

# Etat des lieux des initiatives GNSS- Rail





# Le chemin...

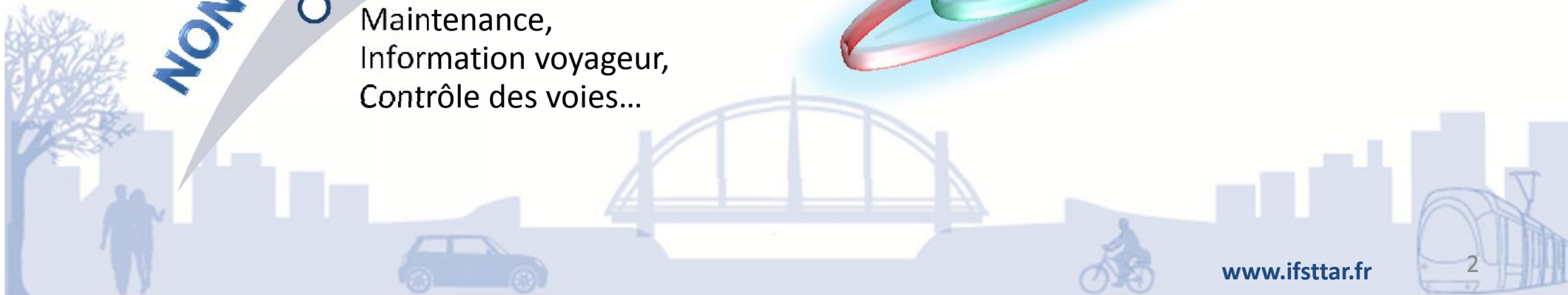
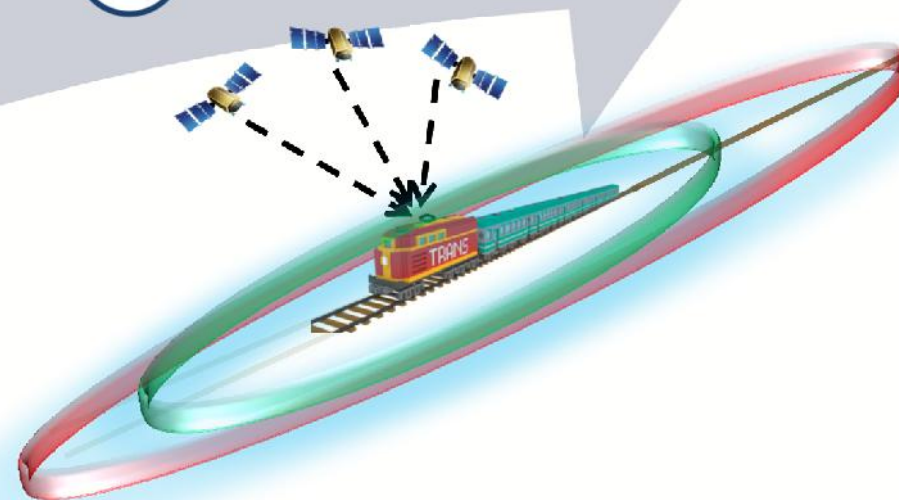


**NON CRITIQUE**

Maintenance,  
Information voyageur,  
Contrôle des voies...

**CRITIQUE**

ERTMS L3



# De nombreux projets en Europe

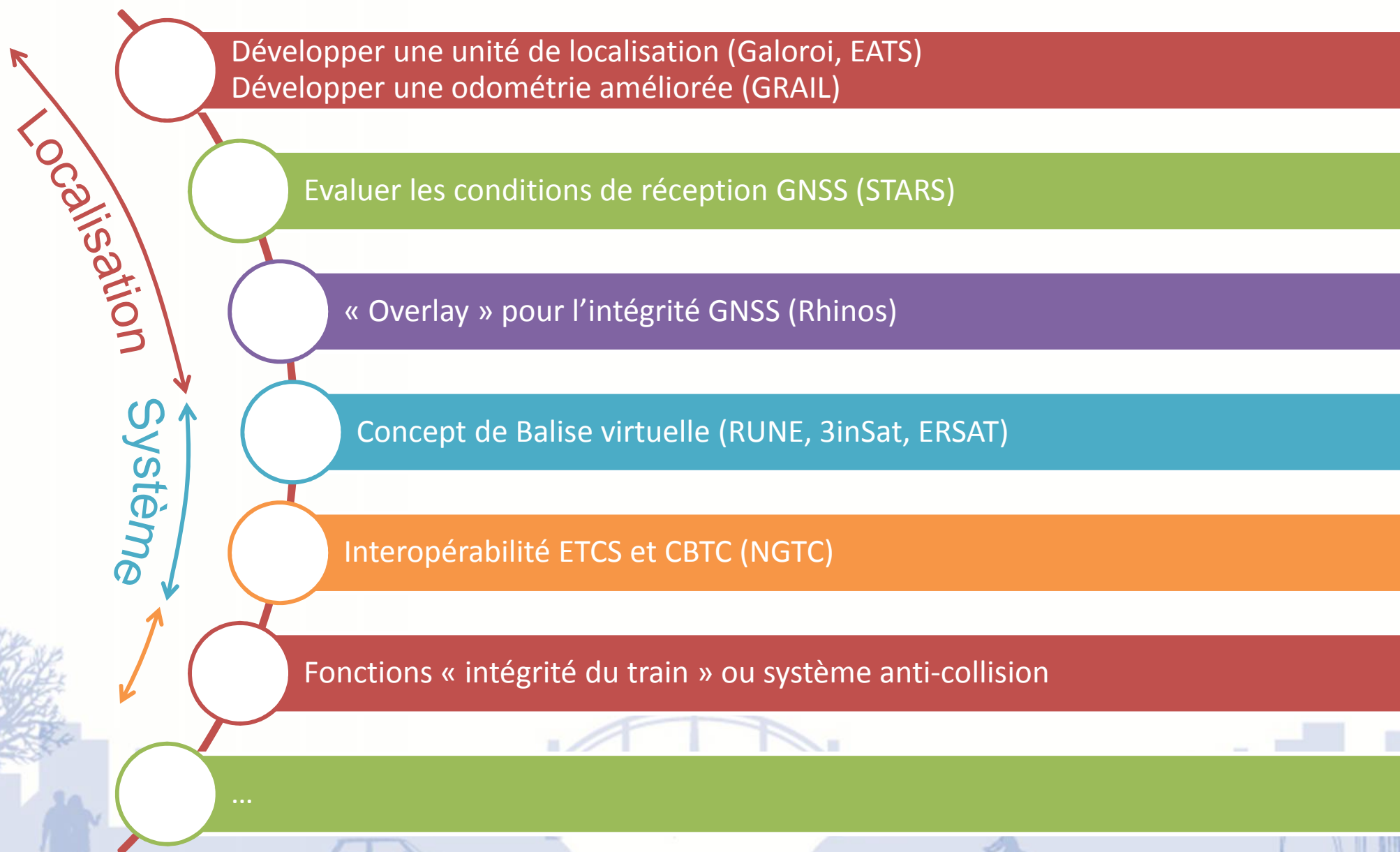


*En cours : SafeRail (ESA), NGTC(FP7), ERSAT (GSA), STARS (GSA H2020), INOGRAMS (BE), RHINOS (GSA H2020)*





# Des périmètres variés





# Des points communs

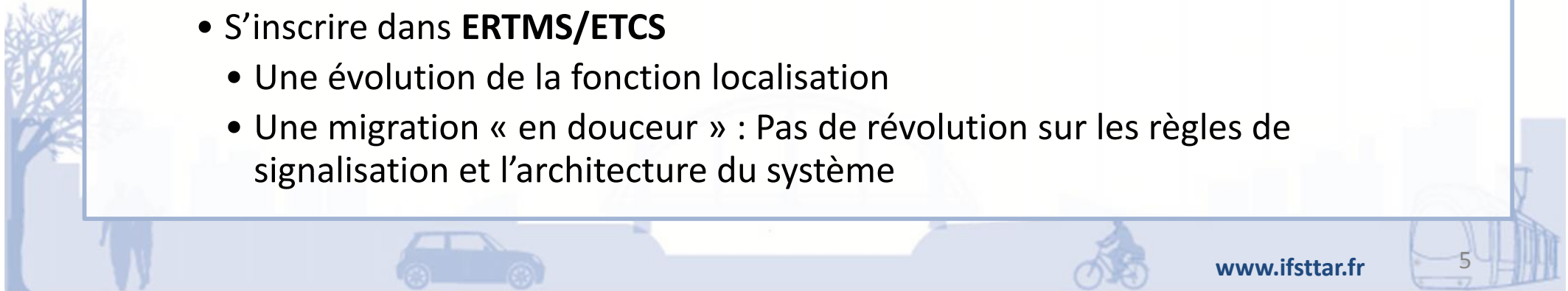
La cible n°1 : les lignes à faible trafic

