34th Annual **INCOSE**
international symposium
hybrid event
Dublin, Ireland
July 2 - 6, 2024

Jul 5, 2024: 09:00-09:40 AM (Session 10.5.1: Modular Open Systems Approach [MOSA])

Towards a Reusable Model-Based Systems Integration [MBSI] Framework

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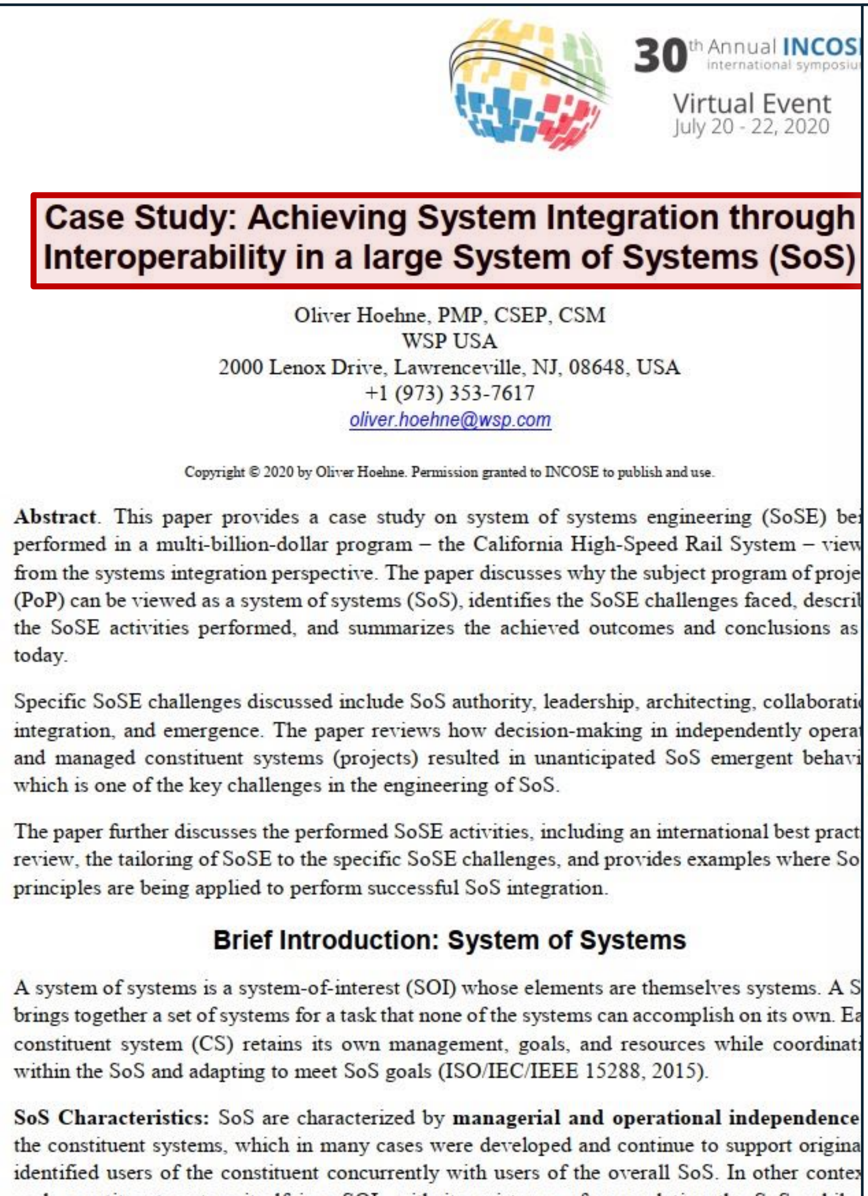
AGENDA

- **Motivation**
- **Background, Challenges & Objectives**
- **Model-Based Systems Integration [MBSI] Framework**
- **MBSI Framework Development**
- **MBSI Framework Use**
- **Summary & Conclusion**

MOTIVATION

IS2020 PAPER: CONSIDERATIONS FOR FUTURE WORK



30th Annual INCOS
international symposiu

Virtual Event
July 20 - 22, 2020

Case Study: Achieving System Integration through Interoperability in a large System of Systems (SoS)

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Abstract. This paper provides a case study on system of systems engineering (SoSE) bei performed in a multi-billion-dollar program – the California High-Speed Rail System – view from the systems integration perspective. The paper discusses why the subject program of proje (PoP) can be viewed as a system of systems (SoS), identifies the SoSE challenges faced, descril the SoSE activities performed, and summarizes the achieved outcomes and conclusions as today.

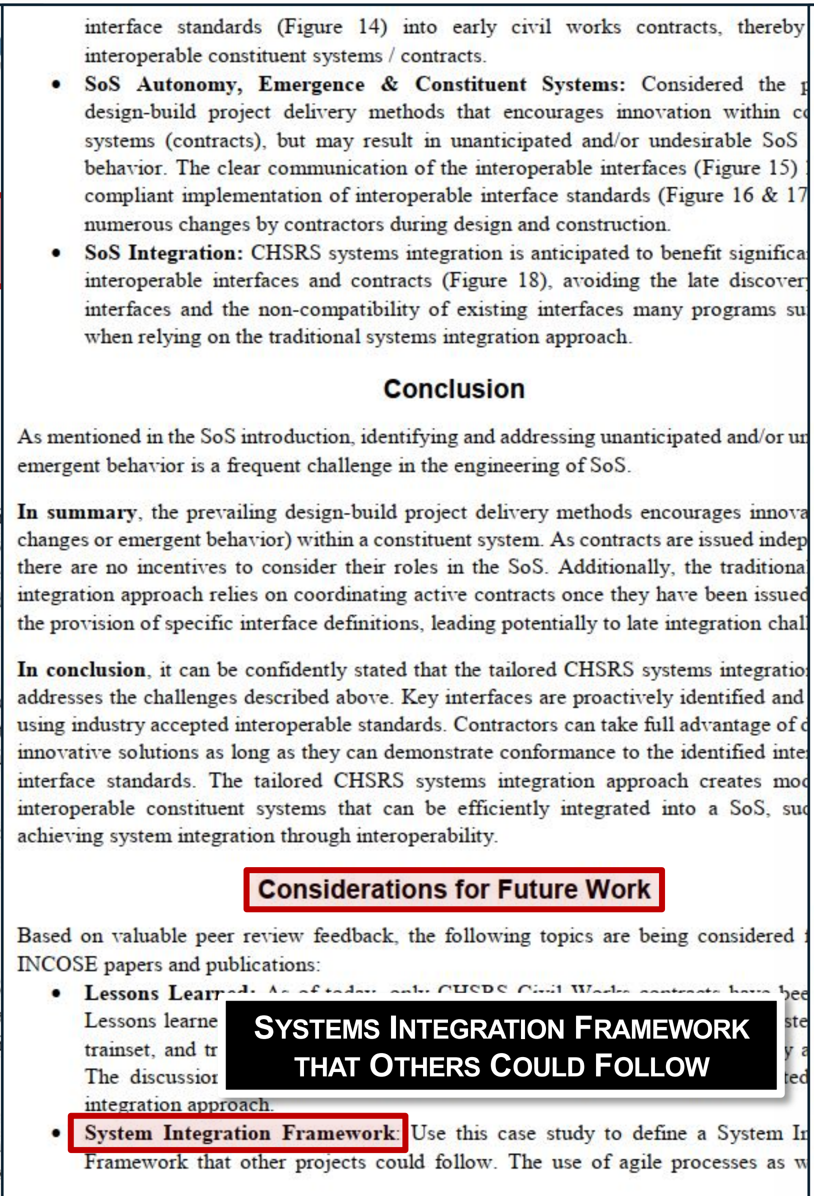
Specific SoSE challenges discussed include SoS authority, leadership, architecting, collaborati integration, and emergence. The paper reviews how decision-making in independently operat and managed constituent systems (projects) resulted in unanticipated SoS emergent behavi which is one of the key challenges in the engineering of SoS.

The paper further discusses the performed SoSE activities, including an international best pract review, the tailoring of SoSE to the specific SoSE challenges, and provides examples where So principles are being applied to perform successful SoS integration.

Brief Introduction: System of Systems

A system of systems is a system-of-interest (SOI) whose elements are themselves systems. A S brings together a set of systems for a task that none of the systems can accomplish on its own. Ea constituent system (CS) retains its own management, goals, and resources while coordinati within the SoS and adapting to meet SoS goals (ISO/IEC/IEEE 15288, 2015).

SoS Characteristics: SoS are characterized by **managerial and operational independence** the constituent systems, which in many cases were developed and continue to support origina identified users of the constituent concurrently with users of the overall SoS. In other contex



interface standards (Figure 14) into early civil works contracts, thereby interoperable constituent systems / contracts.

- **SoS Autonomy, Emergence & Constituent Systems:** Considered the p design-build project delivery methods that encourages innovation within co systems (contracts), but may result in unanticipated and/or undesirable SoS behavior. The clear communication of the interoperable interfaces (Figure 15) compliant implementation of interoperable interface standards (Figure 16 & 17 numerous changes by contractors during design and construction.
- **SoS Integration:** CHSRS systems integration is anticipated to benefit significa interoperable interfaces and contracts (Figure 18), avoiding the late discover interfaces and the non-compatibility of existing interfaces many programs su when relying on the traditional systems integration approach.

Conclusion

As mentioned in the SoS introduction, identifying and addressing unanticipated and/or un emergent behavior is a frequent challenge in the engineering of SoS.

In summary, the prevailing design-build project delivery methods encourages innova changes or emergent behavior) within a constituent system. As contracts are issued indep there are no incentives to consider their roles in the SoS. Additionally, the traditiona integration approach relies on coordinating active contracts once they have been issued the provision of specific interface definitions, leading potentially to late integration chal

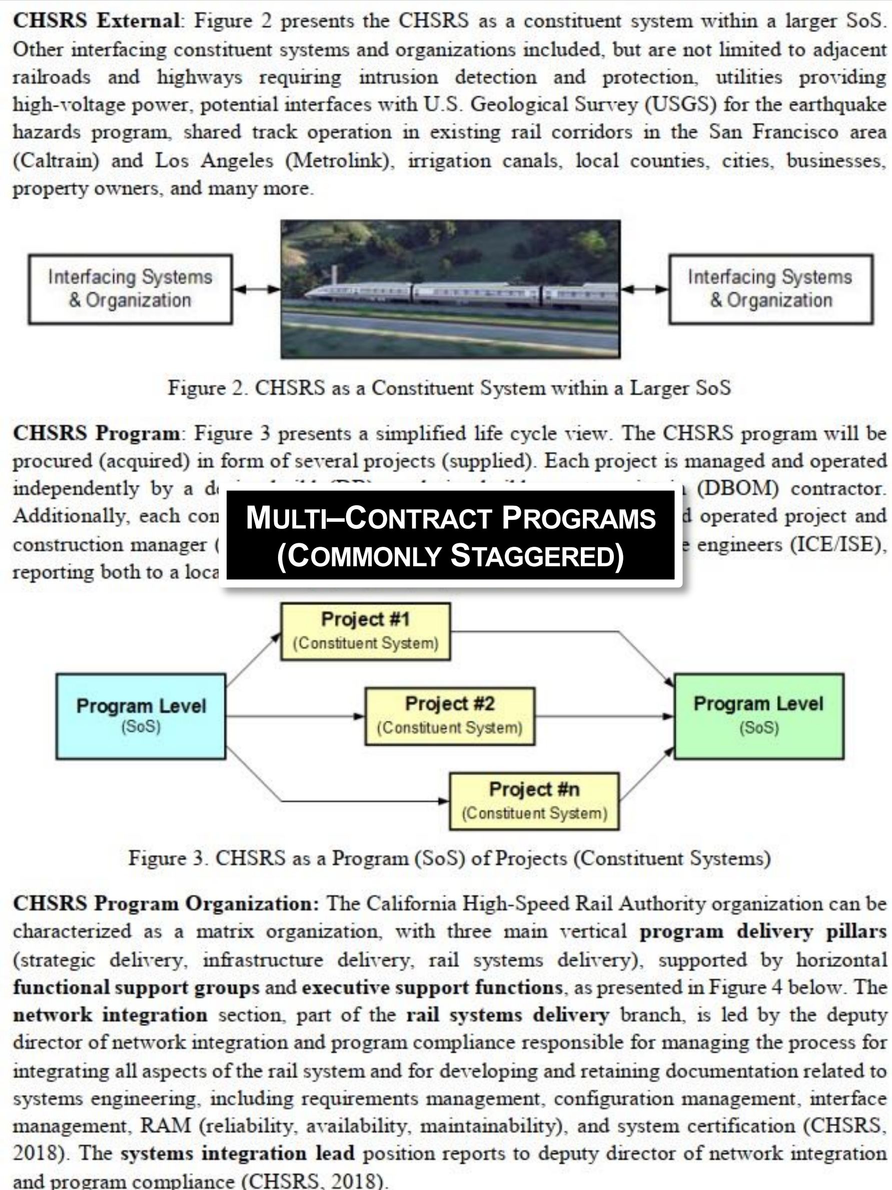
In conclusion, it can be confidently stated that the tailored CHSRS systems integratio addresses the challenges described above. Key interfaces are proactively identified and using industry accepted interoperable standards. Contractors can take full advantage of innovative solutions as long as they can demonstrate conformance to the identified inte interface standards. The tailored CHSRS systems integration approach creates mo interoperable constituent systems that can be efficiently integrated into a SoS, su achieving system integration through interoperability.

Considerations for Future Work

Based on valuable peer review feedback, the following topics are being considered INCOSE papers and publications:

- **Lessons Learned:** As of today, only CHSRS Civil Works contracts have bee Lessons learne trainset, and tr The discussion integration approach.
- **System Integration Framework**: Use this case study to define a System In Framework that other projects could follow. The use of agile processes as w

SYSTEMS INTEGRATION FRAMEWORK THAT OTHERS COULD FOLLOW



CHSRS External: Figure 2 presents the CHSRS as a constituent system within a larger SoS. Other interfacing constituent systems and organizations included, but are not limited to adjacent railroads and highways requiring intrusion detection and protection, utilities providing high-voltage power, potential interfaces with U.S. Geological Survey (USGS) for the earthquake hazards program, shared track operation in existing rail corridors in the San Francisco area (Caltrain) and Los Angeles (Metrolink), irrigation canals, local counties, cities, businesses, property owners, and many more.

Figure 2. CHSRS as a Constituent System within a Larger SoS

CHSRS Program: Figure 3 presents a simplified life cycle view. The CHSRS program will be procured (acquired) in form of several projects (supplied). Each project is managed and operated independently by a d (DBOM) contractor. Additionally, each con d operated project and construction manager (e engineers (ICE/ISE), reporting both to a loca

MULTI–CONTRACT PROGRAMS (COMMONLY STAGGERED)

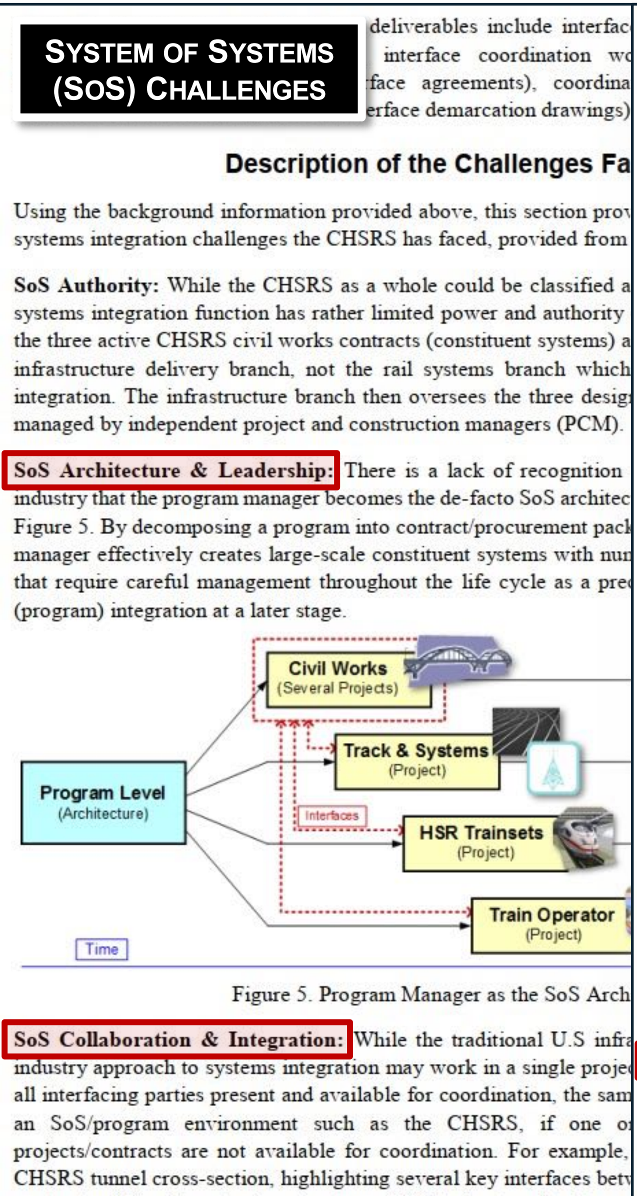
Figure 3. CHSRS as a Program (SoS) of Projects (Constituent Systems)

CHSRS Program Organization: The California High-Speed Rail Authority organization can be characterized as a matrix organization, with three main vertical **program delivery pillars** (strategic delivery, infrastructure delivery, rail systems delivery), supported by horizontal **functional support groups** and **executive support functions**, as presented in Figure 4 below. The **network integration** section, part of the **rail systems delivery** branch, is led by the deputy director of network integration and program compliance responsible for managing the process for integrating all aspects of the rail system and for developing and retaining documentation related to systems engineering, including requirements management, configuration management, interface management, RAM (reliability, availability, maintainability), and system certification (CHSRS, 2018). The **systems integration lead** position reports to deputy director of network integration and program compliance (CHSRS, 2018).

MOTIVATION

IS2020 PAPER: CONSIDERATIONS FOR FUTURE WORK (CONT'D)

SYSTEM OF SYSTEMS (SOS) CHALLENGES



deliverables include interfac
interface coordination wo
face agreements), coordina
erface demarcation drawings)

Description of the Challenges Fa

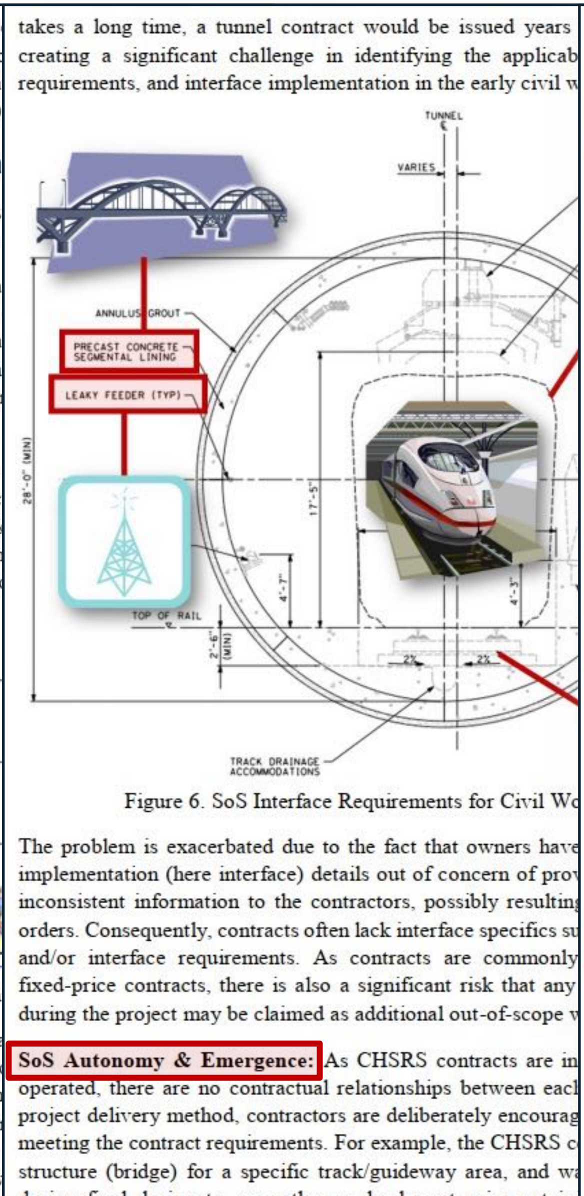
Using the background information provided above, this section prov
systems integration challenges the CHSRS has faced, provided from

SoS Authority: While the CHSRS as a whole could be classified a
systems integration function has rather limited power and authority
the three active CHSRS civil works contracts (constituent systems) a
infrastructure delivery branch, not the rail systems branch which
integration. The infrastructure branch then oversees the three desig
managed by independent project and construction managers (PCM).

SoS Architecture & Leadership: There is a lack of recognition
industry that the program manager becomes the de-facto SoS architec
Figure 5. By decomposing a program into contract/procurement pack
manager effectively creates large-scale constituent systems with num
that require careful management throughout the life cycle as a pred
(program) integration at a later stage.

Figure 5. Program Manager as the SoS Arch

SoS Collaboration & Integration: While the traditional U.S infra
industry approach to systems integration may work in a single proje
all interfacing parties present and available for coordination, the sam
an SoS/program environment such as the CHSRS, if one o
projects/contracts are not available for coordination. For example,
CHSRS tunnel cross-section, highlighting several key interfaces betw



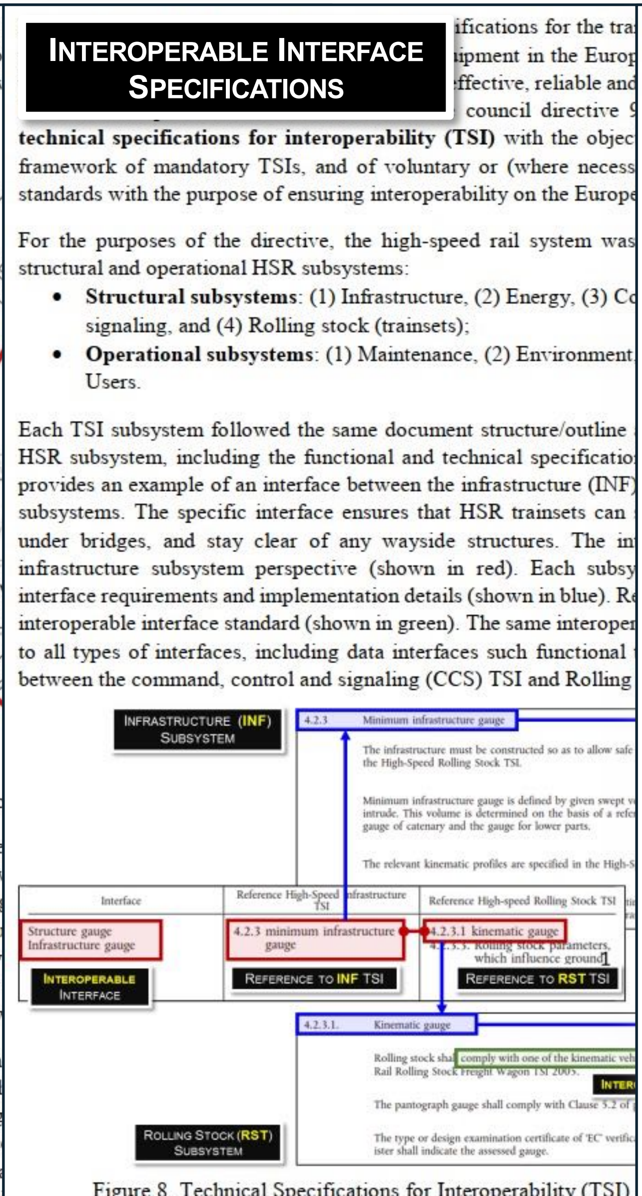
takes a long time, a tunnel contract would be issued years
creating a significant challenge in identifying the applicab
requirements, and interface implementation in the early civil w

Figure 6. SoS Interface Requirements for Civil Wo

The problem is exacerbated due to the fact that owners have
implementation (here interface) details out of concern of prov
inconsistent information to the contractors, possibly resulting
orders. Consequently, contracts often lack interface specifics su
and/or interface requirements. As contracts are commonly
fixed-price contracts, there is also a significant risk that any
during the project may be claimed as additional out-of-scope w

SoS Autonomy & Emergence: As CHSRS contracts are in
operated, there are no contractual relationships between each
project delivery method, contractors are deliberately encourag
meeting the contract requirements. For example, the CHSRS c
structure (bridge) for a specific track/guideway area, and wa

INTEROPERABLE INTERFACE SPECIFICATIONS



ifications for the tra
ipment in the Europ
ffective, reliable and
council directive 9
technical specifications for interoperability (TSI) with the objec
framework of mandatory TSIs, and of voluntary or (where necess
standards with the purpose of ensuring interoperability on the Europe

For the purposes of the directive, the high-speed rail system was
structural and operational HSR subsystems:

- **Structural subsystems**: (1) Infrastructure, (2) Energy, (3) Co
signaling, and (4) Rolling stock (trainsets);
- **Operational subsystems**: (1) Maintenance, (2) Environment,
Users.

Each TSI subsystem followed the same document structure/outline
HSR subsystem, including the functional and technical specificatio
provides an example of an interface between the infrastructure (INF)
subsystems. The specific interface ensures that HSR trainsets can
under bridges, and stay clear of any wayside structures. The in
infrastructure subsystem perspective (shown in red). Each subsy
interface requirements and implementation details (shown in blue). Re
interoperable interface standard (shown in green). The same interope
to all types of interfaces, including data interfaces such functional
between the command, control and signaling (CCS) TSI and Rolling

4.2.3 Minimum infrastructure gauge

The infrastructure must be constructed so as to allow safe
the High-Speed Rolling Stock TSI.

Minimum infrastructure gauge is defined by given swept v
intrude. This volume is determined on the basis of a refe
gauge of catenary and the gauge for lower parts.

The relevant kinematic profiles are specified in the High-S

Interface	Reference High-Speed Infrastructure TSI	Reference High-speed Rolling Stock TSI
Structure gauge Infrastructure gauge	4.2.3 minimum infrastructure gauge	4.2.3.1 kinematic gauge 4.2.3.3. Rolling stock parameters, which influence ground

4.2.3.1. Kinematic gauge

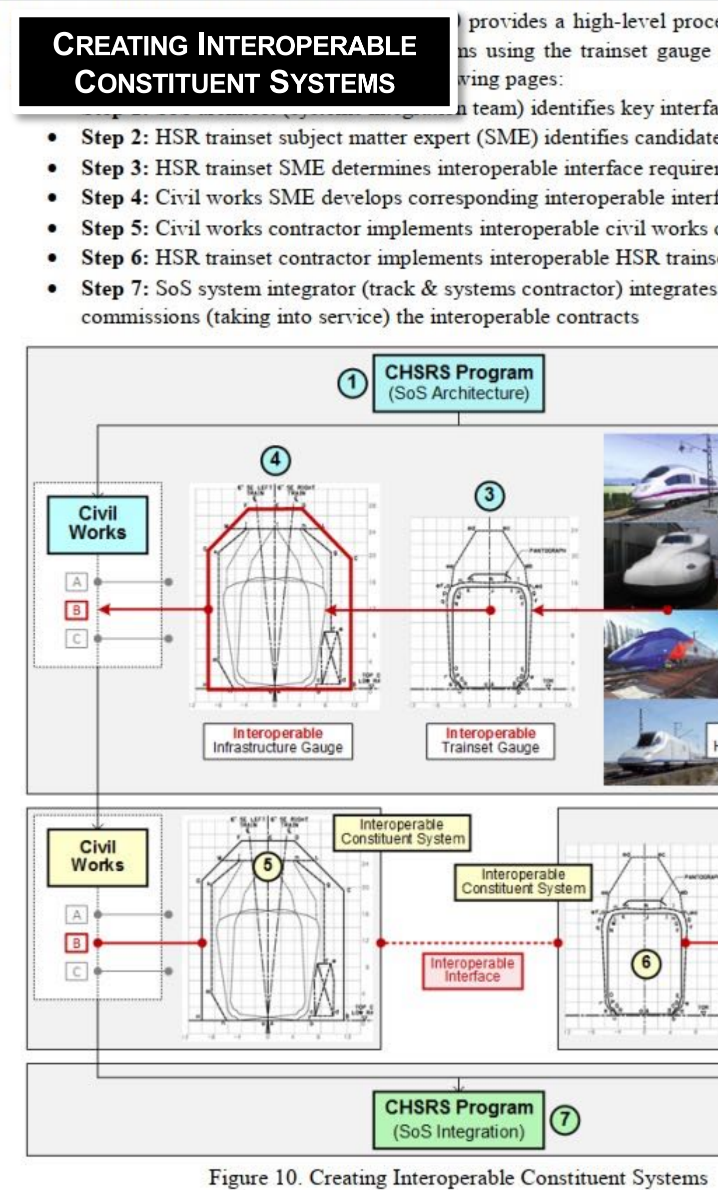
Rolling stock shal comply with one of the kinematic veh
Rail Rolling Stock Freight Wagon TSI 2005.

The pantograph gauge shall comply with Clause 5.2 of

The type or design examination certificate of 'EC' verific
ister shall indicate the assessed gauge.

Figure 8. Technical Specifications for Interoperability (TSI)

CREATING INTEROPERABLE CONSTITUENT SYSTEMS



) provides a high-level proce
ns using the trainset gauge
wing pages:
n team) identifies key interfa

- **Step 2:** HSR trainset subject matter expert (SME) identifies candidate
- **Step 3:** HSR trainset SME determines interoperable interface requirer
- **Step 4:** Civil works SME develops corresponding interoperable interf
- **Step 5:** Civil works contractor implements interoperable civil works c
- **Step 6:** HSR trainset contractor implements interoperable HSR trains
- **Step 7:** SoS system integrator (track & systems contractor) integrates
commissions (taking into service) the interoperable contracts

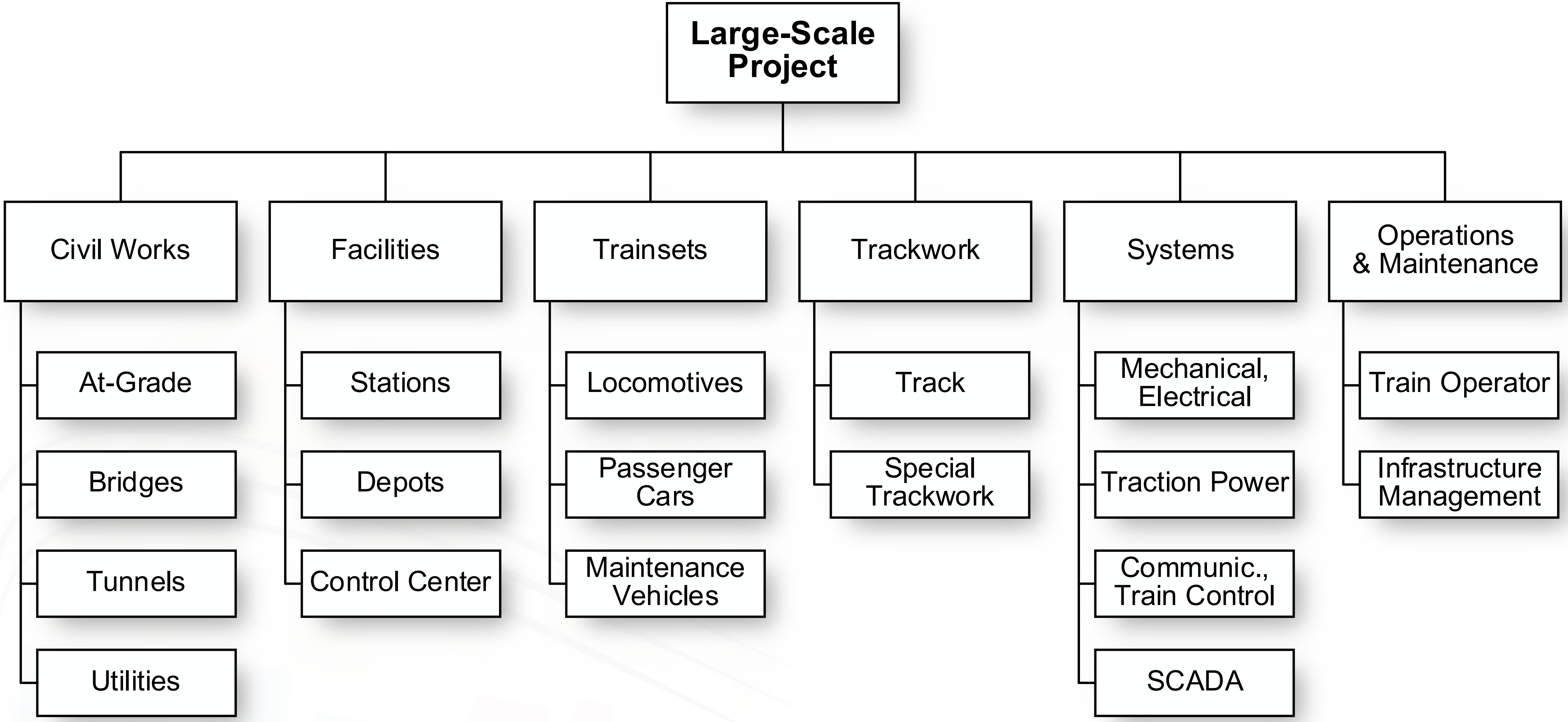
Figure 10. Creating Interoperable Constituent Systems

PROGRESS

- **Motivation**
- **Background, Challenges & Objectives**
  - Large Scale Projects
  - Common Contract Breakdown Structures
  - Interface & Integration Challenges
- **Model-Based Systems Integration Framework**
- **MBSI Framework Development**
- **MBSI Framework Use**
- **Summary & Conclusion**

BACKGROUND, CHALLENGES & OBJECTIVES

LARGE-SCALE PROJECTS: INDUSTRY TYPICAL CONTRACT BREAKDOWN STRUCTURE



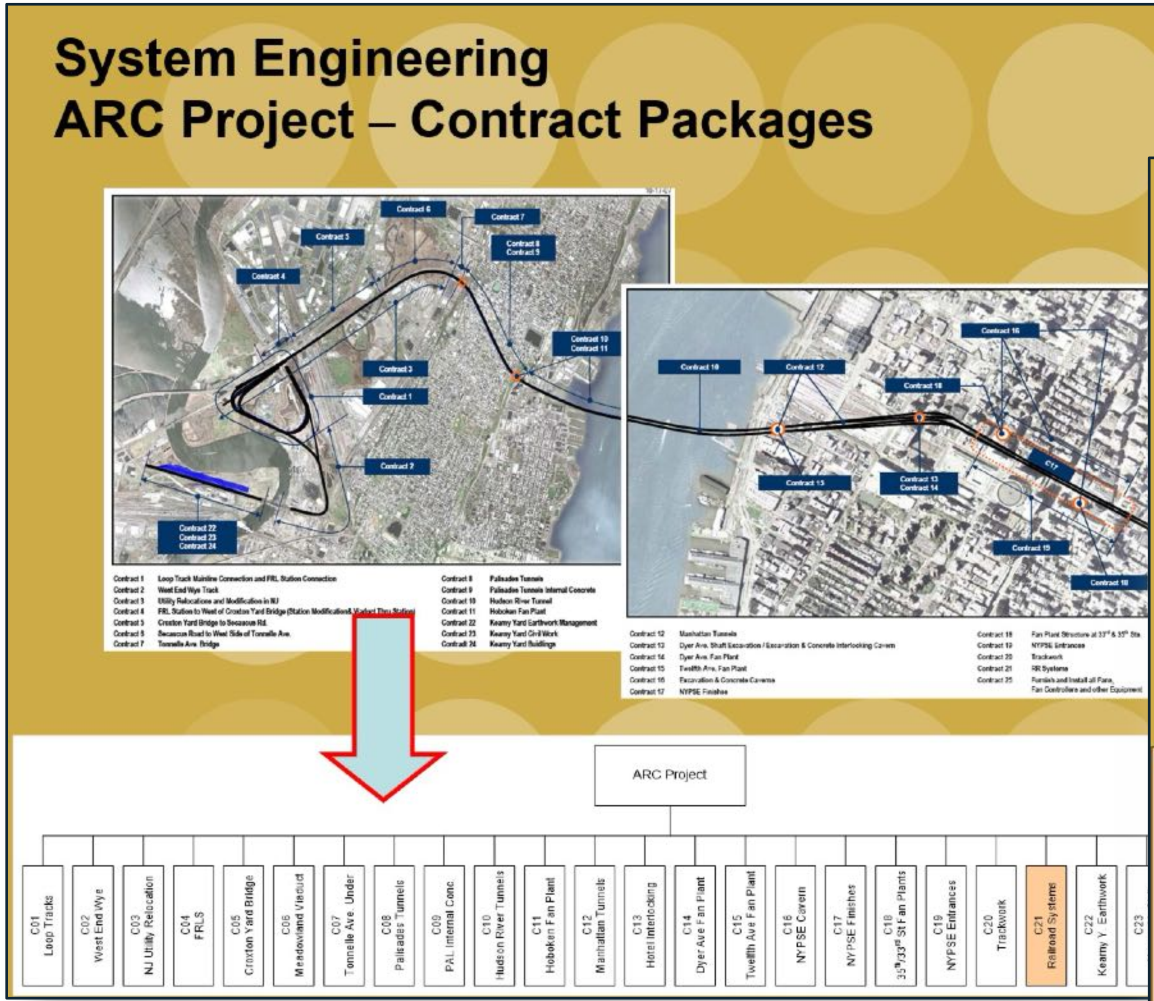
Large-Scale Project

- Civil Works
  - At-Grade
  - Bridges
  - Tunnels
  - Utilities
- Facilities
  - Stations
  - Depots
  - Control Center
- Trainsets
  - Locomotives
  - Passenger Cars
  - Maintenance Vehicles
- Trackwork
  - Track
  - Special Trackwork
- Systems
  - Mechanical, Electrical
  - Traction Power
  - Communic., Train Control
  - SCADA
- Operations & Maintenance
  - Train Operator
  - Infrastructure Management

BACKGROUND, CHALLENGES & OBJECTIVES

LARGE-SCALE PROJECTS: EXAMPLE – ARC TUNNEL PROJECT

Source: Hoehne, O., 2009, "Access to the Region's Core (ARC) Tunnel, Scaling Systems Engineering to Transit Challenges", 2009 APTA Rail Conference, Chicago, IL, 2009



