ERTMS ETCS trackside engineering rules and their effect on operations

ERTMS Conference 2022 - 26/4/2022

ERA – EUG – ALE

EUROPEAN UNION AGENCY FOR RAILWAYS

Scope of the workshop

- Elaborate on the close **link between engineering and operational rules** and on the need to **integrate Human and Organisational Factors (HOF)**.
- Different "**user experience**" depending on how the ETCS toolbox is used.
- **OPE TSI Appendix D3**, first introduced in TSI 2022, with trackside engineering information relevant for operations and not otherwise known to the driver.
- The role of **harmonised marker boards**.
- **Further harmonisation** of trackside engineering rules mandated at TSI level.

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CCS TSI vs OPE TSI

CCS TSI

Sets out specifications for **technical interoperability** of ETCS and Radio, as well as modalities for deployment, testing and validation.

OPE TSI

Sets out provisions for **operational interoperability** between railway actors, mainly between signallers and drivers.

How are these linked?

- **CCS Annex A document ERA_ERTMS_015560**:

Specifications of harmonised Driver Machine Interface

- **OPE Appendix A: ERTMS Operational Principles and Rules:**

Generic rules applicable in all ERTMS trackside configurations

- **OPE Appendix B: Common operational principles and rules:**

Generic rules applicable in all circumstances

- **OPE Appendix C: Safety-related communication methodology:**

Formalized oral communication rules & written operational instructions

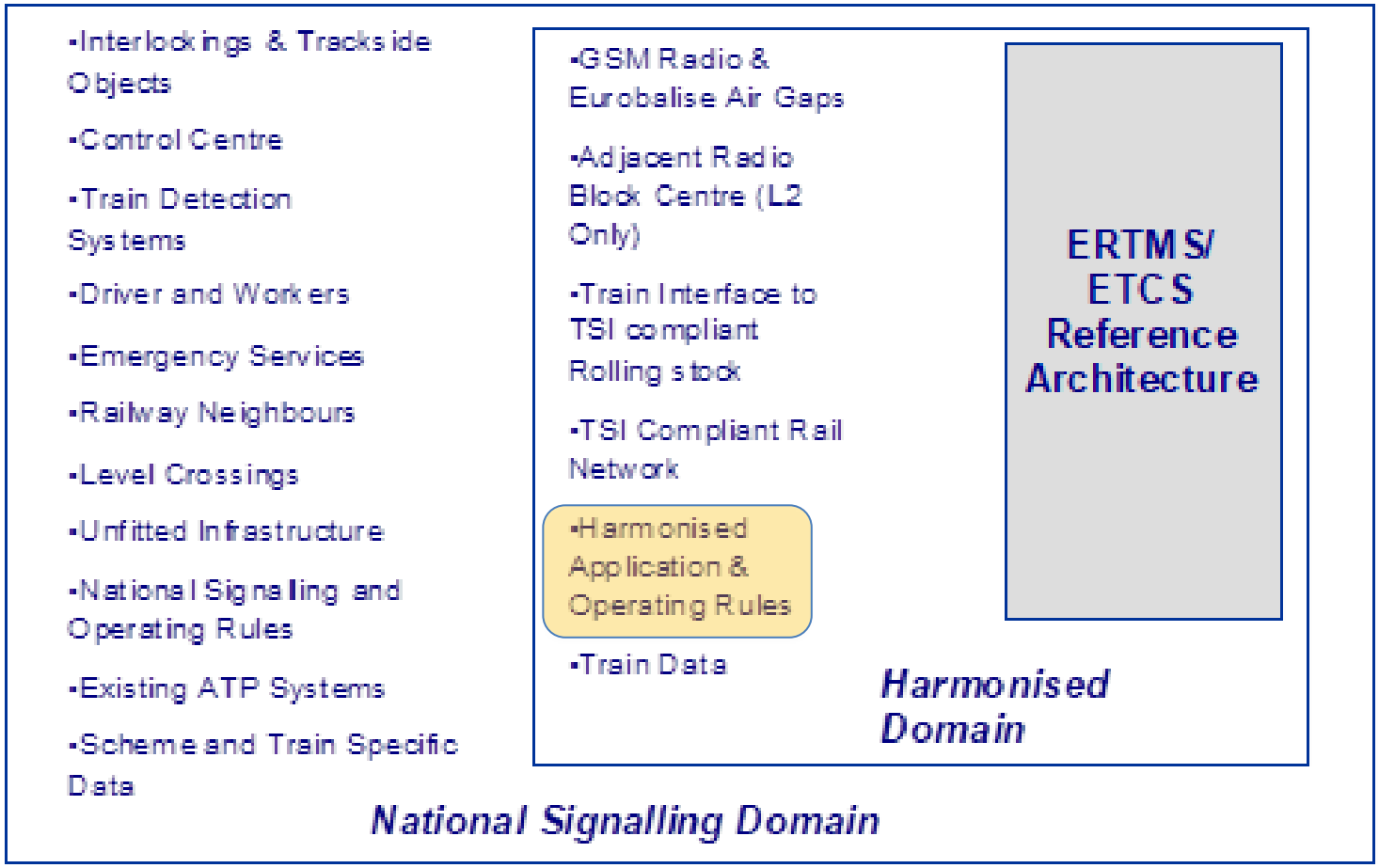
- **OPE Appendix D: Route compatibility and route book:**

Train-route compatibility criteria & information for the route book

These are necessary for operational interoperability, but…

are they sufficient?

ERTMS/ETCS Reference Architecture



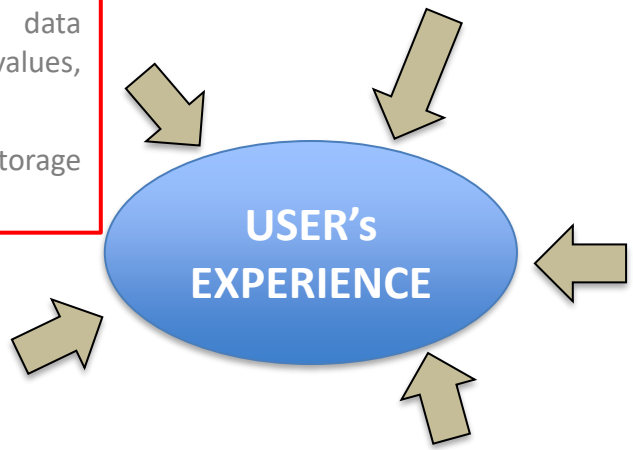
Engineering rules and Operational rules

Dimensioning and Engineering rules constraints (**SS-040**) (**mandatory**) :

- Placement of devices (max distance between 2 balises of the same BG, min distance of a balise in rear of EoA, on-board antenna position with reference to the 1st train axle and front of the train, track conditions …)
- Constraints in ETCS language (telegrams/messages)
- Rules for on-board configuration data (conditions for braking curves values, supported levels …)
- Rules for on-board dimensioning (storage capacity)

Engineering rules (**non mandatory**):

- Functional implementation
- Configuration
- Installation
- Placement of devices
- …



