ERTMS: European Rail Traffic Management System

1. Introduction: some historical background

The European Rail Traffic Management System (ERTMS) is part of the European Commission's policy of revitalizing the railway sector, which it pursued since 1989. The creation of a single European railway system, with an open market for train operation as well as the creation of a common system architecture and a common approach to safety management through a single set of Technical Specifications for Interoperability (TSIs), was consequently adopted as the prime objective. Together with other differences like gauge, rolling stock, voltage etc., the existing national train control systems have been seen as the main obstacle to developing an interoperable, flexible and reliable international rail transport system. The question of how to manage the replacement of the existing train control systems (more than twenty) with a new interoperable system was at the beginning approached with the definition of the Functional Requirements Specification (FRS) of ETCS issued in June 1991. The FRS requirements, developed by railway experts, have been the basis for the industrial development of ETCS. The EUROSIG¹ consortium, in cooperation with Railways, defined the first version of an on-board computer (EUROCAB) and two systems for data transmission: one discontinuous (Eurobalise), and one continuous (Euroradio).

2. Following steps

- In 1993 the first Interoperability Directive was issued by the Commission and the decision to have a structure to define the TSIs was taken.
- In 1995 the EC within a "Master Plan of Activities" defined the further development of ERTMS and in 1998 the UNISIG² Consortium was formed to finalise the specifications of this new system. At the same time it was decided to develop a validation process for ERTMS including specific test campaigns to be carried out on simulators and in the field in a number of different countries with the scope to refine and finalise the specifications.
- In April 2000 the ERTMS class 1 functions were signed. Following this formal act the EEIG³ Users Group, with a mandate received from the Commission and in cooperation with the UNISIG Consortium, has managed the Change Control Management (CCM) of the ERTMS process updating, checking and fine tuning the Technical Specification as well as the drafting of the first set of ERTMS Operational Rules for driver and signaller (ETCS and GSM-R rules and principles version 1). These rules, after assessment by the EEIG User Group, were included in both the OPE TSIs (High Speed and Conventional Rail) as Appendix A.
- In April 2004, with the Regulation (EC) N° 881/2004 of the European Parliament and of the Council, the European Railway Agency was set up with a clear mandate for the development and implementation of ERTMS. As a consequence the whole CCM process for ERTMS was transferred to the ERA ERTMS Unit. The current version of the specifications (SRS 2.3.0d) was adopted by the EC in April 2008 and ERA is now in charge of the specification's maintenance.

¹ EUROSIG consortium was composed of the following European Companies working in the Railway Signalling area: ACEC Transport, Adtranz Signal, Alcatel SEL, GEC Alsthom Transport, Ansaldo Trasporti, CSEE Transport, SASIB Railway, Siemens, and Westinghouse Signal.

² UNISIG (Union Industry OF Signaling) is an associated member of the UNIFE (Union of the Industries Ferroviaires = federation of the European railway industry) and it involves as Full Members: Alstom, Ansaldo STS, Bombardier, Invensys, Siemens and Thales (which have worked together in UNISIG since 1998/99). AŽD Praha became the first Associated Member in 2009, whilst MERMEC became Associated Member on 1 January 2010.

³ EEIG: European Economic Interest Group was composed of some European Railways managing the implementation of ERTMS/ETCS trial sites aimed at full functional verifications.

Meanwhile, the Commission has confirmed its support of the deployment of ERTMS as a single European signalling and train control system. ERTMS is still considered by the EC *"the best way of ensuring interoperability of the national railway systems reducing the purchasing and maintenance costs of the signalling system as well as increasing the speed of trains, the capacity of infrastructure and the safety in rail transport^{#4}. Currently the implementation of ETCS in Europe is based on different versions of the SRS: 2.2.2, 2.3.0, 2.3.0d. A new version SRS 3.?.0 (baseline 3) is soon to be available.*

3. ERTMS concept

ERTMS is a new train signalling and traffic management system created to assist interoperability by using a unique signalling and communication standard throughout Europe. The basic concept of ERTMS can be summarised in the following way. Trackside equipment sends (e.g. via balises, via radio, etc.) information to the train. A dedicated on-board computer receives the information sent from trackside equipment and combines them with those stored on board elaborating a dynamic speed profile to be respected by the train while running. Thanks to this speed profile the on-board computer continuously checks the permitted speed against the current train speed. In case the current speed is exceeding the authorised one the on-board computer slows the train down automatically.



