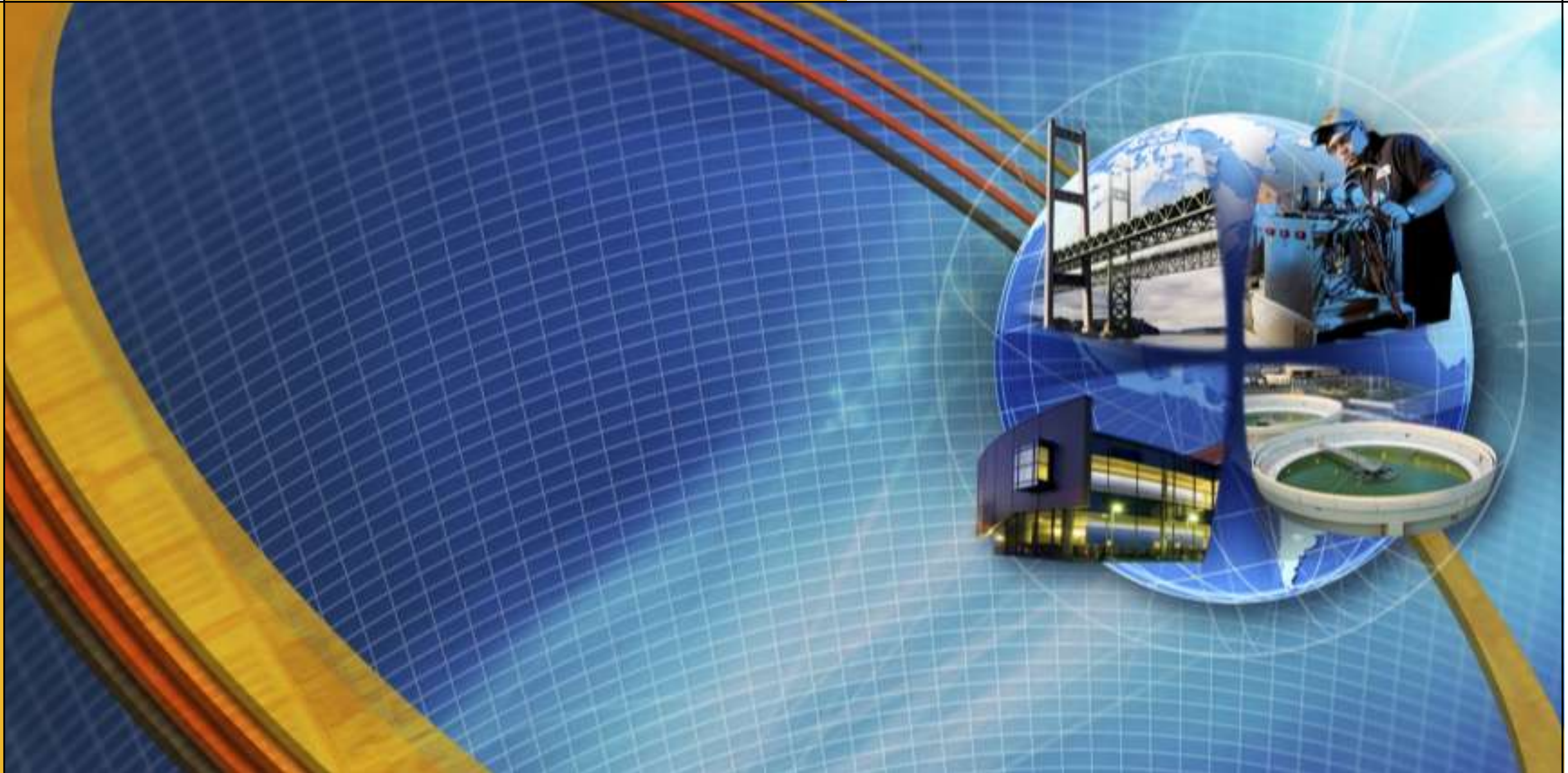
PARSONS

Optimization focus points in the management of rail operations

Alex FANEA



Abstract

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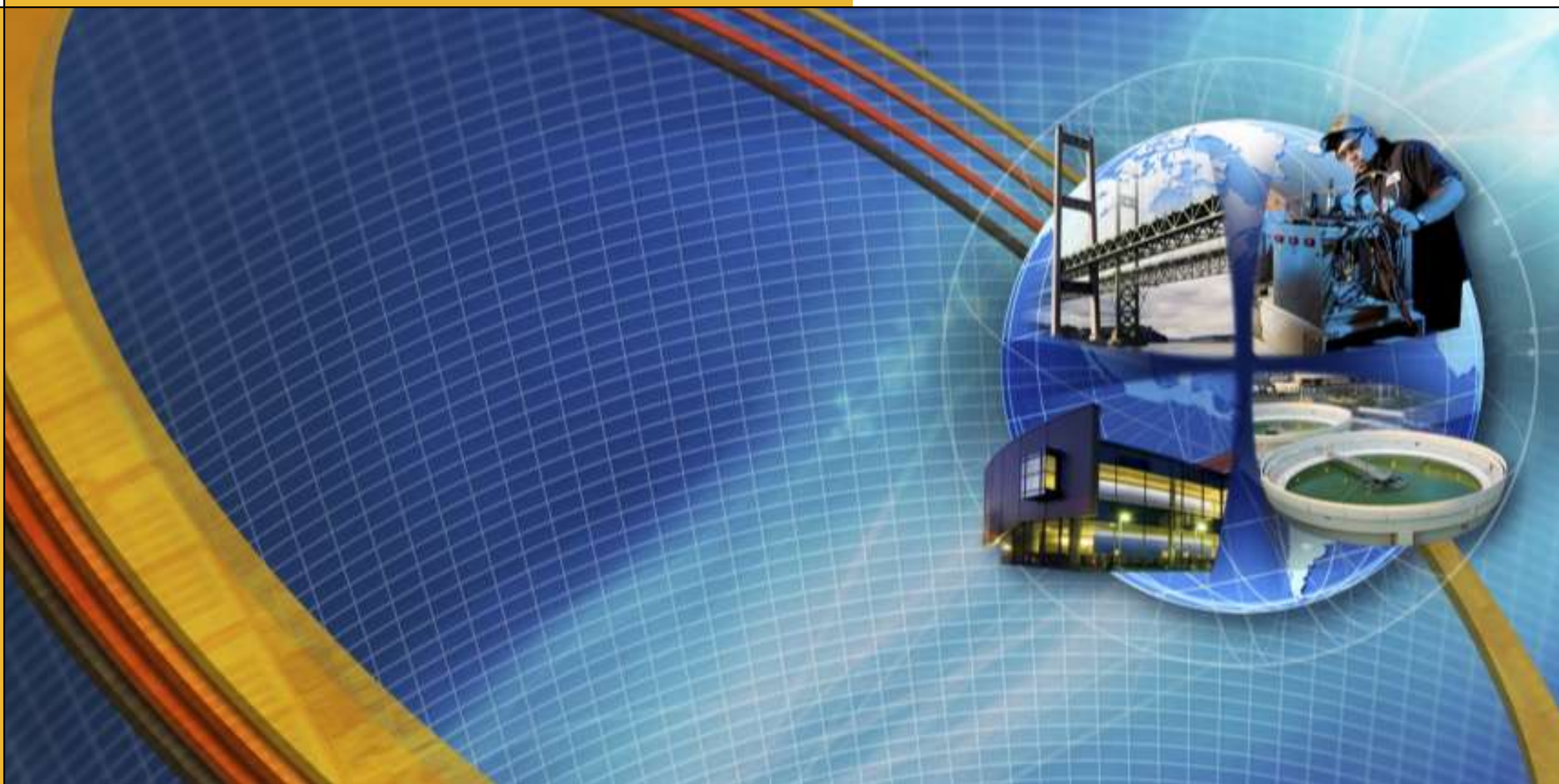
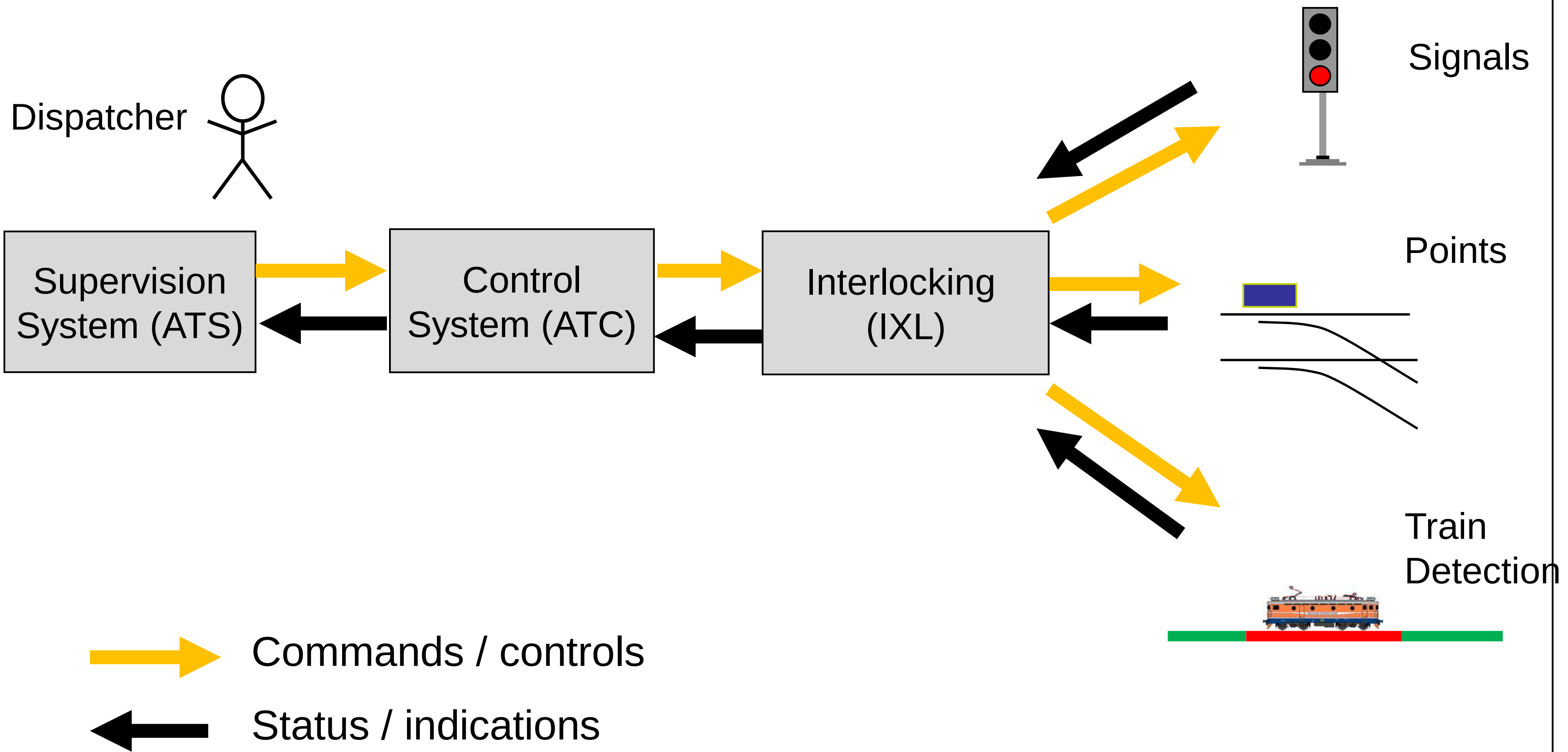
- The presentation looks into a few optimization focus points in the management of rail operations
  - energy savings (in peak and off-peak modes) in closed urban subway networks
  - cross-border railway interoperability and incident management on open national railway infrastructures

