Breakthrough Satellite Technologies for Automated Rail Transport and Driver-less cars applications

Francesco Rispoli

Ansaldo STS A Hitachi Group Company

Imperia, 5 July 2017

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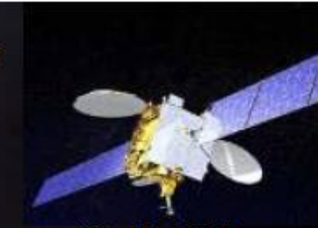
Numerous Applications of GPS/GNSS Today
How Many Are/Will Be Automated ?



Rail Transport systems are already higly automated

European challenge: interoperability

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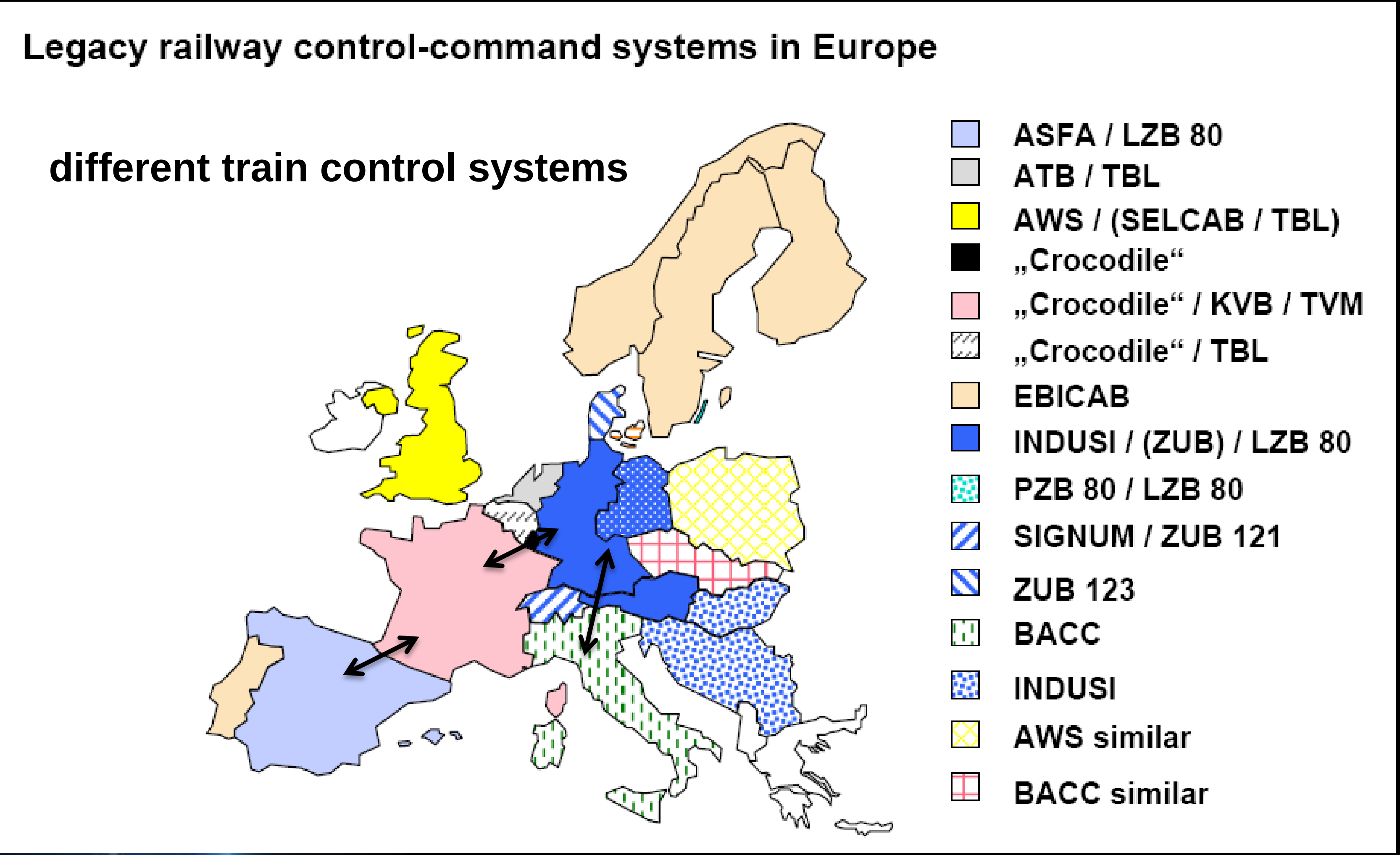
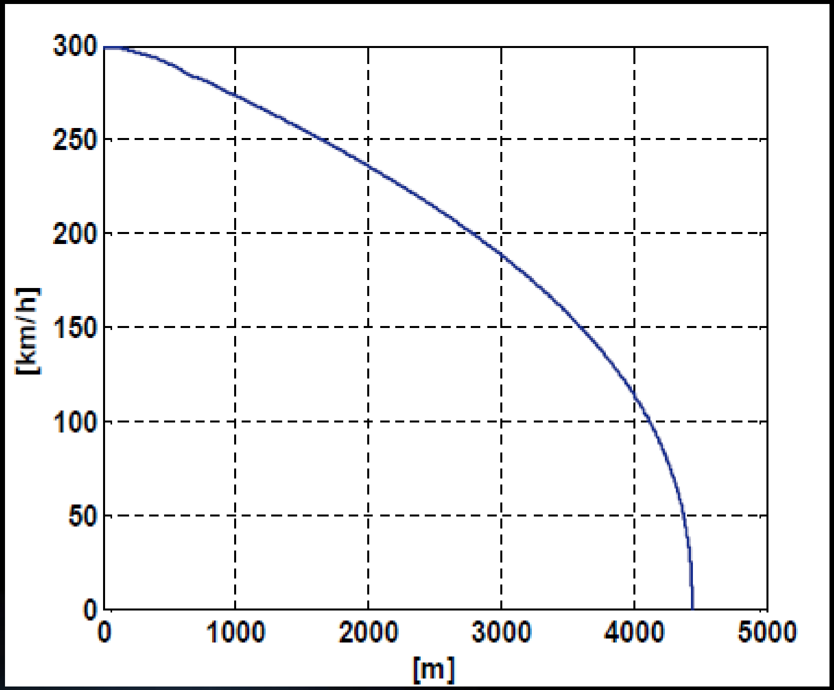


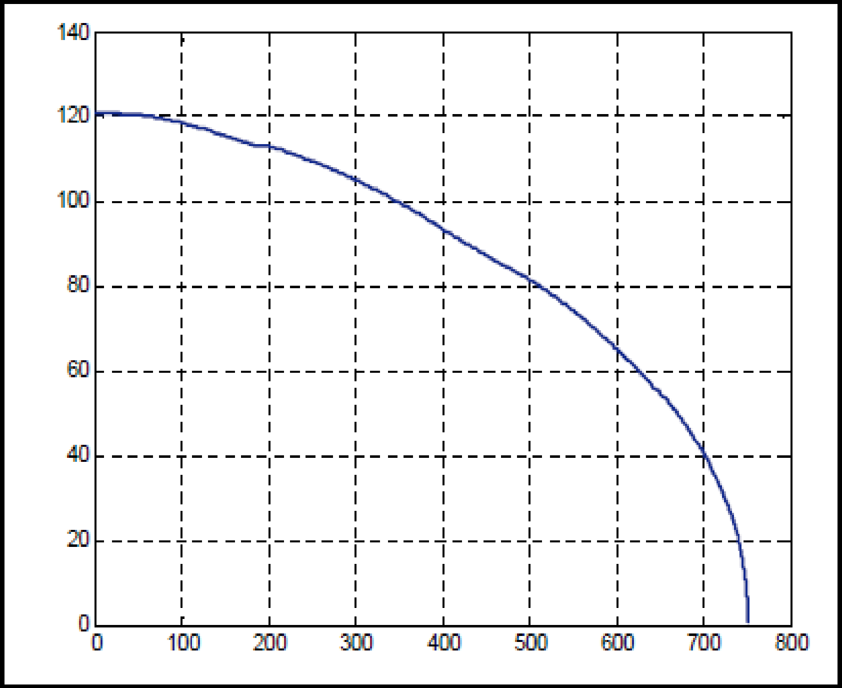
To stop the train in emergency

300 km/h



4500 m

120 km/h



750 m

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ETCS principle of operation

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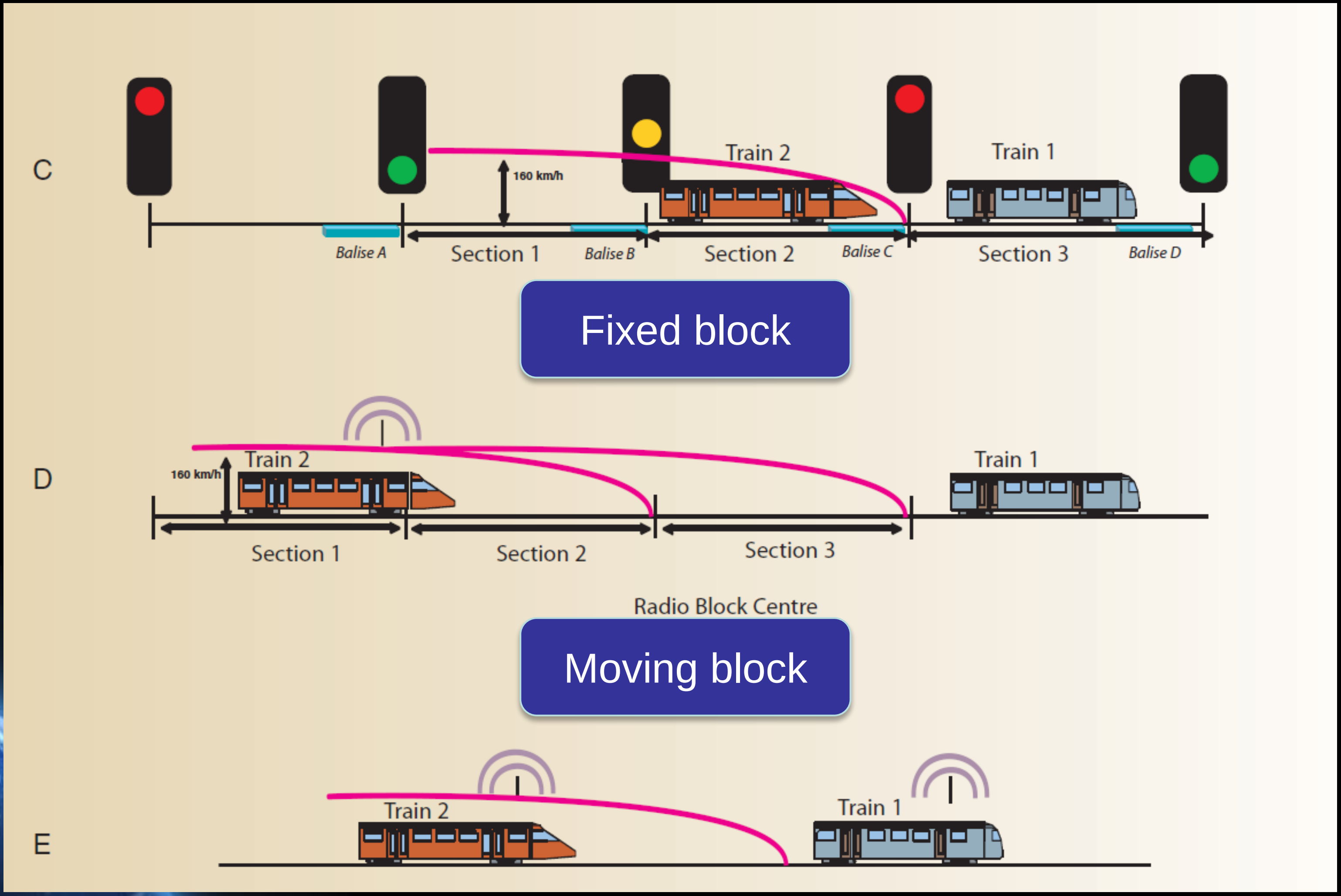
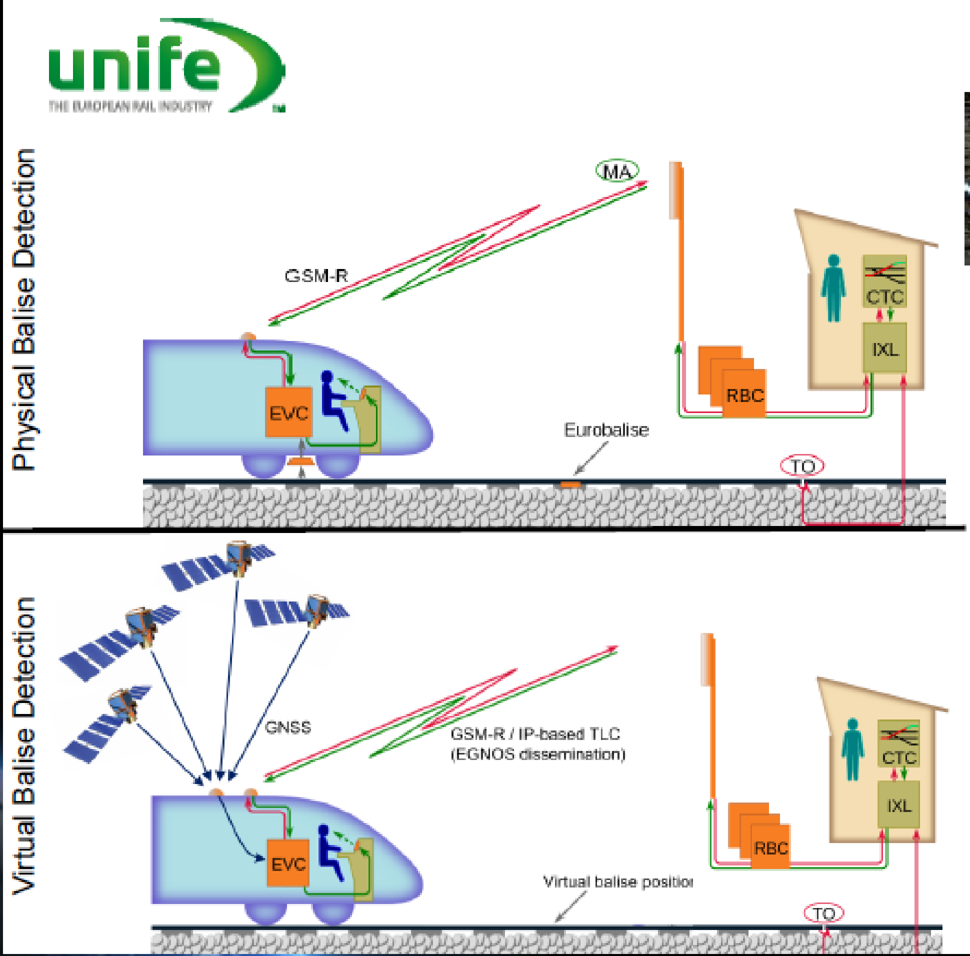


