SUMMARY

1. What does interoperability mean?
2. Main aspects affecting interoperability:
   1. Track gauge.
   2. Catenary voltage.
   3. Signaling.
   4. Telecommunications.
3. Rail interoperability in Spain:
   1. Spain as the world leader in rail interoperability.
   2. Integration tests.
4. Rail interoperability in Europe:
   1. Current situation in the different countries
   2. European TEN-T core corridors
5. How to solve interoperability problems before placing in service a new line?: Rail interoperability labs.
6. Conclusions related to Spain, Europe and Worldwide.
1. What does interoperability mean?

**European Process: Trans-European Network**

**First Interoperability Directives**

- Creation of Trans-European Transport Network (Decision 1692/1996/EC).
- Directive 96/48/EC on interoperability of the European high speed railway system
- Directive 2001/16/EC on interoperability of the European conventional railway system

Interoperability means the ability of the Trans-European rail system to allow the safe and uninterrupted movement of trains which accomplish the specified levels of performance.

2.1. Track Gauge Interoperability.
A look at the different gauges worldwide

Spain is world leader in Variable gauge trains and changeover facilities

TALGO from 1969

CAF from 1998

Three rails solution is just implemented in some specific places

Detail of fastening of closer rails, possible with Pandrol or SKL-1 clip.
Around 400,000 trains and 90,000,000 passengers since 1969
1969 - First Talgo changeover facility in Portbou
1981 - Second Talgo changeover facility in Irun
1992 – Connection of convencional lines (1668 mm) with the first Spanish High Speed Line Madrid - Sevilla in UIC gauge (1435 mm)
2000 – Development of the first dual changeover facility for Talgo and CAF trains.
2008 – Integration of both TALGO and CAF systems in the same platform and the latest innovation: CAF + TALGO + DB RAFIL / SUW 2000 platform
2009 – 14 inner changeover facilities in daily operation in Spain + 2 international connections Irun: (Madrid-Paris) and PortBou (Barcelona to Paris, Milan and Zurich and Montpellier-Cartagena)

INFRASTRUCTURE ELEMENTS TO MAKE COMPATIBLE STANDARD AND BROAD GAUGES IN THE SPANISH NETWORK YEAR 2009

MONTHLY TRAFFIC THROUGH GAUGE CHANGEOVER FACILITIES IN SPAIN

Traffic through changeover facilities in January 2012

<table>
<thead>
<tr>
<th>Cambiador</th>
<th>Servicio Empresa</th>
<th>Nº Pasos</th>
</tr>
</thead>
<tbody>
<tr>
<td>MADRID</td>
<td>LDistancia Férrea</td>
<td>476</td>
</tr>
<tr>
<td>ALCOLEA</td>
<td>LDistancia Férrea</td>
<td>80</td>
</tr>
<tr>
<td>ANTEQUERA</td>
<td>LDistancia Férrea</td>
<td>244</td>
</tr>
<tr>
<td>ATODA</td>
<td>LDistancia Férrea</td>
<td>151</td>
</tr>
<tr>
<td>BARCELONA</td>
<td>LDistancia Férrea</td>
<td>35</td>
</tr>
<tr>
<td>MADRID CAMÍN</td>
<td>LDistancia Férrea</td>
<td>123</td>
</tr>
<tr>
<td>NAVARRA</td>
<td>LDistancia Férrea</td>
<td>246</td>
</tr>
<tr>
<td>SERRA DEL CAMINO</td>
<td>LDistancia Férrea</td>
<td>62</td>
</tr>
<tr>
<td>SORIA CAMÍN</td>
<td>LDistancia Férrea</td>
<td>33</td>
</tr>
<tr>
<td>PORTBASIL</td>
<td>LDistancia Férrea</td>
<td>270</td>
</tr>
<tr>
<td>VALENCIA</td>
<td>LDistancia Férrea</td>
<td>147</td>
</tr>
<tr>
<td>VALENCIA</td>
<td>LDistancia Férrea</td>
<td>111</td>
</tr>
<tr>
<td>VALENCIA</td>
<td>LDistancia Férrea</td>
<td>124</td>
</tr>
<tr>
<td>VALENCIA</td>
<td>LDistancia Férrea</td>
<td>510</td>
</tr>
<tr>
<td>ZARAGOZA DELIA</td>
<td>LDistancia Férrea</td>
<td>26</td>
</tr>
<tr>
<td>ZARAGOZA DELIA</td>
<td>LDistancia Férrea</td>
<td>543</td>
</tr>
<tr>
<td>ZARAGOZA DELIA</td>
<td>LDistancia Férrea</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>2356</td>
</tr>
</tbody>
</table>

