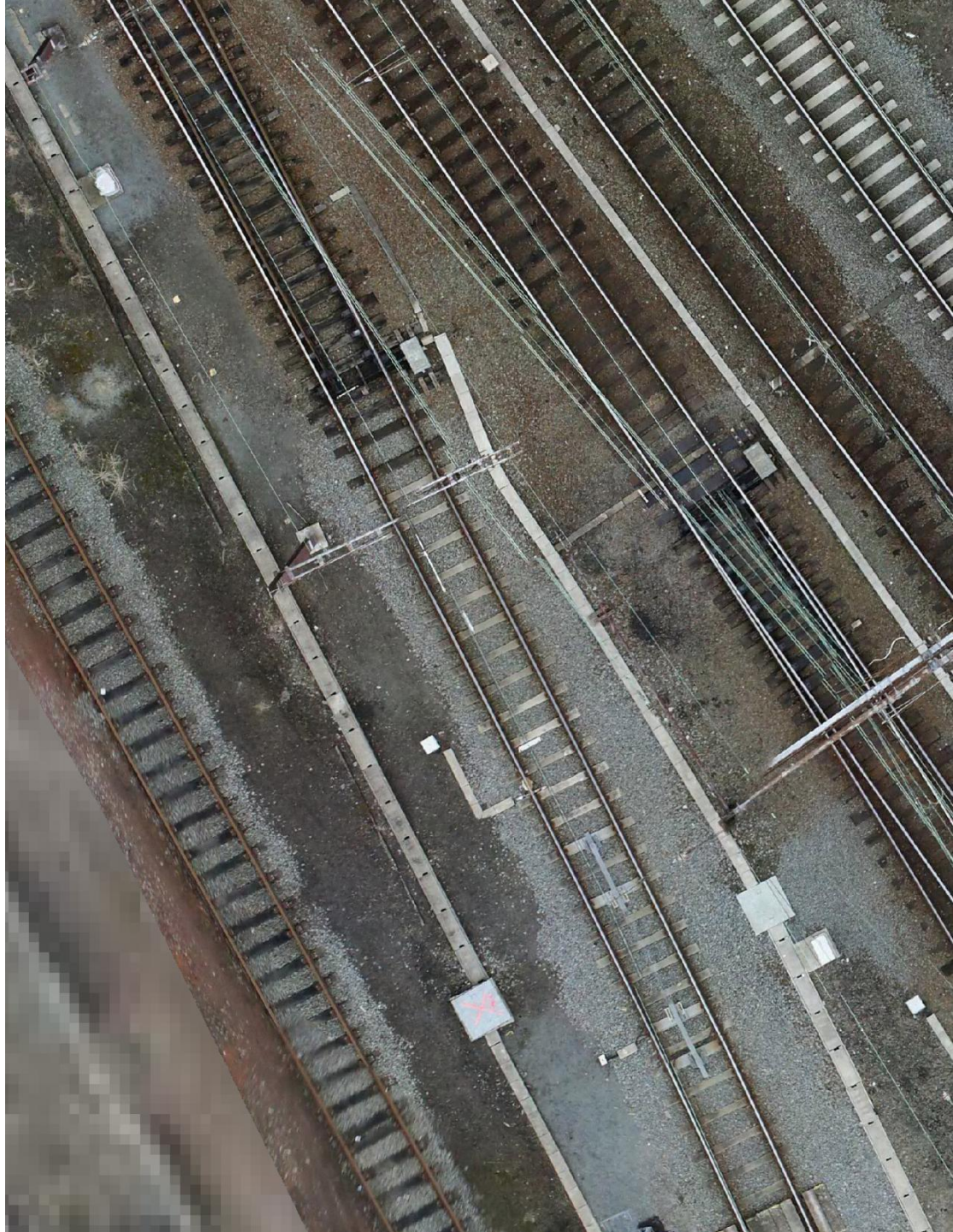
- measure each rail
- max difference on site: 1m
- max distance: 250m

Light, cheap, minimal formation needed

Slow, short range, not very accurate,
only measure lengths, needs protection

Orthorectified aerial images

- not all information possible (panel values, slopes, …)
- Only ground level information usable
- even internal sources often unreliable – unprecise data processing or zoom level issues
- Google Earth and similar – not approved