ETCS: European Train Control System

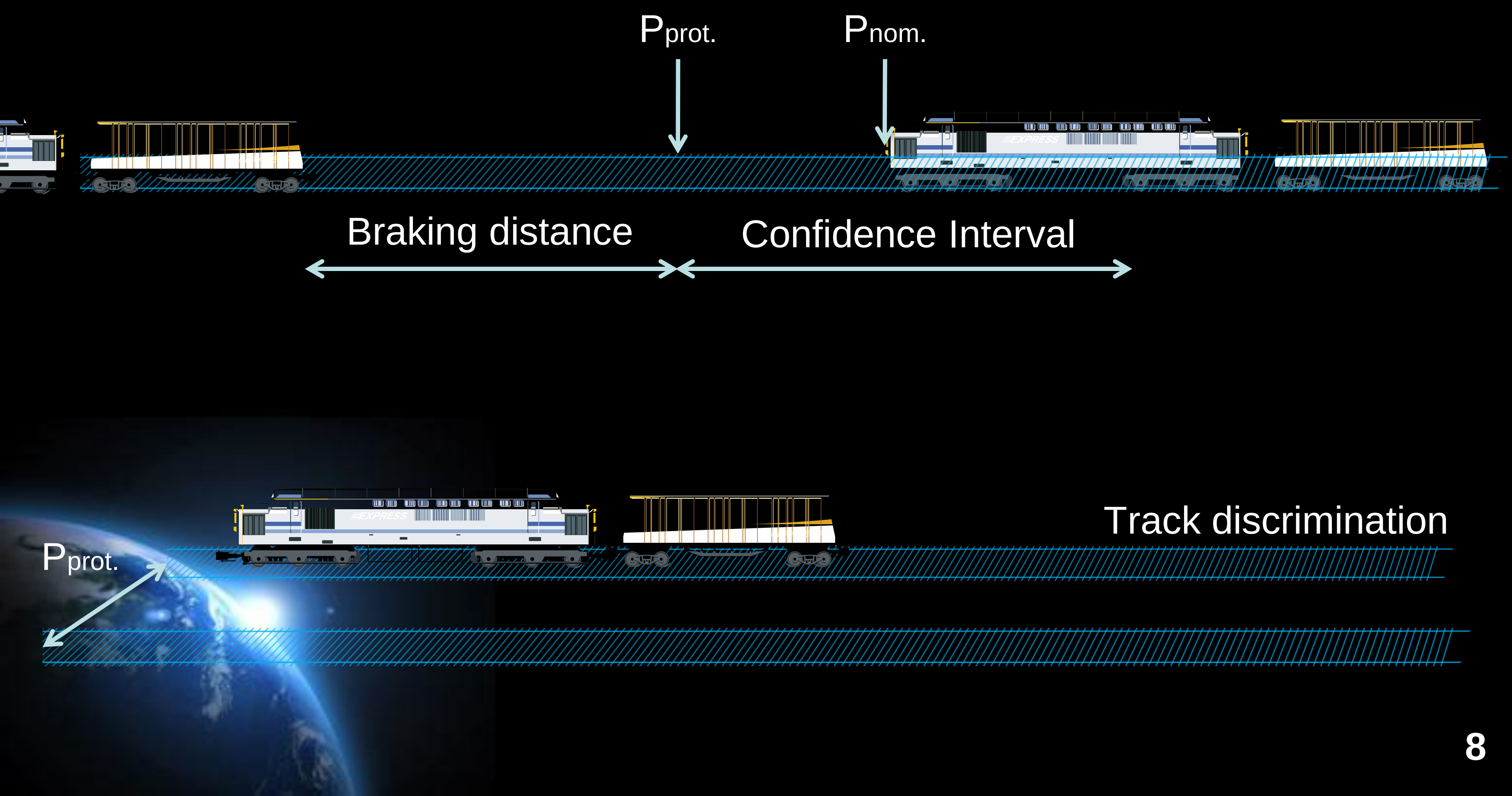
"Virtual Balise Concept"



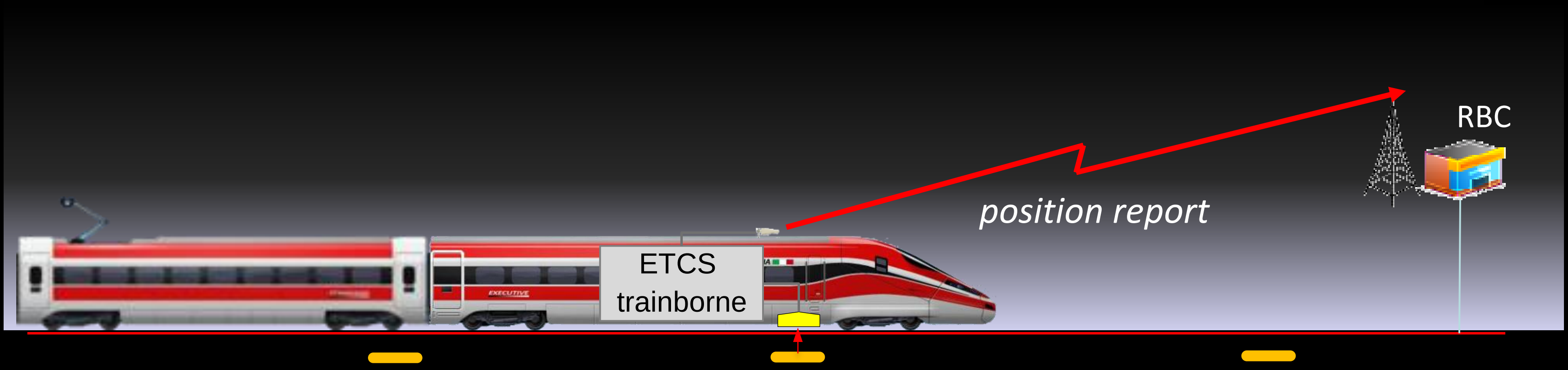
- ETCS - based Train Positioning :
  - ETCS Balise provides an absolute location reference to ETCS on-board
  - Balise information is used by train for locating itself within a "Moving Authority" section
  - Balise-based positioning information allows the trackside (RBC) to position a train, including the track
  - Physical balise is used as well to transmit static data to ETCS on-board (e.g. announcement of ETCS border)

ETCS Safety Requirements

ETCS target Level of Safety: 2.0E-9/hours x train ~ **1 event each 6 years assuming 10,000 circulating trains**

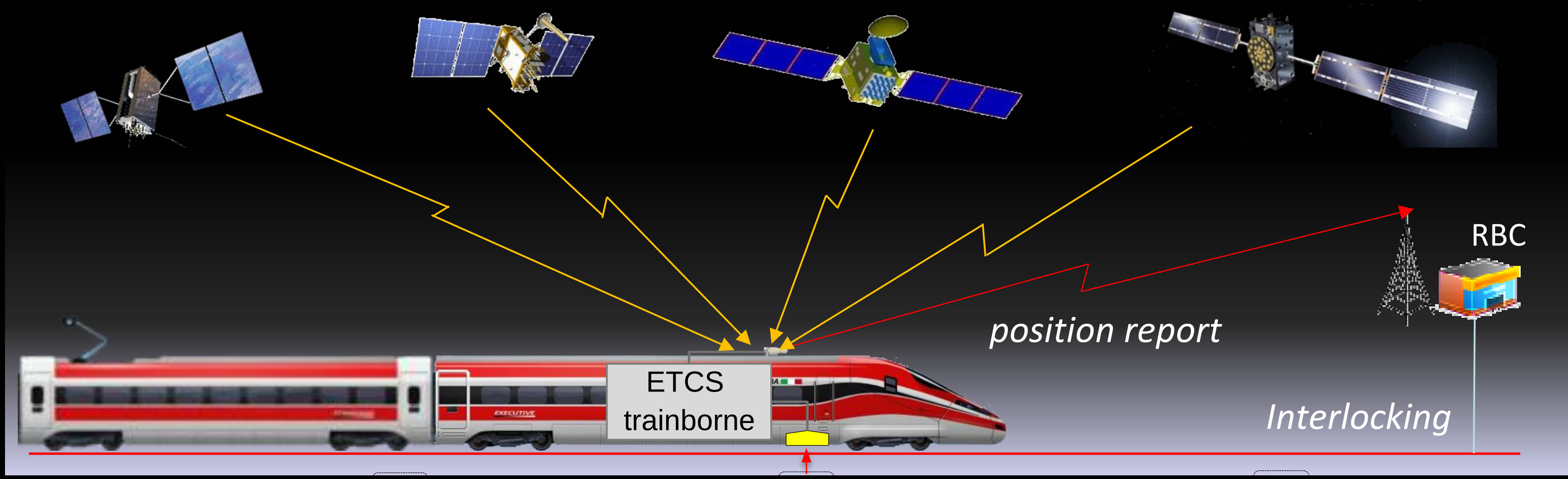


ETCS Train Localization



- In ERTMS/ETCS Train location is determined by means of **BALISES** and **ODOMETRY**
- The Balises are transponders deployed at georeferenced points
- The odometer provides the **relative positioning** w.r.t. the last balise
- When the Balise Reader energizes a balise, it receives a message with the balise Id
- The on board computer (EVC) sends a **POSITION REPORT** to the Radio Block Center

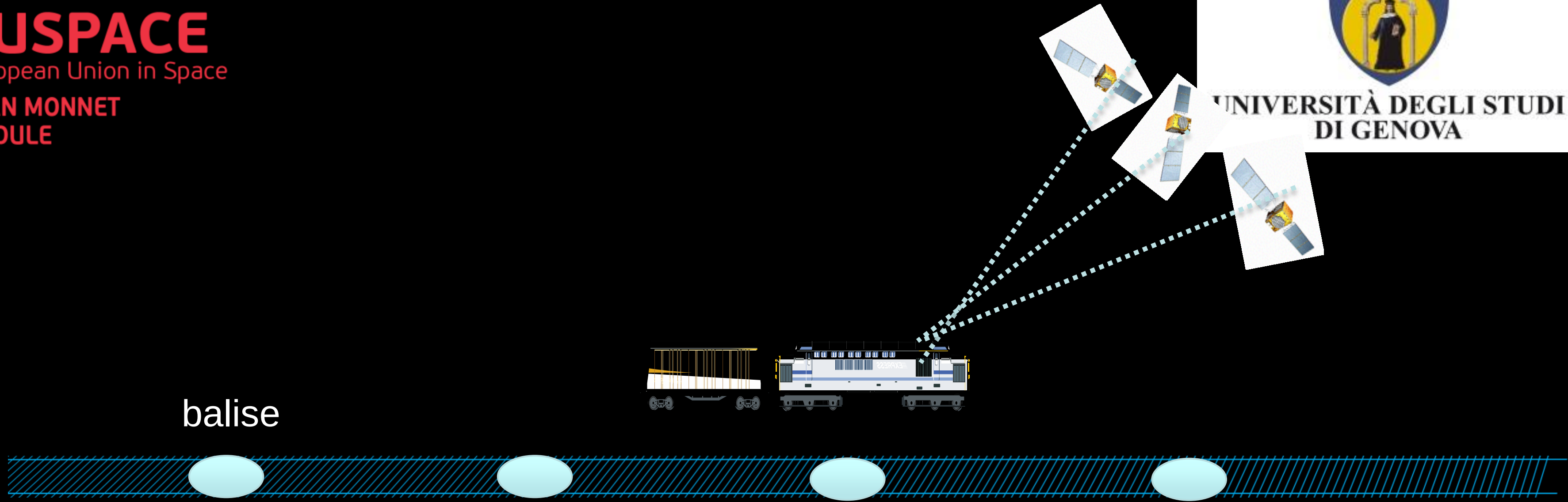
Virtual Balise Concept



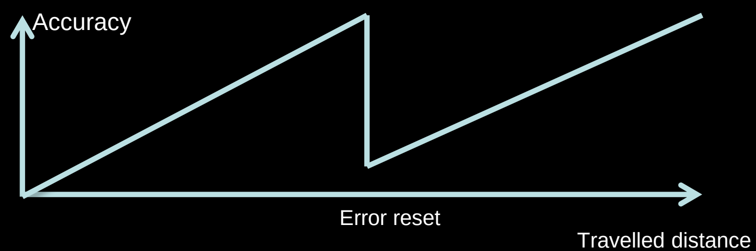
- The GNSS based **VIRTUAL BALISE READER** generates the same information produced by a Balise Reader detecting a physical Balise, through the same logical and physical interface, then emulating the Balise reader behavior with respect to the train equipment.

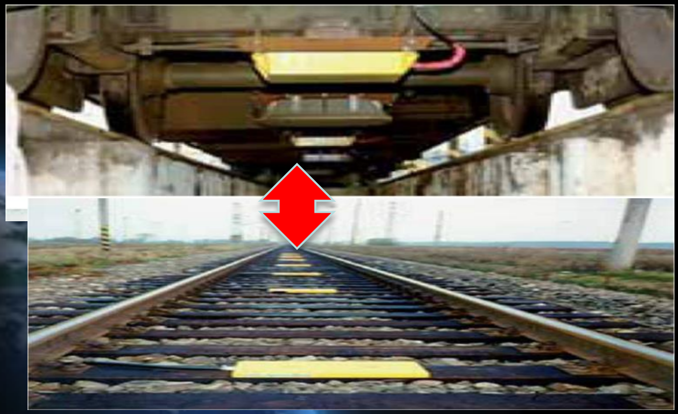
- **In this way the On Board ERTMS/ETCS location determination functions do not need to be changed.**

ETCS Odometric function

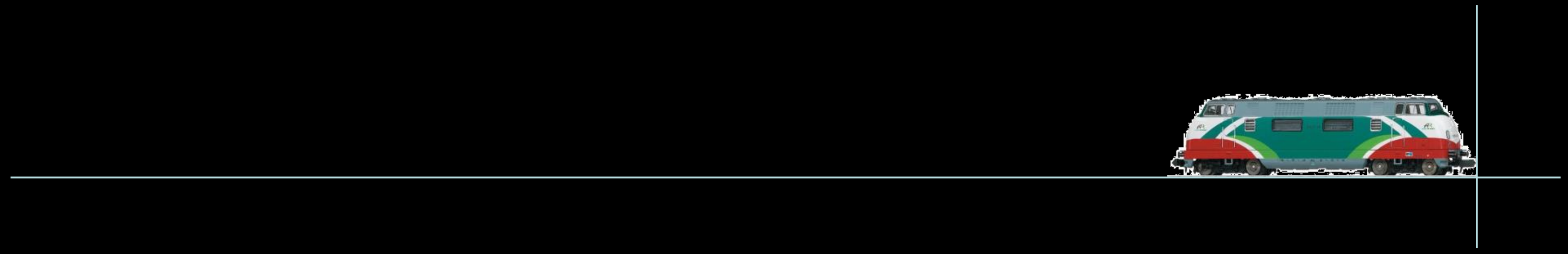


Accuracy: 5m + 5% travelled distance
(SIL 4)



