

UNISIG®



ERTMS® - Europe's Digital Rail Backbone

Leveraging Stability to Streamline Requirements and Reduce Costs UNIFE's ERTMS® Vision

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UNIFE – The European Rail Supply Industry Association



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ERTMS®

Executive Summary

ERTMS® was first mentioned in European legislation in 2002, specifically in the first version of the CCS TSI of the trans-European high-speed rail system based on Council Directive 96/48/EC of 1996 with the visionary concept of a pan-European interoperable control-command and signalling (CCS) of the European rail system.

A quarter of a century later, ERTMS® stands as a truly remarkable achievement. It has become a European standard for automatic train protection (ETCS), radio communication (GSM-R (2G), FRMCS (5G)) and automatic train operation (ATO).

From Europe to networks across the world, especially ETCS is now advancing railways globally, improving safety for passengers and freight alike and often unlocking extra capacity on existing lines. The system is flexible by design, offering a large toolbox developed by ideas of the European operating community based on diverse operational philosophies and geographies in Europe. This makes the system functionally versatile and adaptable. As an interoperable standard, it unleashes competition: users can choose from the products and systems from a vibrant lineup of world-leading European vendors. This makes ETCS a unique and highly competitive solution.

Over the years, ERTMS® has evolved into a highly sophisticated and robust system. Building on this strong foundation, we are excited about the opportunity to advance the system to the next level.

Essential evolutionary steps are necessary, including the unavoidable transition from 2G to 5G radio communication and the strengthening of cybersecurity measures to safeguard operations in an increasingly digital environment. At the same time, we advocate for a disciplined approach – guided by the principle of stability: any functional enhancements or architectural changes that are not required should be carefully avoided.

Furthermore, the ERTMS® ecosystem currently carries certain requirements in its legacy - technical and legal and purely European - that contribute disproportionately to costs in Europe. By addressing these elements thoughtfully, we can streamline implementation, reduce lifecycle costs and enhance overall value for railway undertakings and infrastructure managers alike.

We are enthusiastic about this path forward: a stable, evolved ERTMS® that maximises benefits, minimises burdens, and continues to drive the future of safe, efficient and interoperable rail transport.

We present this paper as the launchpad for our practical initiatives, first detailing the significant benefits and current challenges of ERTMS®. We are committed to continuously refining our approach; therefore, future appendices to this paper will offer – based on the challenges outlined here – ongoing details and strategic suggestions from the supply industry community designed to ensure ERTMS® realises its full potential.

This paper and its subsequent appendices outline our ERTMS® vision.



ERTMS® at a glance – benefits, challenges and suggestions for improvement

The benefits

ERTMS® is at the heart of digitalisation driving forward the European Commission's Sustainable and Smart Mobility Strategy. It is the core of the SERA[1] target architecture for CCS. Its radio capabilities unlock opportunities to significantly reduce trackside equipment, driving down costs and complexity across the network. Its functional richness provides a foundation for harmonising operational rules continent-wide. Together, these two benefits - the pan-European target architecture and the harmonised operation - represent a leap forward for European rail. When correctly implemented and supported by a well-designed migration plan, the full potential of ERTMS® will be unleashed.

ETCS is the digital safety backbone of modern rail and lies at the core of it all. ETCS ensures safe protection by

continuously supervising and enforcing safe speed and target supervision, preventing any exceedance whether caused by other subsystems like ATO, or by human actions.

FRMCS is set to revolutionise rail communications as the successor to GSM-R. Built on 5G technology, FRMCS will deliver mission-critical voice and data for ETCS and ATO, while unleashing an array of transformative new applications.

ATO takes efficiency to new heights, by supporting drivers with precise, optimised acceleration and deceleration profiles and holding the promise of fully automated driving. ATO boosts operational efficiency, maximises line capacity, reduces energy consumption, enhances punctuality and delivers smoother, more comfortable journeys for passengers.

[1] Single European Railway Area

CASE STUDY

Lean implementation: ETCS Level 1 Limited Supervision

ETCS Level 1 Limited Supervision (LS) offers a practical and interoperable approach for migrating to ETCS on existing infrastructures.

This mode allows railways to implement ETCS on the operational base of existing lineside signalling with minor modifications. As a result, it significantly reduces the planning and implementation effort compared to full ETCS deployment, particularly on lines that are already equipped with legacy signalling systems providing information that can be used by ETCS.

