EU-RAIL JU System Pillar

Report on FRMCS V2 and V3 Scope and Planning

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DISCLAIMER

The majority of the information contained in this document is sourced from the UIC FRMCS Program, particularly regarding the aspects related to FRMCS Specifications content, planning and timeline. This sourcing has been authorized in anticipation by UIC as per the MoU established between EU-Rail and UIC, and currently under validation and signature according to respective statutory rules.

For the easiness of reading, the sourcing of information has not been repeated systematically, except for illustrations and tables.

Additional information from relevant entities associated to the FRMCS development, such as for instance but not exhaustively 3GPP and ETSI, is also provided, to the extent of the knowledge and the understanding of the authors.

The present document has then to be solely considered as a report based on the available information, with additional analysis provided by the authors when it was seen as relevant.

ABBREVIATIONS AND ACRONYMS

3GPP	3rd Generation Partnership Project
5GRail	Project financed by DG Connect for FRMCS prototyping and testing under the programme H2020 ICT-53 (Grant Agreement #951725)
ACS	Adaptable Communication System
ATO	Automatic Train Operation
CCS TSI	Control Conmmand and Signaling Technical Specifications for Interoperability
CEPT	Conférence Européenne des administrations des Postes et Télécommunications
DG Connect	Directorate-General for Communications Networks
DG Move	Directorate-General for Mobility and Transport
EC	European Commission
ECC	European Communications Committee
ENISA	European Union Agency for Cybersecurity
ERA	European Union Agency for Railway
EU-RAIL JU	Europe's Rail Joint Undertaking
ERTMS	European Railway Traffic Management System
ETCS	European Traffic Control System
ETSI TC-RT	ETSI Technical Committee - Railway Telecom
FRMCS	Future Railway Mobile Communication System
GSM-R	Gobal System for Mobile Railway Communications
KMS	Key Management System
MCX	Mission Critical Services
MNO	Mobile Network Operator
R2DATO	Rail to Digital Automated up to autonomous Train Operation
RAT	Radio Access Technology
RMR	Railway Mobile Radio
S2R	Shift to Rail
TCMS	Train Control and Monitoring System
UIC	Union Internationale des Chemins de Fer
FRMCS V1, V2, V3	UIC FRMCS Specifications version 1, 2 or 3

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INTRODUCTION

GSM-R, invented in Europe and fully specified by UIC and ETSI, is both an ERTMS component and ETCS Level 2 enabler. It is in operation on more than 130,000 km of tracks in Europe, and more than 200,000 km of tracks in the world.

As an independent ERTMS component, GSM-R enables the train driver to dispatcher voice communications, necessary to run train operations, including the Railway Emergency Call key function to support safe train operation.

Recently, with the introduction of GPRS, GSM-R became also an enabler for ATO GoA1/2 (2023 CCS TSI).

The GSM-R Specifications, developed and maintained by UIC, are part of the technical annexes of the European CCS TSI.

The GSM-R technology, based on 3GPP 2G, is becoming now obsolete, and the railway telecom manufacturers have made clear that GSM-R networks, components and support will start to be life-expired by 2030, making their maintenance more and more costly, complex and then carrying operational risks for railway operations.

Aware of this inevitable reality, the European railways explored the concept from 2013 onwards and, as a consequence, have put in place in 2018 through UIC a specific program to define a new railway mobile system based on 3GPP 5G, the UIC FRMCS Program. This Program has the ambition to facilitate, in addition to GSM-R replacement, the modernization and digitalization of the railway operations, by making possible the introduction of new systems and applications, such as ATO GoA1/2/3/4, TCMS, video services and more generally essential services requiring telecom quality, flexibility and capacity.

Furthermore, the System Pillar Steering Group, in its decision N°1/2023 released in February 2023 providing the approach taken for FRMCS Specifications at global European level, highlighted the criticality and the essential role in railway digitalization of FRMCS, as well as the time pressure for FRMCS readiness due to GSM-R announced obsolescence.

1. DOCUMENT SCOPE

The intent of the report and associated process is to have a transparent and formalised process to align the FRMCS programme with the broader sector, DG MOVE, ERA, and EU-Rail, with the objective to save time and increase efficiency overall by addressing any open issues now rather than later in the process.

More specific objectives of this document are described in the Decision of the System Pillar Steering Group 1/2023.

The purpose of this document is consequently to list the scope, content and planning of the FRMCS V2 Specifications, whose main objective is to define all the FRMCS Specifications for an industrial European trial, code name “Morane 2”, focused on validating an ecosystem of specifications for a safe migration of GSM-R networks in Europe. An additional focus of this European trial should be to validate the FRMCS requirements relevant for interoperability in the European Union.

This safe migration implies first the full mirroring of existing GSM-R functions, for all voice applications and ETCS application. It also implies the consideration of impact of the existence of hybrid networks (GSM-R and FRMCS), and the newly defined ATO GoA1/2 over ETCS application.

With the aim to provide a global vision towards the start of FRMCS migration, the present document is also presenting the planning for the introduction of FRMCS V3, also called “FRMCS 1st Edition”, up to the adoption of it as part of CCS TSI. This version would be integrating the outcomes of the Morane 2 project and would then constitute the first “market ready” version for the start of implementation of FRMCS in Europe.

2. FRMCS SPECIFICATION MAP

Since the beginning of its FRMCS Program, UIC has set a global plan for the achievement of FRMCS Specifications inside a global initiative, with the clear target to deliver a FRMCS first "market ready version" of these specifications, enabling then the start of FRMCS first implementations in Europe.

The schematic map of all these documents is provided here.

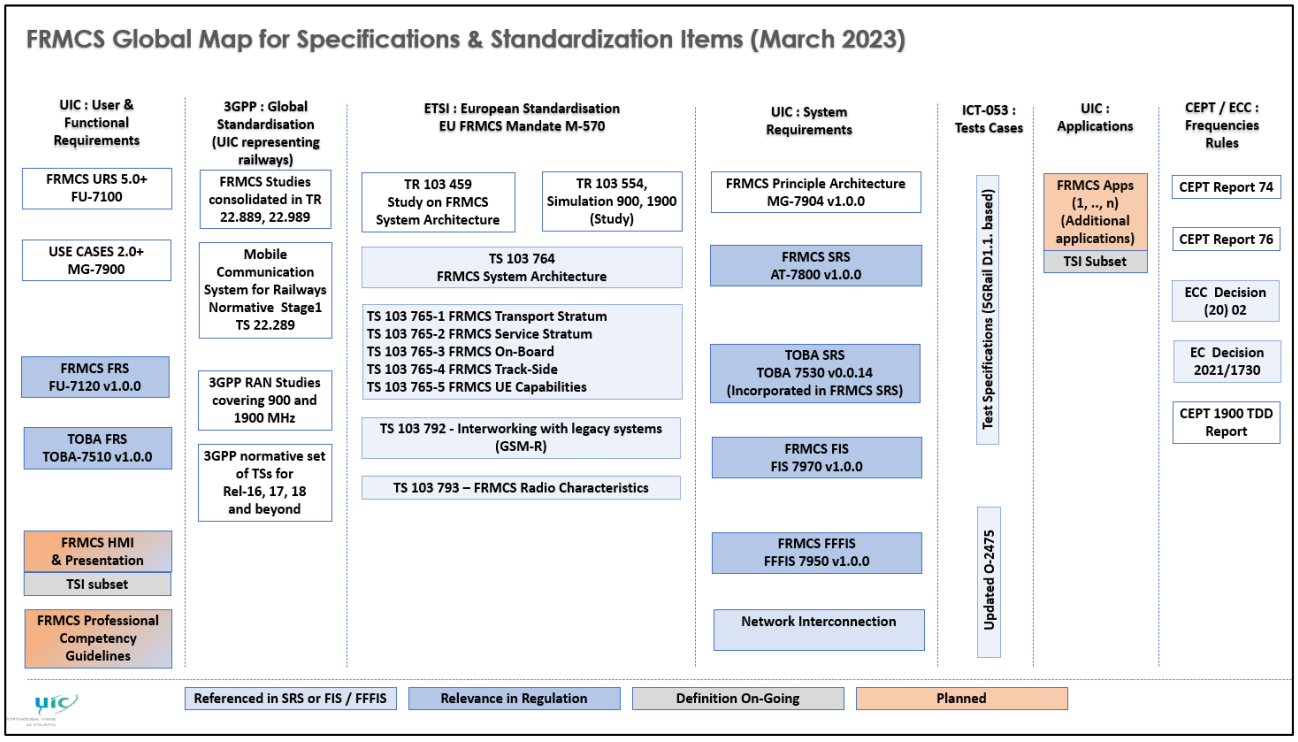


Figure 1: UIC FRMCS Global Plan for Specification & Standardization (source UIC)

This global map for specifications includes different categories of documents:

- The FRMCS User Requirements & Use Cases, foundational to the elaboration of the future system, developed by UIC
- The FRMCS Specifications (User & System for both track-side / on-board), developed by UIC
- The 3GPP Technical Specifications, and particularly the ones relative to Critical Communications (MCX) including elements introduced in 3GPP by UIC on the basis of FRMCS Use Cases
- The ETSI FRMCS Technical Specifications, based on one side on the 3GPP Technical Specifications and on the other side on UIC FRMCS Specifications, and providing the standardization references to detailed telecom building-blocks useful for FRMCS usage
- The FRMCS Test Cases, whose first occurrence has been developed by UIC in the frame of the 5GRail project, that will be the basis to enrich for future tests and to support the first FRMCS pilots or deployments

- The CEPT and ECC documents related to FRMCS frequencies (European harmonization and conditions of usage)
- Looking forward, the FRMCS Applications guidelines, planned to be developed by UIC, that will define rules and context for future railway applications using FRMCS.

Since 2018, and as per the plan, there has been a significant advance on all levels:

- The FRMCS User Requirements Specification is reaching now V5
- The FRMCS Use Cases, which was a key starting document to launch all other activities (specification and standardization, mainly in 3GPP), is mature and lists all the necessary uses cases for applications known today, plus some for future applications not defined at this moment
- There has been a considerable work done in 3GPP under the leadership of UIC and with a strong support of some railway telecom suppliers, where railways requirements for functionalities, quality of service or radio aspects have been introduced and treated in the 3GPP releases 16, 17 and 18, with the work already started for the release 19,
- There has been a considerable work done within ETSI TC-RT (Technical Committee for Railway Telecomm), where both railways and telecom railway suppliers mainly from UNITEL are present and developed jointly the necessary ETSI FRMCS Technical Reports, first step towards ETSI FRMCS Technical Specifications
- Valuable frequencies (including both original GSM-R slightly extended frequencies plus additional frequencies) have been allocated for FRMCS in Europe, see decision ECC (20) 02
- The UIC FRMCS V1 Specifications have been fully developed as per initial plan and provided to ERA for inclusion in CCS TSI.
- ETCS or ATO related specification activity. Common technical elements regarding ETCS and ATO interfaces have been and are being defined by permanent interactions between UNISIG and the UIC FRMCS program these groups in the frame of Shift2Rail Contract “ERTMS MoU Consortium”, and subsequently System Pillar Lot 3.

3. FRMCS SPECIFICATION HIERARCHY

The various functionalities expected for FRMCS are regularly recorded in the UIC User Requirements Specification (URS), then adapted to 3GPP Use Cases (UC), verified in ETSI TC-RT with the support of the industrial partners and finally addressed for standardization to 3GPP by UIC.

Figure 2: Workflow Principle between UIC and 3GPP / ETSI (source UIC)

3GPP Technical Specifications ("3GPP standards") provide the reference telecom generic FRMCS building blocks in general, for 5G and MCX particularly. Of course, a lot these 3GPP generic building blocks are used in FRMCS. Nevertheless, it is important to note that 5G is a strongly flexible and open standard, much more complex than previous ones defined by 3GPP (and infinitely more complex than 2G), and it is then important to define subsets with common parameters for FRMCS networks.

ETSI Technical Specifications ("ETSI standards") will sum up and organize, based on requirements from the UIC FRMCS Specifications, the necessary FRMCS building blocks defined in 3GPP and additionally cover remaining gaps (as for instance GSM-R/FRMCS interworking telecom building blocks which are not covered by 3GPP).