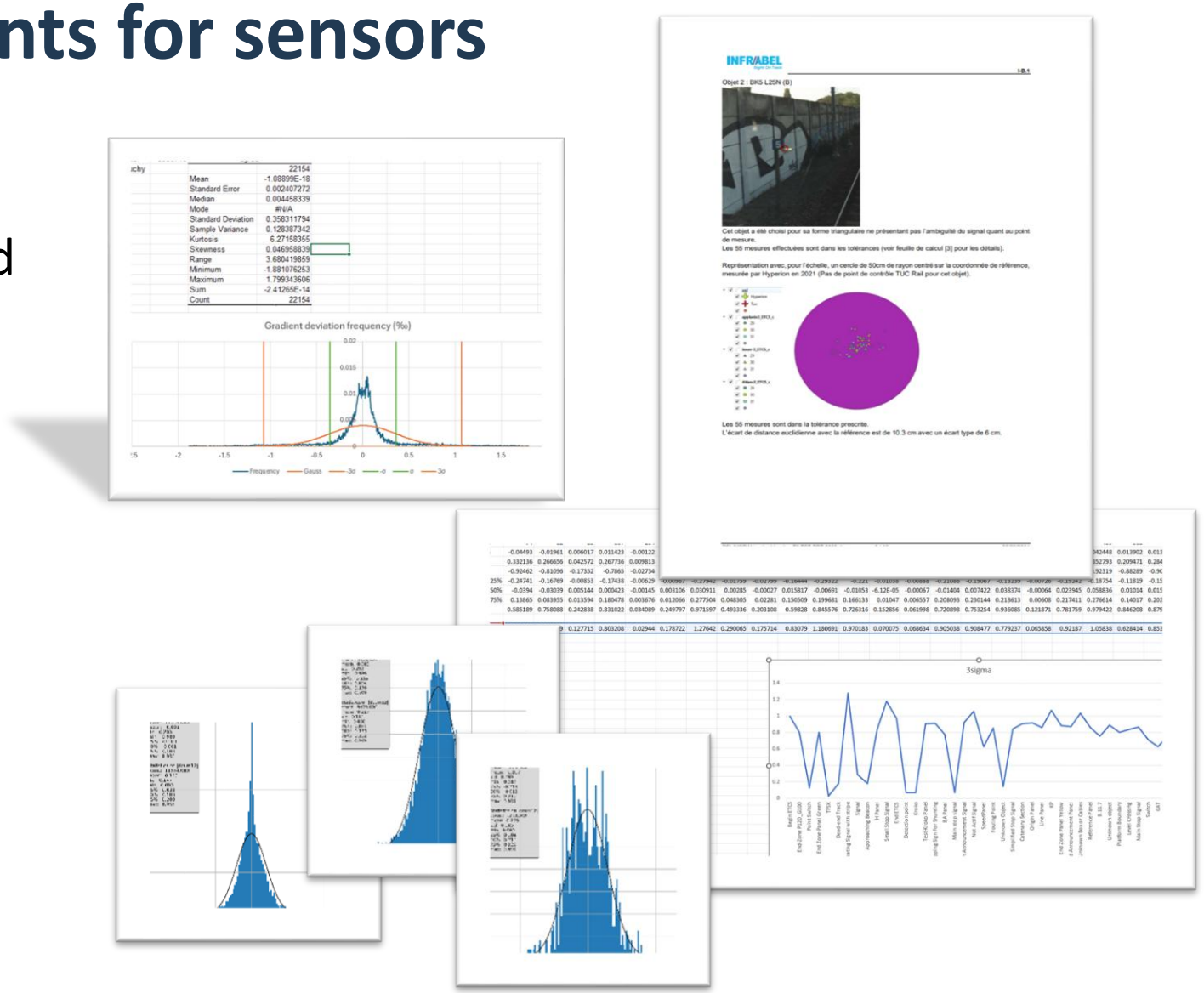


Accuracy Assessments for sensors

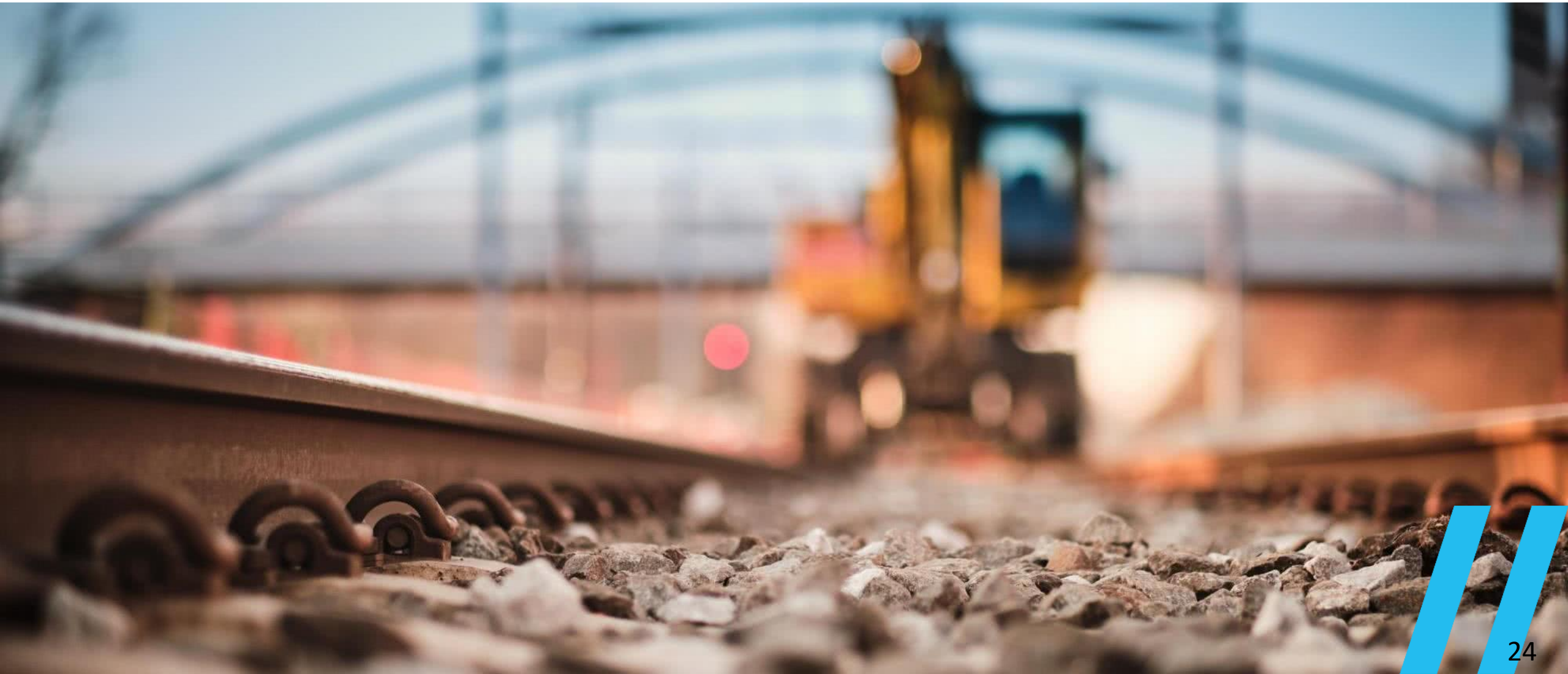
Each sensor’s accuracy is carefully assessed and verified on a regular basis

This includes :

- Sensor itself
- Human aspects
- Data manipulation
- Manual measurements on those data