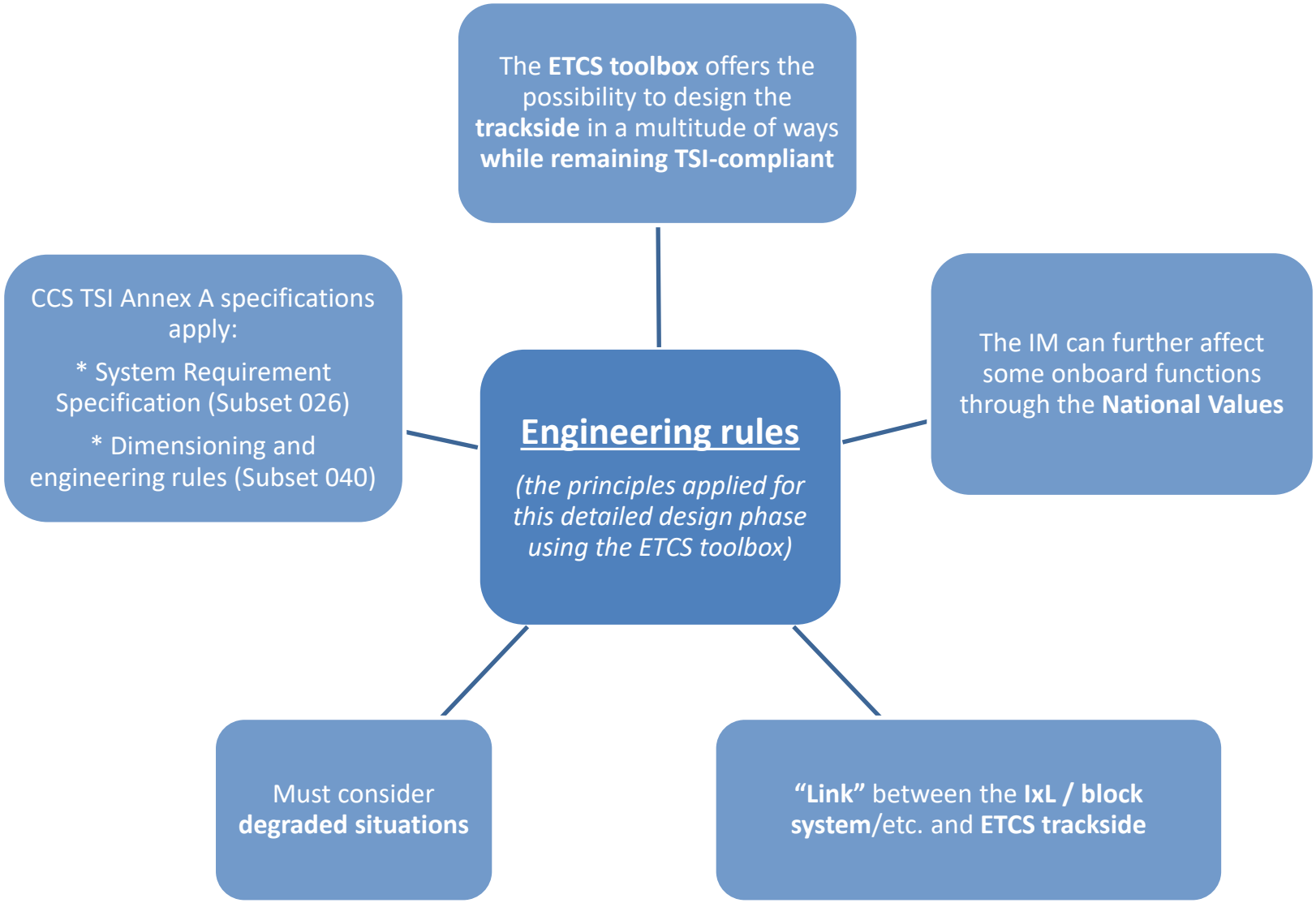
National Operational rules intended to regulate the interaction between drivers and signalers

Harmonised (**mandatory**) Technical specification for interoperability (**SS-026**)

ETCS "on-board" functions are mandatory, while ETCS "trackside" functions are not.

Harmonised Operational rules (**OPE TSI**) (**mandatory**) intended to regulate the interaction between drivers and signallers

The ETCS toolbox (1/2)



The ETCS toolbox (2/2)

The above result to **“non-uniform”** trackside systems.

Although the driver is in principle trained to react to any system behaviour as long as it is TSI-compliant, it will still create different **“user experience”** to the driver.

In order to minimize such “operational specificities”, **Human and Organisational Factors** should be considered to increase the overall performance of the system.

Although ETCS is largely harmonised, both technically and operationally, **variability in system behaviour** will always exist due to different use of the ETCS toolbox.

HOW IMPORTANT IS SUCH VARIABILITY TO THE DRIVERS' TASKS?

Drivers' experiences (ALE)

- Examples of trackside implementations giving **different "user experience"** to the drivers.
- Examples of onboard implementations requiring **different driver actions** to carry out the same operation.

HSL MADRID – GALICIA. SECTION TABOADELA - OURENSE

The last 14 kilometres of the HSL Madrid - Galicia in UIC gauge, run along the old line that linked Madrid with Galicia. This is the Taboadela - Ourense section. The difficulty of building an exclusive High Speed track has made it necessary to adopt this measure on a temporary basis. Taboadela is the location of the gauge changer for trains travelling beyond Ourense to the rest of Galicia.

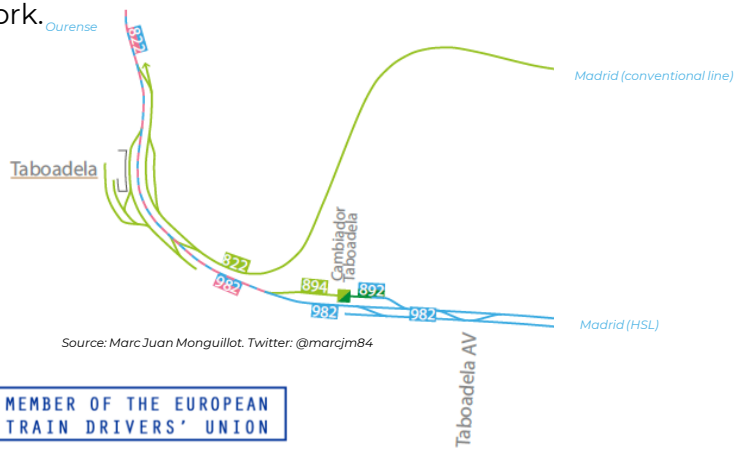
In this section, the track has three rails to allow circulations in both Iberian and standard gauge.

Source: Marc Juan Monguillot. Twitter: @marcjm84

HSL MADRID – GALICIA.
SECTION TABOADELA – OURENSE (II)

Trains passing through the gauge changer located in Taboadela towards Galicia must run with ETCS Level 0, given the possible incompatibilities that may exist when trains with ETCS Level 2 run on either of the two gauges.

This situation is unique throughout the Spanish network.