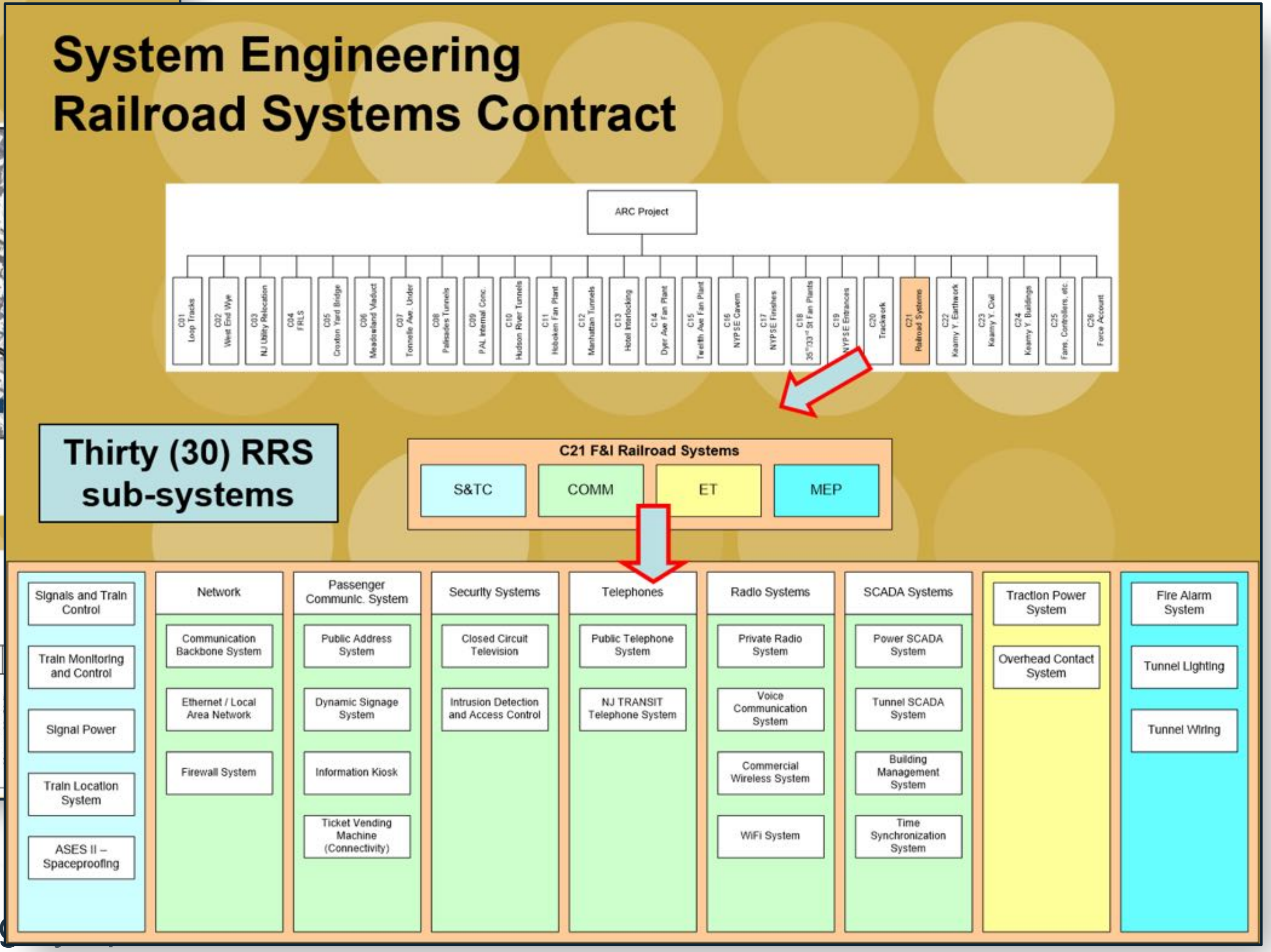
System Engineering
ARC Project – Contract Packages

Contract 1	Loop Track Mainline Connection and FRL Station Connection
Contract 2	West End Wye Track
Contract 3	Utility Relocations and Modification in NJ
Contract 4	FRL Station to West of Croxton Yard Bridge (Station Modification& Viaduct Thru Station)
Contract 5	Croxton Yard Bridge to Secaucus Rd.
Contract 6	Secaucus Road to West Side of Tonnelle Ave.
Contract 7	Tonnelle Ave. Bridge
Contract 8	Palisades Tunnels
Contract 9	Palisades Tunnels Internal Concrete
Contract 10	Hudson River Tunnel
Contract 11	Hoboken Fan Plant
Contract 22	Kearny Yard Earthwork Management
Contract 23	Kearny Yard Civil Work
Contract 24	Kearny Yard Buildings
Contract 12	Manhattan Tunnels
Contract 13	Dyer Ave. Shaft Excavation / Excavation & Concrete Interlocking Cavern
Contract 14	Dyer Ave. Fan Plant
Contract 15	Twelfth Ave. Fan Plant
Contract 16	Excavation & Concrete Caverns
Contract 17	NYPSE Finishes
Contract 18	Fan Plant Structure at 33rd & 35th Sts
Contract 19	NYPSE Entrances
Contract 20	Trackwork
Contract 21	RR Systems
Contract 25	Furnish and Install all Fans, Fan Controllers and other Equipment

ARC Project

- C01 Loop Tracks
- C02 West End Wye
- C03 NJ Utility Relocation
- C04 FRLS
- C05 Croxton Yard Bridge
- C06 Meadowland Viaduct
- C07 Tonnelle Ave. Under
- C08 Palisades Tunnels
- C09 PAL Internal Conc.
- C10 Hudson River Tunnels
- C11 Hoboken Fan Plant
- C12 Manhattan Tunnels
- C13 Hotel Interlocking
- C14 Dyer Ave Fan Plant
- C15 Twelfth Ave Fan Plant
- C16 NYPSE Cavern
- C17 NYPSE Finishes
- C18 35th/33rd St Fan Plants
- C19 NYPSE Entrances
- C20 Trackwork
- C21 Railroad Systems
- C22 Kearny Y. Earthwork
- C23

25 PROCUREMENT CONTRACTS



System Engineering
Railroad Systems Contract

ARC Project

- C01 Loop Tracks
- C02 West End Wye
- C03 NJ Utility Relocation
- C04 FRLS
- C05 Croxton Yard Bridge
- C06 Meadowland Viaduct
- C07 Tonnelle Ave. Under
- C08 Palisades Tunnels
- C09 PAL Internal Conc.
- C10 Hudson River Tunnels
- C11 Hoboken Fan Plant
- C12 Manhattan Tunnels
- C13 Hotel Interlocking
- C14 Dyer Ave Fan Plant
- C15 Twelfth Ave Fan Plant
- C16 NYPSE Cavern
- C17 NYPSE Finishes
- C18 35th/33rd St Fan Plants
- C19 NYPSE Entrances
- C20 Trackwork
- C21 Railroad Systems
- C22 Kearny Y. Earthwork
- C23 Kearny Y. Civil
- C24 Kearny Y. Buildings
- C25 Fans, Controllers, etc.
- C26 Force Account

Thirty (30) RRS sub-systems

C21 F&I Railroad Systems

- S&TC
- COMM
- ET
- MEP

- Signals and Train Control
- Train Monitoring and Control
- Signal Power
- Train Location System
- ASES II – Spaceproofing

Network
- Communication Backbone System
- Ethernet / Local Area Network
- Firewall System

Passenger Communic. System
- Public Address System
- Dynamic Signage System
- Information Kiosk
- Ticket Vending Machine (Connectivity)

Security Systems
- Closed Circuit Television
- Intrusion Detection and Access Control

Telephones
- Public Telephone System
- NJ TRANSIT Telephone System

Radio Systems
- Private Radio System
- Voice Communication System
- Commercial Wireless System
- WiFi System

SCADA Systems
- Power SCADA System
- Tunnel SCADA System
- Building Management System
- Time Synchronization System

- Traction Power System
- Overhead Contact System

- Fire Alarm System
- Tunnel Lighting
- Tunnel Wiring

BACKGROUND, CHALLENGES & OBJECTIVES

LARGE-SCALE PROJECTS: EXAMPLE – GATEWAY PROGRAM (NY/NJ)

HUDSON TUNNEL PROCUREMENT STRATEGY

Large-Scale Project

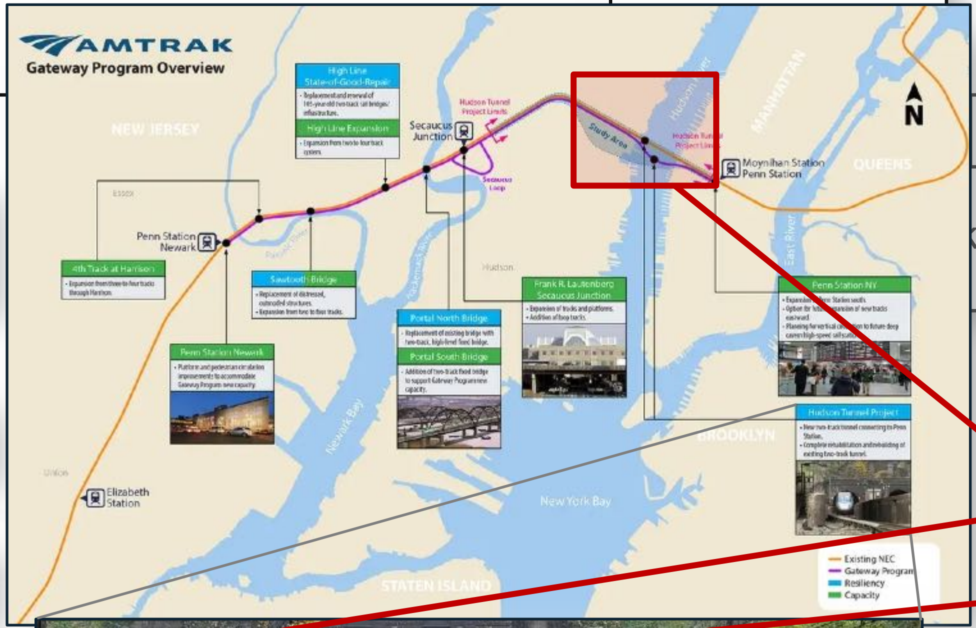
Civil Works

At-Grade

Bridges

Tunnels

Utilities



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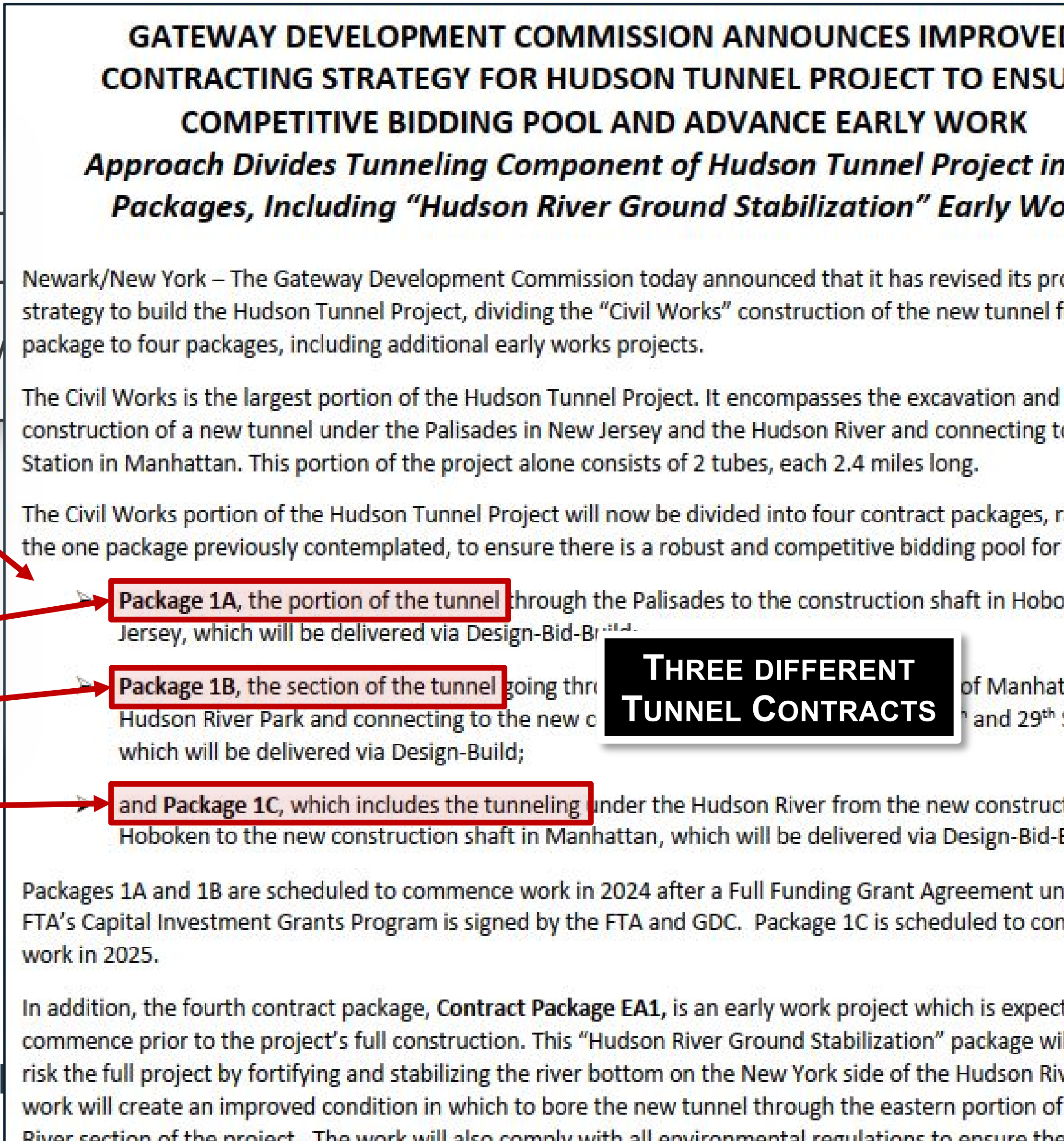


GATEWAY DEVELOPMENT COMMISSION ANNOUNCES IMPROVE
CONTRACTING STRATEGY FOR HUDSON TUNNEL PROJECT TO ENSU
COMPETITIVE BIDDING POOL AND ADVANCE EARLY WORK

Approach Divides Tunneling Component of Hudson Tunnel Project in
Packages, Including "Hudson River Ground Stabilization" Early Wo

Newark/New York – The Gateway Development Commission today announced that it has revised its pr
strategy to build the Hudson Tunnel Project, dividing the "Civil Works" construction of the new tunnel f
package to four packages, including additional early works projects.

The Civil Works is the largest portion of the Hudson Tunnel Project. It encompasses the excavation and
construction of a new tunnel under the Palisades in New Jersey and the Hudson River and connecting t
Station in Manhattan. This portion of the project alone consists of 2 tubes, each 2.4 miles long.

The Civil Works portion of the Hudson Tunnel Project will now be divided into four contract packages, r
the one package previously contemplated, to ensure there is a robust and competitive bidding pool for

- **Package 1A**, the portion of the tunnel through the Palisades to the construction shaft in Hobo
  Jersey, which will be delivered via Design-Bid-Br
- **Package 1B**, the section of the tunnel going thr of Manhat
  Hudson River Park and connecting to the new c and 29th
  which will be delivered via Design-Build;
- and **Package 1C**, which includes the tunneling under the Hudson River from the new construct
  Hoboken to the new construction shaft in Manhattan, which will be delivered via Design-Bid-

Packages 1A and 1B are scheduled to commence work in 2024 after a Full Funding Grant Agreement un
FTA's Capital Investment Grants Program is signed by the FTA and GDC. Package 1C is scheduled to com
work in 2025.

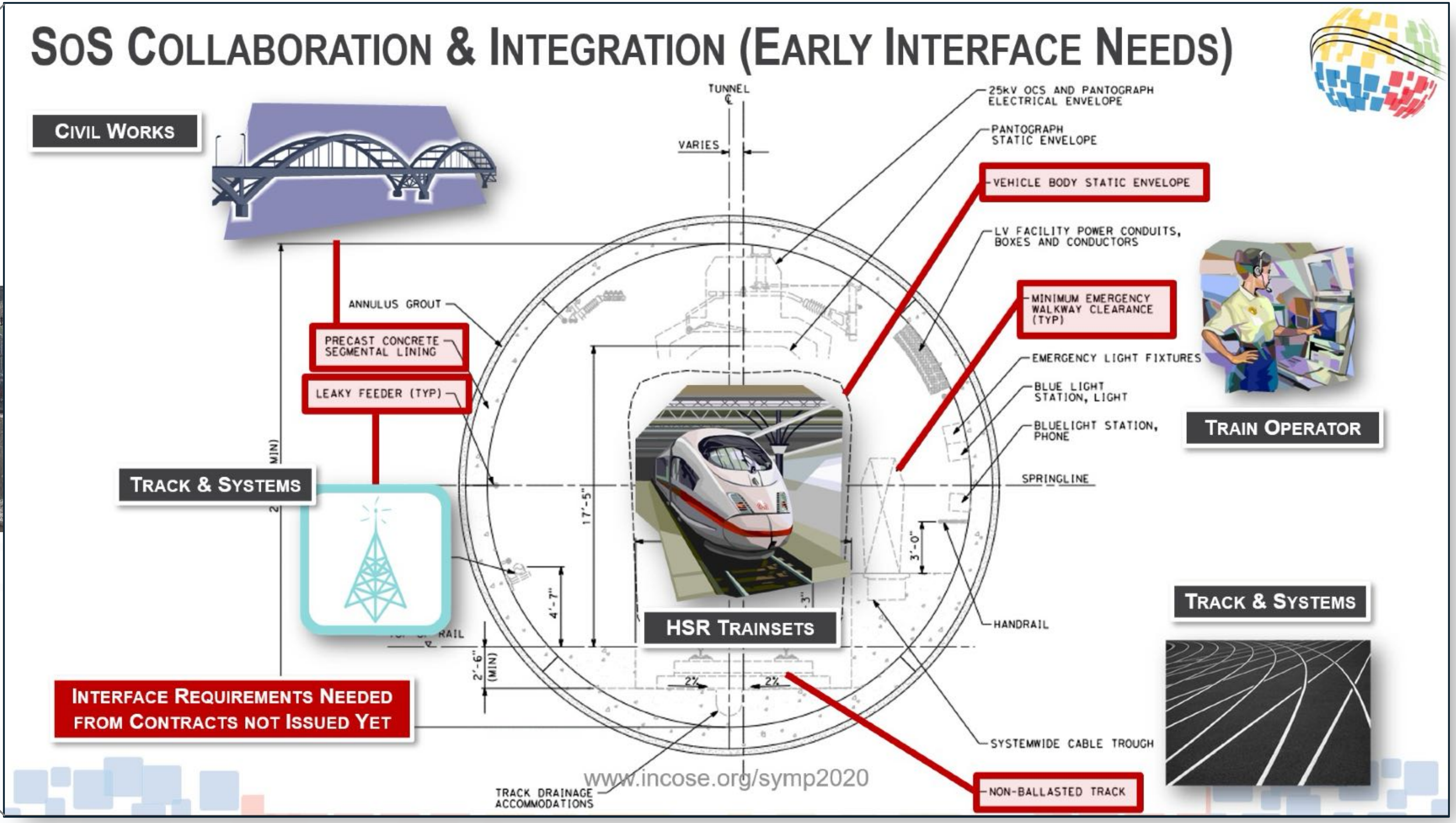
In addition, the fourth contract package, **Contract Package EA1,** is an early work project which is expec
commence prior to the project's full construction. This "Hudson River Ground Stabilization" package wi
risk the full project by fortifying and stabilizing the river bottom on the New York side of the Hudson Riv
work will create an improved condition in which to bore the new tunnel through the eastern portion of
River section of the project. The work will also comply with all environmental regulations to ensure the

THREE DIFFERENT TUNNEL CONTRACTS

BACKGROUND, CHALLENGES & OBJECTIVES

2020 PAPER

CURRENT NORTH RIVER TUNNELS



SOS COLLABORATION & INTEGRATION (EARLY INTERFACE NEEDS)

CIVIL WORKS

TRACK & SYSTEMS

HSR TRAINSETS

TRAIN OPERATOR

TRACK & SYSTEMS

INTERFACE REQUIREMENTS NEEDED FROM CONTRACTS NOT ISSUED YET

www.incose.org/symp2020

BACKGROUND, CHALLENGES & OBJECTIVES

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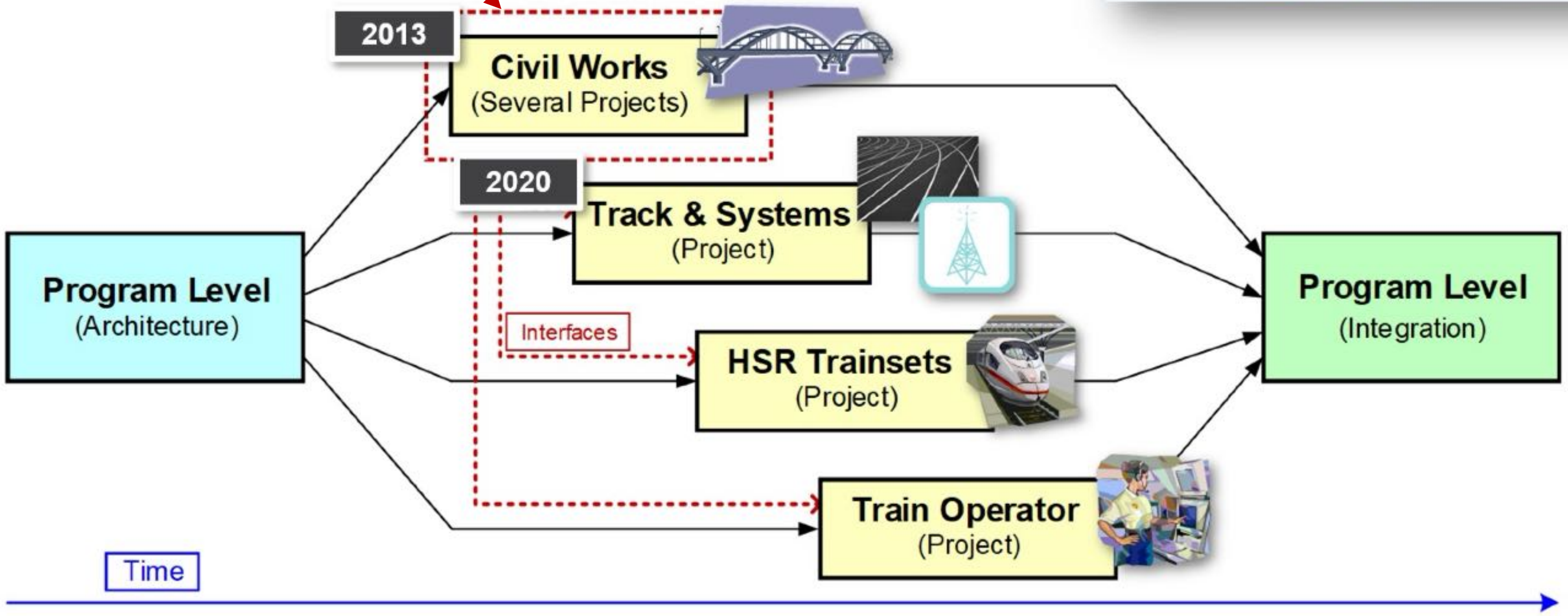
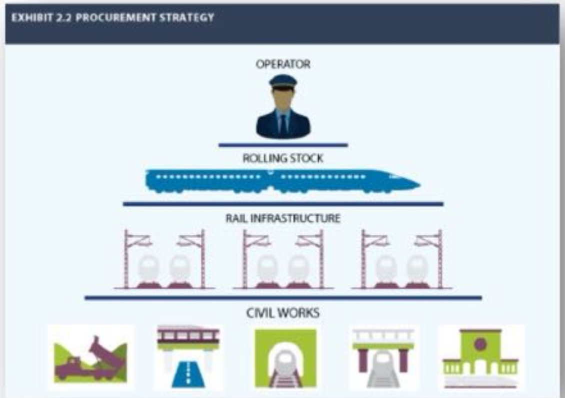
SoSE CHALLENGES FACED

SoS ARCHITECTURE & LEADERSHIP (CONT'D)

STAGGERED CONTRACT AWARD & EXECUTION

SoS ARCHITECTURE (CONTRACTS & INTERFACES)





TRAIN OPERATOR

HSR TRAINSETS

TRACK & SYSTEMS

CIVIL WORKS

PROGRAM INTERFACE & INTEGRATION CHALLENGES

BACKGROUND, CHALLENGES & OBJECTIVES

LARGE-SCALE PROJECTS: INDUSTRY TYPICAL INTERFACE MANAGEMENT APPROACH

- **Interface Management Working Group(s):** (Interface Management "As You Go")
  - **Purpose:**
    - Regularly meet to "**liaise**" and "**cooperate**", and "**coordinate**" interfaces
  - **Attendees:**
    - **Contractor(s)**
    - **Interfacing contractors**
    - Project Oversight
    - Client
  - **Scope:**
    - **Develop interface management program**
    - Coordinate schedule development (including site access, handovers)
    - **Identify interfaces**
    - **Develop interface requirements**
    - **Coordinate design development**, including information exchange
    - Address, manage and **resolve interface issues as they arise**
    - Manage interface status

Sources/Credits:
https://www.clker.com/clipart-617868.html
https://de.freepik.com/vektoren-kostenlos/glueckliche-kinder-halten-haende-um-regenbogen-kreis_1250832.htm

BACKGROUND, CHALLENGES & OBJECTIVES

LARGE-SCALE PROJECTS: INTERFACE MANAGEMENT REALITIES

How a French rail company spent £12bn on trains that are "too wide"

Apparently, it's the sort of thing that occurs when you separate the rail operators from train companies, so will probably be happening soon at a platform near you

TRAINS

STATIONS

Source/Credit: https://www.theguardian.com/world/shortcuts/2014/may/21/french-rail-company-sncf-trains-too-wide

'Unspeakable botch': Spain spends €258 million on trains that are too big for its tunnels

OPERATORS

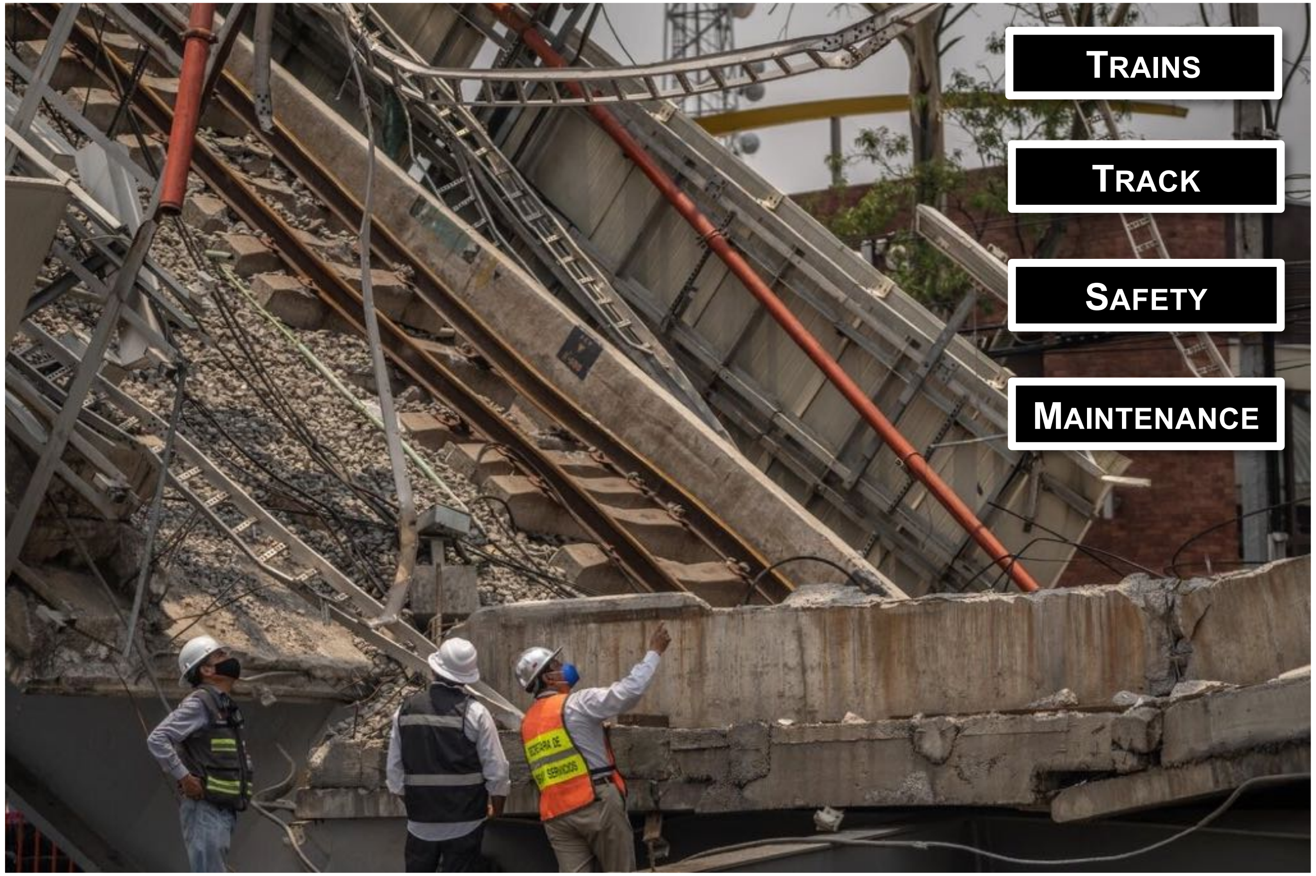
TUNNELS

Source/Credit: https://www.euronews.com/travel/2023/02/21/unspeakable-botch-spain-spends-258-million-on-trains-that-are-too-big-for-its-tunnels

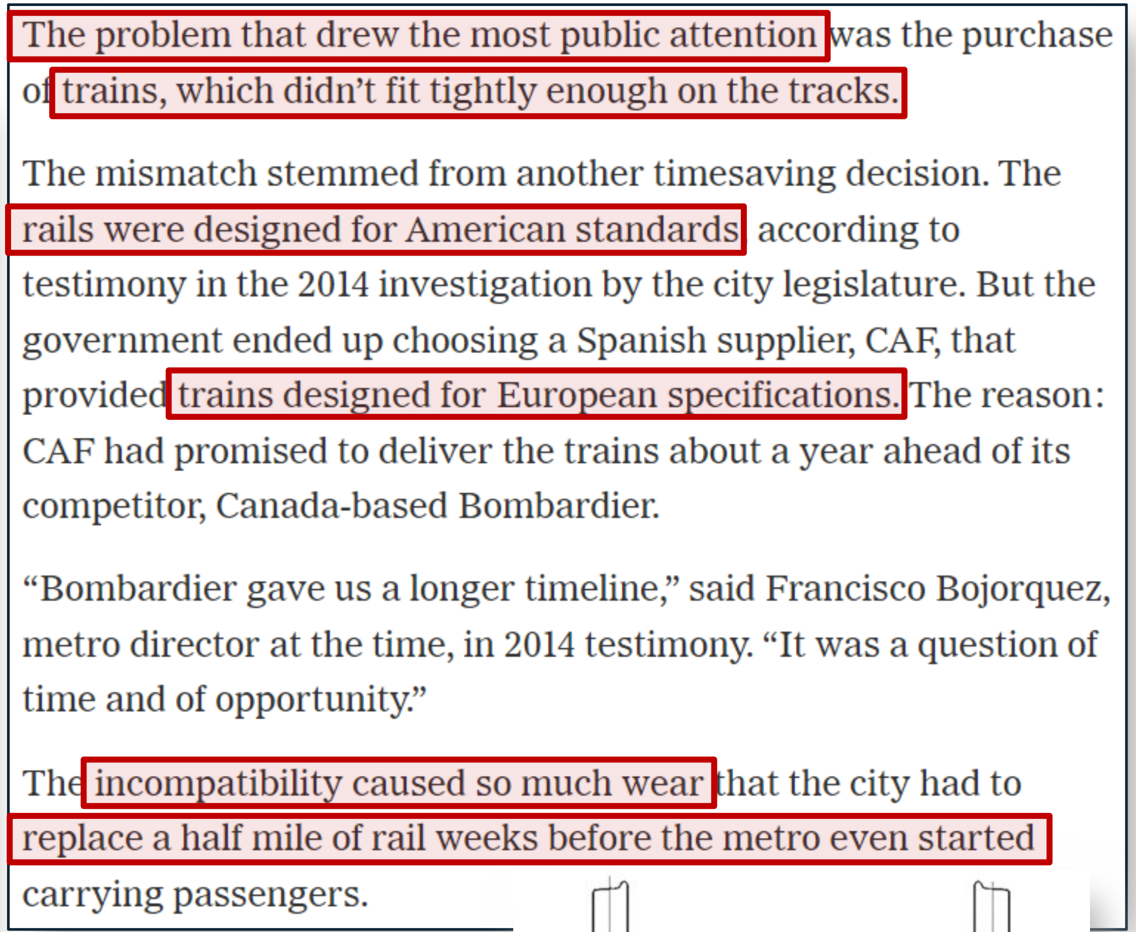
BACKGROUND, CHALLENGES & OBJECTIVES

LARGE-SCALE PROJECTS: INTERFACE MANAGEMENT REALITIES (CONT'D)

MEXICO CITY METRO



Source/Credit: https://www.nytimes.com/interactive/2021/06/12/world/americas/mexico-city-train-crash.html?searchResultPosition=3



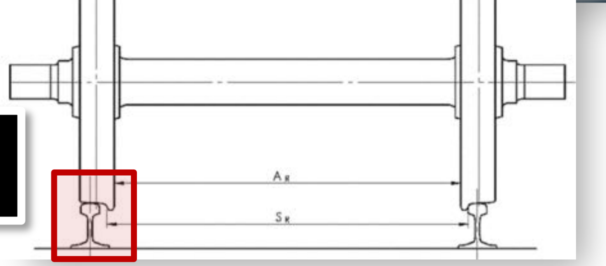
The problem that drew the most public attention was the purchase of trains, which didn't fit tightly enough on the tracks.

The mismatch stemmed from another timesaving decision. The rails were designed for American standards, according to testimony in the 2014 investigation by the city legislature. But the government ended up choosing a Spanish supplier, CAF, that provided trains designed for European specifications. The reason: CAF had promised to deliver the trains about a year ahead of its competitor, Canada-based Bombardier.

"Bombardier gave us a longer timeline," said Francisco Bojorquez, metro director at the time, in 2014 testimony. "It was a question of time and of opportunity."

The incompatibility caused so much wear that the city had to replace a half mile of rail weeks before the metro even started carrying passengers.

RAIL-WHEEL INTERFACE



BACKGROUND, CHALLENGES & OBJECTIVES

OBJECTIVES: PREDICTABLE, REPEATABLE PROCESS, CONVENIENT, INTEROPERABLE

CMMI Level 1: Initial

- Unpredictable Processes, relying on SME Expertise (or Lack Thereof)

CMMI Level 2: Managed

- Repeatable Processes w/in Project

CMMI Level 3: Defined

- Repeatable Processes w/in Organization
- Project Tailors Processes from Organizational Standards

Additional Objectives

- Convenience: Ready (Easy) to Use
- Interoperable: Compatible w/ Future Contracts

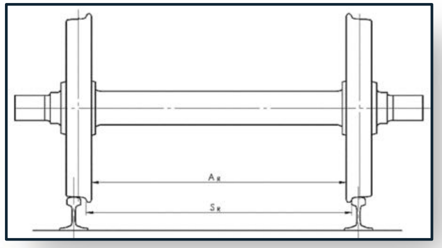
BACKGROUND, CHALLENGES & OBJECTIVES

OBJECTIVES: INTEROPERABLE CONSTITUENT SUBSYSTEM(S)

STATIONS

TRAINS

TUNNELS



TRACK

How a French rail company spent £12bn on trains that are "too wide"

Apparently, it's the sort of thing that occurs when you separate the rail operators from train companies, so will probably be happening soon at a platform near you

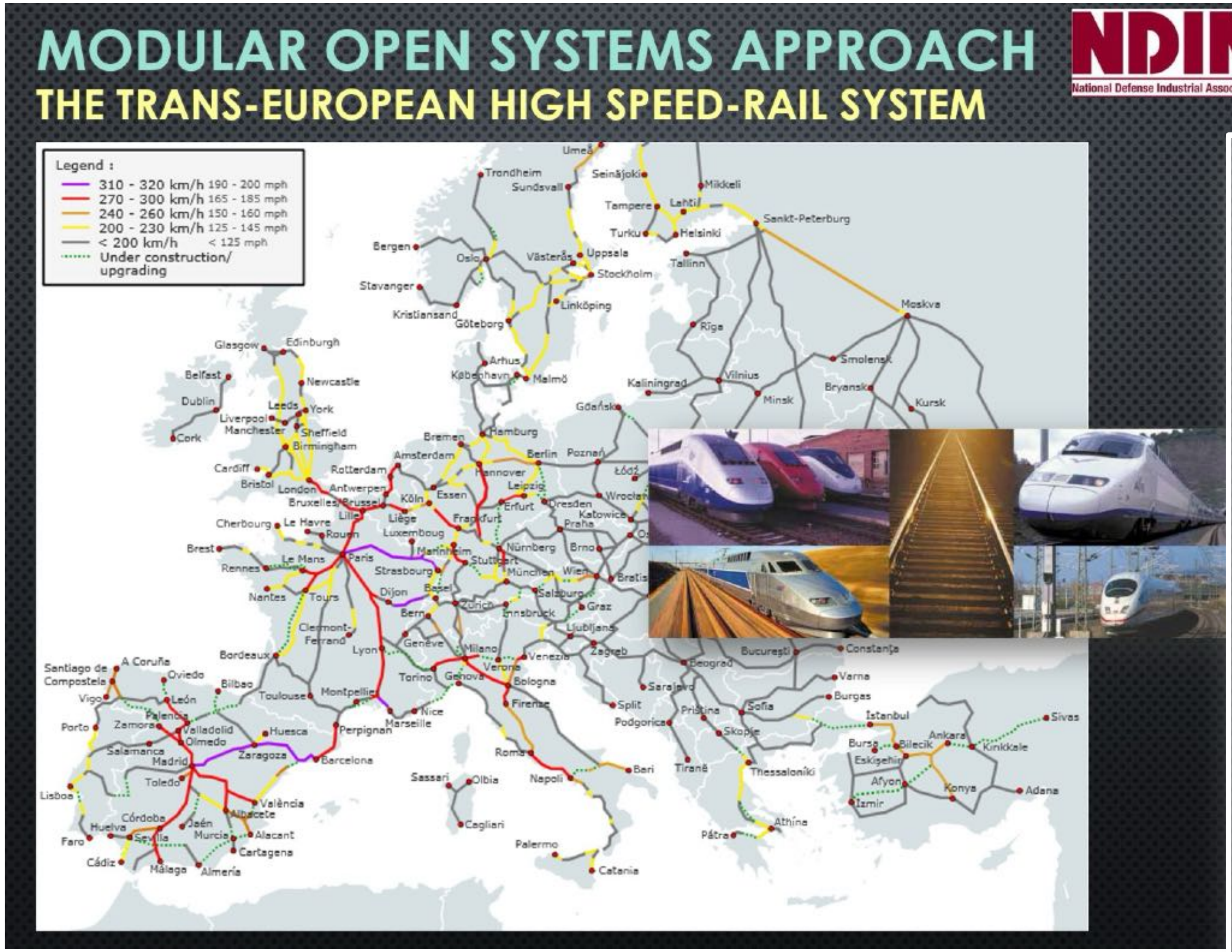
'Unspeakable botch': Spain spends €258 million on trains that are too big for its tunnels

PROGRESS

- **Motivation**
- **Background, Challenges & Objectives**
- **Model-Based Systems Integration Framework**
  - Modular Open Systems Approach
  - Interoperability
- **MBSI Framework Development**
- **MBSI Framework Use**
- **Summary & Conclusion**

MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

MODULAR OPEN SYSTEMS APPROACH (MOSA)