Situación a 31 de Enero de 2012. 14 Cambiadores
GAUGE CHANGEOVER FACILITIES IN COMMERCIAL EXPLOITATION IN SPAIN

Number of passes through the 14 changeover facilities in Spain

<table>
<thead>
<tr>
<th>Year</th>
<th>Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>24,036</td>
</tr>
<tr>
<td>2010</td>
<td>28,540</td>
</tr>
<tr>
<td>2011</td>
<td>38,690</td>
</tr>
<tr>
<td>2012</td>
<td>39,122</td>
</tr>
</tbody>
</table>

High Speed network (1435 mm)  
Conventional network (1668 mm)

DAILY SERVICES OF VARIABLE GAUGE TRAINS

Total variable gauge trains circulating per year: 41,245

Very few incidences in changeover facilities (av. 1 per month)
**Yearly kms-train of variable gauge services**

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**Number of Kms-train in 2011 with Variable Gauge Trains**

<table>
<thead>
<tr>
<th>Train composition</th>
<th>Kms*train per year in UIC gauge</th>
<th>Kms*train per year in Iberian gauge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Talgo S-130</td>
<td>4,613,600</td>
<td>2,937,520</td>
</tr>
<tr>
<td>Talgo Conventional trains</td>
<td>1,916,980</td>
<td>1,578,260</td>
</tr>
<tr>
<td>CAF S-120</td>
<td>3,900,025</td>
<td>2,995,920</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>10,430,605</strong></td>
<td><strong>7,511,700</strong></td>
</tr>
</tbody>
</table>

**TOTAL Kms*train/year** 17,942,305

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**Gauge Changeover Facilities Evolution**

1st Generation
- Talgo Plataform 1969
- French Border
  - Irún
  - Port Bou

2nd Generation
- Talgo Plataform 1992
- LAV Madrid-Sevilla
  - Majarabique
  - Atocha
  - Córdoba
- CAF Plataform 1998

3rd Generation
- Dual Vertical TCRS01 2002
  - Olmedo-Medina Tests Track
    - Río Adaja
- Dual Vertical TCRS01 2003
  - Dual Horizontal TCRS02 2007
  - Unique Plataform TCRS03 2009
  - Unichanger TCRS04 2010
  - LAV Madrid-Leida
    - Zaragoza
    - Delicias
    - Viana del Páramo
    - Alcoy (tipo TALGO)

4th Generation
- Prototype Under Development
  - Valdepeñas
  - Medina del Campo
  - Campo Grande (tipo TCRS01)
Signaling & Communication Systems Interoperability.

ERTMS: ETCS (European Train Control System) + GSM-R

Track Gauge Interoperability

Different track gauges in different European countries.

GENERAL DIRECTION FOR INFRASTRUCTURE DEVELOPMENT

Technological innovation Direction

VIDEO OF A S-130 TRAIN PASSING OVER A CHANGEOVER FACILITY

2.2 Energy System Interoperability.
Electric system interoperability is easily solved by means of using Bi-voltage (25 kV ac-3 kV dc) trains or locomotives.

"ENERGY" SUBSYSTEM INTEROPERABILITY

General view

The interoperability of the Subsystem "Energy" is due to the fact that the catenary voltages are not equal around Europe and also is conditioned by the pantograph and the neutral zones.

- Voltage and frequency
- Pantograph type
- Neutral zones between phases (only in 25000 V CA 50 Hz systems)
Four different systems are currently operating in Europe (25 kV AC 50 Hz, 15 kV AC 16.7 Hz, 3 kV DC y 1.5 kV DC).

Furthermore the barriers imposed by the different energy systems have been overcome by using multivoltage rolling stock.

The most special case is the Thalys PBKA train (connecting Paris, Brussels, Cologne and Amsterdam) which is a tetra-voltage train (the four above mentioned systems are installed).
2.3 Signaling & Communication Systems Interoperability.