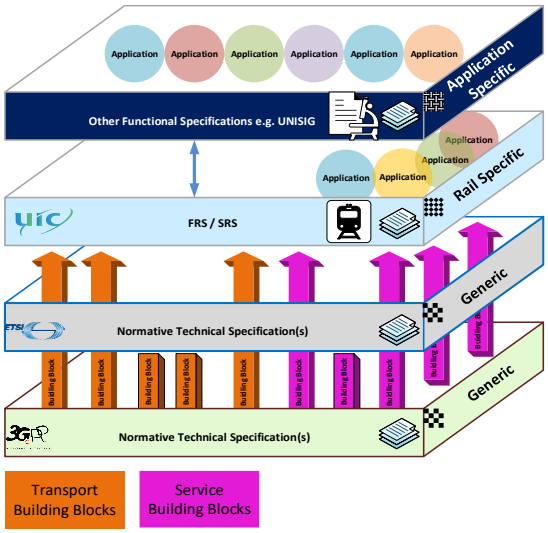


Figure 3: FRMCS Specification Hierarchy (source UIC)

UIC SRS (for both end-to-end services including on-board specifics) reflects the architectural and system view of the functional user requirements and provide the bridge to all applications, where UIC FRS documents focuses more on functional aspects of the applications. In addition, specifications for interfaces (FIS and FFFIS) provide the necessary information regarding how railway applications will use FRMCS, and as such are a specific complement to general specifications (SRS and FRS).

Interoperable and additional relevant elements will be part of the CCS TSI, the scope of which is first proposed by the European Commission, developed and integrated with ERA as ERTMS System Authority, and finally voted on by Member States in the Rail Interoperability and Safety Committee.

The output will also feed into the overall CCS target architecture developed in the EU-Rail System Pillar.

4. FRMCS V1 SPECIFICATIONS

The main objective of the FRMCS V1 Specifications was to define all the known functions of the system, as well as the key elements of the system (both on-board and trackside) in terms of architecture, inter-dependencies between elements as well as interfaces (including protocols) with key applications like ETCS, ATO (GoA1/2, the other not being specified at this stage) and voice.

FRMCS V1 high-level scope is the following:

- Consideration of the following applications: ERTMS data applications (ETCS, ATO, KMS) - This however also cover the principles of the train performance Loose Coupling data applications (for instance for future TCMS)
- Voice applications, including the Railway Emergency Communications (REC)
- Limitation to RMR spectrum in fact, even if the bearer flexible concept has been considered in view of V2
- Limitation to MCX Loose Coupling (for ERTMS Data applications) and Tight Coupling application regimes
- Usage of "real 5G System" and MCX (with limitation to MCData IPCon and MCPTT)
- Limitation to Telecom On-board Architecture (TOBA) equipment (no handhelds, no ground-to-ground communications)
- Based on ETSI specific TR for the Interworking with GSM-R.

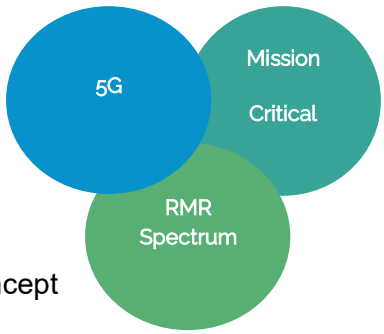


Figure 4: FRMCS 5G High-Level Components (source UIC)

The following set of specifications have been then finalized by UIC by the end of 2022, with the target to be included in the Appendix A of Annex I of CCS TSI 2023:

- **FRMCS FRS v1.0.0** (Functional Requirements Specification, CCS TSI, Annex I, Table A 2 Index 93)
- **FRMCS TOBA FRS v1.0.0** (Telecom On-Board Architecture Functional Requirements Specification, CCS TSI, Annex I, Table A 2 Index 99)
- **FRMCS SRS v1.0.0** (System Requirements Specification, CCS TSI, Annex I, Table A 2 Index 94)
- **FRMCS FIS v1.0.0** (Functional Interface Specification, CCS TSI, Annex I, Table A 2 Index 95)
- **FRMCS FFFIS v1.0.0** (Form Fit Functional Interface Specification, CCS TSI, Annex I, Table A 2 Index 92).

As already stated previously, this was achieved in parallel with the development by UNISIG of a new ETCS system architecture, where the ETCS readiness for FRMCS concept was introduced on the request of the DG Move and ERA in the frame of S2R "ERTMS MoU Consortium" contract. The principle of the ETCS readiness for FRMCS is that once the update to this ETCS version is done, ETCS core part will become independent to any telecom changes, eg. for instance from 5G to 6G.

Consequently, following ETCS documents have been introduced or updated by UNISIG:

- **ETCS SS 037-1/2/3** (Euroradio interface description for GSM-R, Safety Module and FRMCS))
- **ETCS SS 146** (End-to-end security layer for ETCS/ATO)

ETCS SS 147 (Network communication layers interface description)

- **ETCS SS 148** (Communication systems description for ATO).

Finally, the FRMCS V1 Specification hierarchy, dependencies and interconnections are represented here under:

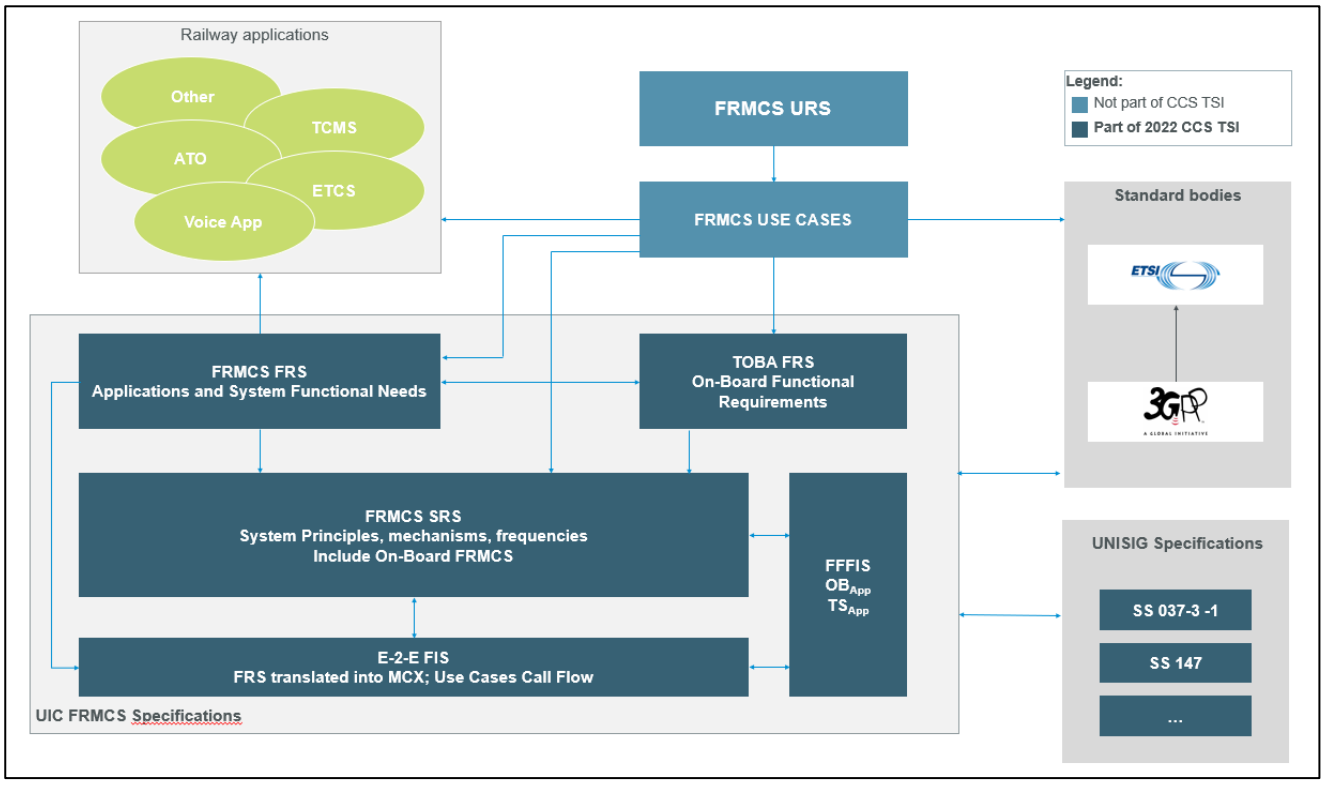


Figure 5: FRMCS V1 Specification Hierarchy & Dependencies (source UIC)

The FRMCS V1 is considered as the necessary **legal anchor** of FRMCS within the CCS TSI, as it guarantees to the railways that the future standard to be used will be effectively FRMCS and ETCS currently build according to these specifications can be easily (without hardware change) coupled with upcoming FRMCS equipment. It also provides the solid foundation for all telecom mechanisms to be used by the future radio mobile networks, ensuring the coverage of all identified functional needs for railway operations, to the extent of the usages that are sufficiently defined as of today.

The five documents that form the Technical Annexes of FRMCS in CCS TSI have been delivered and validated by ERA and then voted by EC RISC on the 30 of March 2023.

With this, the FRMCS introduction phase (“FRMCS V1”) is closed and provides all the necessary elements to perform the achievement of FRMCS V2.

5. FRMCS V2 SPECIFICATIONS

This chapter is presenting the various constitutive elements of the FRMCS V2 Specifications.

5.1 ERIG's View on FRMCS Roadmap

The UIC ERIG (European Railways EIRENE Implementers Group) is the historical UIC forum of the European railways Heads of Telecom, which are monitoring and orientating the UIC Telecom projects.

The ERIG has been over the last 20 years and remains today the leading management force in the definition, maintenance and evolution of the GSM-R Specifications and Standards in Europe, always in a context of fruitful collaboration with the European railway supplying industry, represented today by UNITEL, a UNIFE Committee, and with ERA.

It has consequently and naturally endorsed the same role for the creation and the development of FRMCS, monitoring all the groups of the UIC GSM-R and FRMCS Programs, each of them in charge of a specific remit for GSM-R and / or FRMCS Specifications.

As of today, 23 European railway companies, RUs and IMs, are officially members of this forum: ADIF, Bane Nor, BLS, CFL, Irish Rail, CFR CP, DB, FS, FTA, Infrabel, IP, MAV, Network Rail, NS, OBB, Prorail, SBB, SNCF, SZ, SZDC, Trafikverket, ZSR.

This forum of railway telecom managers endorsed at the end of 2022 a technical roadmap for FRMCS V2, providing then to UIC the technical orientations for the next development of the FRMCS Specifications. This roadmap is captured in the ERIG document E-4286 provided in Annex 1 and classifies different items in terms of priority 1 (necessary for V2) and 2 (optional for V2, needed for V3). The prioritization has been done with an arbitration between timeline, complexity and effort required.

The consideration of GSM-R obsolescence puts at risk the railway operations in the whole Europe due to the duration of migrations. This has led the railway telecom managers in their vast majority to put the absolute emphasis and priority on the substitution of current GSM-R services (voice services, ETCS and ATO GoA1/2 applications) while ensuring that the system to be finalized for FRMCS 1st Edition will not block for the support of new applications in future versions of FRMCS after V3 that would lead then to costly network or on-board updates.

The FRMCS V2 detailed content explained in the following sub-chapters is consequently built on the base of all these ERIG technical orientations, choices and requests.

5.2 Alignment of V2 Scope

In order to address issues of planning of regulation and future activities, from the perspective of DG MOVE, ERA, and EU-Rail, it is important to address now any considerations on scope and planning of the planned FRMCS specifications based on UIC ERIG strategic orientations particularly in the context of

- DG MOVE and ERA views on scope given their respective roles in coordinating European rail policy, and as ERTMS system authority;
- DG MOVE and ERA assurance on scope and planning given their roles in initiating, planning and coordinating any relevant changes to TSIs, and the initiating role in the standardisation process;
- EU-Rail, through the System Pillar, supporting the broader sector alignment process, and associated considerations against the future development of the system;
- EU-Rail, in its role to potentially support future testing and validation processes, and the need for robust planning and agreement on scope (including the necessary support of DG MOVE and EU-Rail members).

This report should be seen in the light of achieving this alignment.