Les objectifs :

- **Réduire les coûts** liés à l'équipement et la maintenance des voies (en particulier pour les lignes à faible trafic) – sauver ces lignes
- **Augmenter la capacité** du réseau.

Des exigences :

- Assurer un niveau de sécurité **au moins aussi bon** que le niveau actuel (enjeu GAME)
- S'inscrire dans **ERTMS/ETCS**
  - Une évolution de la fonction localisation
  - Une migration « en douceur » : Pas de révolution sur les règles de signalisation et l'architecture du système





# Les axes de travail



Consolider les besoins ?



Fournir une solution qui y réponde



Evaluer les performances  
(dans tous les environnements)



Démontrer la sécurité



Certifier la solution





Consolider les besoins ?



GNSS rail user forum (2000)



# L'expression des besoins

## Des initiatives diffuses ?

Table 1: Requirements


No	Application	
<b>Safety related applications</b>		
I	ex: ATC on high density lines / Station / Parallel	
II	ex: Train Control on medium density lines	
III	ex: Train Control on low density lines	
<b>Mass commercial / information</b>		
IV	Tracing & Tracking of vehicles	
V	Cargo monitoring	
VI	Dispatching	
VII	Passenger information	
<b>Infrastructure &amp; civil engineering, professional applications</b>		
VIII	Positioning of machines	1 cm
IX	Infrastructure survey	1 cm
X	Fix point applications	5 mm

3.2.7.2 Accuracy (horizontal)

a) Position accuracy  
±(5m + 5%)


It is the accuracy of §5.3.1.1 for location

b) Accuracy of speed  
2 km/h for 500 km/h scenarios



User Requirements

**RFI-DB Netz partner of ERSAT EAV Project**



Ansaldo STS A Hitachi Group Company



Supporting partner



<sup>2</sup> For efficient use in architectures accomplishing safety related functions integrity risk should be assessed.

<sup>3</sup> Note: the figures in italics for the safety applications are recommended values. The use for system certification is not applicable.



Consolider les besoins ?

# Analyses coûts/bénéfices



Ansaldo STS

A Hitachi Group Company

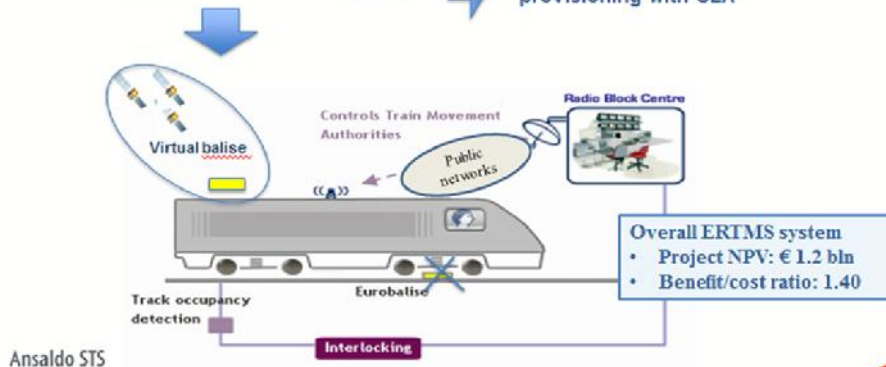
## Expected impacts

→ the case of ERTMS on 30% local lines (~ 18,000 km)

~ 62% Opex reduction

~ 3.5M Movement Authority daily

GNSS Augmentation services provisioning with SLA



Ansaldo STS

Reference: ERSAT EAV University Bocconi preliminary assessment of the economic effects at the system level

## Etude sur les cas allemands et italiens

Ansaldo STS

A Hitachi Group Company

## Other Potential impacts

Relevant savings in operating expenses: **-67% each year** compared to the traditional ERTMS → **Thus, it can contribute to the diffusion of ERTMS:**

- In low density lines, where the low traffic and the deriving poor economics of the service generate the risk of **disruption of services** (forcing a shift to road which increases the generalized logistics cost by some € 0.1 per pax\*km)
- In local lines where safety standards are currently not SIL4, thus reducing the risks of accidents (which can be valued at about € 0.6 per 1000 pax\*km), at lower costs (deriving **benefits in safety in Europe = € 23 mln per year**)
- In all lines where ERTMS is to be deployed, allowing the implementation of the «EcoDriving» concepts, which generates benefits for up to **€ 70 mln per year** in savings in energy consumption and braking equipment.
- In **international markets** especially in remote and difficult to access areas
- In exploiting **satellite assets** and creating a synergy with EGNOS-GALILEO



Reference ERSAT EAV University Bocconi preliminary assessment of the economic effects at the system level





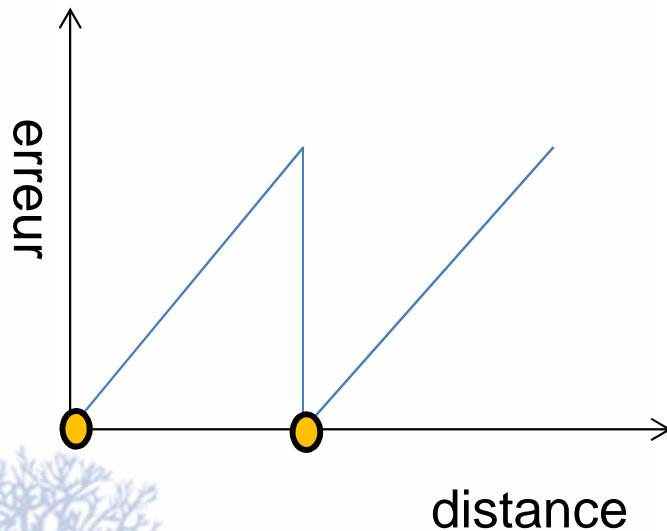
Consolider les besoins ?



