The ERTMS/Etcs system
The ERTMS/ETCS standard, which is one of the most significant innovations to have been introduced into the railway field, makes it possible for trains of different nationalities to travel throughout the network sharing a common information base defined using a common language, managed using common interoperable ground and on-board constituents.

More specifically, the standard defines the procedures for the ground and on-board exchange of signalling information between the ground-based and on-board equipment, identifying the transmission techniques to be used and the message format.

The ground-based and on-board ERTMS/ETCS basically removes the constraints on international train traffic caused by the differences between the present systems in different countries. The ERTMS/ETCS system provides the driver, in a standard format, with all the information needed for optimum driving, constantly controlling the effect of every action taken in terms of train safety, and activating emergency braking should the train speed exceed the maximum safety limits.

Italian railways were among the first in Europe to adopt the European Rail Traffic Management System/European Train Control System (ERTMS/ETCS) Level 2 on the new High-Speed/High Capacity network. ERTMS/ETCS has been installed to guarantee interoperable traffic on the European railway network; it is a system that is capable of guaranteeing train safety, thanks to the adoption of state-of-the-art technologies and functionality.

Trials are currently being conducted with the ERTMS/ETCS Level 2 system, without any fall-back systems or line-side signalling on the Rome-Naples High-Speed/High Capacity line which will be brought into commercial operation next year.
RFI’s Industrial Mission

Rete Ferroviaria Italiana, the Ferrovie dello Stato Group’s infrastructure company, operates under a government franchise, and relations with the government are regulated by the Programme Contract which lays down the investments that RFI is required to make. RFI has been given the task of identifying, studying and implementing the development of railway infrastructure in order to optimise the network’s capacity offering, developing infrastructure use, offering train traffic services and other complementary services, and allocating and regulating network access.

RFI also keeps the rail infrastructure in efficient working order, maintaining and renewing it and guaranteeing the highest possible standards in terms of quality and safety.

In a liberalised and deregulated transport market scenario, like Italy’s, RFI’s role as the infrastructure manager includes responsibility for issuing the Safety Certificate to operating companies without a license (granted by the Ministry of Transport) after ascertaining that they meet all the statutory eligibility requirements. It also gives the operating companies access to the infrastructure, and markets the lines, levying and collecting the toll charges.

In incorporating RFI, the Ferrovie dello Stato Group implemented the EU directive requiring network management and train operation to be entrusted to separate companies.
How did we reach ERTMS/ETCS?

Following the decision taken by the transport ministers in December 1989 a group of railway experts began studying the fundamental requirements for a European interoperable system and defining the *Project Declaration* (the UIC-ERRI-S 1069 study group).

**Figure 1** The ERTMS/ETCS block system set out in the *Project Declaration*
In June 1991, the industry (EUROSIG) and the railways (UIC) agreed on the principles for pursuing collaboration to develop new equipment for the European control and command system based on the ERRI-UIC specifications. The agreement made provision for the development of a new onboard display (EUROCAB), a new discontinuous ground-to-train transmission system (EUROBALISE), and a new continuous ground-to-train transmission system (EURORADIO).

After the definition of the ERTMS/ETCS Master Plan by the Commission, in 1995 the French, German and Italian railways jointly founded the European Economic Interest Group ERTMS/ETCS Users Group (EEIG-ERTMS/ETCS Users Group). The Spanish, British and Dutch railways subsequently joined the Group.

The purpose of the EEIG (which is also known by the French acronym GEIE) was to finalise the ERTMS/ETCS specifications produced by the UIC and to manage trial sites in France, Germany and Italy.

Under Article 155 of the Treaty instituting the European Community, which provides that all the citizens of the Union, businesses and national and regional authorities must be able to fully benefit from the advantages provided by an area without internal borders, it was decided to establish the conditions for guaranteeing more efficient international train circulation by issuing a European interoperability directive.
The interoperability directive for the High-Speed network


In order to define the solutions to meet the criteria laid down in the directive the European Union commissioned the AEIF (European Association for Railway Interoperability) to draft the Technical Specifications for Interoperability (STIs) for High-Speed Rail.