Source: Marc Juan Monguillot. Twitter: @marcjm84

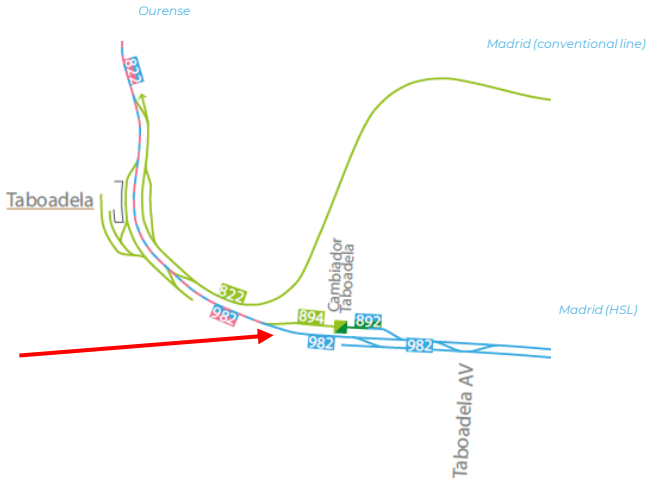
Source: "ATLAS. High Speed Rail in Spain". Spanish Railway Foundation.

Specific regulations have been established for driving on this stretch of road.

HSL MADRID – GALICIA.
SECTION TABOADELA – OURENSE (III)

With 102/112 series the ETCS on board system is full operable from Madrid to Ourense (Level 2, and Level 0+Class B)

With 130/730 series the ETCS on board system must be disconnected at Taboadela (Level 2 is incompatible with RBC from Orense, only be possible Level 0+Class B). It´s needed a National Rule to operate.



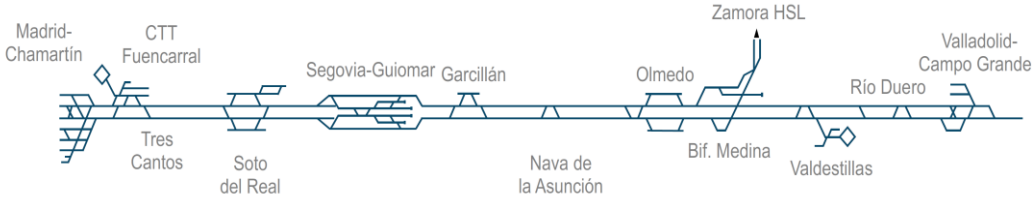
Source: "ATLAS. High Speed Rail in Spain". Spanish Railway Foundation.

Specific regulations have been established for driving on this stretch of road.

HSL MADRID – VALLADOLID: LEVEL 1 & 2

The Madrid - Valladolid HSL was inaugurated at the end of 2007. Level 1 runs from Madrid to a few kilometers before Valladolid, specifically Río Duero, as it was planned that these last kilometers would be provisional but, in the end, they remained as the definitive route. This line is extended to León from Valladolid, giving this new section Level 2 status.

Source: "ATLAS. High Speed Rail in Spain". Spanish Railway Foundation.

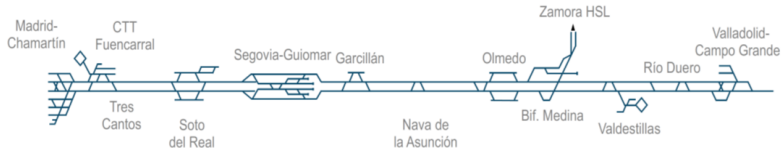


Source: "ATLAS. High Speed Rail in Spain". Spanish Railway Foundation.

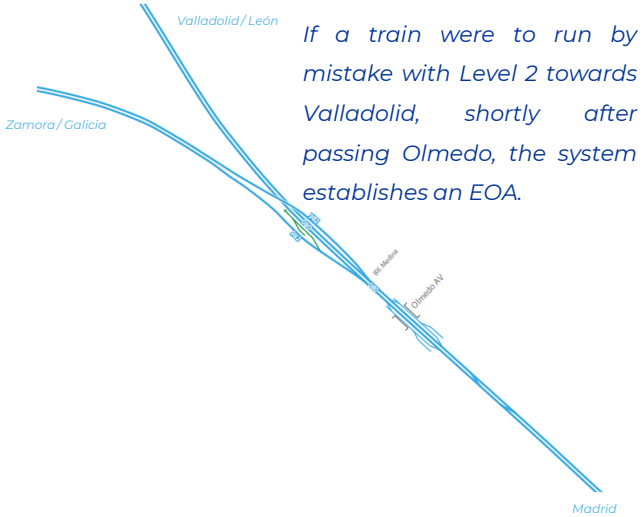
HSL MADRID – VALLADOLID: LEVEL 1 & 2 (II)

In 2019, the line was equipped with Level 2 but with a special feature: only trains running from Madrid to Zamora and Galicia were able to use it. These trains run on the HSL Madrid - Valladolid to Olmedo, where they are diverted to the HSL Madrid - Galicia. Trains running to Valladolid run on Level 1.

This is due to the fact that a new modification is going to be made to the Olmedo - Valladolid section, including the section which currently has no level (Río Duero - Valladolid). For this reason, a transition from Level 2 to Level 1 has not been established in Olmedo, as it was to be a temporary transition. This means that on the same line, depending on the destination of the train, it will be connected to one level or another.



Source: "ATLAS. High Speed Rail in Spain". Spanish Railway Foundation.



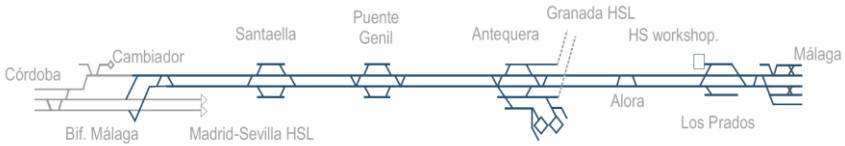
If a train were to run by mistake with Level 2 towards Valladolid, shortly after passing Olmedo, the system establishes an EOA.

Source: Marc Juan Monguillot. Twitter: @marcjm84

HSL CÓRDOBA – MÁLAGA. LEVEL 1, 2 & LZB

The first section of the Córdoba - Málaga line opened in December 2006 to Antequera, was extended to Málaga a year later. At the time when this line was put into operation, the development of ERTMS was not fully completed, which led to the line being equipped with the LZB system. Subsequently, the line was equipped with Level 1 and later with Level 2. This peculiarity means that it is currently possible to run with all three systems. Depending on the destination of the train and the possible transitions, one system or another is used, all of which are compatible with each other.

Source: "ATLAS. High Speed Rail in Spain." Spanish Railway Foundation.



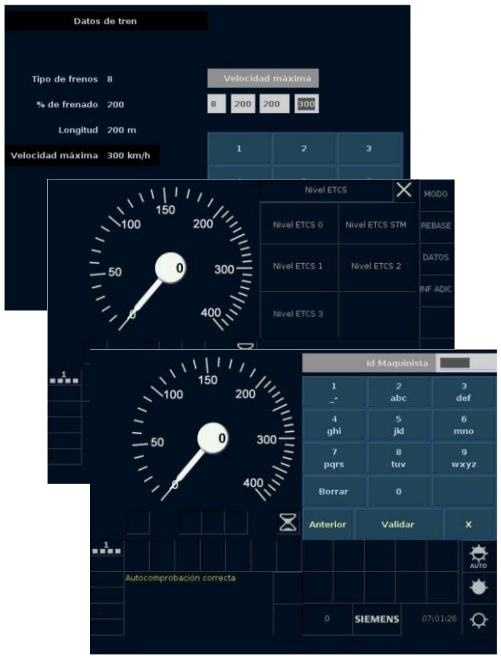
Source: "ATLAS. High Speed Rail in Spain." Spanish Railway Foundation.