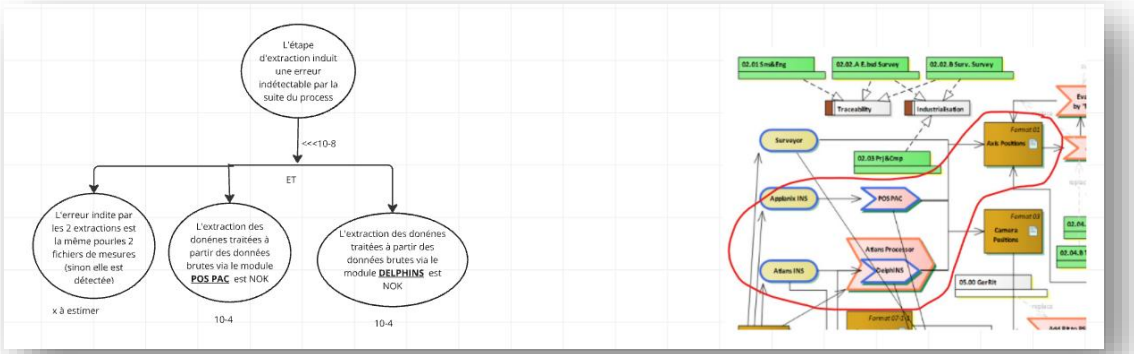


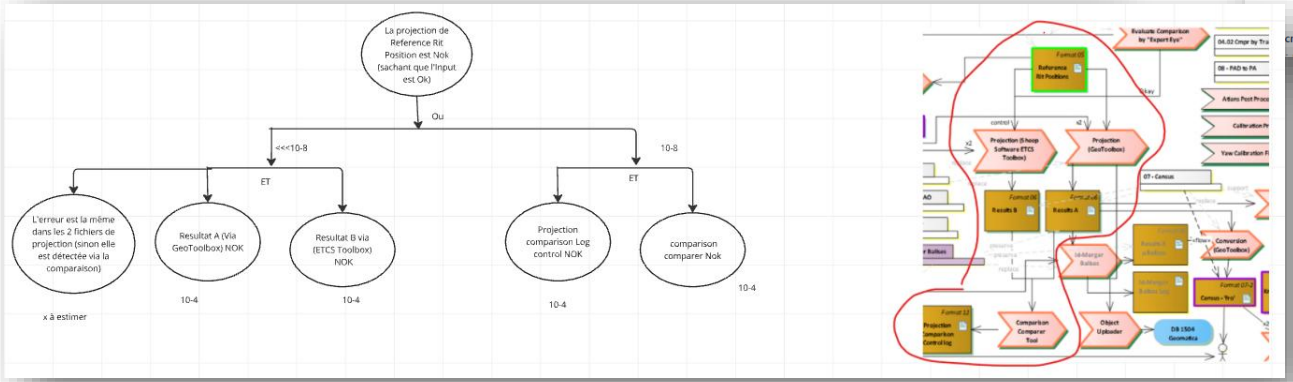
Processes

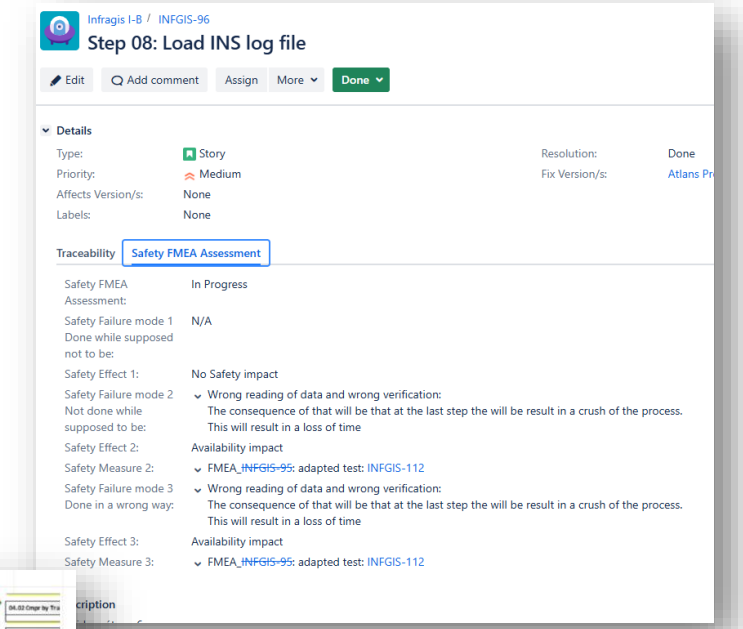


Process design : Risk assessment

FMEA and risk quantification for each step







Goal : undetected error rate < 10^{-8}.

Introduction of risk mitigation measures where needed.

Aiming for a 10^{-4} Human failure rate

Key factors :

- No time pressure
- Well trained operators
- Well documented operations and procedures
- Easy to use tools ("job aids"), alerts, ...
- Good and structured communication

Generic tasks

Title	Description	HEP	References
0. Human performance limit	Highest obtainable reliability (minimal error rates).	1E-4 (single) 1E-5 (team)	(Kirwan 1994)
1. Simple routine	Simple, familiar and frequent task skill-based or rule-based, for which procedures are available	4E-4 (0.00014-0.0009)	HEART, (Hickling 2007)
2.Nontrivial familiar	Familiar, relatively frequent task, requiring knowledge-based performance and judgment. (Normal tasks involving a deviation from planned operations.)	1.6E-2 (0.012-0.028)	HEART, (Hickling 2007)
3. Communication, routine	Familiar content routinely conveyed, and where at least a limited template for communication is available, and error capture and correction is possible.	6 E-3	(Kirwan et al. 2004;Kirwan & Gibson 2007)
4. Communication, nonroutine	Unforeseen, novel content, where no template – or only a rudimentary one – is available.	3 E-2	(Kirwan 1994)
5. Emergency scenarios - known	Task characterized by some urgency and stress due to safety or production concerns, for which a plan of action (a template, a script) and relevant information are available.	1 E-1	(Kirwan 1994)
6. Emergency scenarios -	Task characterized by high degree of urgency and stress due to safety or production concerns, where no adequate plan	3E-1	(Kirwan 1994)

Performance Shaping Factors

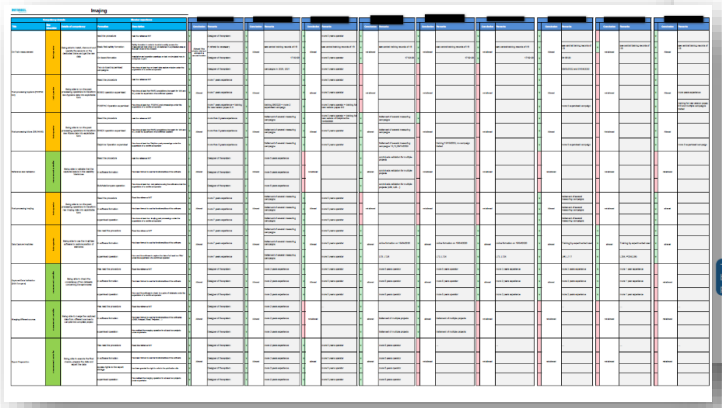
Titel	Explanation	Multiplier	References	Caution for 'double counting' *Tasks, PSFs*
1. Supervision	Having a supervisor who monitors or who is in the background or on call will generally improve reliability and thus reduce the error rate.	0.5	(Dickinson & Lowe 2007;Weber 1992)	
2. Job aids	Different types of aids or tools will support the operator and reduce the error rate. E.g. a checklist to support memory; alarm to direct attention; a fixed format for communication may reduce omissions or misunderstandings	0.1	(Cullen et al 2004)	3;5
3. Task competition	Error rates increase when an operator must perform more than one task at the same time, e.g. when being distracted by other tasks and thus forced to prioritize	6	(Cullen et al 2004)	PSF 4
4. Time pressure	Error rates increase when operator is under time pressure	11	(Williams 1986)	5;6; PSF 3

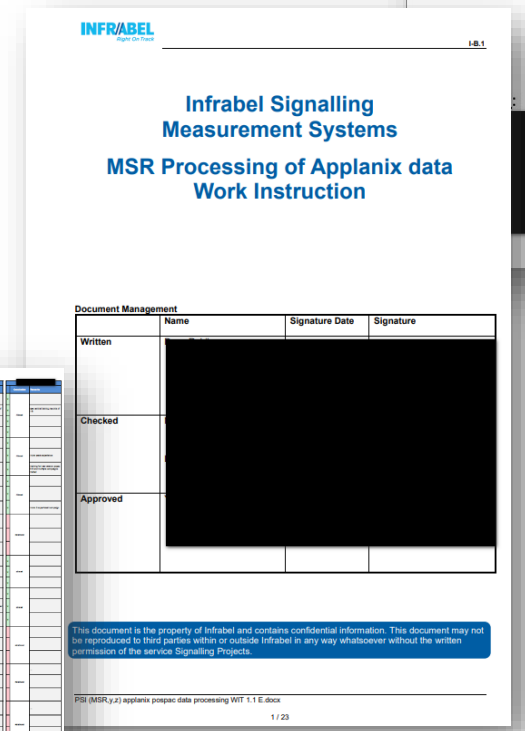
source : Human Error Probabilites (HEPs) for generic tasks and Performance Shaping Factors (PSFs) selected for railway operations

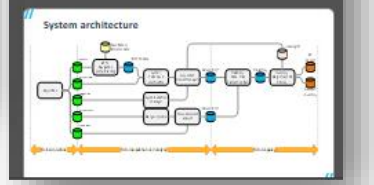
By Jacob Thommesen, Henning Boje Andersen

Operators continuous training

- Well documented process
- Prepare didactical material.
- Prepare work instructions.
- Continuously inform them for procedural changes.
- Maintain competency matrices.