Energy savings in closed urban networks



Closed Urban Networks

Signalling Systems – Overview



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Signalling Systems – Purpose

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- IXL – Interlocking (ensure safety)
  - Detects safely the track occupancy
  - Manages safely the signals, the switches and the routes
  - Avoids conflicts between routes

- ATC – Automatic Train Control
  - Components installed onboard the train and trackside
  - 2 functions:
    - ATP: Automatic Train Protection (ensure safety)
    - ATO: Automatic Train Operation

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Signalling Systems – Purpose

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- The ATS (Automatic Train Supervision) is the system directly interfaced with the Dispatcher
- The goals of the Dispatcher are:
  - "make it happen" (all trips being run as planned)
  - Minimize the impact of incidents (passenger alarms, mechanical issues, energy,…)
  - Optimize the usage of resources (rolling stock, Energy)

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Main ATS functions

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- The main ATS functions on an Urban / Subway application (closed network, not communicating with the "outside" world)
  - Monitoring and Manual operations
    - **Train Tracking**, Monitoring & Controls, Inhibitions
  - Automated operations
    - Trip Management, Train/Trip Linking, **Automatic Train Regulation** and Automatic Route Setting
  - Support functions and services
    - Rolling Stock management, Crew Management and **Advanced Time-Table Management**

Closed Urban Networks

Achieving Energy Savings

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- How can be achieved energy savings on an Urban / Subway application:
  - Closed network – all the Rolling Stock is fully known and its dynamic behaviour can be captured in a precise model
  - "Modern" rolling stock, using regenerative brakes
  - At peak hours, the headway (time between two following trains) regulation is the key criteria. There are lower tolerances for delays, but high-density traffic
  - At off-peak hours, timetable adherence is the key criteria, higher tolerances are acceptable at departure (increased dwell time at the platform)

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Energy Saving with regenerative braking

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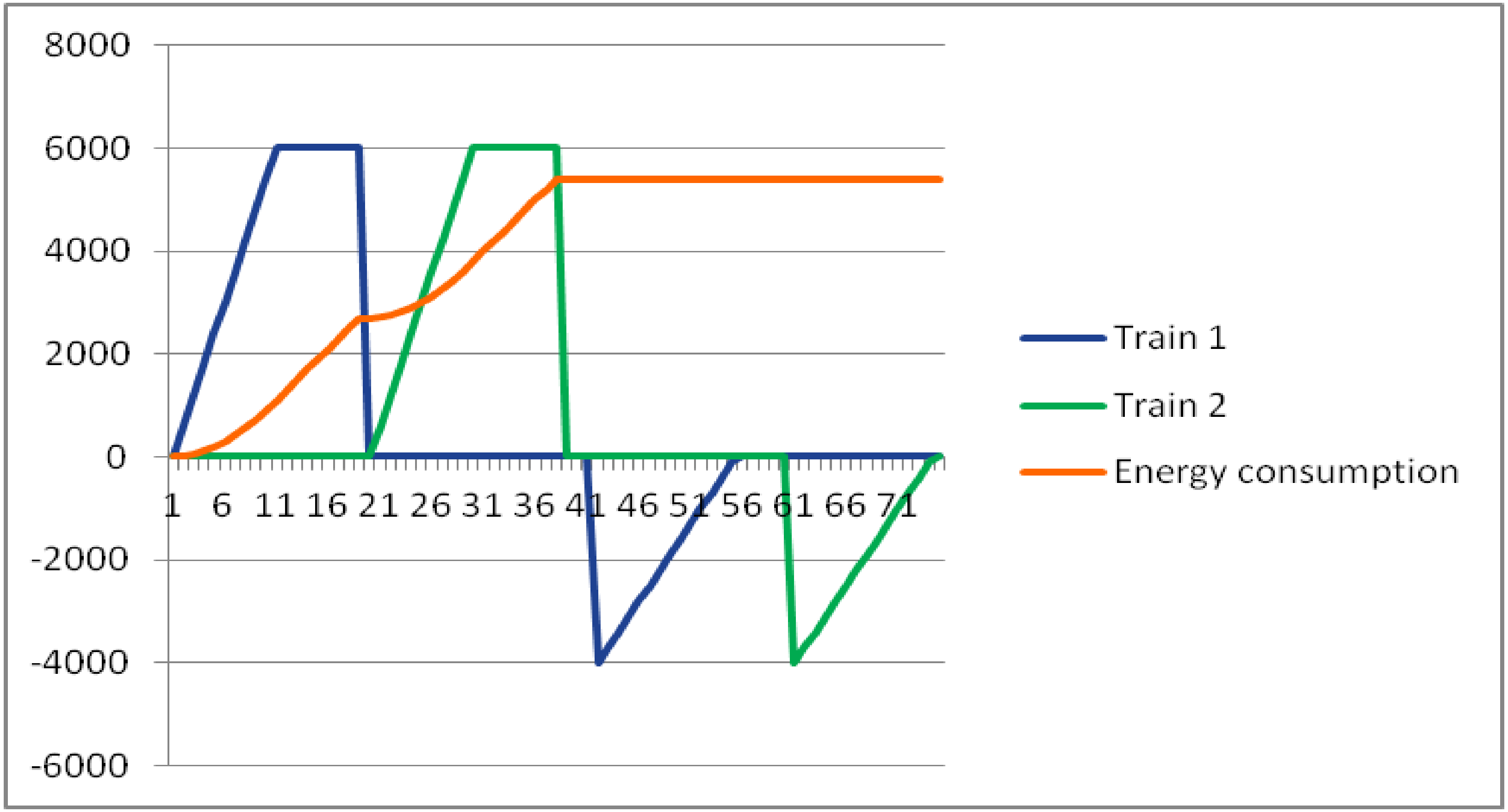
- Regenerative energy not used. Time-table not optimized



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Energy Saving with regenerative braking