The railway administrations and the industries worked together within AEIF to develop the STIs, laying down the essential requirements (safety, reliability, health, worker protection, technical compatibility, operations), the interoperability components and interfaces, the European procedures for evaluating conformity/suitability of use, the functional and technical specifications, and the migration strategy for interoperability.

The solutions laid down for interoperability must be applied in all new applications and when the European High-Speed network lines are renewed.

In 2001 a new interoperability directive was adopted (2001/16/EC) for the conventional rail system. The Article 21 Committee approved the Technical Specifications for the Interoperability of the Control-Command System relating to the new directive on 23rd November 2004.

The essential element of the STIs for the conventional system is the adoption of the ERTMS/ETCS requirements into the specifications with small adjustments to the contents which, through the Change Control Management process will also be introduced into the STIs for the High-Speed rail system currently adopted.
With the new directive the *Migration* process has taken on a major role regarding the criticalities associated with the use of ERTMS/ETCS on existing conventional track. A great effort is currently being deployed to harmonise the overall migration plans of the European networks.

Discussions are in progress on the priority criteria and the optimum methods, also in terms of the cost benefit analysis (CBA), to create an interoperable network made up of the main corridors as identified within the TEN network. A map of the corridors recently agreed upon appears above.
WHAT IS ERTMS/ETCS?

ERTMS/ETCS is the European system for automatically controlling train movement and is the solution identified by Europe’s railways and industries for achieving rail interoperability. The specifications of the requirements are public, and define the so-called *kernel* and its interfaces with the ground-based and on-board equipment. The current specifications are ERTMS/ETCS Class 1 published in the European Journal in 2000.

At the present time the specifications are currently being consolidated by modifying and supplementing them in order to remove any errors and ambiguities that emerged in the trial stages and in the commercial applications of ERTMS/ETCS. The responsibility for appraising the admissibility of requests for modifications/supplements to the specifications and for indicating the ways in which they are to be incorporated into the existing specifications lies, as laid down in the process for the AEIF Change Control Management (figure 2), with the Board and the Steering Committee.

Generally speaking, the technical aspects of the requests for modifications and supplements made by railway networks are analysed in advance by the Eeig ERTMS/ETCS Users Group, which also provides its input to the CCB AEIF.

Decisions regarding requests for changes produced by the CCSC AEIF are formally submitted to the Article 21 Committee (the official representatives of the EU member states) for final adoption so that they can be published in the Official Journal of the European Union. The modified version of the specifications published in the Official Journal totally replaces the previous version.
Particularly important is the System Requirements Specification (SRS) which describes the ERTMS/ETCS kernel comprising the whole EUROCAB, the interface equipment with the GSM-R, the data transmission equipment with EUROBALISE, EUROLOOP and EURORADIO, and the interface with the lineside signalling systems (interlocking, signals) and other on-board systems (braking systems).
ERTMS/ETCS functionality

In conceptual terms, the functionality of ERTMS/ETCS can be summarised in the figure 3 flow chart. The ways in which the train can receive lineside information depends on the application level chosen for the ERTMS/ETCS.

There are three levels of application.

**Application level 1** (figure 4) uses a discontinuous type of transmission system for onboard transmission of data from the ground station using fixed balises or switchable balises appropriately positioned and linked to the signalling systems which constitute the information source (signals). The information and their coding method and their allocation in the telegram transmitted by the balise are standardised to comply with ERTMS/ETCS specifications.
The train position is determined by the conventional train position detection systems (track circuits). The onboard software manages the functionality described in the diagram shown in figure 3 with the available lineside and onboard information.