5.3 FRMCS V2 Scope

The FRMCS V2 is reputed to be in the majority of the cases a completion of the V1, with the main objective to have a technically defined FRMCS to execute an ad-hoc industrial project (Morane 2) for the finalisation of the industrial FRMCS ecosystem, and including all the necessary functions for voice, ETCS and ATO (GoA1/2) applications. In addition, FRMCS V2 will set the baseline for the FRMCS requirements relevant for interoperability in the European Union.

An important side element of this version is the achievement by ETSI - with the support of UIC and in full synchronization with UIC FRMCS Specifications - of the ETSI Technical Specifications for FRMCS. This work defines telecom standards used by FRMCS, the majority being based on 3GPP standards presented by UIC teams to 3GPP over the last 4 years. As per its own calendar, ETSI has planned to deliver the necessary TS by 3Q 2024, with stable drafts by 2Q 2024.

The V2 Specifications will also include the return of experience from the 5GRail industrial project facilitated by DG Connect and piloted administratively and technically by UIC with the co-coordination of UNIFE, that has permitted to develop and test the first prototypes of the FRMCS ecosystem (TOBA box, base stations in 1900 MHz, ETCS and ATO simulators with FRMCS interfaces, etc.), to be finalized by end 2023.

This V2 Specification set will also have to be aligned with EU-RAIL JU System Pillar technical strategy, as per the specific agreement established between EU-RAIL JU and UIC.

The FRMCS V2 Specifications will then be built on the foundations of FRMCS V1 Specifications, completed by a series of additional inputs:

- ERIG E-4286 (annex 1) requests
- FRMCS issues that have been agreed by EECT as For-Further-Study (FFS), this list being prioritized as per V2 scope
- 5GRail project results and findings
- 3GPP 5G & MCX Specification evolutions (Functional, QoS and Radio)
- For certain cases, final selection of adequate standardized telecom protocols to cover functional or systems requirements (typically for the multipath concept where several solutions could be envisaged) to guarantee national and international interoperability schemes
- ETSI FRMCS Technical Reports / Technical Specifications advanced drafting (typically GSM-R - FRMCS Interworking)
- UIC Cyber Security Assessment, organized in the frame of a specific UIC cybersecurity group, currently on-going
- EU-RAIL JU System Pillar technical strategy
- Other relevant initiatives and / or work frames (for instance, the RACOM project).

The work for V2 has already started at the end of 2022, following the agreement on ERIG technical orientations.

5.4 FRMCS V2 Detailed Content

The planned FRMCS V2 content is here after divided in four categories of different nature: applications, reference points, capabilities and spectrum & RAT. This presentation completes and / or precises certain points developed in ERIG E-4286 (Annex 1).

Table 1: FRMCS V2 Content - Applications (source UIC)

Building block	**Work item**	FRMCS V2	Included in V2	Excluded from V2
Railway Application	**ATP/ETCS L2**	Yes		
Railway Application	**ATO GoA1-2**	Yes		
Railway Application	**ATO GoA3-4**	No	Best effort / Depending on EU-RAIL JU precise input	MCVideo[1]
Railway Application	**Key Management System**	Yes		
Railway Application	**Public Key Infrastructure**	Yes		
Railway Application	**Voice Application**	Yes	Voice applications Coordinating function Dispatching system TOBA Dual Mode Voice Only concept[2] Requirements for corresponding IC	
Railway Application	**Railway Emergency Call**	Yes		Merging REC Multi User Talker Control
Railway Application	**Messaging**	Yes		
Railway Application	**Shunting**	Yes	Best effort	Data
Railway Application	**TCMS**	Yes	MCData	
Railway Application	**CCTV**[2]	Yes	MCData	MCVideo[1]
Railway Application	**Remote control of engines**	Yes	MCData	MCVideo[1]
Railway Application	**C-DAS**[2]	Yes	Best effort	MCVideo[1]
Railway Application	**Passenger Information System**[2]	Yes	MCData	
Railway Application	**Critical real-time video**[2]	Yes	Best effort (MCData)	MCVideo[1]

[1] MCVideo not included in V2 scope due to its immaturity in 3GPP, it can then be considered only in the V3 context
[2] It is the current view of DG MOVE/ERA/EU-Rail that this item could be considered lower priority

Table 2: FRMCS V2 Content - Reference Points (source UIC)

Building block	**Work item**	FRMCS V2	Included in V2	Excluded from V2
On-Board FRMCS	**OB_{APP}**	Yes	Tight and loose Coupling IPV4 / V6	
FRMCS Trackside Gateway	**TS_{APP}**	Yes	FRMCS Trackside architecture FRMCS Trackside Gateway function	
FRMCS Multipath Function	**FS_{MPM}**	Yes	Bearer flex/Multipath function (On-Board and Infrastructure) + use cases	
Interconnection, roaming and border crossing	**FS_{NNI}**	Yes	FRMCS Domains, including IMS and MCX Interconnection. This covers a MNO domain, which is compatible with FRMCS architecture, but potentially with different 5G frequency bands. One or Two UE's for BX	
Interworking with External systems	**FS_{IWF}**	Yes	GSM-R/FRMCS interworking, Dispatching system	
Interworking with External systems	**FS_{ONI}**	No	User to User communication between a FRMCS domain and a non-FRMCS domain e.g. 4 or 5G / non MCX	FS_{ONI} will be studied in V3 or V4
OAM	**FS_{OMR}**	Yes	Exchange of certificates, OTA Update	
On-Board FRMCS	**OB_{OM}**	Yes		
On-Board FRMCS	**OB_{RAD}**	Yes	Radio modules, interchangeability, remote radio modules	

			(Study on concept to derive functional requirements)	
On-Board FRMCS	**OB_{ANT}**	Yes		

Table 3: FRMCS V2 Content - Capabilities (source UIC)

Building block	**Work item**	FRMCS V2	Included in V2	Excluded from V2
FRMCS Service Domain	**Functional addressing/Role management**	Yes		
FRMCS Service Domain	**Multi-user talker control**	Yes	Voice group calls	Ad hoc group calls
FRMCS System	**Location & Positioning for voice applications**	Yes	Requirements Architecture Implementation options	
FRMCS Service Domain	**Authorisation of communication**	Yes		
FRMCS System	**QoS and priority**	Yes	QoS requirements (values per supported application)	
Railway Application	**Arbitration**	Yes		
FRMCS System	**Identification and addressing**	Yes	H2H and implicit registration, H2N Routing and IP assignment including IPv4/IPv6 interworking	
FRMCS System	**Interconnection, roaming and border crossing**	Yes	FSNNI + On-board FRMCS, including FRMCS domain change, and FRMCS-GSM-R interworking	FRMCS inter-domain interworking (for V3)
Transport Domain	**Network slicing**	No[3]		
FRMCS System	**Cybersecurity**	Yes	Generic measures stemming from a standard-based cybersecurity risk assessment. Implementation Options.	

FRMCS System	**Subscriber configuration**	Yes	FRMCS profile(s) (USIM, ISIM, SIP and MCX profiles), requirements for corresponding IC	
FRMCS System	**“Best Effort" Applications Regime**	Yes	Study the concept for non-critical applications	
FRMCS System	**Voice Function**	Yes	Tight Coupling HMI Coordinating Function	
On-Board FRMCS	**Auxiliary Function**	Yes	Agree Scope	
FRMCS Handheld	**Requirements**	No		
FRMCS System	**Recording**	Yes	Agree Concept	

[3] Network slicing has been a generic function of telecom networks for years, particularly emphasized in the 5G context of serving vertical segments, and then is as such is applicable to FRMCS networks by construction - What is excluded here is the precise technical specification of the conditions for ensuring critical communications in an undefined network, what does not prohibit at all the particular study of these conditions for a given and precisely known network (“project-specific view”)

Table 4: FRMCS V2 Content - Spectrum and RAT (source UIC)

Building block	Work item	FRMCS V2	Included in V2	Excluded from V2
Transport Domain	**FRMCS 900MHz: 5G NR FR1 FDD n100/PC3 UE**	Yes	High speed usage	
Transport Domain	**FRMCS 900MHz: 5G NR FR1 FDD n100/PC1 UE**	Yes	High speed usage	
Transport Domain	**FRMCS 1900MHz: 5G NR FR1 TDD n101/PC3 UE**	Yes	High speed usage	
Transport Domain	**FRMCS 1900MHz: 5G NR FR1 TDD n101/PC1 UE**	Yes	High speed usage	
Transport Domain	**FRMCS 900MHz: CBW<5Mhz**	Yes	High speed usage	
Transport Domain	**White Space**	Yes	Based on 5G RACOM	
Transport Domain	**RF QoS/coverage quality**	Yes	Coverage quality for ERTMS, N100 & 101only scenario.	
Transport Domain	**Migration scenarios**	Yes	Assess Migration Guideline implications on SRS	
Transport Domain	**Multi access**	Yes	Bearer flex/Multi access	
Transport Domain	**FRMCS Dual Connectivity**	Yes	Best effort	
Transport Domain	**FRMCS Carrier Aggregation**	Yes	Best effort	
Transport Domain	**European MNOs (5G bands + coexistence with FRMCS)**	Yes	Subset of 5G bands for ensuring railway potential interoperability and coexistence with FRMCS	
Transport Domain	**Bands outside EU**	No		
FRMCS Handheld	**Spectrum bands/RAT for Handhelds**	No		
Transport Domain	**Unlicensed spectrum/Wi-Fi**[4]	No		
Transport Domain	**Satellite (legacy NT RAT)**	No	Best effort	
Transport Domain	**Satellite (5G NR NT)**	No	Best effort	

[4] *It is the current view of DG MOVE/ERA/EU-Rail that this item should be included in V2*

5.5 Migration

This report is focussed on the content and scope of the specification development of V2 and V3 of the FRMCS specifications.

In addition, a major element of work that needs to be considered both at national and European level are the considerations for a successful migration from GSM-R to FRMCS.

As part of this, strategic considerations in the design of the system, and principles of deployment and migration should be derived as part of the FRMCS program in order to inform national deployment and migration plans to be included in the ERTMS NIPs.

Migration considerations for both onboard and trackside will need to be considered in detail, taking into account Member State specific planning, and the FRMCS over ETCS on board readiness. Economic and business considerations should be central to the analysis.

The planning and development of such work should happen in parallel to the specification linked activities, and where appropriate, inform such activities.

UIC has started some activities regarding this topic, for instance in UGFA (Frequencies) group. However, this will need to be further developed going forward.

5.6 Process and organisation of the work for FRMCS V2 Specifications

The UIC FRMCS Specifications are developed by the UIC FRMCS working groups:

UIC Working Group	Acronym	Specification
FRMCS Functional Working Group (WG)	FWG	FRMCS FRS
TOBA Working Group / Functional WG	TOBA	TOBA FRS
Architecture & Technology WG	ATWG	FRMCS SRS
TOBA WG / System	TOBA	UE, Antenna System, Voice Function chapters of the SRS
UIC Group For Frequencies	UGFA	Frequencies aspects of SRS
FIS WG	FIS	FRMCS FIS
FFFIS WG	FFFIS	FRMCS FFFIS

These Working Groups have been organised for some years and have a good composition of railway telecom specific experts:

- FWG, TOBA and ATWG are composed from railway experts
- UGFA and FIS are composed of mixed railway and UNITEL experts.
- FFIS is planned to be also a mixed componence group for the V2 activities.

The group members are each leading the work as rapporteurs for one or more working items. The WGs meet monthly, in plenary meetings. In addition, ad-hoc meetings are organized by rapporteurs.

The working items that needs special attention due to complexity or multitude of choices are discussed in and decided by the UIC FRMCS Core Group (see 5.8).

The WG's Chairs together with the UIC FRMCS Core Group and the ETSI TC-RT Chair are forming the UIC FRMCS Steering Committee, that meets every 8 weeks. The scope of this meeting is a view on the work status, alignment between the workstreams and discussion of various work items.

FRMCS V2 Specifications work will advance by treating the work items in prioritized way, and in parallel, function of working groups assessment capacity.

For each of these working items, the sequence is that the work item is developed in the assigned WG. In addition, the TOBA and ATWG are organizing ad-hoc meetings with UNITEL representatives.

When the Work Item content has sufficient maturity, the work item is brought in mixed UIC / UNITEL / UNISIG (when relevant for ETCS or ATO) working groups.

All this work is done in complete transparency to ERA that has access to all meetings and documents.