4. Glossary

A lot of significant "terms and abbreviations" used in the ERTMS (European Rail Traffic Management System) domain (European Directives, FRS and SRS, Operational Rules, etc) have been defined elsewhere but, taking into account the purpose of this document, it has been agreed to provide a new list of those terms and abbreviations, choosing those that are most useful for the scope of the AIMESC project. Taking into account the possible users of this document, the given meaning for each term is a general meaning and the list cannot be considered exhaustive or official. This new glossary is contained in Appendix 1 of this document.

5. ERTMS Documents (main)

In the table below are listed the main⁵ official technical documents used (at European level) as reference documents for ERTMS.

Document Reference Title ERA public website links	Title ERA public	website links
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⁴ (Statement made by the President of the European Commission on the 6 May 2008 in Brussels at 20th anniversary reception for CER)

⁵ The full list of the ERTMS specifications contained in the ERA website can be found using the link: http://www.era.europa.eu/Core-Activities/ERTMS/Pages/ERTMSCurrentBaseline.aspx in the section Reference Documents.

Document Reference	Title	ERA public website links
ERA_ERTMS_003204	ERTMS/ETCS Functional Requirement Specification v 5.5	http://www.era.europa.eu/Document- Register/Pages/003204.aspx
SUBSET-026	System Requirement Specification SRS (issue 2.3.0d)	http://www.era.europa.eu/Document- Register/Pages/UNISIGSUBSET-026.aspx
SUBSET-108	Interoperability-related consolidation on TSI annex A documents	http://www.era.europa.eu/Document- Register/Pages/ERASUBSET-108.aspx
ERA_ERTMS_015560	ETCS Driver Machine Interface - version 2.3	http://www.era.europa.eu/Document- Register/Documents/ERA-ERTMS- 015560v2.3.pdf
PSA167D005	EIRENE- FRS 7.0 GSM-R	http://www.era.europa.eu/Document- Register/Documents/EIRENE-FRS-v7.pdf

6. ERTMS System's components: ETCS and GSM-R

The ERTMS System is based on two main system's components: ETCS (European Train Control System) and GSM-R (Global System for Mobile Communications – Railway).

- ETCS is an Automatic Train Control system (ATC) developed by UNISIG in cooperation with the European Union, Railway stakeholders and the GSM-R industry. The current official ETCS Specifications are SRS 2.3.0d. A new version of the SRS (baseline 3) is still on the way.
- GSM-R is the trackside communication Network used for exchange of information between the onboard sub-system and trackside equipment. The current official GSM-R Specifications are FRS 7.0 /SRS 15.

7. ERTMS/ETCS operating Levels

The application levels of ERTMS are a way to express the possible relationships between track and train. These relationships are related to the trackside equipment used, to the way trackside information reaches the on-board units and to which functions are processed trackside and on-board.

Level "0" application

This level is used with trains equipped with ERTMS/ETCS operating on a line not fitted with ERTMS/ETCS or a national system or with the ERTMS/ETCS systems in commissioning. Technically this level is not really an ETCS level because the movement authorities to the driver are given by a signalling system external to ETCS (e.g. line side optical signals, etc.). In level "0" train location and train integrity proving are performed by the trackside equipment and not ERTMS/ETCS functions.



In level "0" application the main offered functions/protections are:

- Supervision of maximum train speed (the value is entered during the data entry);
- Supervision of maximum permitted speed in an unfitted area (using the national value for UNFITTED);
- Reading of Eurobalises to detect level transitions and certain special commands (e.g. announcement/command level transitions, etc). All other messages are rejected;
- No cab signalling to the driver.

No supervisory information is displayed on the DMI except the train speed. The operational rules to be applied are purely "National Rules". Train data has to be entered in order to avoid stopping the train at a level transition.

