Executive Summary:
The main scope of the Next Generation Train Control (NGTC) project was to analyse the commonality and differences of required functionality of two major train control systems ETCS (European Train Control System) and CBTC (Communications-based train control), and determining the level of commonality of architecture, hardware platforms and system design that can be achieved. The proposed NGTC solutions are based on the experience of ETCS and its standardised train protection kernel and by using experiences suppliers have gained by having developed very sophisticated and innovative CBTC systems around the world.
Nevertheless, the goal of the project was not to develop a system of ‘one size fits all’, but to make progress for all railway domains in terms of increasing the commonality in system design and hardware, with various benefits like increasing economies of scale for suppliers, and amongst other things customers having the benefit of being able to choose the most competitive supplier, based on standardised functions and interfaces.

NGTC has also delivered general moving block principles for rail applications, in-depth study on future generations of IP-based radio communications and significantly progressed in research on satellite-based train positioning suitable for ETCS.

Project Context and Objectives:
The wide and successful deployment of ETCS technology across the EU network and worldwide is providing new opportunities for safety and capacity improvements, and cross-border operations on the mainline network. Likewise, numerous new innovative CBTC based control and command signalling systems are being introduced in the urban rail area, equally providing capacity and reliability improvements.

On the one hand ETCS defines a standard train protection system which is based on a set of defined functions and track-to-train messages (airgap) providing full interoperability between the infrastructure and the trains. On the other hand, the various control and command systems in the urban world (CBTC) have proven to be successful performers, yet are not “interoperable” between themselves. The same European industry is the world leader for both of these types of systems.

With the continuous growth of large cities, the market is more and more looking to signalling solutions to provide a smooth connection between dense urban network and the surrounding suburban/mainline network. The next generations of rail systems will have to address the following different markets:

- Urban systems (metro) operated on fully independent infrastructure; many with very high performance requirements;
- Mainline systems connecting cities;
- Regional systems (sometimes suburban) which are fully part of the mainline domain;
- Suburban systems (like the Paris RER or the London Crossrail and Thameslink) which are neither “fully mainline” nor “fully urban”.

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Finally, achieving these objectives will help the European Industry maintain a competitive advantage.
NGTC paved the way for standardized train control systems for mainline and urban domains which provide ATP, ATO, and ATS functionality and support train operation from Grade of Automation GOA0 to GOA4, whilst reducing TCO/Life cycle costs, and achieving an overall improvement in performance at lower cost. In addition, it must be possible to offer scalability for different customer requirements (ranging from low density lines to high performance lines).

A major condition for the project was to preserve the backward compatibility with the current Baseline 3 ETCS in order to protect the already large investments made by the Customers and Suppliers in this field.

More specifically, NGTC has followed four main objectives with the number of research activities, described below:

1) Further development of CBTC (Communication Based Train Control) based control systems including the onboard and wayside equipment and associated standard interfaces:
NGTC work has been based on CBTC Standardisation such as, MODURBAN deliverables, existing standard IEC62290-1 and 2, and the IEEE 1474 series of standards with the overall objective to overcome the past constraints of proprietary CBTC solutions.

2) Introduction of new technologies in the ERTMS (European Rail Train Management System) standard architecture to fit further requirements from railway undertakings:
Based on worldwide market driven requirements, NGTC has undertaken research work on Satellite positioning and IP based radio communication, as potential future add-ons to the existing Baseline 3 ETCS. Also, a further study of the Moving Block concept from a system point of view has been addressed.

3) Investigation of the next generation of ERTMS technical specifications and their associated standard interfaces: The new ERTMS message structures have been proposed to make the system a more scalable solution, while maintaining, the backward compatibility with the Baseline 3 ETCS message specifications.

4) Investigation of various possible industrial synergies between the control systems of the two domains, in terms of specifications for on-board and wayside equipment, certification processes, as well as the facilitation of trans-border operations between the mainline and suburban systems:
Functional requirements common to the mainline and urban domains have been identified and common functional allocation for mainline and urban applications has been developed. This provided the opportunity for common hardware and software platforms for suppliers and making the obsolescence management challenges less problematic for operators.