In Limited Supervision mode, ETCS provides continuous supervision of the movement authorisation in the background. Unlike full ETCS in Level 1 or Level 2, it does not require the transmission of a complete speed profile. Instead, the system focuses on core protection functions similar to those performed by traditional ATP systems.

This makes ETCS Level 1 LS a suitable start-up version for networks seeking to achieve ETCS interoperability while keeping costs and operational disruption to a minimum. Several European countries, such as Switzerland and Belgium, have successfully implemented or are progressing with this option as part of their migration strategies, using it as a step towards higher ETCS application levels.

Sophisticated implementations: ETCS Hybrid Train Detection and Moving Block

ETCS Level 2 with Hybrid Train Detection (ETCS HTD) advances capacity enhancement while reducing reliance on extensive trackside equipment. This hybrid approach combines conventional trackside train detection with train-based rear-end detection and position reporting.

Fixed block sections defined by conventional trackside train detection systems are subdivided into smaller virtual sub-sections. This subdivision enables shorter headways and higher line capacity without additional physical infrastructure, leveraging existing trackside assets.

Train length and integrity confirmation are derived from information on-board. As a result, responsibility for train integrity monitoring shifts partially from trackside equipment to on-board.

To advance the system even further, ETCS Level 2 is also prepared to operate without conventional trackside train detection systems. With the so-called Moving Block, a movement authorisation is computed by utilising precise knowledge of the rear end position of the preceding train, provided that the information about train integrity (completeness of the train) and the train length are safely provided to the ETCS on-board. This approach establishes a dynamic safe zone in rear of the moving train.

The resulting Moving Block systems significantly reduce the headway between successive trains, enabling following trains to close up to a distance that corresponds to the braking distance of the leading train.

The challenges**Trackside diversity**

While the ETCS on-board equipment is required to implement the complete set of functions in a fully standardised manner, ETCS trackside implementation offers considerably greater flexibility.

In essence, ETCS provides a rich palette of trackside design possibilities. This versatility is a distinct advantage, enabling the system to support virtually any conceivable operational scenario.

At the same time, it presents two notable challenges:

1. A lack of ETCS trackside harmonisation has resulted in inconsistent implementations throughout Europe. Although compliance with the specification is maintained, varying implementation principles encourage bespoke solutions, thereby hindering suppliers from realising economies of scale.

2. Anticipating trackside versatility is crucial during verification and validation throughout ETCS on-board product development. This proactive approach helps prevent unforeseen behaviour in the ETCS on-board caused by variations in trackside implementation. Greater flexibility in trackside design naturally leads to a more complex - and expensive - testing regime for the on-board product.

Quote

Striving for harmonisation

"I have been striving for standard design and the manufacture of fewer types for 15 years. But it is very difficult! Every railway and management has its own preferences. We have never received orders for hundreds of identical devices; there is no such thing as mass production!"

Werner von Siemens to his brother Carl

The topic of harmonised operation rules and harmonised trackside design specifications for a European Trackside Protection System (ETPS) has been systematically advanced by EU-Rail's System Pillar, thanks to the collaboration between the rail operating community and the supply industry. We believe this joint effort has the potential to deliver compelling, game-changing results, if supported by all infrastructure managers in Europe.

Scope

Over the years, ETCS has matured into a robust and sophisticated ATP system, incorporating a wide array of innovative features.

Nevertheless, not all of the advancements are classified as mandatory for an ATP system. Furthermore, certain ETCS concepts and functions remain underutilised, highly specialised or limited in their deployment.

Quote

Striving for simplicity

"That's been one of my mantras - focus and simplicity. Simple can be harder than complex: You have to work hard to get your thinking clean to make it simple. But it's worth it in the end because once you get there, you can move mountains."

Steve Jobs

Similarly, we must avoid repeating this pattern with FRMCS. UNIFE has requested that FRMCS functionalities be limited to what is essential for the migration from GSM-R to FRMCS. Unfortunately, we do not feel that this concern is being addressed by other stakeholders. The primary objective must be to secure railway operations during this unavoidable technological transition. To achieve this, limiting the functional core of FRMCS to the level of functional equivalence with GSM-R will be sufficient. The extended benefits of FRMCS can then be implemented in later stages through step-wise enhancements.