Application level 2 (figure 5) uses a continuous type of transmission system for the onboard transmission of lineside data through safe radio links between a Radio Block Centre (RBC) and the train.
The Radio Block Centres are linked to signalling units forming the data source (central equipment). Antennas linked to the Radio Block Centre at appropriate places along the line are used for transmission. The information in the radio messages and their coding method and allocation in the telegram transmitted are standards defined in the ERTMS/ETCS specifications.

Also for ERTMS/ETCS level 2, the position of the trains is determined by the conventional position detection systems (track circuits) while the onboard software manages the functionality that is similar to the one described in figure 3, using available ground-based data (of the same type, but better defined and more promptly supplied than at level 1) and train-borne data.

The GSM-R system used for track-train transmission is now being installed along all the lines in the basic network, border crossings and the High Speed network under construction (7,500 kilometres of network to be covered by 2006-2007).

ERTMS/ETCS level 2 requires the train to be capable of travelling on lines equipped with both ERTMS/ETCS level 2 and level 1.
An ERTMS/ETCS application level 3 has also been defined, even though it has not yet been brought into use. This does not use the traditional devices to detect train positions. The train position is detected on-board, and only calibration balises are installed track side.

For this solution, train integrity must be guaranteed, but this is a problem that is still far from having been satisfactorily resolved.

With the adoption of the mobile block which is no longer linked to sections of the line but to the real position of the moving train, level 3 makes it possible to establish the optimum distance between trains. This is another aspect that still leaves many problems unanswered, including those relating to the impact on operating rules and standards.

ERTMS/ETCS trains with the national system’s Specific Transmission Module (STM) installed on-board can travel along the lines that are equipped with this system. STM equipment can provide ERTMS/ETCS with standard information taken from the information in the ground-based national systems and make it possible for the national system’s services to be used.

A summary of the equipment needed for the different ERTMS/ETCS application levels is given in table 1.

<table>
<thead>
<tr>
<th>ERTMS/ETCS level</th>
<th>On board</th>
<th>Track-side</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Check of train integrity</td>
<td>Data transmission</td>
</tr>
<tr>
<td>1</td>
<td>no</td>
<td>balises+loops (option)</td>
</tr>
<tr>
<td>2</td>
<td>no</td>
<td>balises+radio</td>
</tr>
<tr>
<td>3 (planned)</td>
<td>yes</td>
<td>balises+radio</td>
</tr>
</tbody>
</table>
ERTMS/ETCS DEVELOPMENT PLANS

ERTMS/ETCS is considered to be the most appropriate technological signalling solution for the future. Equipping the new High Speed/High Capacity lines with ERTMS/ETCS limits the use of the more dated national systems and prevents the development of new national systems. With the large-scale use of ERTMS/ETCS, apart from the resulting interoperability, train circulation safety is improved, particularly in countries that have more primitive signalling systems.

For the conventional lines, on which Austria and a number of Eastern European countries are extensively installing ERTMS/ETCS level 1, the highest priority set out in the European transport policy documents is to establish interoperability in the so-called international corridors, firstly at the technical level and then at the operating regulation level.

Within the next five years a number of international corridors will become interoperable, at least at the technical level, thanks to the adoption of trackside and on-board ERTMS/ETCS as an alternative and/or in addition to the pre-existing systems. Spain, Belgium, France, Italy, Germany, the Netherlands, Sweden, Switzerland, Austria, Bulgaria, Hungary, Luxembourg and Romania expect to introduce ERTMS/ETCS on most of their networks.

