GNSS for rail automation & driverless cars: a Give and Take paradigm

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Speakers:
Massimiliano Ciaffi, Fabio Senesi

Miami, September 28, 2018
01 Overview of ERTMS
02 Adoption of GNSS within ERTMS
03 The certification process
04 Synergy on trains and cars automation
05 Roadmap for the operational exploitation
ERTMS has been designed to

- **replace** the different railway signalling systems in Europe with a **single system**:
  - Interoperable
  - Standard
  - Certifiable with harmonised procedures

- **further improve the safety**

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**The European Railway Traffic Management System (ERTMS)**

[Graph showing rail accidents in EU from 2010 to 2016] (source Eurostat)

[Graph showing ERTMS trackside contracts by region] (Africa, Middle East, Asia, Europe, Latin America)

[Bar chart showing ERTMS trackside contracts in track km] (July 2015: 76,000 km, June 2017: 94,000 km)
ERTMS reference architecture

in operation by 2005 in Italy @ 300 km/h, 2 train operators and 5 minutes headway

Radio Block Centre
+ Interlocking

Radio Communication Network
(GSM-R)

Position Report

Movement Authority

ETCS Kernel On-Board

Physical Balise

28/09/2018

ION GNSS+ 2018 | M. Ciaffi – F. Senesi
GNSS positioning in the ERTMS
ERSAT: ERTMS + SATellite positioning

Radio Communication Network (GSM-R)

Radio Block Centre
+ Interlocking
+ GNSS Augmentation Verification

Movement Authority
+ Augmentation Data

Position Report

Physical Balise
+ Virtual Balise

ETCS Kernel
On-Board
+ GNSS Antenna&Receiver

GNSS Constellations (GPS-Galileo)

Reference Stations for the Local Augmentation System
Why introducing GNSS on the ERTMS

GNSS is one of the Game-Changer innovations for the ERTMS

- **Cost reduction**
- **Interoperability**
  - the system is detected in the same way worldwide, certifiable for safety with an harmonised approach
- **Additional revenues**
- **Applicability**
  - broadening of use, including regional and local lines

- virtual balises
- Higher accuracy to increase line capacity
- Physical balises will disappear
Challenges for the GNSS positioning

Along-track accuracy and track discrimination

Local threats to the Signal in Space

- Multipath
- Non-Line-of-Sight Interferences
- Degraded performances

Time and space dependency of the Signal

Using independent diagnostics the target GNSS integrity can be 10E-6/h

ERTMS

Safety Integrity Level SIL-4

THR <10^{-9} [hazard/(h x Train)]

<table>
<thead>
<tr>
<th>GNSS Functionality</th>
<th>Alert Limit</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>VB detection VITAL</td>
<td>1 m</td>
<td>25 cm</td>
</tr>
<tr>
<td>VB detection NON VITAL</td>
<td>5 m</td>
<td>125 cm</td>
</tr>
<tr>
<td>Track discrimination</td>
<td>2 m</td>
<td>50 cm</td>
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</tbody>
</table>
Train Positioning and Control Enhancement: ERSAT Program

|------|------|------|------|------|------|------|------|------|

3inSAT
GNSS & Satcom Signalling Demonstrator

ERSAT EAV + GGC
ERTMS Application + Test Site

DB4RAIL
Anti-spoofing and Anti-jamming technology

SAT4Train
TLC Application

SBS phase 2
Technology Demonstrator

PILOT LINE
Regional line Pinerolo - Sangone

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2013-2016
Feasibility Study

2015-2019
Trail Site & Standardization

2017-2019
Technology readiness

2017-2019
Commissioning

2018-2020

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Working Group for the certification of GNSS into the ERTMS
Pilot line “Pinerolo – Sangone” (Piemonte, Italy)

Formal process already activated
First step for the Railway certification
Safe introduction of GNSS with step-by-step approach

GNSS Augmentation System
(Local or Space-based)

RBC – IXL – GSM-R

28/09/2018
One of the main challenges is a technique to reduce multipath that troubles the rail application and so we must monitor the air and automotive applications of PPP, hoping they would provide economy of scale for the user equipment.