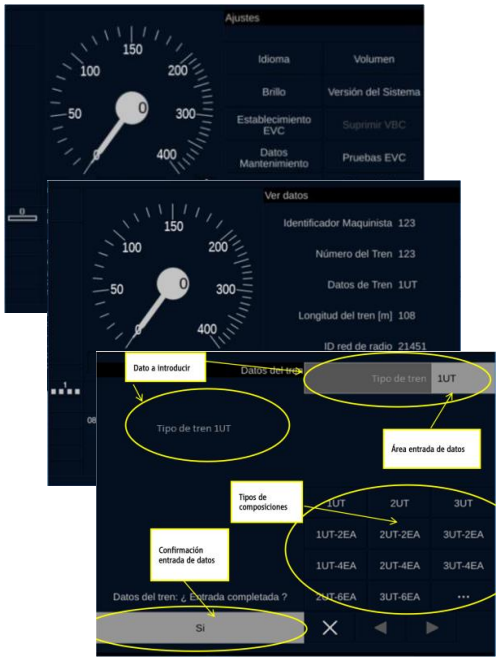
The peculiarities of this line mean that the signaling conditions are special, and specific regulatory documentation must be applied to travel on this line.

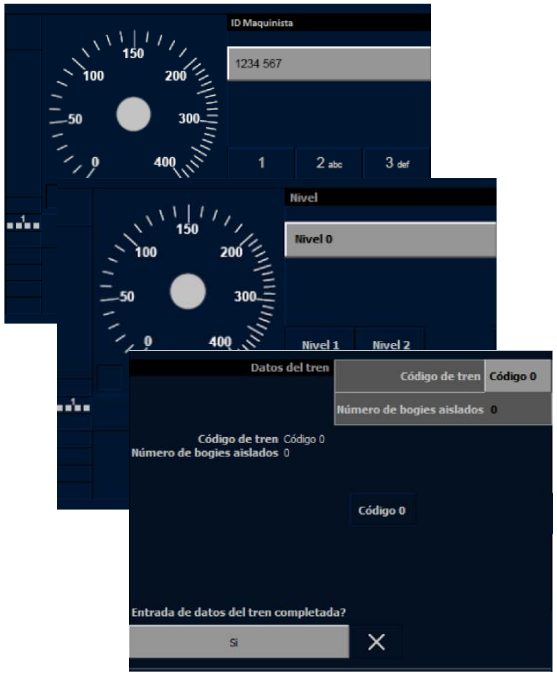
In on-board equipment, the levels or the system that is not to be used must be inhibited.

Common User Experience (On board)

Differences between on board systems depending on the supplier and vehicle:



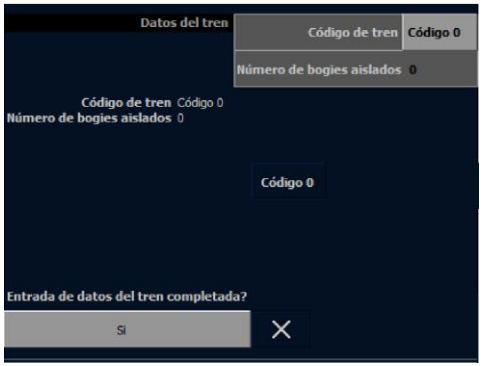




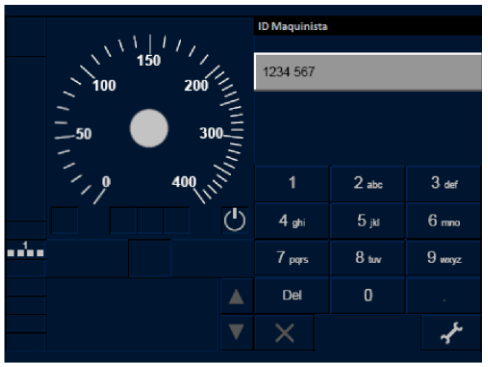
Common User Experience (On board)

Human Organizational Factors:

The way we introduce data of the train:



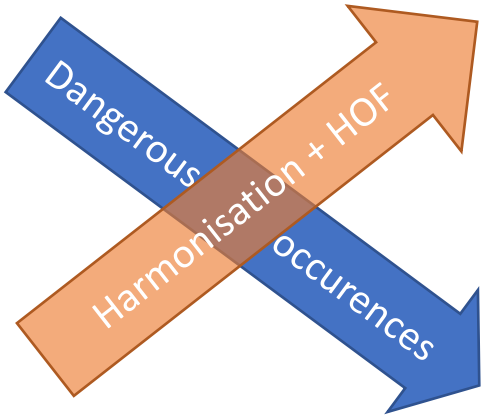
The way we manage information through the system:



Common User Experience

Human Organizational Factors:

Technical harmonisation



Operational risks

Why to integrate Human and Organisational Factors (HOF)?

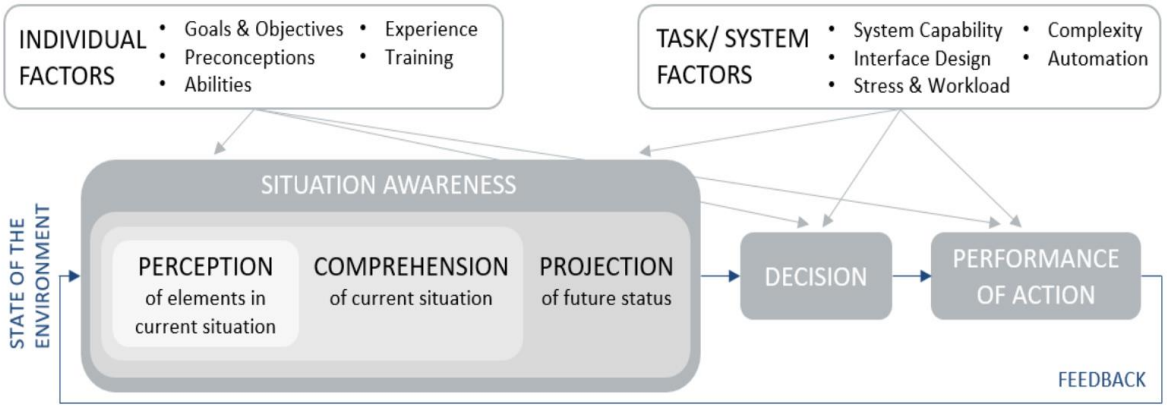


Fig. 1: Three-level model of situation awareness adapted from Endsley (1995)