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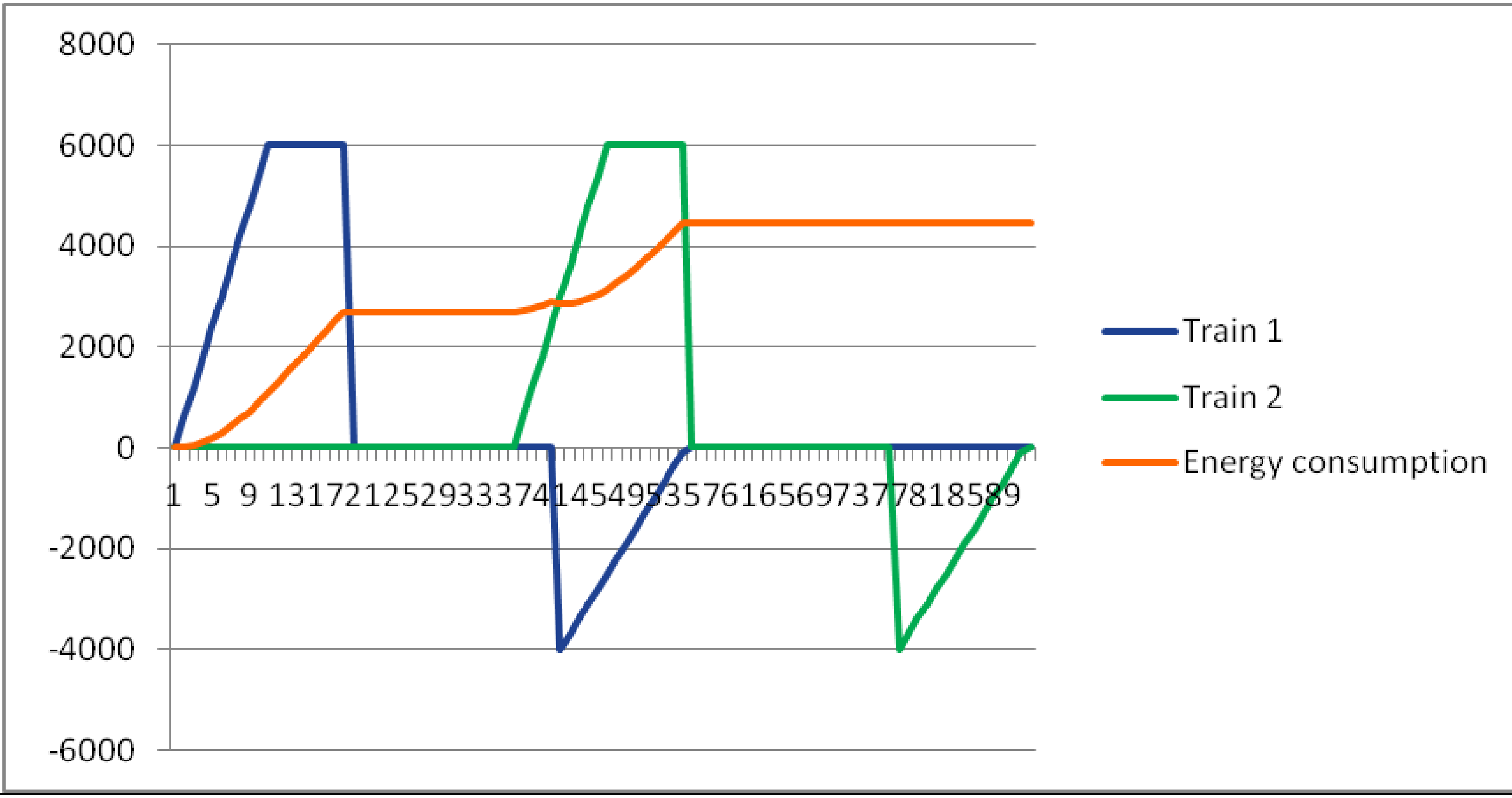
- Regenerative energy used. Optimized time-table
  - Train 2 accelerates when Train 1 brakes



Closed Urban Networks

Energy Saving with regenerative braking

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- Regenerative energy used. Optimized time-table
  - Gain depends on acceptable tolerance on deviation of original planned timetable
    - Higher energy losses in off-peak hours (less trains)
    - A 15" deviation is more acceptable at 5 min headway than at 90" headway
  - There are several thousand interstation runs during a single operational day (multiplicative effect of optimization)
  - The best results are reached with a double approach:
    - Off-line to reach the best optimization possible
    - On-line to react on perturbations

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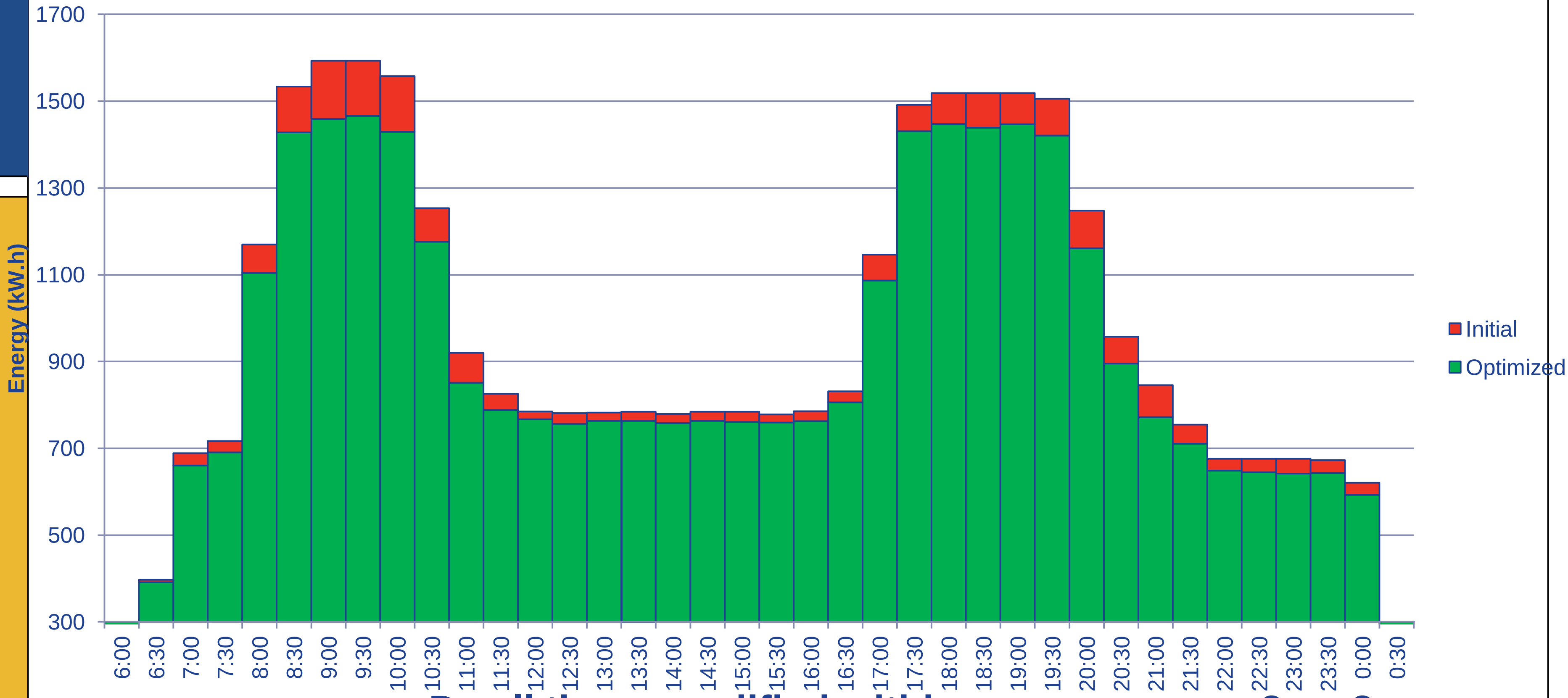
Regenerative braking savings - weekday

Timetable Energy Optimization
Initial consumption: 194.1 MWh
Optimized consumption: 184.0 MWh (5.1% savings)



Dwell times modified within: -3s..+3s
Maximum headway modification : -15s..+15s

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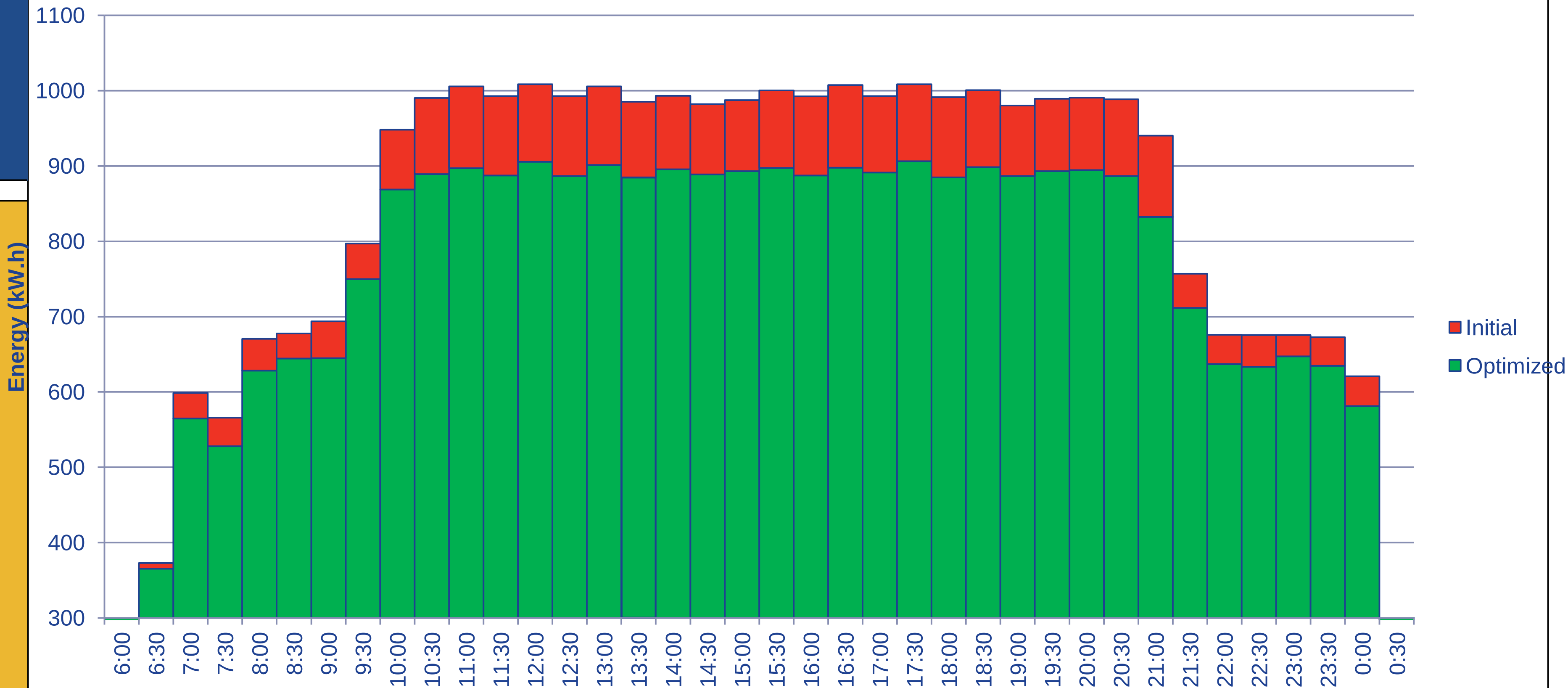
Regenerative braking savings - Sunday