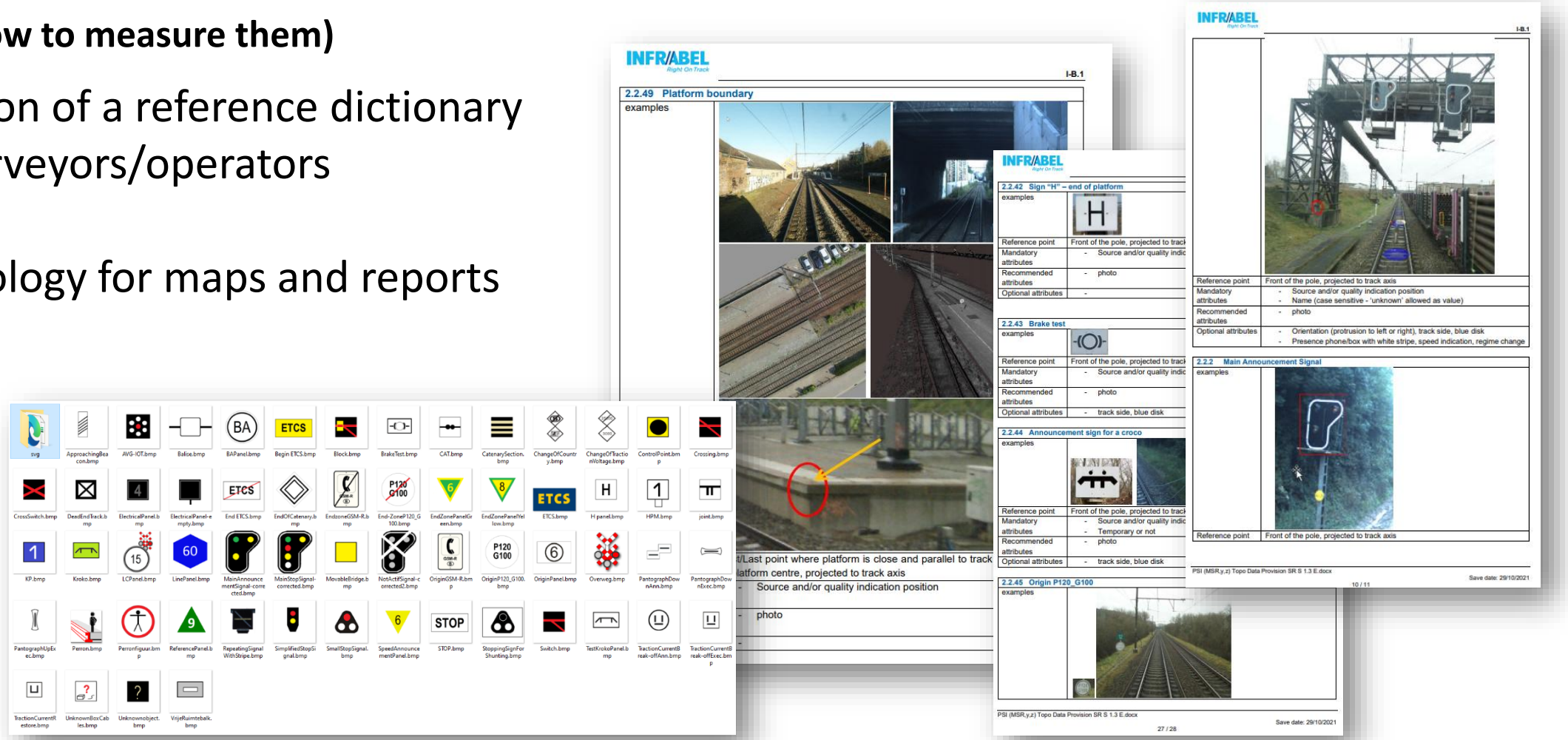


Unambiguously define the objects to measure

(and how to measure them)

Creation of a reference dictionary for surveyors/operators

Symbology for maps and reports



Process design : Mitigation measures

Rule of thumb : two

- At least one of those :
  - Two sensors
  - Two software
  - Two operators
  - Two datasets

- Compare and investigate the differences

(each branch should be assessed to have a 10^{-4} failure rate)

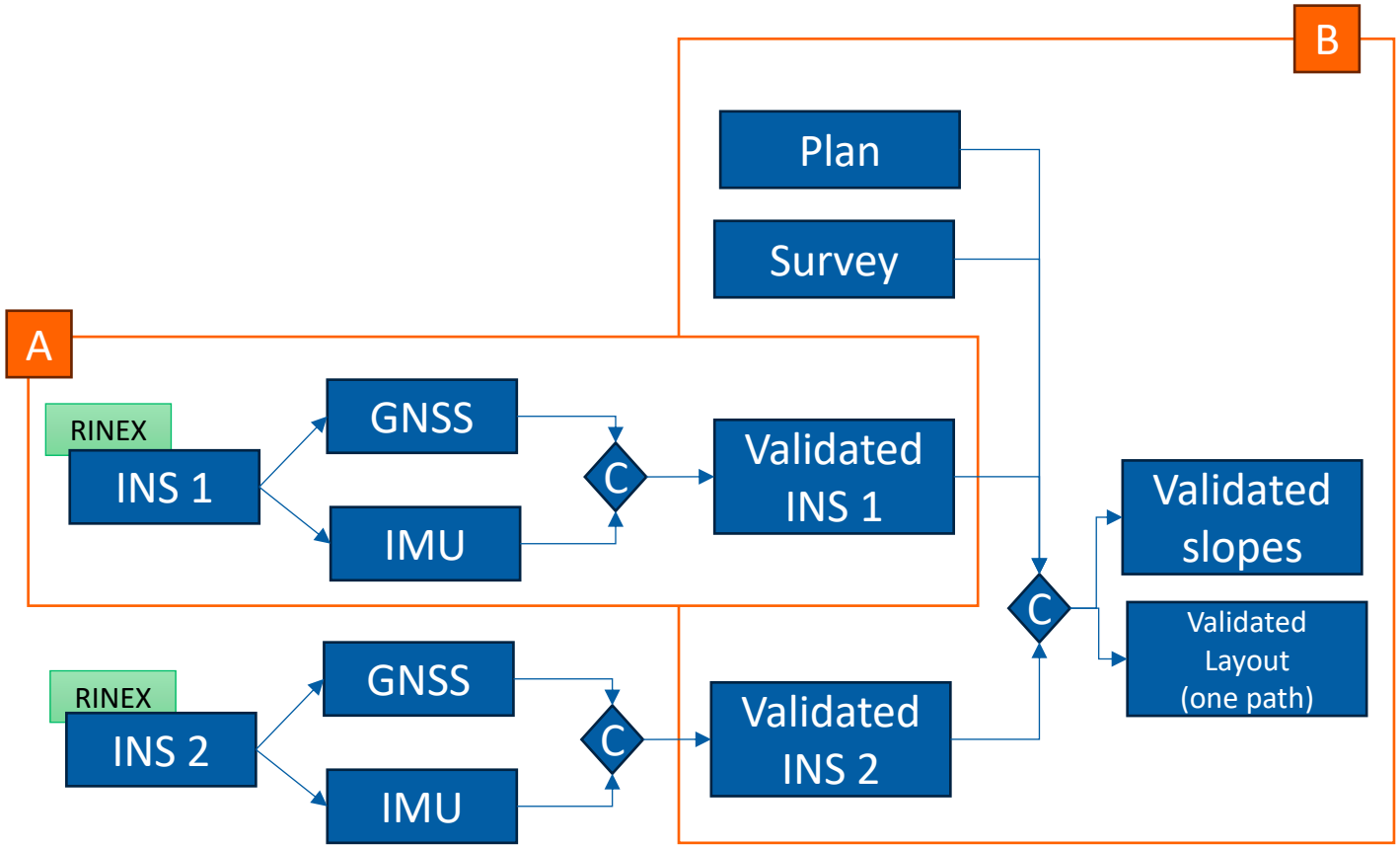
Slopes :

A) For each INS : Post Process with CORS RINEX, Compare GNSS and smoothed IMU (slope)

- Detects direction errors
- Detects IMU misalignment
- Validates noise removal
- Validates IMU internal coherency

B) Compare track layout from two sources

- Detects source malfunctions/errors
- Validates slopes
- (validates 3D geometry as well)