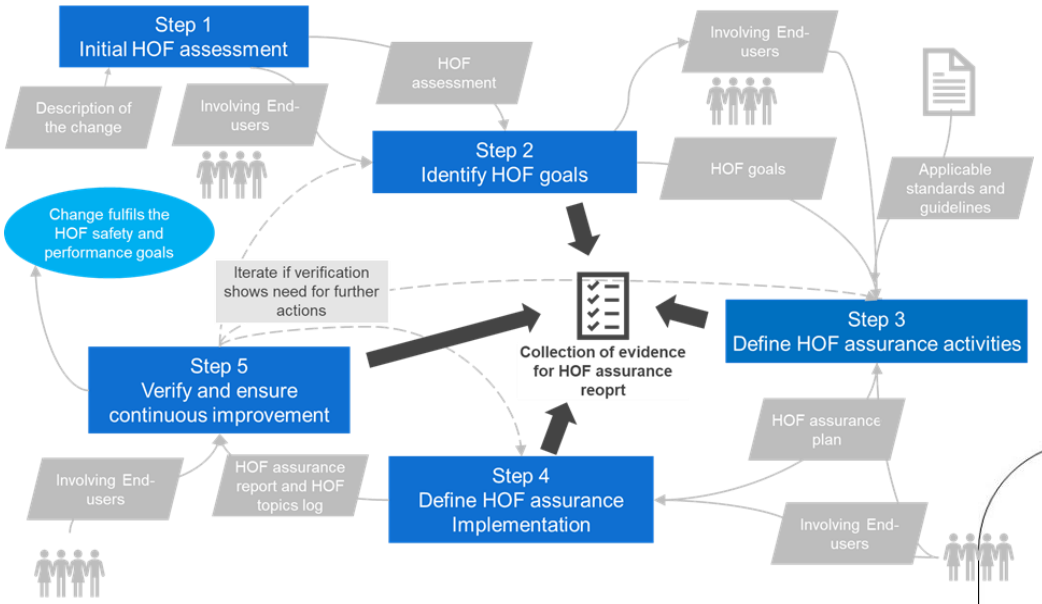
AUTOMATION MYTH #1 Situational Awareness Remains the Same – No Need for Additional Information – Kristin Mühl

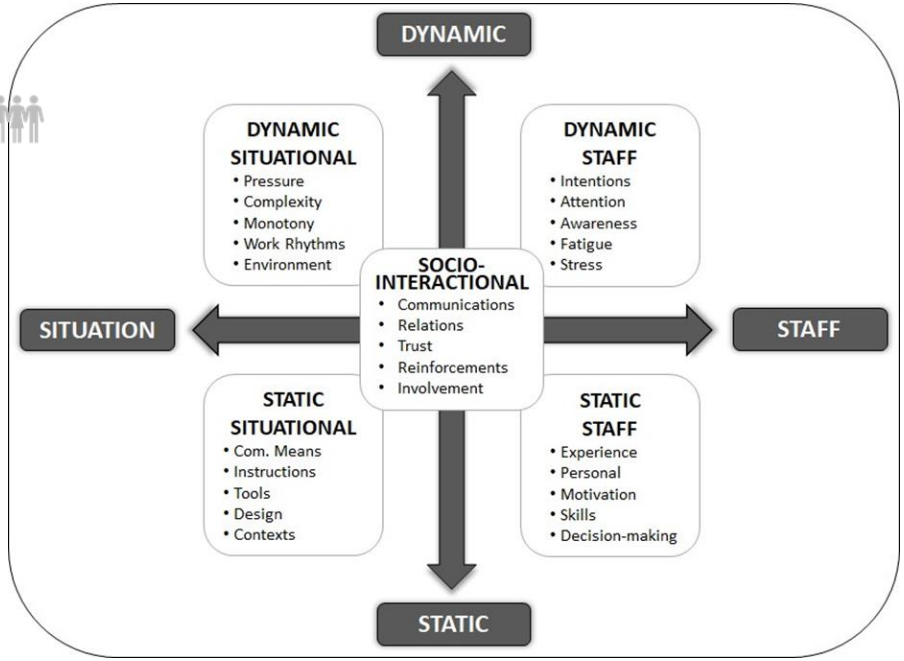
Involving drivers from the start with **Human-centred methods for design** can improve overall performance (safety and availability of the system), for example by*:

- Better understanding the context of use and the system;
- Increasing easiness to understand and usability;
- Reducing risks of misinterpretation of information and errors;
- Reducing workload and stress;
- Reducing occurrences;
- Increasing operational efficiency.

*Derived from research, return on experience and ISO standards

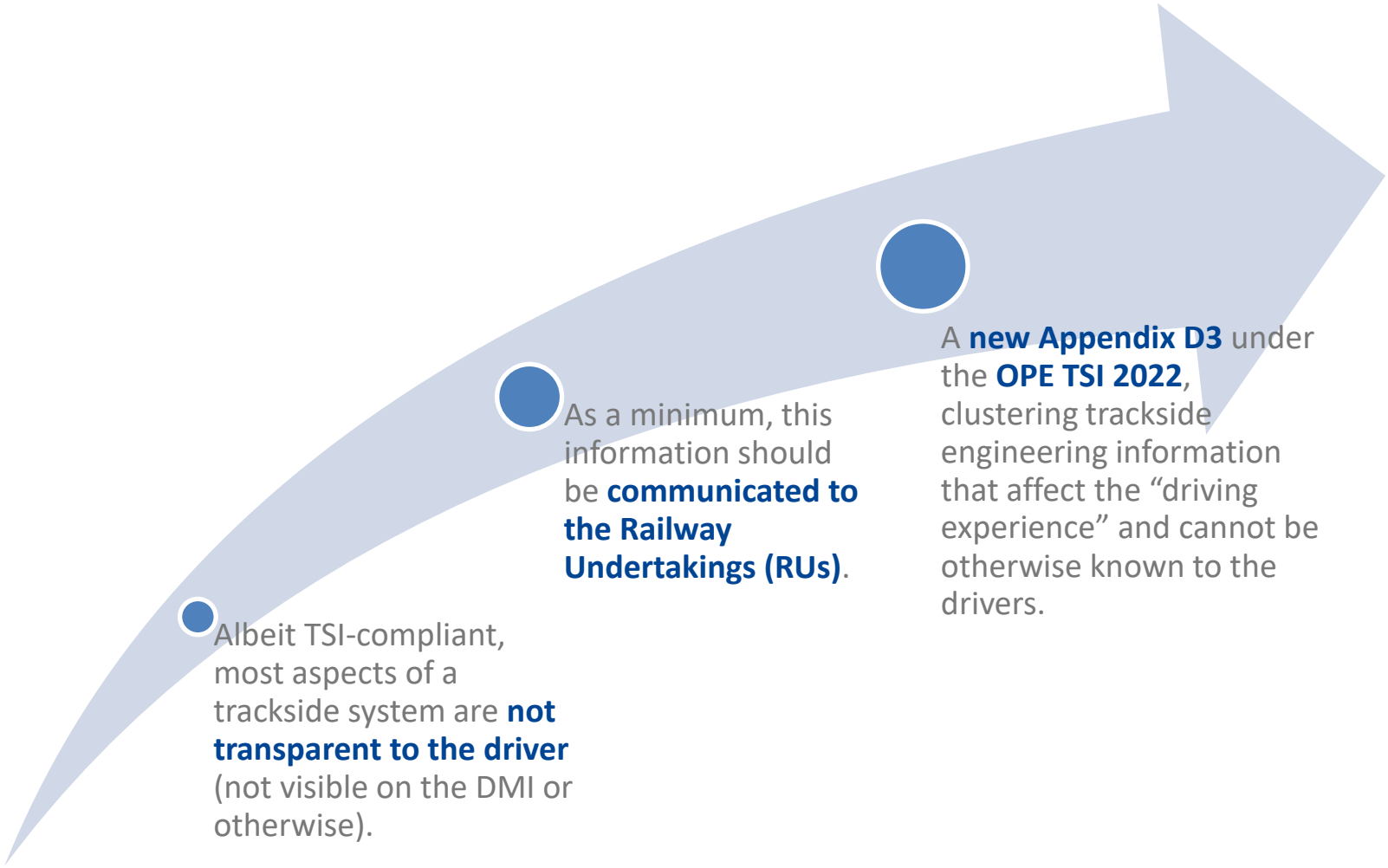
How to integrate Human and Organisational Factors?