5.7 FRMCS V2 Specification Planning and Risks

The delivery of the UIC FRMCS Specifications V2, considered as stand-alone, is planned today by UIC to happen by 2Q 2024, with the following milestones:

- Closing of the major sensitive technical items still under assessment for which different options have not been decided as of today (around 15 listed items such as choice of procols for multipath, technical strategy for inter-domain change, OB_{rad}, etc.) in collaboration with the supply industry : December 2023
- First stable draft of UIC FRMCS V2: March 2024
- Final version of UIC FRMCS V2 : June 2024.

In the case where it would be decided by competent authorities to consider the inclusion of these specifications into a Technical Opinion to be issued by the Agency, preliminary discussions between UIC and ERA are leading to the following planning:

- Permanent collaboration between UIC and ERA (and other relevant entities, such as UNITEL) all along the phase of preparation of V2, in the context of the System Pillar Lot 3, particularly with the objective to identify any missing or insufficiently defined element of the specification that could endanger the objective of the V2 (provide all the specification elements for a Morane 2 project)
- Delivery of the first stable draft to ERA EECT (to begin the EECT process) by March 2024
- Usual process of exchange / correction / amendments between UIC and ERA, with the contribution of other stakeholders of the EECT process for a duration evaluated to 7 months at this point of time
- Finalisation of a FRMCS V2 Specification set of documents (5 documents foreseen, identical to the current ones in CCS TSI) validated through the EECT process, including publication of Technical Opinion by October 2024.

Three important comments need to be added at this stage:

- In the context of this report, this timeline linked to a potential Technical Opinion is a proposal from UIC, and as such it will need appropriate assessment between ERA, UIC and the EU-RAIL JU inside the System Pillar Lot 3 to define more in detail the way forward and the methodology, as it was achieved for the FRMCS V1
- It is here considered that the delivery of first stable versions by March 2024 should be deemed sufficient to secure the start of Morane 2 project, as all the necessary technical elements will be present in those, then making possible for railway telecom suppliers to engage on the preparation and finalization of their products
- The interaction with EU-RAIL JU System Pillar in this way forward, even if existing by nature through the Lot 3, will need to be more precisely defined.

Regarding UIC FRMCS V2 Specifications, the high-level risk assessment on the proposed planning is seen as follows:

- The completion on the right time of some important technical decisions for V2, depending directly on an agreement between railways and railway telecom suppliers (namely represented by UIC and UNITEL generally speaking), then potentially impacting in some cases the whole system progress
    - ⇒ The “FRMCS Supergroup” (under creation), regrouping the selected top level railway telecom experts from UIC and UNITEL, with large experience on telecom standards, telecom networks and telecom product conception, is reputed to focus on these highly technical points to anticipate potential blocking situations - ERA should be assigned a role of observer in this group
    - ⇒ In case of continued disagreement, a proposal for specifications will be nevertheless done towards ERA for arbitration whenever needed
- The quantity and complexity of items to be treated in the 5 reference documents of FRMCS V2 Specifications may lead to certain delays or local blocking situations in a given UIC group in charge of delivering a reference document, due to the short timeline and due to the high level of interactions between the various concepts and documents
    - ⇒ The “UIC FRMCS Core Group”, regrouping the core experts from UIC regarding railway telecom, will in that case proactively support the UIC group, helping to de-block situations and / or accompanying the group in the redaction of the piece of specification
- The extreme scarcity of the profiles (people) having a sufficient level of knowledge in telecoms, and a good knowledge of railways, to ensure the specification activities of FRMCS in general: the UIC staff and groups have been growing at an important pace, continuously trying to identify and recruit these very rare profiles over the last years, but the defection of some key individuals remain a risk to be noted, as their replacement is nearly impossible in a short period
    - ⇒ UIC has already launched actions to identify corresponding profiles outside or railway industry with this aim and will keep on doing
    - ⇒ Proposedly, any specific action facilitating the identification of people with high level skills on railway telecoms should be encouraged.
- The temptation of introducing or advancing some elements in the content of FRMCS V2, that are considered for instance as second priority in the ERIG plan: there is a shared understanding at technical level between UIC and UNITEL that the current plan is already challenging in terms of content, and that the capacity / competence necessary to increase the deliveries will not be available in the next one-year period
    - ⇒ A clear understanding of the ambition of V2 (and following V3) has to be largely shared in the sector, to avoid delaying steps back.

As already explained before in this document, the FRMCS V2 Specifications have a corresponding “counterpart” in terms of pure telecom standardization, with the mission to identify or define when needed the “technical building blocks” from telecom standards, particularly 3GPP for the very large part of them. These building blocks, consolidated in the form of ETSI TSs (Technical Specifications) are in the remit of the ETSI TC-RT (Technical Committee for Railway Telecommunications). As such, the UIC FRMCS V2 Specifications are referring to these TSs when needed.

The ETSI TC-RT is working on the base of the UIC FRMCS Specifications on one side and with the outcomes for 3GPP FRMCS Use Cases, in a full synchronized manner with UIC.

After the first stage of producing TRs (Technical Reports) regarding FRMCS, the ETSI TC-RT has engaged the development of the FRMCS TSs necessary for FRMCS V2, with the objective to finalize them by 3Q 2024, with stable drafts available as of 2Q 2024, to stay compatible with the global V2-Morane-V3 overall planning.

Nevertheless, potential delays were flagged recently by ETSI TC-RT due to some administrative issues within the EC related to the financing of the FRMCS mandate from EC to ETSI, these issues remaining unsolved as of today and then jeopardizing the commitment from several contributors to the ETSI TSs to be developed, particularly in the supplying industry field

⇒ It is recommended that the European railway sector finds rapidly an adequate way to financially support these activities for a better guarantee that ETSI would deliver the required elements as per its announced plan.

Lastly, the 3GPP activities may suffer from some delays in the various assessment levels of the piece of standardization proposed by all the worldwide actor, and consequently in some proposed by UIC on the behalf of railways in the 3GPP MCX framework

⇒ The near totality of the 3GPP railway use cases developed by UIC and presented in 3GPP ad-hoc committees are already adopted or in course of adoption

⇒ Some uncertainty may remain on some items (for instance broadcast function, or MCX interconnect at domain change scheme) in terms of time needed for adoption: the mechanism of these specific functions having been defined well in advance by UIC, with the support of ETSI TC-RT, the elements necessary for their early implementation in products are known, and then the railway telecom suppliers have the possibility to anticipate 3GPP publications

⇒ In case some specific standardization use cases would not been accepted by 3GPP, the ETSI TC-RT may decide to implement an ad-hoc piece of standardization based on the same requirements, as it is the case for instance regarding the functions linked to interconnection 2G-5G, necessary for railway networks in Europe.

6. FRMCS V3 SPECIFICATIONS

With the closure of the Phase 1 of the FRMCS Introduction Plan, the current launch of the final stage of 5GRail (filed tests of the prototyping system), and the start of FRMCS V2 Specifications, we have now some of the needed elements to estimate the FRMCS 1st Edition planning, corresponding to the delivery of FRMCS V3 Specifications.

6.1 FRMCS V3 High-Level Scope & Dependency on Morane 2

The FRMCS V3 Specification set is to be the “market ready version” for launching the first ordering, pilot and/or deployment of FRMCS in Europe. Its overall goal is to define a FRMCS that can safely replace GSM-R, whilst functioning in coexistence with it. In addition, FRMCS V3 will set the RMR baseline 1, i.e. the FRMCS requirements relevant for allowing Railway Undertakings to tender on-board-FRMCS after receiving a notification of GSM-R end of life from an Infrastructure Manager

It will be based on V2 full testing, amendments and specific add-ons, such as quality of service, and measurements in real conditions, such as high-speed.

As such, FRMCS V3 will validate all what will have been defined in FRMCS V2, and will complete certain functional items, particularly but not exhaustively:

- Completion of the items indicated as managed in best effort in V2
- Support of additional selected applications, in the domain of TCMS for instance, or linked to the identification in the System Pillar of specific use cases compatible with the V3 timeline
- Consideration of handsets
- Assessment regarding the technical conditions and / or restrictions of usage of MNOs networks depending on applications, independently of other non-technical considerations (coverage, maintenance, responsibility, etc.

Obviously, the FRMCS V3 has a direct dependency with the set-up of an ad-hoc industrial project (Morane 2). In terms of timing, the first phase of the Morane 2 project should be executed in a period of 24 to 30 months and should / must ideally start the latest by mid-2024, leading then to FRMCS V3 “market ready” by end 2026. Obviously, V3 planning is highly dependent on the launch of the Morane 2 project and the perfect adequation of the Morane 2 project to railways’ objective: having a FRMCS system capable to substitute without major risks to GSM-R and managing voice services, ETCS and ATO GoA1/2.

Looking onwards, a second phase of the Morane 2 project will allow enlarging the scope of application testing (GoA3 and 4 as a first example), beyond the essential activities within the first phase of the Morane 2 project focussed on interoperability and on-board FRMCS. Later testing might focus on more complex situations such as multi-networks transitions and materialize the global solution for interconnection management of European networks (evolution of the interconnection GSM-R hubs currently managed by railways through the UIC ENIR group).

6.2 FRMCS V3 High-Level Plan & Risks

Based on previous elements, the proposed roadmap to FRMCS 1st Edition is illustrated here after.

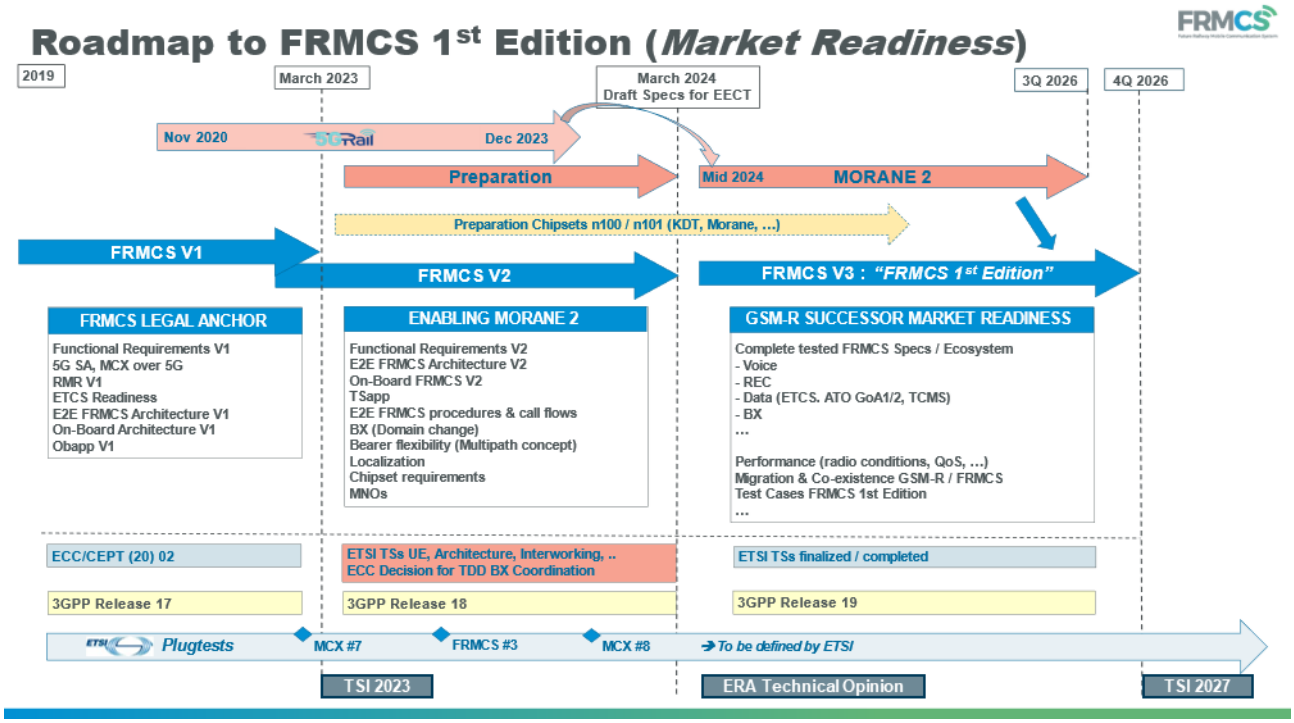


Figure 6: Roadmap to FRMCS 1st Edition (source UIC)

The assumptions for this roadmap are as follows:

- FRMCS V2 Specifications to be delivered in 2Q 2024
- ETSI FRMCS TS corresponding to FRMCS V2 delivered in 3Q 2024
- ERA Technical Opinion for FRMCS V2 delivered in 4Q 2024
- Start of the Morane 2 project by mid-2024
- Duration of the Morane 2 project of 27 months, letting the time to railway telecom suppliers to productize their FRMCS elements, capitalizing on prototyping already achieved
- Completion in parallel by UIC FRMCS Program of the FRMCS V3, as explained in the previous sub-chapter, to be delivered by 3Q 2026 to ERA for EECT process
- In parallel to the development of the FRMCS V3 specifications, preparation by the EECT group of the corresponding ERA technical documents to be included in the CCS TSI
- Once the technical documents are available the CCS TSI can be adopted[1].