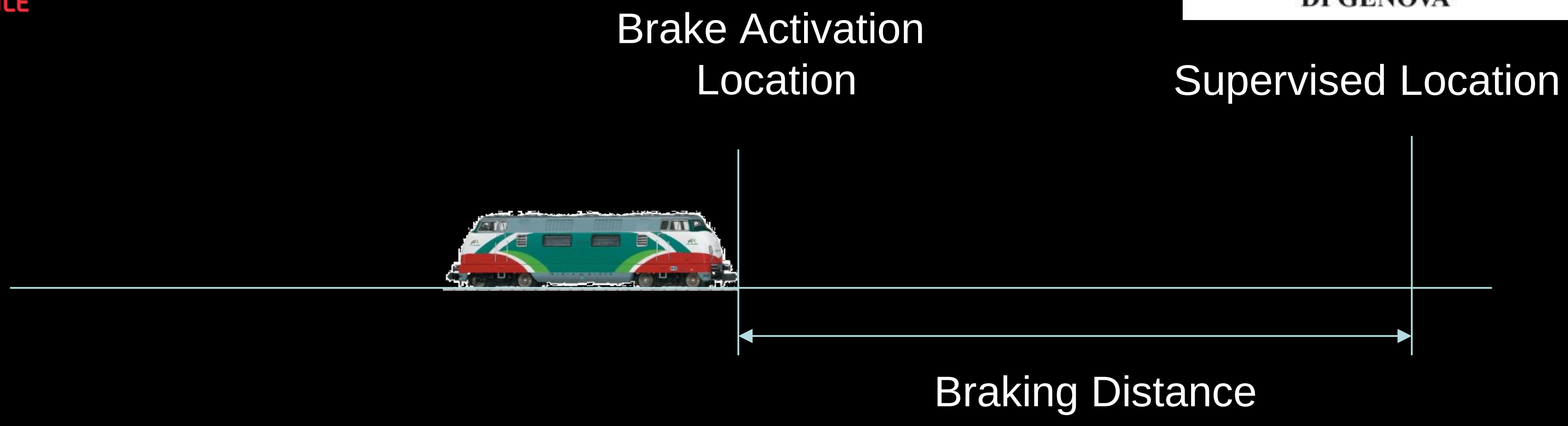


VBR Accuracy Requirements

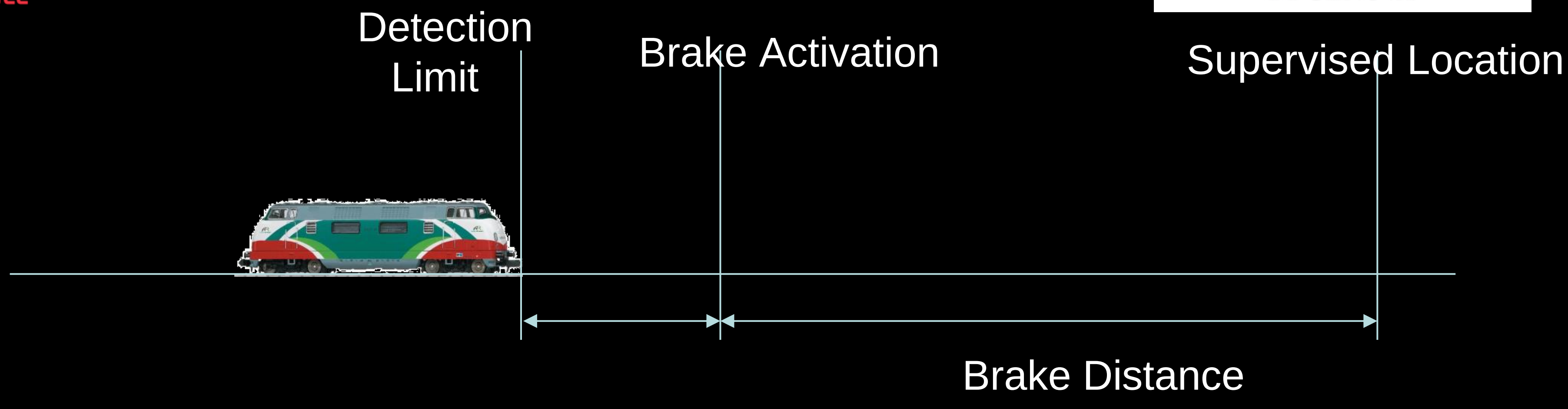


The train shall not trespass the Supervised Location without specific Moving Authority

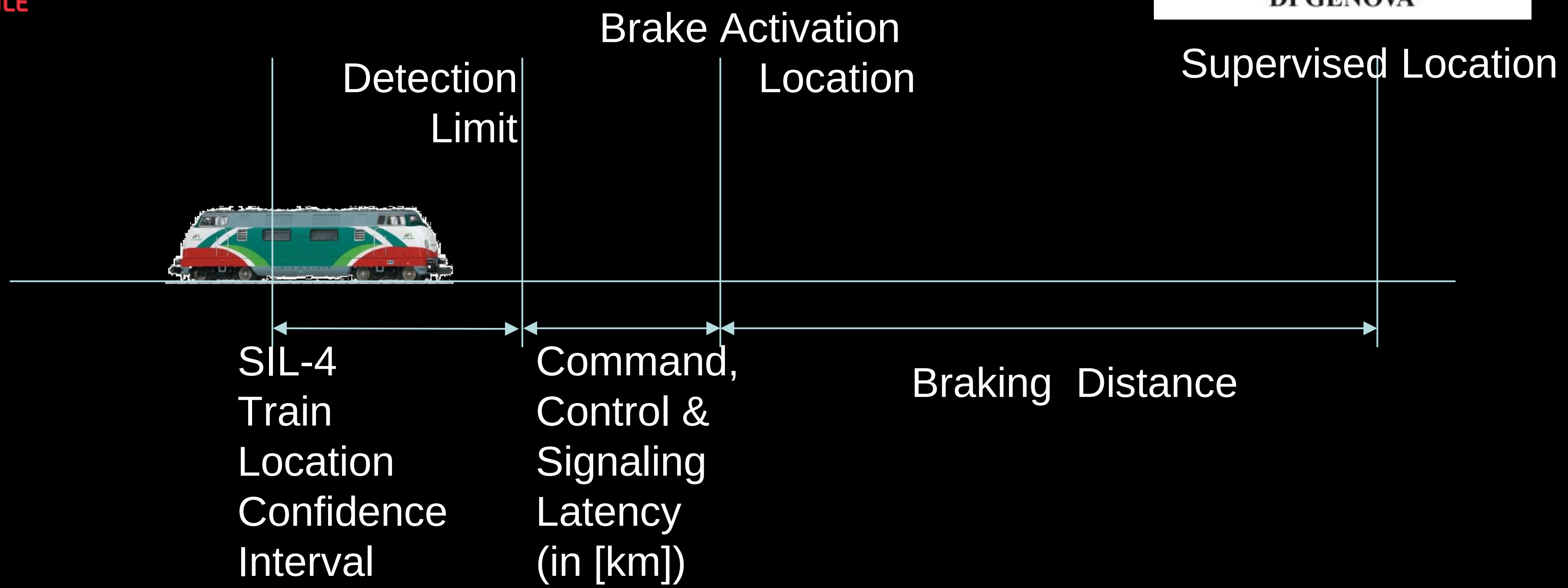
VBR Accuracy Requirements



VBR Accuracy Requirements



VBR Accuracy Requirements



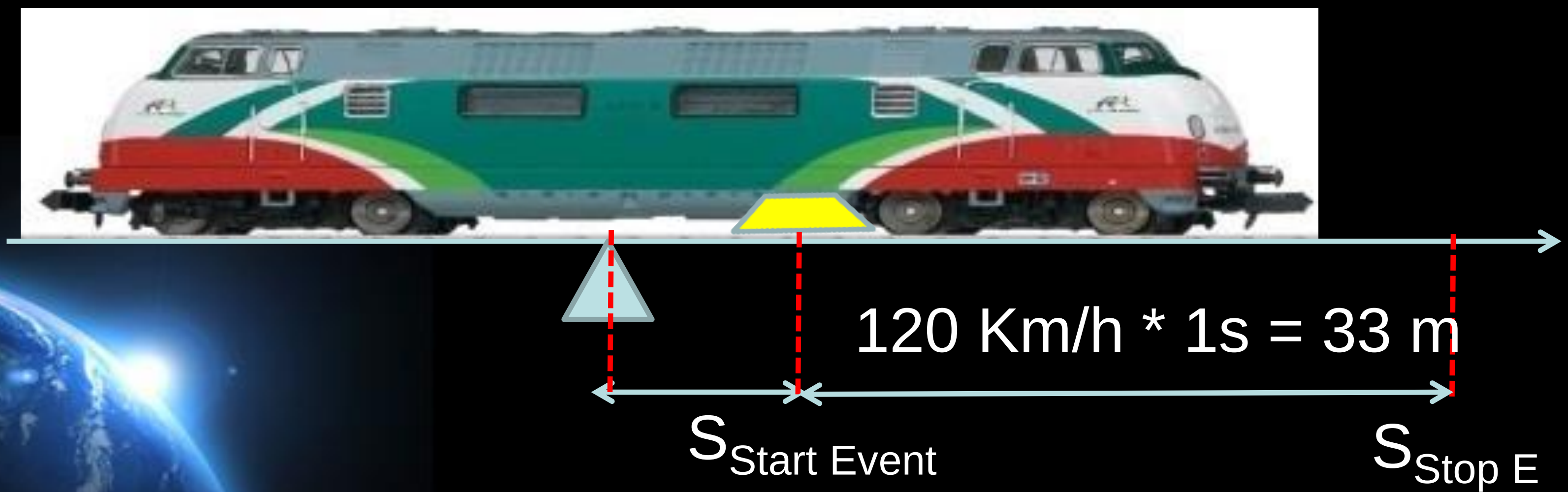
Req.: *To support **INTEROPERABILITY** Infrastructure Managers require that the same engineering rules are employed to deploy physical and virtual balises, In this way heterogeneous traffic consisting of trains equipped with physical BTM and trains equipped with Virtual BR can be handle by a a Radio Block Center, without modifications.*

Additional Requirements

Delay between receiving of a balise message and applying the required action

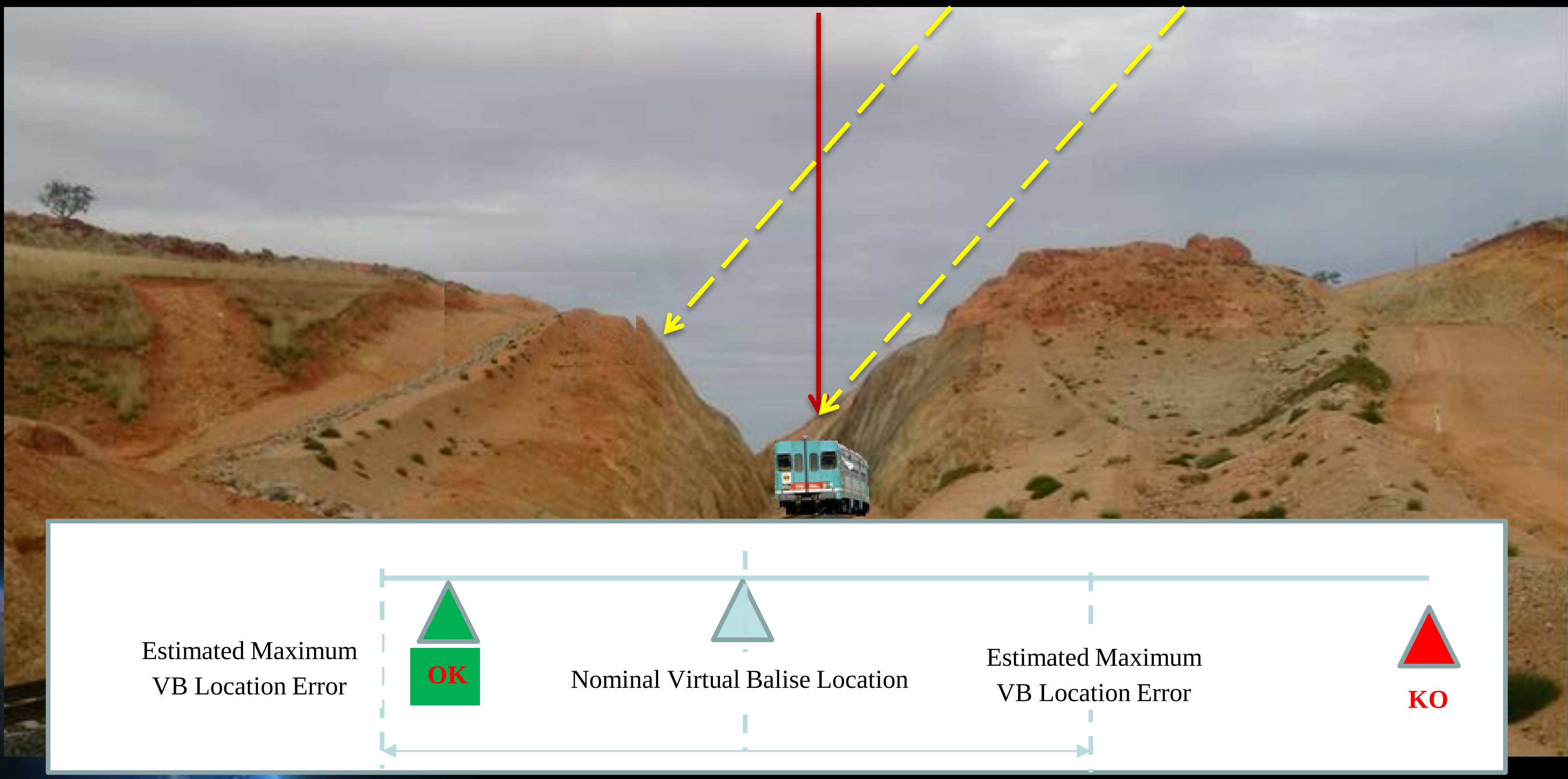
The reference mark of the on-board antenna leaving the “side lobe zone” of the last balise in the group (1.3 m from the reference mark of the balise)

Beginning of applying the required action



Multipath effects

Areas as Suitable or Not Suitable for Locating Virtual Balises



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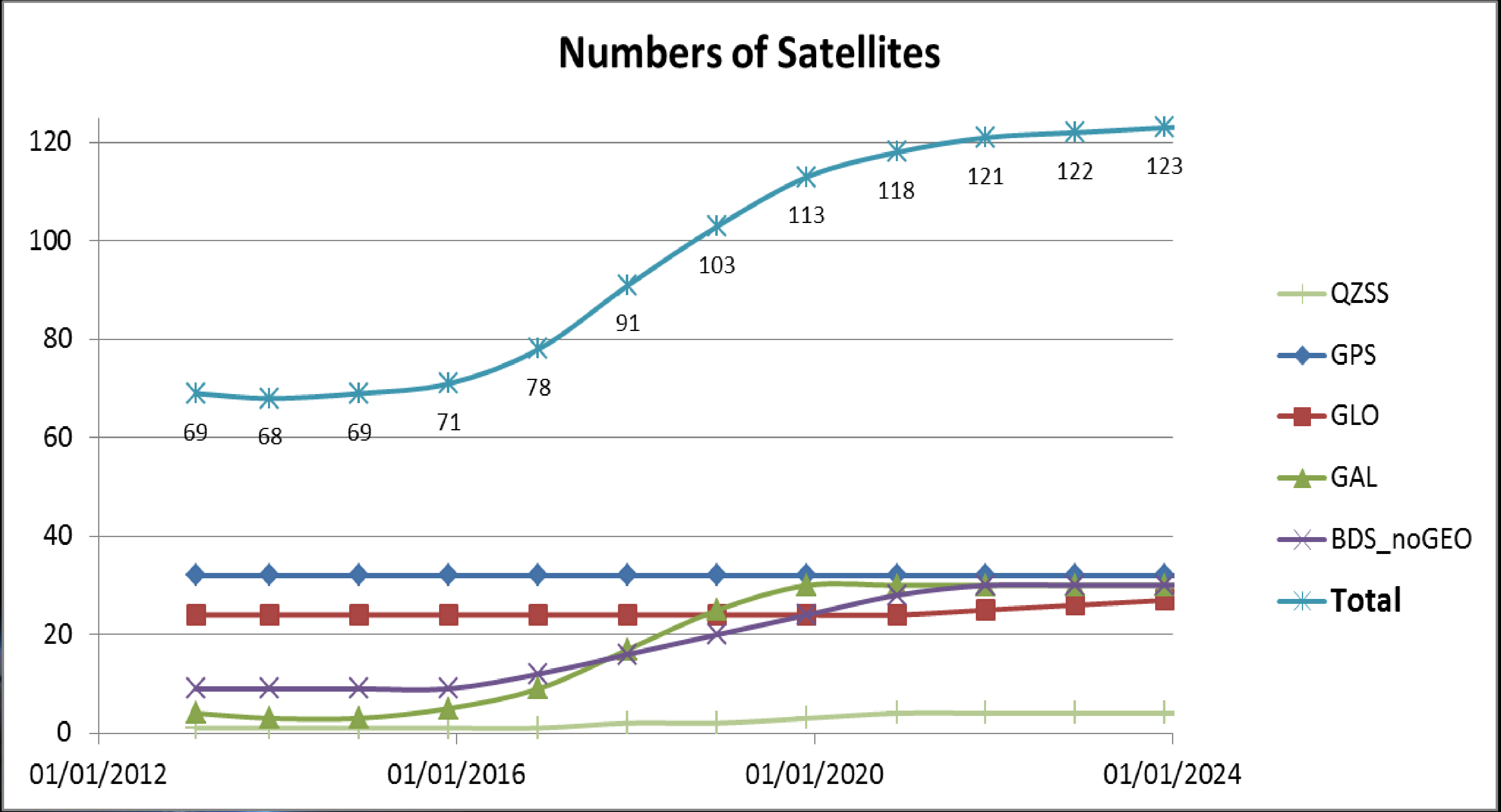
GNSS & 5G: the new Technologies breakthroughs