Timetable Energy Optimization
Initial consumption: 168.8 MWh
Optimized consumption: 153.8MWh (8.9% savings)



Dwell times modified within: -3s..+3s
Maximum headway modification : -20s..+20s

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Regenerative braking savings - Sunday

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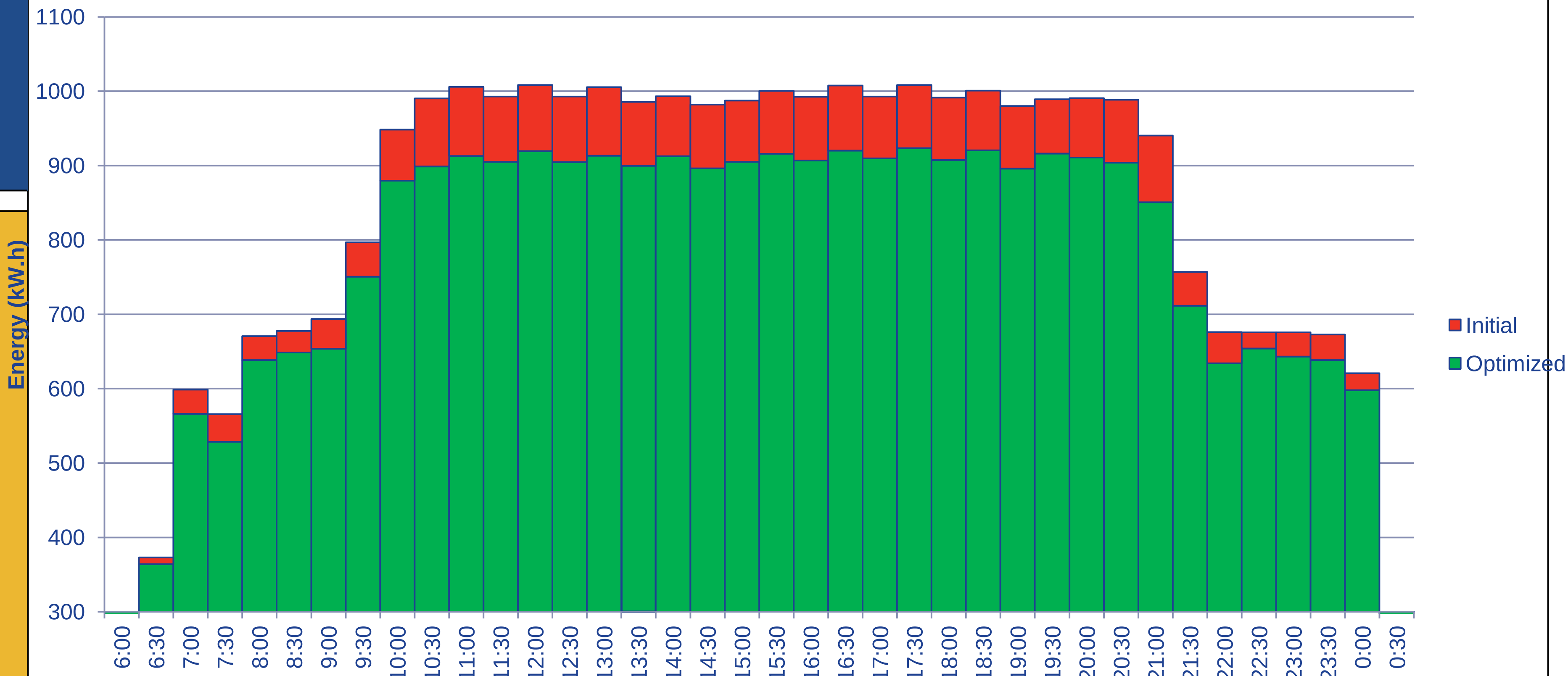
Timetable Energy Optimization
Initial consumption: 168.8 MWh
Optimized consumption: 155.7MWh (7.5% savings)



Dwell times modified within: -3s..+3s
Maximum headway modification : -15s..+15s

Regenerative braking – Energy Savings

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- The energy consumption of the timetable is evaluated by a non-linear approximation of the real behaviour of the line, based on a model of the energy transfers between braking and accelerating trains
- Optimizations done with a greedy heuristic algorithm that minimizes the global energy consumption by rescheduling the dwell times:
  - increasing the overlapping times between braking and accelerating metros
  - privileging synchronizations that globally decrease the energy consumption

Regenerative braking – Energy Savings

Benchmarking

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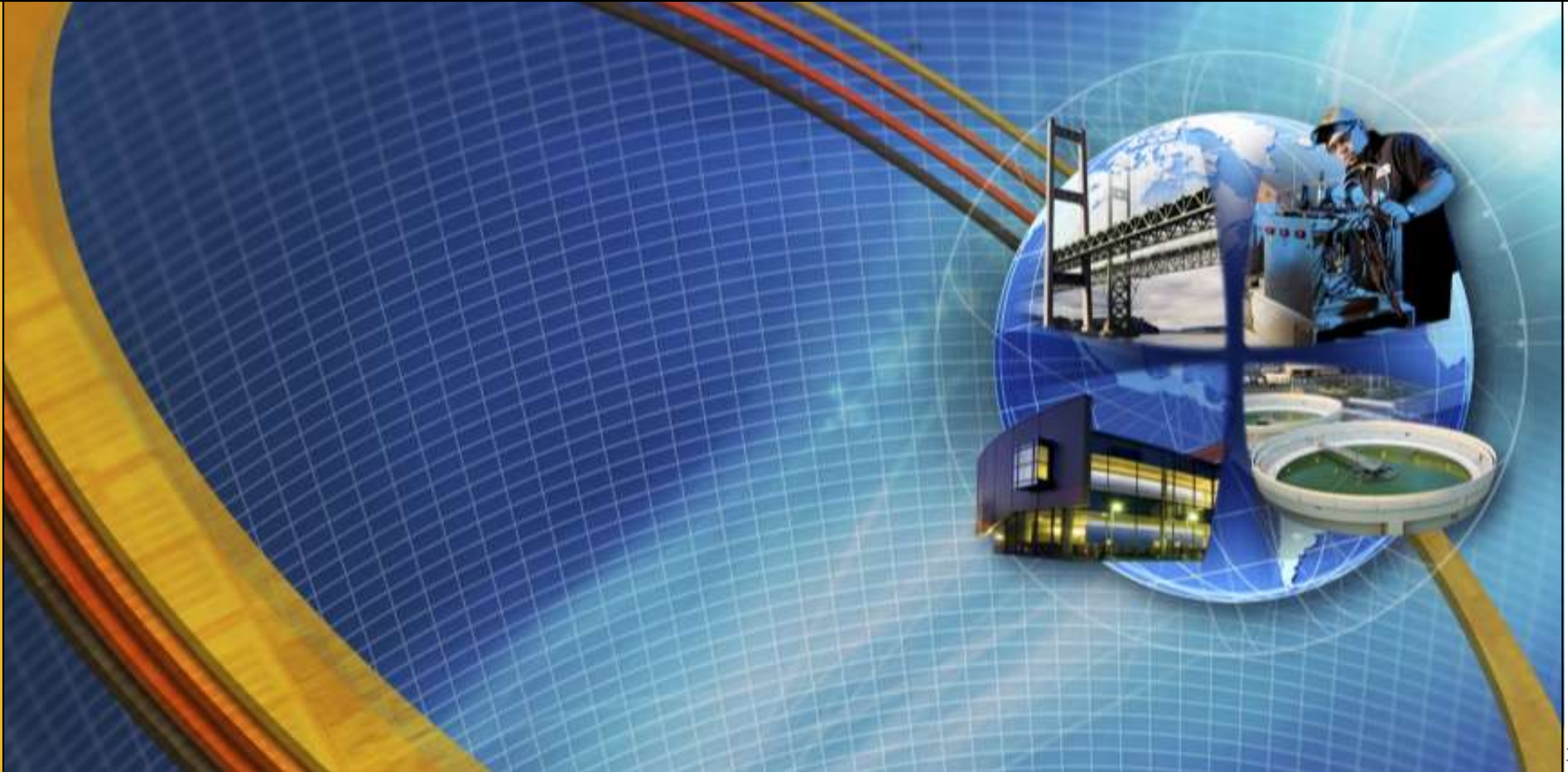
- Extensive tests have shown the approach
  - to give robust solutions faster and of higher quality than:
    - Mixed Integer Linear Programming (MILP)
    - state-of-the-art evolutionary algorithm covariance matrix adaptation evolution strategy (CMA-ES)
  - To be suitable for real size timetables
    - 7679 variables on a Sunday configuration
    - 9585 variables for a weekday configuration
- A set of benchmark instances, with typical peak and off-peak hours timetables for a generic metro line, is available to compare different optimization techniques at http://lifeware.inria.fr/wiki/COR14/Bench