[1] The estimate of the time required from the availability of technical documents to the adoption of CCS TSI is six months (2 meetings of the Railway Interoperability and Safety Committee and adoption of the CCS TSI by the Commission afterwards). This process assumes full alignment of the entire sector, hence no need for meetings of the 4th railway package expert groups.

This proposed roadmap concludes on the adoption of FRMCS V3 in by 2Q 2027.

It is important to mention here that a certain number of railway companies, considering their global vision of migration of their Control-Command System and the constraints of timing caused by the obsolescence of GSM-R, are requesting a more aggressive plan, mainly by advancing the start of the Morane 2 project in early 2024.

The main risks identified to date regarding this roadmap are as follows:

- Delay of completion of V2 specifications
- Delay to start Morane 2 project
- Lack of appropriate competences in the Morane 2 project
- Appropriate transfer of knowledge from 5GRail project
- Completion by ETSI TC-RT in a reasonable timeframe of necessary FRMCS TS (cf. previous chapter on FRMCS V2)
- Availability of FRMCS / 900 MHz and 1900 MHz chipsets.

The first three risks are self-explanative, the fourth one deserves more explanation:

- The usage of 900 MHz and 1900 MHZ harmonized frequencies, as well as the conditions of usage defined at ECC-CEPT and 3GPP levels (these conditions being very advantageous in terms of reduction of investment by railways compared to classical public networks), requires an adaptation of the generic 5G chipsets available or to be available in the market
- Such an adaptation has been demonstrated with a prototype of 5G 1900 MHz by Qualcomm in the frame of the 5GRail project
- A real productization has consequently to be achieved by at least one chipset manufacturer to enable the productization of certain elements of the FRMCS system (TOBA and handhelds)
- The chipset manufacturers, although developing a positive strategy on vertical markets, have a lot of solicitations from the different markets regarding 5G, and then will probably give priority in their plans to industrial segments capable to incentive the industrialization effort of their chipset
- A typical cycle of industrial adaptation of a chipset is generally estimated at 18 months.

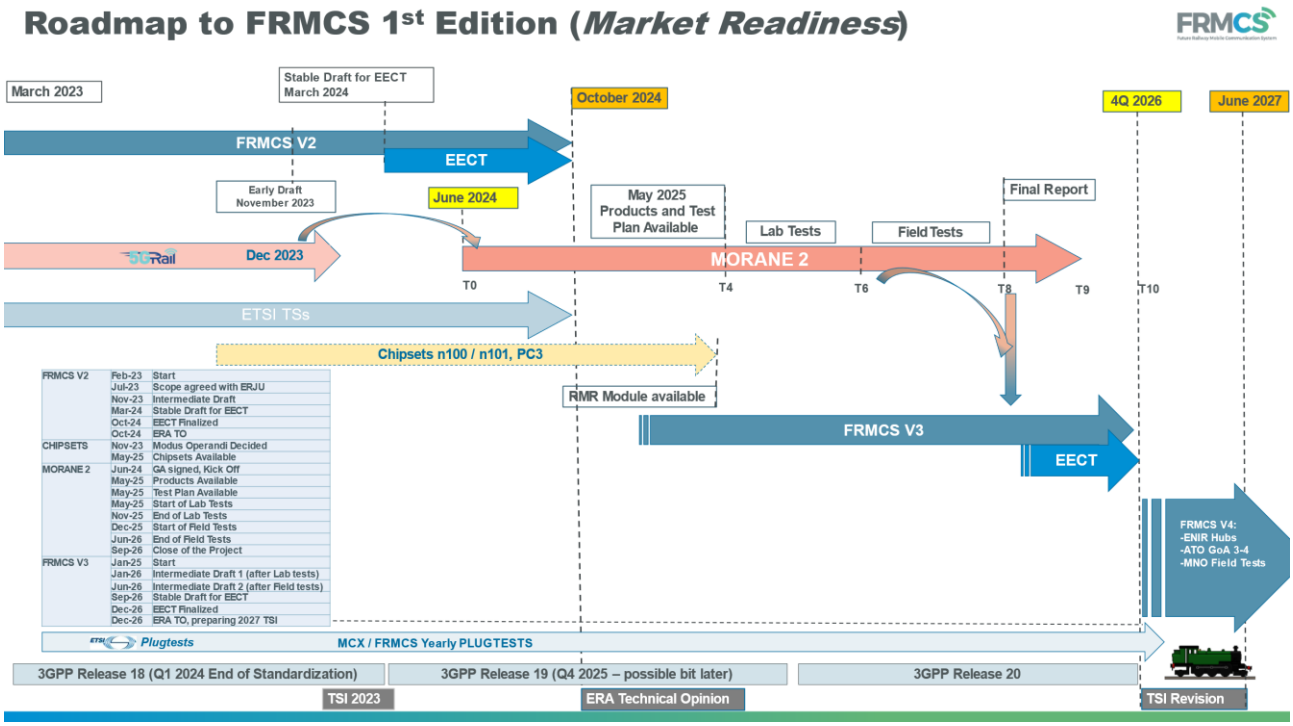
At the time of this report, different initiatives and / or assessments have been started by EU-RAIL JU, UIC or individual telecom suppliers, including direct contacts with potential chipset manufacturers, but no conclusion has been reached yet, the first key element to be solved being the financing of the industrial adaptation activity.

The global consideration of the FRMCS V3 roadmap implies, to keep this roadmap safe, a way forward, including a financing plan, to be defined at the end of 2023 for activation in early 2024.

7. OVERALL PROGRAMME PLANNING

The roadmap to FRMCS 1st Edition is composed of three stages:

- Prepare and deliver FRMCS V2
- Start and execute the Morane 2 project
- Prepare and deliver FRMCS V3, up to and including a positive vote and inclusion in the CCS TSI.



These phases are strongly sequential, as shown in the following figure:

Figure 7: Detailed roadmap to FRMCS 1st Edition (source UIC)

7.1 FRMCS V2

FRMCS V2 is developed according to a methodology very similar to the one used by ETSI in terms of internal milestones and work organization (refer to § 5.6). It is considered important that ERA is already an observer in all UIC Working Groups and should also be an observer in the FRMCS Supergroup to monitor potential arising technical blocking points.

The current plan, based on the FRMCS Specifications readiness for the Morane 2 project start, is to deliver these specifications in three steps:

- Step 1: An early draft to be delivered in November 2023 - This early draft is to be understood as a checkpoint allowing the verification of global coherence, adequation with objectives and level of criticality for the finalization of different items
- Step 2: A stable draft to be delivered to ERA in March 2024 to start EECT process - This stable draft contains all mandatory features as per the plan and is free from critical open points
- Step 3: The final draft to be delivered to ERA in October 2024, concluding a phase of 6 months for the completion of the EECT process, permitting therefore ERA to release a technical opinion.

  Note: ERA and DG MOVE should take the necessary actions to ensure the timely publication of the technical opinion defining the corpus of technical specifications necessary for performing EU and national trials on FRMCS

The activities in 3GPP are driven by UIC with the support of some UNITEL companies in parallel, seeding the FRMCS V2 when applicable.

ETSI TC-RT is developing the specific ETSI TSs in parallel, based on the UIC FRMCS Specifications (V1 and on-going V2) and on the outcomes obtained from 3GPP, with the objective to deliver these TSs by 3Q 2024.

7.2 Morane 2

The first phase of the industrial project Morane 2, whose an essential characteristic is to be a full TRL 8 project, has a duration estimated by both UIC and UNITEL at 27 months.

The main explanation for such a short period of execution is coming from the precedence of the 5GRail R&I project, EU-funded, whose outcomes, results, prototyping and global experience from UNITEL manufacturers, UIC and railways will permit to accelerate the production of final products, with the important condition there is a necessary continuity in the project participants and an absolute and sole focus on the FRMCS TRL 8 objective. It is also important to remind that the FRMCS V2 is the evolution of FRMCS V1, tested in the framework of 5GRail.

The Morane 2 project should be organized around 4 main sequential activities:

- Activity 1 (duration 12 months): Definition of test scenarios and test plans
- Activity 2 (duration 6 months): Lab tests, using equipment and applications built by suppliers during the period of Activity 1, by capitalizing on 5GRail prototypes, including
    - Integration testing, functional testing, quality of service testing
    - All relevant scenarios and use cases in view of FRMCS 1st Edition, including transitions between different networks (for instance with RMR and other band frequencies, enabling the validation of the MNO use case) and border crossing context
- Activity 3 (duration 6 months): Field tests with two different testbeds (conventional and high speed), reproducing lab tests in real conditions with an additional dimension of concrete (and not theoretical) quality of service impacts
- Activity 4 (duration 3 months): Reporting and conclusions.

A key condition to the Morane 2 project execution is the availability of RMR chipsets with all necessary characteristics. The experience of 5GRail, with the testing of RMR chipsets in prototyping mode, demonstrates that there is no technical major difficulty to adapt an existing 5G chipset platform to RMR needs, the issue being more to incentive chipset makers to achieve this adaptation.

UIC and UNITEL consequently convened that a specific plan for chipsets is needed (most likely including pre-financing, not defined as of today) by November 2023, leading to the availability of adequate chipsets by May 2025 in phase with the Morane 2 project laboratory tests, and UIC is then currently working on this plan with the support of some UNITEL companies.

Considering a start of the Morane 2 project by 1st June 2024, what should be the rational sector's objective, the timeline would then be approximately as follows:

- May 2025: start of lab tests, ending by November 2025
- December 2025: start of field tests, ending by June 2026
- September 2026: closing of the Morane 2 project Phase 1.

7.3 FRMCS V3

All along the Morane 2 project, and particularly during the execution of lab and field tests, the UIC FRMCS Program will have to consider the various results to amend or precise the FRMCS specifications when applicable, with the objective to secure FRMCS V3 and then FRMCS 1st Edition (first FRMCS implementable version for European railways).

ETSI TC-RT will have to consider obviously the same process in synchronization with the FRMCS Program.

As of today, the timeline is foreseen as follows:

- June 2024 - December 2025: FRMCS V3 preparation
- January 2026 (at closing of lab tests): delivery of FRMCS V3 Draft 1
- June 2026 (at closing of field tests): delivery of FRMCS V3 Draft 2
- September 2026: delivery of a stable draft of FRMCS V3 to ERA for EECT process
- December 2026: completion of EECT process and then FRMCS V3 ready for inclusion of FRMCS V3 in CCS TSI.
- June 2027: adoption of CCS TSI by the Commission after a positive vote of the RISC committee[2]

  Note: ERA and DG MOVE should take the necessary actions to ensure the timely update of the CCS TSI reflecting the completion of FRMCS specifications allowing Railway Undertakings to tender on-board-FRMCS after receiving a notification of GSM-R end of life from an Infrastructure Manager, as per § 7.3 on RMR specific implementation rules of 2023 CCS TSI

[2] As explained above, this process requires 2 meetings of the Railway Interoperability and Safety Committee and adoption of the CCS TSI by the Commission afterwards. It assumes full alignment of the entire sector, hence no need for meetings of the 4th railway package expert groups. Obviously, if no entire sector alignment was achieved before, this process may take longer.

8. ELEMENTS TO BE CONSIDERED WITHIN FRMCS V2 / V3

This chapter provides some precision on certain subjects linked to the development of FRMCS in general, and of the FRMCS V2 and V3 Specifications in general.

8.1 Consideration of the Usage of MNOs

All along the course of FRMCS activities, there has been a lot of discussions about the opportunity and the scope of usage of MNOs networks to perform railways services.