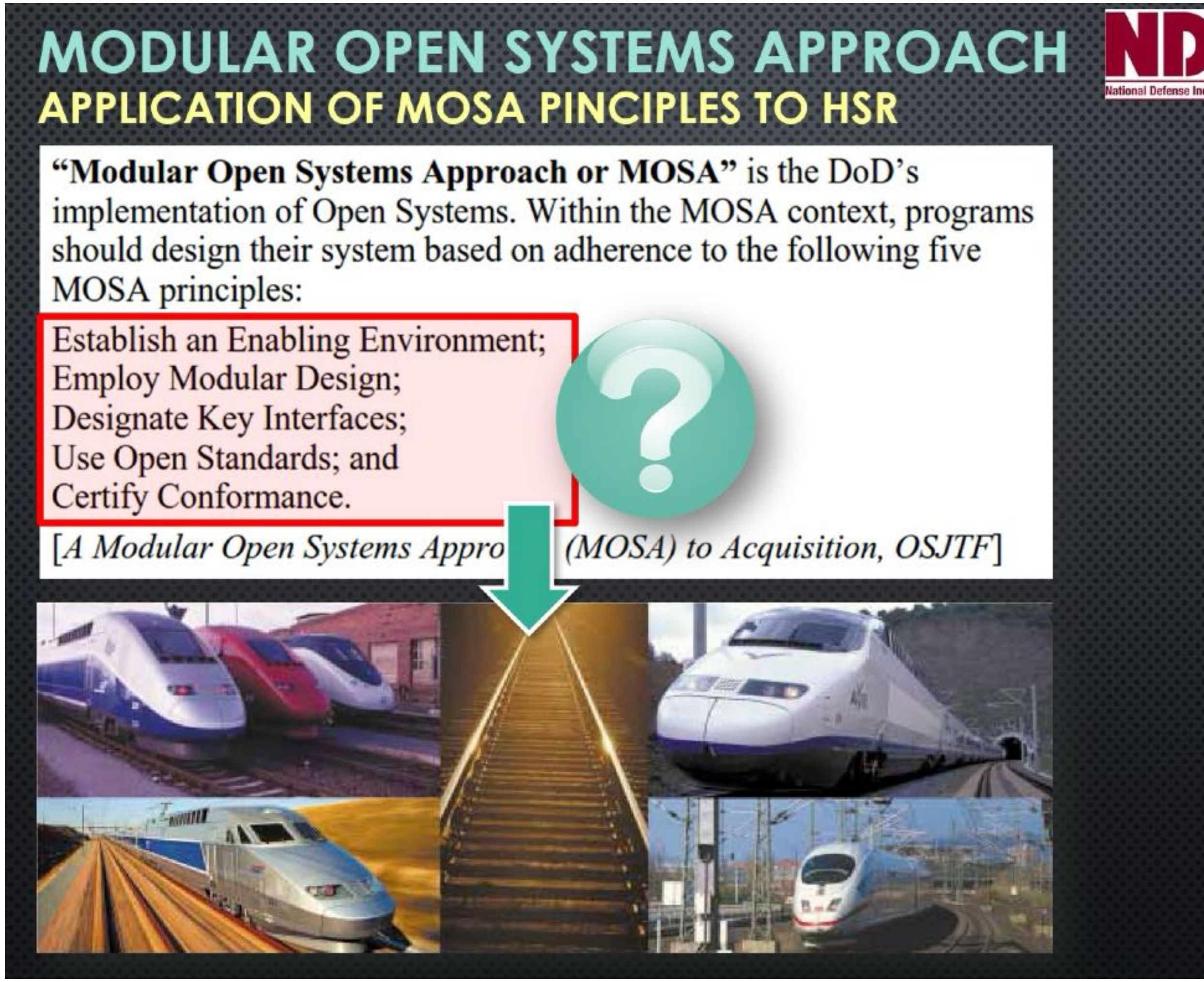
MODULAR OPEN SYSTEMS APPROACH

THE TRANS-EUROPEAN HIGH SPEED-RAIL SYSTEM

NDIA National Defense Industrial Association

Legend :
- 310 - 320 km/h 190 - 200 mph
- 270 - 300 km/h 165 - 185 mph
- 240 - 260 km/h 150 - 160 mph
- 200 - 230 km/h 125 - 145 mph
- < 200 km/h < 125 mph
- Under construction/ upgrading

Source: Hoehne, O., 2016, “*Implementing an Effective Modular Open Systems Approach [MOSA] Framework Insights into the Application of MOSA to Non-Defense Industries* “, 19th Annual Systems Engineering Conference, Springfield, VA, 2016



MODULAR OPEN SYSTEMS APPROACH

APPLICATION OF MOSA PINCIPLES TO HSR

“Modular Open Systems Approach or MOSA” is the DoD’s implementation of Open Systems. Within the MOSA context, programs should design their system based on adherence to the following five MOSA principles:

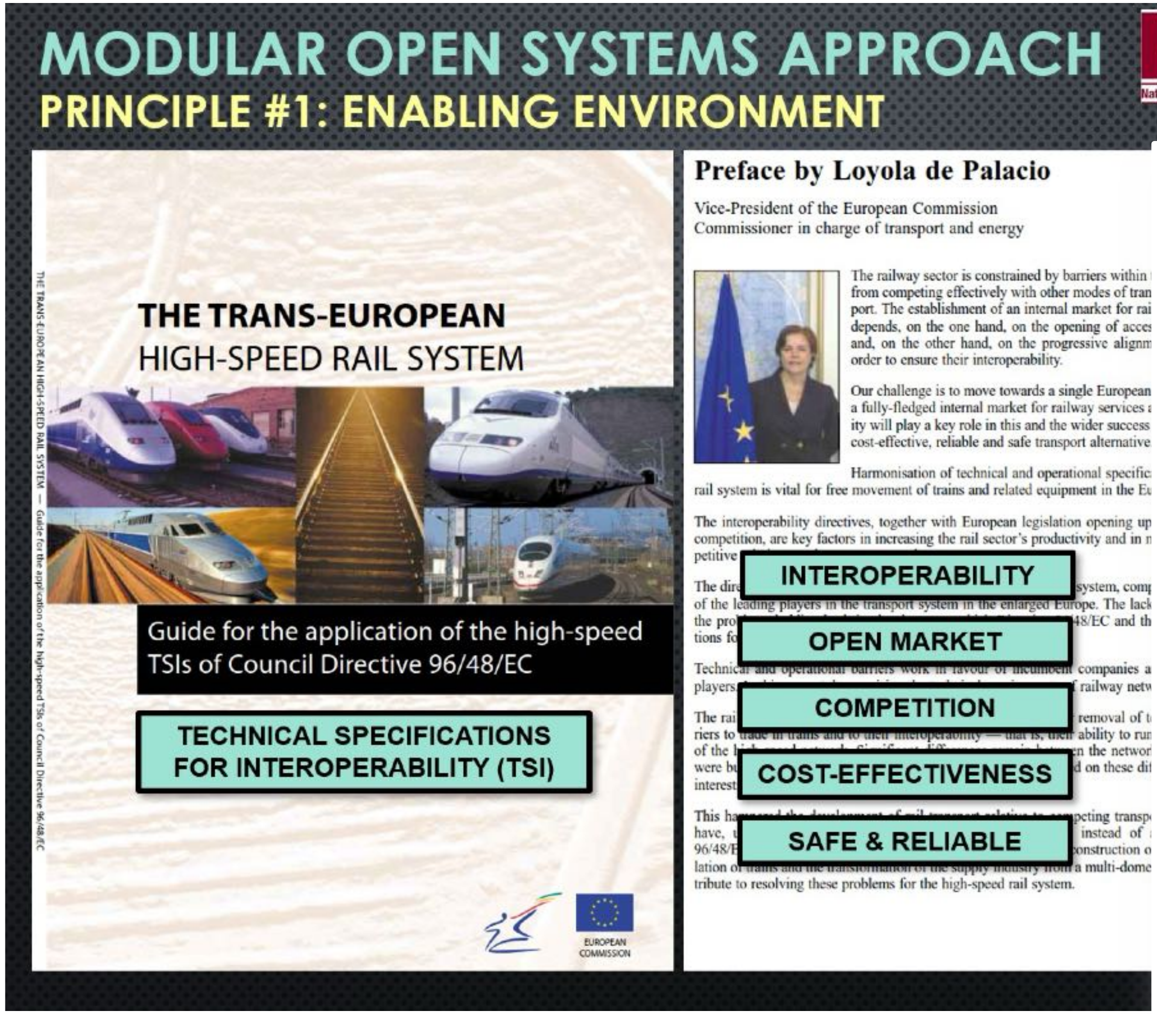
Establish an Enabling Environment;
Employ Modular Design;
Designate Key Interfaces;
Use Open Standards; and
Certify Conformance.

[*A Modular Open Systems Appro* *(MOSA) to Acquisition, OSJTF*]

MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

MOSA APPLIED TO LARGE RAIL PROJECTS – ENABLING ENVIRONMENT, MODULARITY

Source: Hoehne, O., 2016, “*Implementing an Effective Modular Open Systems Approach [MOSA] Framework Insights into the Application of MOSA to Non-Defense Industries* “, 19th Annual Systems Engineering Conference, Springfield, VA, 2016



MODULAR OPEN SYSTEMS APPROACH

PRINCIPLE #1: ENABLING ENVIRONMENT

THE TRANS-EUROPEAN
HIGH-SPEED RAIL SYSTEM

Guide for the application of the high-speed TSIs of Council Directive 96/48/EC

TECHNICAL SPECIFICATIONS FOR INTEROPERABILITY (TSI)

Preface by Loyola de Palacio

Vice-President of the European Commission
Commissioner in charge of transport and energy

The railway sector is constrained by barriers within
from competing effectively with other modes of tran
port. The establishment of an internal market for rai
depends, on the one hand, on the opening of acces
and, on the other hand, on the progressive alignm
order to ensure their interoperability.

Our challenge is to move towards a single European
a fully-fledged internal market for railway services
ity will play a key role in this and the wider success
cost-effective, reliable and safe transport alternative

Harmonisation of technical and operational specific
rail system is vital for free movement of trains and related equipment in the E

The interoperability directives, together with European legislation opening up
competition, are key factors in increasing the rail sector's productivity and in
petitive

The dir system, com
of the leading players in the transport system in the enlarged Europe. The lack
the pro 48/EC and th
tions fo

Technical and operational barriers work in favour of incumbent companies a
players railway netw

The rai removal of t
riers to ability to run
of the h n the networ
were bu d on these di
interest

This h peting transp
have, instead of
96/48/E construction o
lation o a multi-dome
tribute to resolving these problems for the high-speed rail system.

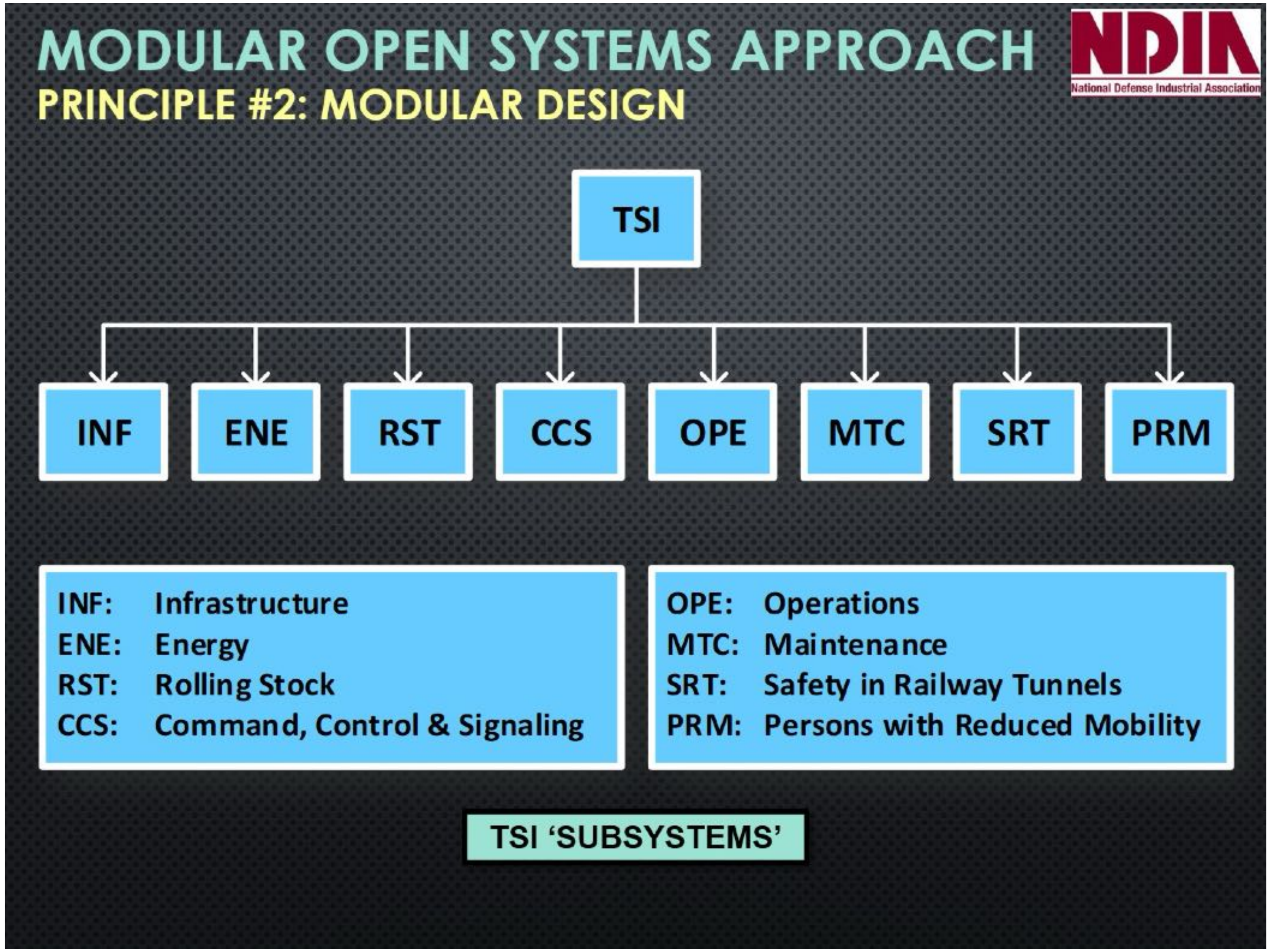
INTEROPERABILITY

OPEN MARKET

COMPETITION

COST-EFFECTIVENESS

SAFE & RELIABLE



MODULAR OPEN SYSTEMS APPROACH

PRINCIPLE #2: MODULAR DESIGN

TSI

INF ENE RST CCS OPE MTC SRT PRM

INF:	Infrastructure
ENE:	Energy
RST:	Rolling Stock
CCS:	Command, Control & Signaling
OPE:	Operations
MTC:	Maintenance
SRT:	Safety in Railway Tunnels
PRM:	Persons with Reduced Mobility

TSI ‘SUBSYSTEMS’

MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

TECHNICAL SPECIFICATIONS FOR INTEROPERABILITY (TSI) – KEY INTERFACES

TSI INFRASTRUCTURE

02014R1299 — EN — 28.09.2023

4.3. **Functional and technical specification of the interfaces**

From the standpoint of technical compatibility, the interfaces of the infrastructure subsystem with the other subsystems are like described in the following points.

4.3.1. *Interfaces with the rolling stock subsystem*

▼M1

Table 15

▼M2

Interfaces … **passenger rolling**

INTERFACING SYSTEMS

▼M1

Interface	►M2 Reference in TSI INF ◄	►M2 Reference in TSI LOC&PAS ◄
Track gauge	4.2.4.1 Nominal track gauge 4.2.5.1 Design geometry of switches and crossings 4.2.8.6 The immediate action limits for switches and crossings	4.2.3.5.2.1 Mechanical and geometrical characteristics of wheelset 4.2.3.5.2.3 Variable gauge wheelsets
Gauge	4.2.3.1 Structure gauge 4.2.3.2 Distance between track centres 4.2.3.5 Minimum radius of vertical curve 4.2.9.3 Platform offset	4.2.3.1 Gauging
		10 Load conditions eighed mass 2.1 Axle load eter
		4.2.1 Limit values for g safely 4.2.2 Track loading values
Ride stability	4.2.4.4 Equivalent conicity	4.2.3.4.3 Equivalent

How a French rail company spent £12bn on trains that are "too wide"

Apparently, it's the sort of thing that occurs when you separate the rail operators from train companies, so will probably be happening soon at a platform near you

TSI ROLLING STOCK

02014R1302 — I

▼M5

Reference TSI LOC & PAS		Reference TSI Energy	
Parameter	Point	Parameter	Point
Energy consumption measuring function	4.2.8.2.8	On-ground energy data collecting system	4.2.17
Height of pantograph	4.2.8.2.9.1	Geometry of the overhead contact line	4.2.9
Pantograph head geometry	4.2.8.2.9.2		
Contact strip material	4.2.8.2.9.4	Contact wire material	4.2.14
Pantograph static contact force	4.2.8.2.9.5	Mean contact force	4.2.11
Pantograph contact force and dynamic behaviour	4.2.8.2.9.6	Dynamic behaviour and quality of current collection	4.2.12
Arrangements of pantographs	4.2.8.2.9.7	Pantograph spacing	4.2.13
Running through phase or system separation section	4.2.8.2.9.8	Separation sections:	
		— phase	4.2.15
			4.2.16
Electrical protec			4.2.7
Harmonics and for AC systems			4.2.8

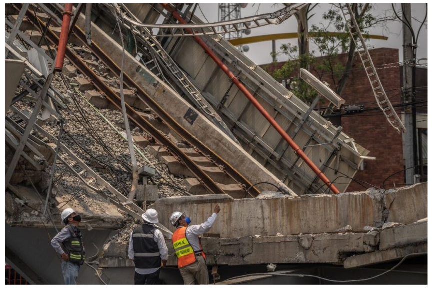
'Unspeakable botch': Spain spends €258 million on trains that are too big for its tunnels

4.3.2. *Interface with In*

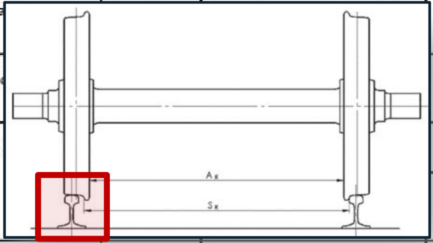
Reference TSI LOC & PAS		Reference TSI Infrastructure	
Parameter	Point	Parameter	Point
Rolling stock kinematic gauge	4.2.3.1.	Structure gauge	4.2.3.1
		Distance between track centres	4.2.3.2
		Minimum radius of vertical curve	4.2.3.5
Axle load parameter	4.2.3.2.1	Track resistance to vertical loads	4.2.6.1

02014R1302 — EN — 28.09.2023 — 005.001 — 137

▼M5

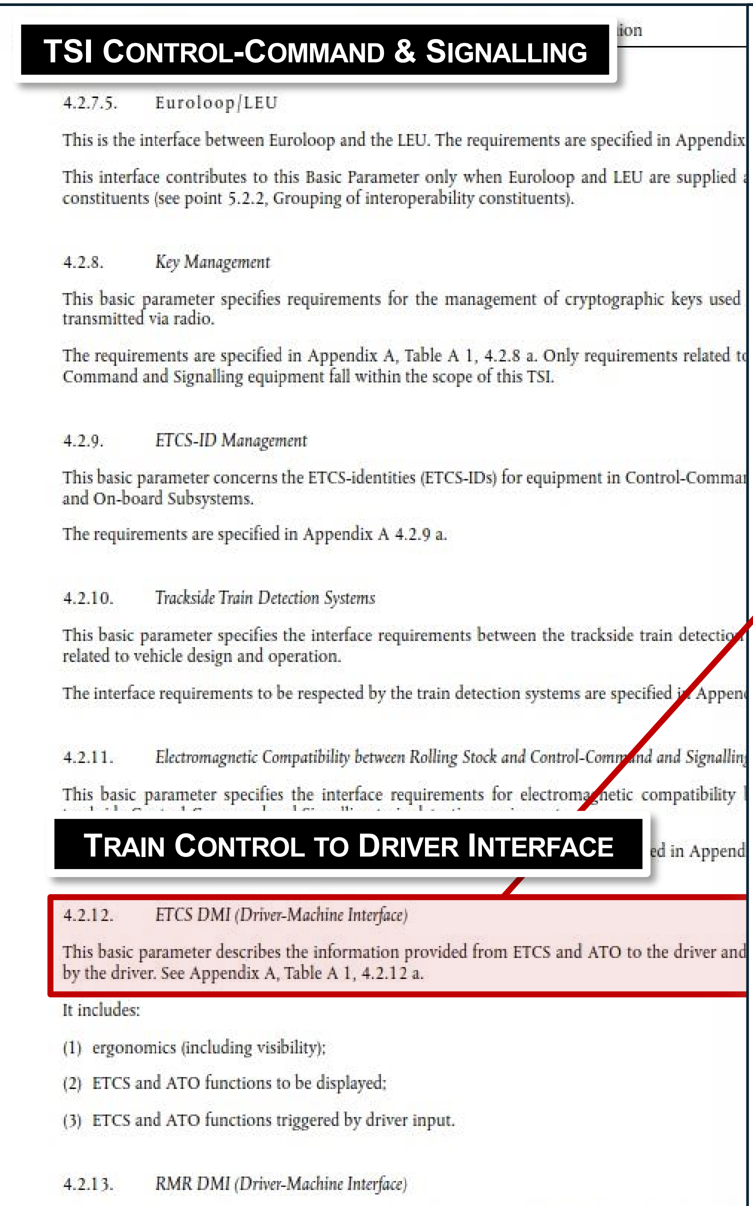


Reference TSI LOC & PAS		Reference TSI Infrastructure	
Parame			Point
Running dynamic			4.2.4.3
Running dynamic for track loading			4.2.6.1
			4.2.6.3
Equivalent conicity			4.2.4.5
Geometrical char wheelset			4.2.4.1
Geometrical characteristics of wheels	4.2.3.5.2.2	Rail head profile for plain line	4.2.4.6
Automatic varia systems			4.2.5.3
Minimum curve ra			4.2.3.4
Maximum average			4.2.6.2
			4.2.7.1.5
Slipstream effects	4.2.6.2.1	Resistance of new structures over or adjacent to tracks	4.2.7.3
Head pressure pulse	4.2.6.2.2	Maximum pressure variations in tunnels	4.2.10.1
Maximum pressure variations in tunnels	4.2.6.2.3	Distance between track centres	4.2.3.2
Crosswind	4.2.6.2.4	Effect of crosswinds	4.2.10.2
Aerodynamic effect on ballasted track	4.2.6.2.5	Ballast pick-up	4.2.10.3
Toilet discharge system	4.2.11.3	Toilet discharge	4.2.12.2
Exterior cleaning through a	4.2.11.2.2	Train external cleaning facilities	4.2.12.3



MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

TECHNICAL SPECIFICATIONS FOR INTEROPERABILITY (TSI) – OPEN STANDARDS



TSI CONTROL-COMMAND & SIGNALLING

ion

4.2.7.5. Euroloop/LEU

This is the interface between Euroloop and the LEU. The requirements are specified in Appendix

This interface contributes to this Basic Parameter only when Euroloop and LEU are supplied a constituents (see point 5.2.2, Grouping of interoperability constituents).

4.2.8. *Key Management*

This basic parameter specifies requirements for the management of cryptographic keys used transmitted via radio.

The requirements are specified in Appendix A, Table A 1, 4.2.8 a. Only requirements related to Command and Signalling equipment fall within the scope of this TSI.

4.2.9. *ETCS-ID Management*

This basic parameter concerns the ETCS-identities (ETCS-IDs) for equipment in Control-Comman and On-board Subsystems.

The requirements are specified in Appendix A 4.2.9 a.

4.2.10. *Trackside Train Detection Systems*

This basic parameter specifies the interface requirements between the trackside train detectio related to vehicle design and operation.

The interface requirements to be respected by the train detection systems are specified in Append

4.2.11. *Electromagnetic Compatibility between Rolling Stock and Control-Command and Signallin*

This basic parameter specifies the interface requirements for electromagnetic compatibility

TRAIN CONTROL TO DRIVER INTERFACE

ed in Append

4.2.12. *ETCS DMI (Driver-Machine Interface)*

This basic parameter describes the information provided from ETCS and ATO to the driver and by the driver. See Appendix A, Table A 1, 4.2.12 a.

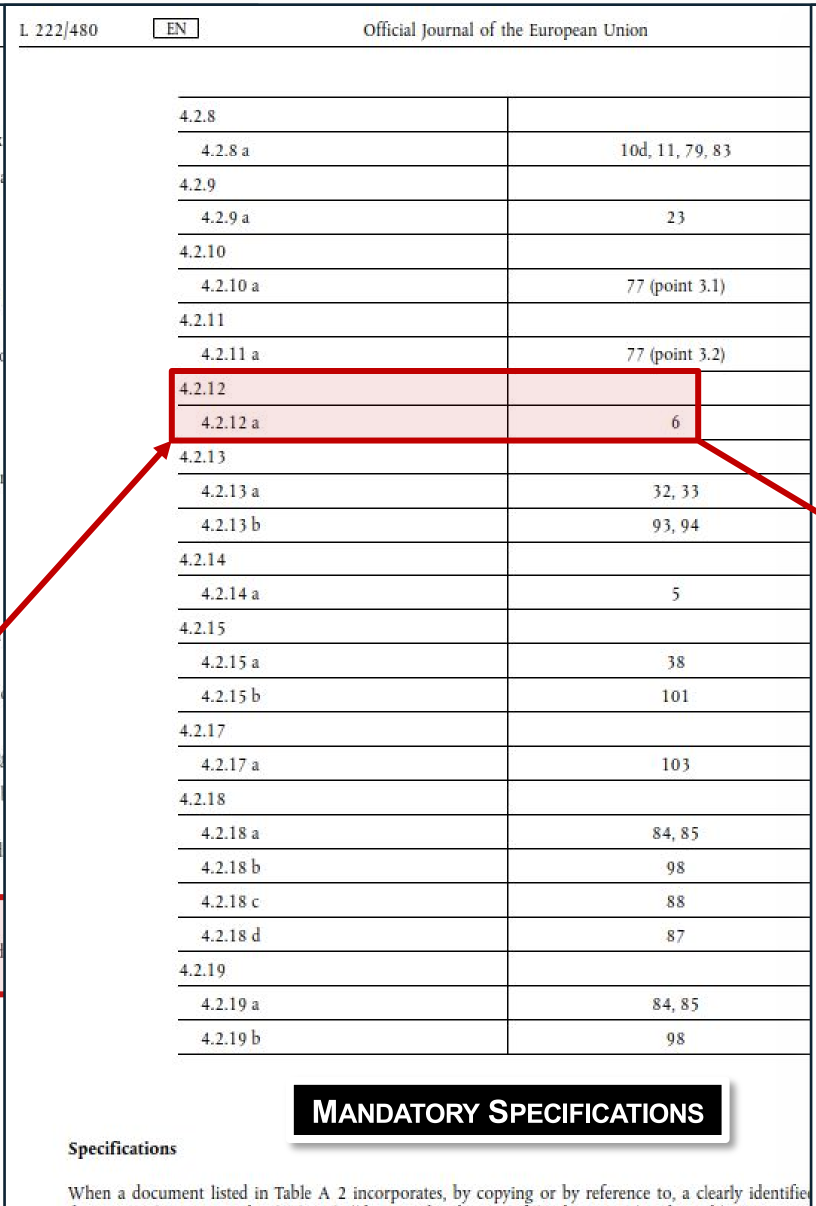
It includes:

(1) ergonomics (including visibility);

(2) ETCS and ATO functions to be displayed;

(3) ETCS and ATO functions triggered by driver input.

4.2.13. *RMR DMI (Driver-Machine Interface)*



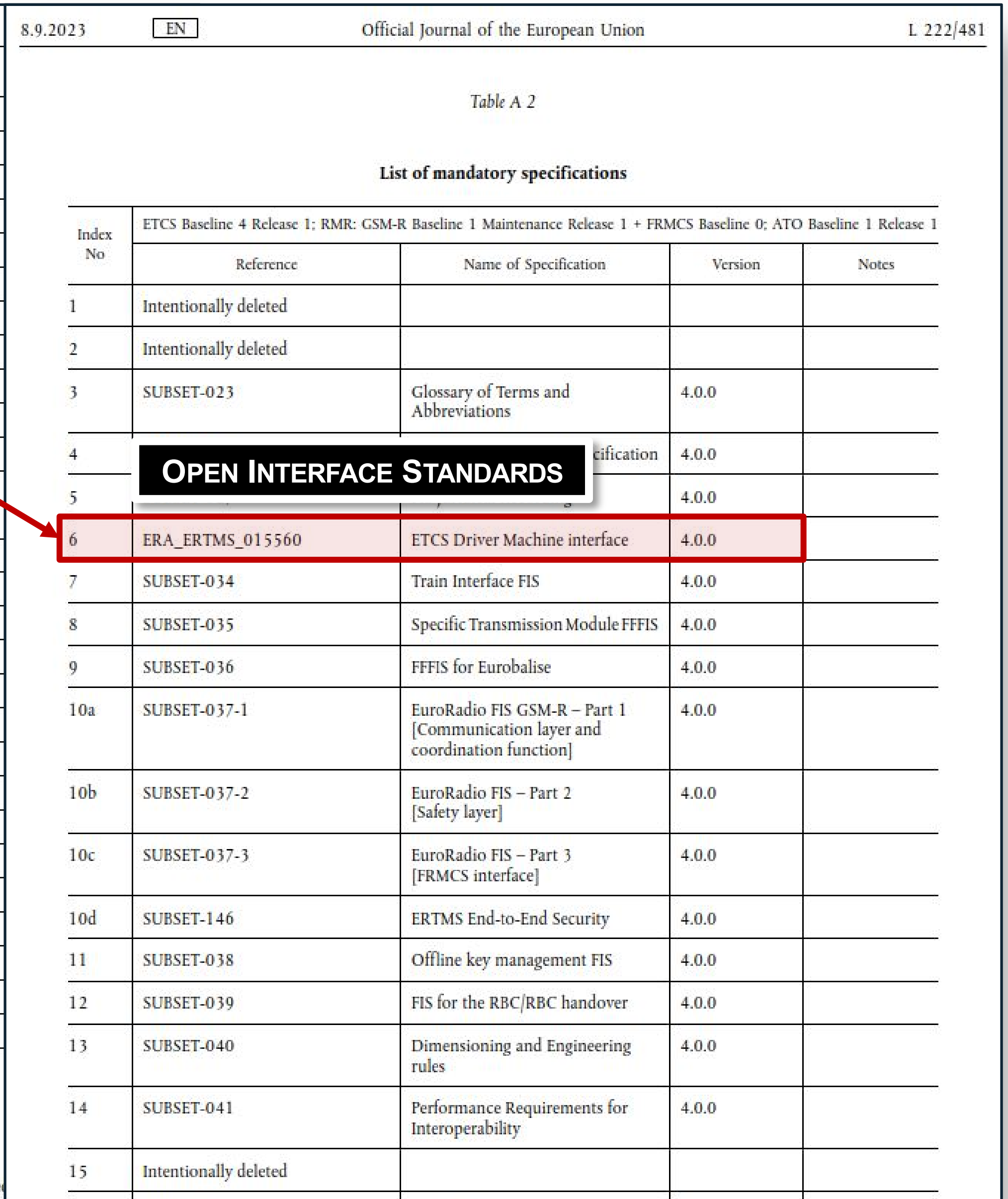
L 222/480 EN Official Journal of the European Union

4.2.8	
4.2.8 a	10d, 11, 79, 83
4.2.9	
4.2.9 a	23
4.2.10	
4.2.10 a	77 (point 3.1)
4.2.11	
4.2.11 a	77 (point 3.2)
4.2.12	
4.2.12 a	6
4.2.13	
4.2.13 a	32, 33
4.2.13 b	93, 94
4.2.14	
4.2.14 a	5
4.2.15	
4.2.15 a	38
4.2.15 b	101
4.2.17	
4.2.17 a	103
4.2.18	
4.2.18 a	84, 85
4.2.18 b	98
4.2.18 c	88
4.2.18 d	87
4.2.19	
4.2.19 a	84, 85
4.2.19 b	98

MANDATORY SPECIFICATIONS

Specifications

When a document listed in Table A 2 incorporates, by copying or by reference to, a clearly identifie



8.9.2023 EN Official Journal of the European Union L 222/481

Table A 2

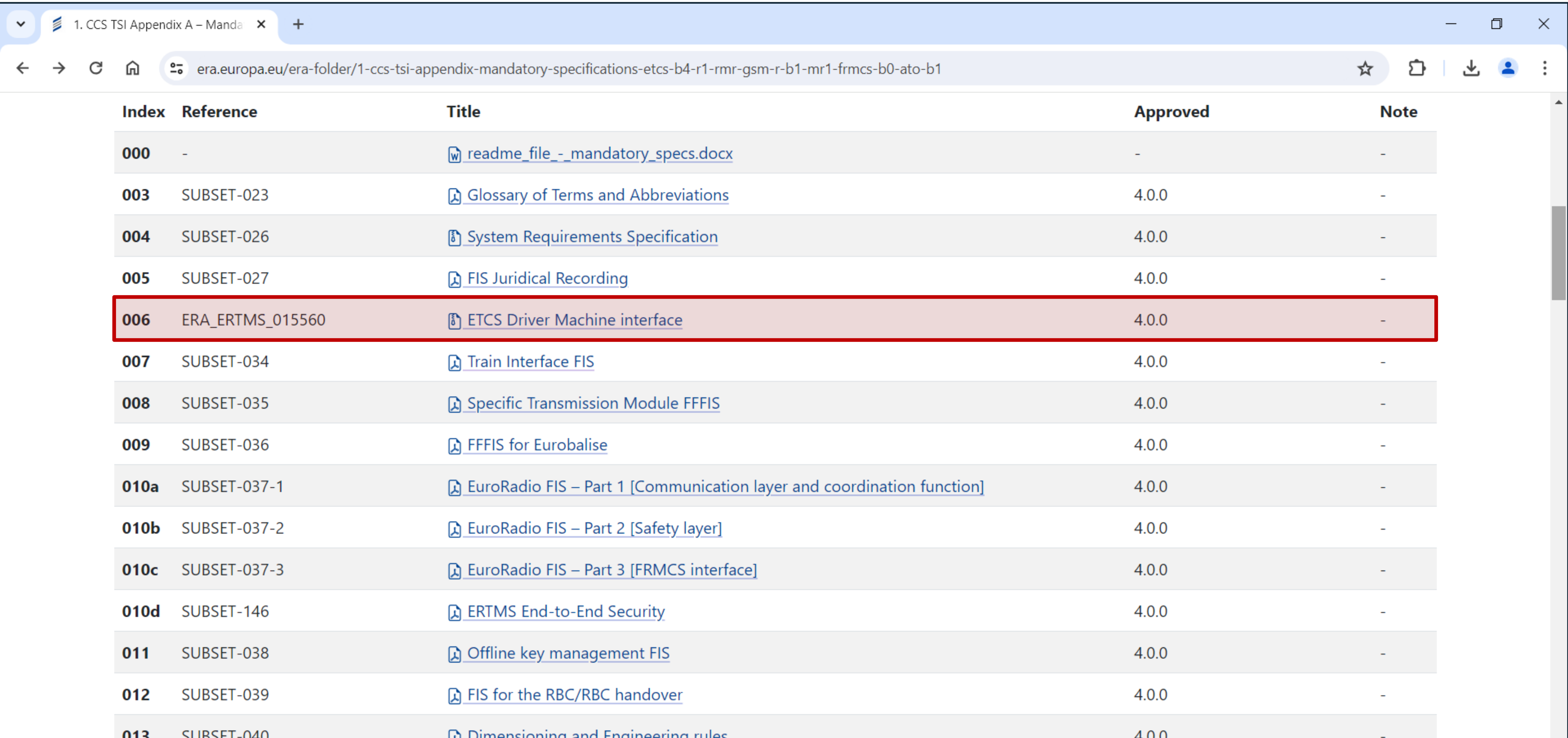
List of mandatory specifications

Index No	ETCS Baseline 4 Release 1; RMR: GSM-R Baseline 1 Maintenance Release 1 + FRMCS Baseline 0; ATO Baseline 1 Release 1			
	Reference	Name of Specification	Version	Notes
1	Intentionally deleted			
2	Intentionally deleted			
3	SUBSET-023	Glossary of Terms and Abbreviations	4.0.0	
4		cification	4.0.0	
5			4.0.0	
6	ERA_ERTMS_015560	ETCS Driver Machine interface	4.0.0	
7	SUBSET-034	Train Interface FIS	4.0.0	
8	SUBSET-035	Specific Transmission Module FFFIS	4.0.0	
9	SUBSET-036	FFFIS for Eurobalise	4.0.0	
10a	SUBSET-037-1	EuroRadio FIS GSM-R – Part 1 [Communication layer and coordination function]	4.0.0	
10b	SUBSET-037-2	EuroRadio FIS – Part 2 [Safety layer]	4.0.0	
10c	SUBSET-037-3	EuroRadio FIS – Part 3 [FRMCS interface]	4.0.0	
10d	SUBSET-146	ERTMS End-to-End Security	4.0.0	
11	SUBSET-038	Offline key management FIS	4.0.0	
12	SUBSET-039	FIS for the RBC/RBC handover	4.0.0	
13	SUBSET-040	Dimensioning and Engineering rules	4.0.0	
14	SUBSET-041	Performance Requirements for Interoperability	4.0.0	
15	Intentionally deleted			

OPEN INTERFACE STANDARDS

MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

TECHNICAL SPECIFICATIONS FOR INTEROPERABILITY – OPEN STANDARDS (CONT'D)



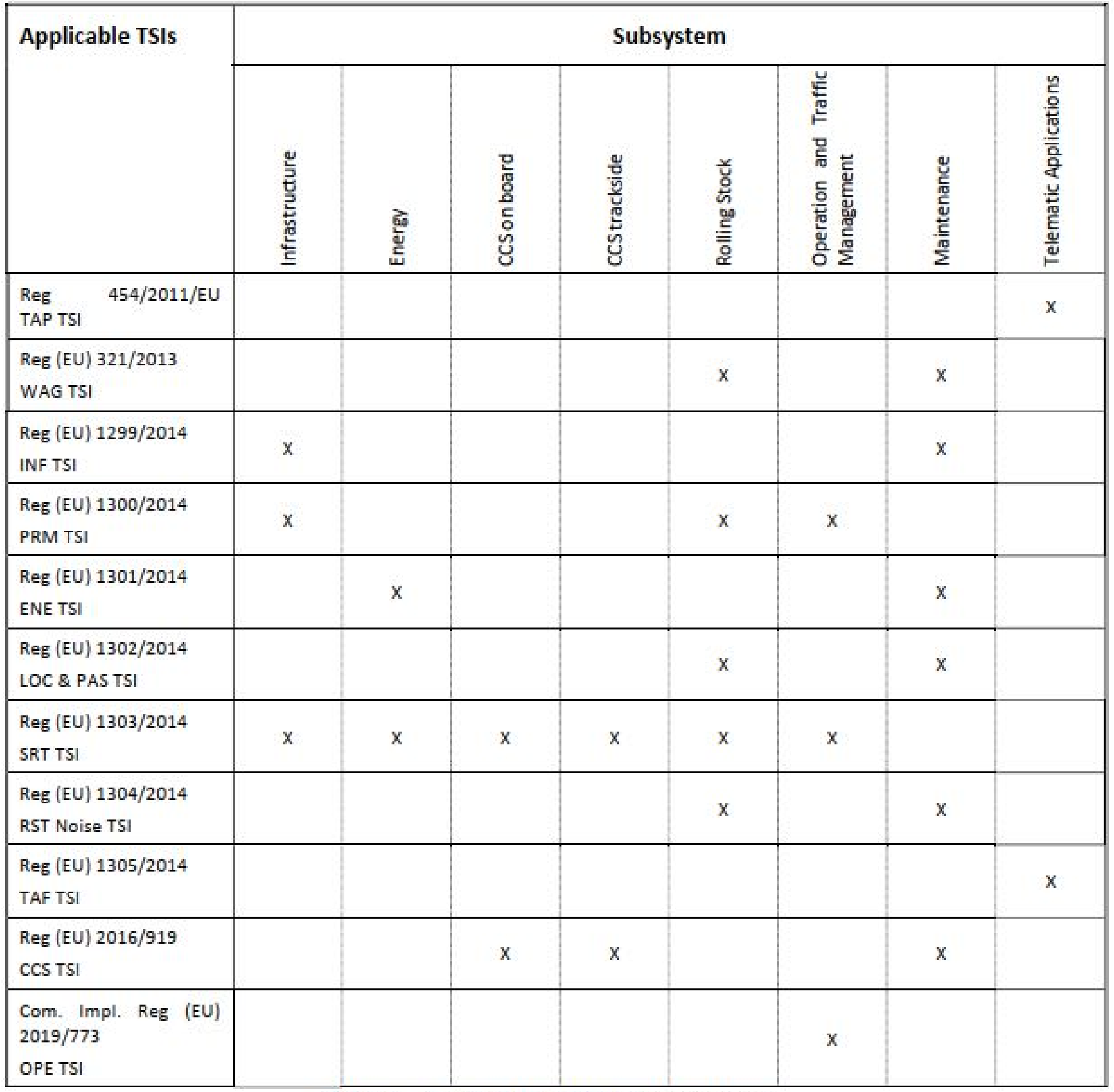
Index	Reference	Title	Approved	Note
000	-	readme_file_-_mandatory_specs.docx	-	-
003	SUBSET-023	Glossary of Terms and Abbreviations	4.0.0	-
004	SUBSET-026	System Requirements Specification	4.0.0	-
005	SUBSET-027	FIS Juridical Recording	4.0.0	-
006	ERA_ERTMS_015560	ETCS Driver Machine interface	4.0.0	-
007	SUBSET-034	Train Interface FIS	4.0.0	-
008	SUBSET-035	Specific Transmission Module FFFIS	4.0.0	-
009	SUBSET-036	FFFIS for Eurobalise	4.0.0	-
010a	SUBSET-037-1	EuroRadio FIS – Part 1 [Communication layer and coordination function]	4.0.0	-
010b	SUBSET-037-2	EuroRadio FIS – Part 2 [Safety layer]	4.0.0	-
010c	SUBSET-037-3	EuroRadio FIS – Part 3 [FRMCS interface]	4.0.0	-
010d	SUBSET-146	ERTMS End-to-End Security	4.0.0	-
011	SUBSET-038	Offline key management FIS	4.0.0	-
012	SUBSET-039	FIS for the RBC/RBC handover	4.0.0	-
013	SUBSET-040	Dimensioning and Engineering rules	4.0.0	-