# La position dans ETCS

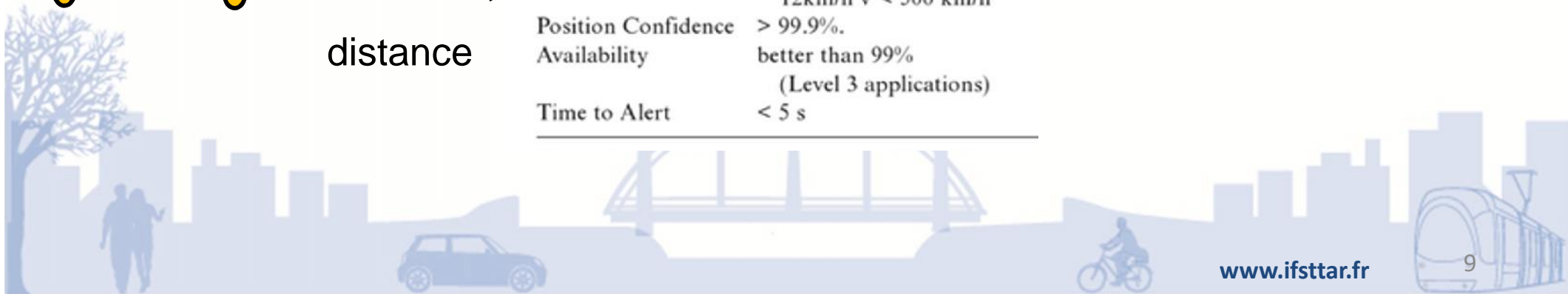


ETCS :  
Position tête de train = position balise + distance parcourue



ERTMS	
Position Accuracy	5m + 5 % of travelled space
Velocity Accuracy	2 km/h $v < 30$ km/h 12km/h $v < 500$ km/h
Position Confidence	> 99.9%.
Availability	better than 99% (Level 3 applications)
Time to Alert	< 5 s

© Siemens Mobility





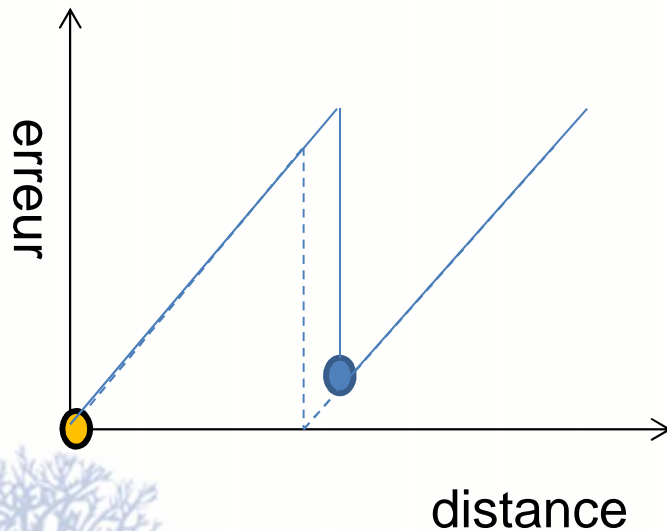
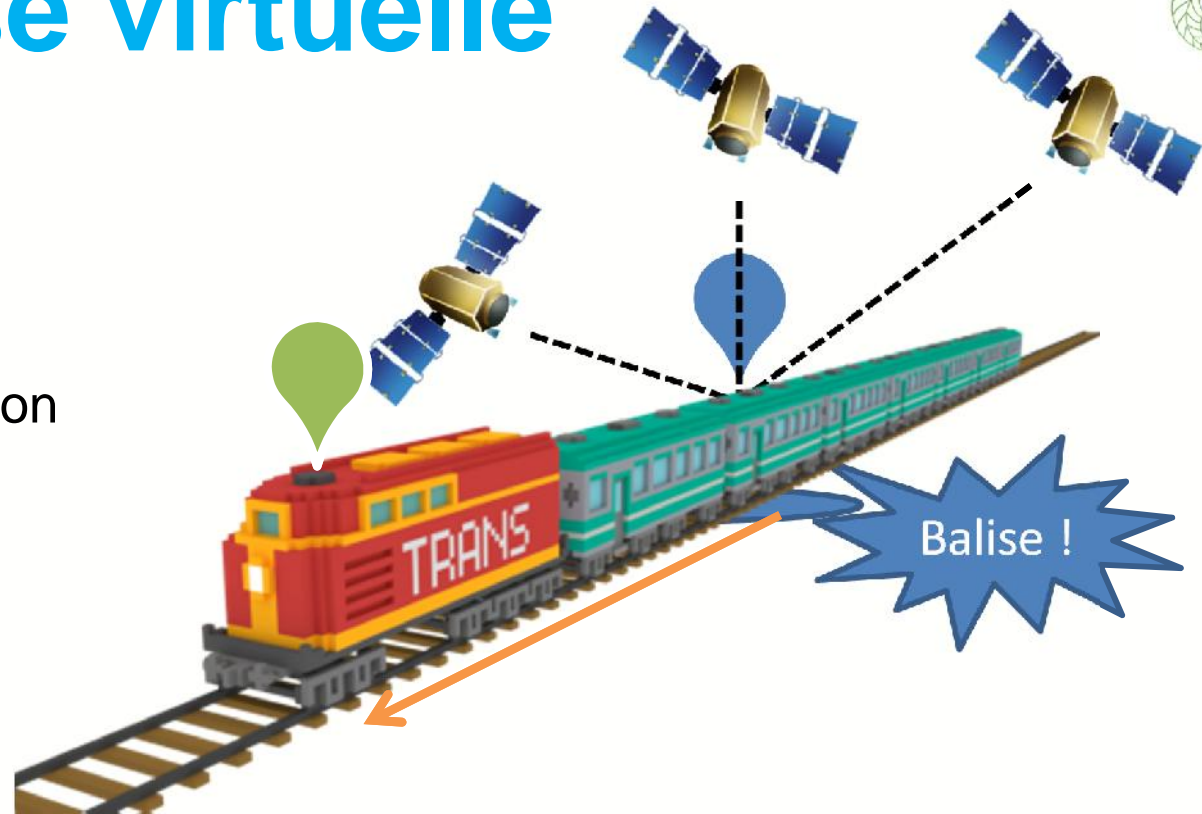
Consolider les besoins ?



# La balise virtuelle

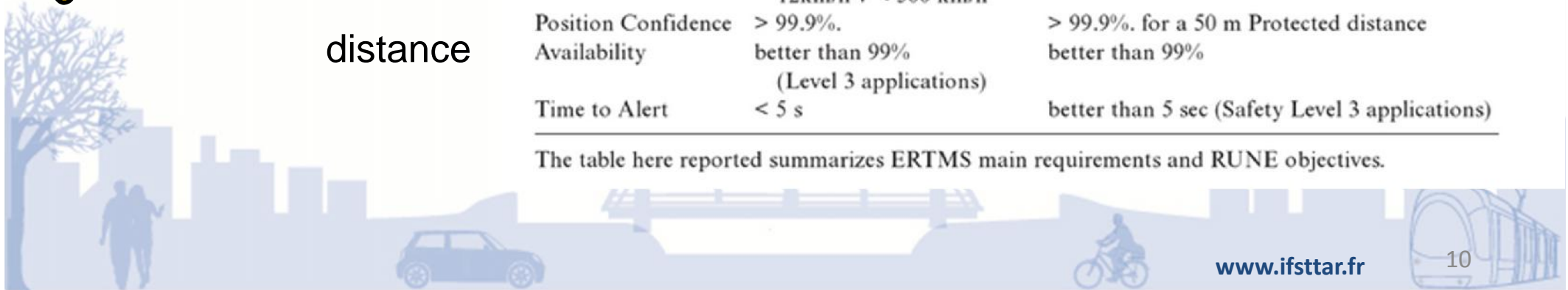


Position tête de train = position balise virtuelle + distance parcourue



	ERTMS	RUNE objectives
Position Accuracy	5m + 5 % of travelled space	3 m, 95% (GNSS + WAAS/EGNOS)
Velocity Accuracy	2 km/h $v < 30$ km/h 12km/h $v < 500$ km/h	2 km/h 95% (GNSS + WAAS/EGNOS)
Position Confidence	> 99.9%.	> 99.9%. for a 50 m Protected distance
Availability	better than 99% (Level 3 applications)	better than 99%
Time to Alert	< 5 s	better than 5 sec (Safety Level 3 applications)

The table here reported summarizes ERTMS main requirements and RUNE objectives.