An Unique Multi-Supplier Signaling System

Full Open Markets
ERTMS BASIC PRINCIPLES

- Movement Authority (MA)
- Linking.
- Speed restrictions. Static Speed Profile (SSP).
- Braking curve management.
- Track conditions.
- TSR’s (Temporary Speed Restrictions).
ERTMS BASIC PRINCIPLES

MOVEMENT AUTHORITY

1. Allowed distance to be traveled by the train.
2. Includes the following information: 1) Final of MA (End of Authority-EoA), 2) Final speed at the EoA, 3) Danger Point location, 4) Release speed (signal approach) and 5) Sections inside the MA.
3. Each section is time limited by means of timers fixing the maximum time to run over the established route.
4. MA information is updated by passing over the balises (L1) or periodically by the RBC(L2).
5. SSP for the whole MA distance is continuously supervised
6. TSR’s for the whole MA distance are managed
7. All balises are linked (safety requirement).
8. Track conditions are respected by the OBU.

Descripción Técnica del ERTMS.

Permitted speed in the approach and passing over a switch.
ERTMS MAIN FEATURES

1. ERTMS is a continuous (L2-3) or discrete (L1) transmission system that provides continuous train supervision during the whole train route.

2. Track subsystem transmits the whole needed information to the train to allow it calculating the train braking curves. This is the way of guaranteeing a fully supervised train movement.

3. ERTMS is a “fail safe” system guaranteeing a safe status under any fail condition.

The example of Railways Communications System
GSM-R Communications System Architecture

Interoperability tests between commutation subsystem (NSS) and Radio subsystem (BSS) from different suppliers (Nokia-Siemens and Nortel-Kapsch).

Near Future GSM-R evolution (without impacting ETCS specs):
GSM-R (circuit switching) → GPRS (packet switching) → LTE → IP based technology
3. Rail interoperability in Spain:

3.1 Spain as the world leader in rail interoperability.
3.2 Integration tests.
ERTMS in Spain

1952 Kms in commercial operation with ERTMS with 17 interoperability cases tested. L2 already in operation.

The longest (1250 Kms) interoperable HSL from Barcelona to Malaga: Paradigm of Interoperability (3 ETCS suppliers plus STM LZB on track and a different supplier for the EVC).

231 train sets equipped with ETCS.

2. Spain as the world leader in interoperability.

### HIGH SPEED/ LONG DISTANCE/ MEDIUM DISTANCES TRAINS

<table>
<thead>
<tr>
<th>Train supplier</th>
<th>Alstom</th>
<th>Talgo</th>
<th>Siemens</th>
<th>Alstom</th>
<th>CAF (Variable Gauge)</th>
<th>Talgo (Variable Gauge)</th>
</tr>
</thead>
<tbody>
<tr>
<td>renfe trainset</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class</td>
<td>160 + 191</td>
<td>102 + 112</td>
<td>103</td>
<td>164</td>
<td>114</td>
<td>120 + 120,850</td>
</tr>
<tr>
<td>Fleet</td>
<td>24</td>
<td>46</td>
<td>26</td>
<td>29</td>
<td>15</td>
<td>29</td>
</tr>
<tr>
<td>Signalling</td>
<td>ETCS N1/N2 LZB ASFA</td>
<td>ETCS N1/N2 STM LZB ASFA</td>
<td>ETCS N1/N2 STM LZB ASFA</td>
<td>ETCS N1/N2 L2B ASFA</td>
<td>ETCS N1/N2 L2B ASFA</td>
<td>ETCS N1/N2 L2B ASFA</td>
</tr>
<tr>
<td>ERTMS Supplier</td>
<td>Alstom</td>
<td>Siemens</td>
<td>Siemens</td>
<td>Alstom</td>
<td>Alstom</td>
<td>Alstom</td>
</tr>
<tr>
<td>ETCS SRS Version</td>
<td>2.35 d compatible</td>
<td>2.22 + OR</td>
<td>2.22 + OR</td>
<td>2.22 + OR</td>
<td>2.35 d compatible</td>
<td>2.22 + OR</td>
</tr>
</tbody>
</table>
Interoperability cases: Cross ERTMS interoperability table

<table>
<thead>
<tr>
<th>CROSS INTEROPERABILITY IN SPAIN</th>
<th>TRACK EQUIPMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abtrom S-100/104/114-465</td>
<td>15</td>
</tr>
<tr>
<td>Ansaldo S-120/121</td>
<td>7</td>
</tr>
<tr>
<td>Bombardier S-130/730</td>
<td>9</td>
</tr>
<tr>
<td>Dimetronic 450/446/447</td>
<td>16</td>
</tr>
<tr>
<td>Siemens S-102/103-252</td>
<td>15</td>
</tr>
<tr>
<td>Thales</td>
<td>No On Board Unit from Thales in Spain</td>
</tr>
</tbody>
</table>

ERTMS reliability: Distance between incidences in Madrid-Barcelona HSL

Kms between incidences

*Level 2 started in October 2011*
2. Spain as the world leader in interoperability.