PROGRESS

- Motivation
- Background, Challenges & Objectives
- Model-Based Systems Integration Framework
- MBSI Framework Development
  - Design Terms, Nomenclature
  - Requirements
  - Structure
  - Interfaces
- MBSI Framework Use
- Summary & Conclusion

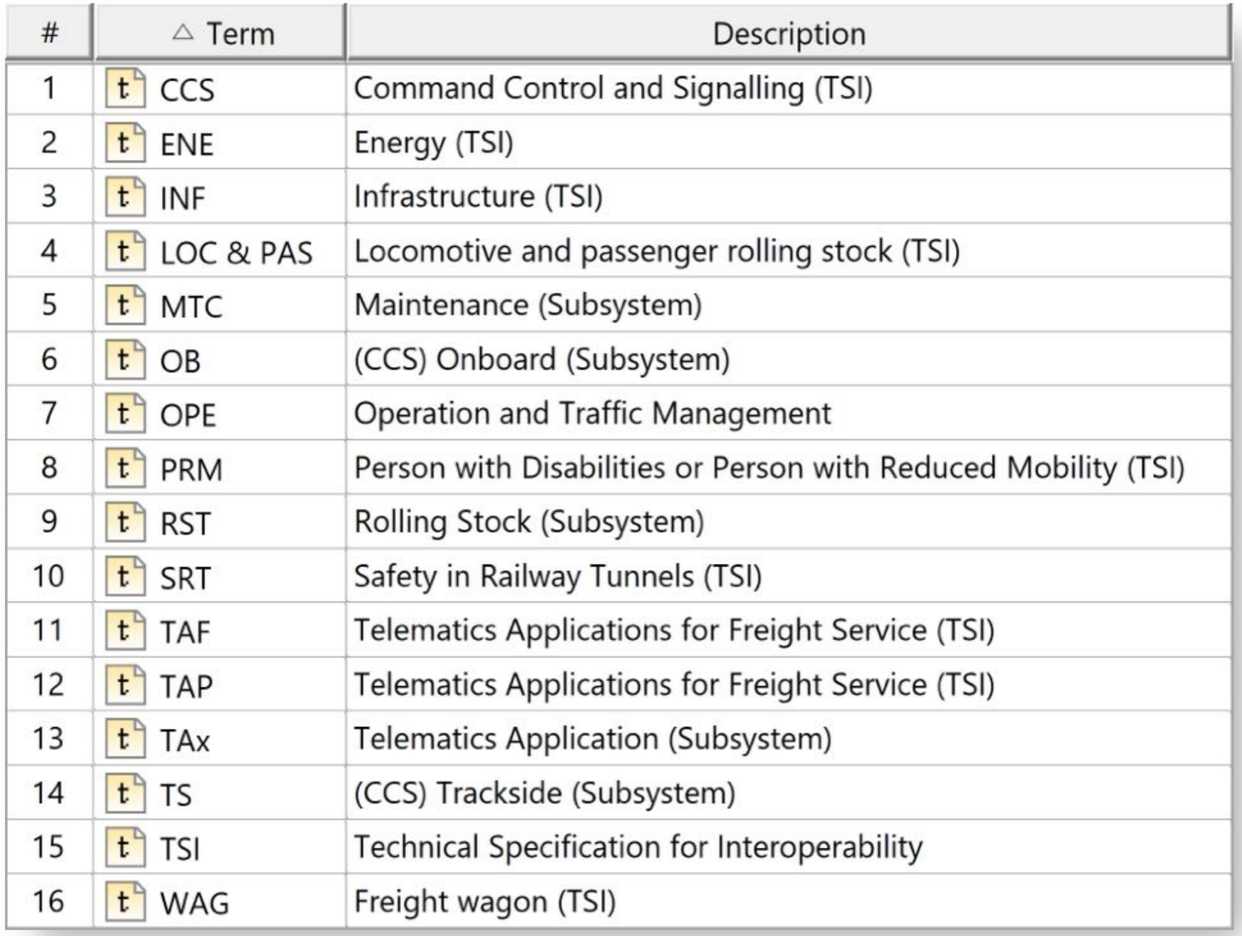
MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

MBSI REFERENCE ARCHITECTURE – DESIGN TERMS, NOMENCLATURE



Applicable TSIs	Subsystem							
	Infrastructure	Energy	CCS on board	CCS trackside	Rolling Stock	Operation and Traffic Management	Maintenance	Telematic Applications
Reg 454/2011/EU TAP TSI								x
Reg (EU) 321/2013 WAG TSI					x		x	
Reg (EU) 1299/2014 INF TSI	x						x	
Reg (EU) 1300/2014 PRM TSI	x				x	x		
Reg (EU) 1301/2014 ENE TSI		x					x	
Reg (EU) 1302/2014 LOC & PAS TSI					x		x	
Reg (EU) 1303/2014 SRT TSI	x	x	x	x	x	x		
Reg (EU) 1304/2014 RST Noise TSI					x		x	
Reg (EU) 1305/2014 TAF TSI								x
Reg (EU) 2016/919 CCS TSI			x	x			x	
Com. Impl. Reg (EU) 2019/773 OPE TSI						x		

Table 6 – Applicability of TSIs to subsystems

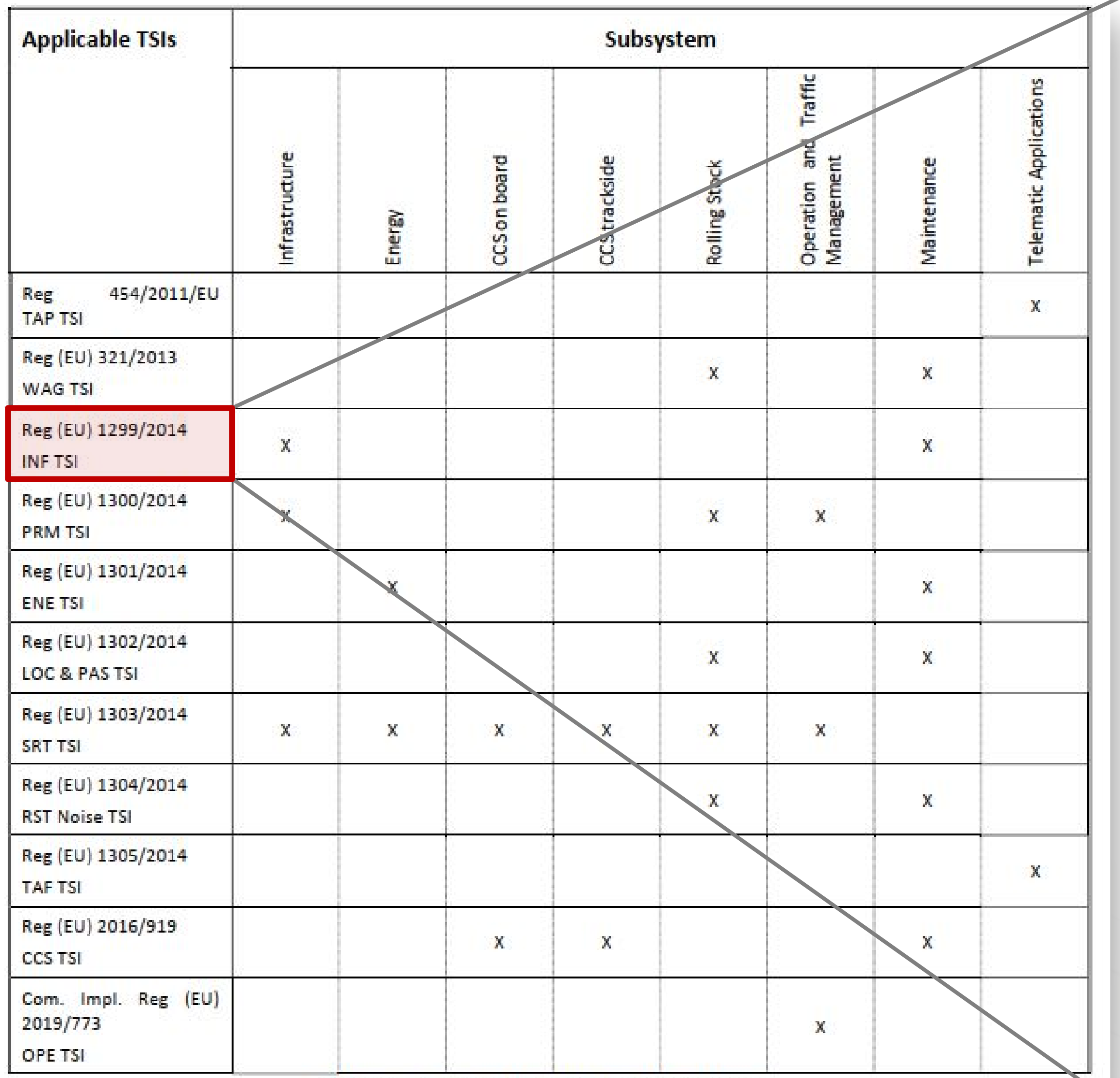


#	Term	Description
1	CCS	Command Control and Signalling (TSI)
2	ENE	Energy (TSI)
3	INF	Infrastructure (TSI)
4	LOC & PAS	Locomotive and passenger rolling stock (TSI)
5	MTC	Maintenance (Subsystem)
6	OB	(CCS) Onboard (Subsystem)
7	OPE	Operation and Traffic Management
8	PRM	Person with Disabilities or Person with Reduced Mobility (TSI)
9	RST	Rolling Stock (Subsystem)
10	SRT	Safety in Railway Tunnels (TSI)
11	TAF	Telematics Applications for Freight Service (TSI)
12	TAP	Telematics Applications for Freight Service (TSI)
13	TAx	Telematics Application (Subsystem)
14	TS	(CCS) Trackside (Subsystem)
15	TSI	Technical Specification for Interoperability
16	WAG	Freight wagon (TSI)

2023 GUIDE FOR THE APPLICATION OF THE TECHNICAL SPECIFICATIONS FOR INTEROPERABILITY (TSI)

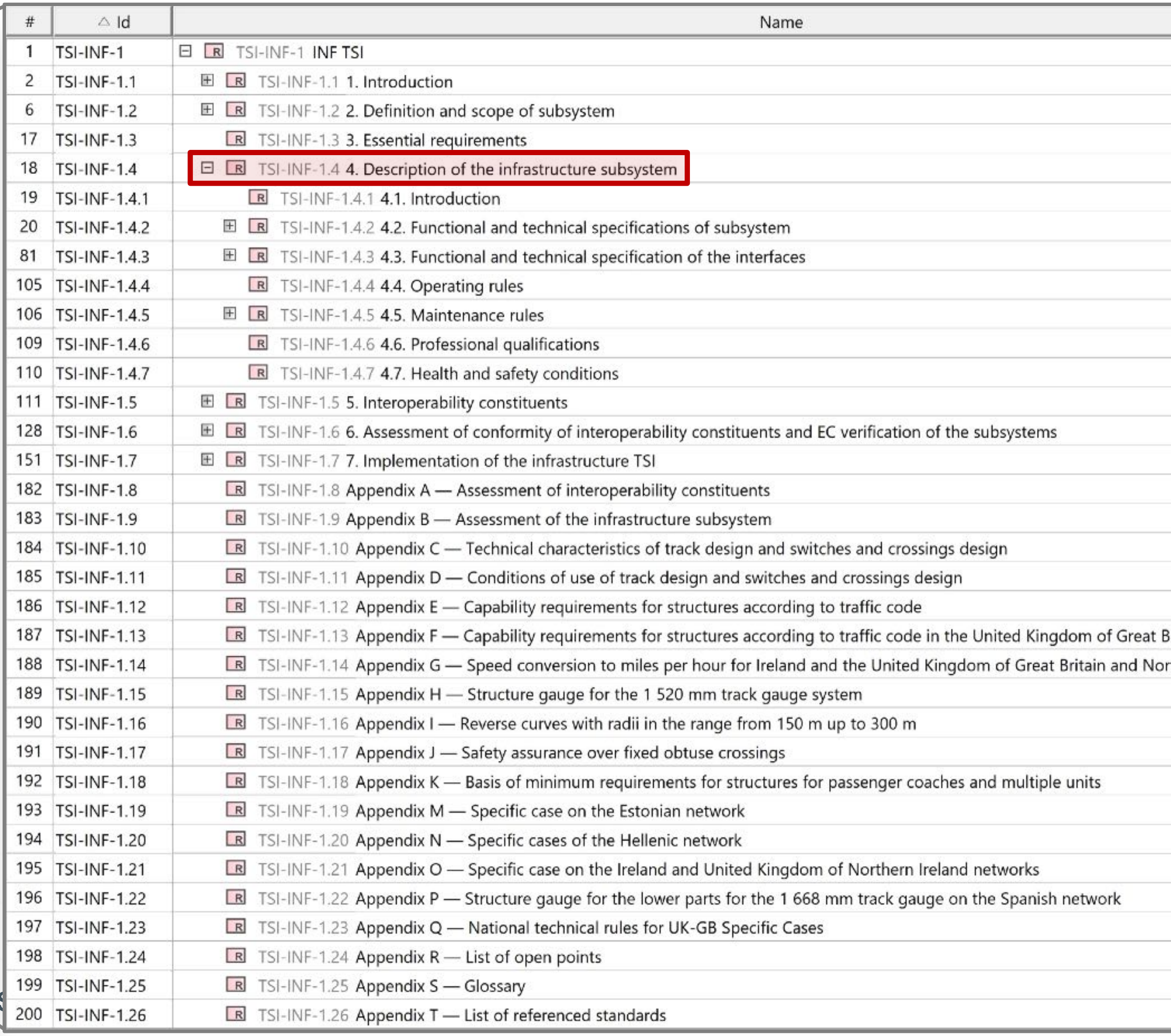
MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

MBSI REFERENCE ARCHITECTURE – REQUIREMENTS



Applicable TSIs	Subsystem							
	Infrastructure	Energy	CCS on board	CCS trackside	Rolling Stock	Operation and Traffic Management	Maintenance	Telematic Applications
Reg 454/2011/EU TAP TSI								x
Reg (EU) 321/2013 WAG TSI					x		x	
Reg (EU) 1299/2014 INF TSI	x						x	
Reg (EU) 1300/2014 PRM TSI	x				x	x		
Reg (EU) 1301/2014 ENE TSI		x					x	
Reg (EU) 1302/2014 LOC & PAS TSI					x		x	
Reg (EU) 1303/2014 SRT TSI	x	x	x	x	x	x		
Reg (EU) 1304/2014 RST Noise TSI					x		x	
Reg (EU) 1305/2014 TAF TSI								x
Reg (EU) 2016/919 CCS TSI			x	x			x	
Com. Impl. Reg (EU) 2019/773 OPE TSI						x		

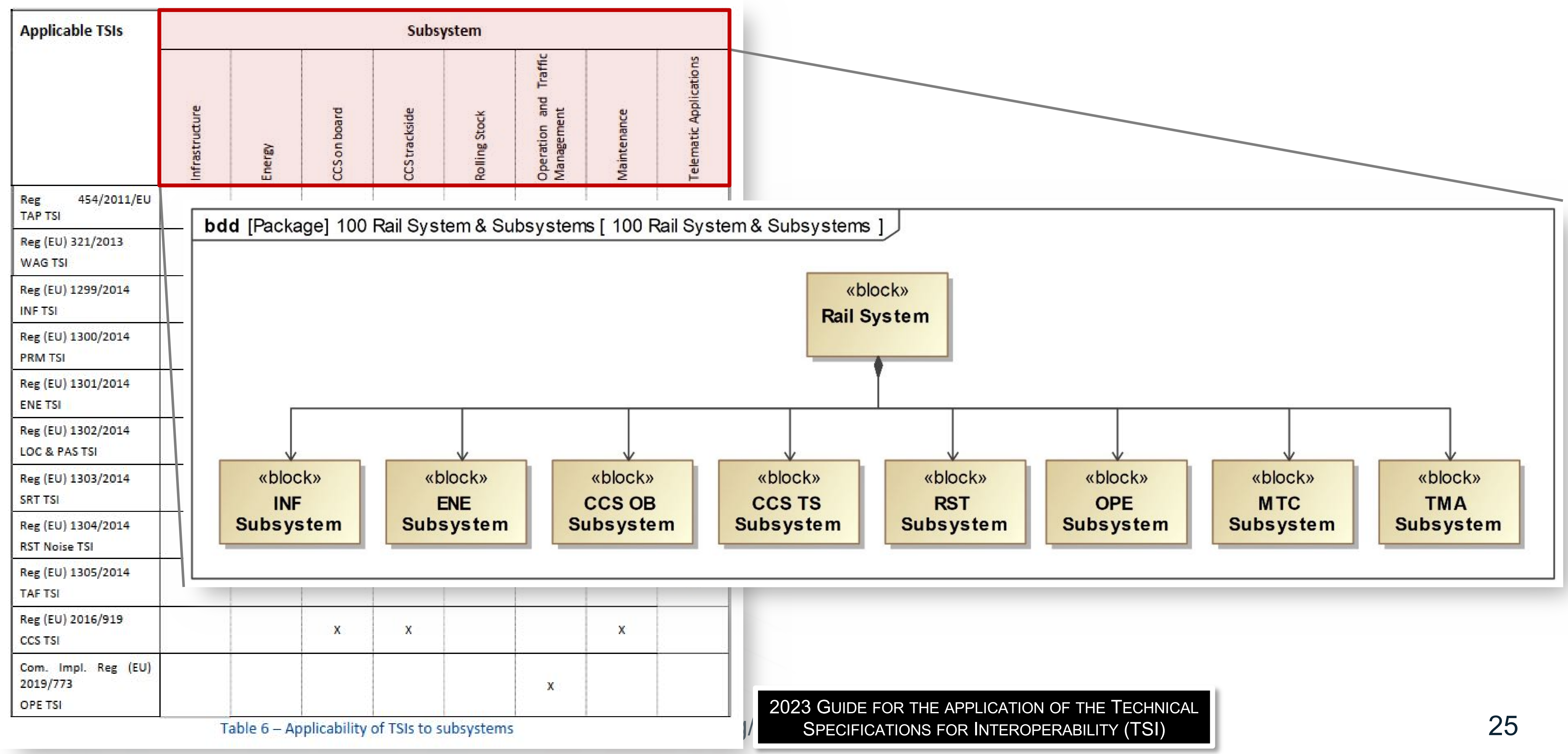
Table 6 – Applicability of TSIs to subsystems



#	Id	Name
1	TSI-INF-1	TSI-INF-1 INF TSI
2	TSI-INF-1.1	TSI-INF-1.1 1. Introduction
6	TSI-INF-1.2	TSI-INF-1.2 2. Definition and scope of subsystem
17	TSI-INF-1.3	TSI-INF-1.3 3. Essential requirements
18	TSI-INF-1.4	TSI-INF-1.4 4. Description of the infrastructure subsystem
19	TSI-INF-1.4.1	TSI-INF-1.4.1 4.1. Introduction
20	TSI-INF-1.4.2	TSI-INF-1.4.2 4.2. Functional and technical specifications of subsystem
81	TSI-INF-1.4.3	TSI-INF-1.4.3 4.3. Functional and technical specification of the interfaces
105	TSI-INF-1.4.4	TSI-INF-1.4.4 4.4. Operating rules
106	TSI-INF-1.4.5	TSI-INF-1.4.5 4.5. Maintenance rules
109	TSI-INF-1.4.6	TSI-INF-1.4.6 4.6. Professional qualifications
110	TSI-INF-1.4.7	TSI-INF-1.4.7 4.7. Health and safety conditions
111	TSI-INF-1.5	TSI-INF-1.5 5. Interoperability constituents
128	TSI-INF-1.6	TSI-INF-1.6 6. Assessment of conformity of interoperability constituents and EC verification of the subsystems
151	TSI-INF-1.7	TSI-INF-1.7 7. Implementation of the infrastructure TSI
182	TSI-INF-1.8	TSI-INF-1.8 Appendix A — Assessment of interoperability constituents
183	TSI-INF-1.9	TSI-INF-1.9 Appendix B — Assessment of the infrastructure subsystem
184	TSI-INF-1.10	TSI-INF-1.10 Appendix C — Technical characteristics of track design and switches and crossings design
185	TSI-INF-1.11	TSI-INF-1.11 Appendix D — Conditions of use of track design and switches and crossings design
186	TSI-INF-1.12	TSI-INF-1.12 Appendix E — Capability requirements for structures according to traffic code
187	TSI-INF-1.13	TSI-INF-1.13 Appendix F — Capability requirements for structures according to traffic code in the United Kingdom of Great B
188	TSI-INF-1.14	TSI-INF-1.14 Appendix G — Speed conversion to miles per hour for Ireland and the United Kingdom of Great Britain and Nor
189	TSI-INF-1.15	TSI-INF-1.15 Appendix H — Structure gauge for the 1 520 mm track gauge system
190	TSI-INF-1.16	TSI-INF-1.16 Appendix I — Reverse curves with radii in the range from 150 m up to 300 m
191	TSI-INF-1.17	TSI-INF-1.17 Appendix J — Safety assurance over fixed obtuse crossings
192	TSI-INF-1.18	TSI-INF-1.18 Appendix K — Basis of minimum requirements for structures for passenger coaches and multiple units
193	TSI-INF-1.19	TSI-INF-1.19 Appendix M — Specific case on the Estonian network
194	TSI-INF-1.20	TSI-INF-1.20 Appendix N — Specific cases of the Hellenic network
195	TSI-INF-1.21	TSI-INF-1.21 Appendix O — Specific case on the Ireland and United Kingdom of Northern Ireland networks
196	TSI-INF-1.22	TSI-INF-1.22 Appendix P — Structure gauge for the lower parts for the 1 668 mm track gauge on the Spanish network
197	TSI-INF-1.23	TSI-INF-1.23 Appendix Q — National technical rules for UK-GB Specific Cases
198	TSI-INF-1.24	TSI-INF-1.24 Appendix R — List of open points
199	TSI-INF-1.25	TSI-INF-1.25 Appendix S — Glossary
200	TSI-INF-1.26	TSI-INF-1.26 Appendix T — List of referenced standards

MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

MBSI REFERENCE ARCHITECTURE – STRUCTURE



Applicable TSIs	Subsystem							
	Infrastructure	Energy	CCS on board	CCS trackside	Rolling Stock	Operation and Traffic Management	Maintenance	Telematic Applications
Reg 454/2011/EU TAP TSI								
Reg (EU) 321/2013 WAG TSI								
Reg (EU) 1299/2014 INF TSI								
Reg (EU) 1300/2014 PRM TSI								
Reg (EU) 1301/2014 ENE TSI								
Reg (EU) 1302/2014 LOC & PAS TSI								
Reg (EU) 1303/2014 SRT TSI								
Reg (EU) 1304/2014 RST Noise TSI								
Reg (EU) 1305/2014 TAF TSI								
Reg (EU) 2016/919 CCS TSI			x	x			x	
Com. Impl. Reg (EU) 2019/773 OPE TSI						x		

Table 6 – Applicability of TSIs to subsystems

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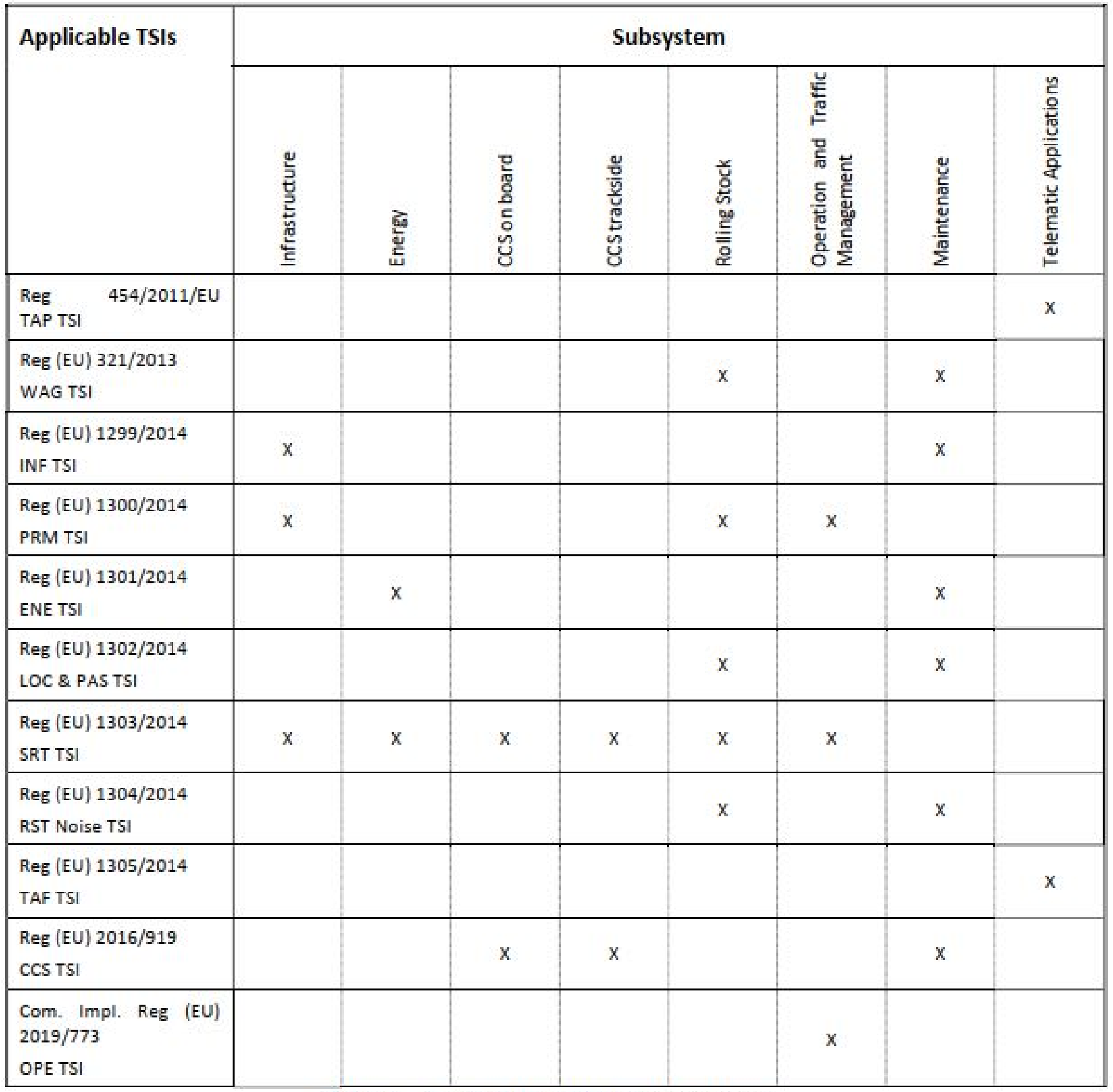
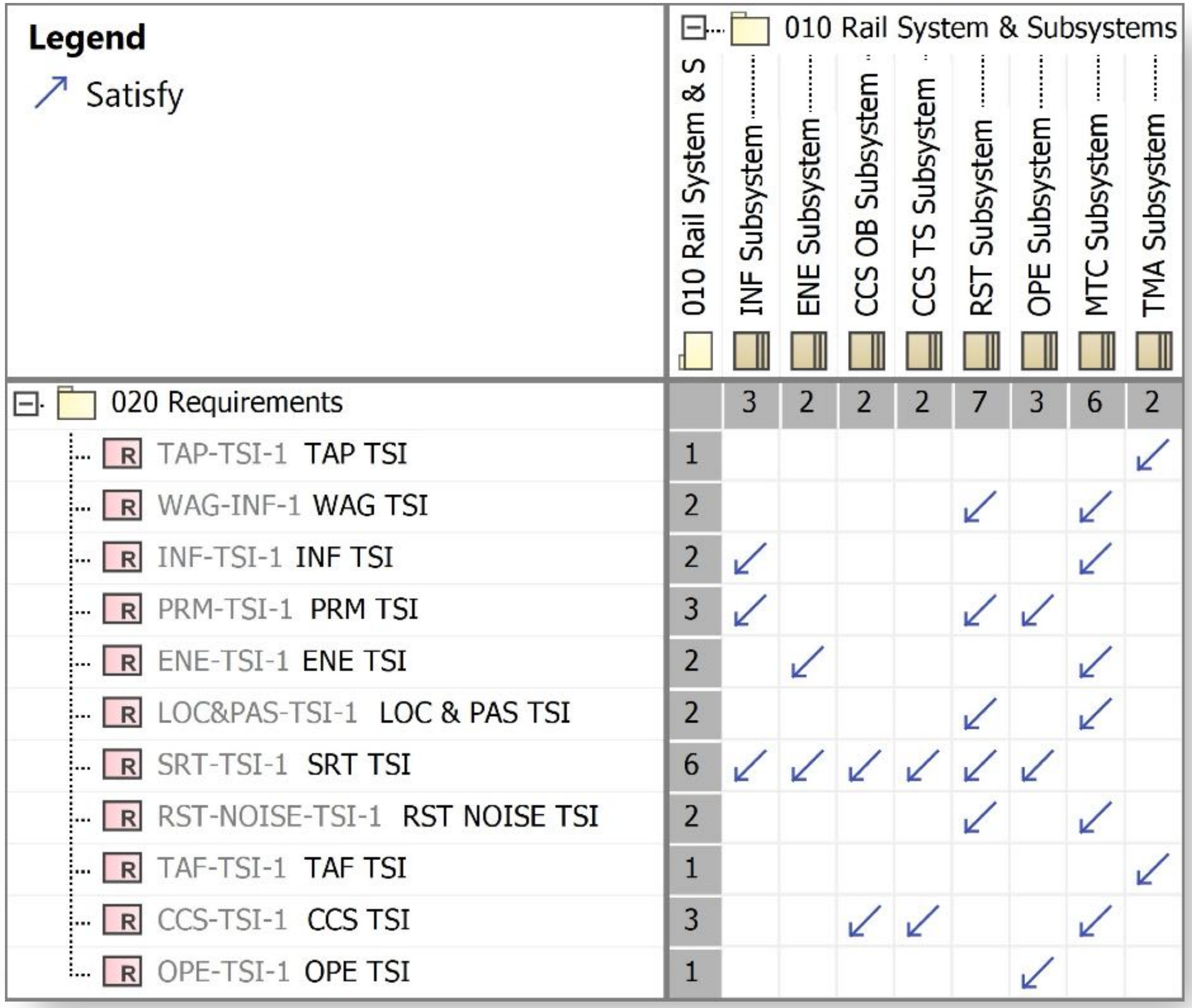
MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

MBSI REFERENCE ARCHITECTURE – SATISFY REQUIREMENTS MATRIX



Applicable TSIs	Subsystem							
	Infrastructure	Energy	CCS on board	CCS trackside	Rolling Stock	Operation and Traffic Management	Maintenance	Telematic Applications
Reg 454/2011/EU TAP TSI								x
Reg (EU) 321/2013 WAG TSI					x		x	
Reg (EU) 1299/2014 INF TSI	x						x	
Reg (EU) 1300/2014 PRM TSI	x				x	x		
Reg (EU) 1301/2014 ENE TSI		x					x	
Reg (EU) 1302/2014 LOC & PAS TSI					x		x	
Reg (EU) 1303/2014 SRT TSI	x	x	x	x	x	x		
Reg (EU) 1304/2014 RST Noise TSI					x		x	
Reg (EU) 1305/2014 TAF TSI								x
Reg (EU) 2016/919 CCS TSI			x	x			x	
Com. Impl. Reg (EU) 2019/773 OPE TSI						x		

Table 6 – Applicability of TSIs to subsystems



Legend

↗ Satisfy

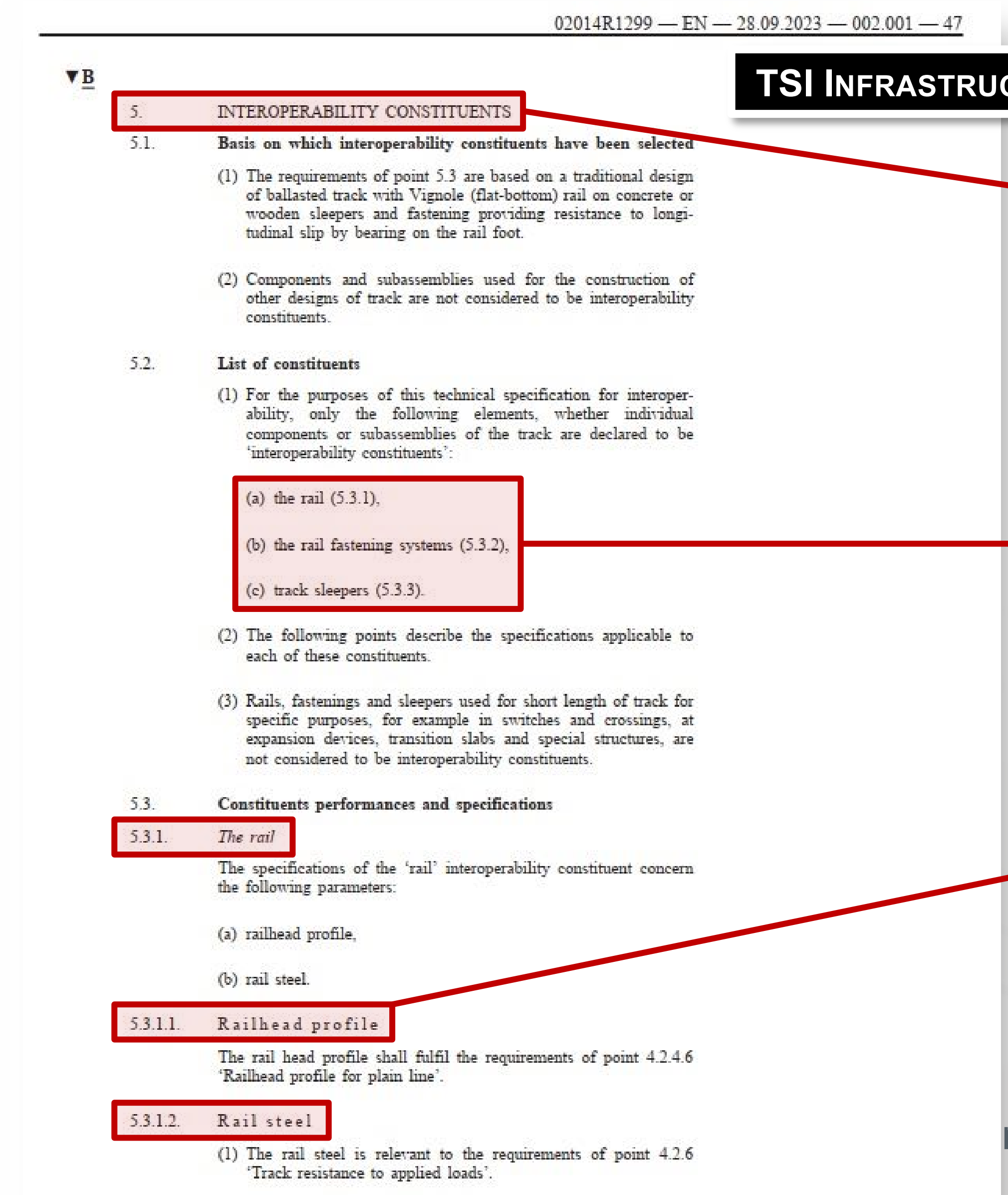
010 Rail System & Subsystems	010 Rail System & S	INF Subsystem	ENE Subsystem	CCS OB Subsystem	CCS TS Subsystem	RST Subsystem	OPE Subsystem	MTC Subsystem	TMA Subsystem
020 Requirements		3	2	2	2	7	3	6	2
R TAP-TSI-1 TAP TSI	1								↙
R WAG-INF-1 WAG TSI	2					↙		↙	
R INF-TSI-1 INF TSI	2	↙						↙	
R PRM-TSI-1 PRM TSI	3	↙				↙	↙		
R ENE-TSI-1 ENE TSI	2		↙					↙	
R LOC&PAS-TSI-1 LOC & PAS TSI	2					↙		↙	
R SRT-TSI-1 SRT TSI	6	↙	↙	↙	↙	↙	↙		
R RST-NOISE-TSI-1 RST NOISE TSI	2					↙		↙	
R TAF-TSI-1 TAF TSI	1								↙
R CCS-TSI-1 CCS TSI	3			↙	↙			↙	
R OPE-TSI-1 OPE TSI	1						↙		

2023 GUIDE FOR THE APPLICATION OF THE TECHNICAL SPECIFICATIONS FOR INTEROPERABILITY (TSI)

MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

SUBSYSTEM ELEMENTS – INTEROPERABILITY CONSTITUENTS (INF – RAIL)

TSI INFRASTRUCTURE



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▼B

5. INTEROPERABILITY CONSTITUENTS

5.1. **Basis on which interoperability constituents have been selected**

(1) The requirements of point 5.3 are based on a traditional design of ballasted track with Vignole (flat-bottom) rail on concrete or wooden sleepers and fastening providing resistance to longitudinal slip by bearing on the rail foot.

(2) Components and subassemblies used for the construction of other designs of track are not considered to be interoperability constituents.

5.2. **List of constituents**

(1) For the purposes of this technical specification for interoperability, only the following elements, whether individual components or subassemblies of the track are declared to be 'interoperability constituents':

(a) the rail (5.3.1),

(b) the rail fastening systems (5.3.2),

(c) track sleepers (5.3.3).

(2) The following points describe the specifications applicable to each of these constituents.

(3) Rails, fastenings and sleepers used for short length of track for specific purposes, for example in switches and crossings, at expansion devices, transition slabs and special structures, are not considered to be interoperability constituents.