GNSS evolution



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GPS Accuracy

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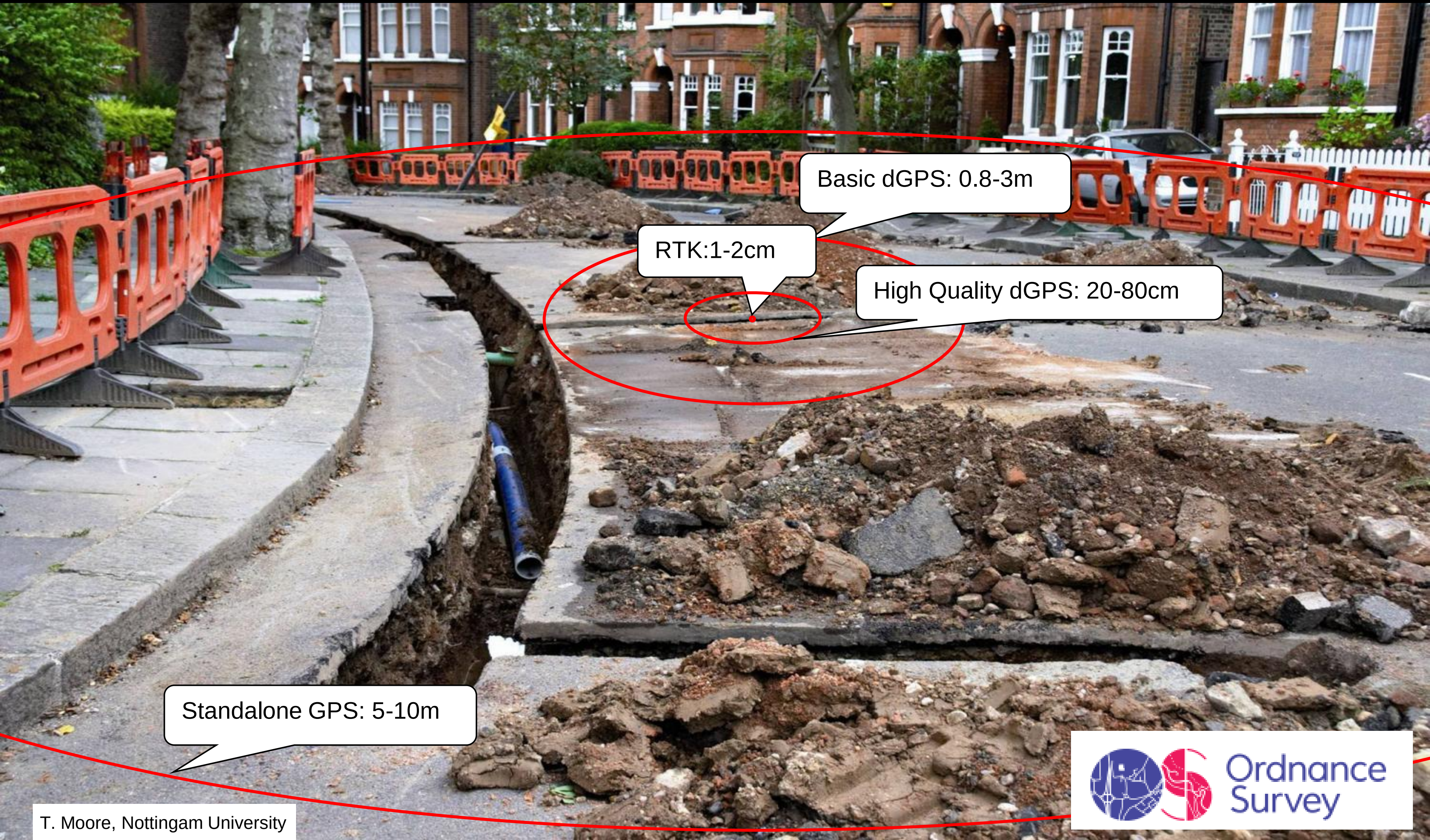

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Our 5G vision: a unifying connectivity fabric

5G

Enhanced mobile broadband

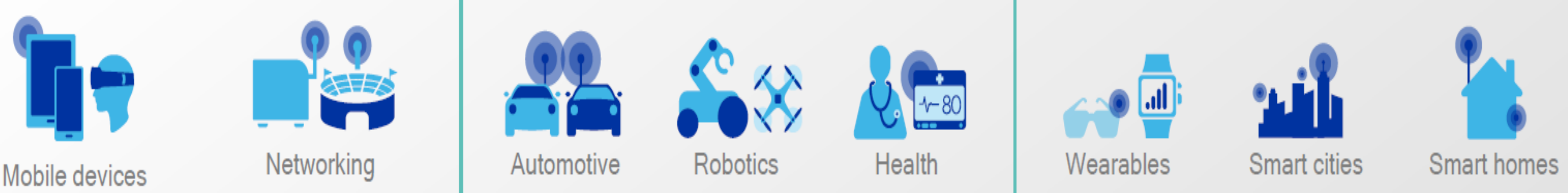
- Multi-Gbps data rates
- Uniformity
- Extreme capacity
- Deep awareness

Mission-critical services

- Ultra-low latency
- High availability
- High reliability
- Strong security

Massive Internet of Things

- Low cost
- Deep coverage
- Ultra-low energy
- High density



Unified design for all spectrum types and bands from below 1GHz to mmWave

Ref. Qualcomm

Diversified Challenges and Gaps to Reach 5G

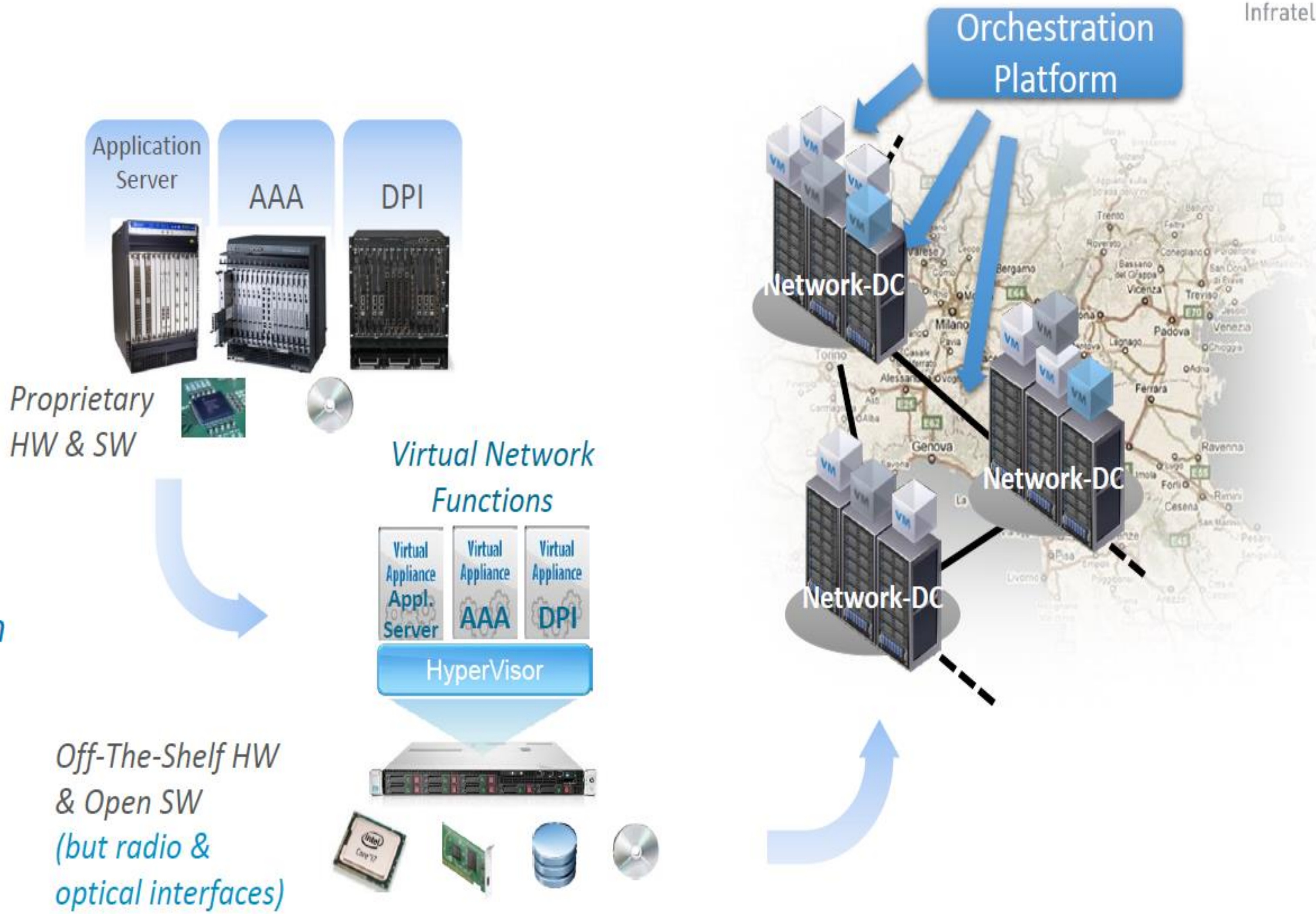
	Latency	Throughput	Connections	Mobility	Network Architecture
5G	1 ms E2E Latency	10Gbps Per Connection	1,000K Connections Per km^2	500km/h High-speed Railway	Slicing Ability Required
GAP	30~50x	100x	100x	1.5x	NFV/SDN
LTE	30~50ms	100Mbps	10K	350Km/h	Inflexible

Challenges because many of these requirements are conflicting

Source: Huawei, 2016

Network Virtualization

Cloud Computing:
Network Virtualization



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Italy on the forefront of innovation in rail

The Italian Rail Network

Lines classification related to the traffic development

(6%) **~ 1000 km** — **High Speed Network**

Command Control System : ERTMS/ETCS L2
Train spacing with radio block

(5%) **~ 950 km** — **Metropolitan Traffic Lines**

Command Control System : CTC, SCC, SCC-M
Train spacing with short block sections (High Capacity)

(18%) **~ 2.900 km** — **Fast Lines**

Command Control System : CTC, SCC
Train spacing with SCMT

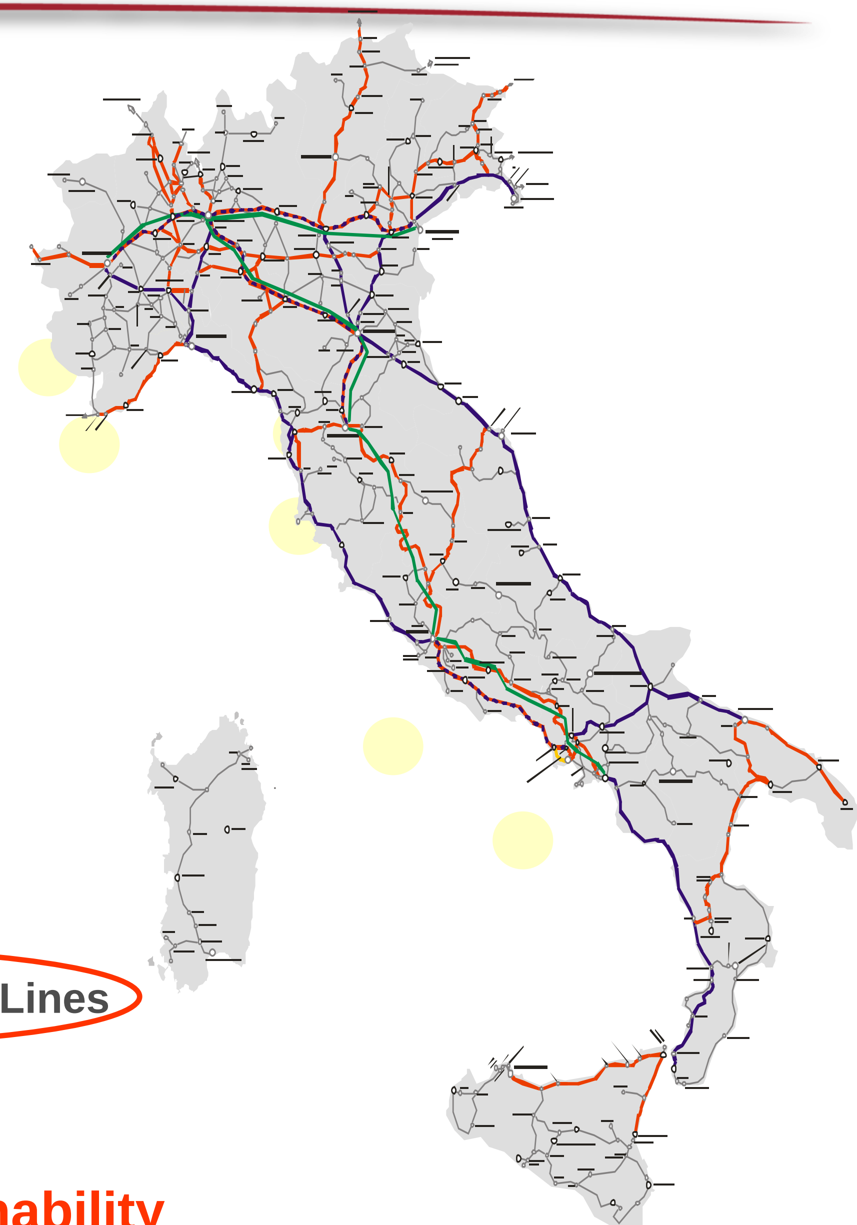
(23%) **~ 3.900 km** — **Middle performances + Freight lines**