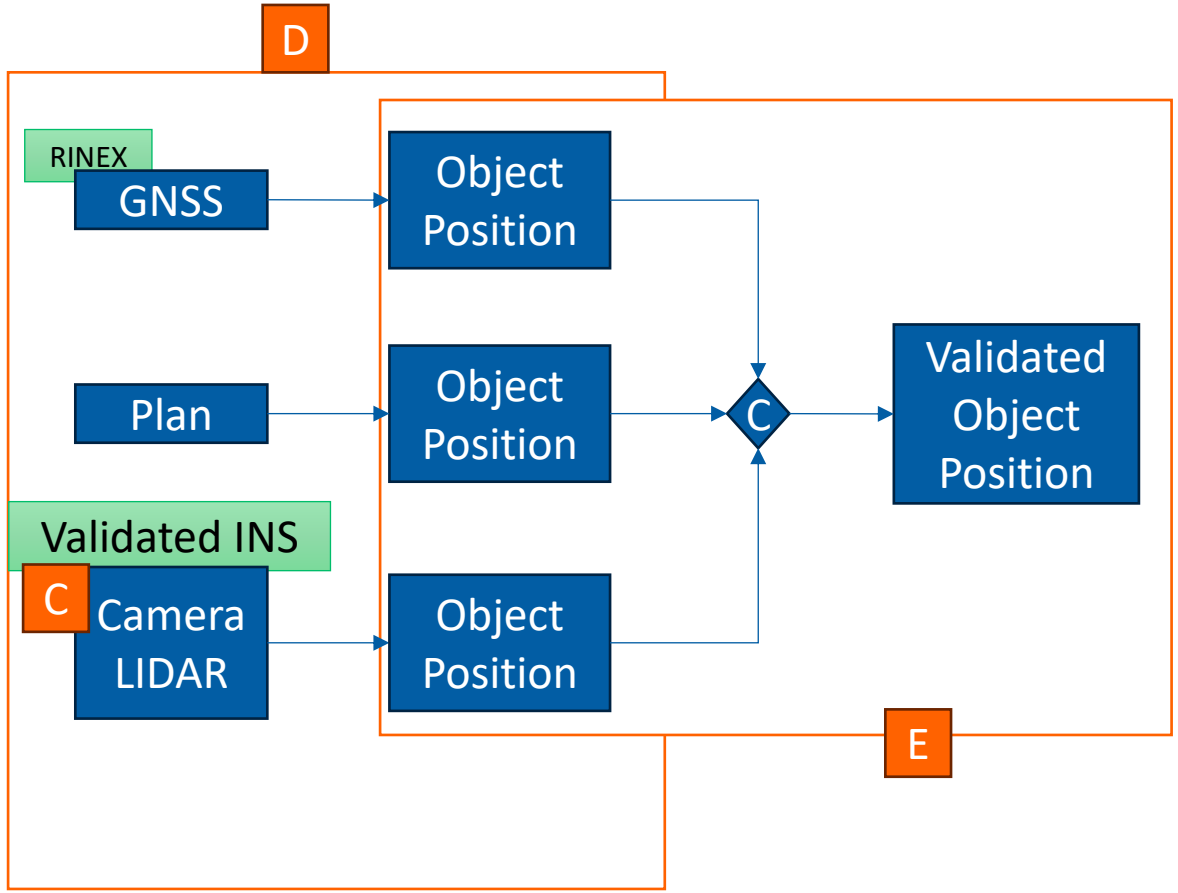
Objects positions

C) Validate camera or LIDAR position with a validated INS

D) Measure object positions (stereophotogrammetry, GNSS or LIDAR)