5.3. **Constituents performances and specifications**

5.3.1. *The rail*

The specifications of the 'rail' interoperability constituent concern the following parameters:

(a) railhead profile,

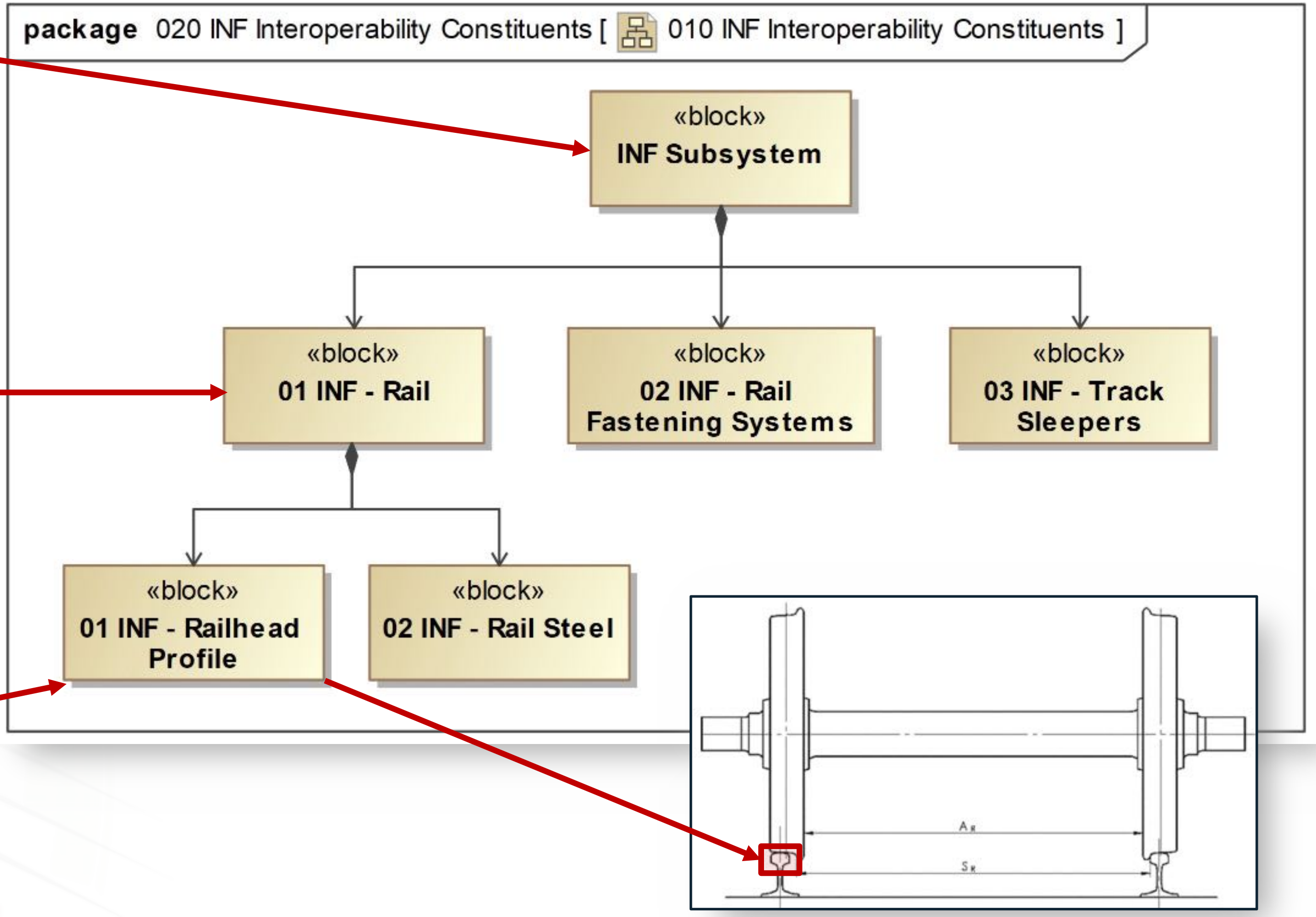
(b) rail steel.

5.3.1.1. Railhead profile

The rail head profile shall fulfil the requirements of point 4.2.4.6 'Railhead profile for plain line'.

5.3.1.2. Rail steel

(1) The rail steel is relevant to the requirements of point 4.2.6 'Track resistance to applied loads'.



MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

SUBSYSTEM ELEMENTS – INTEROPERABILITY CONSTITUENTS REQUIREMENTS

TSI INFRASTRUCTURE

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▼B

5. INTEROPERABILITY CONSTITUENTS

5.1. **Basis on which interoperability constituents have been selected**

(1) The requirements of point 5.3 are based on a traditional design of ballasted track with Vignole (flat-bottom) rail on concrete or wooden sleepers and fastening providing resistance to longitudinal slip by bearing on the rail foot.

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5.2. **List of constituents**

(1) For the purposes of this technical specification for interoperability, only the following elements, whether individual components or subassemblies of the track are declared to be 'interoperability constituents':

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(b) the rail fastening systems (5.3.2),

(c) track sleepers (5.3.3).

(2) The following points describe the specifications applicable to each of these constituents.

(3) Rails, fastenings and sleepers used for short length of track for specific purposes, for example in switches and crossings, at expansion devices, transition slabs and special structures, are not considered to be interoperability constituents.

5.3. **Constituents performances and specifications**

5.3.1. *The rail*

The specifications of the 'rail' interoperability constituent concern the following parameters:

(a) railhead profile,

(b) rail steel.

STRUCTURE

5.3.1.1. Railhead profile

The rail head profile shall fulfil the requirements of point 4.2.4.6 'Railhead profile for plain line'.

5.3.1.2. Rail steel

(1) The rail steel is relevant to the requirements of point 4.2.6 'Track resistance to applied loads'.

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(5) Instead of points (1) to (4), for the 1 520 mm track gauge system, no assessment of equivalent conicity is required.

4.2.4.6. Railhead profile for plain line

REQUIREMENTS

▼M2

(1) The railhead profile shall be selected from the range set out in one of the specifications referenced in Appendix T, Index [7] and Index [8], or shall be in accordance with point (2).

▼B

(2) The design of railhead profiles for plain line shall comprise:

(a) a lateral slope on the side of the railhead angled to between vertical and 1/16 with reference to the vertical axis of the railhead;

(b) the vertical distance between the top of this lateral slope and the top of the rail shall be less than 20 mm;

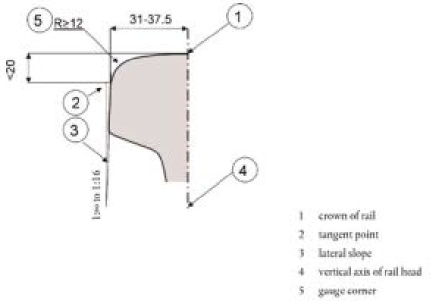
(c) a radius of at least 12 mm at the gauge corner;

(d) the horizontal distance between the crown of the rail and the tangent point shall be between 31 and 37,5 mm.

▼M1

Figure 1

Railhead profile

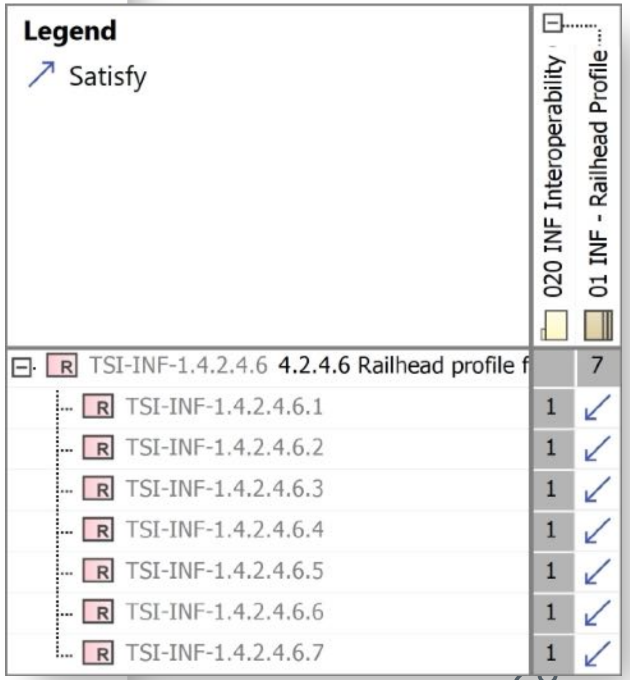


▼B

(3) These requirements are not applicable to expansion devices.

4.2.4.7. Rail inclination

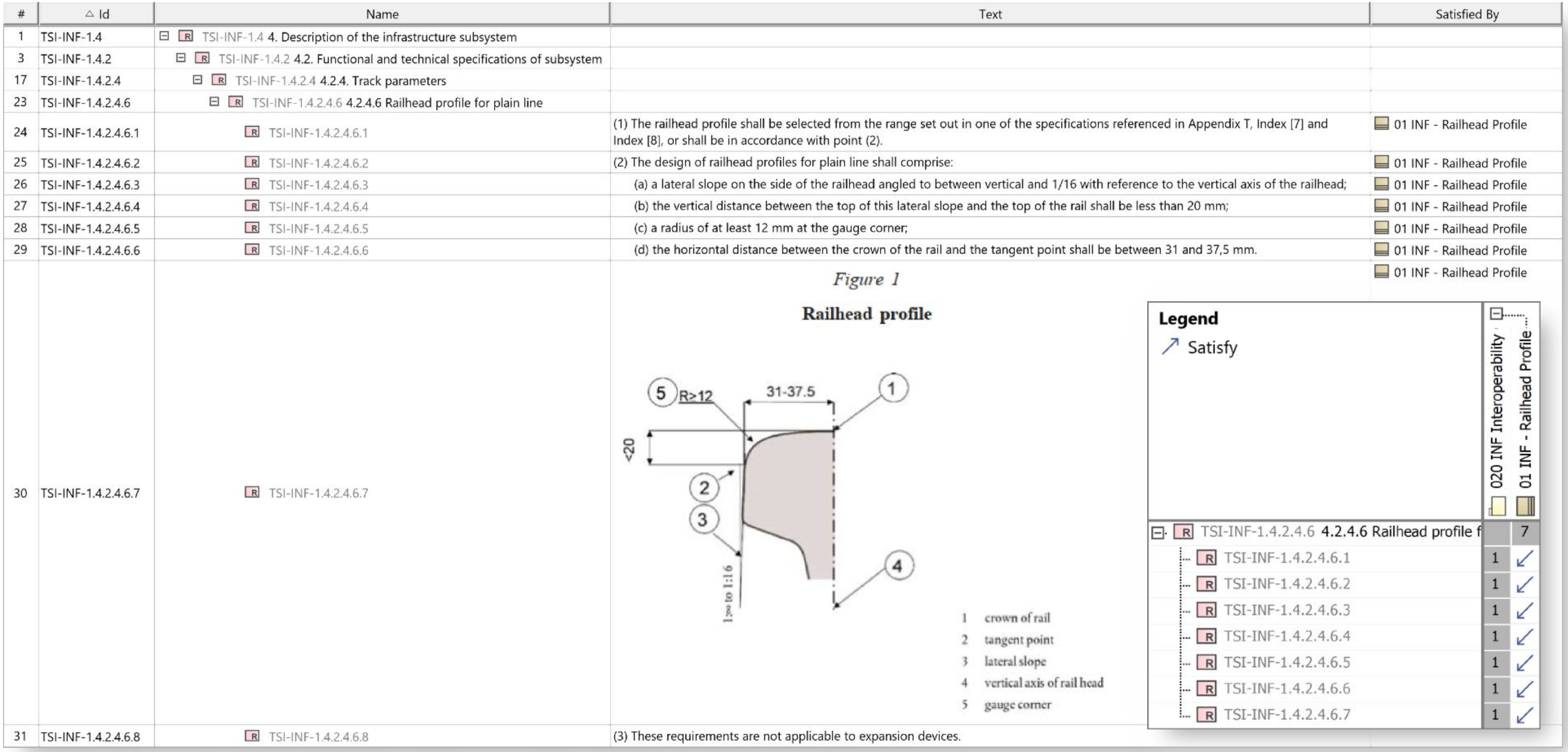
4.2.4.7.1. Plain line



	020 INF Interoperability	01 INF - Railhead Profile
⊟ R TSI-INF-1.4.2.4.6 **4.2.4.6 Railhead profile f**		7
R TSI-INF-1.4.2.4.6.1	1	↙
R TSI-INF-1.4.2.4.6.2	1	↙
R TSI-INF-1.4.2.4.6.3	1	↙
R TSI-INF-1.4.2.4.6.4	1	↙
R TSI-INF-1.4.2.4.6.5	1	↙
R TSI-INF-1.4.2.4.6.6	1	↙
R TSI-INF-1.4.2.4.6.7	1	↙

MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

SUBSYSTEM ELEMENTS – INTEROPERABILITY CONSTITUENTS REQUIREMENTS (CONT'D)



#	△ Id	Name	Text	Satisfied By
1	TSI-INF-1.4	⊟ R TSI-INF-1.4 4. Description of the infrastructure subsystem		
3	TSI-INF-1.4.2	⊟ R TSI-INF-1.4.2 4.2. Functional and technical specifications of subsystem		
17	TSI-INF-1.4.2.4	⊟ R TSI-INF-1.4.2.4 4.2.4. Track parameters		
23	TSI-INF-1.4.2.4.6	⊟ R TSI-INF-1.4.2.4.6 4.2.4.6 Railhead profile for plain line		
24	TSI-INF-1.4.2.4.6.1	R TSI-INF-1.4.2.4.6.1	(1) The railhead profile shall be selected from the range set out in one of the specifications referenced in Appendix T, Index [7] and Index [8], or shall be in accordance with point (2).	01 INF - Railhead Profile
25	TSI-INF-1.4.2.4.6.2	R TSI-INF-1.4.2.4.6.2	(2) The design of railhead profiles for plain line shall comprise:	01 INF - Railhead Profile
26	TSI-INF-1.4.2.4.6.3	R TSI-INF-1.4.2.4.6.3	(a) a lateral slope on the side of the railhead angled to between vertical and 1/16 with reference to the vertical axis of the railhead;	01 INF - Railhead Profile
27	TSI-INF-1.4.2.4.6.4	R TSI-INF-1.4.2.4.6.4	(b) the vertical distance between the top of this lateral slope and the top of the rail shall be less than 20 mm;	01 INF - Railhead Profile
28	TSI-INF-1.4.2.4.6.5	R TSI-INF-1.4.2.4.6.5	(c) a radius of at least 12 mm at the gauge corner;	01 INF - Railhead Profile
29	TSI-INF-1.4.2.4.6.6	R TSI-INF-1.4.2.4.6.6	(d) the horizontal distance between the crown of the rail and the tangent point shall be between 31 and 37,5 mm.	01 INF - Railhead Profile
30	TSI-INF-1.4.2.4.6.7	R TSI-INF-1.4.2.4.6.7	*Figure 1* **Railhead profile** 1 crown of rail 2 tangent point 3 lateral slope 4 vertical axis of rail head 5 gauge corner	01 INF - Railhead Profile
31	TSI-INF-1.4.2.4.6.8	R TSI-INF-1.4.2.4.6.8	(3) These requirements are not applicable to expansion devices.	

Legend

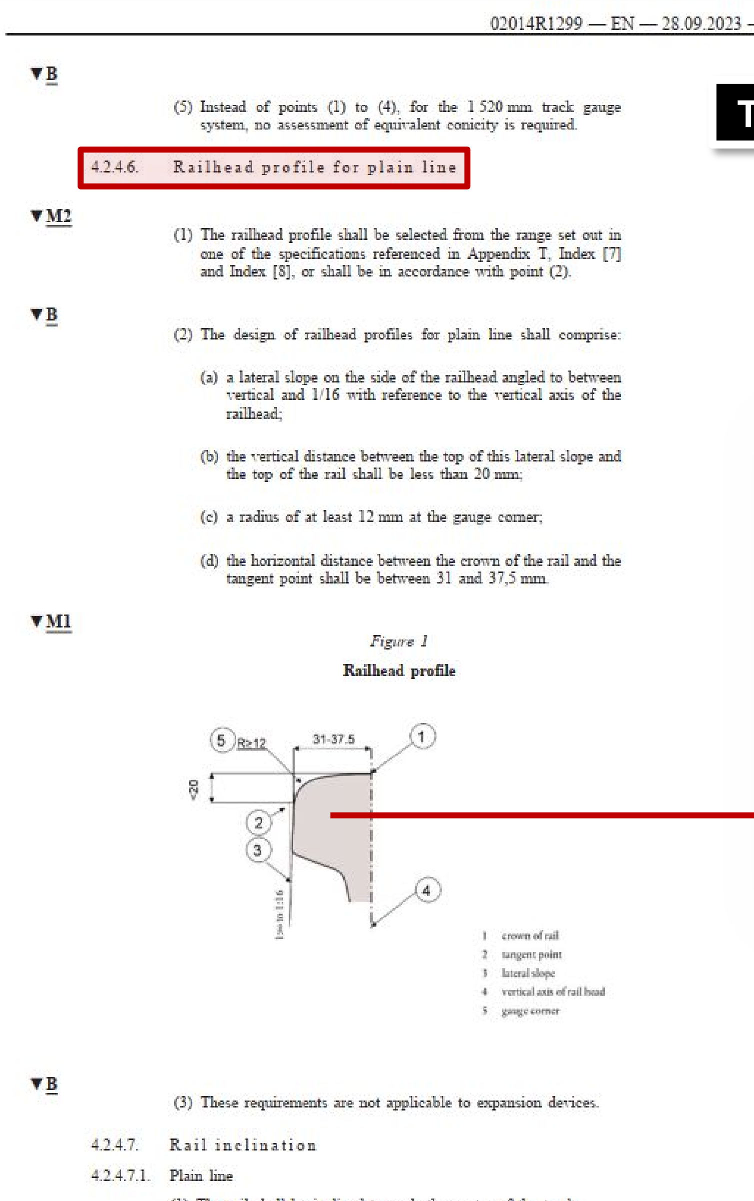
↗ Satisfy

	020 INF Interoperability	01 INF - Railhead Profile
⊟ R TSI-INF-1.4.2.4.6 4.2.4.6 Railhead profile f		7
R TSI-INF-1.4.2.4.6.1	1	↙
R TSI-INF-1.4.2.4.6.2	1	↙
R TSI-INF-1.4.2.4.6.3	1	↙
R TSI-INF-1.4.2.4.6.4	1	↙
R TSI-INF-1.4.2.4.6.5	1	↙
R TSI-INF-1.4.2.4.6.6	1	↙
R TSI-INF-1.4.2.4.6.7	1	↙

MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

INTERFACE IDENTIFICATION

TSI INFRASTRUCTURE



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▼B

(5) Instead of points (1) to (4), for the 1 520 mm track gauge system, no assessment of equivalent conicity is required.

4.2.4.6. Railhead profile for plain line

▼M2

(1) The railhead profile shall be selected from the range set out in one of the specifications referenced in Appendix T, Index [7] and Index [8], or shall be in accordance with point (2).

▼B

(2) The design of railhead profiles for plain line shall comprise:

(a) a lateral slope on the side of the railhead angled to between vertical and 1/16 with reference to the vertical axis of the railhead;

(b) the vertical distance between the top of this lateral slope and the top of the rail shall be less than 20 mm;

(c) a radius of at least 12 mm at the gauge corner;

(d) the horizontal distance between the crown of the rail and the tangent point shall be between 31 and 37,5 mm.

▼M1

Figure 1

Railhead profile

1 crown of rail
2 tangent point
3 lateral slope
4 vertical axis of rail head
5 gauge corner

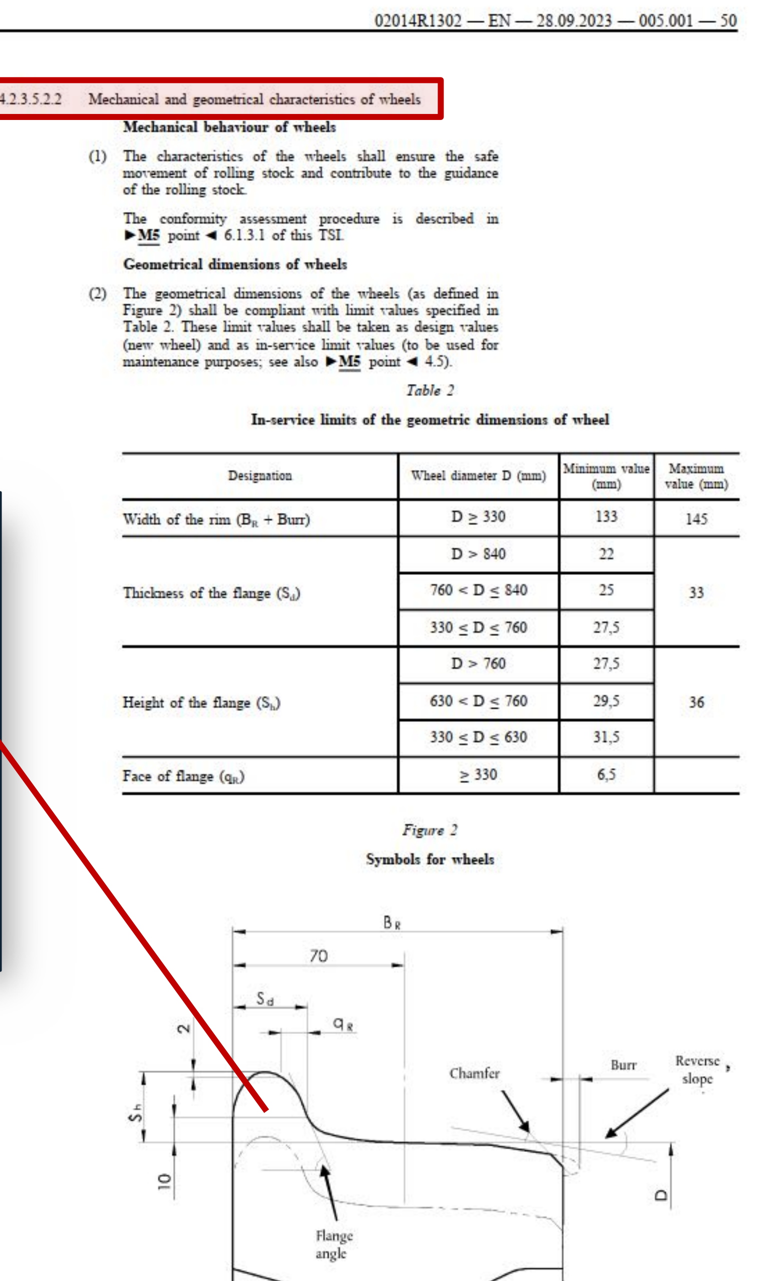
▼B

(3) These requirements are not applicable to expansion devices.

4.2.4.7. Rail inclination

4.2.4.7.1. Plain line

TSI ROLLING STOCK (LOC&PAS)



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4.2.3.5.2.2 Mechanical and geometrical characteristics of wheels

Mechanical behaviour of wheels

(1) The characteristics of the wheels shall ensure the safe movement of rolling stock and contribute to the guidance of the rolling stock.

The conformity assessment procedure is described in ►M5 point ◄ 6.1.3.1 of this TSI.

Geometrical dimensions of wheels

(2) The geometrical dimensions of the wheels (as defined in Figure 2) shall be compliant with limit values specified in Table 2. These limit values shall be taken as design values (new wheel) and as in-service limit values (to be used for maintenance purposes; see also ►M5 point ◄ 4.5).

Table 2

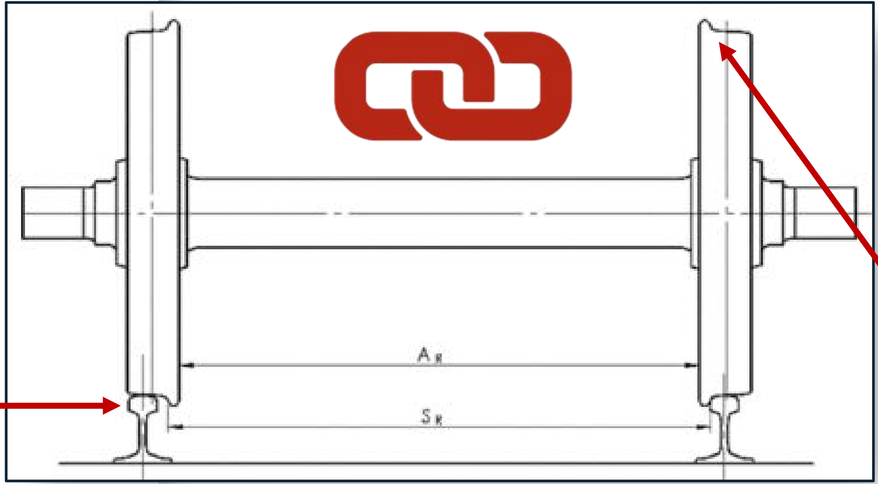
In-service limits of the geometric dimensions of wheel

Designation	Wheel diameter D (mm)	Minimum value (mm)	Maximum value (mm)
Width of the rim (B_R + Burr)	D ≥ 330	133	145
Thickness of the flange (S_d)	D > 840	22	33
	760 < D ≤ 840	25	
	330 ≤ D ≤ 760	27,5	
Height of the flange (S_h)	D > 760	27,5	36
	630 < D ≤ 760	29,5	
	330 ≤ D ≤ 630	31,5	
Face of flange (q_R)	≥ 330	6,5	

Figure 2

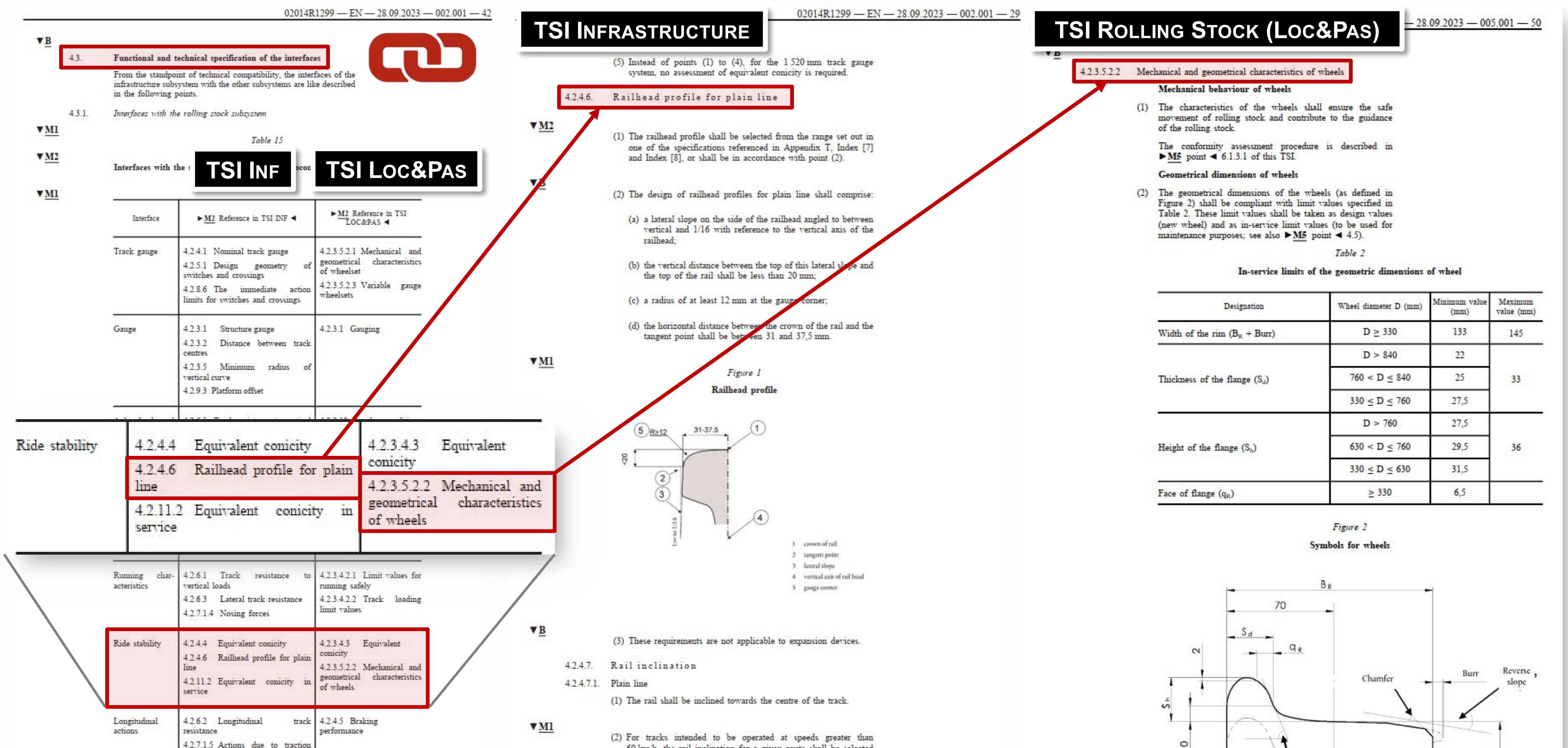
Symbols for wheels

INTERFACE BETWEEN
INF RAILHEAD PROFILE &
RST WHEEL CHARACTERISTICS



MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

INTERFACE IDENTIFICATION: TSI INTERFACE TABLES



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▼B

4.3. Functional and technical specification of the interfaces

From the standpoint of technical compatibility, the interfaces of the infrastructure subsystem with the other subsystems are like described in the following points.

4.3.1. *Interfaces with the rolling stock subsystem*

▼M1

Table 15

▼M2

Interfaces with the

TSI INF

TSI LOC&PAS

▼M1

Interface	►M2 Reference in TSI INF ◄	►M2 Reference in TSI LOC&PAS ◄
Track gauge	4.2.4.1 Nominal track gauge 4.2.5.1 Design geometry of switches and crossings 4.2.8.6 The immediate action limits for switches and crossings	4.2.3.5.2.1 Mechanical and geometrical characteristics of wheelset 4.2.3.5.2.3 Variable gauge wheelsets
Gauge	4.2.3.1 Structure gauge 4.2.3.2 Distance between track centres 4.2.3.5 Minimum radius of vertical curve 4.2.9.3 Platform offset	4.2.3.1 Gauging
Running characteristics	4.2.6.1 Track resistance to vertical loads 4.2.6.3 Lateral track resistance 4.2.7.1.4 Nosing forces	4.2.3.4.2.1 Limit values for running safely 4.2.3.4.2.2 Track loading limit values
Ride stability	4.2.4.4 Equivalent conicity 4.2.4.6 Railhead profile for plain line 4.2.11.2 Equivalent conicity in service	4.2.3.4.3 Equivalent conicity 4.2.3.5.2.2 Mechanical and geometrical characteristics of wheels
Longitudinal actions	4.2.6.2 Longitudinal track resistance 4.2.7.1.5 Actions due to traction	4.2.4.5 Braking performance

Ride stability	4.2.4.4 Equivalent conicity 4.2.4.6 Railhead profile for plain line 4.2.11.2 Equivalent conicity in service	4.2.3.4.3 Equivalent conicity 4.2.3.5.2.2 Mechanical and geometrical characteristics of wheels

TSI INFRASTRUCTURE

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(5) Instead of points (1) to (4), for the 1 520 mm track gauge system, no assessment of equivalent conicity is required.

4.2.4.6. Railhead profile for plain line

▼M2

(1) The railhead profile shall be selected from the range set out in one of the specifications referenced in Appendix T, Index [7] and Index [8], or shall be in accordance with point (2).

▼B

(2) The design of railhead profiles for plain line shall comprise:

- (a) a lateral slope on the side of the railhead angled to between vertical and 1/16 with reference to the vertical axis of the railhead;
- (b) the vertical distance between the top of this lateral slope and the top of the rail shall be less than 20 mm;
- (c) a radius of at least 12 mm at the gauge corner;
- (d) the horizontal distance between the crown of the rail and the tangent point shall be between 31 and 37,5 mm.

▼M1

Figure 1

Railhead profile

1 crown of rail
2 tangent point
3 lateral slope
4 vertical axis of rail head
5 gauge corner

▼B

(3) These requirements are not applicable to expansion devices.

4.2.4.7. Rail inclination

4.2.4.7.1. Plain line

(1) The rail shall be inclined towards the centre of the track.

▼M1

(2) For tracks intended to be operated at speeds greater than

TSI ROLLING STOCK (LOC&PAS)

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▼B

4.2.3.5.2.2 Mechanical and geometrical characteristics of wheels

Mechanical behaviour of wheels

(1) The characteristics of the wheels shall ensure the safe movement of rolling stock and contribute to the guidance of the rolling stock.

The conformity assessment procedure is described in ►**M5** point ◄ 6.1.3.1 of this TSI.

Geometrical dimensions of wheels

(2) The geometrical dimensions of the wheels (as defined in Figure 2) shall be compliant with limit values specified in Table 2. These limit values shall be taken as design values (new wheel) and as in-service limit values (to be used for maintenance purposes; see also ►**M5** point ◄ 4.5).

Table 2

In-service limits of the geometric dimensions of wheel

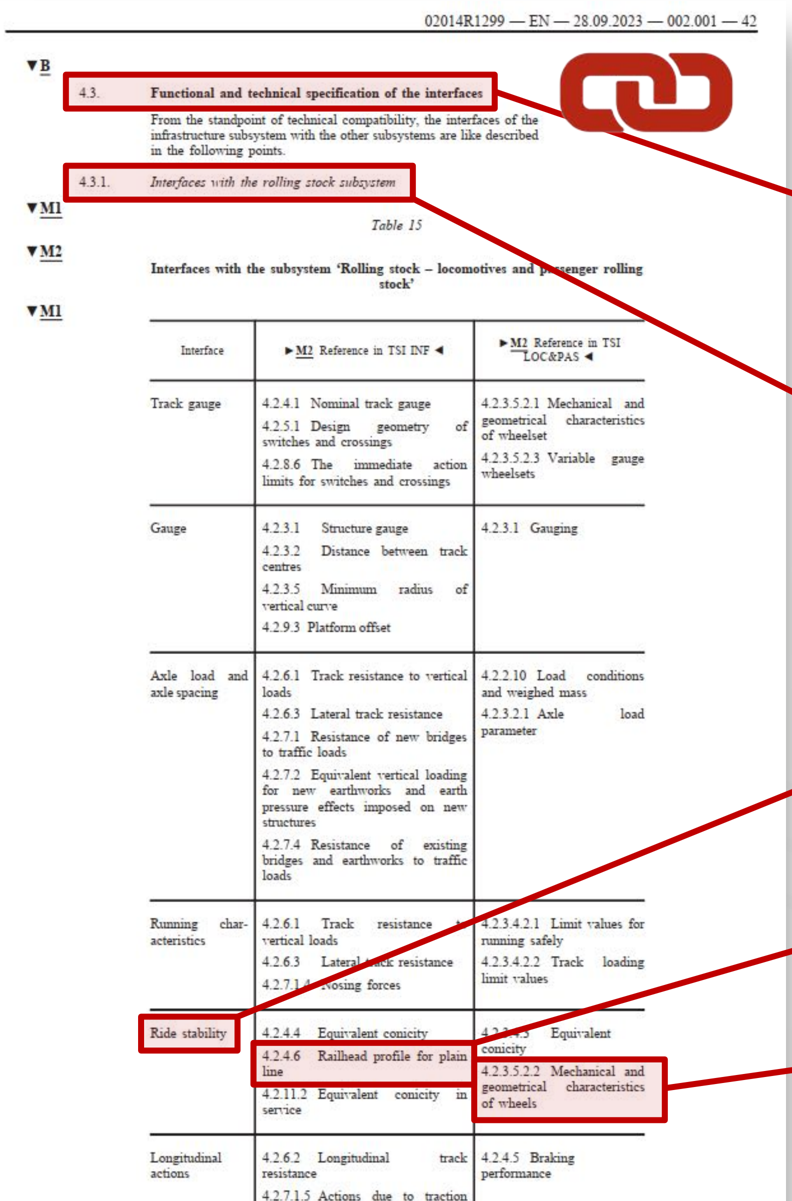
Designation	Wheel diameter D (mm)	Minimum value (mm)	Maximum value (mm)
Width of the rim (B_R + Burr)	D ≥ 330	133	145
Thickness of the flange (S_d)	D > 840	22	33
	760 < D ≤ 840	25	
	330 ≤ D ≤ 760	27,5	
Height of the flange (S_h)	D > 760	27,5	36
	630 < D ≤ 760	29,5	
	330 ≤ D ≤ 630	31,5	
Face of flange (q_R)	≥ 330	6,5	

Figure 2

Symbols for wheels

MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

INTERFACE IDENTIFICATION: CREATING INTERFACE TABLES IN MBSI FRAMEWORK



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▼B

4.3. Functional and technical specification of the interfaces

From the standpoint of technical compatibility, the interfaces of the infrastructure subsystem with the other subsystems are like described in the following points.