Project Results:
WP2 (ETCS/CBTC investigation of operational and functional consistencies & differences)
Deliverable D2.1 provided a guidance on the working practices and methodology for performing the functional requirements analysis by the Urban and Mainline railways. Deliverable D2.2 introduced the operational principles of both mainline and urban state-of-the-art train control systems, mostly based for mainline rail on ERTMS/ETCS principles and for urban rail on UGTMS/CBTC principles. Deliverable D2.3 presents the current level of functional commonality between the urban and mainline train control systems, based on the “AS IS” analysis. Deliverable D2.4 describes the final results of the “TO BE” functional analysis of mainline and urban train control systems. The report is based on the delivered full comparison analysis in the form of extensive Excel Spreadsheet. The final functional requirements specifications are presented in the Deliverable D2.5 “FRS for NGTC - Core and for the functions and requirements specific to each domain – Mainline and Urban”. The NGTC FRS was the major input for developing the NGTC
WP3 (Technical Coherence)
Deliverable D3.3 specifies the architectures and initial functional allocation to subsystems for a future train control system for both the mainline and urban railway domains. Deliverable D3.4 contains the detailed description of those functions that require changes to the existing ETCS messaging. Deliverable D3.5 (System Architecture and Function Allocation) specifies the final architectures and functional allocation to subsystems for a future train control system. Separate architectures are provided for each domain as well as descriptions for Urban ATP functions, Mainline ATP functions, ATO functions, and ATS functions and sub-functions. The NGTC specification increases the level of commonality between mainline and urban systems by defining the common ATO component. Based on the NGTC system design and function allocation, deliverable D3.6 specifies the interfaces within NGTC that are common for urban and mainline, as well as the urban specific interfaces. Deliverable D3.7 reports on the consistency achieved between NGTC Functional Requirement Specification and actual NGTC design.

WP4 (Message Structure for Mainline)
NGTC has specified additional functions for ETCS:
- Platform Doors Management;
- Automatic Turn-back Operation;
- Automatic Coupling;
- Automatic Splitting.
Deliverable D4.1 describes the information needed to be exchanged between on-board and trackside for the above mentioned new functions. Deliverable D4.2 describes the messaging and its content and deliverable D4.3 provides the detailed structure of Messages and Packets. Deliverable D4.4 reviews and considers the current practices of safety engineering processes and checks for conditions and requirements to the new introduced functions. Deliverable D4.5 provides a simulation with designed scenarios to analyse proposed message structures, field element densities and timing scales vector for an IP based radio candidate suitable for mainline railway applications.

WP5 (Moving Block Principles)
Deliverable D5.1 defines generic Moving Block Principles, applicable to all classes of railway in normal as well as under failure conditions. The NGTC experts performed a detailed validation for proposed Moving Block Principles thorough a series of normal operation and failure scenarios for different railway types. The results are summarised in D5.2 report.

WP6 (IP based radio communication)
Deliverable D6.1 provides Requirements Specifications for NGTC, IP-based, radio communication system that describe both mainline and urban functional requirements and system performance requirements with a focus to increase the convergence of the two systems. D6.2 specifies a number of technical criteria to classify the potential candidates for future radio communications and selects 3 of them for further detailed study. D6.3 details recommendations from NGTC project towards external stakeholders for the following aspects:
- frequency selection;
- possible radio vectors;
• IP Suite integration.