Command Control System : CTCev, SCC
Train spacing with block sections: SSC,SCMT

(48%) **~ 7.950 km** — **Subsidiary + Low Traffic Lines**

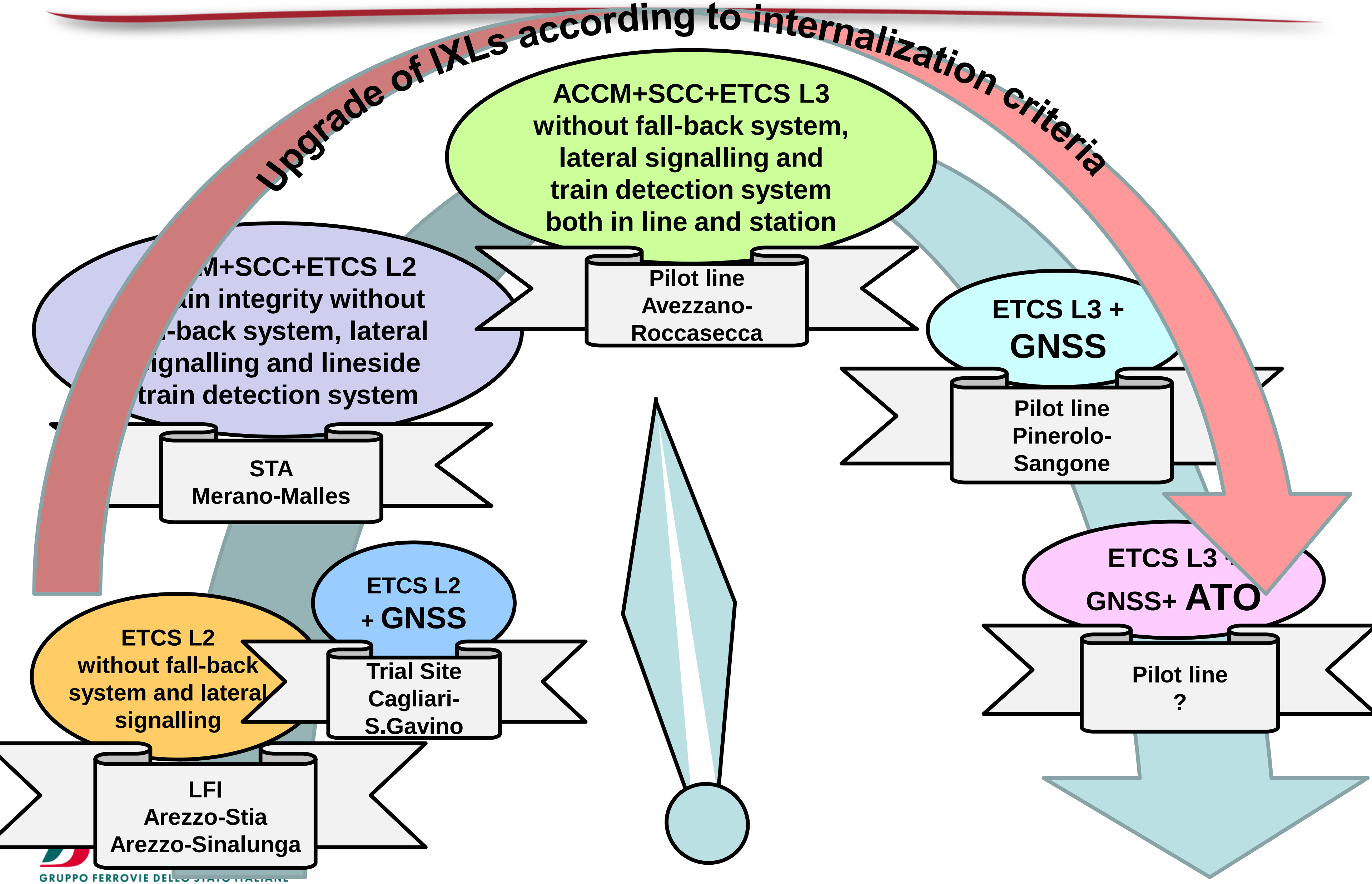
Command Control System : CTC
Train spacing with block sections: SSC

Economic Sustainability

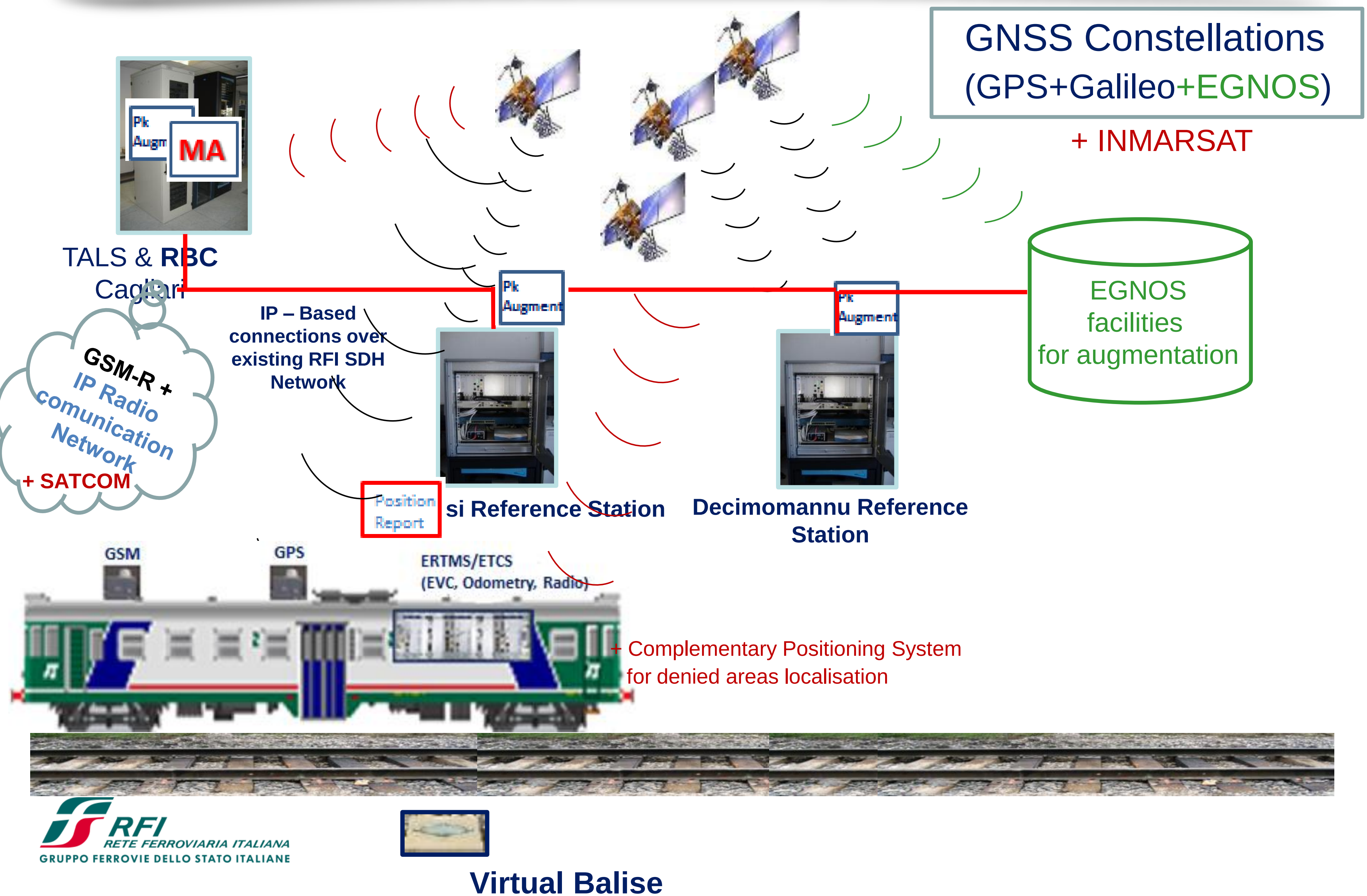


RFI RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

Main steps of an incremental strategical way



Functionality of ERSAT Trial Site



Satellite Application Development Plan

2012 | 2013 | 2014 | 2015 | 2016 | 2…

3InSat

GNSS Signalling Demonstrator

GSA

ERSAT
ERTMS-ETCS Test Site

ERTMS application

Commissioning Pinerolo – Sangone First Pilot Line By 2020

Regional & Local lines renewal at lower costs, with higher capacity and ensuring the highest safety level of ERTMS

Validation and Certification

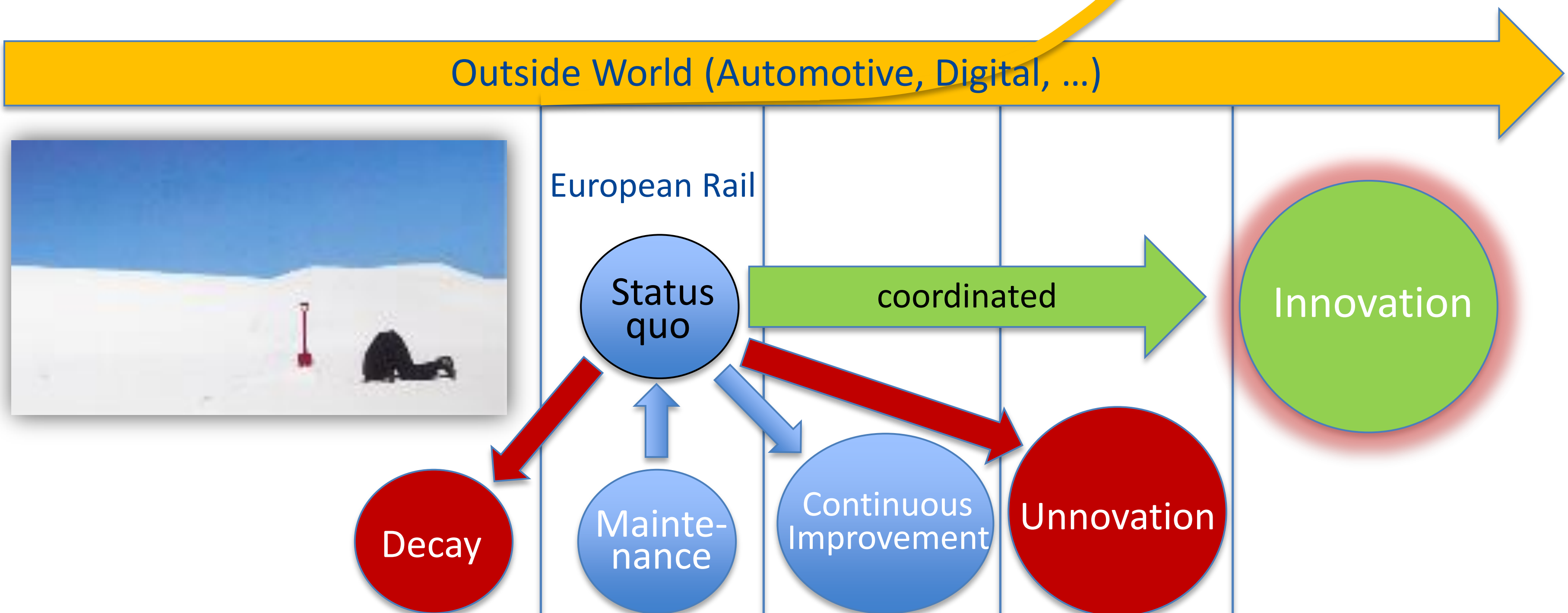
RFI
RETE FERROVIARIA ITALIANA
GRUPPO FERROVIE DELLO STATO ITALIANE

From Rail to Automotive

http://www.radiolabs.it

Ansaldo STS S.p.A. – Hitachi Systems CBT S.p.A.
University of Rome "Tor Vergata" – University of "L'Aquila" – Università of Rome "Roma Tre"

The European Railway System Needs to Innovate!



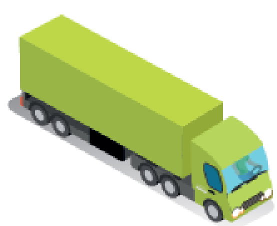
Aspect					
Novelty	-			+++	+++
Scalability	-			-	+++
Better	-		+	-	+++
Faster	-		+	-	+++
Cheaper	-		+	-	+++
More customised	-		+	++	+++

Road Transport landscape

Sector mobility: **5%**

The Mobility sector employs more than 11 million people, accounting for 5% of total employment.

Almost **50%** of freight transport

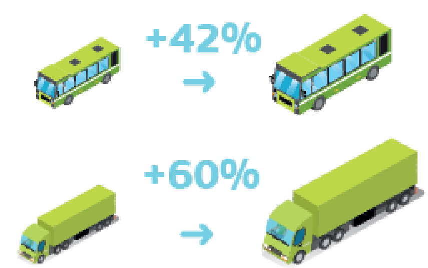


Road transport accounts for almost half of the total freight transport activity

13% of household expenditure

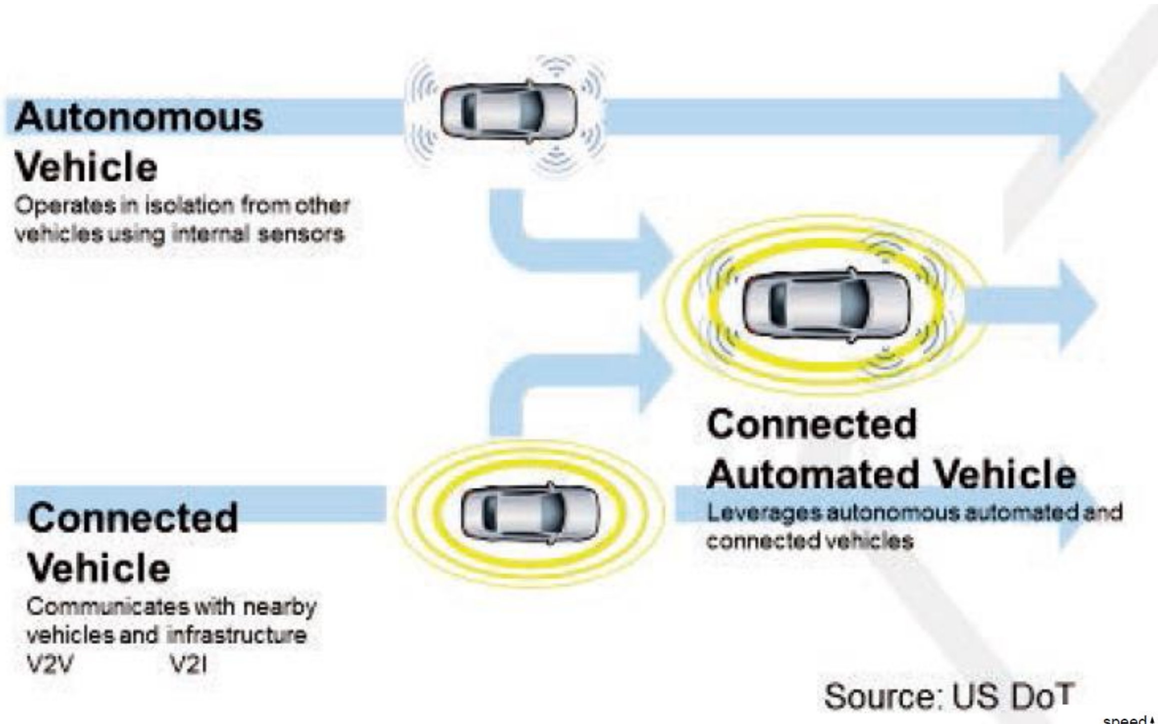
Transport accounts for 13% of the total household expenditure