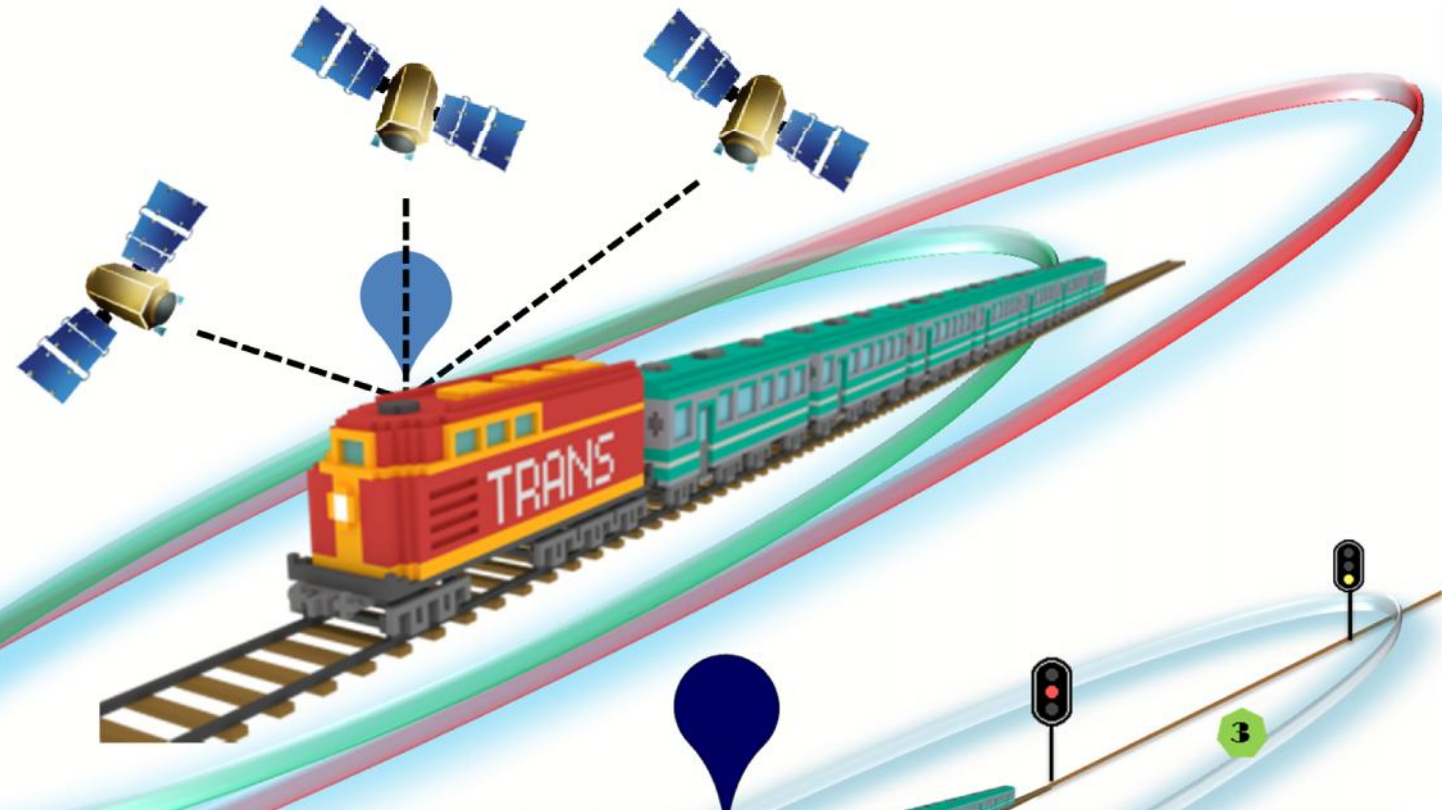




Consolider  
les besoins ?

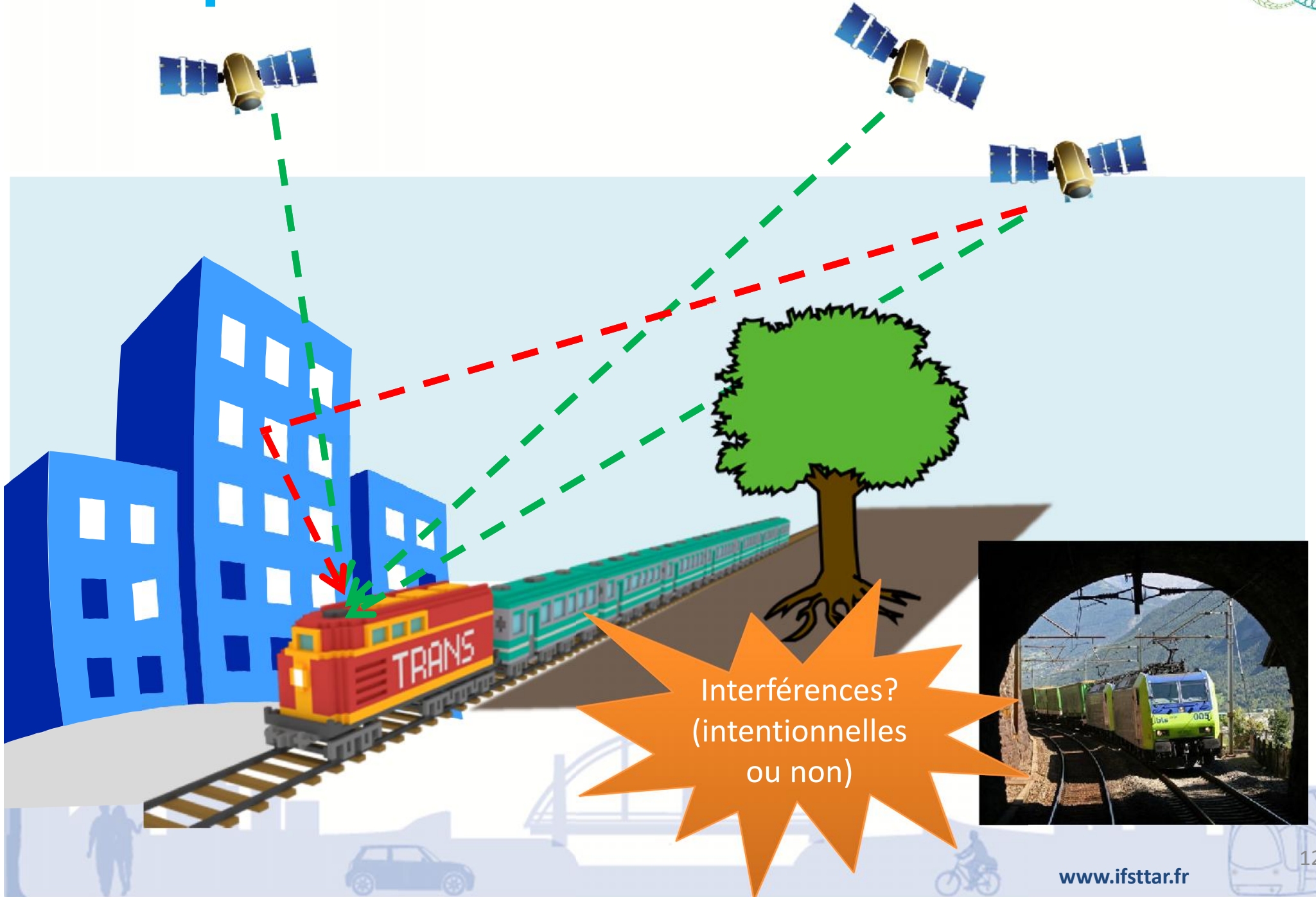


# Puis le canton mobile



- Localisation en continu
- Canton de taille variable  
 $f(\text{vitesse})$

# Impact de l'environnement local



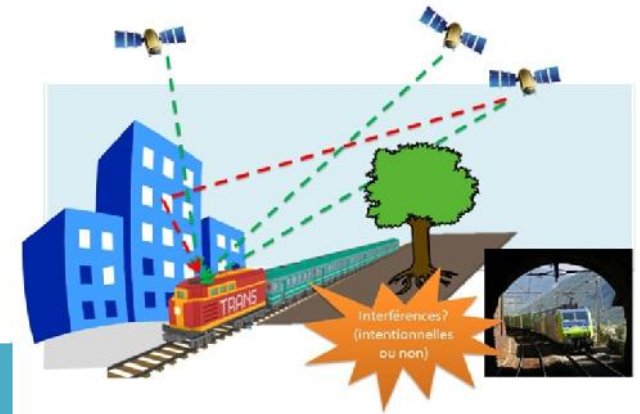
Interférences?  
(intentionnelles  
ou non)