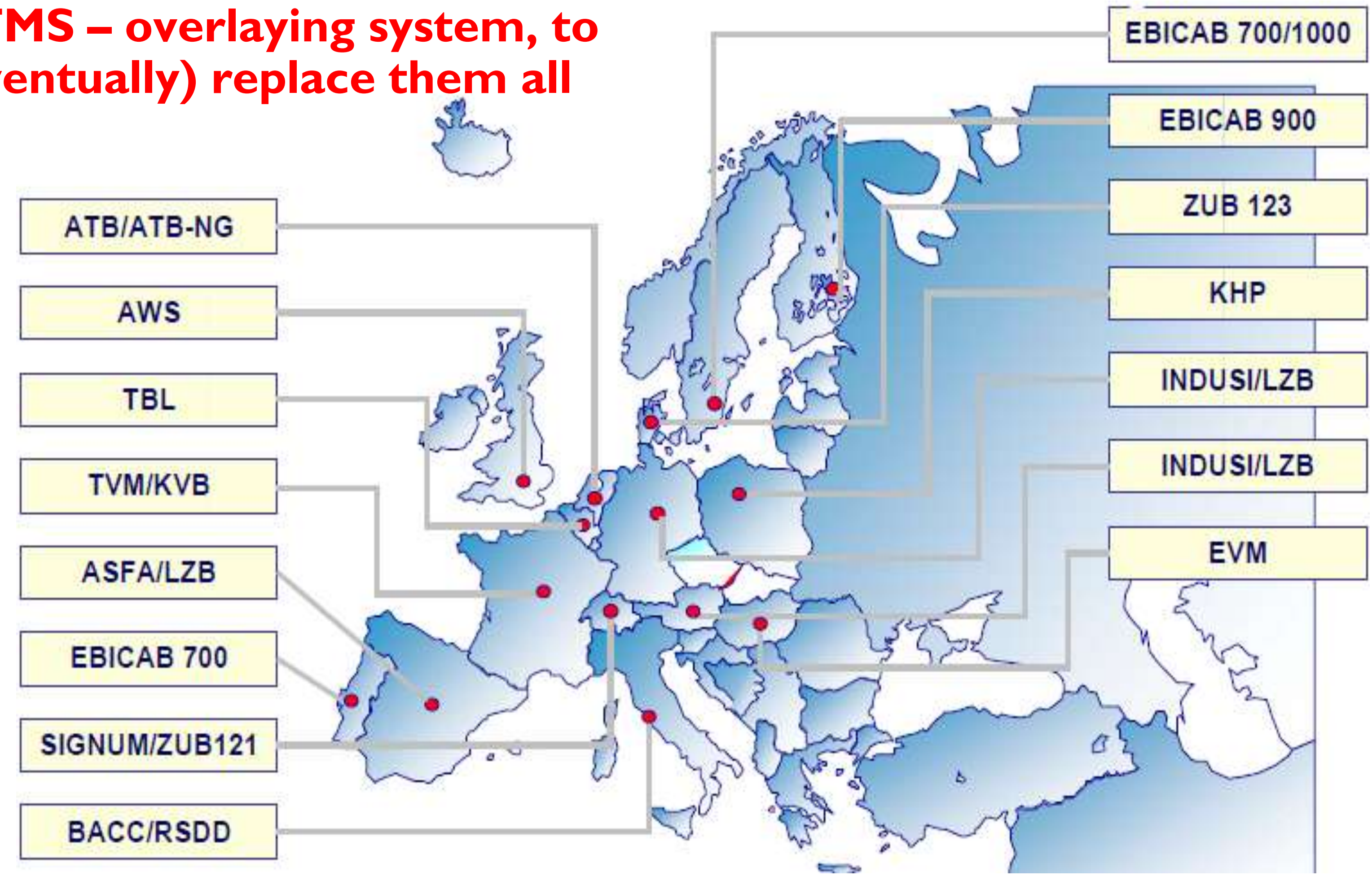
Cross-border rail interoperability



Cross-border rail interoperability

- Europe's National Train Control systems

ERTMS – overlaying system, to (eventually) replace them all



Cross-border rail interoperability

- ERTMS is the umbrella term for:
  - European Train Control System (ETCS) – the 'signalling' part
  - GSM-R – standardized mobile communications for railways
  - European Traffic Management Layer (ETML / EurOptirails):
    - Traffic routing and performance optimization, across Europe
    - International re-routing of trains in case of degraded situations
  - Operating Rules – the operating rules for the ERTMS/ETCS-fitted lines

Cross-border rail interoperability

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- Very short history:
  - Towards the end of the '80s there was a realisation that rail was losing out to air and road transport for cross border journeys
  - The patchwork nature of Europe's railway infrastructure meant that crossing borders was, and still is problematic
  - Technical and operational rules were required to achieve interoperability, with a standard available to all potential suppliers, allowing increased and open competition

Cross-border rail interoperability

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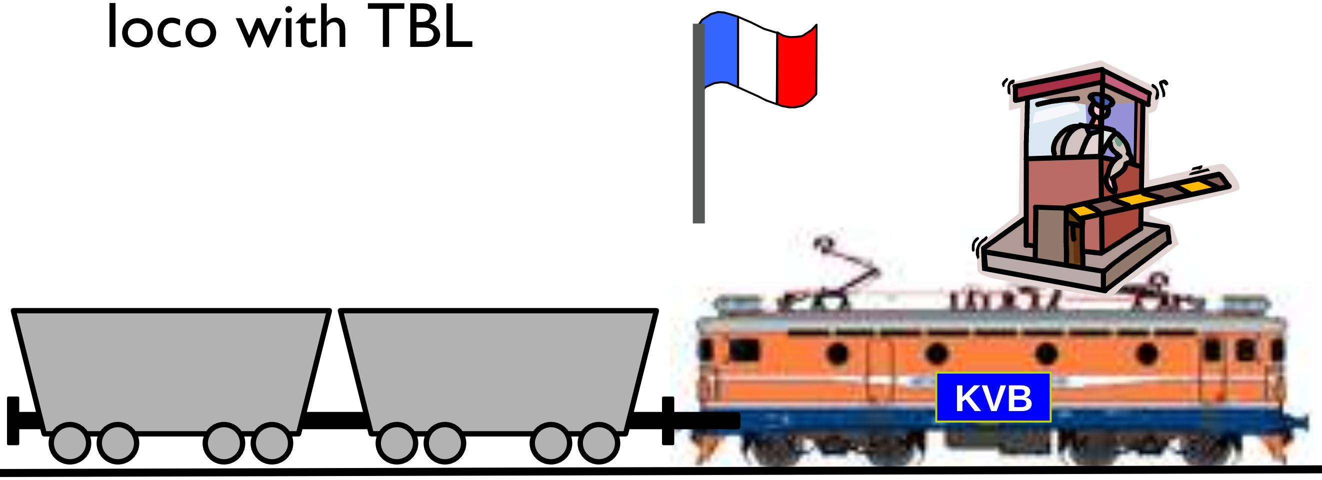
Crossing Borders the slow way

- Suppose we have a freight shipment going from Paris to Amsterdam
- For travelling in France, the loco needs KVB
- When we get to the Belgian border, it has to be swapped for a loco with TBL



Cross-border rail interoperability

Crossing Borders the slow way

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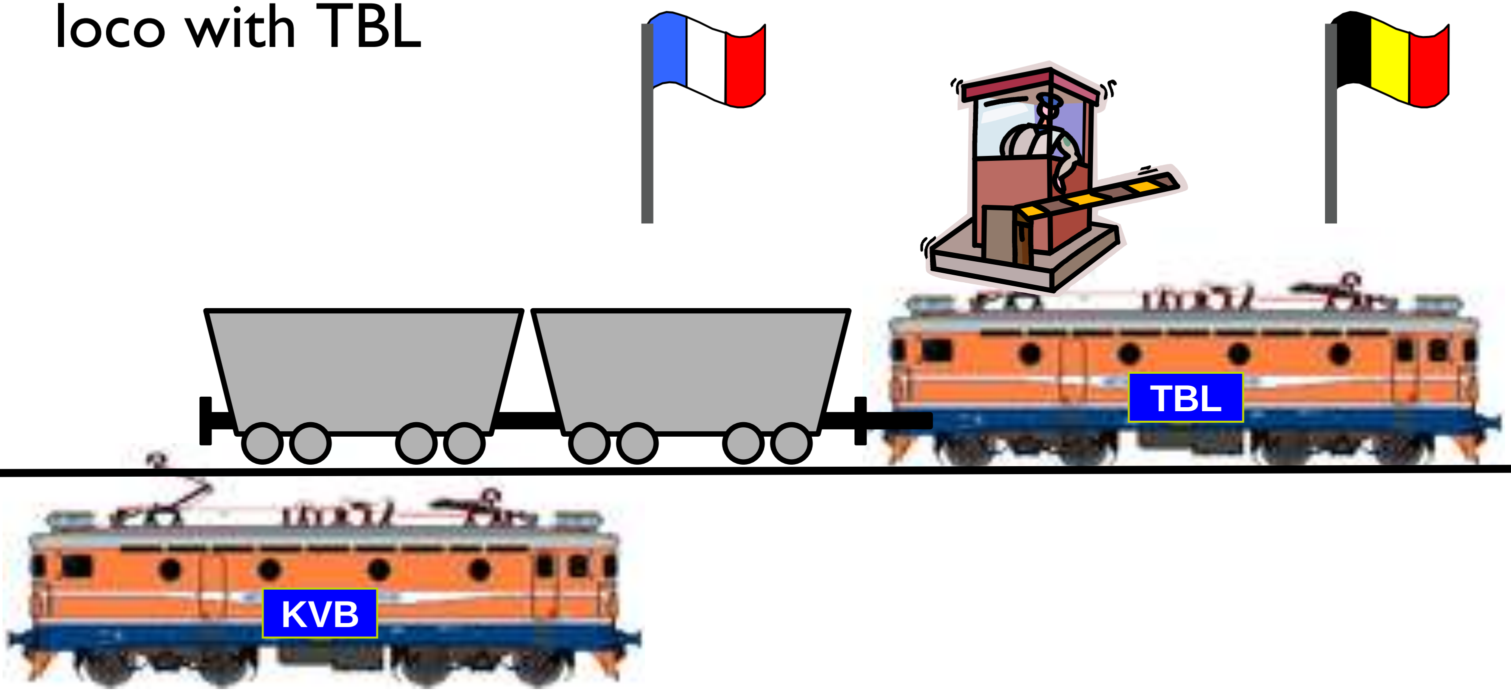