The reduction of scope in the current ERTMS® framework represents a critical priority that must be decisively addressed by the European Union Agency for Railways (ERA) and the European Commission with the support of the ERTMS Users Group (EUG) and UNIFE/UNISIG®. Tackling this issue is essential to safeguard the substantial investments made by railway undertakings and infrastructure managers, while also enabling the rail supply industry to achieve the necessary economies of scale and deliver cost-effective, reliable solutions across the Single European Railway Area.

Maturity of functions

One of the most significant challenges within the ETCS landscape is the ongoing necessity to issue change requests to address identified errors or technical ambiguities in the current specification. While continuous maintenance and rigorous quality improvements are both expected and necessary for a system of such sophisticated engineering and scope, this iterative process presents substantial hurdles for the entire European rail community.

The fragmented implementation across the continent demands seamless, high-level alignment between Infrastructure Managers, Railway Undertakings and suppliers. Under the leadership of ERA, stakeholders must navigate the complex task of determining exactly how and when these change requests should be integrated, or whether localised mitigation measures are sufficient to ensure safety and interoperability.

At its core, this challenge stems from the functional richness of ETCS, coupled with the inherent difficulties in maturing specifications for newly introduced requirements. Currently, the regulatory framework does not mandate that functions be fully implemented and proven before they become legally enforced.

Addressing this gap is essential to fostering a more stable, predictable and streamlined deployment of ETCS across Europe.

Maturity of requirements

“Finding and fixing a software problem after delivery is often 100 times more expensive than finding and fixing it during the requirements and design phase.”

Barry W. Boehm

Quote

Certification and authorisation

The regulatory burden in railway signalling projects is overwhelmingly driven by the certification and authorisation processes in the European Union. What stands out most is not the external costs from assessment bodies or authorising entities, but rather the challenge faced by highly specialised experts in navigating and mastering the dense, ever-evolving jungle of regulations, directives and diverse national implementations.

Steering the approval process has evolved into a sophisticated sub-project management discipline in its own right. It requires coordination of numerous activities and above all, of the many people and organisations involved. Even activities that may feel superfluous, such as requirements capture or repeated quality management approvals, must be rigorously performed.

Despite the European Union’s ambitious efforts to achieve a higher-level of harmonisation - most notably through the Fourth Railway Package - authorisation-related costs have continued to rise.

The primary driver? The sheer volume and granularity of details that must now be addressed: one additional process step here, a new mandatory document or updated template there. Compounding this, many regulations still lack sufficient clarity – particularly when applied for the first time – which inevitably leads to misunderstandings and divergent views.

Regulatory burden

“[...] we claim to favour innovation, but we continue to add regulatory burdens onto European companies, which are especially costly for SMEs and self-defeating for those in the digital sectors. More than half of SMEs in Europe flag regulatory obstacles and the administrative burden as their greatest challenge.”

Draghi Report

Quote

Finally, the combination of thousands of highly detailed requirements for ERTMS® - coupled with the uncompromising expectation of 100% compliance - has dramatically intensified both the effort required and the inherent risks. In practice, there is almost always at least one item that falls short of perfect compliance. The decision as to whether it is a minor deviation, a genuine problem, or even a critical impediment is often a matter of personal opinion, sometimes unpredictable - adding yet another layer of complexity to the entire process.

Risk and market fragmentation

A key challenge lies in seamlessly integrating ERTMS® into existing environments which are often not originally designed for this advanced technology. This goes far beyond simply supplying an ERTMS® product. Successful implementation demands sophisticated integration of trackside ERTMS® with interlockings, traffic management systems and legacy Class B signalling solutions.

On the on-board side, the achievements are equally impressive yet demanding. Integrating ERTMS® with Class B[2] and combining ERTMS® and Class B display/control elements into a unified, intuitive driver-machine interface represents a major engineering challenge. Furthermore, integrating the system into the vehicle environment and navigating the complexities of vehicle authorisation add another layer of precision and expertise.

Suppliers who already provided the original infrastructure or the vehicle types hold a clear advantage. Not every company is positioned or chooses to shoulder the substantial investments and inherent risks that come with these complex projects.

To overcome these challenges and unlock the full potential of ERTMS® deployment, we must strategically reduce project complexity and foster a more competitive, efficient and inclusive environment for all stakeholders. This is an opportunity to streamline processes, accelerate migration and drive broader industry participation. A key technical advancement in this direction is the increased modularity designed to streamline the integration of ETCS on-board units into the vehicle, following the 2023 CCS TSI. This builds upon the UNISIG® concept for the Ethernet CCS Consist Network (ECCN) outlined in Subset-150[3]. The most recent iteration of Subset-150 details the methods for further progression. Within the ECCN framework, this development is driven by EU-Rail’s System Pillar, supported fully by UNIFE/UNISIG®.