STARS

SATELLITE TECHNOLOGY  
FOR ADVANCED  
RAILWAY SIGNALLING

# Le projet EU STARS 2016-2018



Principaux objectifs et  
résultats attendus

Développer une approche universelle pour **prédire les performances GNSS en environnement ferroviaire**

en particulier pour des applications ERTMS à caractère sécuritaire et déterminer les évolutions d'ETCS nécessaires pour inclure les services GNSS

Quantifier les bénéfices économiques, la réduction des coûts et l'appel sur le marché ERTMS;

Assurer l'interopérabilité entre équipement de différents fournisseurs;

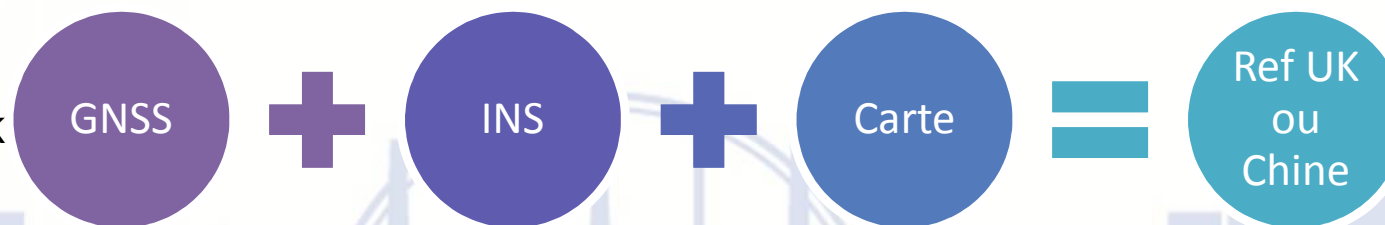
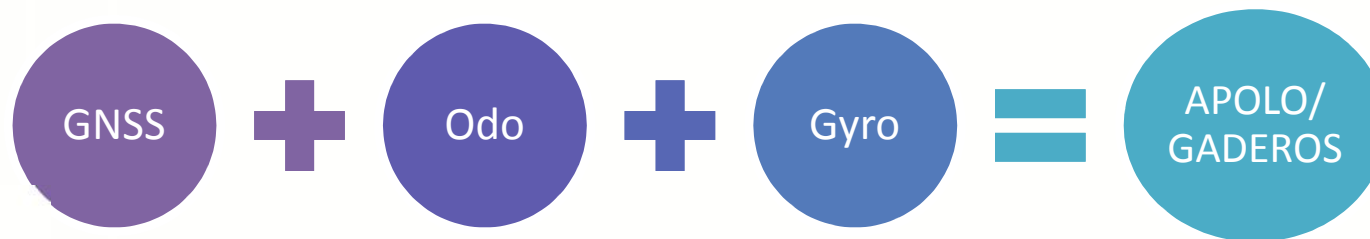
Permettre l'inclusion du GNSS dans ERTMS



# Des solutions multi capteurs

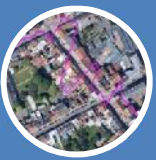


Fournir une solution qui y réponde



**DISPONIBILITÉ**  
**PRÉCISION**  
**INTÉGRITÉ**

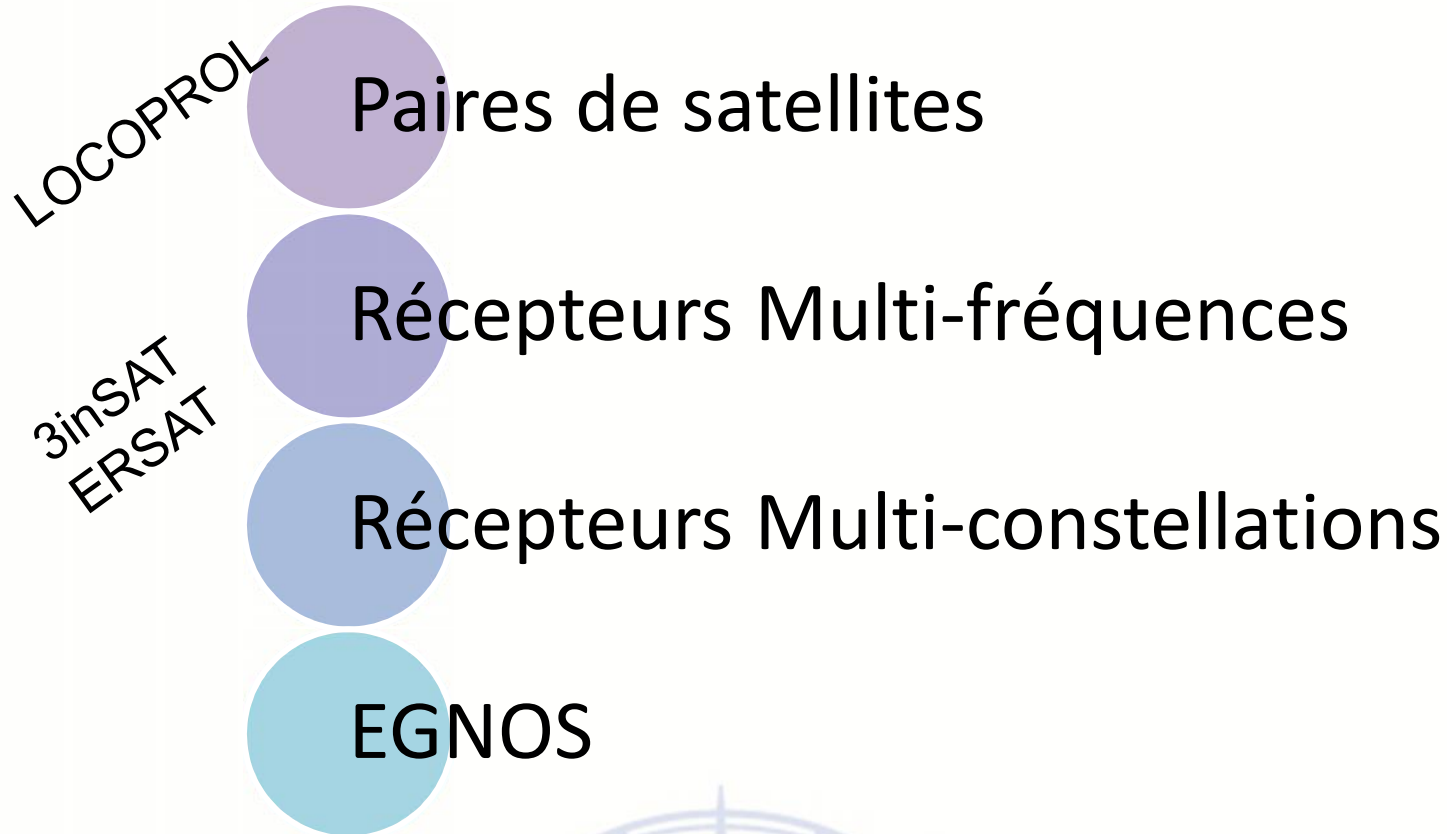
- Zheng&Cross (2012) – UK
- Lui&al (2011) Chinese Train Control System