Level "STM" application

Train equipped with ERTMS/ETCS operating on a line equipped with a national train control and speed supervision system to which it interfaces by use of an STM⁶. The train control information, generated trackside by the national train control system, is transmitted to the ERTMS/ETCS on board system by using the communication channel of the underlying national system and translated into information interpretable by ERTMS/ETCS. In level "STM" train location and train integrity supervision are performed by the trackside equipment and not by ERTMS functions.

⁶ The STM (Specific Transmission Module) is a device which allows the on board equipment to utilize the transmission system of the national system. For STM level in the new DMI document it has been agreed to replace the text 'STM' by the distinct abbreviation of the corresponding STM (e.g. KVB, PZB, ASFA etc.).



In level "STM" application the achievable level of supervision is similar to the one provided by the underlying national system. Level STM does not use ERTMS/ETCS track-train transmissions except for the announcement/command of level transitions and certain special commands. For that reason Eurobalises still have to be read. The displayed information depends on the functionality of the underlying national system. The active STM is indicated to the driver. In case of a combination of different national systems this combination takes place externally to ERTMS/ETCS (the on-board system remains in STM). Train data has to be entered in order to avoid stopping the train at a level transition.

Level "1" application

Spot transmission based train control system to be used as an overlay on an underlying system⁷. Trains equipped with ERTMS/ETCS operating on an ERTMS line equipped with an underlying system where Eurobalises and, optionally, Euroloop or Radio infill have been added. In level "1" some Eurobalises have to be switchable because they must be able to transmit variable information. In this level both train location and train integrity proving is performed by the trackside equipment and not ERTMS functions. The movement authorities are generated trackside and are transmitted to the train via balises. Trackside equipment doesn't know the train to which it sends information.

⁷ Lineside signals are required in Level "1" applications except if semi-continuous in-fill is provided.



In level "1" application the main offered functions/protections are:

- Continuous speed supervision which also protects against overrun of the given EoA. For this kind of
 supervision the on-board system selects the most restrictive value of different permitted speeds at
 each location ahead, calculates the dynamic speed profile taking into account the train
 characteristics (which are known on-board), and the received track description data, and compares
 the actual train speed with the permitted speed commanding the brake application if necessary;
- Reading of Eurobalise to detect movement authority, track description data, level transitions and certain special commands (e.g. announcement/command level transitions, etc). Because level "1" is mainly based on spot transmission devices, in case a line side signals clears, an approaching train cannot receive this information until it passes the balise group located at that signal. In this situation the driver is asked to observe the lineside signal to know when he is authorised to proceed and he is asked to approach the stopping location below a maximum permitted release

speed. To reduce the delay in receiving new information additional balises can be placed to transmit infill information⁸;

• Can be considered "cab signalling system" to the driver.

Level "2" application

Radio based train control system that can be used with/without an underlying system and with or without lineside signals. Train equipped with ERTMS/ETCS operating on an ERTMS line equipped with Eurobalises and Euroradio and controlled by a Radio Block Centre (RBC). In level "2" train location and train integrity proving are performed by the trackside equipment and not ERTMS functions. In level "2" track to train communication is bidirectional and based on Euroradio whereas Eurobalises are mainly used as spot transmission devices for location referencing (position reports). The movement authorities are generated trackside and are transmitted to the train via Euroradio (GSM-R). Trackside equipment knows each ERTMS/ETCS controlled train individually by using the ERTMS/ETCS identity of the leading ERTMS on-board equipment.



In level "2" application the main offered functions/protections are:

- Continuous speed supervision as in Level 1;
- Reading of Eurobalises to send train position, relative to the detected balises, to the RBC;
- Movement authority and track description are transmitted by RBC via Euroradio;
- "Cab signalling system" to the driver.