4.3.1. Interfaces with the rolling stock subsystem

▼M1

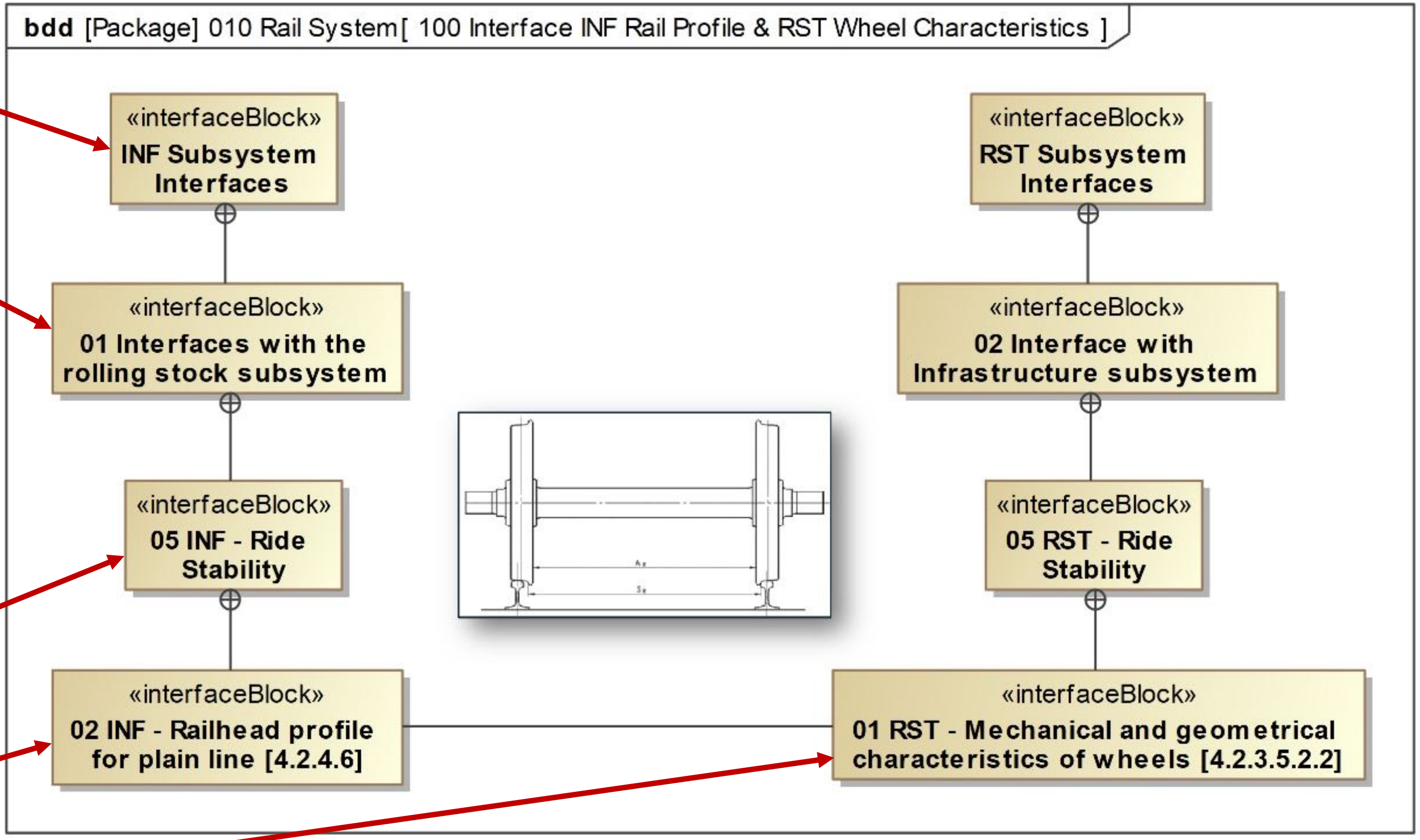
Table 15

▼M2

Interfaces with the subsystem 'Rolling stock – locomotives and passenger rolling stock'

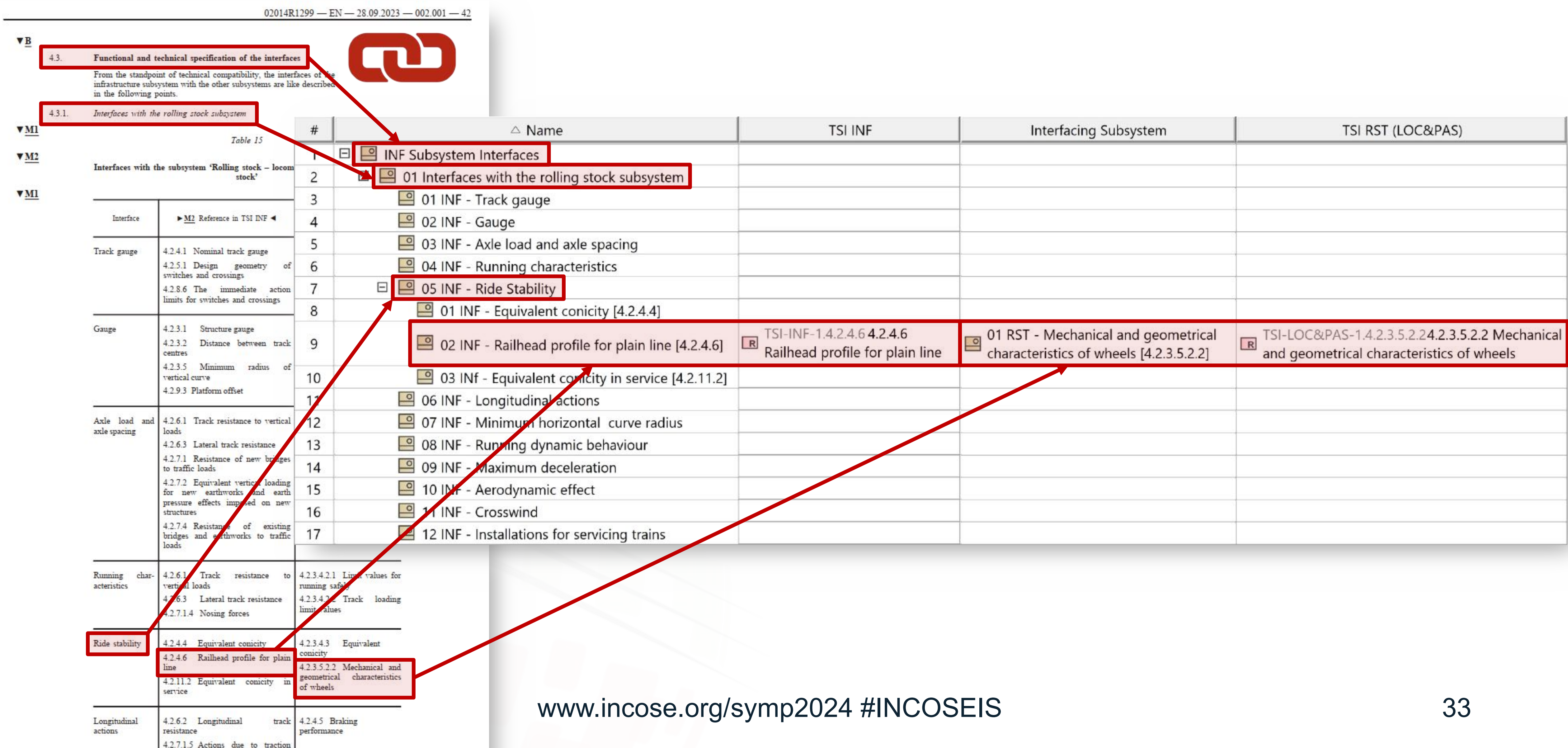
▼M1

Interface	►M2 Reference in TSI INF ◄	►M2 Reference in TSI LOC&PAS ◄
Track gauge	4.2.4.1 Nominal track gauge 4.2.5.1 Design geometry of switches and crossings 4.2.8.6 The immediate action limits for switches and crossings	4.2.3.5.2.1 Mechanical and geometrical characteristics of wheelset 4.2.3.5.2.3 Variable gauge wheelsets
Gauge	4.2.3.1 Structure gauge 4.2.3.2 Distance between track centres 4.2.3.5 Minimum radius of vertical curve 4.2.9.3 Platform offset	4.2.3.1 Gauging
Axle load and axle spacing	4.2.6.1 Track resistance to vertical loads 4.2.6.3 Lateral track resistance 4.2.7.1 Resistance of new bridges to traffic loads 4.2.7.2 Equivalent vertical loading for new earthworks and earth pressure effects imposed on new structures 4.2.7.4 Resistance of existing bridges and earthworks to traffic loads	4.2.2.10 Load conditions and weighed mass 4.2.3.2.1 Axle load parameter
Running characteristics	4.2.6.1 Track resistance to vertical loads 4.2.6.3 Lateral track resistance 4.2.7.1.4 Nosing forces	4.2.3.4.2.1 Limit values for running safely 4.2.3.4.2.2 Track loading limit values
Ride stability	4.2.4.4 Equivalent conicity 4.2.4.6 Railhead profile for plain line 4.2.11.2 Equivalent conicity in service	4.2.3.4.3 Equivalent conicity 4.2.3.5.2.2 Mechanical and geometrical characteristics of wheels
Longitudinal actions	4.2.6.2 Longitudinal track resistance 4.2.7.1.5 Actions due to traction	4.2.4.5 Braking performance



MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

INTERFACE IDENTIFICATION: TABLE VIEW (INTERFACE REGISTER VIEW)



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▼B

4.3. **Functional and technical specification of the interfaces**

From the standpoint of technical compatibility, the interfaces of the infrastructure subsystem with the other subsystems are like described in the following points.

4.3.1. *Interfaces with the rolling stock subsystem*

▼M1

Table 15

▼M2

Interfaces with the subsystem 'Rolling stock – locom… stock'

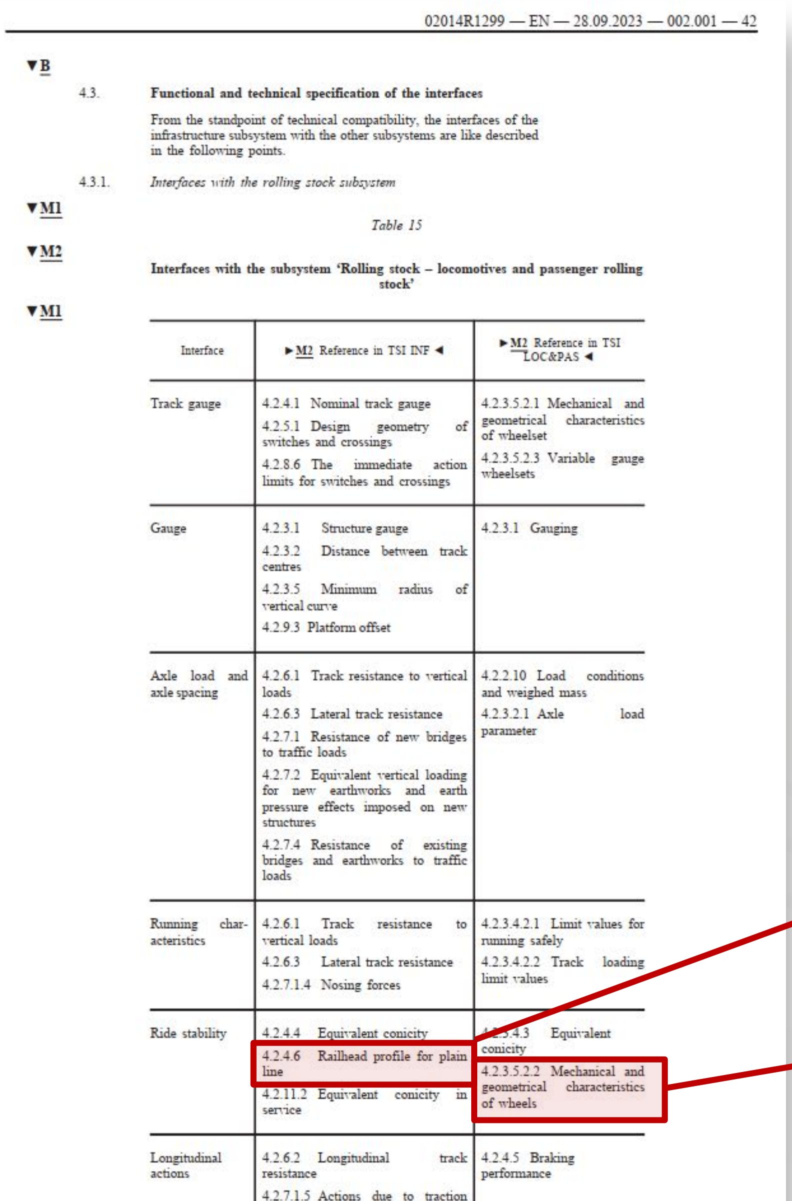
▼M1

Interface	► M2 Reference in TSI INF ◄	
Track gauge	4.2.4.1 Nominal track gauge 4.2.5.1 Design geometry of switches and crossings 4.2.8.6 The immediate action limits for switches and crossings	
Gauge	4.2.3.1 Structure gauge 4.2.3.2 Distance between track centres 4.2.3.5 Minimum radius of vertical curve 4.2.9.3 Platform offset	
Axle load and axle spacing	4.2.6.1 Track resistance to vertical loads 4.2.6.3 Lateral track resistance 4.2.7.1 Resistance of new bridges to traffic loads 4.2.7.2 Equivalent vertical loading for new earthworks and earth pressure effects imposed on new structures 4.2.7.4 Resistance of existing bridges and earthworks to traffic loads	
Running characteristics	4.2.6.1 Track resistance to vertical loads 4.2.6.3 Lateral track resistance 4.2.7.1.4 Nosing forces	4.2.3.4.2.1 Limit values for running safety 4.2.3.4.2.2 Track loading limit values
Ride stability	4.2.4.4 Equivalent conicity 4.2.4.6 Railhead profile for plain line 4.2.11.2 Equivalent conicity in service	4.2.3.4.3 Equivalent conicity 4.2.3.5.2.2 Mechanical and geometrical characteristics of wheels
Longitudinal actions	4.2.6.2 Longitudinal track resistance 4.2.7.1.5 Actions due to traction	4.2.4.5 Braking performance

#	△ Name	TSI INF	Interfacing Subsystem	TSI RST (LOC&PAS)
1	⊟ INF Subsystem Interfaces			
2	01 Interfaces with the rolling stock subsystem			
3	01 INF - Track gauge			
4	02 INF - Gauge			
5	03 INF - Axle load and axle spacing			
6	04 INF - Running characteristics			
7	⊟ 05 INF - Ride Stability			
8	01 INF - Equivalent conicity [4.2.4.4]			
9	02 INF - Railhead profile for plain line [4.2.4.6]	R TSI-INF-1.4.2.4.6 **4.2.4.6** Railhead profile for plain line	01 RST - Mechanical and geometrical characteristics of wheels [4.2.3.5.2.2]	R TSI-LOC&PAS-1.4.2.3.5.2.2 **4.2.3.5.2.2** Mechanical and geometrical characteristics of wheels
10	03 INf - Equivalent conicity in service [4.2.11.2]			
11	06 INF - Longitudinal actions			
12	07 INF - Minimum horizontal curve radius			
13	08 INF - Running dynamic behaviour			
14	09 INF - Maximum deceleration			
15	10 INF - Aerodynamic effect			
16	11 INF - Crosswind			
17	12 INF - Installations for servicing trains			

MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

INTERFACE IDENTIFICATION: DEPENDENCY MATRIX VIEW (N^2 CHART VIEW)



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▼B

4.3. **Functional and technical specification of the interfaces**

From the standpoint of technical compatibility, the interfaces of the infrastructure subsystem with the other subsystems are like described in the following points.

4.3.1. *Interfaces with the rolling stock subsystem*

▼M1

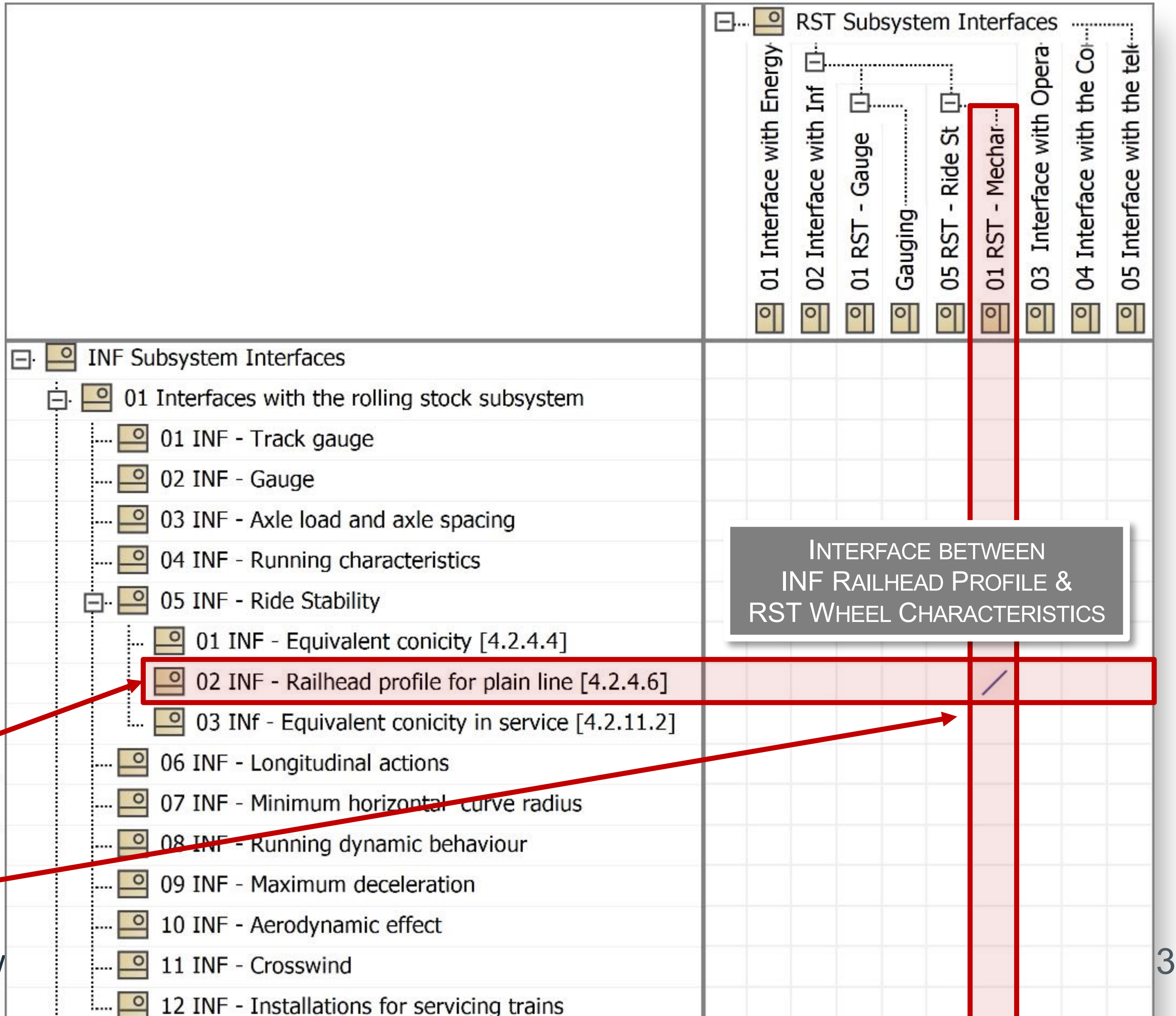
Table 15

▼M2

Interfaces with the subsystem 'Rolling stock – locomotives and passenger rolling stock'

▼M1

Interface	►M2 Reference in TSI INF ◄	►M2 Reference in TSI LOC&PAS ◄
Track gauge	4.2.4.1 Nominal track gauge 4.2.5.1 Design geometry of switches and crossings 4.2.8.6 The immediate action limits for switches and crossings	4.2.3.5.2.1 Mechanical and geometrical characteristics of wheelset 4.2.3.5.2.3 Variable gauge wheelsets
Gauge	4.2.3.1 Structure gauge 4.2.3.2 Distance between track centres 4.2.3.5 Minimum radius of vertical curve 4.2.9.3 Platform offset	4.2.3.1 Gauging
Axle load and axle spacing	4.2.6.1 Track resistance to vertical loads 4.2.6.3 Lateral track resistance 4.2.7.1 Resistance of new bridges to traffic loads 4.2.7.2 Equivalent vertical loading for new earthworks and earth pressure effects imposed on new structures 4.2.7.4 Resistance of existing bridges and earthworks to traffic loads	4.2.2.10 Load conditions and weighed mass 4.2.3.2.1 Axle load parameter
Running characteristics	4.2.6.1 Track resistance to vertical loads 4.2.6.3 Lateral track resistance 4.2.7.1.4 Nosing forces	4.2.3.4.2.1 Limit values for running safely 4.2.3.4.2.2 Track loading limit values
Ride stability	4.2.4.4 Equivalent conicity 4.2.4.6 Railhead profile for plain line 4.2.11.2 Equivalent conicity in service	4.2.3.4.3 Equivalent conicity 4.2.3.5.2.2 Mechanical and geometrical characteristics of wheels
Longitudinal actions	4.2.6.2 Longitudinal track resistance 4.2.7.1.5 Actions due to traction	4.2.4.5 Braking performance

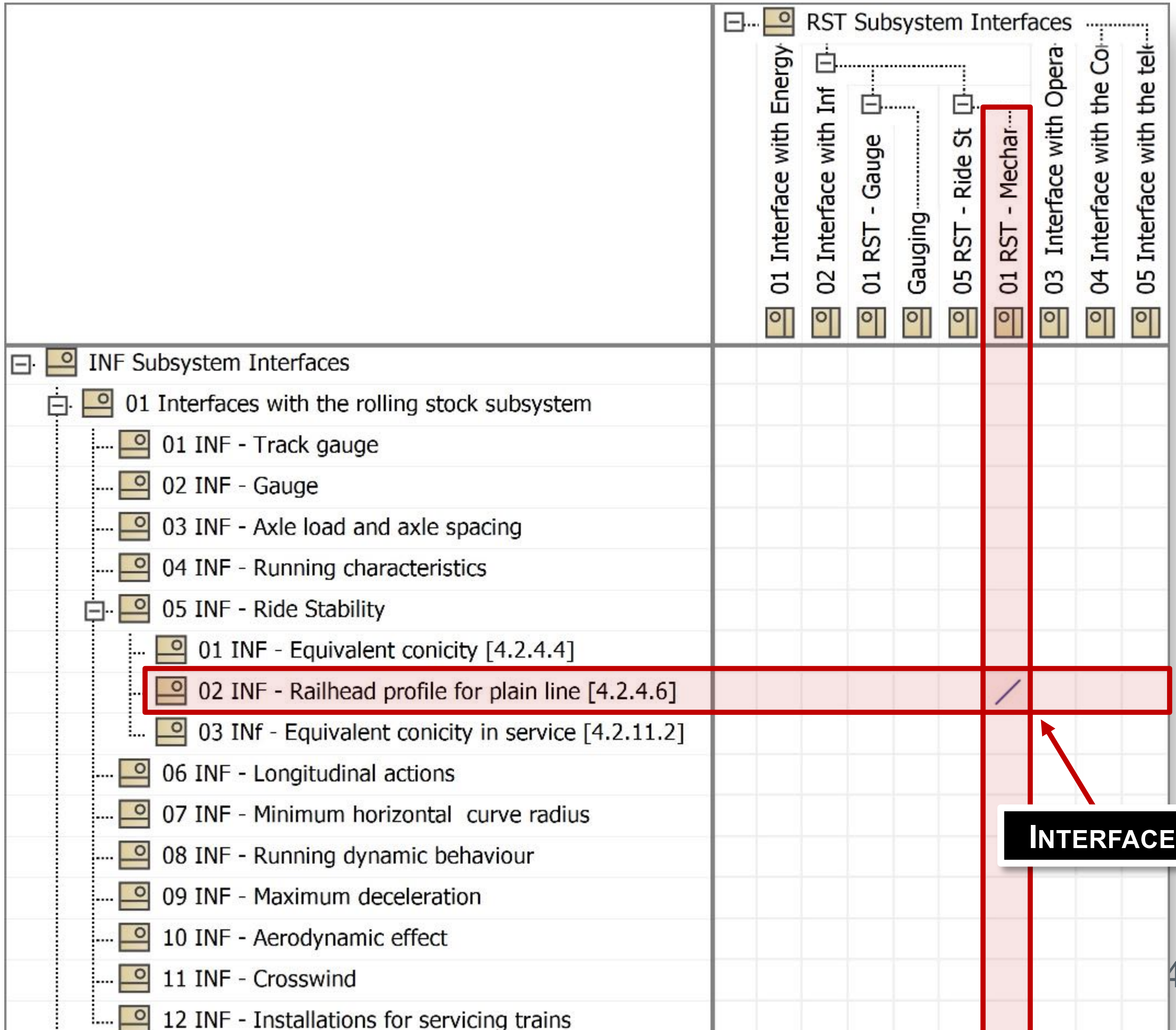


INF Subsystem Interfaces
- 01 Interfaces with the rolling stock subsystem
  - 01 INF - Track gauge
  - 02 INF - Gauge
  - 03 INF - Axle load and axle spacing
  - 04 INF - Running characteristics
  - 05 INF - Ride Stability
    - 01 INF - Equivalent conicity [4.2.4.4]
    - 02 INF - Railhead profile for plain line [4.2.4.6]
    - 03 INf - Equivalent conicity in service [4.2.11.2]
  - 06 INF - Longitudinal actions
  - 07 INF - Minimum horizontal curve radius
  - 08 INF - Running dynamic behaviour
  - 09 INF - Maximum deceleration
  - 10 INF - Aerodynamic effect
  - 11 INF - Crosswind
  - 12 INF - Installations for servicing trains

INTERFACE BETWEEN
INF RAILHEAD PROFILE &
RST WHEEL CHARACTERISTICS

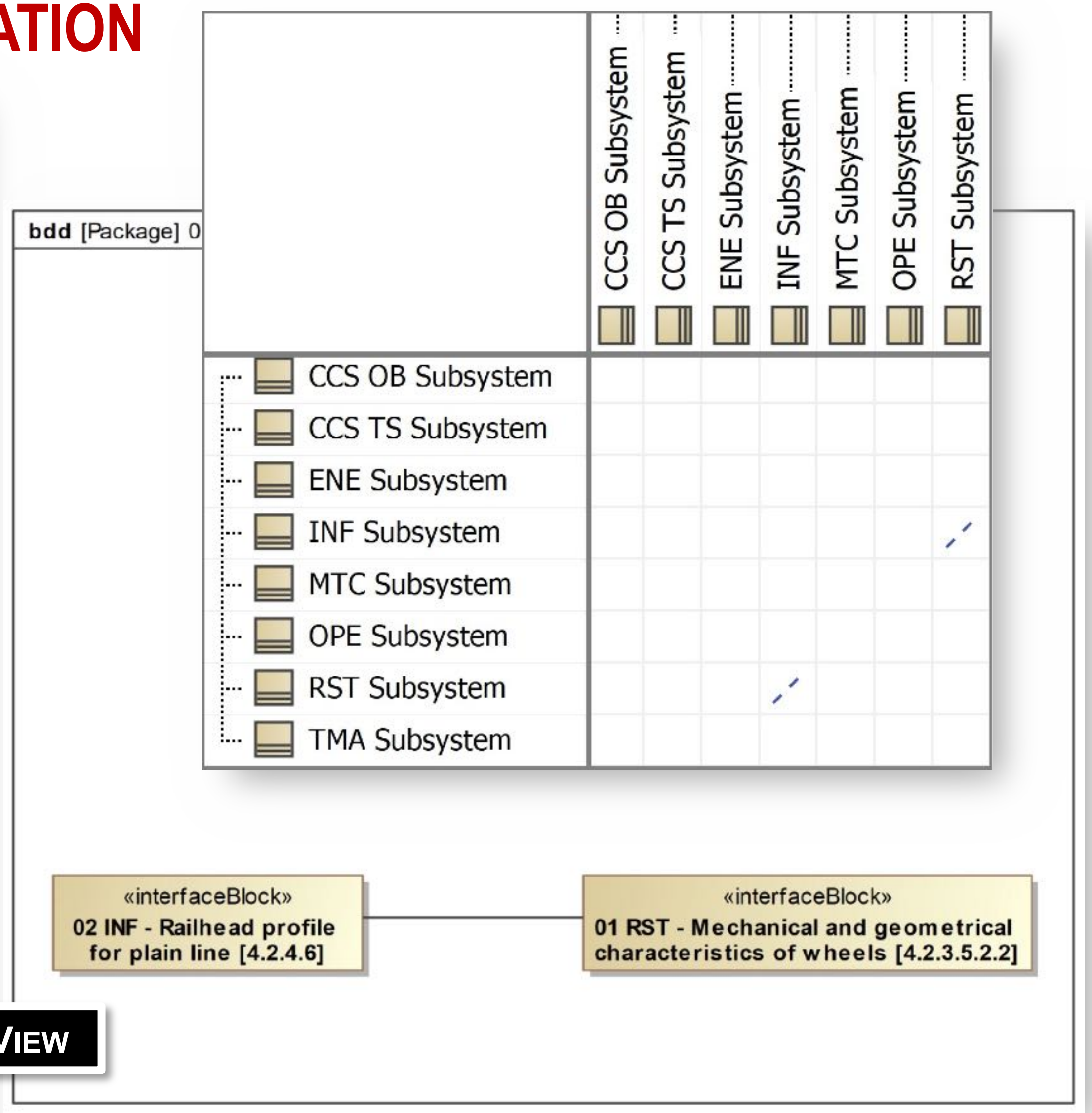
MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

INTERFACE IDENTIFICATION: SUBSYSTEM ALLOCATION



	RST Subsystem Interfaces: 01 Interface with Energy	02 Interface with Inf: 01 RST - Gauge	Gauging	05 RST - Ride St	01 RST - Mechar	03 Interface with Opera	04 Interface with the Co	05 Interface with the tele
INF Subsystem Interfaces								
01 Interfaces with the rolling stock subsystem								
01 INF - Track gauge								
02 INF - Gauge								
03 INF - Axle load and axle spacing								
04 INF - Running characteristics								
05 INF - Ride Stability								
01 INF - Equivalent conicity [4.2.4.4]								
02 INF - Railhead profile for plain line [4.2.4.6]					↗			
03 INf - Equivalent conicity in service [4.2.11.2]								
06 INF - Longitudinal actions								
07 INF - Minimum horizontal curve radius								
08 INF - Running dynamic behaviour								
09 INF - Maximum deceleration								
10 INF - Aerodynamic effect								
11 INF - Crosswind								
12 INF - Installations for servicing trains								

INTERFACE VIEW



	CCS OB Subsystem	CCS TS Subsystem	ENE Subsystem	INF Subsystem	MTC Subsystem	OPE Subsystem	RST Subsystem
CCS OB Subsystem							
CCS TS Subsystem							
ENE Subsystem							
INF Subsystem							↗
MTC Subsystem							
OPE Subsystem							
RST Subsystem				↗			
TMA Subsystem							

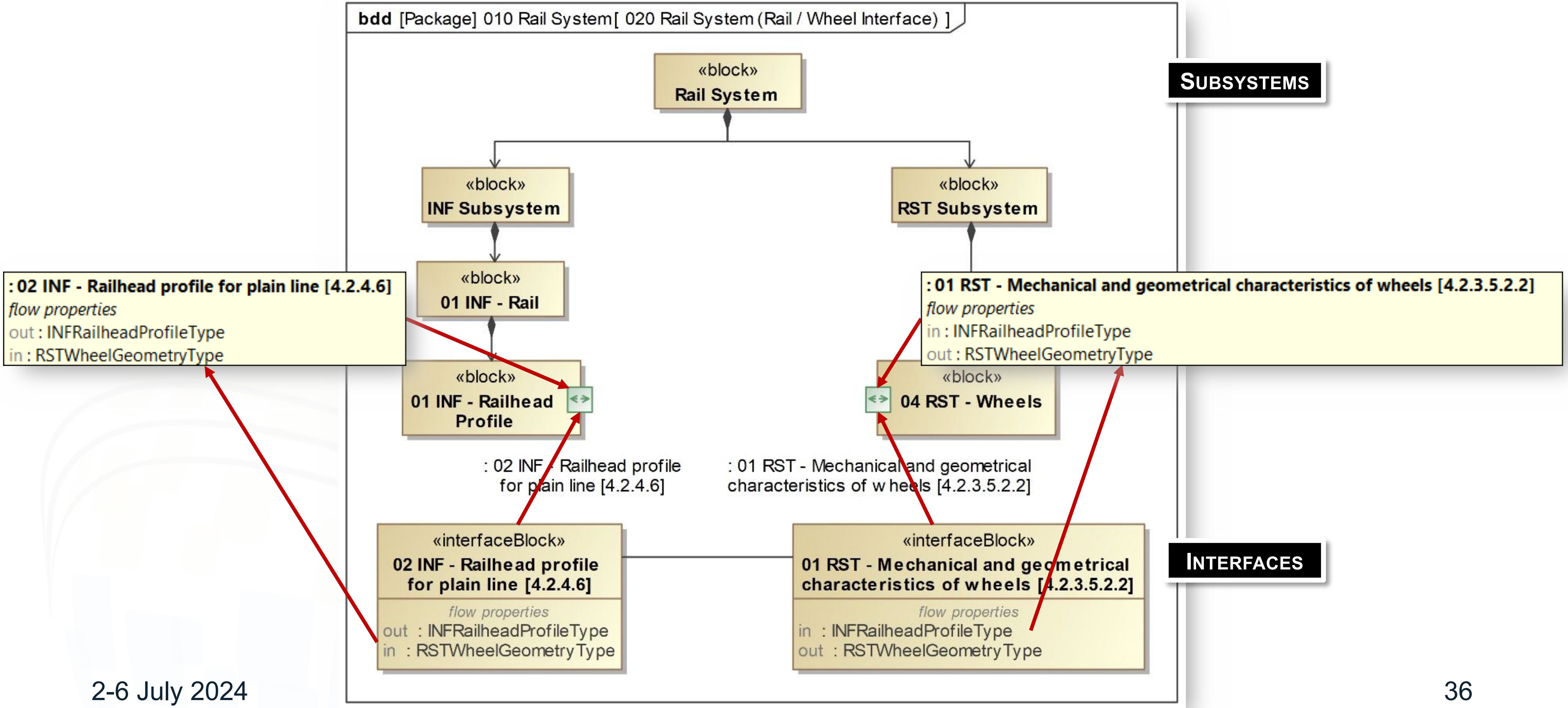
bdd [Package] 0

«interfaceBlock»
02 INF - Railhead profile for plain line [4.2.4.6]

«interfaceBlock»
01 RST - Mechanical and geometrical characteristics of wheels [4.2.3.5.2.2]

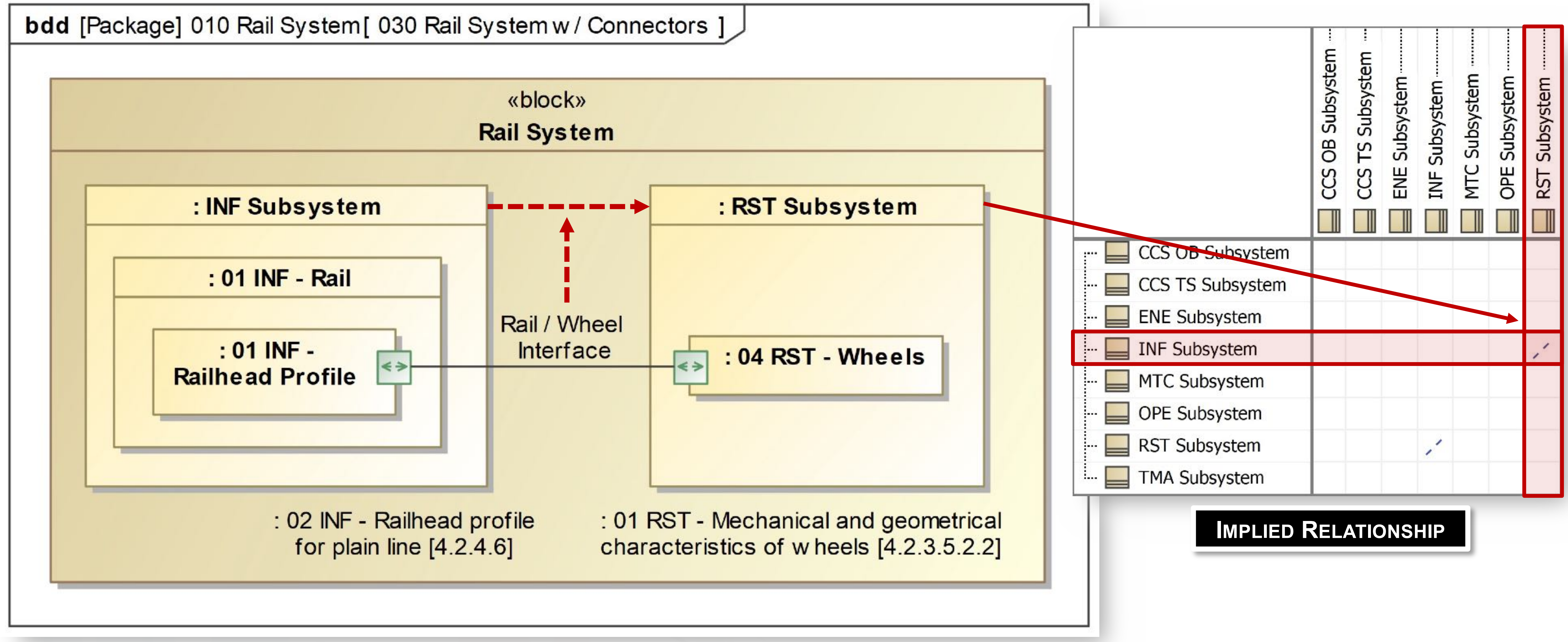
MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

INTERFACE IDENTIFICATION: SUBSYSTEM ALLOCATION (CONT'D)



MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

INTERFACE IDENTIFICATION: RAIL SYSTEM WITH INTERNAL STRUCTURE VIEW

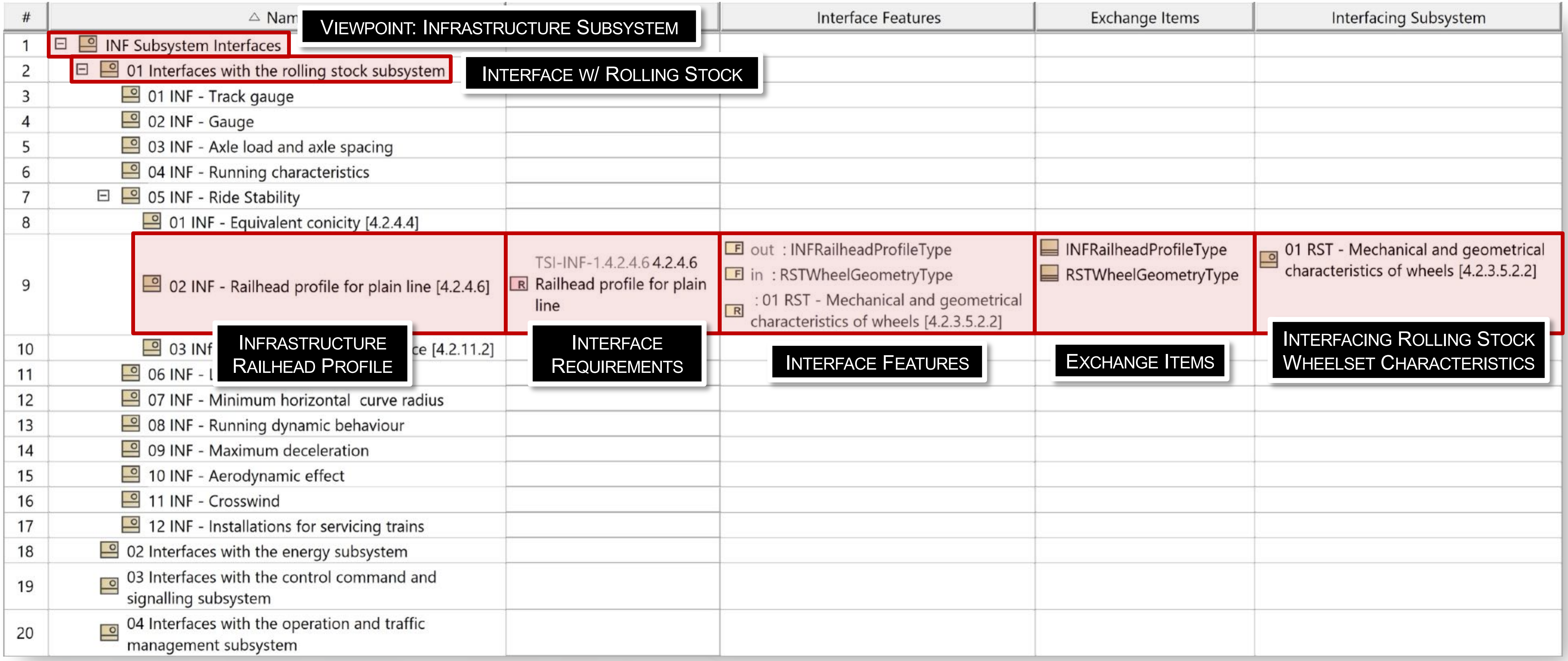


	CCS OB Subsystem	CCS TS Subsystem	ENE Subsystem	INF Subsystem	MTC Subsystem	OPE Subsystem	RST Subsystem
CCS OB Subsystem							
CCS TS Subsystem							
ENE Subsystem							
INF Subsystem							⋰
MTC Subsystem							
OPE Subsystem							
RST Subsystem				⋰			
TMA Subsystem							

IMPLIED RELATIONSHIP

Model-Based Systems Integration Framework

Interface Register: Infrastructure View w/ Details (Rail/Wheel Interface)



#	△ Nam		Interface Features	Exchange Items	Interfacing Subsystem
1	⊟ INF Subsystem Interfaces				
2	⊟ 01 Interfaces with the rolling stock subsystem				
3	01 INF - Track gauge				
4	02 INF - Gauge				
5	03 INF - Axle load and axle spacing				
6	04 INF - Running characteristics				
7	⊟ 05 INF - Ride Stability				
8	01 INF - Equivalent conicity [4.2.4.4]				
9	02 INF - Railhead profile for plain line [4.2.4.6]	TSI-INF-1.4.2.4.6 **4.2.4.6** R Railhead profile for plain line	F out : INFRailheadProfileType F in : RSTWheelGeometryType R : 01 RST - Mechanical and geometrical characteristics of wheels [4.2.3.5.2.2]	INFRailheadProfileType RSTWheelGeometryType	01 RST - Mechanical and geometrical characteristics of wheels [4.2.3.5.2.2]
10	03 INF ce [4.2.11.2]				
11	06 INF - l				
12	07 INF - Minimum horizontal curve radius				
13	08 INF - Running dynamic behaviour				
14	09 INF - Maximum deceleration				
15	10 INF - Aerodynamic effect				
16	11 INF - Crosswind				
17	12 INF - Installations for servicing trains				
18	02 Interfaces with the energy subsystem				
19	03 Interfaces with the control command and signalling subsystem				
20	04 Interfaces with the operation and traffic management subsystem				

Viewpoint: Infrastructure Subsystem

Interface w/ Rolling Stock

Infrastructure Railhead Profile

Interface Requirements

Interface Features

Exchange Items

Interfacing Rolling Stock Wheelset Characteristics

MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

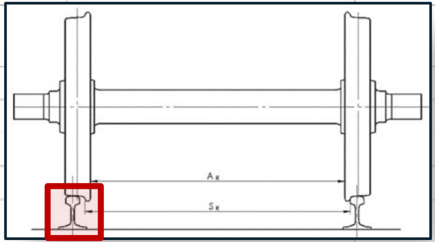
INTERFACE REGISTER: BUILDING THE INTERFACE REGISTER