E) Compare two sources for each position

- Validates the object position

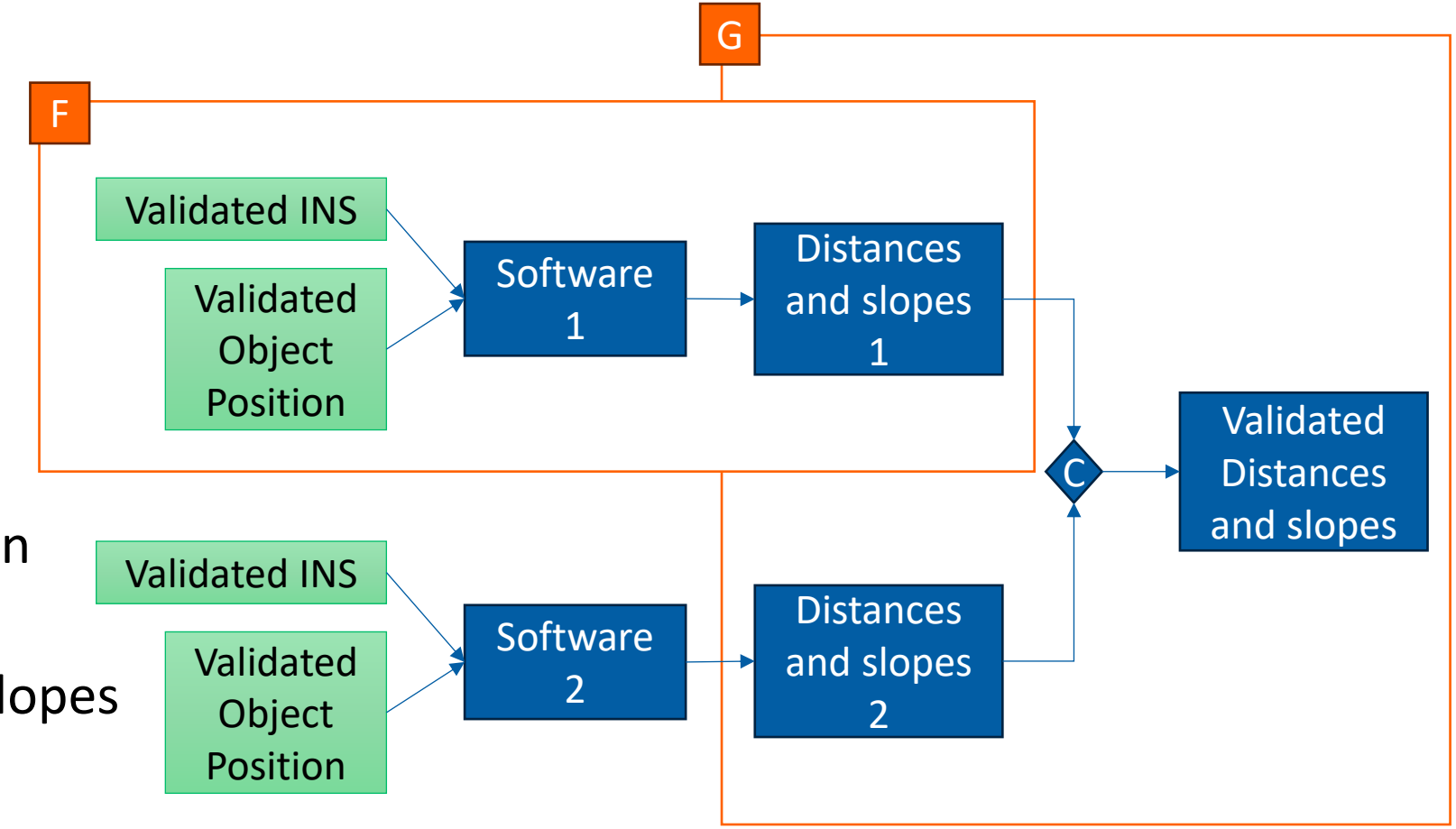


Distances

F) Project on the track and compute distances with each software

G) Compare distances between objects

- Validates distances and slopes between objects



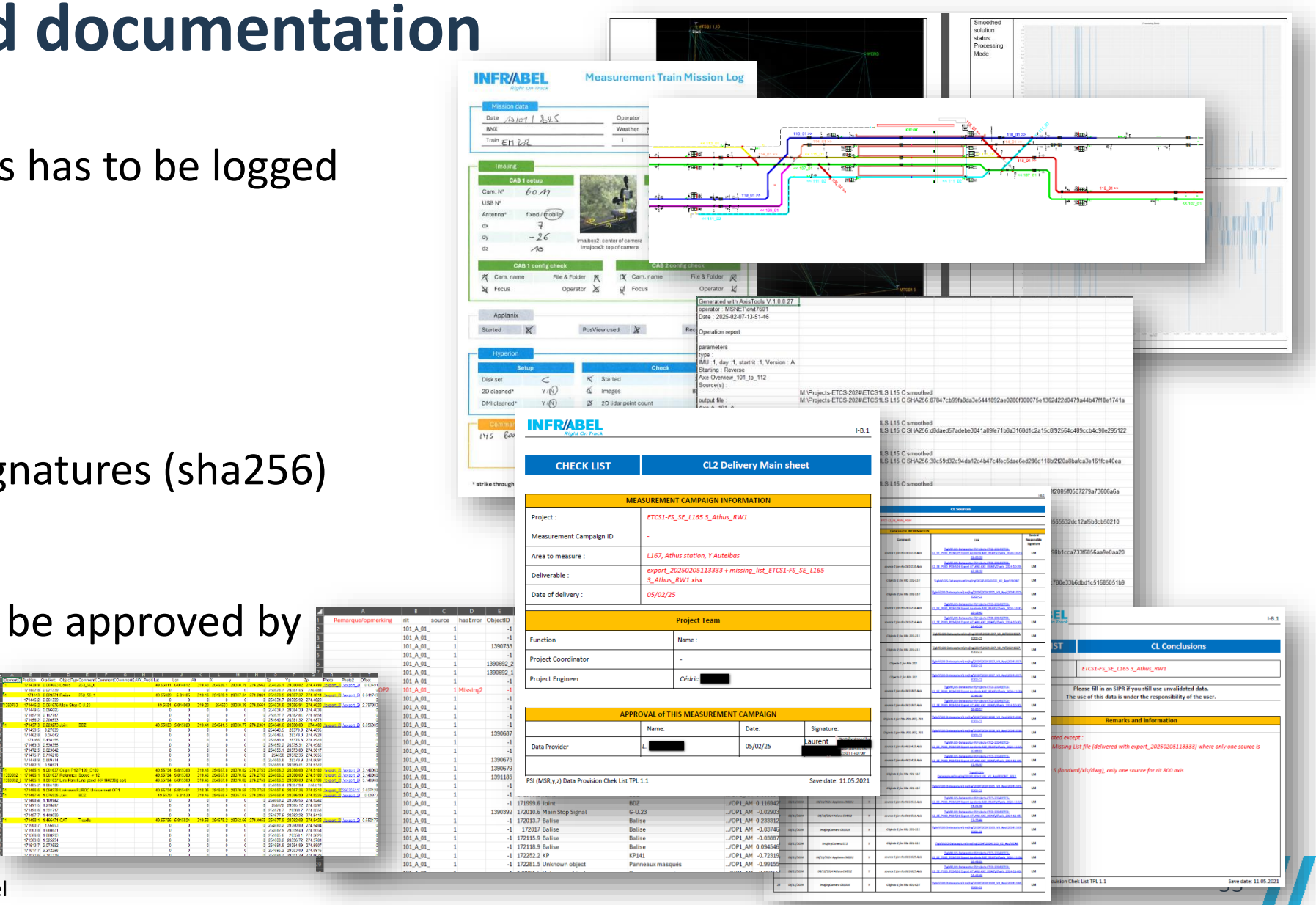
Traceability and documentation

Each step of the process has to be logged

- Check lists
- Operator name
- Sensors used
- Input/output files signatures (sha256)
- Parameter files

Each verification has to be approved by two operators

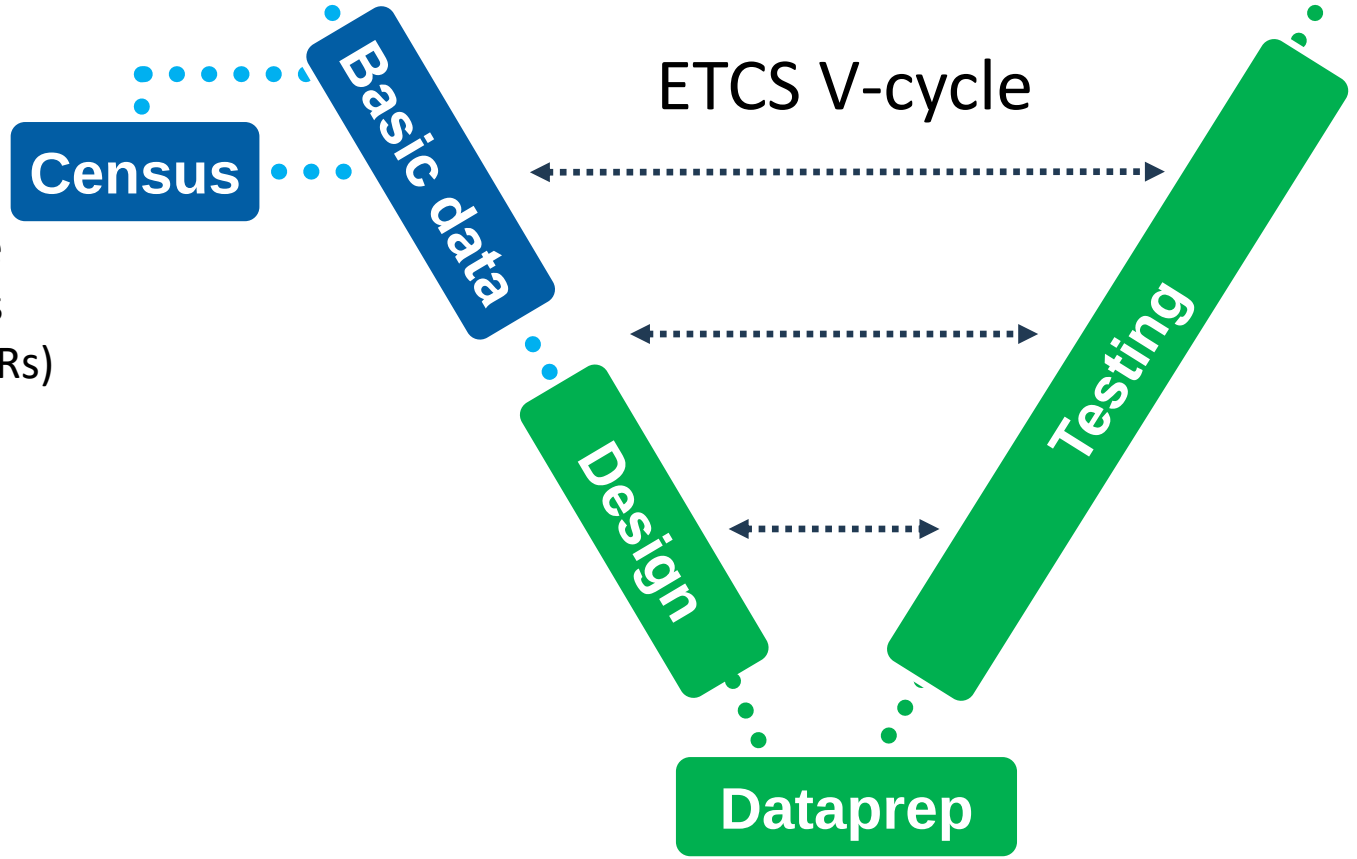
Found to be needed



Validation using AI

Existing data is considered one validated source
New measurement runs with simplified process
AI detections and measurements (Photo + LIDARs)
Detection of differences