ERTMS reliability: Punctuality in Madrid-Barcelona HSL

<table>
<thead>
<tr>
<th>Punctuality (delay &lt;5’)</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>100.0%</td>
<td>99.50%</td>
<td>99.00%</td>
<td>98.50%</td>
<td>98.00%</td>
<td>97.50%</td>
<td>97.00%</td>
<td>96.50%</td>
</tr>
<tr>
<td>Level 2</td>
<td>95.50%</td>
<td>95.00%</td>
<td>2011</td>
<td>2012</td>
<td>2013</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Rail interoperability in Europe:

4.1 Current situation in the different countries

4.2 European TEN-T core corridors
ERTMS Lines in Commercial Operation in Europe

*Source: UIC ERTMS Atlas 2012

Figure 05: ERTMS Lines in commercial operation in Europe
*Source: UIC ERTMS Atlas 2012
Figure 66: Extra-European ERTMS Lines in commercial operation

*Source: UIC ERTMS Atlas 2012

Figure 67: European ERTMS Lines under construction contracted and Pilot

*Source: UIC ERTMS Atlas 2012
Figure 68: Future extra-European ERTMS Lines

*Source: UIC ERTMS Atlas 2012
ERTMS LINES IN SERVICE IN 2020

*Source: UIC ERTMS Atlas 2012

ERTMS LINES IN SERVICE IN 2025

*Source: UIC ERTMS Atlas 2012
ERTMS LINES IN SERVICE IN 2030

*Source: UIC ERTMS Atlas 2012

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GSM-R is in operation in most of the European Countries and ETCS L2 roll out is based on GSM-R.

✓ 70,000 km of track are in GSM-R operation just in Europe and 84,000 km more are planned to be covered in addition*

✓ GSM-R is expanding worldwide: 138,000 km are planned to be covered outside Europe. **

* Source: UIC e-News, 31
** Source: Kapsch CarriCor, Nokia Siemens Networks - GSM-R in operation
The European experience is now a blueprint for a global deployment

- India
- Turkey
- Saudi/UAE/Qatar/Oman
- Algeria/Libya/Morocco/Tunisia
- South Africa
- Australia
- China
- Russia/Turkmenistan

Contracts awarded* 1998-2013

* Source UIC and GSM-R IG

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Key elements of the TEN-T Regulation

(in force probably as of January 2014)

Support implementation of Transport White Paper through new infrastructure policy including:

- Dual layer approach based on an objective methodology: core and comprehensive network
- Ambitious standards for all infrastructures
- Common deadlines to achieve network (2030/2050)
- Corridors and coordinators for implementation
- Regulation instead of decision
Deadlines

Comprehensive network 2050:

- "Member States shall make all possible efforts with the aim to complete the comprehensive network and comply with the relevant provisions of this Chapter by 31 December 2050."

Core network 2030:

- "Member States shall take the appropriate measures for the core network to be developed in order to comply with the provisions of this Chapter by 31 December 2030"

Standards for rail

Comprehensive network (by 2050)

- ERTMS equipment
- Electrification

Core network (by 2030)

- full electrification
- freight lines: at least 22.5 t axle load, 100 km/h line speed and train length of 740 m;
- full deployment of ERTMS;
- nominal track gauge for new railway lines: 1435 mm
5. How to solve interoperability problems before placing in service a new line?

5.1 Rail interoperability labs.
SYSTEM AUTHORITY AND INTEROPERABILITY (IOP) TESTS

- Within the new European frame where the operators and infrastructure are separated, it is essential the existence of a System Authority to manage the interoperability problems.
- MFOM has played this role in the Spanish ERTMS projects.
- The group led by MFOM (ADIF, RENFE, CEDEX and INECO) has created the validation procedure that allows the opening of railway lines with full warranties of interoperability.

3. How to solve interoperability problems before placing in service a new line?

To achieve full interoperability two options are possible:

1. Performing INT tests once the whole system is installed on the track.
2. Advance interoperability issues by performing INT tests in a lab and after solving the problems appeared, running INT tests on track.