It is important here to recall that some key principles and scope have been agreed between the railway sector and EC within the Strategic Deployment Agenda ‘’5G Connectivity and Spectrum for Rail’’’, published on April 20th, 2020, with the following conclusions:

- The document makes a clear difference between the “Gigabit Train”, offering high-performance connectivity for passengers, and the “Digital Rail Operations” (FRMCS area)
- The dedicated spectrum allocated to Railways via ECC (20) 02 for Digital Rail Operations will allow both mission critical applications and additional performance applications
- FRMCS will allow therefore introduction of new applications like remote train video or ATO
- Sharing active network elements (using for instance “5G slicing” function) is not per se excluded: *“Depending on national policy, public services might be used e.g. for regional lines, performance applications or as a backup. However, the use of public networks for rail operation services is subject to national regulatory, liability and legal constraints.”*
- *“The feasibility of 5G active network sharing is challenging and has to be proven. Critical aspects such as interoperability, QoS, service level agreements, regulations, legal issues and liability requirements must be scrutinised.”*

A large part of the elements highlighted in this sectorial assessment are falling out of pure technical considerations, among which QoS (depending on coverage), service level agreements, regulations, legal issues or liability requirements.

From the sole technical standpoint, the possibility to run FRMCS on MNOs relies on two aspects:

- the ability for the TOBA to use RMR and other frequency bands (c.f. Table 4 of § 5.4)
- the ability for FRMCS system to ensure network transitions between FRMCS domains using different frequencies c.f. Table 2 of § 5.4).

It is reminded here that the FRMCS System is conceived as a “usual” 5G system regarding its architecture, its transport and application layers, even if an additional MCX service layer is introduced to reach specific functions and deliver a strong quality of service. This means simply that it can be implemented and used on all types of frequencies, including the frequencies which are the property of MNOs in the various European countries.

As such, the FRMCS Specifications can be applied to a specific MNO context, as long as the MNO network respects the FRMCS Specifications in terms of architecture, management of layers,

addressing mode and telecom protocols, which means 5G standalone network with MCX (3GPP Standards).

To make possible this MNO usage, it was key to consider the possibility, at the level of TOBA specification, to permit the change of frequencies during a train run. This functioning is integrated in FRMCS V2, the same way it has to ensure the change of FRMCS frequencies between 900 MHz and 1900 MHz.

Consequently, there is no technical blocking factors to the usage of FRMCS V3 in an MNO network, with the normal caveat regarding the respect of FRMCS V3 Specifications obviously.

However, the reality of interconnexion between heterogeneous networks (e.g. having proper technical rules for architecture, layer and addressing management, network management protections, etc.) may cause, when entering in material and operational considerations, a lot of potential issues. These potential issues are in fact fully dependant of the target network implementation and rules and may be of various forms.

This is why the approach considered today in the FRMCS Program has been defined in a pragmatic way:

- Guarantee that FRMCS Specifications can set a framework that does not prohibit by any mean the usage of other frequencies than the FRMCS defined frequencies (900 MHz and 1900 MHz in Europe).
- Identify, for industrial reasons and indirectly linked also to economic criteria (cost of coverage), the part of the 5G spectrum of interest in Europe: this action, independent from the FRMCS Specifications, has been requested to UIC by ERIG in the period of development of FRMCS V2
- Check the “compatibility technical conditions” with EU MNOs for a feasibility study of using MNO as primary or backup bearer of FRMCS for railway purposes, in various scenarios (discussing some of the different usage railway lines: freight, standard, high speed, low density, suburban)
- Consider the development of a set of “compatibility technical conditions” to be duly analysed with a targeted MNO whenever envisaging interoperable functioning with this MNO, to be delivered before the finalisation of the CCS TSI revision based on V3 specifications; this technical activity and document, that should not in any case have impact on the FRMCS Specifications, can be compared, for instance, to the “technical guidelines for interoperability” that was established for various systems such as ETCS.

This practical vision should guarantee:

- In the short term, the possibility to use FRMCS with MNOs (i.e. the ability for the TOBA to use RMR and other frequency bands, and the ability for FRMCS system to ensure network transitions between FRMCS domains using different frequencies) should be validated in an EU trial
- In the middle term, the development of specific tools aiming to facilitate the operational conditions for the usage of MNOs by railways, in the form of technical guidelines.

8.2 Cybersecurity Aspects

FRMCS is basically a 3GPP 5G SA (“Stand Alone”) MCX (“Mission Critical”) System.

As such, it is a potential target for cyber-attacks.

Several technical studies made principally in the context of ETSI TC-RT demonstrate that several security breaches exist in 5G accesses, despite the marketing declarations that 5G would be protected against cyber-attacks.

This is why the FRMCS Program has considered, from inception, the subject of cybersecurity protection as an essential part of FRMCS definition, the difficulty being, at the level of specifications, to set elements providing the guarantee of a certain level of protection without blocking the industrial innovation that will turn to be key in that domain, due to the daily evolution in the typologies of cyber-attacks. To achieve such solutions, the intention is to rely on cyber-security standard solutions.

In the European context, the work on any additional cyber-security measure will be done in close cooperation with ENISA.

With the technical support of another UIC group focused on cybersecurity solutions (“Cyber Security Solutions Platform”), the FRMCS Program has been considering, as of today, four level or strategies of possible protections into the FRMCS system:

- The systematic verification of any application connection demand at the level of TOBA, already implemented in FRMCS V1 under the name of “Local Binding” feature attached to the OB_{app} interface
- The “physical” protection of the 5G radio access, with technical strategies such as the disruption of protocol for instance
- A protection at the network layer through technical strategies such as the implementation of SBC elements or equivalent
- A higher protection at the application level by the usage of end-to-end secure key mechanisms.

Some of these protection schemes will be by the way part of the 5GRail field tests, at the end of 5GRail project, to verify their feasibility and their adequation to FRMCS whole system.

To go further in the construction of adequate responses, UIC started recently a cybersecurity assessment focused on FRMCS, also in the context of its dedicated group on cybersecurity solutions, with the additional support of multi-domain technical experts in cybersecurity.

Specific mechanisms of cyber-protection like the inclusion of specific and specialized hardware elements (for instance for the disruption of protocol of for a sound secure key function) into FRMCS products might be considered, and this has to be decided in a collaborative mode between railways and railway telecom suppliers, with the aim to find an optimized approach.

The objective in FRMCS V2 is consequently to propose implementation options for these cybersecurity aspects and to present some adequate ways to facilitate these implementation options in the FRMCS Specifications.

8.3 Consideration of the Usage of Satellite Systems

The existing satellite systems have network conceptions, architecture rules and telecom properties quite different from terrestrial mobile networks.

This is one of the reasons for which 3GPP developed the ambition with 5G to define a technical framework of interoperability between terrestrial radio networks and satellite networks, with dedicated specifications ensuring a certain level of transparency between these two families of telecom networks.

With the clear intention to avoid the development of proprietary interfaces or specific network architectures that would on one side complexify the FRMCS system and on the other side put at risk its necessary interoperability, the FRMCS Program has taken the approach to monitor the evolution of the 5G framework dedicated to satellite interconnection and transparent support of subsets of 5G features.

This approach has been validated by UNITEL, who pointed out also additional elements to be more deeply assessed, such as:

- The impacts on vehicles, typically antennas
- The management of partial coverage, typically for tunnels or similar cases.

Due to the complexity of the constitution of this framework, but also due to the delays caused by the Covid crisis, 3GPP is still in the development of the corresponding technical specifications. Therefore it does not appear as relevant for the FRMCS Program to dedicate a lot of effort to this topic for the time being.

A logical expectation should be for the FRMCS Program to consider the potential usage of satellite systems in FRMCS V4, waiting to get benefit of the final specifications to be developed by 3GPP and implemented by satellite operators.

In a European context, the railway usage of the new IRIS^2 satellite communication system will need to be assessed and may be a welcome development in terms of MCX communications.

8.4 Consideration of FRMCS within Innovation Pillar Projects

The Innovation Pillar work packages having potentially a direct relation with the FRMCS concept are hosted in the FA2 (Flagship Area 2) R2DATO project.

A full list of the WPs (work packages) mentioning concretely FRMCS is provided in Annex 2, with their expected content. Regarding the sole impact to FRMCS of these WPs, the situation can be analyzed as follows:

1. WP 22 (Absolute Safe Train Positioning - System Architecture, Design & RAMS)

   The outcome for FRMCS should be a use case on absolute positioning information, however no railway telecom supplier is involved.

2. WP 23 (Onboard Communications - Communication Foundations and Basic Functionality)

   The outcome for FRMCS should be an evolution of the UNISIG Subset 147, however no railway telecom supplier is involved.

3. WP 25 (Connectivity Development - FRMCS)

   This WP has more outcomes related to FRMCS - Nevertheless, its clear focus on ATO will limit the FRMCS testing scope and its timing constraints will most likely oblige to re-use the TOBA prototypes of 5GRail, with no major differences in terms of product advancement.

4. WP 28 (Connectivity Development - ACS/Gigabit Train)

   This WP is more dealing with ACS and Gigabit Train, as such, even if interesting for exploratory purposes, it is not directly helping the preparation of FRMCS for market readiness.

5. WP 36 (Onboard Platform Demonstrator)

   This WP aims to produce a demonstrator TRL5/6 (lab test) for an on-board computing environment - It should then re-use the outcomes of 5GRail with no major evolution.

6. WP 43 (Freight Demonstrator)

   This WP includes a pre-integration of TOBA in the locomotive, also based on the 5GRail prototypes with slight evolution only - It should nevertheless give indications related to hardware constraints for the involved suppliers.

7. WP 45 (Moving Block ETCS L3 Demonstrator - Realisation)

   No solid outcome for FRMCS is really expected from this WP, and no railway telecom supplier is involved.

8. WP 48 Innovative Operational Solutions

   No solid outcome for FRMCS is really expected from this WP, and no railway telecom supplier is involved.

The main WPs having a clear relation with FRMCS development or usage are WP25 and WP36. How the results of these WPs can contribute to the overall FRMCS programme need to be further clarified, and the alignment with a future Morane 2 project considered.

8.5 Consideration of compatibility of FRMCS and ACS

A report has been delivered in March 2023 in the context of R2DATO, with the objective to compare FRMCS and ACS.

The main conclusions of this report are:

- The scopes of ACS and FRMCS are nevertheless in general different, with partial but not sufficient overlap to strictly compare the two approaches: the two systems address different use cases, as well as markets, and as such should not be considered to compete between each other
- ACS can be seen in certain aspects as a FRMCS precursor, aiming to achieve a “prove of concept” for bearer flexibility and separation between application and telecom layers, with the definition of a general architecture including service and control plane layers, embedding 3GPP Mission Critical services (however as option) and eventually a distinct IP user plane layer with clear separation to independent transport plane(s)
- On the other side, the FRMCS concrete scope is to replace GSM-R, as an ERTMS subsystem, ensuring at the same time probably 15 years of coexistence between the two systems, what leads to a much more precise and rich system by nature
- As such, FRMCS is similarly managing bearer flexibility and separation of applications from the communication layer, but in addition, due to all its functional and system requirements, it encompasses a comprehensive architecture, with its versatile system interfaces OB_{app} and TS_{app} designed on purpose for ERTMS evolutions, and it focuses on a strong Quality of Service, as it is fundamentally based, among other structuring topics, on 3GPP 5G SA Mission Critical, for economy of scale and future proofness.

It is therefore considered in conclusion that ACS cannot be a substitute to FRMCS but can be reserved for some specific usages in adequation with its technical properties, particularly in the case of a telecom network where the full set of FRMCS functions would not be useful or mandatory.

The additional market interest of the usage of an ACS equipment in a FRMCS network could also be envisaged, at minimum by using the “Best effort” regime of FRMCS giving transparency to external systems. However, in this example, the QoS aspect should be more deeply assessed.

8.6 Consideration of the Access to FRMCS Specifications

It is our analysis the existing agreement between the ERA and the UIC regarding GSM-R and FRMCS collaboration, as well as the proposed amendment to the MoU between the EU-RAIL JU and the UIC, are giving the necessary and sufficient elements to guarantee the access to FRMCS Specifications for the ERA and the EU-RAIL JU, and reversely the access to the EU-RAIL JU useful technical documents for the UIC in the context of the collaboration and alignment on FRMCS between the EU-RAIL JU, the ERA and the UIC.