Similarly, we fully support the interface specifications agreed upon within EU-Rail's System Pillar regarding trackside assets.

These activities must continue in the long term.

Lack of stability

The ERTMS® ecosystem faces diverse pressures from various directions: society rightly demands ever-higher levels of safety and security; the inherently digital and adaptable nature of ERTMS® naturally fuels strong expectations for functional enhancements and architectural improvements, aspirations actively and enthusiastically pursued by key users. At the same time, European regulation built up substantial layers of processes and administration.

Together, these external forces continuously occupy and challenge the entire rail supply industry and its customers. Right now, the pressure is generated by a swirling, unstable exterior: a continuous wave of ambitious user expectations, regulatory layers, and shifting standards that keep everyone reacting instead of advancing.

By providing a period of genuine stability, we free up precious engineering talent, creativity, and financial resources that are currently absorbed by constantly shifting external requirements. Once released from that burden, these forces can be redirected toward innovation, delivering more cost-effective, and faster-to-deploy ERTMS® solutions for the benefit of the entire European rail community.

Stability is not stagnation, it is the essential precondition for the next decisive leap forward.

Recommendations

Despite the European challenges, we are enthusiastic about ERTMS®. We are convinced that it represents the right path forward for European rail and, quite simply, there is no credible alternative. Because of our strong belief in its potential, we listen very carefully to the voices of ERTMS® users and customers. Lawmakers and system authorities must listen just as attentively.



While some criticisms highlight genuine issues that need urgent resolution, others can sometimes obscure the root causes. Rest assured, every one of these challenges is solvable and we are determined to solve them.

Our concrete proposals on how to improve will be part of the appendices to this document. The main policy recommendations we will put forward are the following:

TOPIC	RECOMMENDATIONS
Trackside diversity	Our recommendation is to define and implement harmonised operational rules, trackside specification and engineering rules. ERTMS® and the SERA would strongly benefit from a pan-European streamlined trackside architecture as this will promote greater consistency and efficiency in trackside deployments. At the same time, it will reduce efforts for ETCS on-board design, testing and maintenance.
Scope	Our recommendation is to prioritise a clear focus on CCS TSI and agreed SERA specifications to reduce the total number of requirements, both nationally and project specific. Consolidation of existing requirements will simplify the long-term maintenance of the ETCS system specifications. Prioritising functional equivalence with GSM-R will ensure a faster and more manageable transition to FRMCS.
Maturity of requirements	Our recommendation is to agree on maturity criteria, e.g. a defined Technology Readiness Level (TRL) for new functionality as a precondition before their legal enforcement. A maturity threshold for new functionality will reduce the volume of later change request for error corrections.
Certification & authorisation	Our recommendation is to alleviate the administrative burden and streamline the authorisation processes. Simplification of the authorisation process stands out as perhaps the most immediate and powerful opportunity we have because it delivers substantial efficiency gains at virtually no additional cost.
Risk & market fragmentation	Our recommendation is to reduce project and market fragmentation risks, especially by accelerating the phase-out of legacy national signalling systems or other national specifics. This will eliminate transitional complexities, substantially lower maintenance costs for both vehicle and infrastructure and enable broader supplier participation in tenders.
Lack of stability	Our recommendation is to slow the pace of ERTMS® system evolution, both technically and regulatorily. This will reduce functional, formal and political impacts, thereby freeing up resources, e.g. for use in the ERTMS® roll-out.

To unlock the full potential of ERTMS®, deliver the efficiency gains it promises, and restore the strong, positive reputation it truly deserves, the entire European railway sector must act as one unified team.

ERTMS® is undoubtedly an outstanding technology; nothing else globally approaches its capability within the railway sector. The challenge lies not in the technology itself, but in the surrounding European ecosystem - characterised by

non-harmonised areas, excessive and immature requirements, unnecessary regulatory bureaucracy, and organisational friction. However, these challenges are surmountable, and we are optimistic about what can be achieved through sector-wide collaboration.

Let us seize this opportunity: ERTMS® can and will succeed both in Europe and elsewhere, and we remain fully committed to making it happen.





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