2010 2050

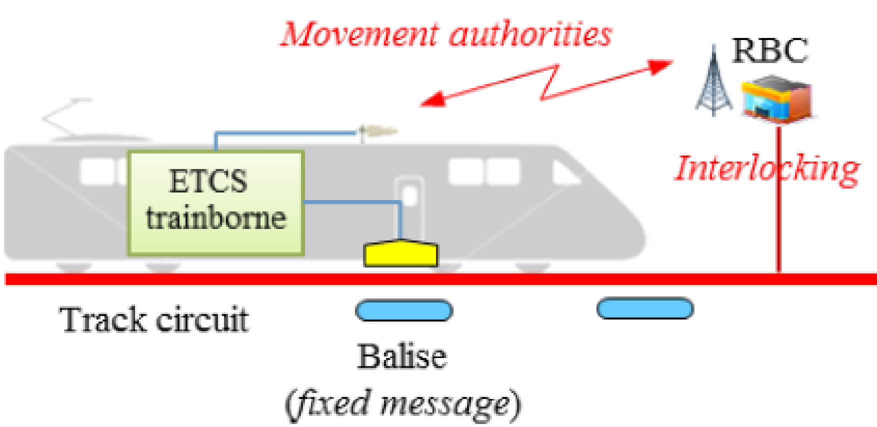


From 2010 to 2050, it is estimated that passenger transport will grow by about 42 per cent. Freight transport is expected to grow by 60 per cent

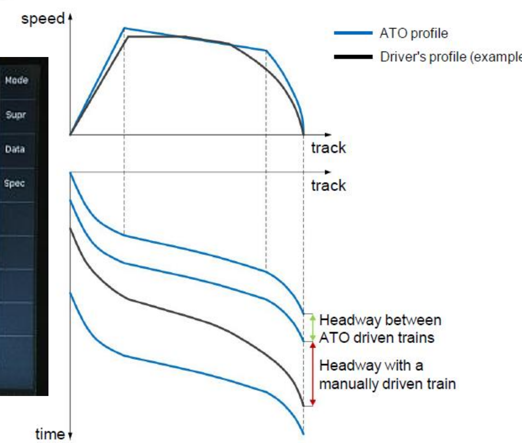
From Connected to Autonomous Vehicle



Source: US DoT



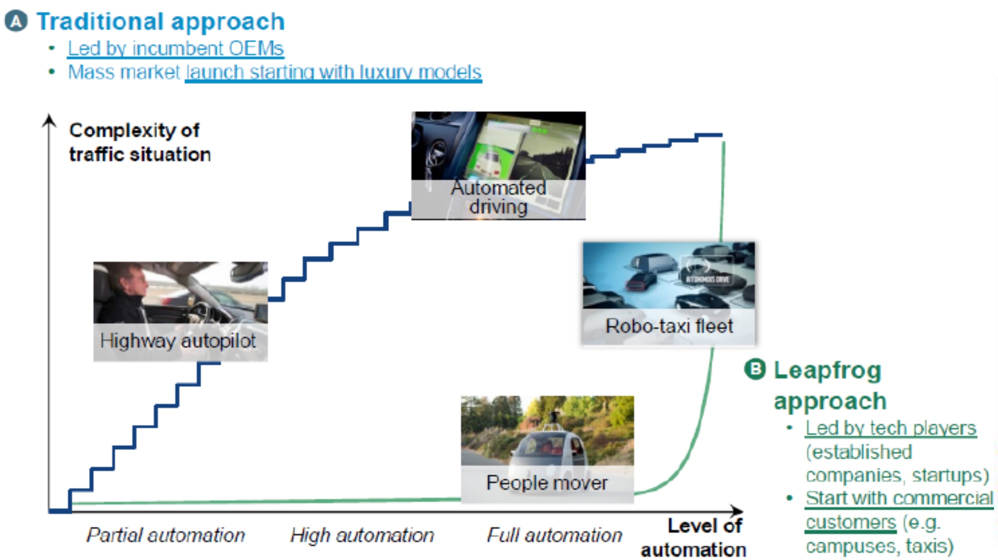
DMI – with «safe» commands

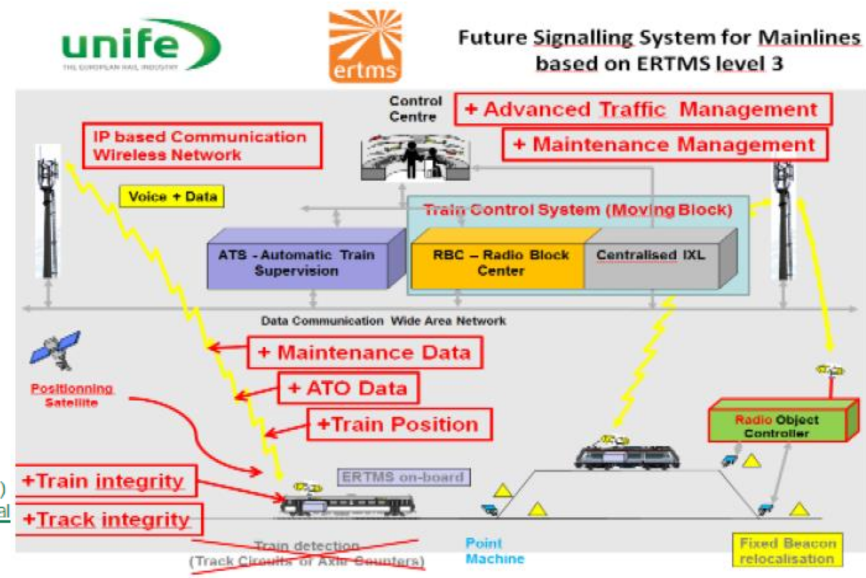


Speed control

ERTMS Level 2 architecture

Autonomous vehicle landscapes





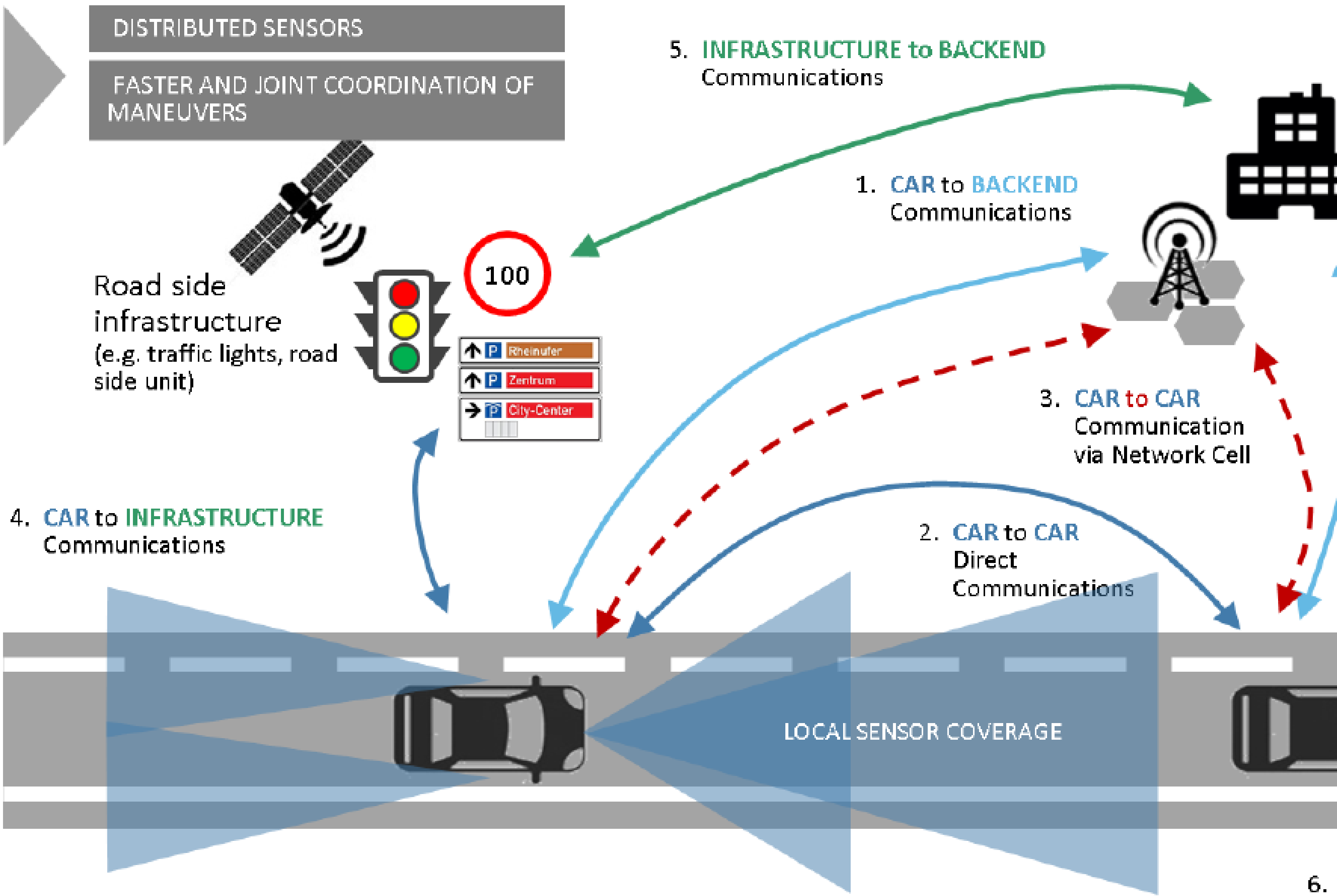
Connected car

Local maps with electronic & cooperative horizon
Cybersecurity
Cooperative navigation function
Safety margin for vehicles

From ERTMS L2 to L3

Local maps of railways enironment
IP-based communications
Autonomous vehicle positioning
Train integrity monitoring