But :
- Not as reliable as a human operator
- Automation difficult to maintain



Other point to take into consideration

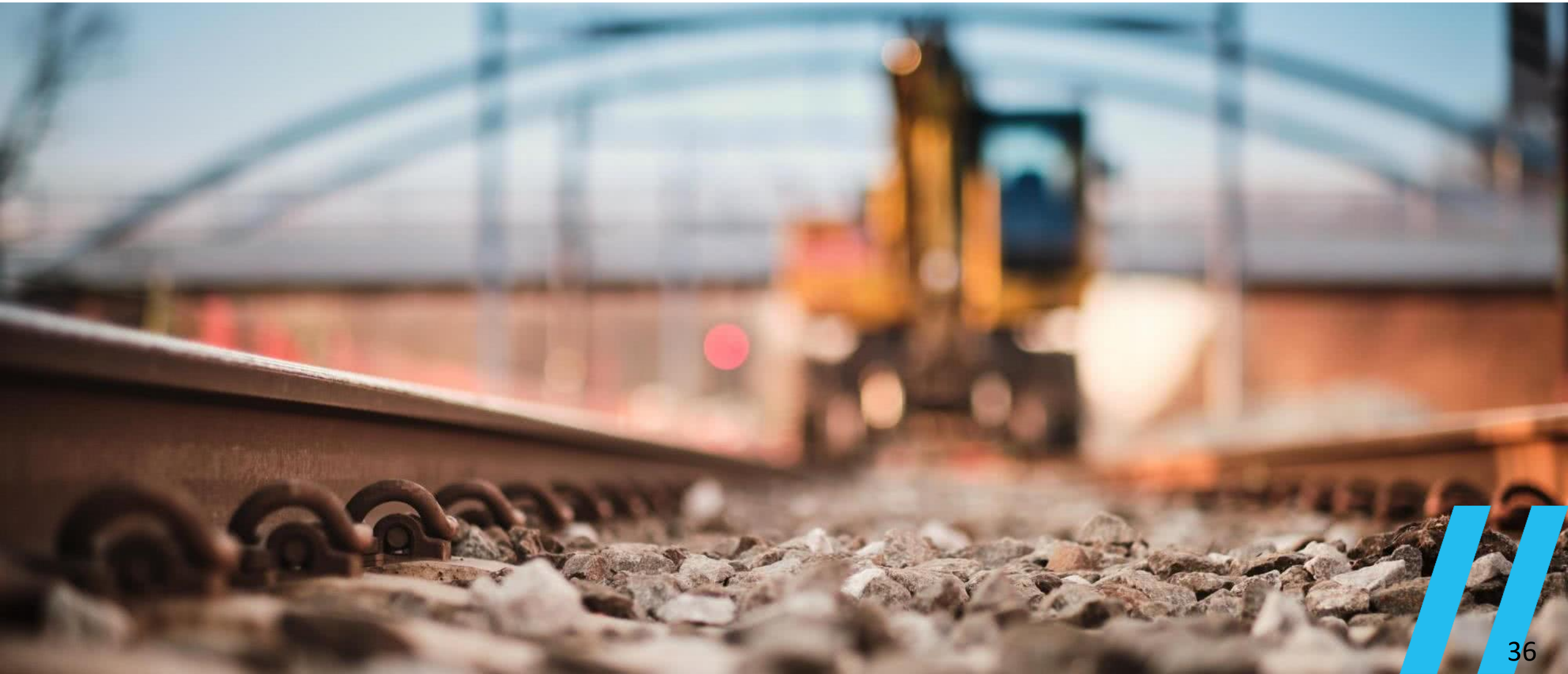
High Data Volume

500GB / measurement day

3-5 GB / ETCS project deliverables

Most data to be kept during
the lifecycle of the installation.

Return on 10 years of experience



Results

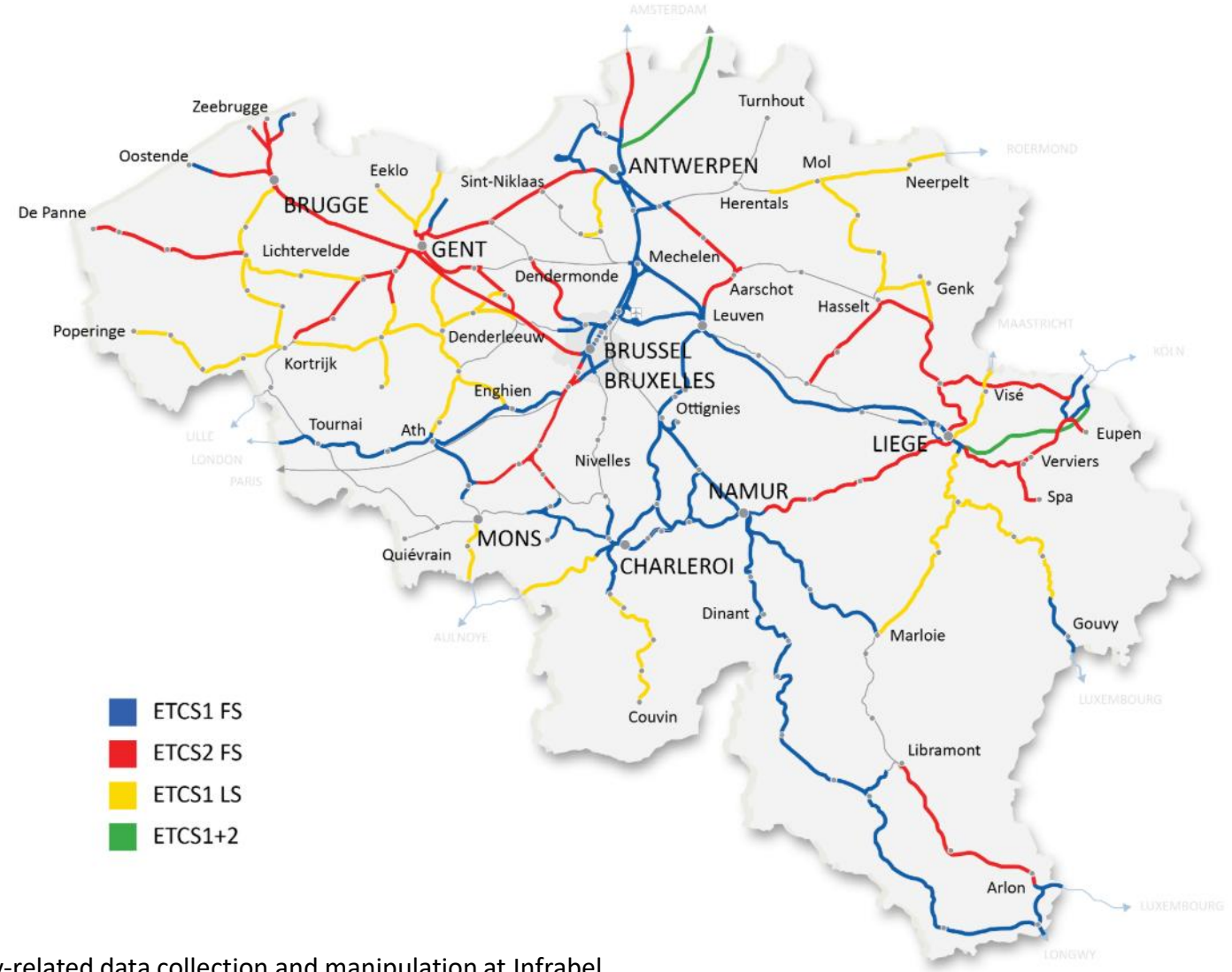
Since 2015 :

60.000 km runs

300.000 objects measured

- Process has been constantly evolving.
- Simpler at the start, heavy process has been proven necessary.
  - Errors still occurred, only to be detected later in the on-site testing or during design.
  - Costly rollbacks had to be done.
  - Documentation helped to find impacted projects and find out where mistakes were done.
  - Documentation helped improve the process.