The main applications being implemented or planned for the European High Speed network are listed in table 2.
### Table 2 ERTMS/ETCS Applications for the European network

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Line</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spain</td>
<td>2003</td>
<td>Madrid-Lleida</td>
<td>1 e 2</td>
</tr>
<tr>
<td>Germany</td>
<td>2004</td>
<td>Ludwigsfelde-J-H/L</td>
<td>2</td>
</tr>
<tr>
<td>Italy</td>
<td>2005</td>
<td>Rome-Naples</td>
<td>2</td>
</tr>
<tr>
<td>UK</td>
<td>2005</td>
<td>WCML</td>
<td>1 e 2</td>
</tr>
<tr>
<td>Netherlands</td>
<td>2005</td>
<td>Betuwe Lin</td>
<td>2</td>
</tr>
<tr>
<td>France</td>
<td>2006</td>
<td>TGV Est</td>
<td>2</td>
</tr>
<tr>
<td>Netherlands</td>
<td>2006</td>
<td>HSL-Sud</td>
<td>2</td>
</tr>
<tr>
<td>Italy</td>
<td>2008</td>
<td>Milan-Bologna</td>
<td>2</td>
</tr>
<tr>
<td>Italy</td>
<td>2008</td>
<td>Bologna-Florence</td>
<td>2</td>
</tr>
<tr>
<td>Italy</td>
<td>2008</td>
<td>Milan-Turin</td>
<td>2</td>
</tr>
<tr>
<td>Italy</td>
<td>2010</td>
<td>Milan-Venice</td>
<td>2</td>
</tr>
</tbody>
</table>

**ERTMS/ETCS for the Rome-Naples High Speed/High Capacity line**

The Rome-Naples HS/HC line has been built using the ERTMS/ETCS level 2 system, without fall-back systems.

This decision was taken as a result of the interoperability directive which provides that the new HS lines should be equipped with ERTMS/ETCS, guaranteeing high standards of operating safety on the national railway network, which is already one of the best in Europe, and optimum traffic management.

On the HS/HC lines, train distancing, drivers cab signalling and ensuring drivers’ compliance with all the procedures will be guaranteed by the ERTMS/ETCS level 2 equipment.

For the HS/HC lines will not be equipped with lineside signalling lights which are difficult to interpret the high speeds. The drivers will operate their trains under full supervision based exclusively on the information displayed on board.

If the maximum permitted speed is exceeded, the system immediately activates the emergency braking system and guarantees that the train will stop before the protected point is passed.
ERTMS/ETCS level 2’s ground technology comprises a central unit, the so-called Radio Block Centre (RBC) installed in specific central posts from which railway circulation is managed and controlled through the System of Command and Control (SCC).

The RBC continuously transmits to every train, via GSM-R radio, the speed and the train distance to be observed depending on the position of all the trains present on the line (train distancing) and the constraints imposed by the track, or by any temporary slowdowns at that particular moment. At the same time, the trains send out radio signals indicating their position to the central unit.

On the basis of the state of the infrastructure (free line, routes in the stations, train speeds, slowdowns) and the position of the train, the RBC transmits *authorisation to proceed* data to the on-train unit, giving details of the free distance and the maximum permitted speed at the point.

![ERTMS/ETCS block diagram](image-url)
ERTMS/ETCS level 2 is characterised, in terms of its onboard technology, by safety equipment which enables the driver to proceed based solely on the RBC information to the onboard EVC (European Vital Computer) subsystem posted on a screen forming part of the Driver Machine Interface (DMI). An ERTMS/ETCS block diagram is shown in figure 6.

The DMI (figure 7) is the European-standard display which not only provides the driver with information on the actual speed and the free downline distance, but also with continuous data on the maximum permitted train speed. Using this information (Full Supervision), the onboard subsystem takes all the appropriate action needed to guarantee the safety of the moving train (operating the braking control system if the driver fails to take action).

ERTMS/ETCS level 2 uses the GSM-Railway (figure 8) system for communications between ground staff and on-board staff. In its railway version, GSM-R enables voice communications and data transmissions for train travelling safety purposes.