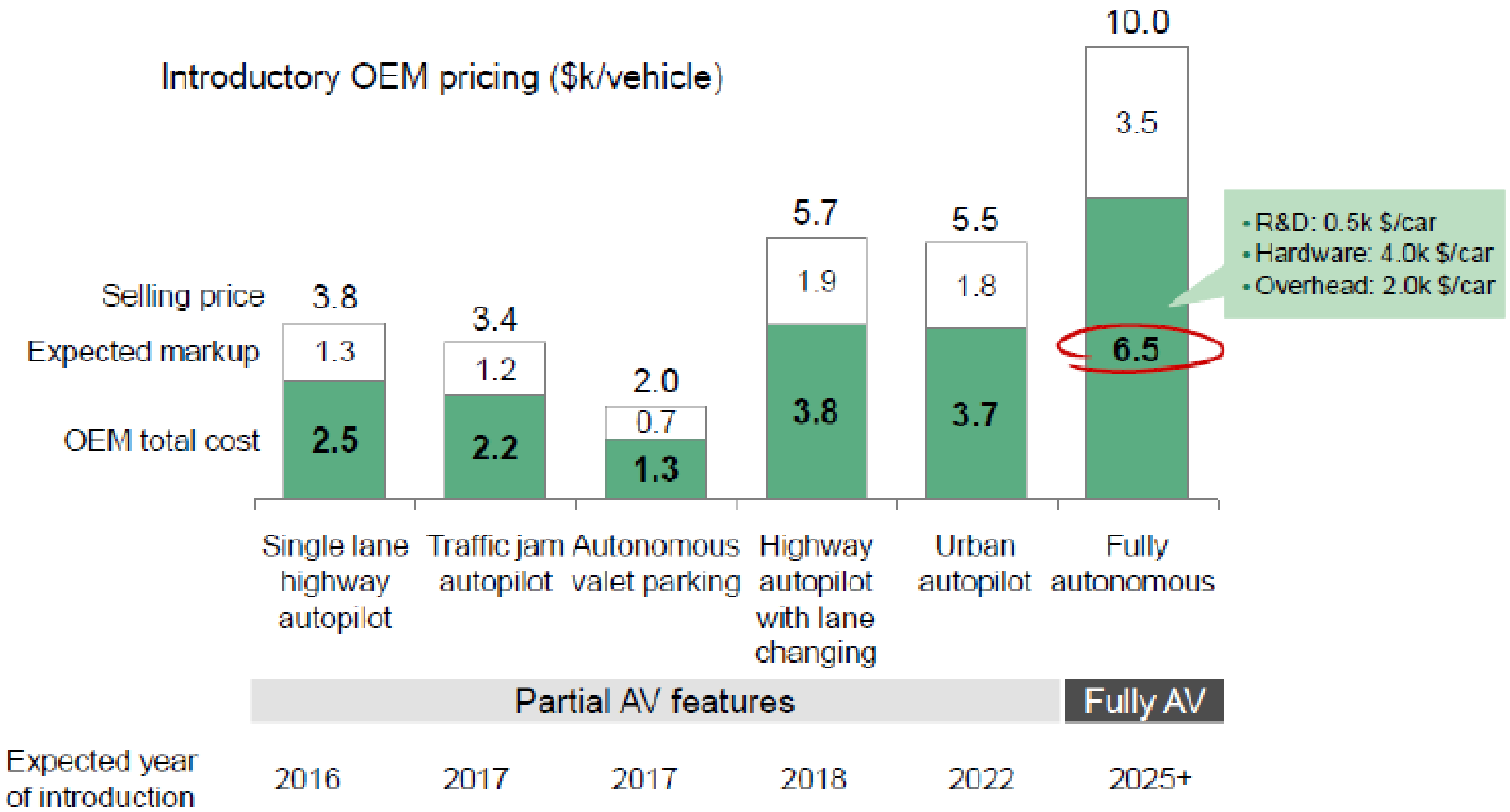
Communications in the Future



Levels of Automation according to SAE

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

Cost forecast vs level of automation

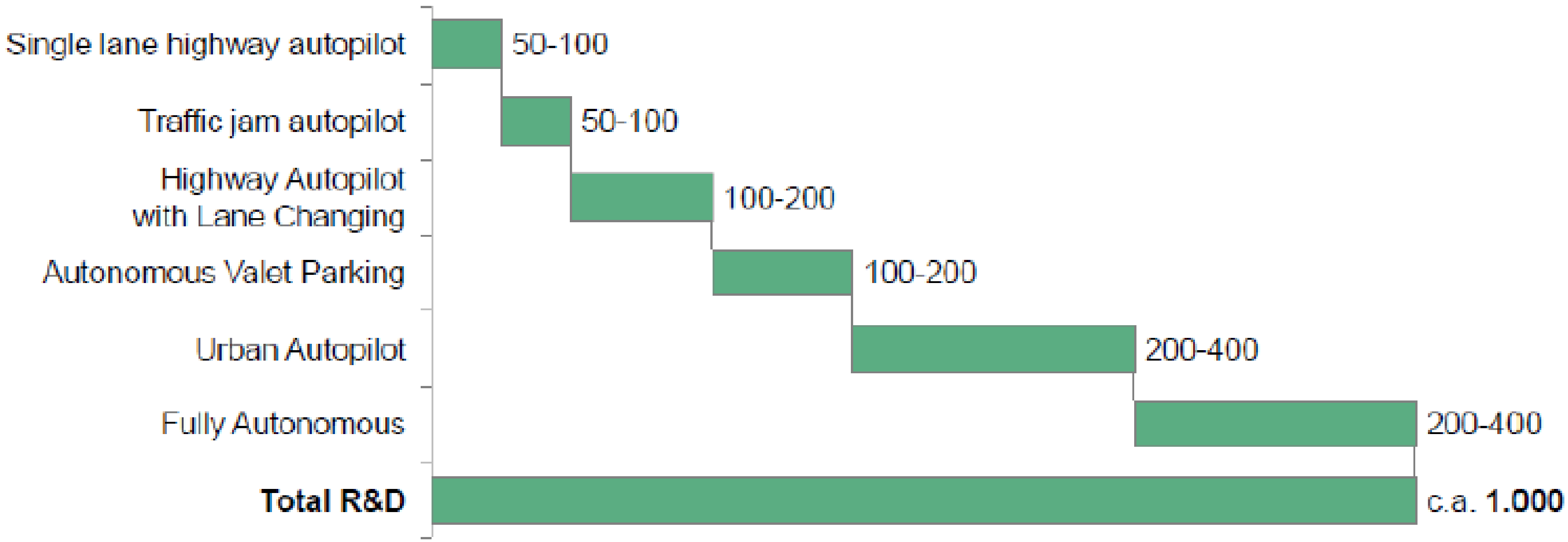


Forecast R&D cost for car manufacturers

RadioLabs

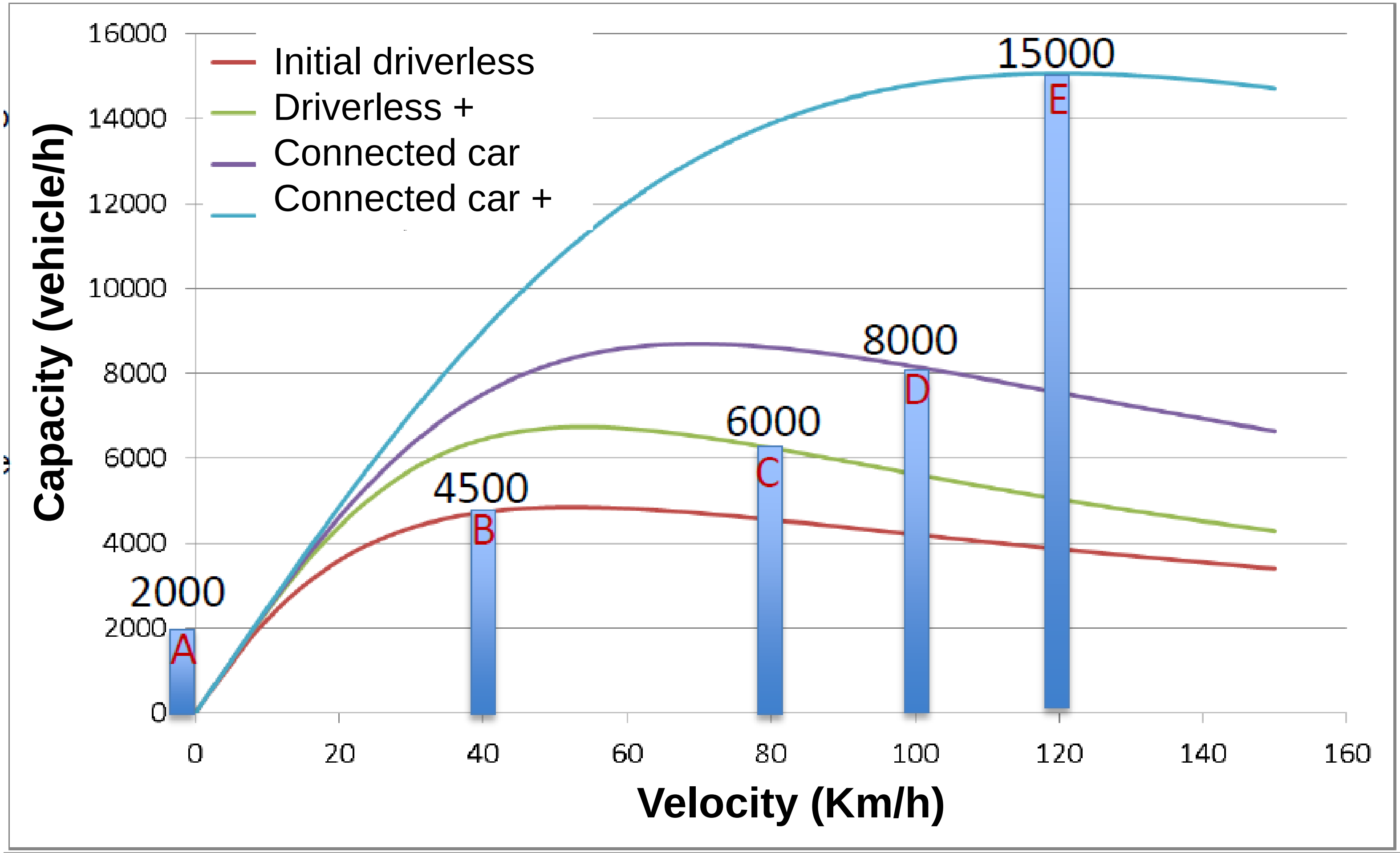
Total R&D cost per OEM (M $)
- Research and engineering personnel cost[1]
- Validation and testing cost[1]
- Supplier markup

Range estimation



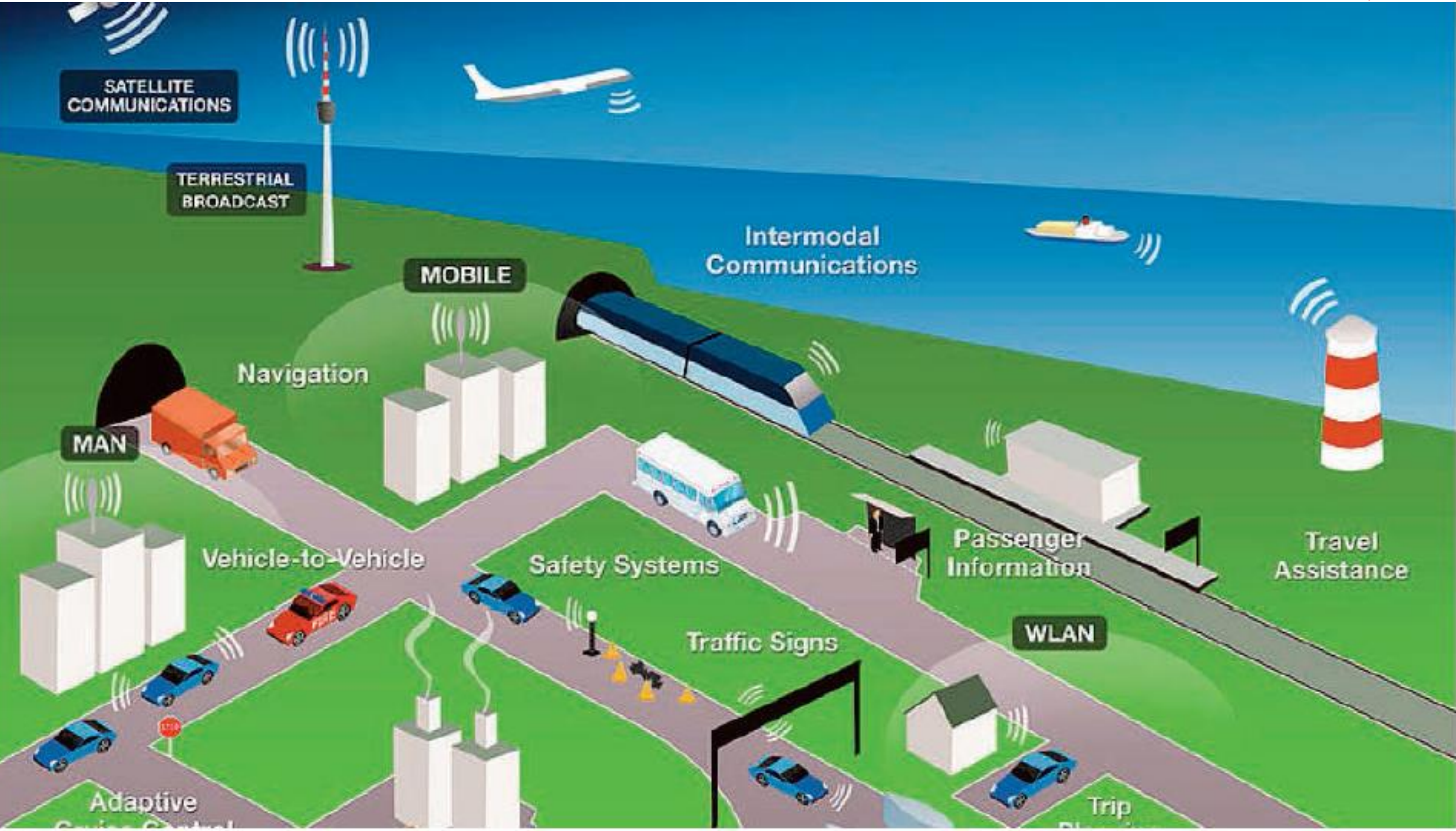
Cost expected to be amortized over total sales volumes in ~3-7 years

Traffic capacity vs automation levels



A Converging landscape

RadioLabs



Fanara 2016b

Rio Tinto AutoHaul: 1st driverless train

180 Trains monitored and controlled via satellite links, less manpower on site

- More productivity because driver changeover times are eliminated avoiding workers to travel more than 43,000 miles each week to get train drivers to where they start or end shifts, with a train trip from a mine to a port lasting 40 hours.

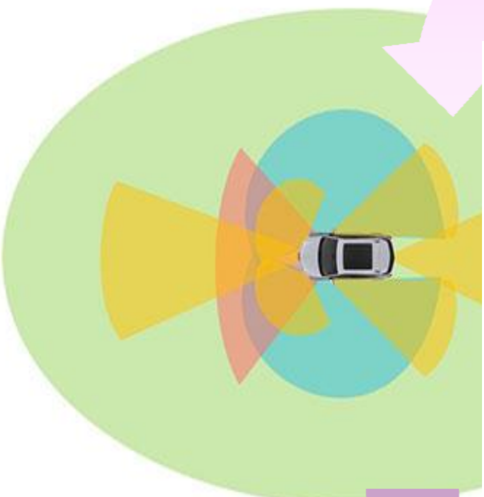
- Trains would also not have to stop to switch drivers twice a day, as they currently have to do to relieve workers (20 to 30 minutes to undertake a controlled stop of locomotives each time a shift changeover is required and further 20 minutes to restart).

http://www.mining-technology.com/features/featurerio-tintos-driverless-train-woes-4944523/

Sinergy Car-Trains towards autonomous vehicle

Localization «accurate» and «safe»
Real time reaction of the vehicle

Automatic Train Control
Centralized intervention in case speed or train stop exceed prescribed values

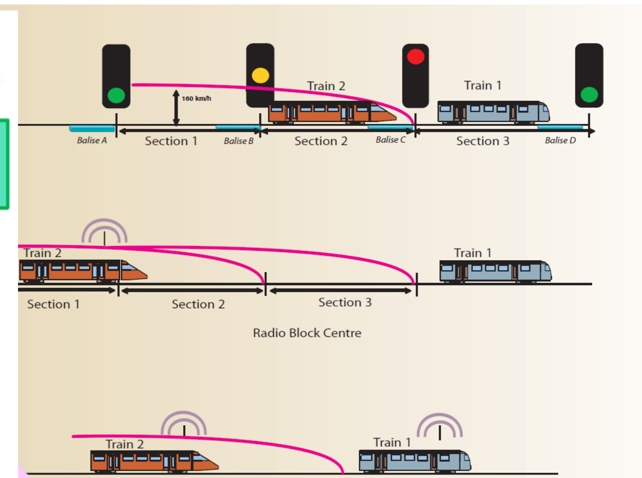


Driveless car: Need of Safety and Interoperability

Technological exchange Rail and Automotive
(eg.:Ferrovie dello Stato Italiane & ANAS)

ER²TMS
- Railway
- *Road ??*

F.Senesi, Workshop ERSAT EAV, Cagliari 24 February 2107

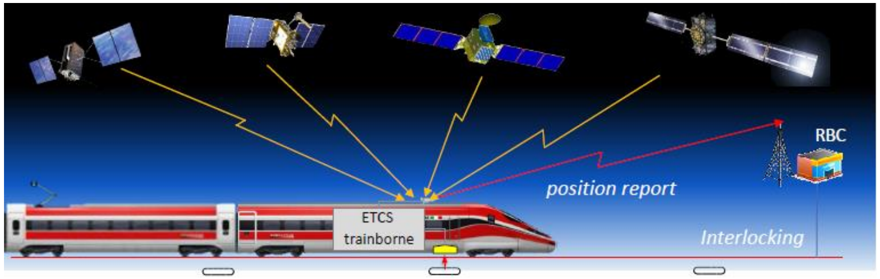


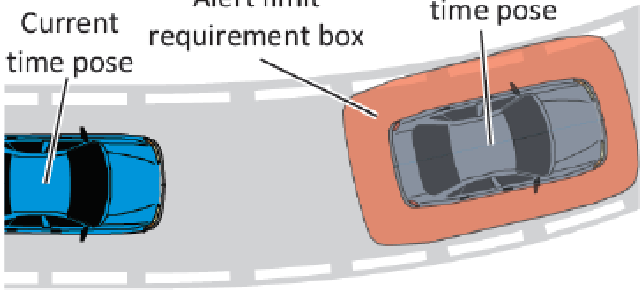
New sensors on vehicle
Road-Rail ICT-Infrastructures

From «centralized» control to autonomous vehicle

- **Video-GNSS positioning**
- **Federated Au Networks**

Car & train operate on similar «environment»





Tolerable Hazard Rate for VB detection: $THR_{VB} < 10^{-9}$ per hour

SIL 4

A purely experimental approach is not sufficient

In the U.S., car accidents cause over 30,000 deaths/year, 90% of which are due to human error [NHTSA '14]

- 3 trillion miles driven per year
  - **1 fatality per 100 million mile driven (MMD)** →