Level "3" application

Radio based train control system. Train equipped with ERTMS/ETCS operating on an ERTMS line equipped with Eurobalises and Euroradio and controlled by a Radio Block Centre (RBC). In level 3 applications lineside signals are not foreseen to be used. In level "3" train location and train integrity supervision are performed by the trackside RBC in co-operation with the train which sends position

⁸ Semi continuous information can be provided using Euroloop or radio in-fill. In this cases new information are shown to the driver as soon as they are received on board and even at standstill. No release speed is required in case of semi continuous information.

reports and train integrity information to RBC. In level "3" track to train communication is bidirectional and based on Euroradio whereas Eurobalises are mainly used as spot transmission devices for location referencing (position reports). The movement authorities are generated trackside and are transmitted to the train via Euroradio (GSM-R). Trackside equipment knows each ERTMS/ETCS controlled train individually by using the ERTMS/ETCS identity of the leading ERTMS on board equipment.



In level "3" application the main offered functions/protections are:

- Continuous speed supervision as in Level 1 and 2;
- Continuous train integrity monitoring, performed by an external (to ERTMS/ETCS) function and sending of this information to the RBC;
- Reading of Eurobalises to send train position relative to the detected balises to the RBC;
- Movement authority and track description are transmitted by RBC via Euroradio relating to a balise;
- "Cab signalling system" to the driver.

In the table below are summed up the main supervision and functions of ETCS Level 1, 2 and 3.

Main ETCS supervisons and functions	Operating Level		
	Level "1"	Level "2"	Level "3"
Max train speed (*)	Yes	Yes	Yes
Max permitted speed	Yes	Yes	Yes
Overrun of given MA	Yes	Yes	Yes
Continuous speed supervision	Yes	Yes	Yes
Reading Eurobalises	Yes	Yes	Yes
Movement Authorities and track description	Yes [by balises (**)]	Yes (by radio)	Yes (by radio)

Main ETCS supervisons and	Operating Level		
Trackside equipment knows the train to wich it sends information	No	Yes	Yes
Train integrity proving performed on board	No	No	Yes (by device external to ETCS)
Train location performed on board	No	Yes (by position reports to RBC)	Yes (by position reports to RBC)
Continuous apgrading of the information	No (because mainly based on spot transmission devices)	Yes (by radio)	Yes (by radio)
Cab signalling to the driver	Can be considered as cab signalling system to the driver	Yes	Yes

(*) Value entered during the Data Entry

(**) With or without Euroloop or Radio Infill

The latest agreed definition of cab signalling (not to be regarded as an operational rule for train driver) is the following: "Cab signalling provides safe movement authorities to trains; these movement authorities are displayed on a device installed in the driver's cab". *Taking into account this definition the correspondent to draft operational rules for the train drivers is the following:* "The operational rules shall be clear for the driver. If he has "to look inside" because of cab signalling operation, he shall first look at the DMI in all cases; then, depending on the displayed information on the DMI he shall react according to the content of the operational rules. These operational rules could require him "to look outside"⁹.

8. ERTMS operational rules

The ERTMS operational rules, originally produced by the EEIG Users Group, are now in the responsibility of the ERA. A dedicated ERA working group "ERTMS Operational Rules" (set up in December 2008) is still developing the rules for baseline 2.3.0d (final version end of 2010) and the same group has been asked to produce a new set of rules for baseline 3 The scope and field of application of those rule is:

- ETCS level 1 application (whether or not trackside signals or infill are present);
- ETCS level 2 application;
- Transitions between level 1 and level 2 applications;
- GSM-R.

Consequently other rules have to be considered as "out of scope" as well in case of implementation of ETCS level 1 or level 2 on lines fitted with other signalling systems. In these cases, the applicability of

⁹ This definition as well the principles to draft the operational rule has been agreed last October after a deep analysis within the ERA Working Party Operational harmonisation of ERTMS.

those rules has to be assessed and, if necessary, national rules may be needed to supplement them. This also applies to all remaining references to national rules that are contained in the harmonised rules for ERTMS.

9. ERTMS engineering rules

The problem of engineering rules is a very sensitive issue because of the amount of different scenarios that can be drawn up at national level while implementing ERTMS in both areas: trackside and onboard. The objective to harmonise engineering rules as well the reduction of "operational specificities" in particular as regards the entrance in ETCS areas has been underlined in the MoU between the EC and European Railway Associations. Engineering rules can determine divergences for the operational rules to be applied and some criteria to be delivered by ERA should be able to help the European Railways to get a new target for a future full interoperability.