The GSM-R radio network project forms part of the agreements which the Ferrovie dello Stato Group has concluded within the UIC to lay down common and interoperable standards with the other European networks.
RFI’s migration strategy

The application of the ERTMS/ETCS system both to the High-Speed lines and to the traditional network and border crossings forms part of the technological renewals programme of RFI, the Ferrovie dello Stato Group’s infrastructure company. The migration strategy, which the Ministry of Transport officially notified to the European Commission when the Sti CC came into force, makes provision for the following:

“The High-Speed lines currently under construction (Rome-Naples, Florence-Bologna, Bologna-Milan, Turin-Milan), which are scheduled to be brought into commercial service between 2005 (Rome-Naples) and 2008, and the other High Speed lines currently in the design stage (Milan-Venice, and the third Giovi border crossing) will all be equipped with ERTMS/ETCS level 2”.

The new High-Speed trains will be equipped with ERTMS/ETCS level 2, and with the national STM for the systems that are set out in schedule B of the TSI Control Command to ensure internal interoperability both with the conventional network lines and with the existing Rome-Florence High Speed line, until it is equipped with ERTMS/ETCS level 2, as scheduled.

“The border lines to be connected to the High-Speed network, which are necessary for European interoperability, will be equipped in the medium-term with ERTMS/ETCS level 2, while keeping the national system as a fall-back system”.

The existing systems, and those currently being implemented, will at all events make it possible for interoperable trains equipped with national STM to circulate.

“The main conventional network lines will be gradually equipped with ERTMS/ETCS in the longer term, based on the principles defined in chapter 7 of TSI Control Command”.


In order to hasten migration towards interoperability in the interoperable corridors identified in the Trans European Transport Network and defined as priorities in June 2003 by the high-level group chaired by Karel Van Miert, possible technical options were examined that might reduce the times for the interoperability of these corridors, seeking also to harmonise the initiatives and the scheduling of the other networks affected by the same corridors, particularly Switzerland, Austria and France. One practicable short term solution for those border crossing lines with a lower traffic capacity and commercial speeds could lead to integrating the functionality of the national SCMT system without BACC with the functionality of the ERTMS/ETCS level 1 system without infill. With this solution, by taking specific precautions, SCMT balises would also be used by ERTMS/ETCS, and would make it possible for both national SCMT trains to circulate, as well as interoperable ERTMS/ETCS trains with similar operating features.
Meetings are currently being held with the Swiss Railways to organise trials with this solution on a line on the Italian-Swiss border (probably the border crossing at Luino). The aim of these trials would show whether this solution will make it possible for an interoperable SBB train to travel along the RFI line equipped in this way without having to add the STM for SCMT. The dual SCMT+ERTMS/ETCS functionality, guaranteed by EUROBALISE, is shown in diagrammatic form in figure 10.
It should be noted that if the trials on the experimental Italian-Swiss line are successful, this could be a solution for interoperability on the conventional network lines as well as on the lines linking the national HS/HC network into the European High-Speed network (including the border crossing lines with low traffic capacity and commercial speeds), and lines linking the basic conventional network to the national HS/HC network.

For wherever it is planned to install SCMT on part of these lines, whether they are presently equipped with axle counter blocks or whether they are without any evolved signalling systems, it might be appropriate to plan such a solution from the outset.

In order for this solution to become an interoperable ERTMS/ETCS standard, the ERTMS/ETCS specifications must introduce a modification so that on-board ERTMS/ETCS with reduced functionality can be used, even if there is a full ERTMS/ETCS level 1 ground installation present.

Full functionality onboard could also be obtained with a ground installation of ERTMS/ETCS level 1, whenever a correct infill functionality is introduced (through GSM-R or a loop).

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**Figure 11: Official map of the interoperable network**

The map shows the planning stages and lines for the interoperable network, with different colors and symbols indicating the status and type of network lines. The map includes key cities and lines such as Milan, Turin, Genoa, Rome, and others, with timelines for deployment.

- **ERTMS/ETCS lev.2 only**: Very short term before 2005
- **ERTMS/ETCS lev.1 overposed On SCMT**: Short term before 2009
- **Conventional network**: Medium term before 2012
- **High Speed network**: Long term after 2012 (some other blue and yellow lines)