Cross-border rail interoperability

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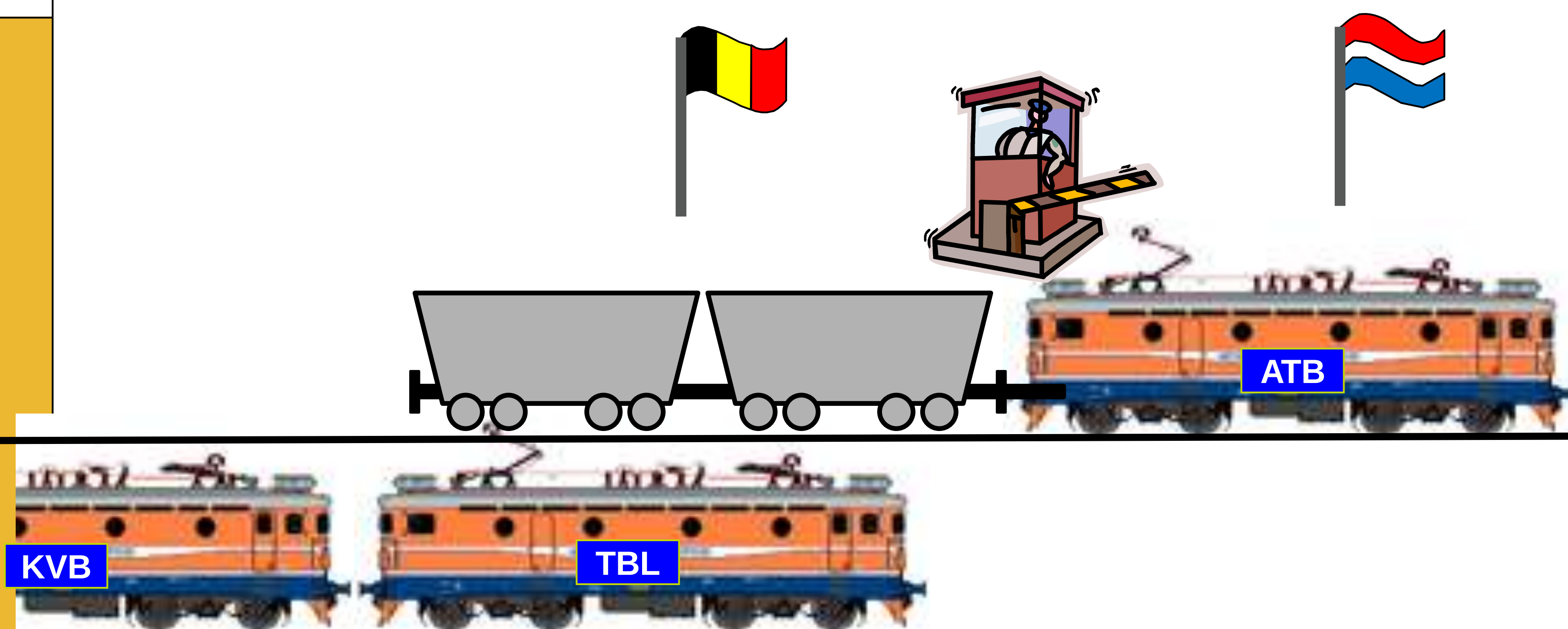
Crossing Borders the slow way

- When we get to the Dutch border, we need to swap the TBL-fitted loco for an ATB-fitted loco.



Cross-border rail interoperability

Crossing Borders the slow way

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- Changing the locomotive at every border crossing is extremely inefficient and causes logistical problems...
- The example showed 3 different locomotives required for one journey, and potentially 3 different drivers

Cross-border rail interoperability

Crossing Borders the fast way

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- A faster way is to follow the Thalys example...
- Thalys offers an international high speed train service operating between Paris, Brussels, Koln and Amsterdam
- To achieve this, the Thalys train is fitted with 7 different signalling systems:
  - TVM, KVB, ATB, TBL, TBL2, INDUSI, LZB

Cross-border rail interoperability

Crossing Borders the fast way

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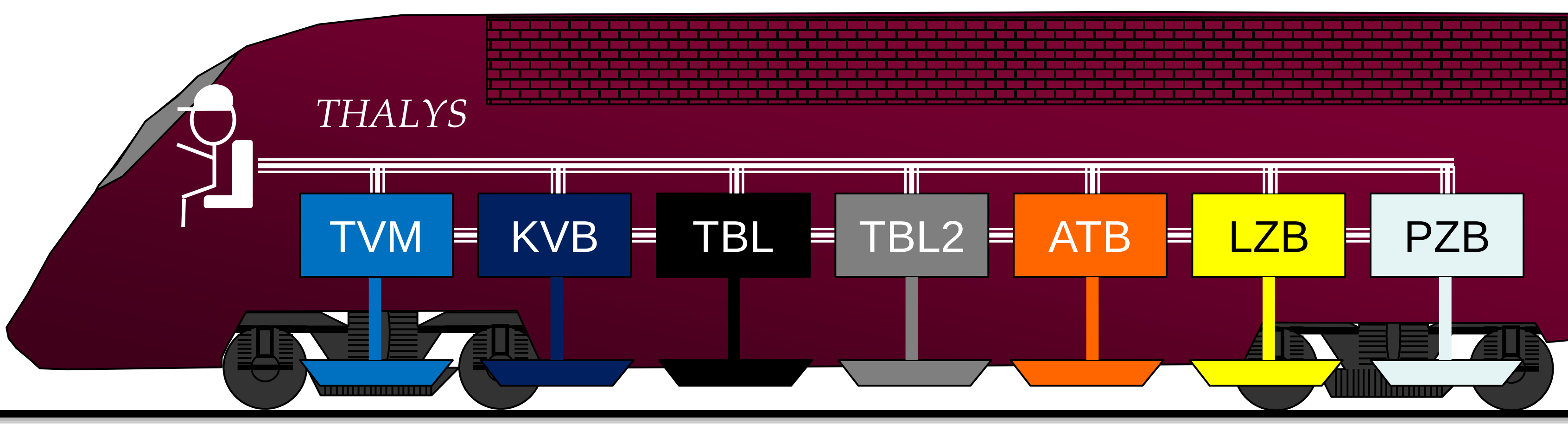
- Space must be found for each system on the train
- Each system needs an antenna, with its own requirements with regards to position under the vehicle, etc.
- Complex interfaces need to be developed between systems, and system-specific indications must be displayed to the driver



Cross-border rail interoperability

Crossing Borders the fast way

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- This complex train control system hierarchy leads to:
  - High development costs for system interfaces
  - Very difficult installation due to space constraints
  - Poorer reliability (the more systems you have the more points of possible failure) and Expensive maintenance
  - High costs for driver training on multiple systems

Cross-border rail interoperability

The fast way with ERTMS/ETCS

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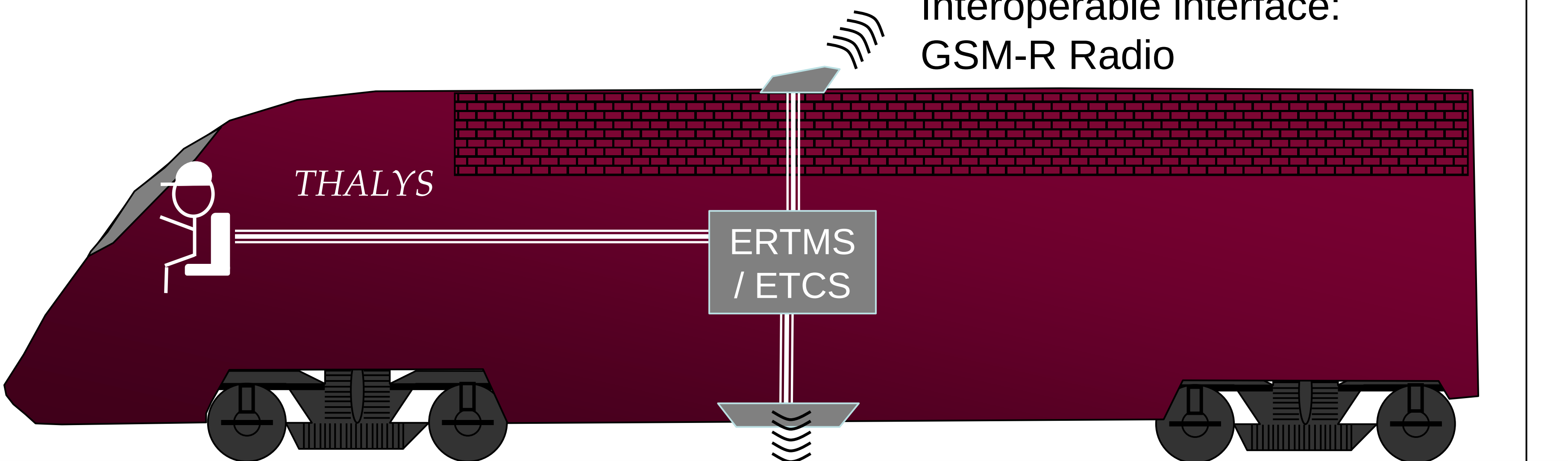
- ERTMS/ETCS is a standardised command, control and signalling system, utilising **standardised interfaces** between:
  - Trackside infrastructure and Onboard system
  - Onboard system and Driver



Cross-border rail interoperability

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- Who's in charge? Who's working?
  - In the early '90s, the EC (European Commission) financed the railways to define a standard for interoperable and seamless transit over the borders.
  - After years spent without achieving the expected results, the EC handed over in 1998 the responsibility to a consortium of 6 major European signalling suppliers – UNISIG (Alstom, Ansaldo, Bombardier, Invensys, Siemens, Thales), joined since by AZD (CZ), CAF (SP) and Mermec (IT).
  - In November 2006, the European Railway Agency (ERA) is mandated by the EC to specify and develop the TSIs.
    ERA becomes the system coordinator for ETCS, with the power to overrule the UNISIG decisions.