Visual representations of the methodology and of the 5*5 HOF categories– draft ERA guidance Human and Organisational Factors integration in change management

ETCS trackside engineering configuration



Albeit TSI-compliant, most aspects of a trackside system are **not transparent to the driver** (not visible on the DMI or otherwise).

As a minimum, this information should be **communicated to the Railway Undertakings (RUs)**.

A **new Appendix D3** under the **OPE TSI 2022**, clustering trackside engineering information that affect the “driving experience” and cannot be otherwise known to the drivers.

OPE TSI Appendix D3 (1/2)

Will include:

- Whether the ETCS trackside is engineered to transmit Track Conditions and if yes, which ones
- Whether the ETCS trackside implements the Level Crossing (LX) procedure or an equivalent solution
- The cant deficiency values used for the Static Speed Profiles (SSP) provided by the ETCS trackside
- Conditions under which the RBC can reject a train
- Whether the GSM-R network is configured to allow forced de-registration of a functional number by another driver
- Specific constraints imposed by the GSM-R network operator on ETCS on-board units only able to operate in CS
- A number of National Values not visible to the driver *(next slide)*

OPE TSI Appendix D3 (2/2)

National Values to be communicated:

- **D_NVROLL**
- **Q_NVEMRRLS**
- **V_NALLOWOVTRP**
- **V_NVSUPOVTRP**
- **D_NVOVTRP**
- **T_NVOVTRP**
- **D_NVPOTRP**
- **T_NVCONTACT**
- **M_NVCONTACT**
- **M_NVDERUN**
- **Q_NVDRIVER_ADHES**
- **the B3-specific NVs affecting the braking model (integrated correction factors)**

The aim is

to improve RU/drivers' understanding of ERTMS trackside features and parameters that affect the way the driver will perceive system operation

and ultimately increase the performance of the overall railway system.

Examples (1/2)

Examples of trackside engineering choices affecting the **“driving experience”**:

- If no **Track Conditions** are transmitted by the trackside, the driver will have to be informed about them in other ways and not expect to see them on the DMI. The driver will also have to react manually even when the rolling stock is configured to perform some operations automatically once instructed, e.g. lower/raise pantograph.
- If the **LX procedure** is not implemented on the trackside, the driver will need to be informed about defective LXs from other sources (text messages, lineside signals, European Instructions from the signaller etc.), and adjust his/her driving accordingly as the onboard system will not supervise the train run over the LX.
- If the GSM-R network is not configured to allow **forced de-registration** of a functional number by another driver, then the signaller will need to step in and perform the de-registration him/herself.
- Depending on the value of V_NVALLOWOVTRP, the driver will be allowed to **override** without having to stop.

Examples (2/2)

(continued)

- The **Cant** Deficiencies used to define the **Static Speed Profiles** transmitted by the trackside are key to determine whether a train will find a **SSP matching its train category** or it will resort to the **basic SSP**. The cant deficiency considered for the basic SSP will determine if it is safe for a train without a matching SSP to follow this (as instructed by the OBU).
- The **integrated correction factors**, when properly implemented, spare the driver from calculating and introducing different brake performance values for the same train when crossing borders.
- **Plain text messages**: when harmonised, they can be transmitted as fixed text messages and automatically **translated**.

Harmonised Engineering Rules

Making RUs aware of engineering rules applied on a trackside is one step but it still does not allow a **common user experience**.

Harmonisation of Engineering Rules: 2 approaches

1

Agree on prevailing engineering practice

- **ERA (limited to 2.3.0d - some obsolete)**
- **EUG**

2

Agree on common operational requirements

- **LinX4Rail Harmonisation of Operational Rules**
- **RCA Cluster Operational Harmonisation**

In both approaches, the effort is to reduce the variability of the related operational requirements put on the CCS trackside, thus allowing less diversity in trackside engineering and by consequence less cost for the adaptation of technical solutions.

What kinds of engineering rules are there?

Harmonisation of **engineering rules** covers a wide range of distinctive rules, such as:

- **Functional implementation**

how to use one or more ETCS functions to cope with a rail operational scenarios

- **ERTMS procedures**

how to engineer an ETCS procedure (e.g. Level Transition, SoM, RBC hand-over)

- **Measurement & configuration**

how to configure an ETCS or radio variable (e.g. measurement criteria, gradient, NVs)

- **Placement of devices**

where to install an ETCS device (e.g. MB, BG)

- **Technical installation**

how to install an ETCS or radio device (e.g. how to fix a balise to the sleeper)

- **Maintenance**

how to maintain an ETCS or radio device (e.g. balise, antennas)

- **Migration**

how to facilitate migration (e.g. class B removal once ETCS is in place)

Way of working at EUG Engineering Support Group (ESG)

Since 2012 collecting and discussing **engineering best practices** and ERTMS **trackside implementation issues**.

Working area for **advanced workshops on multiple topics** of which results are further processed:

- **Shunting activities**
- **(Country) border crossings**
- **ERTMS in station**

The ESG

1) captures members' ERTMS deployment approaches,
2) searches for a common implementation recommendation and
3) describes these implementation recommendations in **Engineering rules guidelines**

to foster engineering harmonisation.

The engineering rules in the scope of the ESG

ETCS design starting from rail operational scenarios (merely functional implementation)	how to use ETCS functions in scenarios such as LX not protected, approach to a buffer, entering into/exiting from a shunting area
Design of ETCS implementation (ERTMS procedures and partially configuration)	which ETCS variables and packets to be used and in which way (when and how to send them to on-board)
Placement of devices	only for ETCS BGs and harmonised MBs

ESG's framework defined by current landscape

Today's ETCS landscape influences engineering rules of ESG's scope

- Mainly ETCS radio signalling (ETCS L2 and Hybrid L3)
- ETCS TSI CCS specification and system versions in law (including error corrections)
- Constraints from legacy devices/architectures (e.g. existing interfaces between interlocking and RBC)
- Class B and national signalling systems only when relevant for ETCS level transition or when non-harmonised solutions are available (e.g. luminous shunting signals)
- Historic practices
- (national) safety principles
- driver ergonomics/visibility (related to the harmonisation of ERTMS MBs)
- performance needs
- kind of rail operation (high speed, high density, regional, etc.)