10. EU objective: speeding up ERTMS deployment

"The construction of a safe, modern and integrated railway network is a priority of the EU".

In attempting to reach this goal the European Commission supports the sectors mainly involved in this project, rail-freight and high-speed, using the trans-European network budget. ERTMS is part of a strategy for revitalising the railway industry and better balancing the different modes of transport, and thereby reducing external costs. In the context of removing technical barriers that are hindering the development of an international rail transport strategy, the first Memorandum of Understanding (MoU) *"establishing the basic principles for the definition of an EU deployment strategy for ERTMS" (17th of March 2005)* was negotiated between the EC and the European railway association (CER-UIC-UNIFE-EIM)¹⁰. All involved parties agreed to work together in order to pursue the implementation of ERTMS on a European-wide network (corridors) and in the definition of the contributions. In order to facilitate the implementation of ERTMS the European Commission appointed a Coordinator to act as ERTMS and rail corridor coordinator. His reports on the progress can be found at the Commission website.

In July 2008 a new MoU¹¹ "concerning the strengthening of cooperation for speeding up the deployment of ERTMS" has been signed between the EC and European railway association (CER-UIC-UNIFE-EIM-GSM-R-ERFA)¹².

This new MoU complements the one signed in 2005. It has clarified some principles:

- the unique and interoperable technical reference to ensure interoperability of all ETCS equipment deployed in EU are contained in the SRS 2.3.0d
- fully supporting "EIRENE options" review by ERA with a view to ensure that they cannot be required as track access conditions;
- TSI amendment by 2012 in order to include additional functionalities requested by IMs and RUs in a new baseline (baseline 3) ensuring a backwards compatibility;
- deeper cooperation between the EC and railway sector organisations.

In addition the last MoU has defined some specific objectives to be reached:

¹⁰ CER **(**Community of European Railway and Infrastructure Companies) - UIC (International Union of Railways - UNIFE (European Rail Industry) - EIM (European Rail Infrastructure Managers).

¹¹ The MoU signed in July 2008 as well all the documents related to ETCS and published by the European Commission can be easily found by scrolling this web page:

http://ec.europa.eu/transport/rail/interoperability/ertms/ertms_en.htm

¹² GSM-R (GSM-R Industry Group) - ERFA(European Rail Freight Association).

- foster coordination and collaboration to ensure the compatibility of existing lines and, by 2012, an error free tested and legalised baseline (baseline 3) should be made available;
- clarification on which baseline is to be used in tenders as an access condition;
- improvement in terms of efficiency and cost effectiveness of the existing testing and certification procedures for ERTMS;
- streamlining of the test procedures with the objective to reach a common, unique and efficient procedure;
- agreement of the sector on a number of measures aimed at speeding up the deployment of ETCS.

In the context of the deployment of TSIs the strategy for the implementation of ERTMS has been summed up in the ERTMS European Deployment Plan (EDP) where priority has been given to 6 Corridors. This plan has the scope to ensure that, gradually, locomotives, railcars and other railway vehicles equipped with ERTMS can have access to an increased number of lines, ports, terminals and marshalling yards without needing national equipment in addition to ERTMS. The last update version (27.05.2010) of the ERTMS Deployment Plan is summarized in Fig. 1

Fig. 1 ERTMS Deployment in 2020 version 27.05.2010

(http://ec.europa.eu/transport/rail/interoperability/ertms/edp_map_en.htm)

(The different national deployment plans per country (not always up to date in real time) can be found at the Commission's website.

The EDP makes ERTMS mandatory for all. A detailed timetable of the implementation on the six corridors A, B, C, D, E and F is given in the Appendix I to the Commission Decision of 22 July 2009¹³.

¹³ Commission Decision of 22 July 2009 amending Decision 2006/679/EC as regards the implementation of the technical specification for interoperability relating to the control-command and signalling subsystem of the trans-European conventional rail system.