Cross-border rail interoperability

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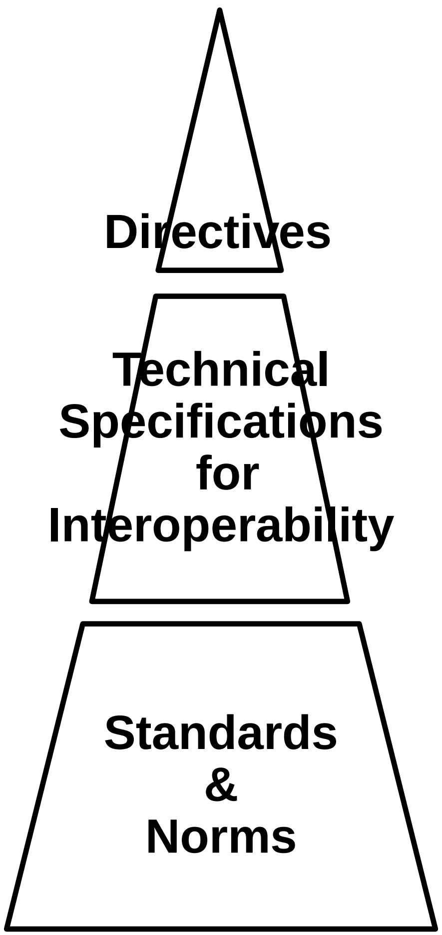
- Laws and regulations



High Speed (HS)

96/48/EC

2002/730/EC
2002/732/EC
2004/50/EC
2006/679/EC

Common (HS+CR)

2008/57/EC

2007/153/EC
2008/386/EC
2010/79/EC
2012/88/EU
2012/696/EU
2015/14/EU

Conventional (CR)

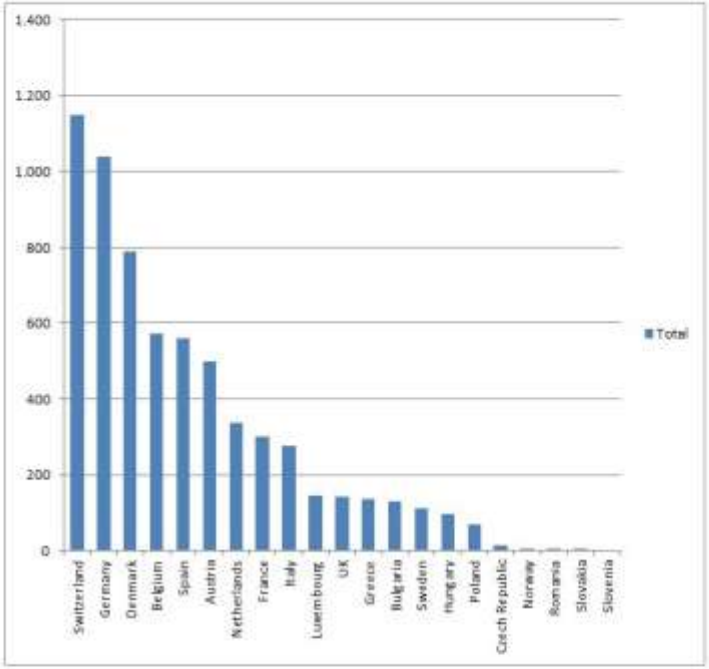
2001/16/EC

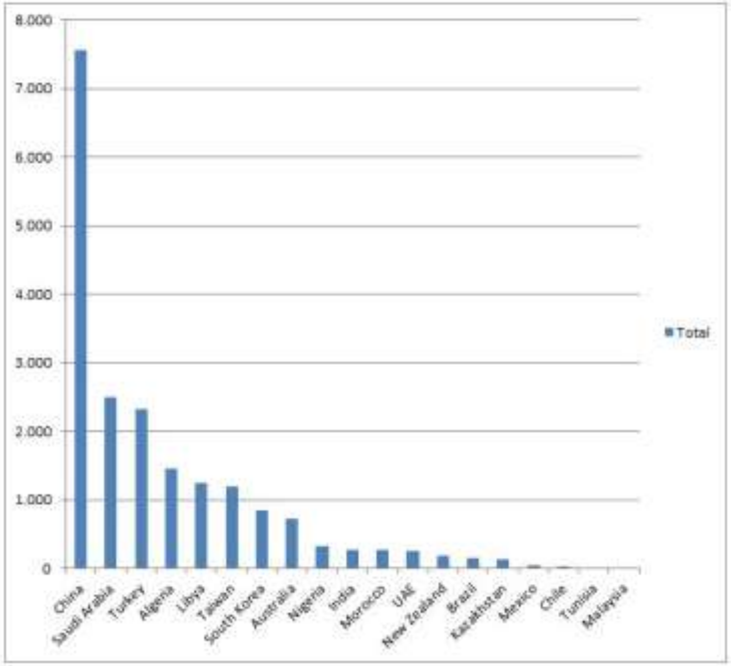
2006/860/EC
2007/32/EC

FRS
SUBSETS (incl. SRS)
EIRENE, MORANE (radio)
CENELEC EN Standards

Cross-border rail interoperability

- From September 2010 to December 2014
  - From 35.000 → 80.000 track km
    - Europe 41%
    - Asia 57%





- From 5.000 contracted vehicles to ~10.000

Cross-border rail interoperability

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- Is it working?
  - Spain – 2000km of lines in service, 3000km more contracted or planned, 537 fitted vehicles
  - Italy – 667km of lines, 183 fitted vehicles
  - Switzerland – 237 km of lines in service, limited coverage of entire network in 2017, 500 on-board units in service, 1000 contracted
  - France – new High Speed lines only
  - Germany – pilot projects
  - China (4000km, 290 vehicles), India, Korea (1500km), Turkey, Taiwan (1200km), Saudi Arabia, Mexico
  - Denmark – renewal of entire network (3245km, over 700 vehicles). Project started in 2012, early deployment in 2016, roll-out after 2018, completion in 2021

Cross-border rail interoperability

- Hot topics to be solved
  - Harmonized operational rules
    - The onboard is the true interoperability constituent, it has to implement ALL applicable requirements
    - The trackside has to implement the minimal set of rules that allow (and guarantee) interoperability
  - A system model of the onboard (not only specifications, but an actual model) → unambiguous specifications
  - Simplified and consistent acceptance procedures of an onboard in different countries – Common Safety Methods, cross-acceptance