This is the selected way in Spanish Projects.
4. Testing the line in the laboratory.

The real track data and configuration is introduced into the real Radio Block Center (RBC).

And the real RBC is connected to the laboratory.
The real train data are introduced into the real On Board Unit (EVC).....

Braking capacity, brakes activation, train interface unit (odometry, pantograph, main switch).....

And the real On Board Unit is connected to the laboratory
4. Testing the line in the laboratory.

RBC and OBU are integrated and tested in the lab connected to all the simulators reproducing the real train and track.

4.1. Simulators with real project data for:
- Interlockings
- Train dynamics
- Train odometry
- Track circuits and switches
- Routes
- Balise telegrams

4.2. Testing the line in the laboratory.

RBC and OBU are integrated and tested in the lab connected to all the simulators reproducing the real train and track.

5. CEDEX Rail Interoperability Lab.

CEDEX Rail Interoperability Lab the first laboratory in the world accredited for certifying ERTMS components and testing ERTMS lines.

- European Test campaigns
- Alstom
- Ansaldo
- Bombardier
- Dimetronic
- Siemens
- VUZ (Chech Republic)*
- CAF*

Level 1:
- Ansaldo
- Thales
- Dimetronic
- Alstom

Level 2:
- Thales
- Dimetronic
- General Electric
- Ansaldo
- CAF
- Infrabel
- European Cross tests
- Kyosan (Japan)
- Shingwoong (Korea)
- CAIRS (China Academy of Railways Science)
- Beijing Jioda Signal
- Beijing Railway Signal
- Lanxin (China)
- Casco (China)
- CAF*

*Programmed
6. Conclusions related to Spain, Europe and worldwide.

CONCLUSIONS RELATED TO SPAIN

1. Spain has been one of the countries promoting interoperability in all the fields but specially in variable gauge and ERTMS: Spain has demonstrated that real interoperability is achievable and not only theoretically but with practical deployment and commercial exploitation of interoperable systems.

2. Due the pioneer role played, we had to solve many interoperability issues which initially had a big impact in the place in service processes.

3. At the time being, Spain is leader in interoperability between different gauge tracks.

4. Spain is one of the most important supplier of variable gauge trains (Talgo and CAF), with around 100 trains circulating up to 250 Km/h daily in Spain with a level of reliability completely similar to fixed gauge trains.

5. The first European reference lab for testing interoperability was set up at CEDEX in Spain.

6. The active participation of Spain in the process of achieving such interoperability level has situated Spain as one of the world leaders in new standard High Speed lines: this is nowadays one of our major strengths.
CONCLUSIONS RELATED TO EUROPE

1. From a technical point of view, rail interoperability is already solved. All the needed tools are on the table: track, electrification, signaling and telecommunications technical issues are fully solved by the TSI.

2. Now is the time of the real political decision to deploy rail interoperability along all the European corridors.

3. TEN-T Executive Agency is the European organism promoting and financing interoperable corridors, but it is not enough....

4. Cross-acceptance between countries is one of the major issues to be solved. Real wish from different countries is vital to solve the problems related with cross homologation, certification and approval.

5. ERA will try to intervene in these process but a firm and strong political decision is needed from the involved member states.

CONCLUSIONS RELATED WORLDWIDE

1. European developments for Rail interoperability will be applicable not only in Europe but in the rest of the world. All the projects developed for harmonizing track, electrification, signaling (ETCS) and telecommunications (GSM-R) has created a set of specifications that will be the worldwide standard (TSI has being used in most international tendering processes).

2. Specially ERTMS is becoming the worldwide standard in signaling: more than 34 countries are installing ERTMS, 68.000 kms of tracks. 9151 vehicles are constructed or contracted with this standard.

3. GSM-R has been installed in 70.000 kms of track and it is planned in 84.000 kms in Europe and in 138.000 kms outside Europe.

4. European companies has therefore reached the worldwide leadership position for having created those specifications.
THANKS A LOT FOR YOUR KIND ATTENTION

Rail Interoperability in Europe

Dr. Eng. Ignacio Jorge Iglesias
Deputy Director of ERTMS and Rail Interoperability Laboratory.
CEDEX (Studies and Research Center of the Ministry of Public Works and Transport-Fomento)

BCN Conference, Barcelona, November 19th 2013

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