For the perspective future candidates for radio-based communication systems, the deliverable D6.4 provides a performance study in terms of throughput. Deliverable D6.5 provides further study details, especially in terms of Quality of Service (QoS). The results of all the studies are then summarised in D6.6. Finally, D6.7 concludes NGTC technical studies and details the key aspects of the IP communication system such as:

• IT Security;
• IP-Rules;
• External Interfaces;
• Multivector Architecture;

WP7 (Satellite Positioning)

D7.1 provides a description of the scenario as well as the roadmap with identified key elements that need to be considered to achieve a successful adoption of satellite positioning, as part of the ERTMS. Deliverable D7.2 specifies generic GNSS receiver characteristics for standardised applications to ensure a minimal positioning performance in a given rail environment. Deliverable D7.3 details the procedures for GNSS-based positioning performance assessment based on the simulations with modelled key effects. D7.4 provides an architecture proposal for the integration into the existing ETCS system together with requirements on the engineering rules for virtual balises. D7.5 specifies the functions linked to the location database, needed to provide track location information on-board. These functions are necessary for reliable GNSS-based location of the train by means of virtual balises. D7.6 summarises additional potential GNSS-based applications that can support rail operations: a) SATELLITE-SUPPORTED SURVEYING, b) ODOMETRY, c) TRAIN INTEGRITY MONITORING SYSTEM and d) WAYSIDE POSSESSION MANAGEMENT. Deliverable D7.7 defines an extensive and stable set of safety concepts around the development of a satellite-based positioning for future evolution of ERTMS.

WP8 (Consensus building)

Deliverable D8.6 provides a final NGTC glossary, specifying all terms and abbreviations used by the different work packages of the project. It represents the common understanding of terms and abbreviations at a System level and allows avoiding the inconsistencies between definitions.

Potential Impact:

Final Results showing below entail the entire project:

• NGTC Functional Requirement Specifications:

NGTC Functional Requirement Specifications document represents the result of a detailed analysis of the existing standards specifying both mainline and urban train control systems and as such has an ambition to become one of the rail sector’s key references regarding the user requirements linked to future design of train control systems.

• NGTC Architecture, System Design and Interface specifications

Based on the comparison analyses performed between the functional requirements of the main line domain (ERTMS Baseline 3 specifications) and the urban domain and the related NGTC Functional Requirement Specifications document (FRS), NGTC has developed the architecture, functional allocation, design specifications and proposed level of standardization for interfaces (FIS, FFFIS) for a new generation of train control systems for the mainline and urban domains. Resulting documentation aimed at
achieving an increased level of commonality between the systems for the two domains, considering the existing ETCS Kernel Baseline 3, and ModUrban D85 as the primary inputs. Further, project has delivered specifications of the interfaces within NGTC that are common for urban and mainline, as well as the urban specific interfaces. These NGTC specifications pave the way for standardized train control systems for mainline and urban domains which provide ATP, ATO, and ATS functionality and support train operation from Grade of Automation GOA0 to GOA4, whilst reducing TCO/Life cycle costs, and achieving an overall improvement in performance at lower cost.

- Message structures for new ETCS functions
  NGTC project has delivered specified detailed operational processes under Automatic Train Operation for: Platform Screen Door Management, Automatic Turn-back, train Splitting and Coupling. These include the specifications for all new Messaging required for the communication RBC – ATP, OCC-ATO, ATP-PDIU and ATO-PDIU and the identification of necessary amendments of ETCS functionalities. The results of NGTC thus contributes to the introduction of the new mainline functions for ETCS leading to increased scope of the system and support future introduction of higher automation levels.

- Validated Moving block principles for different types of rail applications:
  Moving block principles defined within the NGTC project, have been validated at a high level by identification of relevant operational scenarios, providing their detailed descriptions and making the changes in principles as required. On top of that, NGTC has investigated the impact of Moving block on the railway. Capacity has been examined in a quantitative manner, using simulation on the subset of scenarios. In order to allow a comparison, the reference simulation has been performed based on fixed block signalling. The other attributes, including Control System interface, Equipment Count and Operational Rules have been examined in a qualitative way within the scenario descriptions. Introduction of moving blocks function has an overall objective to reduce the installation and operational costs, reliability of train control system and at the same time to increase a track capacity. Standardised approach towards moving block is an important contributor to the deployment of ETCS Level 3.