Work not dealt at level of ESG

They are currently **out of scope** of ESG's harmonised engineering rules:

- Future evolution of ETCS specification (except the case of "mature" CRs)
- Future CCS architecture (except Hybrid L3)
- Radio configurations or constraints
- ETCS measurement
- ETCS and radio devices technical installation and maintenance
- ETCS migration rules

Production of Engineering Guidelines

The **deliverables** are public available on the EUG website: https://ertms.be/

PLEASE GIVE A LOOK TO THEM, ESG WELCOMES ANY COMMENT/CONTRIBUTION/QUESTION AIMING TO UNDERSTAND, USE, IMPROVE THEM !

gridolfi@ertms.be ajoos@ertms.be

Some of the topics treated in the group are:

Guidelines

- 23 – Balise Engineering L2 and L3
- 28 – Gradients Segmentation
- 64 – Handling of Level Crossings with BL3
- 66 – Transition from SV 1.Y to SV 2.Y L1/2/3 with NTC Fallback
- 67 – Level Transition from LNTC to L1 SV2.Y
- 68 – Start of Mission B3
- 69 – Automatic Track Ahead Free (ATAF) B3
- 70 – Transition from L1 to STM
- 71 – Transition from L2 to LSTM
- 72 – Level Transition from level STM to L1
- 74 – RBC-RBC Handover
- 75 – Management of Shunting Activitites
- 76 – Border Crossings
- 77 – Level Transition from LNTC to L2
- 78 – Level Transition from L2 to LNTC
- 79 – Baseline 2 Trackside for Baseline 3 Trains
- 80 – L3 Engineering
- 81 – Extension Key Request Function

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Next ambitions

Work done at ESG may be translated to **TSI**-worthy documents, e.g., the engineering guide of the harmonised Marker Boards.

Engineering guidelines can be merged with the **CCS Application Guide** to boost the harmonisation of engineering and consequently operations.

Incentives for the use of these guidelines can be defined (e.g. through the funding instruments).

ESG core business remain to **maintain, enhance and create guidelines**, linking them to the issues addressed in the new OPE TSI App. D3.

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Next ambitions

A **compendium** of all existing guidelines is currently under construction at ESG, which is fed with smaller not yet addressed ETCS engineering topics.

Special attention will be paid to define and promote **engineering rules aiming to prevent ETCS on-board from using "L1 only" functions** in order to facilitate the simplification of next versions of ERTMS specification.

Harmonised Marker Boards

First step towards a harmonised lineside signalling

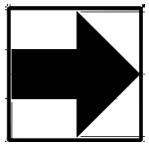
MBs will be required even more where lineside signalling is removed

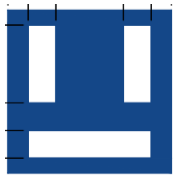
Ensure that a driver will observe the same lineside indication

Harmonised Marker Boards (MB) deployed in a consistent manner play an important role in operational interoperability

Will allow fully interoperable operation, combined with ERTMS and the use of European Instructions ->

less requirements for drivers' knowledge of national signalling systems





Engineering principles for Harmonised Marker Boards

10 harmonised MBs already defined in **EN 16494:**

their use ensures **conformity with interoperability requirements**

however they were not mandated until now

A **revised EN 16494** is under preparation, with more harmonised MBs

Under **CCS TSI 2022** the harmonised MBs will become mandatory

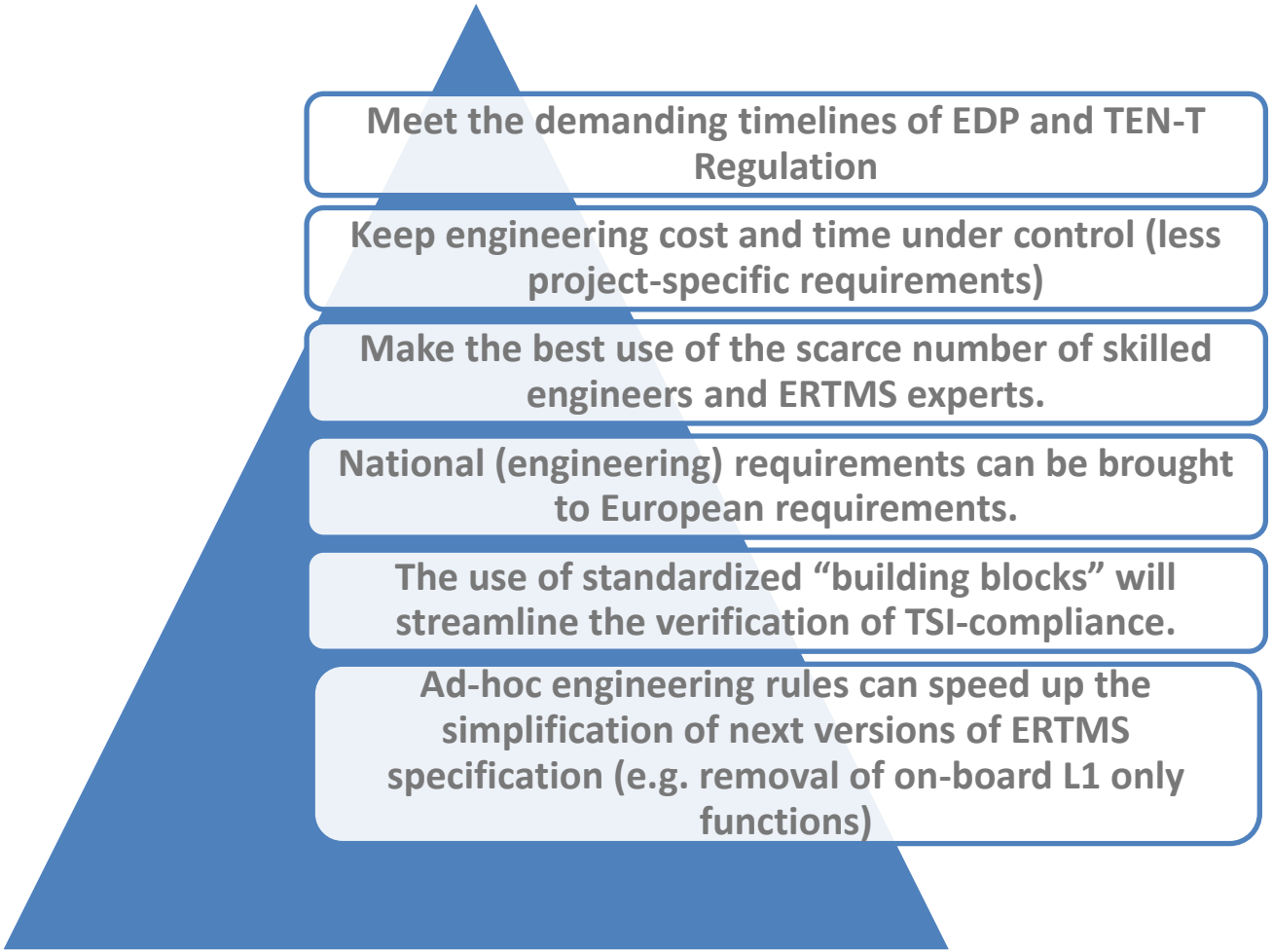
Specific **engineering rules** (EUG+ERA) will apply to ensure consistent MB implementation (under **CCS TSI Annex A index 101**)

Contains a set of generic assumptions and for each harmonised Marker Board, the following:

- The operational purpose(s)
- The rule for the MB location, with justification
- Use cases
- Applicability information according to System Version, existence of lineside signals

Further benefits of engineering harmonisation

The “industrialised” implementation of ERTMS trackside is **the only viable option to**:



Conclusions - next steps

Main conclusions

- ✓ Harmonised trackside engineering is essential for operational interoperability.
- ✓ The development, validation and repeated application of modular “building blocks” for ERTMS installation trackside are a key enabler for efficient deployment of interoperable infrastructure.
- ✓ Human and Organisational Factors (HOF) should be taken into account when engineering an ERTMS trackside system.