11. "On the way" ERTMS development

The EC has invested a lot into the promotion of Interoperability and, as a consequence, into the deployment of ETCS as an interoperable signalling and train control system to be used on the interoperable trans-European network. The ERTMS (ETCS+GSM-R) project, as a unique signalling and communication standard throughout Europe, is still the major industrial project being implemented by Europe. In spite of that, until now, the absence of a single interoperability standard as well the economic effort to be made, by both IMs and RUs, has hampered the deployment of ERTMS in the wider European network. In April 2008 with the creation of SRS 2.3.0d the first obstacle has been removed.

Whereas with the adoption of the European deployment plan and the prioritisation (and co-financing) of the six corridors, the EC intends to contribute to the effective opening and to the competitiveness of the rail market in Europe. Despite these two main actions, the full technical interoperability of ERTMS components has still not been achieved. Indeed IMs and RUs have already requested new functionalities/modifications to the system with the consequence that it will lead to a new version of the ERTMS specification (so-called baseline 3).

To reduce the number of variables to be taken into account for the implementation plan (trackside and on-board) in the last MoU it has been agreed to have this new baseline established and legalised by the end of 2012. For the backward compatibility it is expected that *"trains equipped with baseline 3 shall be able to run on lines equipped with baseline 3 without any additional technical or operational restrictions caused by ERTMS"* whereas it is expected that there will need to be a limited upgrading for trains already equipped with 2.3.0d to run on lines equipped with Baseline3.

12. ERA role

In this process of implementation and in particular in the development of ERTMS the European Railway Agency is in charge of the whole Change Control Management process as the "System Authority". Consequently, via this CCM, ERA is managing all the *"activities which allow moving from one baseline release to another one"*. In this process of maintenance are included the reference specifications and documents listed in the Annex A of the officially published TSI CCS, excluding those not related to ERTMS/ETCS or ERTMS/GSM-R¹⁴. How the representative bodies from the railway sector¹⁵ (theoretically as well the trade unions), can have an impact in this process?

Some Working Groups as well as some Working Parties have been set up by ERA to take into account all coming input for modification requests and for consultations/decisions on the incoming issues. The medium to be used in the CCM process is the change requests (CR). A CR offers "*a transparent, formal and ordered processing of the changes leading to a new release*". All CRs coming from the mentioned representative bodies (including ETF), NSA's, Member States, EC or ERA itself are considered and the Agency ensures that a full traceability between the document changes and the Change Request is provided. Finally it is the responsibility of ERA "*to hand over to the Commission a proposal for an amended version of the specifications, for appropriate embodiment in the European legislation*". More details about the CCM process can be found at ERA website.

13. A new proposal from the Commission to facilitate the deployment of ERTMS

¹⁴ ERA document: ERA_ERTMS_0001 version 2.0 issued on the 3rd June 2010.

¹⁵ Referred to article 3 paragraph 2 of Regulation EC n° 881/2004 and listed by the RISC (Railway Interoperability Safety Committee) on 7 October 2009

In the general objective to have a more efficient and competitive rail transport in the EU the implementation of ERTMS plays a very important role.

The foreseen European Deployment Plan makes ERTMS mandatory for all trackside projects receiving EU funding but the equipment of lines as well as train with ERTMS should proceed accordingly and quite simultaneously.

To reach this goal a new proposal has been made by the Commission within the Recast of the 1st Railway Package: the reduction of infrastructure access charges for trains equipped with ERTMS. It is true that implementation of ERTMS on the six corridors will facilitate international rail transport but, due to the fact that these corridors will continue to be used also by national/regional trains, the corresponding RUs can have two different levels of interest in the equipment of their trains with ERTMS.

Who wants to operate in the international rail traffic will be forced to implement ERTMS on-board whereas who wants to continue operation only on a regional level does not have to do that. In this situation the existing on-board national systems will be retained by the regional trains and, as a consequence, also the relevant IMs will be forced to maintain them.

The availability of a stable set of specifications, the inclusion of standard clauses to cover maintenance and upgrading of the system equipments, reduction of infrastructure access charge can foster the attainment of a faster transition to ERTMS.