- Detailed set of studies and recommendations for next generation of IP-based radio communication systems:
  Based on a number of technical criteria focused on potential adequacy for future next generation of train control systems, NGTC has selected 3 emerging IP-based radio technologies for detailed study: LTE, Wi-Fi and Satellite Communications. They included analyses of achievable throughput, QoS, latency and on the parameters including peak throughput, average sector throughput, cell edge throughput, and user data rate. Experimental data for both LTE and Wi-Fi has been gathered and studied for various factors including impact of antenna system, speed of the mobile unit, range of the communication, etc. An analytic study of the performances of both technologies in the same conditions has been performed, showing an enhancement brought by LTE compared to Wi-Fi. On top of that, a possible architecture for a multi-vector solution for both mainline and urban domains have been introduced as well as recommendations and guidelines for operational use.

For both mainline and mass transit systems, there is an increasing demand for a new IP-based radio communication system that would be able to respond to the current needs for various applications communicating between trains and control centers. Especially, for mainlines, the current GSM-R
technology is becoming obsolete and a future candidate technology is now under a detailed investigation. NGTC provides a comprehensive guidance via complex studies, providing significant knowledge base regarding the suitable communication technologies for the next generation of train control systems.

- Advanced research on satellite based positioning for ETCS:
NGTC has studied several aspects relevant for satellite-based train localisation for mainline applications. Based on the study regarding the key elements that needed to be considered to eventually achieve a successful adoption of GNSS, the NGTC project proposed a roadmap to adopt the virtual balise functionality in the ERTMS system. Number of delivered technical results include a high-level Virtual Balise concept, specifications of receiver characteristics/parameters relevant for interoperable applications, PVT algorithm, definition of a standard process for GNSS performance measurements in rail environment and most importantly a preliminary safety analysis based on current GNSS system and ERTMS architecture. This comprehensive document due to the novelty and absence of relevant references was developed together with a satellite expert team coordinated by GSA. It contains a preliminary functional architecture and reports on outcomes of safety studies, including preliminary functional safety analysis (FMEA), preliminary assessment of the Virtual Balise subsystem for THR apportionment and considerations on GNSS service provision. Introduction of satellite based positioning in ETCS will offer a more scalability of signaling systems especially for the specific type of rail applications, including regional or low-density lines. The concept of virtual balise for ERTMS allows the introduction of the new technology in ERTMS without introducing significant changes in the current system specifications. NGTC has provided an exceptional way forward for developing the concept, delivering unprecedented safety analyses compatible with ETCS system.

- NGTC results will feed directly into Shift2Rail:
NGTC has been designed as a precursor to Shift2Rail Joint Undertaking, directly feeding the results to the linked projects, such as X2Rail-1. Shift2Rail will build on NGTC results and at the end will produce a set of practical demonstrators, using the research and knowledge base developed within NGTC project.

As far as Dissemination is concerned, the aim was threefold:
- To ensure the project outputs reach the relevant rail stakeholders enabling them to implement the achieved results;
- To ensure the project output reaches targeted decision makers at EU, national and local level for input in the standardisation and regulation work where applicable;
- To guarantee the delivery of high-quality results and sound technical solutions with the help of a “NGTC Network of End Users (NEU)”. 

NGTC delivered a high number of dissemination activities including presentations of main outputs during EU and International events (InnoTrans 2016, workshops, NGTC Mid-term and Final Conference, NEU meetings), scientific and general publications in European and International magazines and posters. The NGTC consortium has ensured the highest level of promotion of the main results by targeting both railway experts and the general public.

The following are the main dissemination activities carried out during the whole duration of the project:

- UIC ERTMS World Conferences: The international event entirely dedicated to ERTMS and both its
components ETCS for train control and GSM-R for radio-communications, has become a worldwide reference for all decision-makers and railway professionals involved in the development of rail systems across the world. In 2014, NGTC has been introduced via the given presentation during the main program, and in 2016 NGTC has a poster and a possibility to meet with NGTC experts as well as pick up NGTC brochures at UNIFE stand;

• Transport Research Arena. In 2014 (Paris), project has been represented in poster section and via the dedicated presentation given at EC stand. In 2016 (Warsaw), the consortium presented a scientific paper, issued in TRA conference Proceedings.