Cross-border rail interoperability

International Train Monitoring and Reporting

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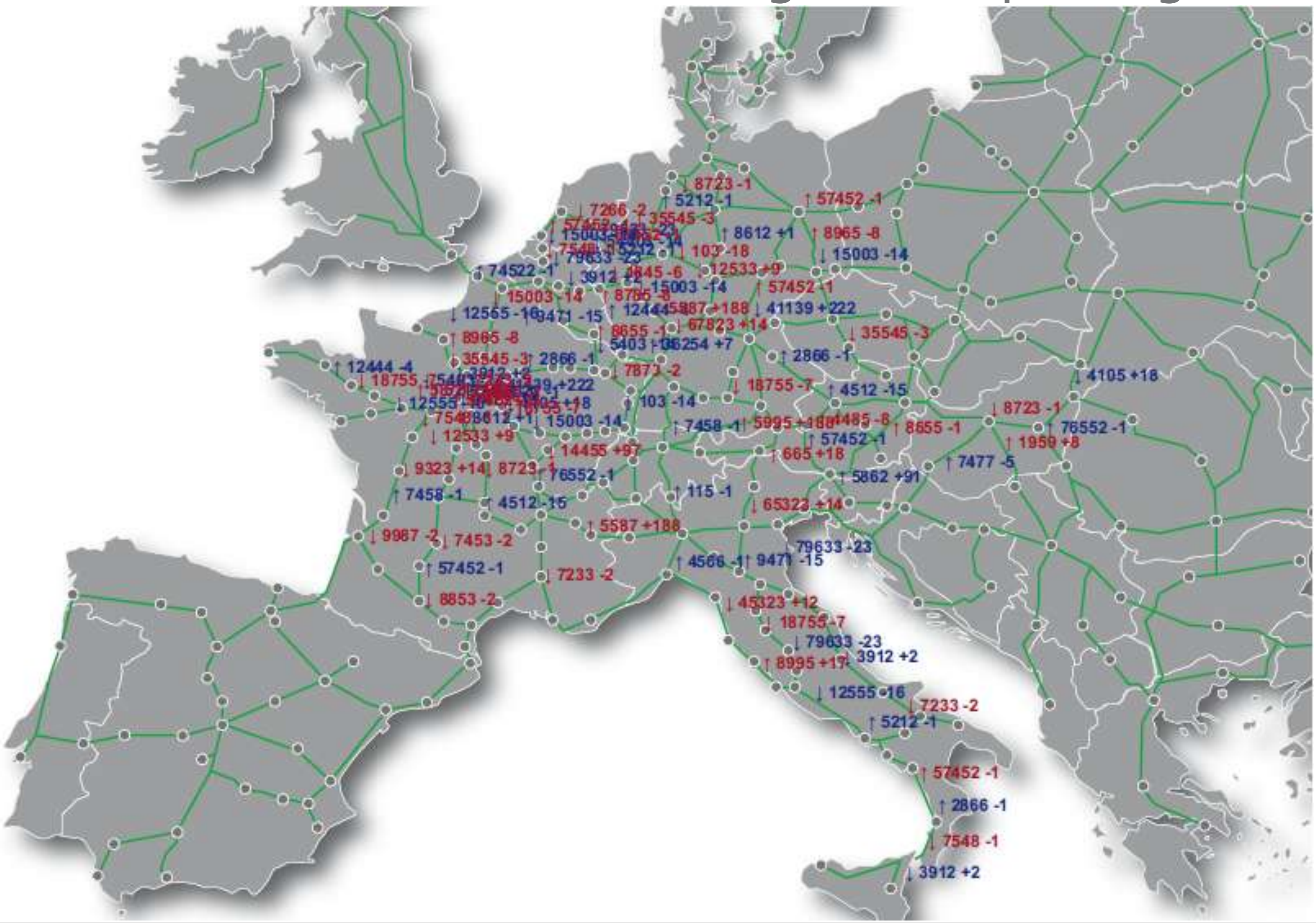

Cross-border rail interoperability

International Train Monitoring and Reporting

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- Rotterdam – Milan corridor achievements
  - International traffic management in real-time
  - Industrial quality prototype
  - Improvement of traffic conditions on international corridors, most notably a marked reduction of delays
    - reduced border crossing times and train delays
    - increased the operational capacity of the corridors
  - Full application scope (passenger and freight transport) for international traffic - albeit its primary design was as a tool for international rail freight traffic
  - "Path Finder" (international timetables) and EICIS (European Infrastructure Charging Information System (cost of international paths)

Cross-border rail interoperability

International Train Monitoring and Reporting

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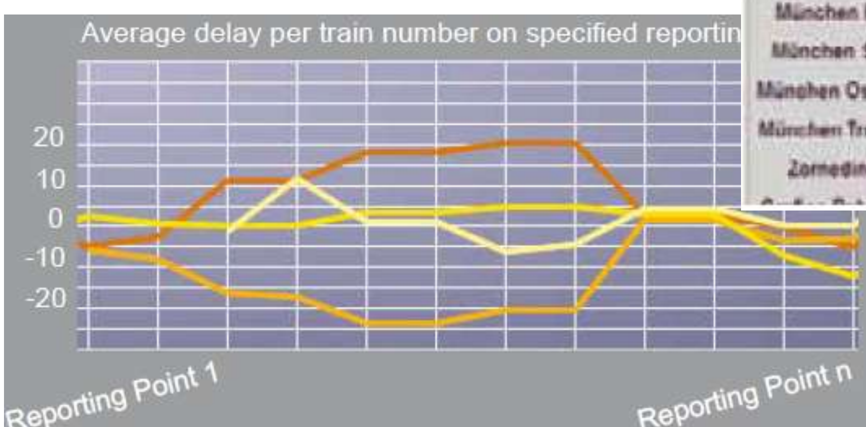
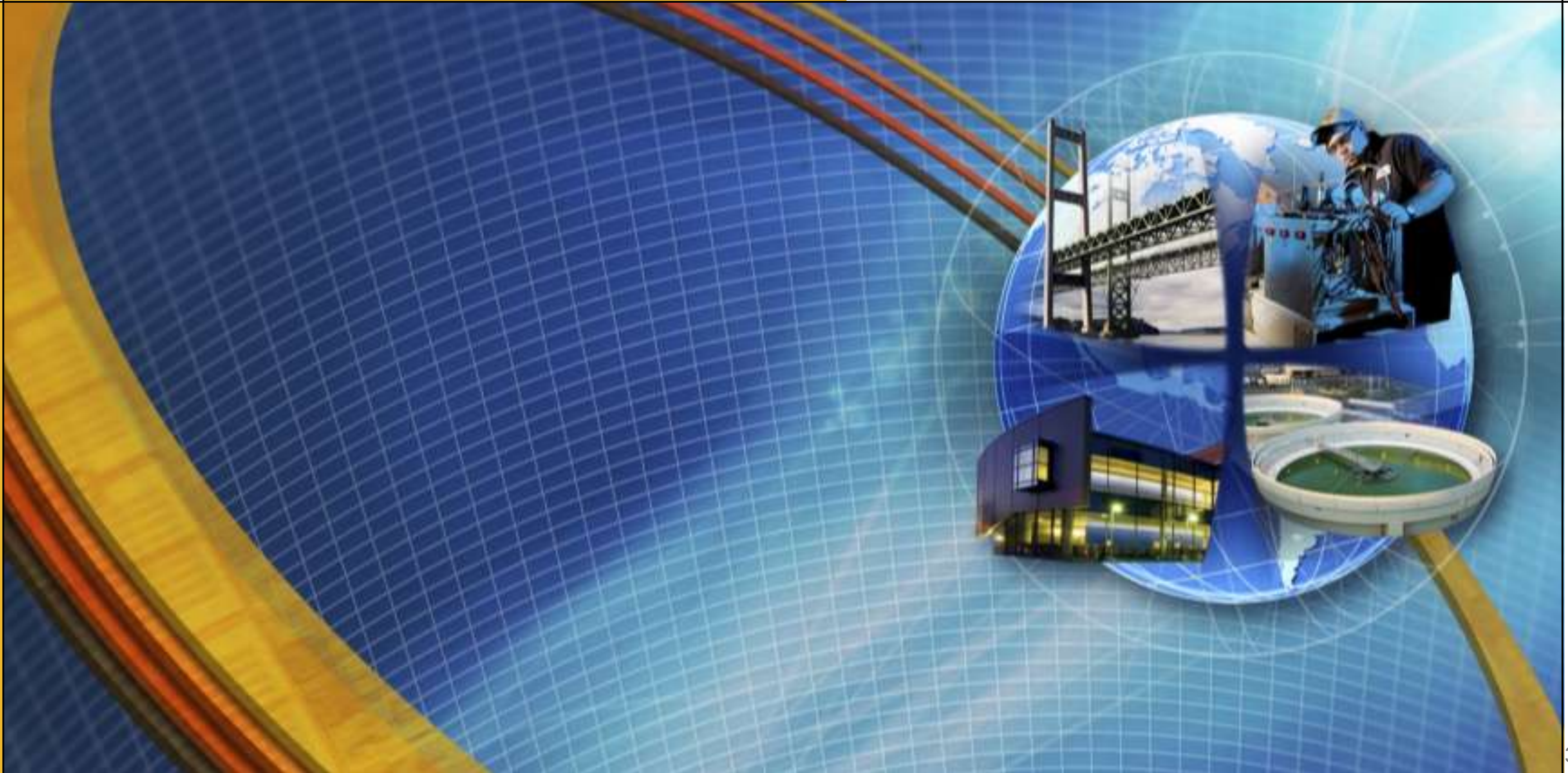
- Rotterdam – Milan corridor key figures
  - 120 000 trains/month
  - 4 700 reporting points (in stations & every 20-30km in open track)
  - 11 Infrastructure Managers from 9 countries

	Contracted		Real-Time/Forecast		Delta	
	Arr	Dep	Arr	Dep	Arr	Dep
München Pasing		20/11/2009 06:33:38		20/11/2009 06:28:38		-8
München-Pasing		20/11/2009 06:36:28		20/11/2009 06:28:28		-8
München-Laim Rb	20/11/2009 06:40:45	20/11/2009 06:42:45	20/11/2009 06:32:45	20/11/2009 06:32:45	-8	-10
München Hbf	20/11/2009 06:52:00	20/11/2009 07:30:48	20/11/2009 06:42:00	20/11/2009 07:20:48	10	10
München Süd		20/11/2009 07:35:30		20/11/2009 07:25:30		-10
München Ost Pbf	20/11/2009 07:28:30	20/11/2009 07:40:30	20/11/2009 07:28:30	20/11/2009 07:30:30	-10	-10
München Trudering		20/11/2009 07:43:41		20/11/2009 07:43:41		+0
Zorneding		20/11/2009 07:50:20		20/11/2009 07:49:20		-1



Credits



Credits and references

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- Ertms.net – fact sheets (UNISIG website. UNISIG is an industrial consortium which was created to develop the ERTMS/ETCS technical specifications) http://www.ertms.net/?page_id=57
- RailNetEurope (RNE) – Europtirail project. RailNetEurope (RNE) is an association set up by a majority of European Rail Infrastructure Managers and Allocation Bodies to enable fast and easy access to European rail, as well as to increase the quality and efficiency of international rail traffic
  http://www.rne.eu/tl_files/RNE_Upload/Supporing%20IT%20EOPT/Europtirails.pdf
  http://www.transport-research.info/web/projects/project_details.cfm?id=13689