ETCS deployment : Current state



	km In service	km foreseen in Master Plan	
ETCS1 FS	2.478	2.783	89%
ETCS2 FS	1.614	2.361	68%
ETCS1 LS	1.105	1.113	99%
ETCS1+2 FS	142	142	100%
Tota(a)l	5.339	6.399	83%

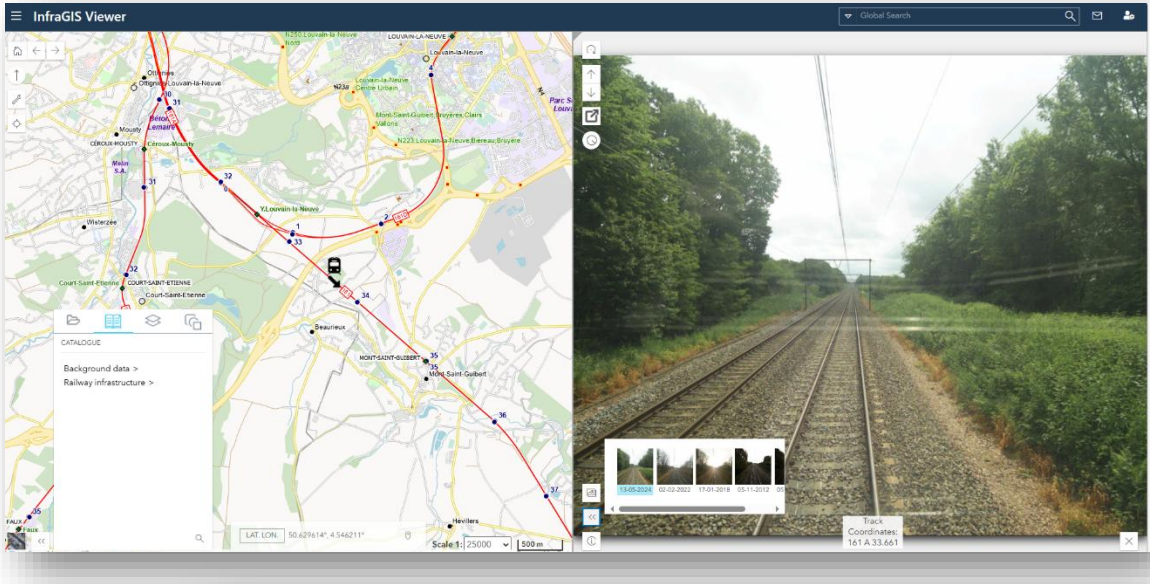
(as of 24/04/2025)

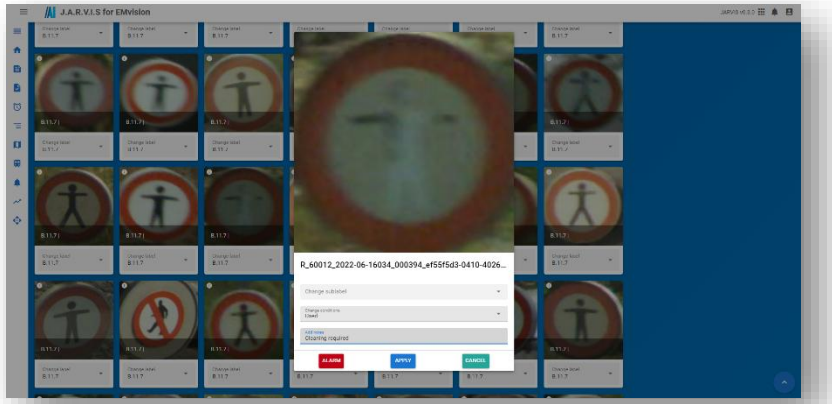
Interesting byproducts

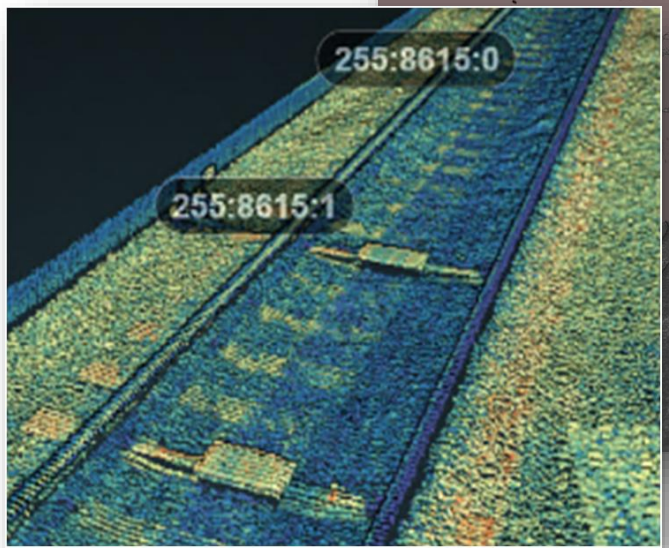
- Photographic evolution of the network
- 3D scans of the network
- Accurate track axis measurement

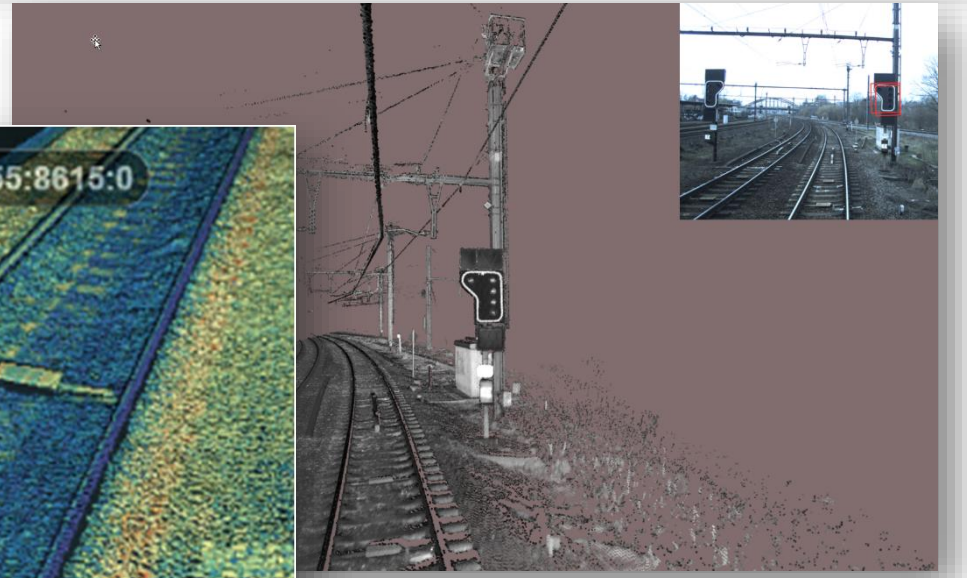
Used in the maintenance to reduce on-site visits (ballast, vegetation, catenary, …)

Used to assess the condition of assets









Questions ?