Fournir une solution qui y réponde



# Bénéficiaire du potentiel des GNSS






# Le niveau de sécurité

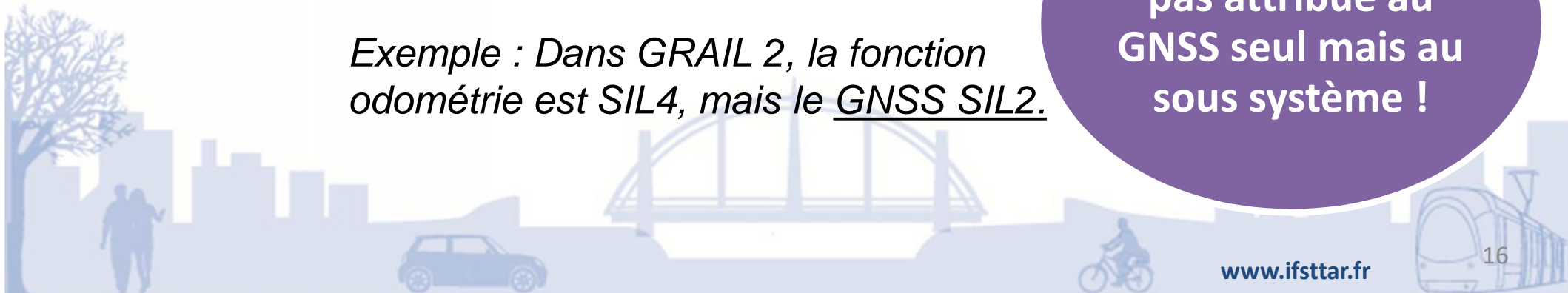
Le niveau de sécurité est défini dans la **Spécification Technique d'Interopérabilité CCS**.  
Le THR (Tolerable Hazard Rate) alloué à la **défaillance de l'ETCS bord ou sol** est de  $1.0 \cdot 10^{-9}$  failure/hour.

Dans les normes de sécurité ferroviaires, cela correspond à un **SIL4**.

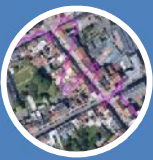


Cet objectif n'est pas attribué au GNSS seul mais au sous système !

*Exemple : Dans GRAIL 2, la fonction odométrie est SIL4, mais le GNSS SIL2.*







Fournir une solution qui y réponde

# Fournir une localisation sûre ?



## Utiliser la redondance

La redondance des signaux (utilisation de paires de satellites)  
(LOCOPROL)

La redondance de capteurs et de l'architecture et un vote pour vérifier leurs cohérences  
(GALOROI, GRAIL2)

## Des méthodes de détection et exclusion de sources défailtantes

Marais&al (2005) L'image pour la **détection** de l'état de réception des satellites GNSS

Liu&al (2011) Une architecture à 3 niveaux – **élimine** les erreurs lors des étapes de collecte des données capteurs, de la fusion et du map-matching

Legrand&al (2014) Analyse de la propagation des erreurs dans un système multi-capteurs basée sur une analyse causale

## Mettre en œuvre des techniques de surveillance de l'intégrité

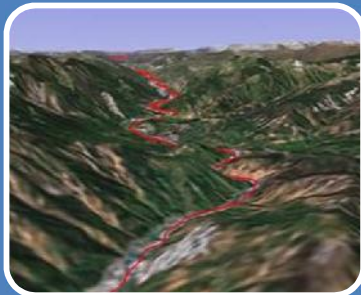
Un **réseau local** de surveillance de l'intégrité basé sur EGNOS + overlays  
(3inSat, Rhinos)



Evaluer les performances  
(dans tous les environnements)



# Evaluer les performances ?



## Simuler

Répétabilité, maîtrise des conditions de tests, variation de la constellation, à moindres coûts

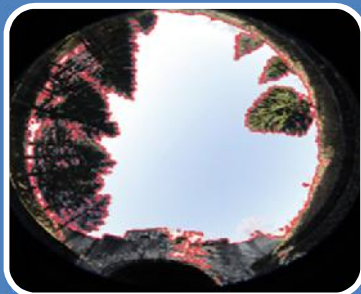
- ⇒ Simulateur ATLAS de CEIT (EATS)
- ⇒ Couplage simulateur ERTMS/GNSS (Ifsttar),
- ⇒ Un objectif de Shift<sup>2</sup>Rail – *zero on-site testing approach*



## Démontrer sur site

Presque tous les projets

- ⇒ SATLOC en Roumanie
- ⇒ 3inSat/ERSAT en Sardaigne et Italie
- ⇒ RSSB T510 et 581 (RSSB 2009) au Royaume Uni



## Combiner les deux

- Méthode hybride
  - ⇒ PREDISSAT (Marais&al 2000)
- SATLOC : des images de l'environnement ferroviaire pour la connaissance du masquage, simulé dans un simulateur de signaux (Marais&al, 2014)



# Démontrer la sécurité ?



Démontrer la sécurité

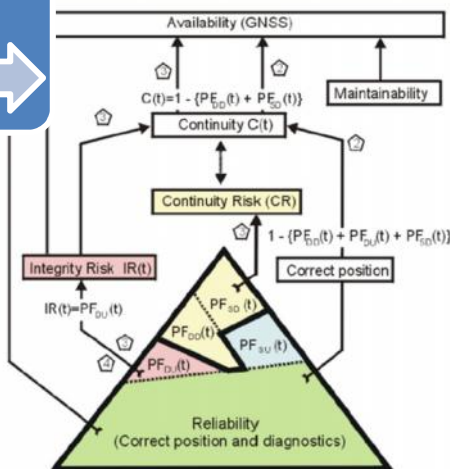


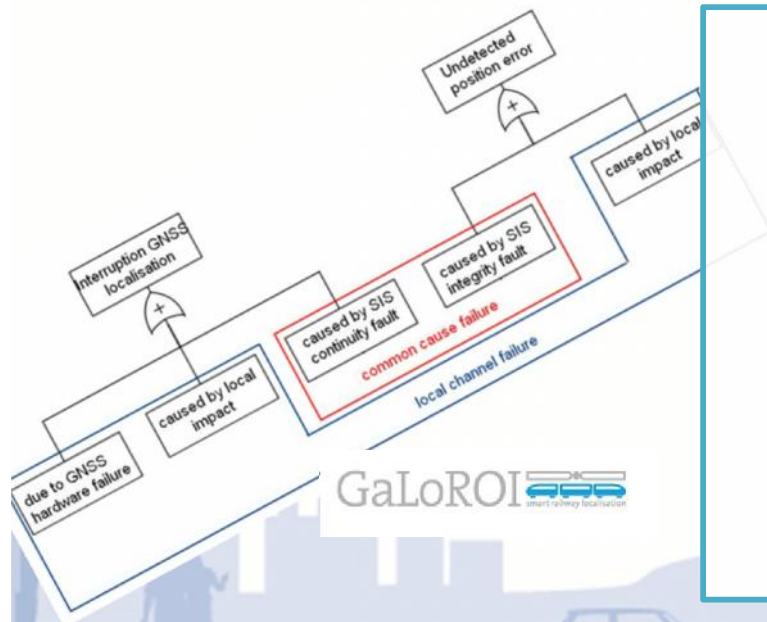
Fig. 6 GNSS Availability vs. failure modes

## 1. Selon quels critères ?

- Les critères de sûreté de fonctionnement ferroviaire (**FDMS**) ne sont pas équivalents aux définitions des performances **GNSS**
- **Des liens établis dans : Filip&al (2008), Beugin&al (2012)**

## 2. Avec quelles méthodes ?

- **Des méthodes de SdF à adapter aux systèmes sans fil ou aux systèmes multi-capteurs** : Utilisation de réseaux de Pétri *Beugin&al (2008), Nguyen&al (2014, 2015)* - **GALOROI**
- **Safety plan, safety assessment process** : Evaluation indépendante du SIL2 atteint par le sous-système odométrique – GNSS UT - effectuée par Veritas (ISA) sur la base de documents fournis par Thales (GRAIL2 2013).



GaLoROI smart railway localisation



Certifier la solution



# Procédures de certification



RFI a démarré un processus de certification pour l'utilisation du GNSS et des réseaux publiques de télécommunications dans le cadre d'ERSAT

**CE 402/2013 Regulation**

Sept.2015

**Preliminary Hazard Analysis**

**User Requirements**

Juin 2016

**Request to put in service the system**

2017 ?