It is our understanding that the conditions set do not infringe the rights on intellectual property of all the considered documents, should it be from the EU-RAIL JU perspective or from the UIC perspective.

In addition, the experience of the existing agreement between the ERA and UIC, that has been used over the last 15 years for the inclusion of the GSM-R Specifications in the technical annexes of the CCS TSI, has demonstrated without ambiguity that the organized framework was relevant and was not presenting issues for the railway sector.

Notwithstanding the above, it is considered a requirement from DG MOVE and ERA that for the FRMCS specifications:

- It should be guaranteed that the accessibility to UIC FRMCS specifications should continue be freely available to any interested party within Europe, i.e. published on UIC website, as is the case currently for GSM-R specifications, notwithstanding the UIC ownership and copyright of these documents.
- UIC should within a reasonable effort guarantee that the FRMCS specifications are not subject to any other intellectual property owned by another party than UIC. Any inclusion of technologies and/or documents (beyond the ones included in 3GPP and/or ETSI standards) in these specifications subject to third party IP needs to be discussed in advance with the European Commission, as long as these specifications may be used in the context of European Commission or ERA, and in this case, once approved by the Commission, such inclusion should at least be transparently publicised.

To the extent of our knowledge and information, these requirements are met at the time of this report.

8.7 Consideration of railway specific features, including chipsets

Based on the GSM-R deployment model, and as highlighted in the Strategic Deployment Agenda "5G Connectivity and Spectrum for Rail", it is desirable to re-use as much as possible the existing infrastructure to mitigate the costs for deployment. To enable this possibility, some functional requirements are expected to be railway specific, especially on radio aspects.

As identified in Table 4 of § 5.4, the main functional needs from a railway perspective are the support of the spectrum harmonised for railway usage[1] and the High Power UEs to be able to reuse the masts deployed for GSM-R networks (R-GSM spectrum in 900 MHz band, and 8 Watts cab radios).

It is also identified in § 6.2 some risks linked to the availability of chipsets supporting those two features. In case needed, alternatives to mitigate this potential risk should be considered at the appropriate time.

------- End of Core Document -----

ANNEX 1: UIC ERIG'S VIEW ON FRMCS ROADMAP

EUROPEAN RADIO IMPLEMENTERS GROUP	Document E-4286
Title:	**ERIG's view on FRMCS roadmap**
Source:	**UIC**
Date:	**December 2022**
Version:	**1.0**
Status:	**Final**
Pages:	**5**

In order to guarantee successful introduction and migration towards FRMCS, ERIG have the following view **on the roadmap of FRMCS**. It includes

- timelines including deadlines of FRMCS specifications and trials,
- summarized scope of FRMCS v1.0 and
- expected scope of FRMCS v2.0

1 Expected timelines of FRMCS specifications and trials/pilots

ERIG estimate the following timelines for FRMCS specifications and trials in order to achieve the targeted starting of deployment of FRMCS starting in 2025. These timelines (and priorities of items) are essential to railways to progress with regard to their ambitious plans on the digitalization of rail operation:

	FRMCS specifications	FRMCS trial/pilot
Milestones until end 2022	**FRMCS v1.0** in **TSI 2022**: • Stable draft submitted to EECT by end October 2022 • FRMCS ICs agreed and included in TSI body text • First step of FRMCS legalization in Europe, in the context of ERTMS evolution (game changers) • Scope: limited functional and system requirements to critical applications and RMR spectrum (as detailed below) without all detailed tech solutions from 3GPP/ETSI	5GRail: 1) test pre-standard FRMCS/TOBA, and 2) use the project results as inputs for both FRMCS v1.0 and v2.0
Milestones 2022- 2024	**FRMCS v2.0** in 2024 published via **ERA opinion**: • Stable draft submitted to EECT for ERA opinion by end of 2023 (risk to shift to Q1 2024)	

	• Related ETSI FRMCS specifications shall be ready in 2024 and shall be considered and referenced in UIC FRMCS specifications • Scope: complete FRMCS specifications based on 3GPP Rel. 17, containing essential functions to replace GSM-R (as detailed below)	
Milestones 2024 - 2025	**FRMCS v3.0** in **assumed TSI 2025** • Stable draft submitted to EECT by end Q1 2025 (risk to shift to Q2 2025) • Using output of the MORANE 2 trial/pilot project	• Validation of FRMCS v2.0 • European trial for final tests with finalization of products and cross border scenarios
Note 1: There shall be no further delay for V2 after Q2 2024, otherwise this will impact tendering plans. FRMCS V2.0 publication planned in Q2 2024.		

Table 1. Expected timelines of FRMCS specifications and trials/pilots

It is to be mentioned that a sector 2024-2025 European Trial is at utmost importance, and an urgent solution is needed to organise and co-finance these at European level, as it is indeed a clear blocking point to FRMCS market readiness and then implementation in railway networks.

2 Summarized scope/high-level content of FRMCS v1.0

FRMCS v1.0 contains limited FRMCS specifications permitting support of voice (Point-to-Point and Group Communication), ETCS, ATO GoA2 and railway emergency communication (REC) (light version).

Here is our currently high-level content of FRMCS v1.0:

- FRMCS onboard readiness
  - Supported system setup: MCX tight coupled and loose coupled modes
  - Introduce reference points: OB_{APP}, OB_{RAD}, $OB_{ANT,}$
  - System requirements for FRMCS onboard system functions including local binding, Auxiliary function, API function, service session function. Minimum high-level requirements for radio modules interchangeability and remote radio modules.
- Priority 1 FRMCS E2E system principles listed in Section 4.3 in MG-7905, including
  - QoS[1]
  - Service user identification, addressing, including role-based identification of service users (transport user identification as priority 2)
  - Bearer flexibility principles: multi-access, multi-path
  - RMR 900 and 1900 MHz spectrum ranges
  - Basic security framework
- Inclusion of 3GPP/ETSI documents without detailed tech solutions/configurations as limited functional and system requirements
  - Mandate 5G Core and MCX as part of FRMCS system architecture [2]
  - Working-in-progress ETSI FRMCS TSs are referenced in UIC FRMCS specifications

[1] Enhanced function like context-aware QoS is not in the scope of V1.0.
[2] Mandate MCX per application category and usage of IMS or SIP core for FRMCS are not in the scope of V1.0.

3 Expected scope/high-level content of FRMCS v2.0

It is assumed that FRMCS v2.0 is the first complete FRMCS specification based on 3GPP Rel. 17 (priority 1) / Rel. 18 (priority 2), containing essential FRMCS functions that can replace main GSM-R functions, i.e. FRS/SRS (MI). The table below shows the anticipated content for FRMCS v2.0.

Scope/high level content		Priority
Support of applications and the required FRMCS services		
Application	**Required FRMCS services**	
ETCS	Data	1
Voice applications[3]	Voice (Point-to-point communication, group communication)	1
REC	Voice (group communication), Alert using data (group communication)	1
Data services defined in FRS (e.g. for enabling national data services e.g. EBuLa in DB, etc.)	Best effort Data (i.e., bypassing MCX)	2
Messaging services defined in FRS (minimum set of services similar to GSM-R to be identified as priority 1)	Data	1
ATO GoA1-2	Data	1
ATO GoA3-4 (pre-condition: application requirements from UNISIG)	Data, video Support of low latency (10 ms)	2
Train control and monitoring system	Data	2
Categorizing FRS applications into harmonized/non-harmonized applications		1
The definitions of harmonized/ non-harmonized communications		1
Support of IPv4 and IPv6		
Infrastructure side: Support options of IPv6 and IPv4. Support options of interworking between IPv6/IPv4		1
Onboard: Support options of IPv4 and IPv6		1
Migration		
FRMCS onboard system for dual mode and cost-effective Cab Radio implementations with needed voice functionality (including best-effort data – to be confirmed)		1
Guidelines for migration (from GSM-R to FRMCS) Note: operational rules are not in the scope of UIC, but UIC will support.		1
Basic interconnection, roaming, border crossing		
Interconnection/roaming between railway domains		1
Interconnection/roaming between railway and public domains (e.g. fallback scenario).		2
Interworking with external systems		
Interworking with GSM-R		1

[3] Train Radio Voice

Interworking with public emergency system (legal constraints to be confirmed. If confirmed, priority 1, else priority 2).	1/2
On-Board FRMCS	
OB_{RAD}: radio modules interchangeability, remote radio modules (specification of the concept)	1
OB_{OM}: including exchange of certificates	1
AUX Function: including possible advanced features	1/2
Positioning, localisation	
Definition of purpose of positioning and localisation: whether the positioning function is used for telecom purpose or for application purpose.	1
Positioning mechanism for the required services, e.g. context aware addressing similar to LDA (location dependent addressing)	1
User equipment (the characteristics of terminals)	
ETSI 103 765-5 for transport UEs (not under control of UIC but UIC will support)	1
ETSI 103 765-2 for service clients (not under control of UIC but UIC will support)	1/2
UE in UIC specifications (e.g. TOBA FRS, FRMCS SRS)	1
Spectrum	
FRMCS 900 MHz band	1
FRMCS 1900 MHz band	1
Minimum set of 5G Public bands as options (EU). Minimum set of 5G Public bands as mandatory to be confirmed by the EC.	1
Bearer flexibility	
Multi-access using 5G Core	1
Multi-path for offloading (parallel usage)	2
Multi-path (e.g. for fallback, redundancy/resilience purpose)	1
High speed considerations	
Radio access requirements for high speed in SRS (including coverage quality…)	1
Radio access requirements for high speed in ETSI (not under control of UIC but UIC will support)	1
Offnet communication	
High-level requirements	2
Complete technical details Note: Depending on solution envisaged, this could be a R18 or later.	2
Network slicing	
Support of network slicing in FRMCS	2
Security	
Security for URLCC communications	2
Security for fallback	1/2
Security for multi-access, multi-path for offloading and redundancy	2

Trusted / untrusted radio access	1
Interconnection / interworking with external non-FRMCS networks, migration, roaming	2
3GPP	
Inclusion of MCX services and 5GS building blocks in Rel 17 to support FRMCS use cases listed in Annex A of MG-7905	1
Mandate MCX per application category (best effort data)	1
Usage of IMS or SIP core shall be decided and specified	1
Inclusion of functions in 3GPP CT1 Rel 18 / 19 • complete support of MCX interconnection • MC gateway UE • MCX control plane and user plane separation • MCX Service Ad Hoc Group Communications (R18 based REC)	2
Note: • Priority 1 means it shall be specified in FRMCS v2.0 • Priority 2 means it shall be specified latest in FRMCS v3.0	

Table 2. Expected scope/high-level content of FRMCS v2.0

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ANNEX 2: EU-RAIL JU FA2 R2DATO ACTIVITIES

Work Package	Title	Communication needs / Contents	Dependencies / Relations / Input
WP22	Absolute Safe Train Positioning - System Architecture, Design & RAMS	The work shall also cover safety evidence, including the interaction with the digital map server (e.g., transmission through FRMCS to the Onboard incl. version check)	No network telecom supplier involvement
WP23	Onboard Communications – Communication foundations and basic functionality	**Task 23.2**: Functional and non-functional requirements of communication functionality and basic services (Leader: SMO; Participants: DB, SNCF, SBB, TRV) (Duration: M3 to M8) • Define requirement including existing ones for OSI layer 1-6 on communication functionality of Onboard Communication Network (a.k.a. One Common Bus), including the FRMCS protocol layers the basic services functionality (e.g. authentication service), including cybersecurity requirements as detailed in IEC62443 (Foundational Requirements) • Select relevant use cases for communication functionality and associated basic services	No network telecom supplier involvement Subset 147
WP25	Connectivity Development – FRMCS	This work package aims to move the developments on FRMCS further forward, by: • Filling the gaps of current specifications, for instance related to how applications like ATO exactly make use of and interface to the FRMCS system • Provide recommendations for antenna design • Provide a common framework for radio planning and optimization • Perform a complete lab and field validation of FRMCS components • Support ETSI plug-tests • Investigate how multiple radio bearers can be used concurrently to serve the needs of both the Gigabit train and future rail operations, and how the FRMCS architecture and specifications can potentially be expanded in this direction … **Task 25.1**: Consolidate prior works (Leader: ADIF; Participants: ATSA, CAF, CEIT, COMSA, DB, DLR, INDRA, KONTRON, SMO, SNCF, TRV) (Duration: M1 to M4) The aim of the work is to determine how ongoing FRMCS standardization works and concepts for ACS relates. In addition, how concepts related to ACS not covered today in the FRMCS architecture can be fed into the FRMCS standardization to have one standard for interoperability. **Task 25.2**: Updated FRMCS prototypes with the latest specifications, integration in lab, test plans and results (Leader:	S2R TD2.1 (ACS) 5GRail WP8.3 FRMCS v1.0