Next steps to consider:

- ❖ **Mandatory implementation of certain ETCS features (list tbd)**
- ❖ **Adoption of Engineering guidelines under CCS TSI Application Guide**
- ❖ **Consider train drivers perspective during trackside system engineering**
- ❖ **Explore impact of engineering harmonisation to operational rules (App. A)**

Views?

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Additional information

(not presented in the workshop)

EUROPEAN
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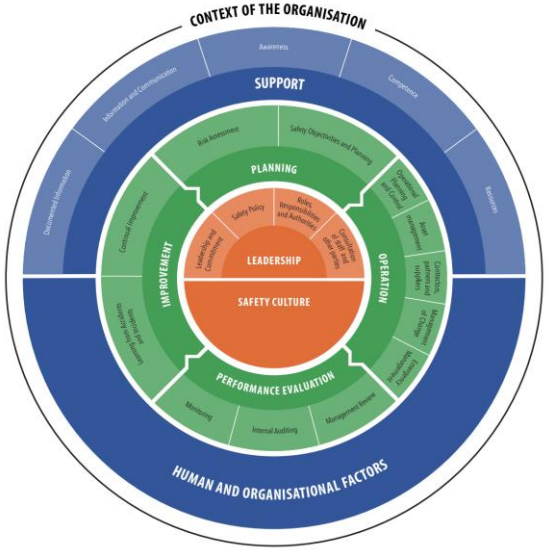
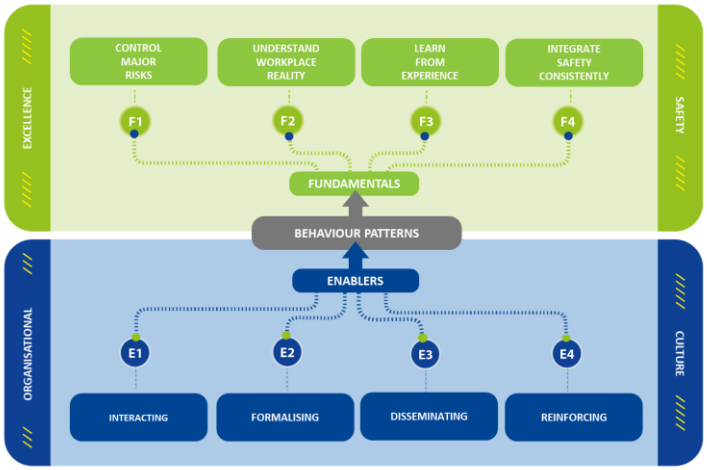
Human and Organisational Factors (HOF)



SMS wheel – ERA guidance on safety management system requirements for safety certification or safety authorization
[Common Safety Methods | ERA (europa.eu)]
[Safety Management System | ERA (europa.eu)]

Do not hesitate to contact us :
hof@era.europa.eu



EUROPEAN RAILWAY SAFETY CULTURE MODEL V2.0
[Safety Culture | ERA (europa.eu)]

[Human and Organisational Factors (HOF) | ERA (europa.eu)]

Production of Engineering Guidelines

The **Engineering rules Guidelines** aim to bridge the gap in harmonisation within multiple ETCS domains on top of SS-040.

Publication of guidelines is the outcome of shared experienced and best practices among the EUG members.

Therein, ESG **recommends** ideally **one choice** in terms of trackside implementation. A multitude of guidelines exist on the following topics:

- **Start of Mission**
- **Balise engineering (installation requirements and telegram engineering)**
- **(H)L3**
- **Shunting**
- **Level crossing**
- **Level transitions (LNTC/STM, L1 and L2)**
- **RBC/RBC Handover**
- **Border crossing**
- **Automatic Track Ahead Free (Automatic TAF)**
- **Etc.**

Topics of the overall ETCS engineering compendium (1/4)

Topics of trackside engineering already published in the **Engineering guidelines**:

- **Balise Engineering**
- **Gradient segmentation**
- **Level Crossings**
- **Level Transition L1/L2/L3 from SV1.y to SV2.y**
- **Level Transitions LNTC ↔ L1**
- **Level Transitions LNTC ↔ L2**
- **SoM B3**
- **ATAF**
- **RBC-RBC Handover**
- **Shunting**
- **Border Crossings**
- **B2 trackside for B3 on-boards**
- **Hybrid L3**

Topics of the overall ETCS engineering compendium (2/4)

Topics of trackside engineering related to **“operation”**:

- **Frequency of Level Transition**
- **Operations in (engineering) work areas**
- **Use of route suitability**
- **ETCS on track machines**
- **Pushing and banking movements in ETCS**
- **L2 Yard Leaving**
- **TSR for specific trains**
- **0km/h speed restriction**
- **Approach to a Buffer**
- **Rescue of trains by another train on a pure ETCS line**
- **Limiting Traction Power**
- **SS-113 - ETCS-H0105**
- **HABD and ETCS**
- **Uphill temporary speed override function**
- **(Operational) reversing (in tunnels)**

Topics of the overall ETCS engineering compendium (3/4)

Topics of trackside engineering related to **“ETCS system design”**:

- **Allocation of train categories**
- **MA, MA request and MA update**
- **Use of CES, UES, Cooperative shortening**
- **Optimising block lengths (without signalling)**
- **Start route release by position report information**
- **Accuracy of infrastructure data**
- **Release speed and overlap timer**
- **Change of traction to diesel**
- **Use of M_DUP**
- **Use of text messages**
- **Elements Positioning and configuration**
- **ETCS L2 without signals in stations**
- **Axle counter information for ATAF function**
- **Partially read BG and override EoA**
- **Track conditions and traction systems**
- **Consecutive mode profiles**
- **Distance to danger point**
- **Allocation of train categories**
- **T_MAR settings**
- **Use of national value**
- **Cant deficiency and SSP engiuneering**
- **Train traction characteristics by RBC**

Topics of the overall ETCS engineering compendium (4/4)

Topics of trackside engineering related to **“Marker Boards”**:

- **Optical signals when entering L2 main line area**
- **Use of MBs**
- **Use of SM for mixed L2 lines with optical lineside**
- **Dwarf marker boards**
- **Location of MBs and BGs relatives to EoA**