**Pilot line**

**Coordinator of technical committee & Responsible for Request to ANSF: RFI**  
**Team of external experts:** Ansaldo STS, Radiolabs, Sogei, Telespazio  
**ANSF:** Agenzia Nazionale per la Sicurezza Ferroviaria

Informations Ansaldo - RFI





# Les actions en cours / France

Un groupe de travail BNF/BNAE sur l'utilisation du GNSS pour le ferroviaire

Quelques acteurs français impliqués dans les actions européennes

Des initiatives plus locales...



**STARS**  
SATELLITE TECHNOLOGY  
FOR ADVANCED  
RAILWAY SIGNALLING

**THALES**

Thales Communications  
& Security



IFSTTAR

ThalesAlenia  
A Thales / Finmeccanica Company  
Space



TECHNOLOGICAL RESEARCH INSTITUTE  
RAILENIUM

[www.ifsttar.fr](http://www.ifsttar.fr)



# Aujourd'hui en Europe

ligne pilote en Sardaigne (2017 – ERSAT)



UNISIG Satellite WG

European GNSS Agency

European Global Navigation Satellite Systems Agency



2013

2015

2016

2022



## Objectives

- Development of an **absolute train positioning** system allowing
- Absolute, interoperable and safe positioning of trains

## Specific Technical outputs

- Study of **different solutions**
- Analysis and modeling of **Local effects**
- Development of **alternative solutions...**

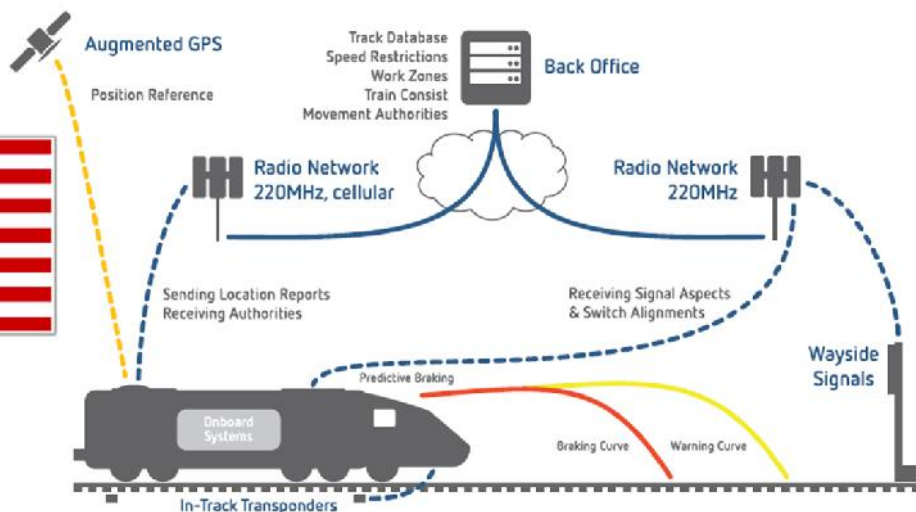
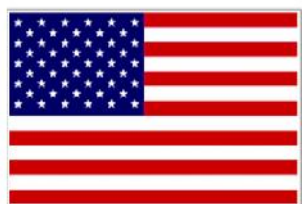
## Expected impacts

- A reduction in installation and maintenance **costs**
- A protection against **vandalism**
- Increased **interoperability**
- Improved **maintainability**



# Aujourd'hui ailleurs

## PTC Operation



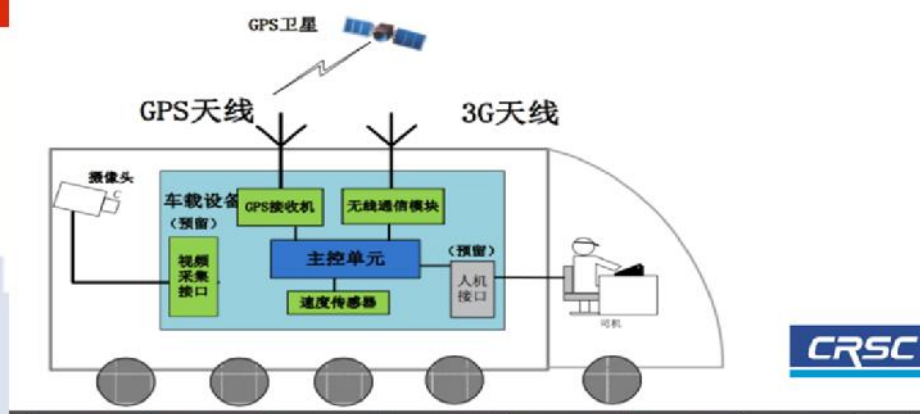
Le déploiement était prévu pour fin 2015

→ report à 2018 + 2 ans de validation sur site

Il existe plusieurs systèmes PTC : I-ETMS (Interoperable Electronic Train Management System) qui repose sur le GPS, et l'ACES (Advanced Civil Speed Enforcement System) qui utilise des transpondeurs sur la voie



- GNSS System in Qinghai-Tibet Line
- GNSS Combined Satellite System



Ligne simple

1 train à la fois entre deux gares





# Aujourd'hui ailleurs

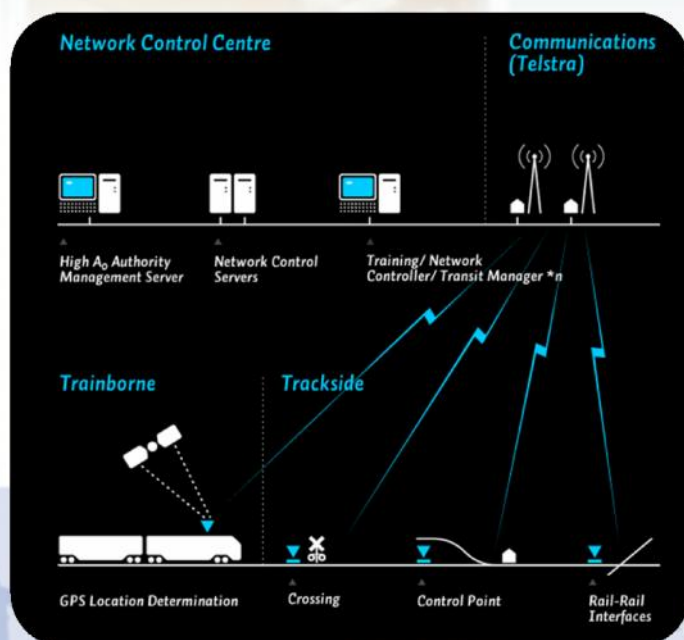
## AFE to install satellite train control

23 Dec 2015



## URUGUAY

Contrat signé (21/12/2015) pour l'introduction d'un système de contrôle basée sur le satellite 1600km/4 prochaines années  
Remplacement des blocs fixes



## Australie

ARTC en partenariat avec Lockheed Martin – ATMS en phase de test



# Ailleurs que dans le rail ?



L'EZ10 d'EasyMile se déplace sur une route préalablement définie dont on a scanné tout l'environnement et déterminé des arrêts pour les stations. Une route virtuelle est ainsi créée et le véhicule suit la trajectoire prédéfinie en se repérant grâce à une série de capteurs.

High performance of EGNOS will allow DSN to decommission about 50 Cat. 1 ILS while reducing its navigation infrastructure costs”



*In 2016, France will offer a minimum operating network with ILS (Red) and about a hundred PBN and EGNOS procedures (Blue)*





# Conclusions (1/2)

Le rail est aujourd'hui reconnu comme un secteur d'applications GNSS !