		ATSA; Participants: SNCF, SMO, DB, KONTRON, DLR, ADIF, FSI, PRORAIL, TRV) (Duration: M4 to M30) The aim of this task is to further develop the On-Board and Trackside Gateways and related interfaces in accordance with the UIC/UNISIG requirements. Then, a preliminary integration in a lab (TRL4) is proposed to complete the unitary tests performed at the supplier stage by system tests involving all components and to perform lab tests before field experimentation (described in Task 25.5). A further update of FRMCS On Board and Trackside Gateways will include the following potential key functions: · OBAPP and TSAPP interfaces; including local binding and API (following UIC FFFIS) · Bearer flexibility through multi-access multi-connectivity · Session management · Dynamic QoS management · Transport service for user plane data · Support multiple modems and radio technologies for both private networks/frequencies and MNOs · Authentication/authorization access to the FRMCS service level · Support of cross-border scenario · OB_GTW redundancy study A further update of ATO application will include the following (subject to external input for this WP): · OBAPP and TSAPP interfaces in Loose-coupled mode: API following UIC FFFIS, local binding (e.g., with TLS using a local or remote PKI) · Adaptation to the underlying UNISIG Subset · End to End Security A further update of ETCS application will include the following (subject to external input to this WP): · OBAPP and TSAPP interfaces in Loose-coupled mode: API following UIC FFFIS, local binding (e.g., with TLS using a local or remote PKI) · Adaptation to the underlying UNISIG Subset · End to End Security for safe and non-safe applications The lab test will leverage the test plan used during 5G-Rail and will be complemented by some items in the following list: · Gateway redundancy · Cross-border scenario · Dynamic QoS · Multi-access and/or multi-connectivity · Integration of OB_GTW with different modem providers (if possible) · TLS and underlying PKI architecture (more detailed in WP3) **Task 25.3**: FRMCS antenna design, development and integration (Leader: SNCF; Participants: SMO, ATSA, ADIF, TRV) (Duration: M4 to M42) Optimizing train-to-trackside radio communications needs further research on antenna design and integration to take into account the specific harmonized frequency bands, deployment constraints (size, weight, location on the roof of the train), avoiding interference problems when coexisting with other co-located radio-based communications systems (legacy and future), for both onboard and trackside antennas. Proposed work will focus on: · Onboard antenna system modelling design optimization and integration to support experimentations and propose hardware solutions for the coexistence of systems:	

		FRMCS, GSM-R, cellular MNO (2G/3G/4G/5G), GNSS and other potential connectivity needs like V2X and Satcom (TRL 5/6). · Trackside antenna system modelling, design optimisation and integration to support experimentations and propose hardware solutions for FRMCS harmonized frequency bands (900, 1900 MHz), and other frequency bands dedicated to 5G verticals (2.6 GHz and 3.8 GHz in France) or to MNOs (TRL 5/6). Existing work from Shift2Rail/X2Rail project will be taken to a field/onsite experimental level. That is, the assessment and testing of antennas (for both onboard and trackside) in the railway environment, including train integration and a performance evaluation in real conditions in the framework of SNCF's FRMCS field experimentations (Task 25.5). Performance evaluation includes: • Definition of generic KPI (Key Performance Indicator) to evaluate antenna design performance from the OB_GTW point of view (e.g., in terms of bandwidth in UL and DL directions, loss of connectivity and duration). These KPI must reflect the quality of the link between on-board and trackside gateways. • Definition of KPI specific to the ATO application, to be used for the measurement campaign (e.g., latency, loss of applicative data). These KPI must reflect the quality of the link between ATO-OB and ATO-TS devices. • Usage of the same equipment used in Task 25.5 for field experimentations • Analysis of the results regarding generic KPI and specific ATO KPI **Task 25.4:** Validate the interoperability through participation to ETSI Plug-Tests (Leader: SNCF; Participants: ATSA, SMO, KONTRON, ADIF) (Duration: M1 to M24) The aim of MCx plug tests (TRL 6) is to validate the interoperability of a variety of implementations using different scenarios based on 3GPP Mission Critical Services. One first session of ETSI Plug-Tests should occur before the lab integration, while another session of ETSI Plug-Tests should occur afterwards. Regarding FRMCS products, this concerns the following: · On-Board and Trackside Gateway which embeds the MCData clients required for Loose-coupled applications. We will focus on MCData IPconn session for Loose-coupled applications. · On-Board and Trackside Gateway + MCPTT applications (in Tight coupling mode) · CN, SIP core and MCx servers The aim is to reach interoperability between the following components involved in FRMCS environment: · OB_GTW and TS_GTW from different providers · GTW (OB_GTW or TS_GTW) and SIP core/MCx server from different providers · MPCTT clients from different providers · MCPTT client and MCx server from different providers	

		Task 25.5: FRMCS field experiment in a real railway environment (Leader: SNCF; Participants: ATSA, SMO, KONTRON, PRORAIL, NS, TRV) (Duration: **M24 to M42**) The aim of this task is to perform a final on-site integration (TRL6) of the FRMCS products specified and developed in the framework of this WP and the on-site tests. The aim is to replay all the tests performed the lab in Task 25.2 in a real railway environment. Various combinations of environment parameters can be proposed, some examples are given below: · High speed line, urban/suburban line · Regional line, · Private 5G network + backup network (e.g., public 4G or 5G network, Wi-Fi in depot or stations) · Public 5G network + backup network (e.g., public 4G or 5G network, Wi-Fi in depot or stations) However, the chosen live environment will depend on the availability of suitable trackside infrastructure sites (well dimensioned power supply, fibre optics connectivity, GSM-R shelters and masts) and on the possibility to organize experimental campaigns with SNCF's test & measure trains (up to 20 days of field experimentations). These field trials will as much as possible take into account the specificities and constraints of the French Freight ATO demonstrator (site, train) in order to prepare potential future ATO/FRMCS demonstrations. Existing work from H2020/5G-RAIL Project will be a major input for this task. **Task 25.6**: Preparatory activities for regional demo FRMCS and connectivity (Leader: ADIF; Participants: KONTRON, COMSA, CEIT, INDRA, TRV) (Duration: M1 to M42) This task consists of the definition, roadmap, requirements and preparation for a regional FRMCS pilot section as an enabler for a future demonstrator. At a 1st stage, it will be a test pilot section for FRMCS and connectivity. On a second stage it will be part of an integrated demonstrator to be used not only in R2DATO also by a regional line application scope to be included inFA6. In this task preparatory works of infrastructure and on-board trains are included per required to enable Gigabit connectivity and FRMCS demos in Spain to be carried out in future projects. Specific activities are: 1. Definition. 2. Technical Requirements for Installation 3. The supply and installation of the required fibre, electrical equipment, powering, and building technical facilities (when needed along the track section, also tower masts for the installation of FRMCS antennas, access network hub in the station facilities, to provide a gigabit connectivity network and any other preparatory works in infrastructure. 4. Preparatory works on-board trains. 5. Preparation of test campaign	
WP28	Connectivity Development – ACS/Gigabit Train	This work package will investigate how multiple radio bearers can be used concurrently to serve the needs of both the Gigabit train and future rail operations, and how the FRMCS	S2R TD2.1 (ACS)

		architecture and specifications can potentially be expanded in this direction	
WP36	Onboard Platform Demonstrator	The aim of this demonstrator is to implement and validate a prototype and blueprint of the future-proof onboard connectivity and IT platforms that are required in a highly automated rail system, with the expectation that latest from EU-RAIL phase 2 on all larger-scale demonstrators would utilize these platforms. The aim of this demonstrator is to implement and validate in a lab environment (up to TRL 5/6) how railway application(s) can be hosted on a modular computing platform, making use of a safe Runtime Environment (RTE), standardized Platform Independent (PI) API, onboard FRMCS functions and a unified diagnostics service API. It shall be demonstrated how modular onboard functionality can integrate on a common onboard network, using train integration concepts such as a Functional Vehicle Adapter and FRMCS gateway functions to be able to communicate safe and securely to onboard and trackside entities in harmonized operations and maintenance, e.g., enabling remote update functionality and IT/OT security. As a key outcome, the demonstrator will help to determine an appropriate level of onboard platform modularity and aggregation (e.g., by utilizing a common hardware pool, most likely through the usage of virtualization or hypervisor technology), and to prove the feasibility of hardware independent integrability and potential certifiability as a blueprint for EU-RAIL phase 2 and future larger-scale demonstrators. • The possible demonstrator scope is shown in the figure below, incl. specific functional chains from demo application(s) to external entities that are to be investigated. The exact demonstrator setup, and its concrete realization are subject to an analysis and specification phase at the beginning of the project. ETCS and ATO functions shown in the figure below will likely not be in the scope of the demonstrator. Technical enablers needed: • Onboard communications • Modular platforms • Communications (FRMCS and possibly Gigabit train) • Further enablers based on the chosen test application(s) (e.g., Safe Train Localization, Digital Register)	WP23, WP24
WP43	Freight Demonstrator	To allow a smooth deployment of GoA 4 technology with different possible technological solutions, the systems need to be tested in real conditions in a demonstrator. The freight demonstrator will be equipped with sub-systems studied in the Technical Enablers. Tests will be performed, enhancing autonomous freight train operations. The following items will have to be tested on the demonstrator: driving rules with ATO on normal mode for freight trains, reaction of the train to incidents not yet covered in S2R, increase of performance of the perception systems for reaching safety requirements, ATO behavior in various environment scenarios (topology,	X2Rail

		hygrometry, weather conditions, …), precise positioning for GoA4 operation needs. To guarantee the most efficient and agile process possible, our testing methodology will be mainly incremental with a series of test scenarios and evaluation cycles. The freight demonstrator is composed of a BB27000 ALSTOM locomotive. It is compatible with France, Luxembourg and Belgium networks. **Task 43.7**:Preparatory studies for FRMCS integration (leader: ATSA; participants :SNCF, KONTRON, TRV) (M1 to M36) ALSTOM will deliver the onboard FRMCS Gateways for trial activities (also named TOBA product) that will be updated from the implementation already achieved during the 5G-RAIL project and learnings from the work in the X2Rail project phases, as well as Alstom's experience on the ETCS over 3GPP technology under deployment. Kontron will deliver the Onboard FRMCS Gateways as well based on the 5G-Rail project including mainly needed evolution of OB_{app}.	
WP45	Moving Block ETCS L3 Demonstrator – Realisation	The main objective is to demonstrate a modular train-centric trackside protection system enabling moving block operations with generic safety core up to TRL6 in R2DATO. By doing that we want to prove that • the architecture (incl. standardized interfaces) based on System Pillar results is feasible • the train-centric ccs logic has additional benefits compared to a block-centric operation • the generic safety logic is a valid concept • the system can operate with any train equipped with radio-based ETCS (Level 2/3/R) the system is capable of using any combination of trackside localization (e.g. axle counter) and on-board localization (e.g. train integrity) to determine the safe trackside view of track occupancy (hybrid sensor configurations, without "thinking" in blocks).	No network telecom supplier involvement WP27
WP48	Innovative Operational Solutions	This work package aims for specific innovative use cases targeting for solutions with even higher grades of automation closer to autonomy. It is one approach to operate trains, consists or even individual vehicles as e.g. freight wagons individually and to enable the infrastructure to react on the requests set by those vehicles. Consequently, this WP shall focus on three innovative operational solutions, which are core to enable this approach, namely, Autonomous Route Setting (AnRS), Virtually Coupled Train Sets (VCTS) and Self-Driving Freight Wagons (SDFW). These operational solutions rely on two core technology elements related to communication and localization: short-range communication (SRC) and relative localization (RL). Both technologies are required in addition to normal train-to ground communication (e.g. by FRMCS) and absolute localization (e.g. by GNSS), which are subject of other WPs in the project. Hence, this WP will focus on the further development based on the state of the art	No network telecom supplier involvement

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