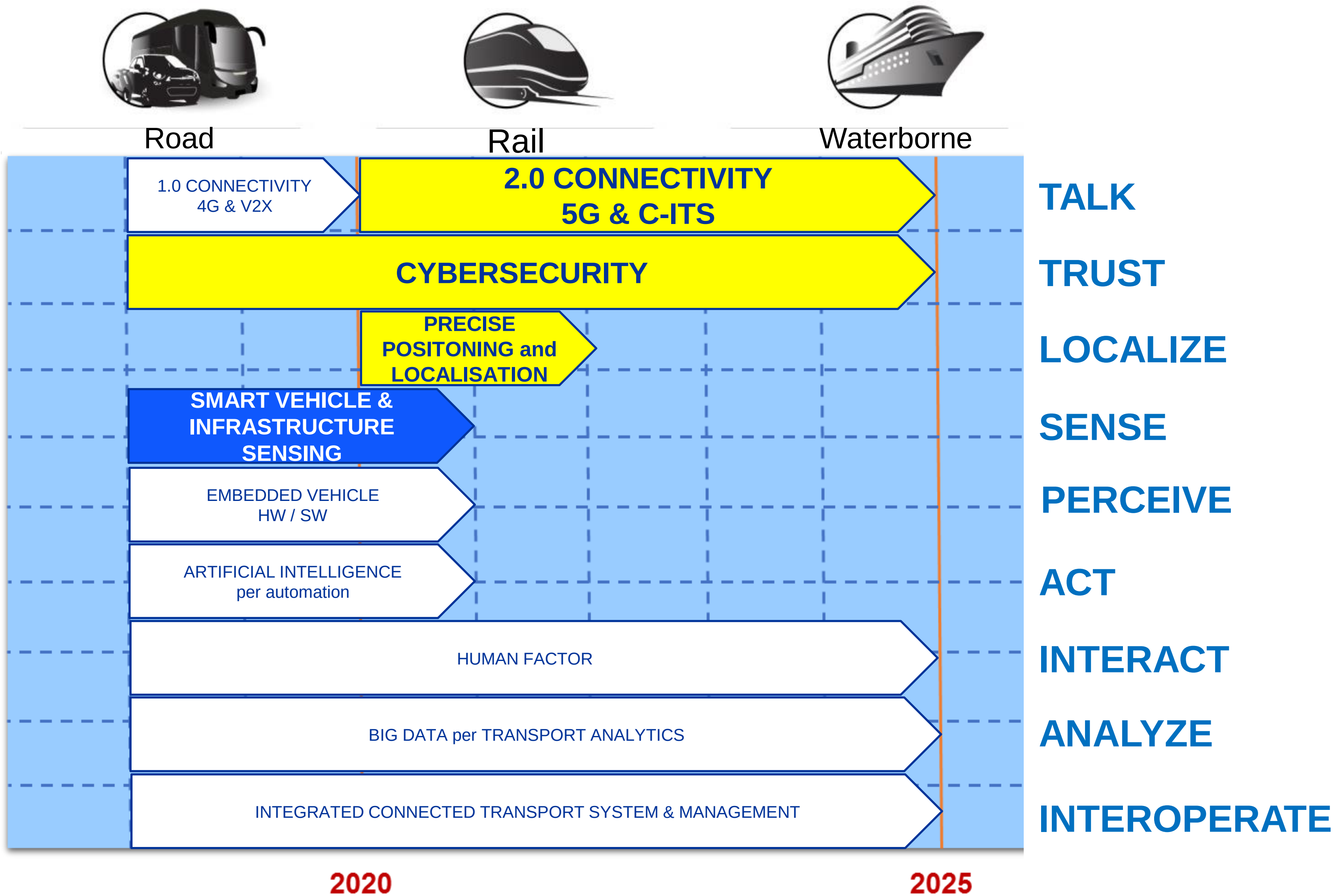
Leverage analytical methods used for train safety

0 fatality on
~ 360 M km year on RFI network

No collisions since 2007 on the RFI network thanks to the Automatic Train Control systems which protect about 100% of railways traffic (ANSF, April 2017)

[NHTSA '14] fars.NHTSA.dot.gov, "Fatality analysis reporting system. Technical report, National Highway Traffic and Safety Administration," 2014

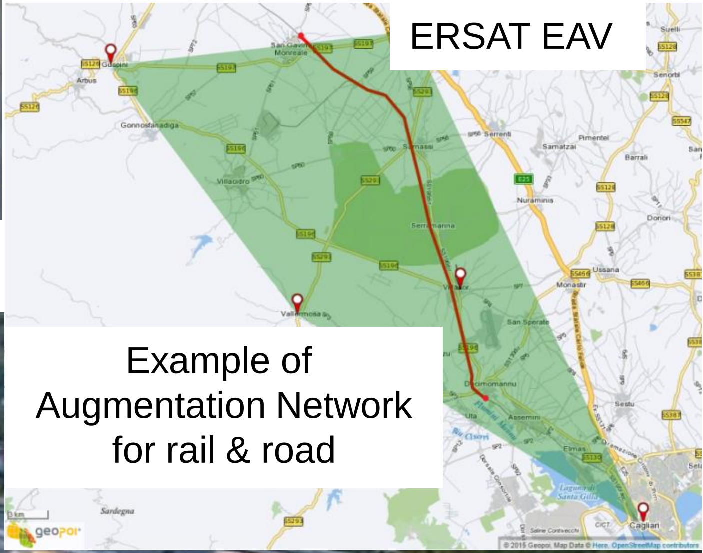
ROADMAP automated & connected vehicles (Mar. 2017)

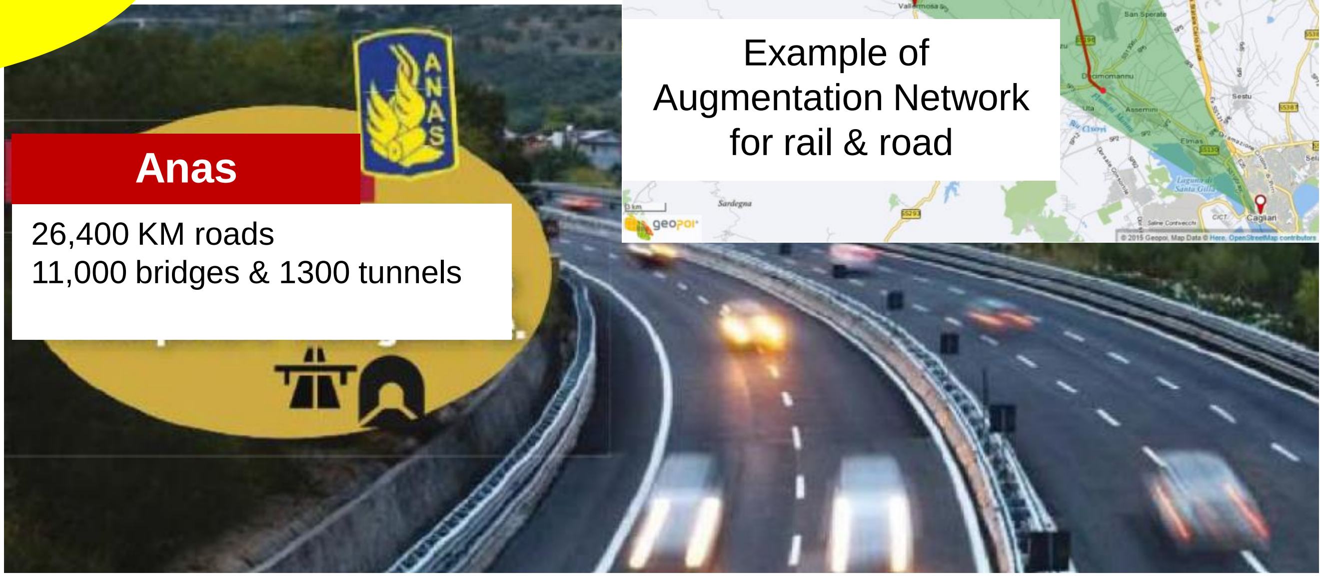


Sinergy rail-roads key to «optimize» ITC infrastructures

RFI & Ansaldo *First Mover* in Europe for the certification of the system based on satellite technologies

«Italian Rails are a technological *benchmark on international level The Signalling system conceived by FS has been adopted in all Europe»**





*«Digitalization that made possible our Rails to distinguish at international level should be implemented also on the roads»**

* Renato Mazzoncini CEO, FSI

… and let’s not forget the benefits of Galileo dual frequency

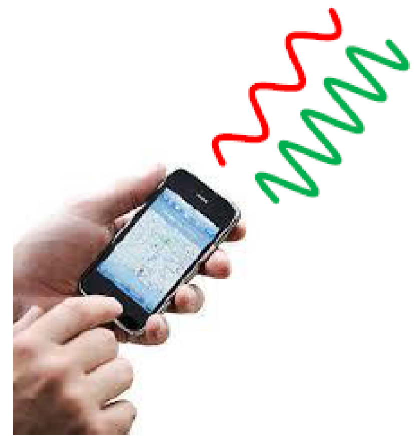
Advantages of dual frequency

Better accuracy
- Ionosphere error correction
- Faster and more reliable carrier phase ambiguity resolution

Increased robustness
- Reduce vulnerability risks of GNSS signals to jamming and/or spoofing

Why L5/E5 is the best solution for a second frequency?

- A protected frequency
- There will be soon more L5/E5 satellites than L2C satellites
- Shared by all GNSS and all SBAS
- More widely separated from L1, thus minimising the iono-free linear combination errors



Specific key advantages of L5/E5 signal

- Better multipath mitigation and better accuracy using L5/E5 signals vs using L2C
- Higher received power for L5/E5 vs L2C

One step ahead: safe as rail, affordable as for automotive

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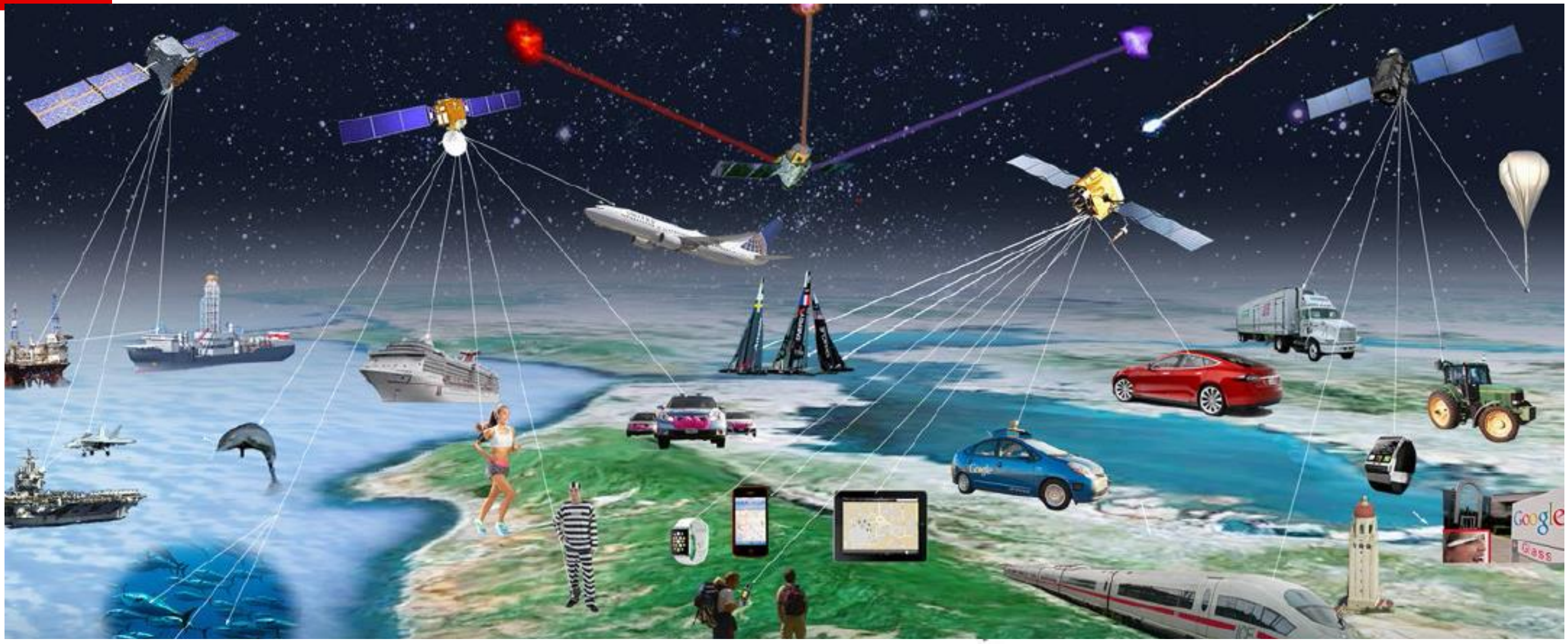

HIGHWAY OF THE FUTURE

Rail & Road → a «*Give & Take*» *paradigm*

Standard – Certifiable - Interoperable

RFI RETE FERROVIARIA ITALIANA GRUPPO FERROVIE DELLO STATO ITALIANE

asi agenzia spaziale italiana

DLR

GSA

esa

The University of Nottingham

EUSPACE
European Union in Space
JEAN MONNET MODULE

Next challenge: GNSS Liability

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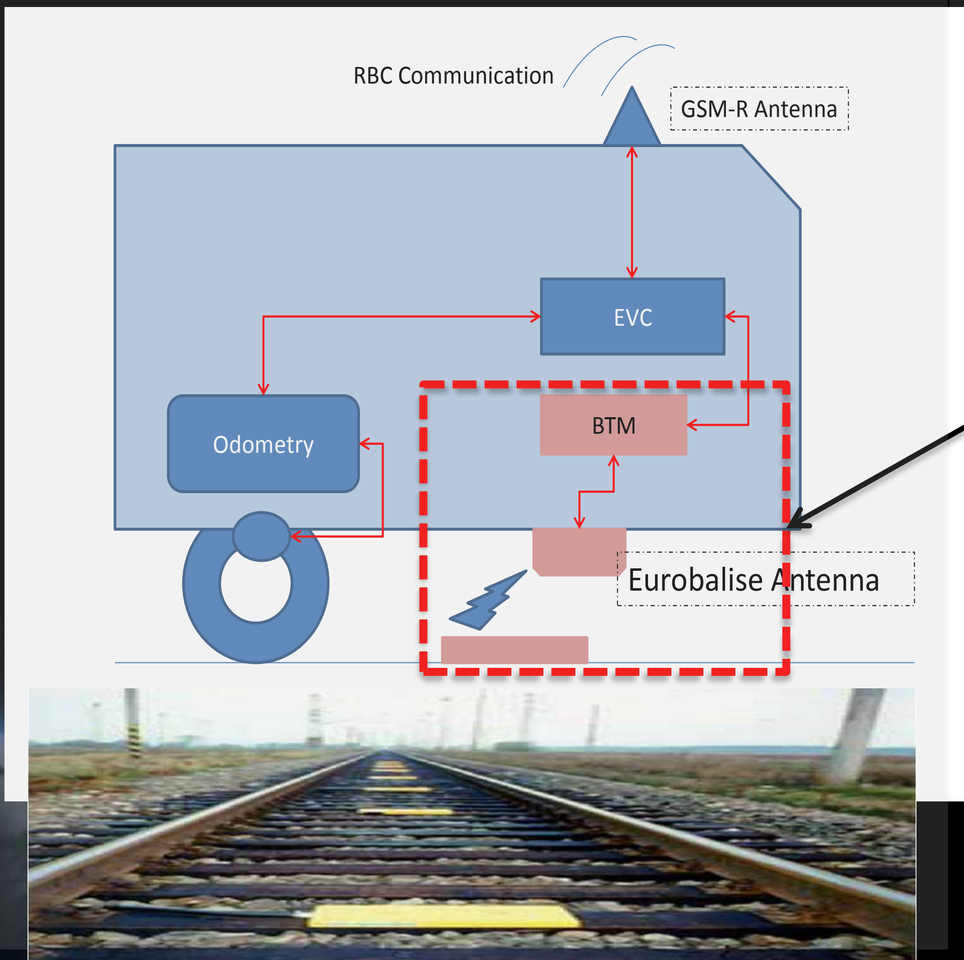

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Research Consortium Universities - Industries

Connectivity

Bearer-independent applications

3/4/5G – Satellite

Software Defined Networks

GEO Localization

High Integrity applications

Multi-constellation, dual frequency

Multi sensors

Security

Network security protocols

Resilient GNSS signal processing

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