Prof. Per Enge,
GSA White Paper – October 22, 2017
ERTMS Linking concept for safety

• Balises are linked: ID, expected position and orientation are known in advance

• Linking Safety Reaction: linking allows the train to check if balises are correctly detected or missed in the expectation window

• The safety reaction – emergency/service brake - is configurable in terms of number of missed balises
Car-Train sinergy for a safer and more efficient autonomous vehicles

- High accuracy & safety
- Automatic Train Control
- GNSS being validated
- Exploit safety primacy of train automation with autonomous cars market potential
- More efficient Train Control

Video-GNSS positioning

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### Stopping Distance

Driverless cars imply enhanced electronic horizons and ground based traffic control.

<table>
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<tr>
<th>Speed (mph)</th>
<th>20</th>
<th>32</th>
<th>40</th>
<th>48</th>
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<th>64</th>
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<td>36</td>
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<td>95</td>
</tr>
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</table>

#### Braking distance

Target Distance vs limit of Electronic Horizon

- **Radar**
- **Vision**
- **LiDAR**
- **V2X**

**Thinking distance** and **Braking distance**

Distance in meters:
- 6 m
- 24 m
- 38 m
- 55 m
- 75 m

Distance in feet:
- 12 metres (40 feet)
- 23 metres (75 feet)
- 36 metres (118 feet)
- 53 metres (175 feet)
- 73 metres (240 feet)
- 95 metres (315 feet)

**Stopping distances**

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Electronic Horizon
Virtual track definition

Driverless cars imply enhanced electronic horizons and ground based traffic control

Safety issues related to:
• On board sensors field of view
• Braking distance requirements

Impact on safety/speed/availability

Definition of a virtual track with a centralized intelligence which
• Detects the line clearance / obstacles
• Foresees the movement of all the cars
Automotive prospects

Million units production rate

Estimated cost of autonomous driving device

Enrico Pisino, Connected and Automated Driving, Workshop ACI – Roma, 13 June 2017
# ERTMS implementation plan in Europe

<table>
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<tr>
<th></th>
<th>Core network corridors</th>
<th>Core network</th>
<th>Comprehensive network</th>
</tr>
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<tbody>
<tr>
<td>Length (km)</td>
<td>51 000</td>
<td>66 700</td>
<td>123 000</td>
</tr>
<tr>
<td>Cost extrapolation trackside (billion euro)</td>
<td>73</td>
<td>96</td>
<td>177</td>
</tr>
<tr>
<td>On-board retrofitment (billion euro)</td>
<td></td>
<td>11</td>
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<tr>
<td>Total (billion euro)</td>
<td>84</td>
<td>107</td>
<td>188</td>
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Highest level of safety: $10^{-9}$ hazards/(hour x train)
Applying the ERTMS principles to the Connected Cars

Public Communication Network (3G-4G-5G-LTE-Satcom)

ERTMS Radio Block Center

Movement Authority

ETCS Kernel On-Board + GNSS Antenna&Receiver + Driverless

GNSS Constellations (GPS-Galileo)

Multi Modal Public Augmentation Network

Virtual track

Position Report
The way forward

2021
Use of public operated augmentation networks

2020
Validation & Certification of a first GNSS-based ERTMS

2022
Safe obstacles detection

2024
Connected car using GNSS and public augmentation networks
Conclusions

• ERTMS achieved the highest safety levels and is a world-wide system

• GNSS introduction will lower TCO costs improving the benefits of ERTMS

• Autonomous vehicles should get know-how from ERTMS+GNSS, especially regarding safety and certification

• Car multi-sensor high-resolution platforms can further improve the ERTMS economical sustainability
A special tribute is due to the memory of professor Per Enge who has inspired this research and contributed to set a roadmap to extend to train control the benefits of GNSS.

Thank you

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