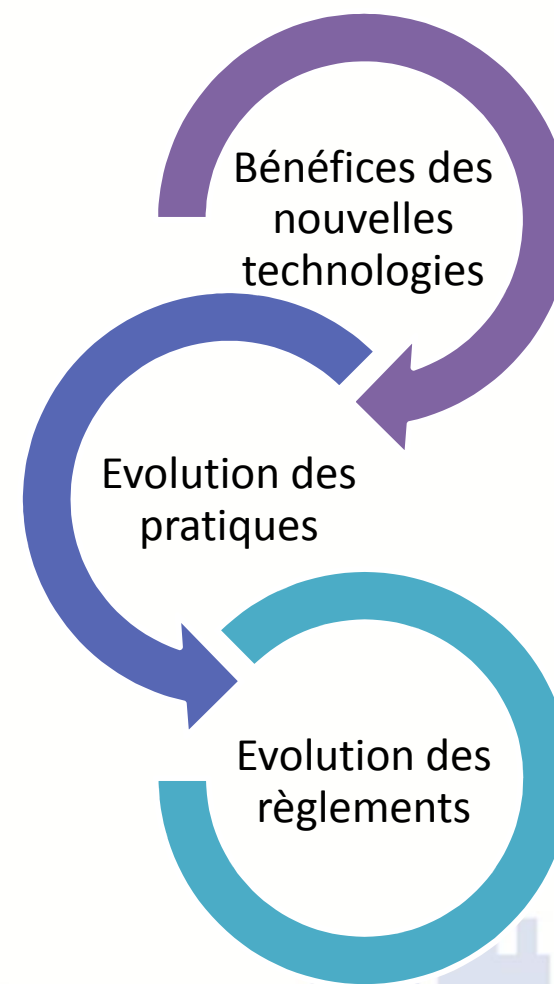
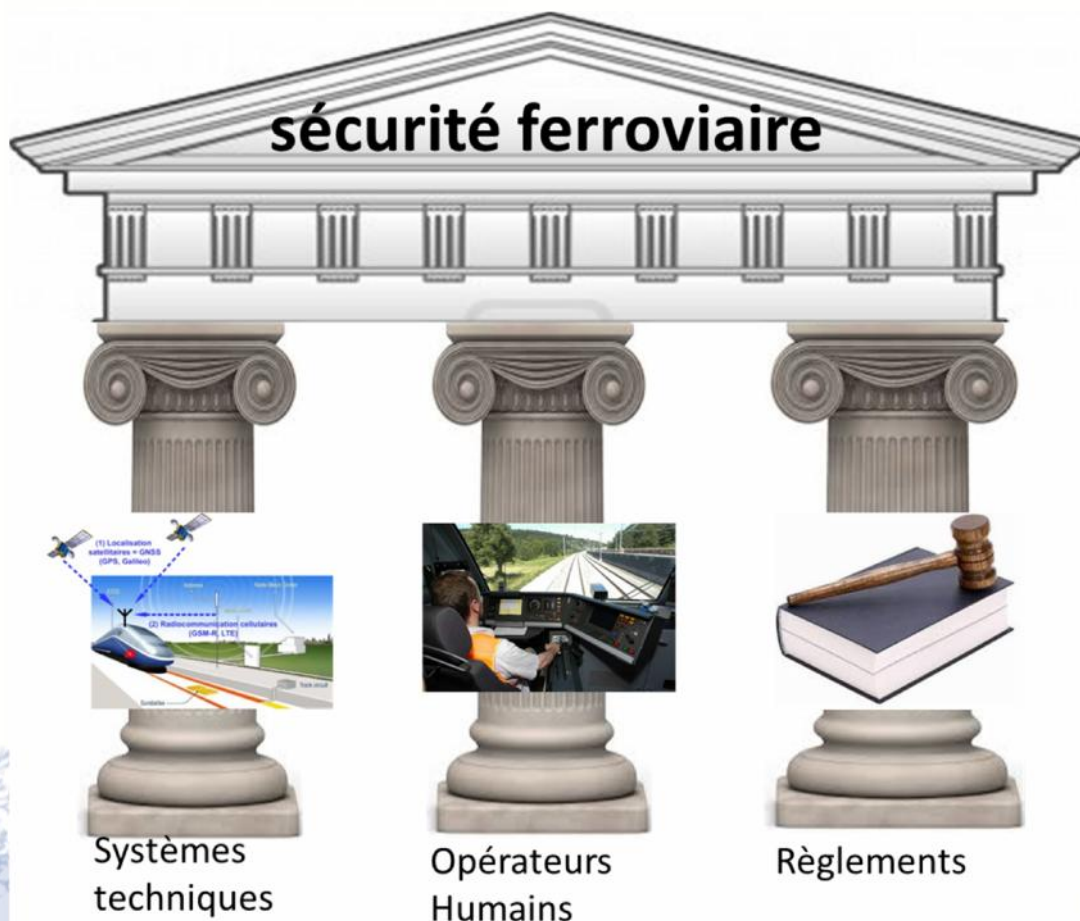
Des résultats nombreux issus de projets et de recherches sur lesquels s'appuyer pour poursuivre et pour s'y insérer





# Conclusions (2/2)

## Objectif : Applications sécuritaires...



@Joaquin Rodriguez, ifsttar/Cosys/Estas





# Merci de votre attention



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## Objectives

- Development of an **absolute train positioning** system allowing
  - Reduction in the number of conventional train detection systems and limitation/removal of ground infrastructure  
→ Establishment of the “**virtual balise**” concept
- Absolute, interoperable and safe positioning of trains based on
  - Application of the **GNSS technology on ERTMS** system
  - **Scalable concept** allowing integration of future sensor technologies

## Specific Technical outputs

- Study of **different solutions** to achieve absolute positioning functionality in railway environment (including multi constellation, GNSS algorithm improvement, multifrequencies receivers, alternative augmentation systems and additional kinematic sensors)
- Analysis and modeling of **Local effects** (obstruction, multipath, NLOS)
- Development of **alternative solutions...**

## Expected impacts

- The use of an absolute location not requiring ground infrastructure involves
  - A reduction in installation and maintenance **costs**
  - A protection against **vandalism**
- The use of GNSS under ERTMS involves
  - Increased **interoperability**
  - Improved **maintainability**

## Different levels of maturity for GNSS consideration in Rail applications

The way in which GNSS is used for train applications is different from one region to another. The amount of initiatives in the world shows the consideration given to Rail and GNSS developments.

**In Europe**, investigations are on-going to include GNSS as a complementing system for safety-relevant operations in the frame of the European Rail Traffic Management System (ERTMS). GNSS, being an innovative solution capable of decreasing costs, has been included in the ERTMS roadmap. **Shift2Rail, the first European Joint Undertaking** initiative for railways, has been launched as a concrete action to accelerate the integration of technologies, including the use of GNSS, into rail solutions. The key stakeholders developing the ERTMS technical specifications are **the European Railway Agency** (system authority), **ERTMS Users Group** and **UNISIG** (a member of UNIFE developing the ERTMS specifications).

**In the US**, PTC (Positive Train Control) implementation is planned soon. PTC combines control, communications, and information systems for safety, security, precision and efficiency of trains movements. It includes GNSS as a positioning technology for the train.

**Russia** developed an Integrated Train Protection System (called KLUB-U) using both GPS and GLONASS technologies for train positioning.

**China** is investing heavily in infrastructure modernisation with the construction of new railways. GPS localisation systems are already used on some rail lines. The entry into operation of BeiDou, planned in 2020, will contribute to the wider-scale deployment of such solutions – and not only in China.

After many years of neglect, rail infrastructure in the **Middle East and North Africa** has experienced a huge growth, especially in railway construction over the last 10 years, and with more significant investments planned (\$200bn). The champion is Saudi Arabia, where half of the investments were made, followed by Algeria and Qatar.

In the **Asian region**, **India** benefits from one of the largest railway networks requiring emphasis on the safety of applications. Huge investments are planned by the Indian government, and trials are on-going to deploy the Train Collision Avoidance System (TCAS). It is considered as a cost-effective solution thanks to the use of GNSS.