• InnoTrans 2014, 2016: InnoTrans is the largest international rail fair in the world, and typically is attended by over 100,000 visitors. Visitors had the opportunity to have the NGTC project presented to them as well as to pick up NGTC brochures giving information on the project. In 2016, there was a dedicated session on NGTC project at the UNIFE stand.

• 11th World Congress on railway research 2016: The NGTC has presented the scientific paper and was present on the UNIFE stand;

• CEN Conference 2014 – “Standards: Your Innovation Bridge”: The project has been presented at the UNIFE stand, providing a specific paper for this conference regarding the standardization.

• BCN Rail 2015 congress, where NGTC has been presented during the dedicated session was attended by 500 cities, 450 exhibitors and over 14,000 visitors.

• IEEE International Conference on Intelligent Rail Transportation in 2016: The NGTC project had a dedicated session during which the Coordinator discussed the scope as well as the results of the project.

• NGTC Mid-Term conference in November 2015: Over 50 participants from the Europe and Asia attended a mid-term/2 year conference/workshop/experts’ evaluation held in Munich. Besides the presentation of the technical progress, it was an unique opportunity to exchange the information with NGTC experts and other invited stakeholders during the three dedicated technical panels.

• NGTC final conference in February 2017 took place on 14 February in Brussels. Attendance of almost 100 participants was above expectation. All the main achieved NGTC results have been presented and then discussed in detail during dedicated sessions with invited experts:

o A) New developments for the next generations of train control systems: How the new technologies like IP-based communications, higher grade of automation and moving blocks will shape the future of modern railways?

o B) New satellite – based Technologies for the railway signalling: Where we are, what is the potential and the current difficulties?

o C) Realistic ways for the CBTC and ETCS convergence: Lessons from the project; Challenges and benefits for customers, Supply industry and way forward in R&I efforts.

• NGTC leaflets: The project leaflets were produced in hard copy and electronic version alike; Its contents was updated around the midterm of the project (2nd edition). The leaflets were designed in accordance with the NGTC visual style and were given out / displayed at events where NGTC was presented to reach out to a wider audience.

• The article: In February 2015, “New functionalities towards higher automation level, Eurotransport magazine, Volume 13, Issue 1, 2015

• The article: April 2016 Scientific Paper: Next Generation Train Control” (NGTC): More effective railways through the convergence of main-line and urban train control systems Proceedings of 6th Transport Research Arena, April 18-21, 2016, Warsaw, Poland

• Scientific Paper, May / June 2016: “Next Generation Train Control” (NGTC) Operational and Functional
Requirements, Proceedings of 11th World Conference on Railway Research, 29th May-2nd June, Milan, Italy

• 6 working meeting / workshops with NGTC Networks of End Users: Brussels, December 2014; London, March 2015; Paris, October 2015; Barcelona, February 2016; Milano, June 2016; Brussels, December 2016. Attended by a total 28 experts from urban operators, mainline operators and infrastructure managers and rail industry (not involved in the project)

• NGTC Workshop on satellite positioning with NEU members in European GNSS Agency in Prague, July, 2016. The workshop was dedicated to the discussion on the results achieved and the way forward for NGTC activities linked to the research and development of “virtual balise concept” for ERTMS.

• UNIFE, UITP and EUG have used the communication channels within their own organisations to inform the members about the actual status of the project and to gain contributions on various technical questions. The project has been presented and discussed during the meetings such as: UITP Metro Committee/Assembly, UITP Light Rail Committee, UITP Regional and Suburban Railways, UNIFE Technical Plennary, UNIFE Signalling Working Group, EUG meetings with CER, etc.

• NGTC website – continually updated and adjusted during the whole course of the project containing the detailed project description, news, articles and the final results;

List of Websites:
http://www.ngtc.eu/

Last update: 10 March 2023
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