#	Name	Interface Requirements	Interface Features		cing Subsystem
1	INF Subsystem Interfaces				
2	01 Interfaces with the rolling stock subsystem				
3	01 INF - Track gauge				
4	01 INF - Nominal track gauge [4.2.4.1]				
5	02 INF - Design geometry of switches and Crossings [4.2.5.1]				
6	03 INF - The immediate action limits for switches and crossings [4.2.8.6]				
7	02 INF - Gauge				
8	01 INF - Structure gauge [4.2.3.1]	TSI-INF-1.4.2.3.1 4.2.3.1 Structure gauge	out : INFStructureGaugeType in : RSTKinematicGaugeType : 01 RST - Rolling stock kinematic gauge [4.2.3.1]	INFStructureGaugeType RSTKinematicGaugeType	01 RST - Rolling stock kinematic gauge [4.2.3.1]
9	02 INF - Distance between track centres [4.2.3.2]				
10	03 INF - Minimum radius of vertical curve [4.2.3.5]				
11	04 INF - Platform offset [4.2.9.3]	TSI-INF-1.4.2.9.3 4.2.9.3 Platform offset	out : INFPlatformOffsetType in : RSTKinematicGaugeType : 01 RST - Rolling stock kinematic gauge [4.2.3.1]	INFPlatformOffsetType RSTKinematicGaugeType	01 RST - Rolling stock kinematic gauge [4.2.3.1]
12	03 INF - Axle load and axle spacing				
13	01 INF - Track resistance to vertical loads [4.2.6.1]				
14	02 INF - Lateral track resistance [4.2.6.3]				
15	03 INF - Resistance of new bridges to traffic loads [4.2.7.1]				
16	04 INF - Equivalent vertical loading for new earthworks and pressure effects imposed on new structures [4.2.7.2]				
17	05 INF - Resistance of existing bridges and earthworks to tra [4.2.7.4]				
18	04 INF - Running characteristics				
19	01 INF - Track resistance to vertical loads [4.2.6.1]				
20	02 INF - Lateral track resistance [4.2.6.3]				
21	03 INF - Nosing forces [4.2.7.1.4]				
22	05 INF - Ride Stability				
23	01 INF - Equivalent conicity [4.2.4.4]				
24	02 INF - Railhead profile for plain line [4.2.4.6]	TSI-INF-1.4.2.4.6 4.2.4.6 Railhead profile for plain line	out : INFRailheadProfileType in : RSTWheelGeometryType : 01 RST - Mechanical and geometrical characteristics of wheels [4.2.3.5.2.2]	INFRailheadProfileType RSTWheelGeometryType	01 RST - Mechanical and geometrical characteristics of wheels [4.2.3.5.2.2]
25	03 INf - Equivalent conicity in service [4.2.11.2]				
26	06 INF - Longitudinal actions				


'Unspeakable botch': Spain spends €258 million on trains that are too big for its tunnels


How a French rail company spent £12bn on trains that are "too wide"

Apparently, it's the sort of thing that occurs when you separate the rail operators from train companies, so will probably be happening soon at a platform near you

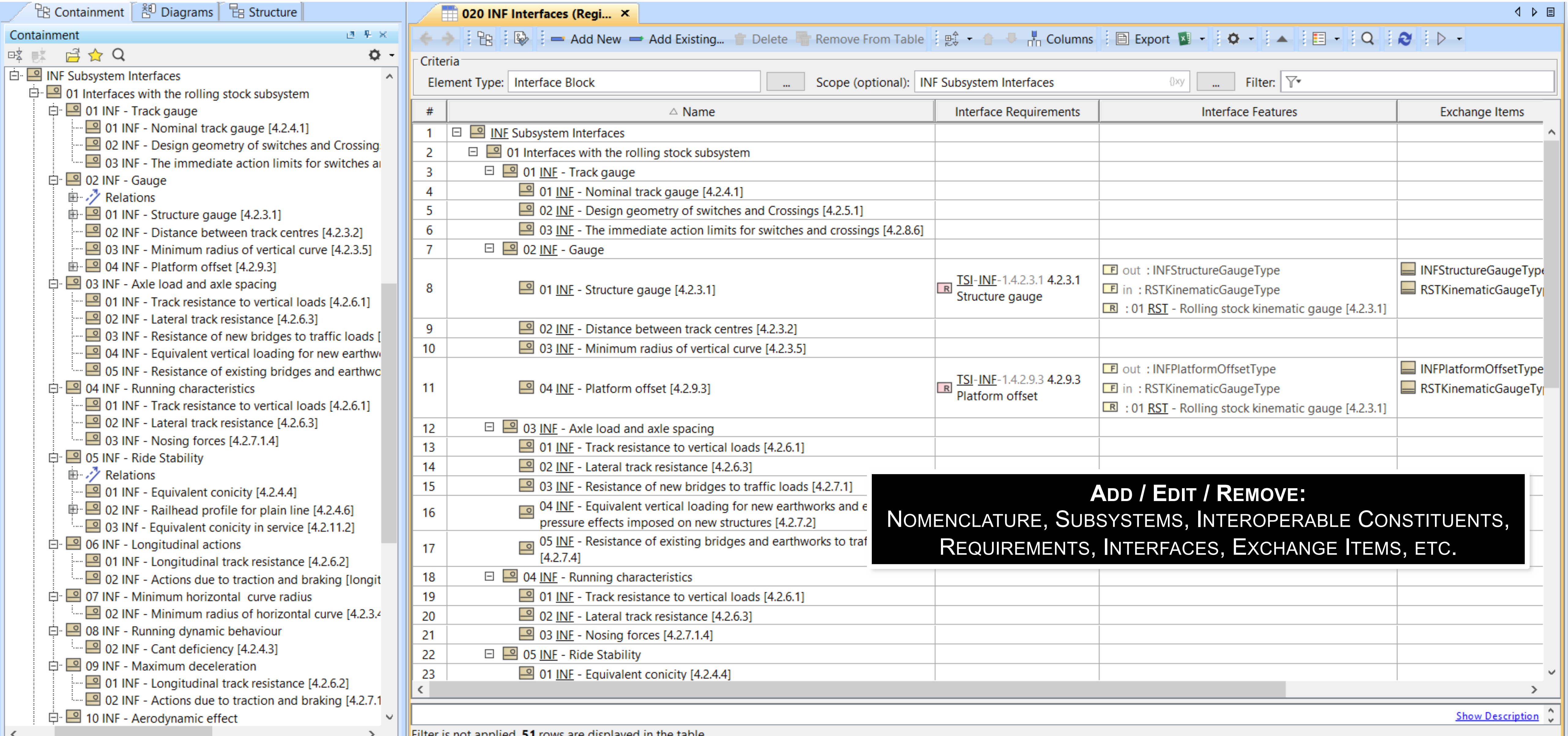


PROGRESS

- **Motivation**
- **Background, Challenges & Objectives**
- **Model-Based Systems Integration Framework**
- **MBSI Framework Development**
- **MBSI Framework Use**
  - Option #1: Use as Template
  - Option #2: Use as Library
  - Option #3: Customize & Taylor
- **Summary & Conclusion**

MBSI FRAMEWORK USE

[1] USE AS TEMPLATE: DIRECT EDIT (E.G., PROJECT SPECIFIC APPLICATION)



- INF Subsystem Interfaces
  - 01 Interfaces with the rolling stock subsystem
    - 01 INF - Track gauge
      - 01 INF - Nominal track gauge [4.2.4.1]
      - 02 INF - Design geometry of switches and Crossing
      - 03 INF - The immediate action limits for switches ar
    - 02 INF - Gauge
      - Relations
      - 01 INF - Structure gauge [4.2.3.1]
      - 02 INF - Distance between track centres [4.2.3.2]
      - 03 INF - Minimum radius of vertical curve [4.2.3.5]
      - 04 INF - Platform offset [4.2.9.3]
    - 03 INF - Axle load and axle spacing
      - 01 INF - Track resistance to vertical loads [4.2.6.1]
      - 02 INF - Lateral track resistance [4.2.6.3]
      - 03 INF - Resistance of new bridges to traffic loads [
      - 04 INF - Equivalent vertical loading for new earthw
      - 05 INF - Resistance of existing bridges and earthwc
    - 04 INF - Running characteristics
      - 01 INF - Track resistance to vertical loads [4.2.6.1]
      - 02 INF - Lateral track resistance [4.2.6.3]
      - 03 INF - Nosing forces [4.2.7.1.4]
    - 05 INF - Ride Stability
      - Relations
      - 01 INF - Equivalent conicity [4.2.4.4]
      - 02 INF - Railhead profile for plain line [4.2.4.6]
      - 03 INF - Equivalent conicity in service [4.2.11.2]
    - 06 INF - Longitudinal actions
      - 01 INF - Longitudinal track resistance [4.2.6.2]
      - 02 INF - Actions due to traction and braking [longit
    - 07 INF - Minimum horizontal curve radius
      - 02 INF - Minimum radius of horizontal curve [4.2.3.4
    - 08 INF - Running dynamic behaviour
      - 02 INF - Cant deficiency [4.2.4.3]
    - 09 INF - Maximum deceleration
      - 01 INF - Longitudinal track resistance [4.2.6.2]
      - 02 INF - Actions due to traction and braking [4.2.7.1
    - 10 INF - Aerodynamic effect

Criteria

Element Type: Interface Block

Scope (optional): INF Subsystem Interfaces

Filter:

#	Name	Interface Requirements	Interface Features	Exchange Items
1	INF Subsystem Interfaces			
2	01 Interfaces with the rolling stock subsystem			
3	01 INF - Track gauge			
4	01 INF - Nominal track gauge [4.2.4.1]			
5	02 INF - Design geometry of switches and Crossings [4.2.5.1]			
6	03 INF - The immediate action limits for switches and crossings [4.2.8.6]			
7	02 INF - Gauge			
8	01 INF - Structure gauge [4.2.3.1]	TSI-INF-1.4.2.3.1 4.2.3.1 Structure gauge	out : INFStructureGaugeType in : RSTKinematicGaugeType : 01 RST - Rolling stock kinematic gauge [4.2.3.1]	INFStructureGaugeType RSTKinematicGaugeTy
9	02 INF - Distance between track centres [4.2.3.2]			
10	03 INF - Minimum radius of vertical curve [4.2.3.5]			
11	04 INF - Platform offset [4.2.9.3]	TSI-INF-1.4.2.9.3 4.2.9.3 Platform offset	out : INFPlatformOffsetType in : RSTKinematicGaugeType : 01 RST - Rolling stock kinematic gauge [4.2.3.1]	INFPlatformOffsetType RSTKinematicGaugeTy
12	03 INF - Axle load and axle spacing			
13	01 INF - Track resistance to vertical loads [4.2.6.1]			
14	02 INF - Lateral track resistance [4.2.6.3]			
15	03 INF - Resistance of new bridges to traffic loads [4.2.7.1]			
16	04 INF - Equivalent vertical loading for new earthworks and e pressure effects imposed on new structures [4.2.7.2]			
17	05 INF - Resistance of existing bridges and earthworks to traf [4.2.7.4]			
18	04 INF - Running characteristics			
19	01 INF - Track resistance to vertical loads [4.2.6.1]			
20	02 INF - Lateral track resistance [4.2.6.3]			
21	03 INF - Nosing forces [4.2.7.1.4]			
22	05 INF - Ride Stability			
23	01 INF - Equivalent conicity [4.2.4.4]			

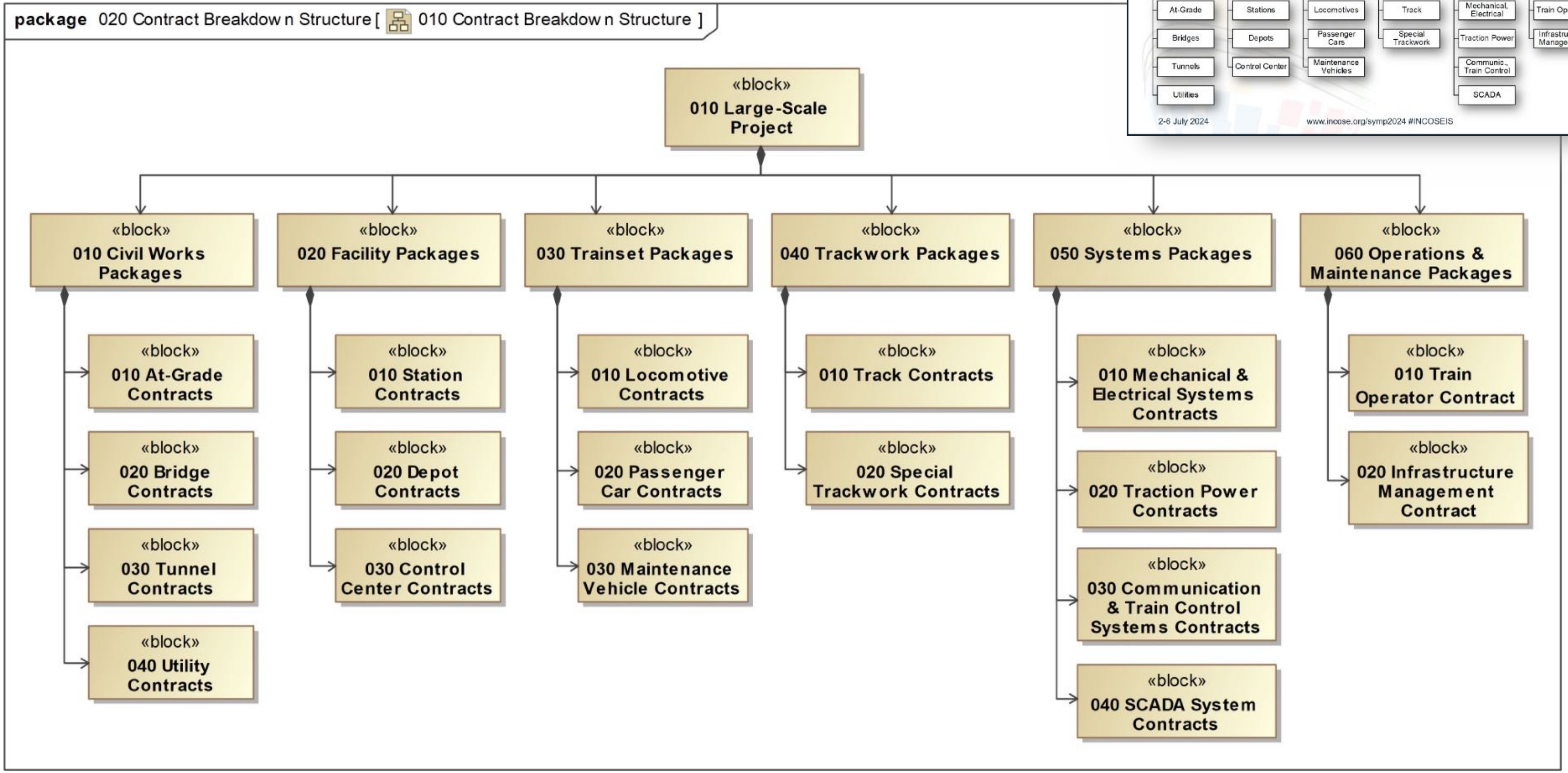
Show Description

Filter is not applied. 51 rows are displayed in the table.

ADD / EDIT / REMOVE:
NOMENCLATURE, SUBSYSTEMS, INTEROPERABLE CONSTITUENTS, REQUIREMENTS, INTERFACES, EXCHANGE ITEMS, ETC.

MBSI FRAMEWORK USE

[2] USE AS LIBRARY: CONTRACT BREAKDOWN STRUCTURE



package 020 Contract Breakdown Structure [010 Contract Breakdown Structure]

«block»
010 Large-Scale Project

«block»
010 Civil Works Packages

«block»
010 At-Grade Contracts

«block»
020 Bridge Contracts

«block»
030 Tunnel Contracts

«block»
040 Utility Contracts

«block»
020 Facility Packages

«block»
010 Station Contracts

«block»
020 Depot Contracts

«block»
030 Control Center Contracts

«block»
030 Trainset Packages

«block»
010 Locomotive Contracts

«block»
020 Passenger Car Contracts

«block»
030 Maintenance Vehicle Contracts

«block»
040 Trackwork Packages

«block»
010 Track Contracts

«block»
020 Special Trackwork Contracts

«block»
050 Systems Packages

«block»
010 Mechanical & Electrical Systems Contracts

«block»
020 Traction Power Contracts

«block»
030 Communication & Train Control Systems Contracts

«block»
040 SCADA System Contracts

«block»
060 Operations & Maintenance Packages

«block»
010 Train Operator Contract

«block»
020 Infrastructure Management Contract

BACKGROUND & CHALLENGES

LARGE-SCALE PROJECTS: INDUSTRY TYPICAL CONTRACT BREAKDOWN STRUCTURE

Large-Scale Project

Civil Works
- At-Grade
- Bridges
- Tunnels
- Utilities

Facilities
- Stations
- Depots
- Control Center

Trainsets
- Locomotives
- Passenger Cars
- Maintenance Vehicles

Trackwork
- Track
- Special Trackwork

Systems
- Mechanical, Electrical
- Traction Power
- Communic., Train Control
- SCADA

Operations & Maintenance
- Train Operator
- Infrastructure Management

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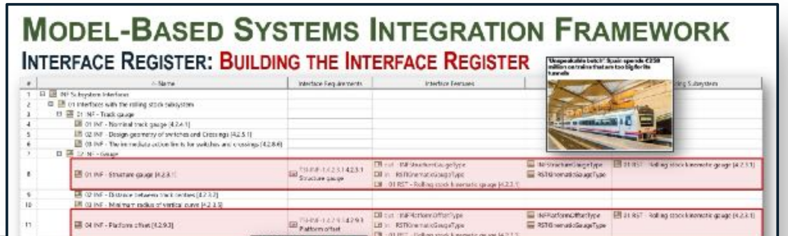
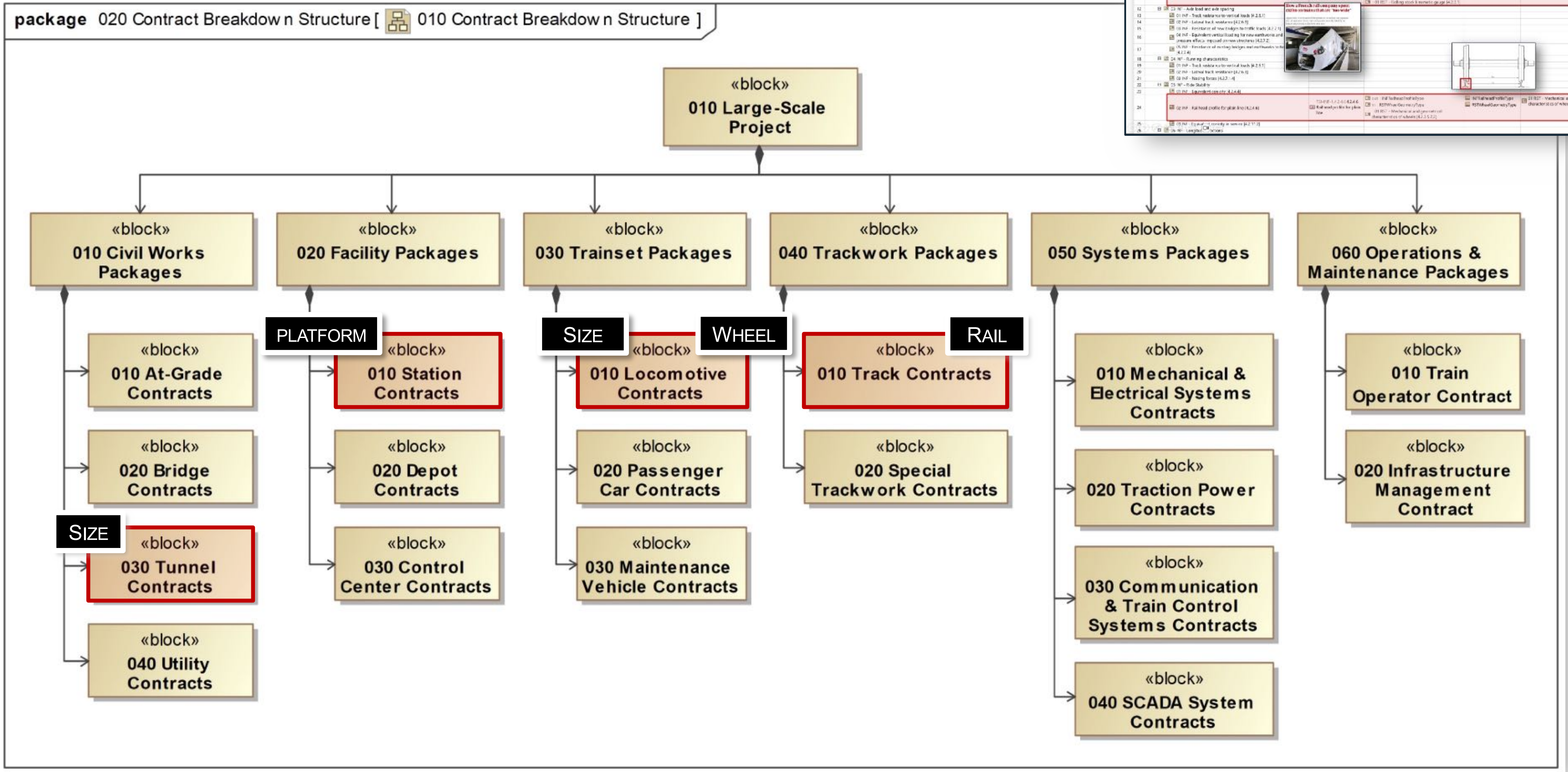
MBSI FRAMEWORK USE

[2] USE AS LIBRARY: INTERFACE EXAMPLE CHALLENGES



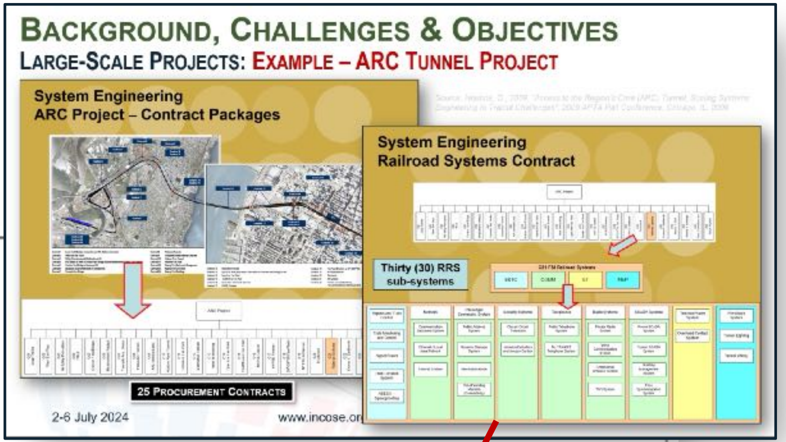
MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

INTERFACE REGISTER: BUILDING THE INTERFACE REGISTER



MBSI FRAMEWORK USE

[2] USE AS LIBRARY: SYSTEM BREAKDOWN STRUCTURE



BACKGROUND, CHALLENGES & OBJECTIVES

LARGE-SCALE PROJECTS: EXAMPLE – ARC TUNNEL PROJECT

System Engineering
ARC Project – Contract Packages

25 PROCUREMENT CONTRACTS

System Engineering
Railroad Systems Contract

Thirty (30) RRS sub-systems

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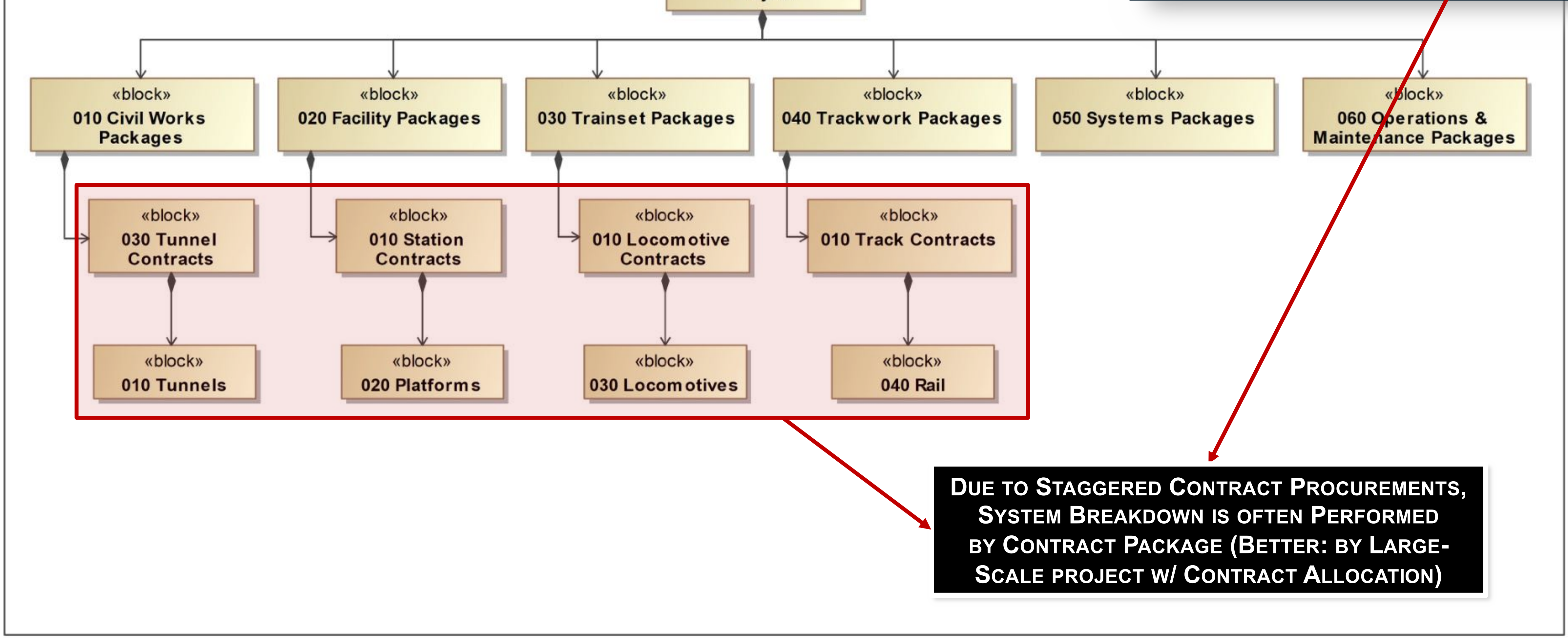


package 030 System Breakdown Structure [010 System Breakdown Structure]

«block»
010 Large-Scale Project

«block»
010 Civil Works Packages

«block»
020 Facility Packages

«block»
030 Trainset Packages

«block»
040 Trackwork Packages

«block»
050 Systems Packages

«block»
060 Operations & Maintenance Packages

«block»
030 Tunnel Contracts

«block»
010 Station Contracts

«block»
010 Locomotive Contracts

«block»
010 Track Contracts

«block»
010 Tunnels

«block»
020 Platforms

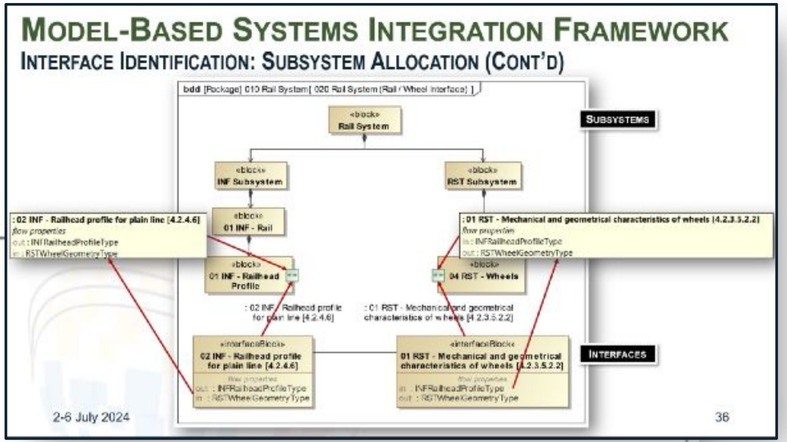
«block»
030 Locomotives

«block»
040 Rail

DUE TO STAGGERED CONTRACT PROCUREMENTS, SYSTEM BREAKDOWN IS OFTEN PERFORMED BY CONTRACT PACKAGE (BETTER: BY LARGE-SCALE PROJECT W/ CONTRACT ALLOCATION)

MBSI FRAMEWORK USE

[2] USE AS LIBRARY: INTERFACE ALLOCATION

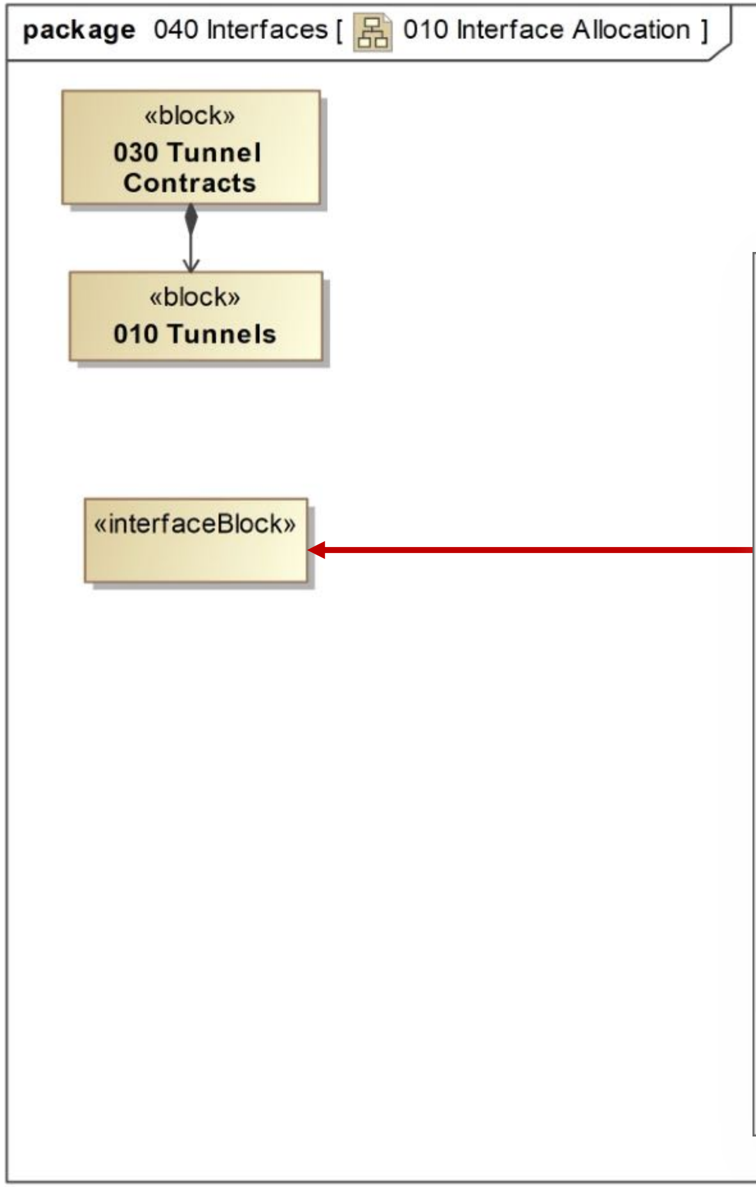


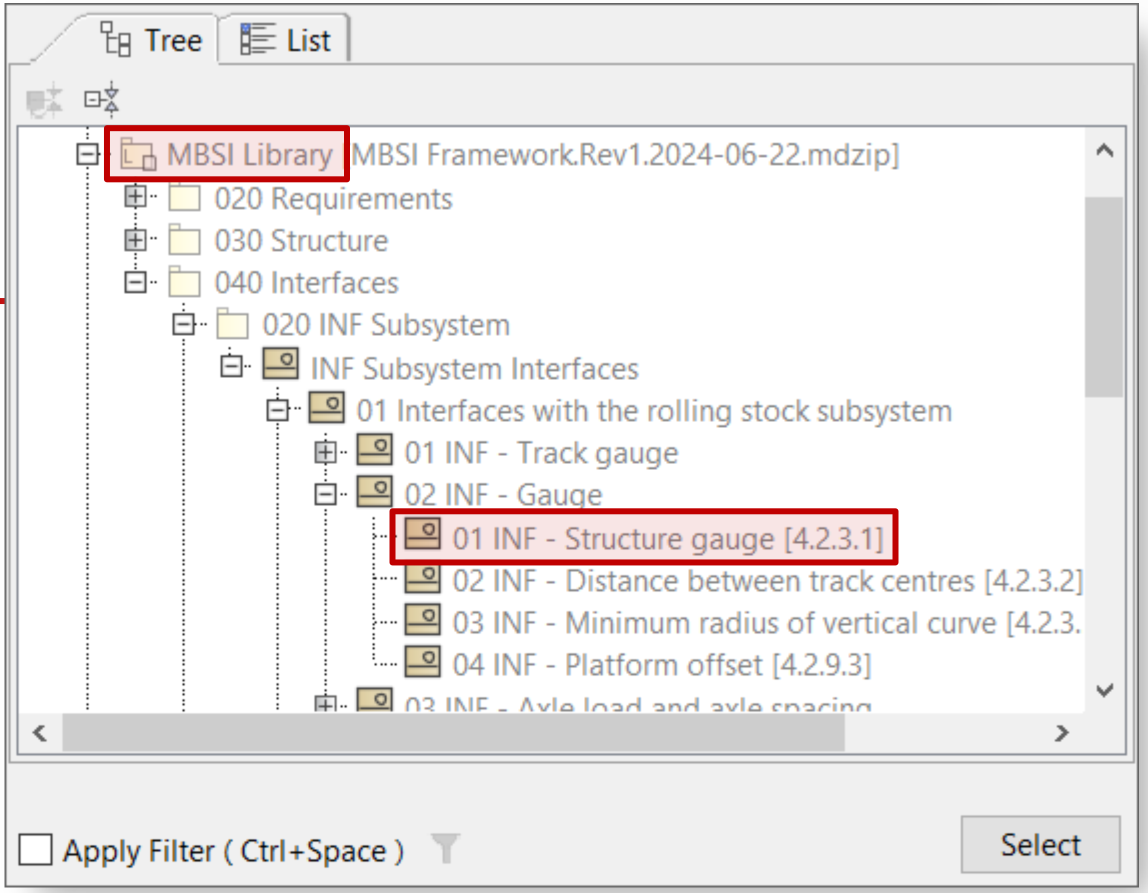
MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

INTERFACE IDENTIFICATION: SUBSYSTEM ALLOCATION (CONT'D)

2-6 July 2024

36

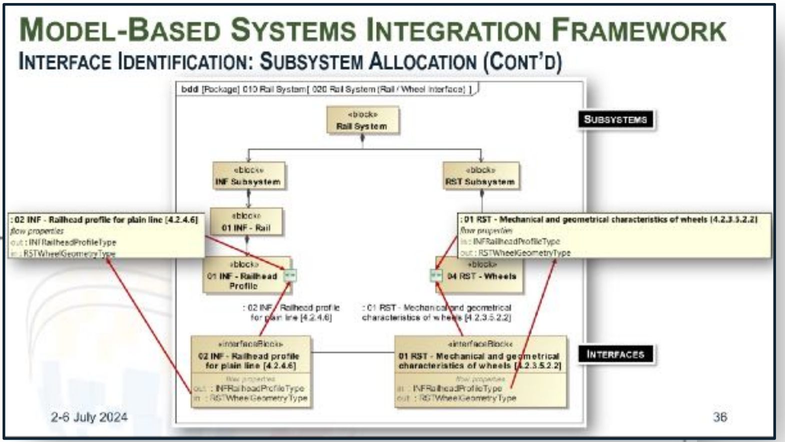




- MBSI Library [MBSI Framework.Rev1.2024-06-22.mdzip]
  - 020 Requirements
  - 030 Structure
  - 040 Interfaces
    - 020 INF Subsystem
      - INF Subsystem Interfaces
        - 01 Interfaces with the rolling stock subsystem
          - 01 INF - Track gauge
          - 02 INF - Gauge
            - 01 INF - Structure gauge [4.2.3.1]
            - 02 INF - Distance between track centres [4.2.3.2]
            - 03 INF - Minimum radius of vertical curve [4.2.3.
            - 04 INF - Platform offset [4.2.9.3]
          - 03 INF - Axle load and axle spacing

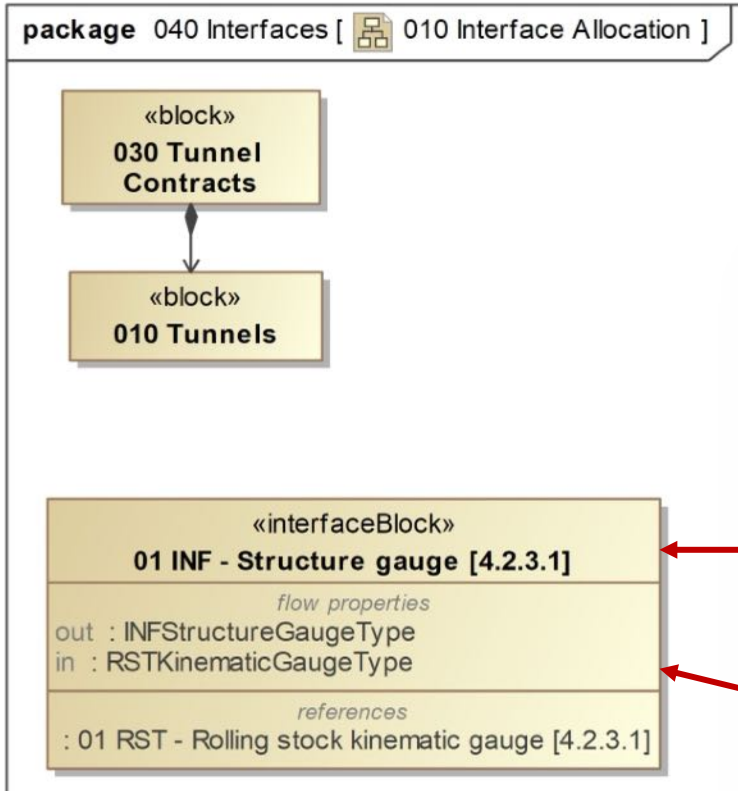
MBSI FRAMEWORK USE

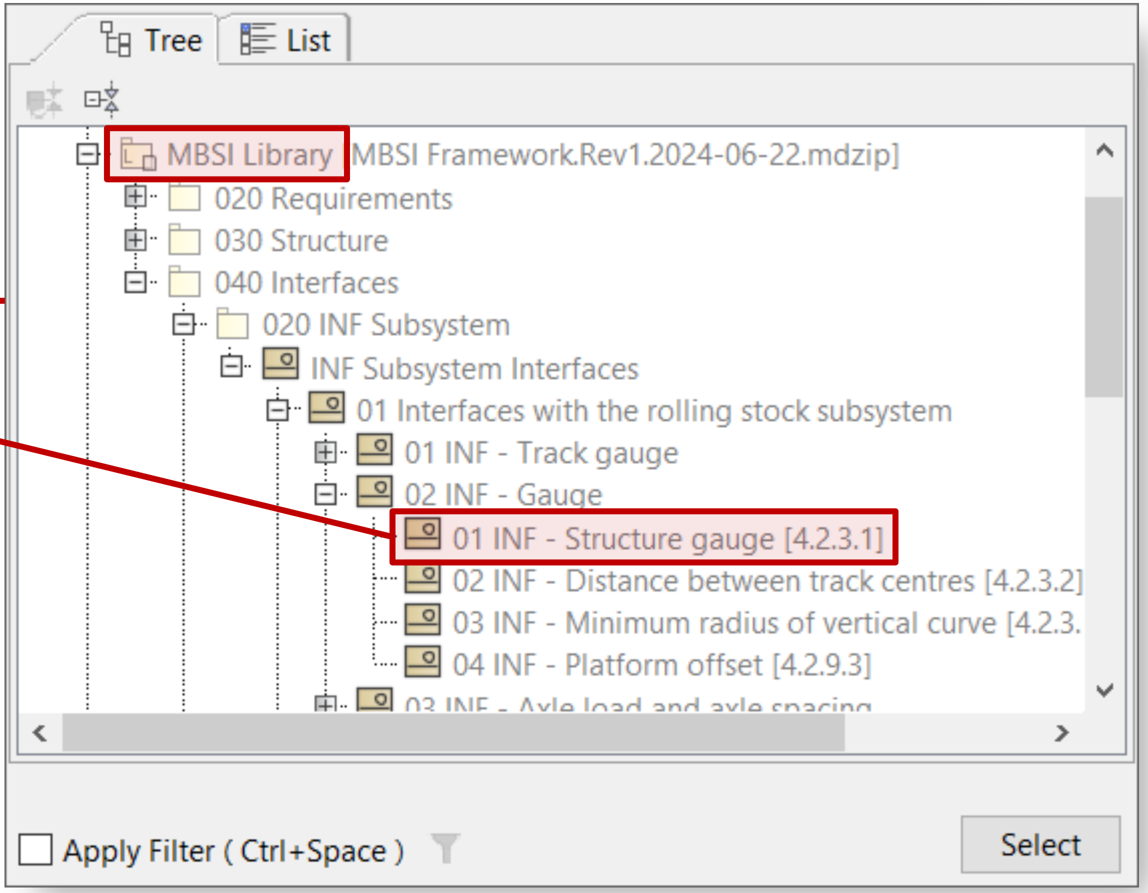
[2] USE AS LIBRARY: INTERFACE ALLOCATION (CONT’D)



MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

INTERFACE IDENTIFICATION: SUBSYSTEM ALLOCATION (CONT’D)





Tree | List

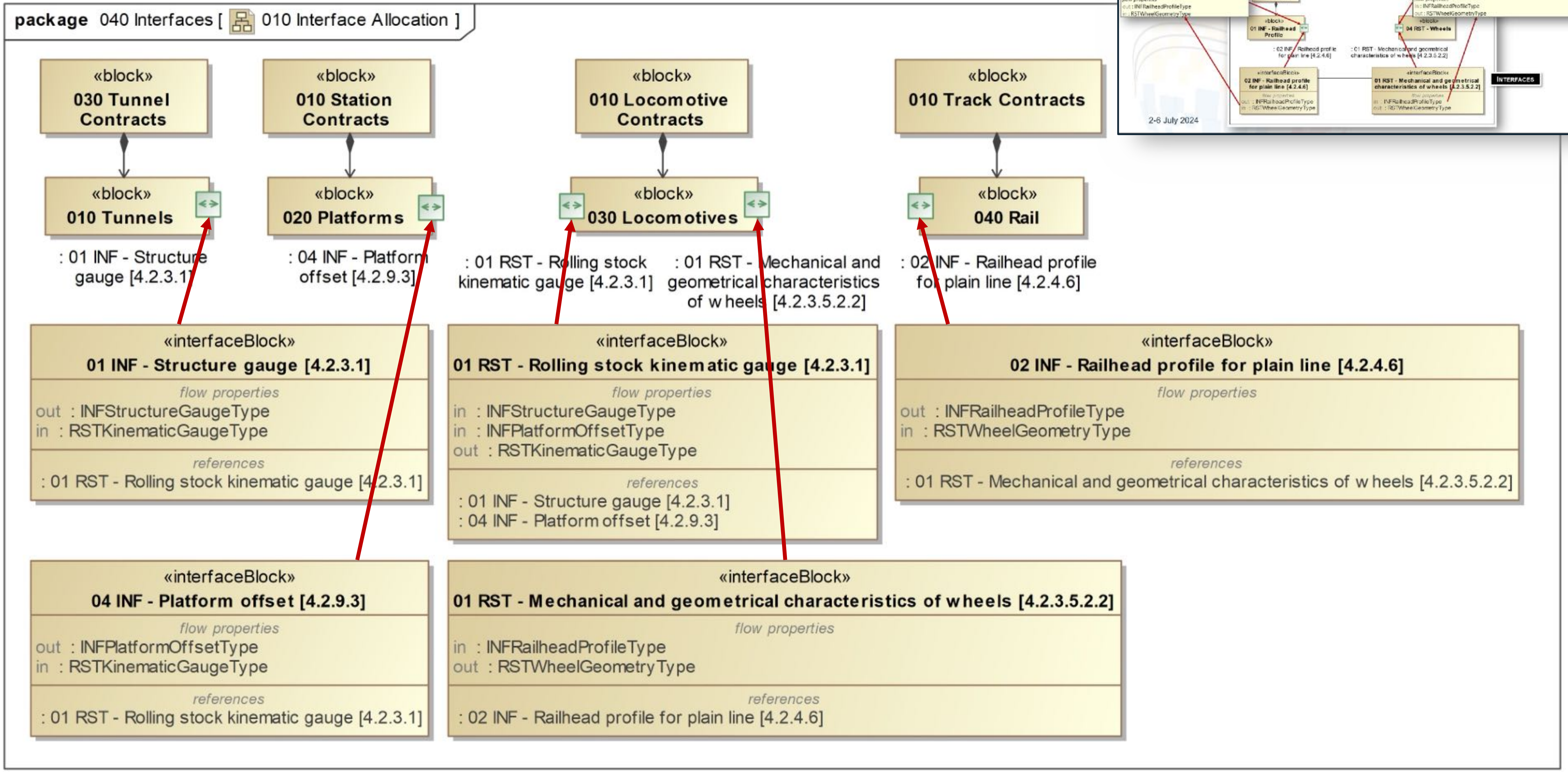
- MBSI Library [MBSI Framework.Rev1.2024-06-22.mdzip]
  - 020 Requirements
  - 030 Structure
  - 040 Interfaces
    - 020 INF Subsystem
      - INF Subsystem Interfaces
        - 01 Interfaces with the rolling stock subsystem
          - 01 INF - Track gauge
          - 02 INF - Gauge
            - 01 INF - Structure gauge [4.2.3.1]
            - 02 INF - Distance between track centres [4.2.3.2]
            - 03 INF - Minimum radius of vertical curve [4.2.3.
            - 04 INF - Platform offset [4.2.9.3]
          - 03 INF - Axle load and axle spacing

☐ Apply Filter (Ctrl+Space)

Select

MBSI FRAMEWORK USE

[2] USE AS LIBRARY: INTERFACE ALLOCATION (CONT'D)



package 040 Interfaces [010 Interface Allocation]

«block»
030 Tunnel Contracts

«block»
010 Tunnels

: 01 INF - Structure gauge [4.2.3.1]

«block»
010 Station Contracts

«block»
020 Platforms

: 04 INF - Platform offset [4.2.9.3]

«block»
010 Locomotive Contracts

«block»
030 Locomotives

: 01 RST - Rolling stock kinematic gauge [4.2.3.1]

: 01 RST - Mechanical and geometrical characteristics of wheels [4.2.3.5.2.2]

«block»
010 Track Contracts

«block»
040 Rail

: 02 INF - Railhead profile for plain line [4.2.4.6]

«interfaceBlock»
01 INF - Structure gauge [4.2.3.1]

flow properties
out : INFStructureGaugeType
in : RSTKinematicGaugeType

references
: 01 RST - Rolling stock kinematic gauge [4.2.3.1]

«interfaceBlock»
01 RST - Rolling stock kinematic gauge [4.2.3.1]

flow properties
in : INFStructureGaugeType
in : INFPlatformOffsetType
out : RSTKinematicGaugeType

references
: 01 INF - Structure gauge [4.2.3.1]
: 04 INF - Platform offset [4.2.9.3]

«interfaceBlock»
02 INF - Railhead profile for plain line [4.2.4.6]

flow properties
out : INFRailheadProfileType
in : RSTWheelGeometryType

references
: 01 RST - Mechanical and geometrical characteristics of wheels [4.2.3.5.2.2]

«interfaceBlock»
04 INF - Platform offset [4.2.9.3]

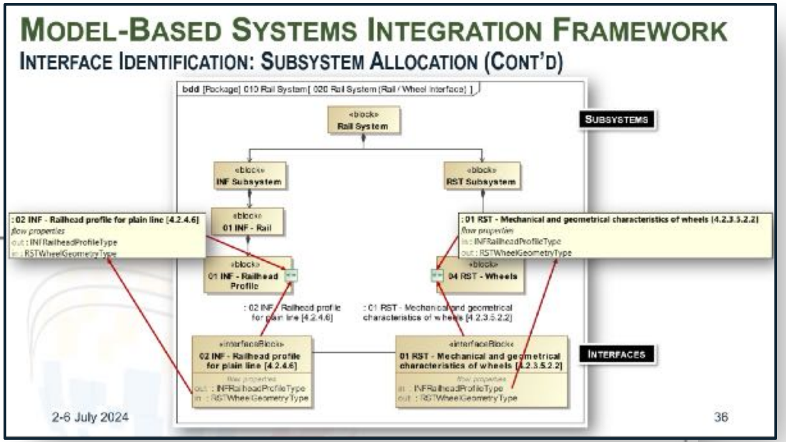
flow properties
out : INFPlatformOffsetType
in : RSTKinematicGaugeType

references
: 01 RST - Rolling stock kinematic gauge [4.2.3.1]

«interfaceBlock»
01 RST - Mechanical and geometrical characteristics of wheels [4.2.3.5.2.2]

flow properties
in : INFRailheadProfileType
out : RSTWheelGeometryType

references
: 02 INF - Railhead profile for plain line [4.2.4.6]



MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

INTERFACE IDENTIFICATION: SUBSYSTEM ALLOCATION (CONT'D)

bdd [Package] 010 Rail System [020 Rail System (Rail / Wheel Interface)]

«block»
Rail System

SUBSYSTEMS

«block»
INF Subsystem

«block»
RST Subsystem

«block»
01 INF - Rail

: 02 INF - Railhead profile for plain line [4.2.4.6]
flow properties
out : INFRailheadProfileType
in : RSTWheelGeometryType

: 01 RST - Mechanical and geometrical characteristics of wheels [4.2.3.5.2.2]
flow properties
in : INFRailheadProfileType
out : RSTWheelGeometryType

«block»
01 INF - Railhead Profile

«block»
04 RST - Wheels

: 02 INF - Railhead profile for plain line [4.2.4.6]

: 01 RST - Mechanical and geometrical characteristics of wheels [4.2.3.5.2.2]

«interfaceBlock»
02 INF - Railhead profile for plain line [4.2.4.6]
flow properties
out : INFRailheadProfileType
in : RSTWheelGeometryType

«interfaceBlock»
01 RST - Mechanical and geometrical characteristics of wheels [4.2.3.5.2.2]
flow properties
in : INFRailheadProfileType
out : RSTWheelGeometryType

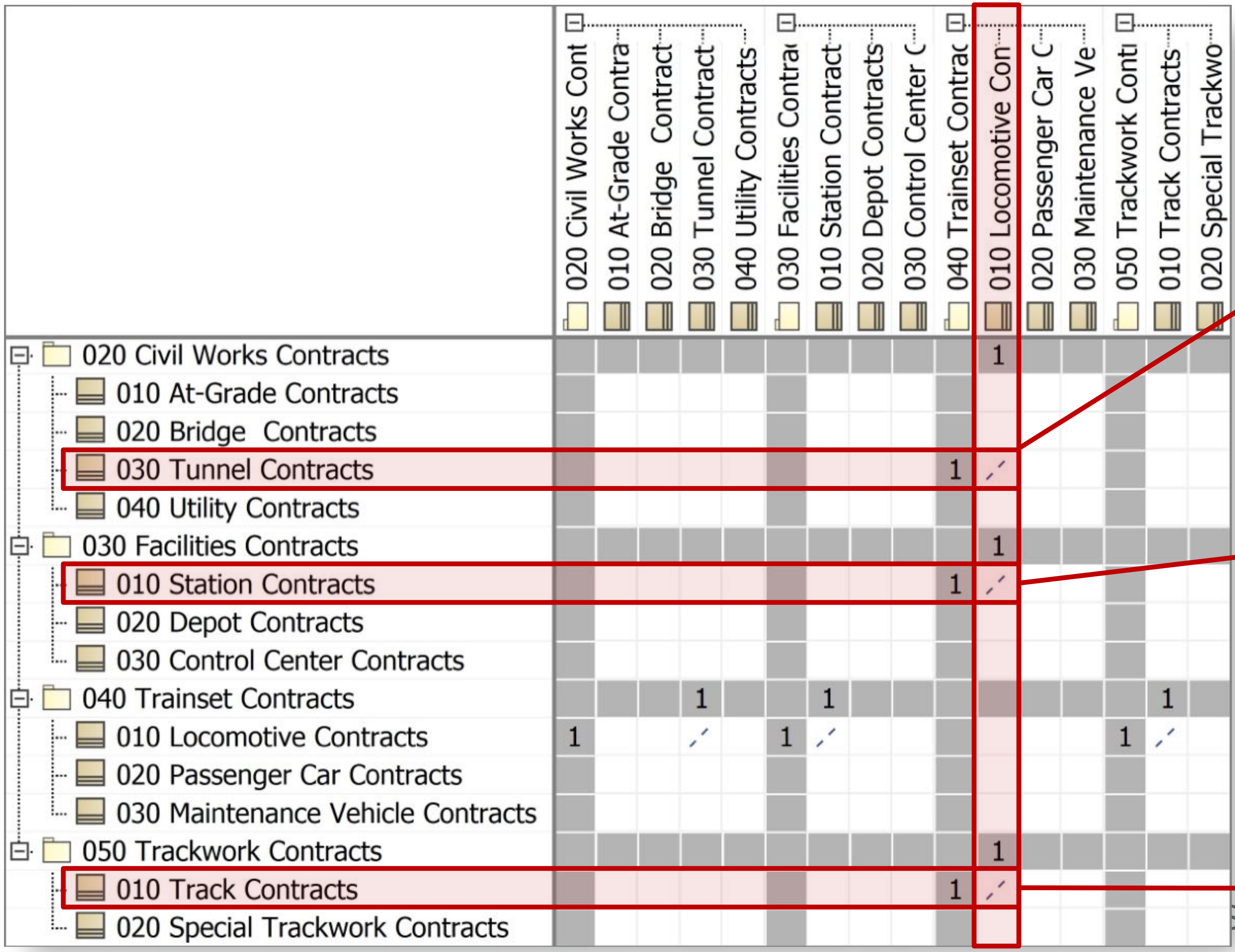
INTERFACES

2-6 July 2024

36

MBSI FRAMEWORK USE

[2] USE AS LIBRARY: CONTRACT INTERFACE MATRIX (N^2 CHART)

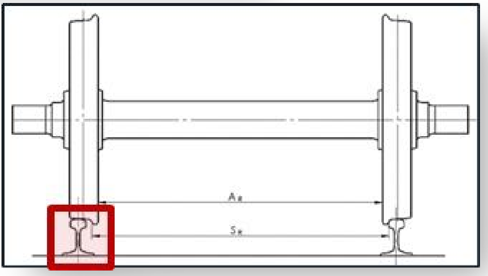


	020 Civil Works Cont	010 At-Grade Contra	020 Bridge Contract	030 Tunnel Contract	040 Utility Contracts	030 Facilities Contra	010 Station Contract	020 Depot Contracts	030 Control Center C	040 Trainset Contrac	010 Locomotive Con	020 Passenger Car C	030 Maintenance Ve	050 Trackwork Cont	010 Track Contracts	020 Special Trackwo
020 Civil Works Contracts											1					
010 At-Grade Contracts																
020 Bridge Contracts																
030 Tunnel Contracts										1	⋰					
040 Utility Contracts																
030 Facilities Contracts											1					
010 Station Contracts										1	⋰					
020 Depot Contracts																
030 Control Center Contracts																
040 Trainset Contracts				1			1								1	
010 Locomotive Contracts	1			⋰		1	⋰							1	⋰	
020 Passenger Car Contracts																
030 Maintenance Vehicle Contracts																
050 Trackwork Contracts											1					
010 Track Contracts										1	⋰					
020 Special Trackwork Contracts																

'Unspeakable botch': Spain spends €258 million on trains that are too big for its tunnels

How a French rail company spent £12bn on trains that are "too wide"

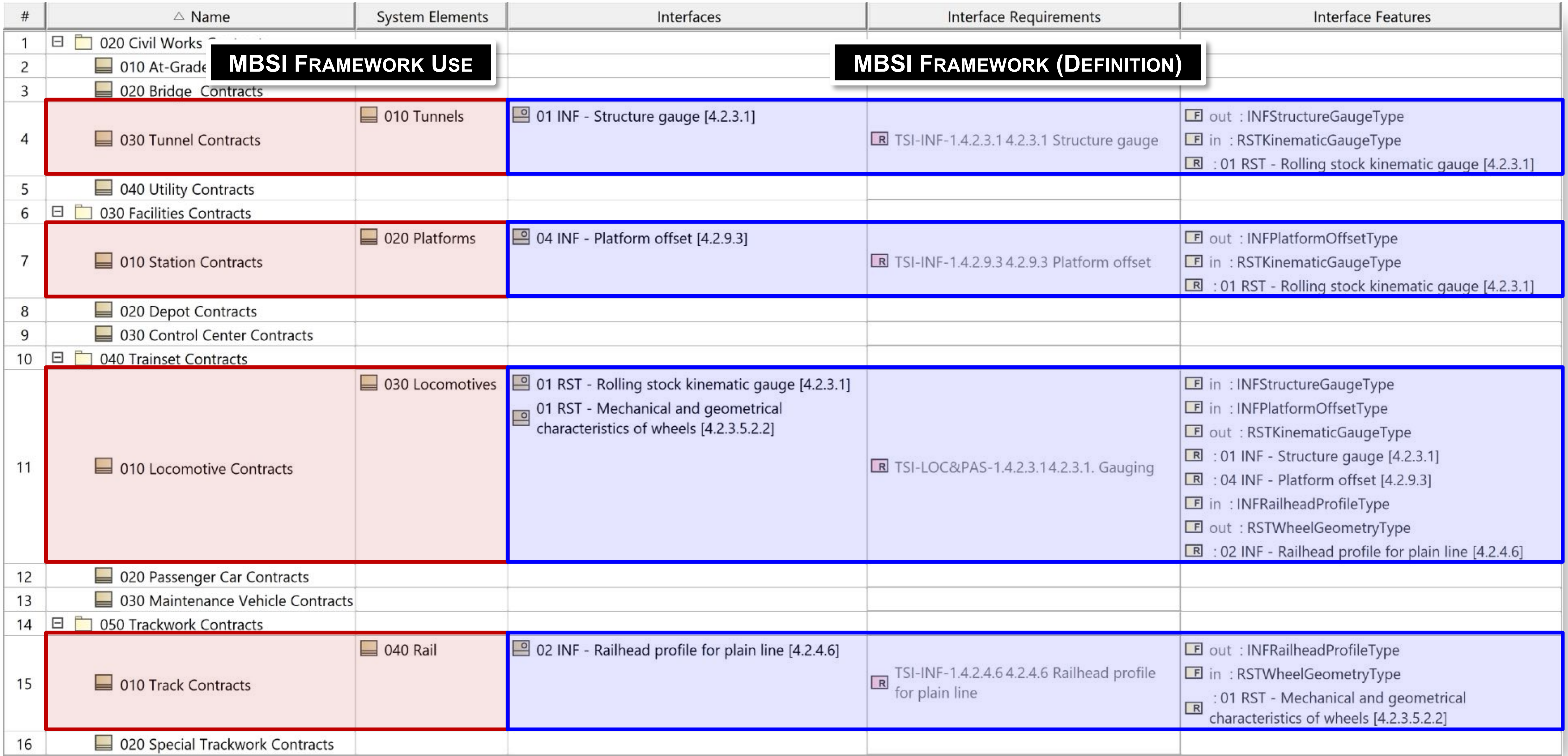
Apparently, it's the sort of thing that occurs when you separate the rail operators from train companies, so will probably be happening soon at a platform near you



SEIS

MBSI FRAMEWORK USE

[2] USE AS LIBRARY: CONTRACT SPECIFIC INTERFACE REGISTER



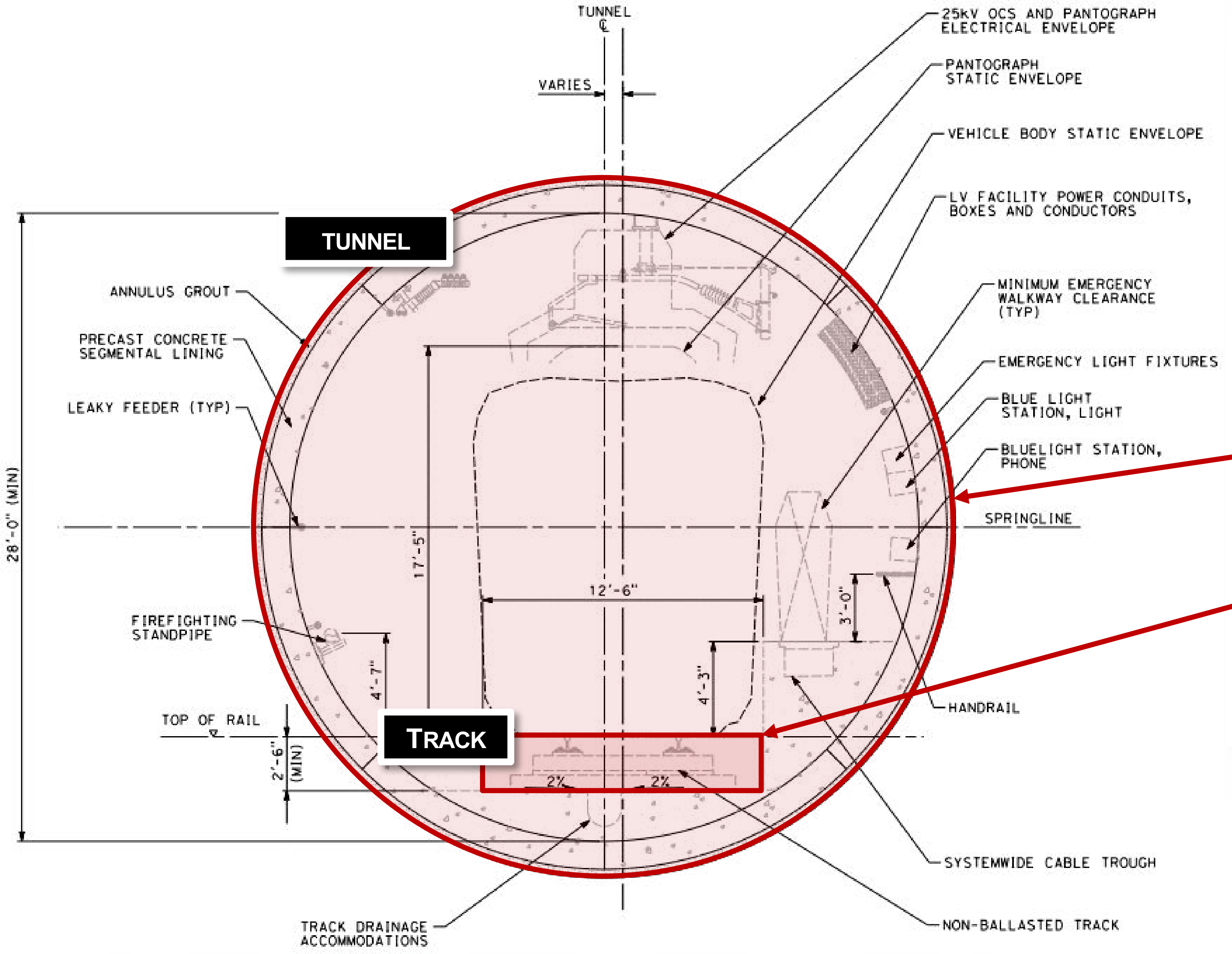
MBSI FRAMEWORK USE

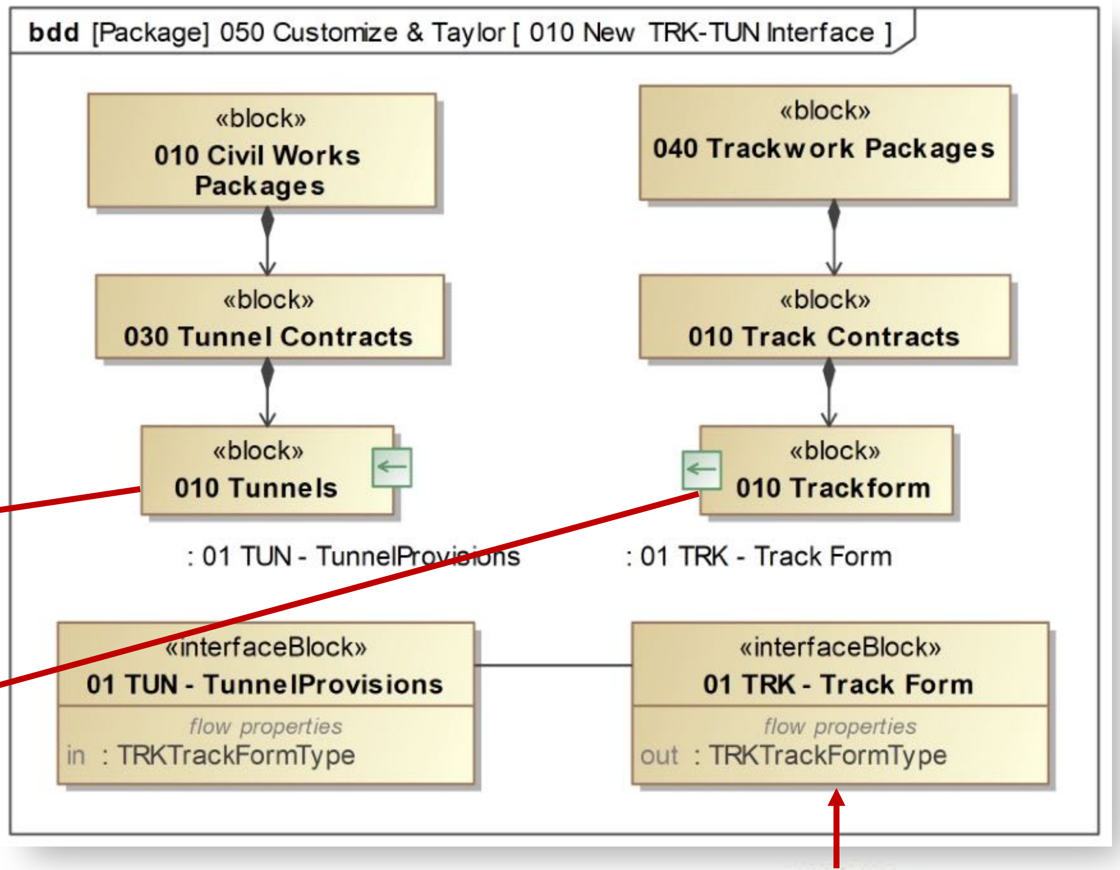
MBSI FRAMEWORK (DEFINITION)

#	Name	System Elements	Interfaces	Interface Requirements	Interface Features
1	020 Civil Works				
2	010 At-Grade				
3	020 Bridge Contracts				
4	030 Tunnel Contracts	010 Tunnels	01 INF - Structure gauge [4.2.3.1]	TSI-INF-1.4.2.3.1 4.2.3.1 Structure gauge	out : INFStructureGaugeType in : RSTKinematicGaugeType : 01 RST - Rolling stock kinematic gauge [4.2.3.1]
5	040 Utility Contracts				
6	030 Facilities Contracts				
7	010 Station Contracts	020 Platforms	04 INF - Platform offset [4.2.9.3]	TSI-INF-1.4.2.9.3 4.2.9.3 Platform offset	out : INFPlatformOffsetType in : RSTKinematicGaugeType : 01 RST - Rolling stock kinematic gauge [4.2.3.1]
8	020 Depot Contracts				
9	030 Control Center Contracts				
10	040 Trainset Contracts				
11	010 Locomotive Contracts	030 Locomotives	01 RST - Rolling stock kinematic gauge [4.2.3.1] 01 RST - Mechanical and geometrical characteristics of wheels [4.2.3.5.2.2]	TSI-LOC&PAS-1.4.2.3.14.2.3.1. Gauging	in : INFStructureGaugeType in : INFPlatformOffsetType out : RSTKinematicGaugeType : 01 INF - Structure gauge [4.2.3.1] : 04 INF - Platform offset [4.2.9.3] in : INFRailheadProfileType out : RSTWheelGeometryType : 02 INF - Railhead profile for plain line [4.2.4.6]
12	020 Passenger Car Contracts				
13	030 Maintenance Vehicle Contracts				
14	050 Trackwork Contracts				
15	010 Track Contracts	040 Rail	02 INF - Railhead profile for plain line [4.2.4.6]	TSI-INF-1.4.2.4.6 4.2.4.6 Railhead profile for plain line	out : INFRailheadProfileType in : RSTWheelGeometryType : 01 RST - Mechanical and geometrical characteristics of wheels [4.2.3.5.2.2]
16	020 Special Trackwork Contracts				

MBSI FRAMEWORK USE

[3] CUSTOMIZE & TAYLOR: ADDING NEW, PROJECT-SPECIFIC INTERFACE(S)




bdd [Package] 050 Customize & Taylor [010 New TRK-TUN Interface]

«block»
010 Civil Works Packages

«block»
030 Tunnel Contracts

«block»
010 Tunnels

: 01 TUN - TunnelProvisions

«block»
040 Trackwork Packages

«block»
010 Track Contracts

«block»
010 Trackform

: 01 TRK - Track Form

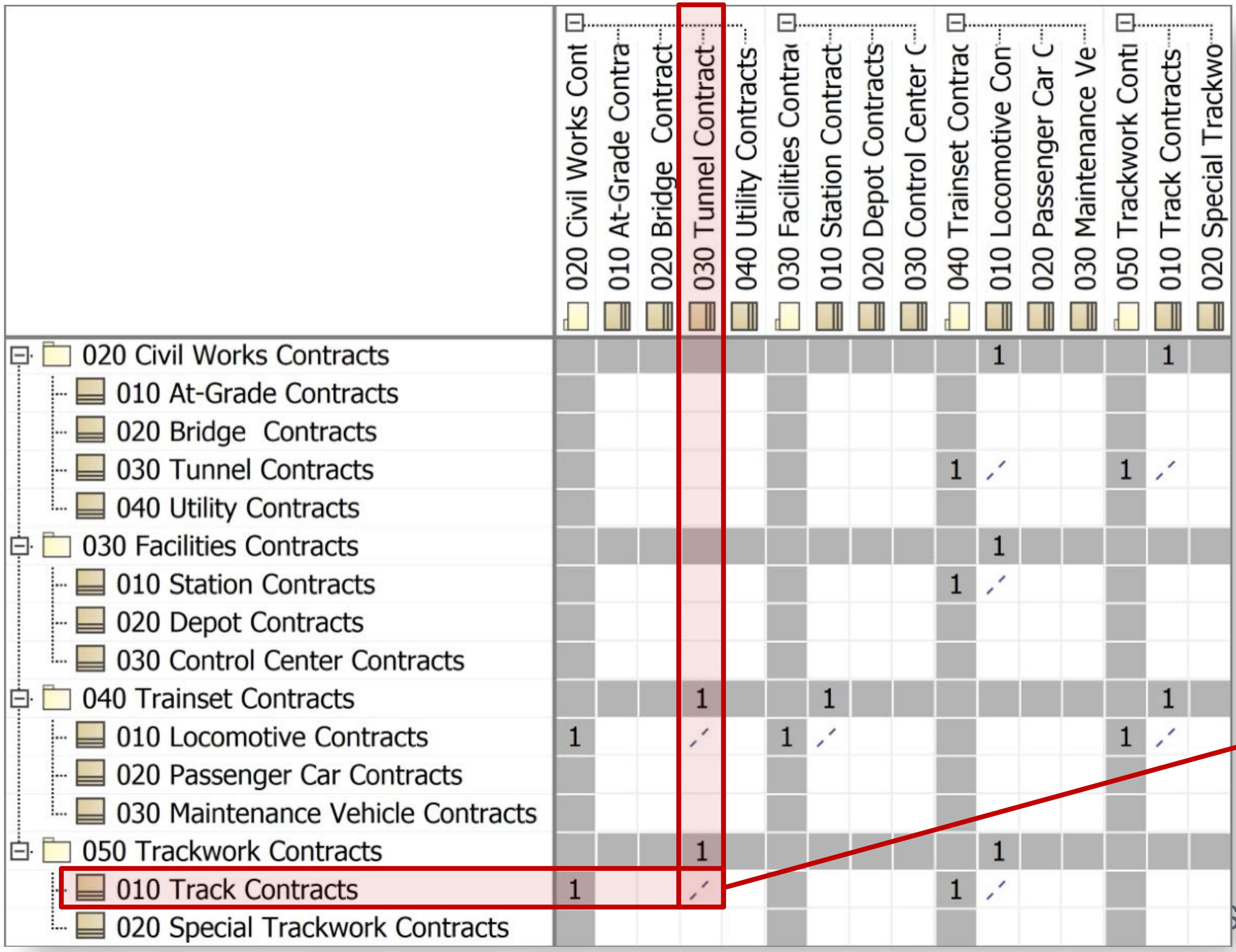
«interfaceBlock»
01 TUN - TunnelProvisions
flow properties
in : TRKTrackFormType

«interfaceBlock»
01 TRK - Track Form
flow properties
out : TRKTrackFormType

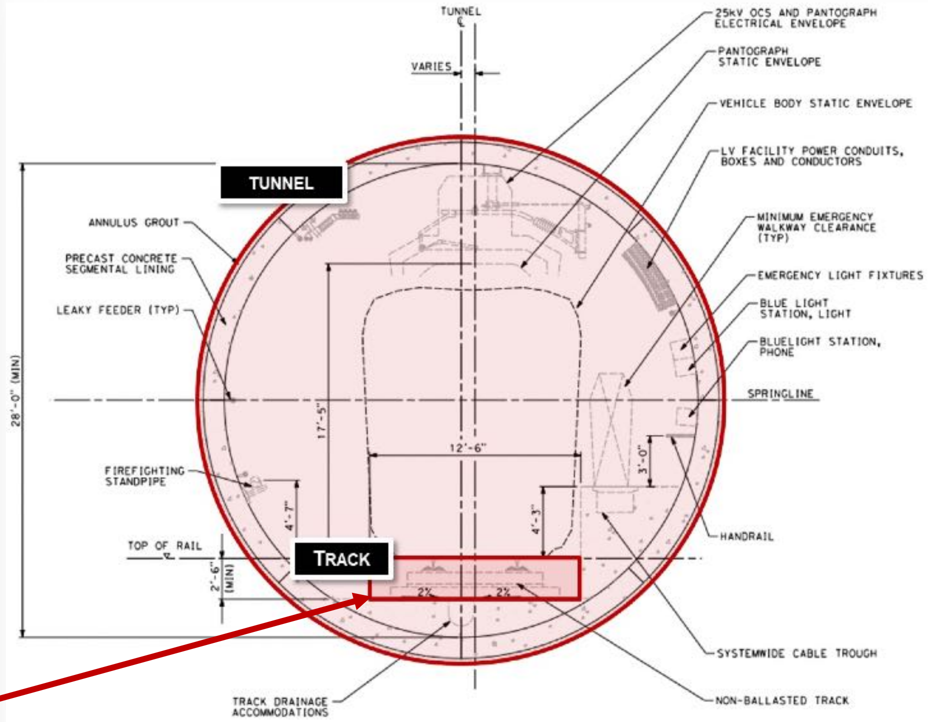
Source/Credit: http://www.railway-fasteners.com/news/ballasted-track-non-ballasted-track-comparison.html

MBSI FRAMEWORK USE

[3] CUSTOMIZE & TAYLOR: CONTRACT INTERFACE MATRIX (N^2 CHART)

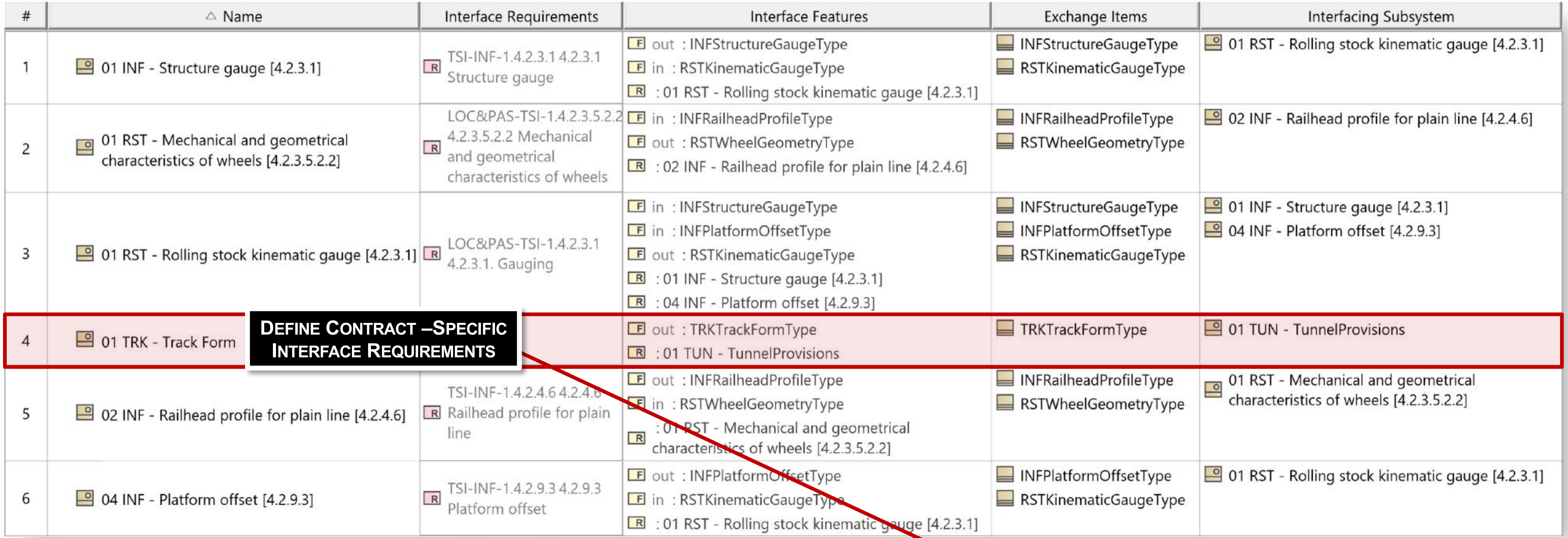


	020 Civil Works Cont	010 At-Grade Contra	020 Bridge Contract	030 Tunnel Contract	040 Utility Contracts	030 Facilities Contra	010 Station Contract	020 Depot Contracts	030 Control Center C	040 Trainset Contrac	010 Locomotive Con	020 Passenger Car C	030 Maintenance Ve	050 Trackwork Conti	010 Track Contracts	020 Special Trackwo
020 Civil Works Contracts											1				1	
010 At-Grade Contracts																
020 Bridge Contracts																
030 Tunnel Contracts										1	⋰			1	⋰	
040 Utility Contracts																
030 Facilities Contracts											1					
010 Station Contracts										1	⋰					
020 Depot Contracts																
030 Control Center Contracts																
040 Trainset Contracts				1			1								1	
010 Locomotive Contracts	1			⋰		1	⋰							1	⋰	
020 Passenger Car Contracts																
030 Maintenance Vehicle Contracts																
050 Trackwork Contracts				1							1					
010 Track Contracts	1			⋰						1	⋰					
020 Special Trackwork Contracts																



MBSI FRAMEWORK USE

[3] CUSTOMIZE & TAYLOR: ADDING PROJECT-SPECIFIC INTERFACE REQUIREMENTS



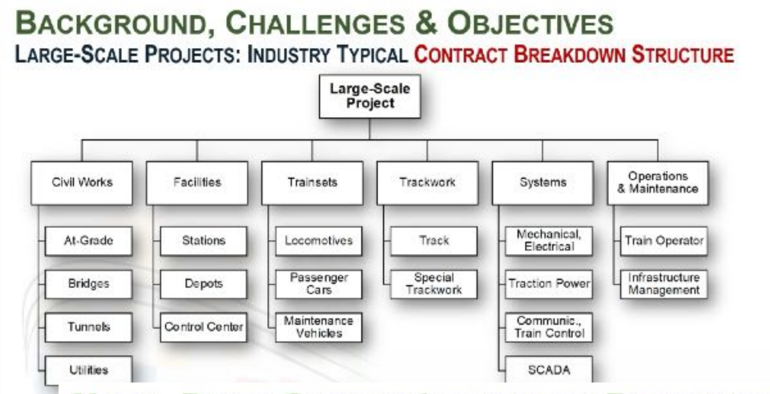
#	Name	Interface Requirements	Interface Features	Exchange Items	Interfacing Subsystem
1	01 INF - Structure gauge [4.2.3.1]	R TSI-INF-1.4.2.3.1 4.2.3.1 Structure gauge	F out : INFStructureGaugeType F in : RSTKinematicGaugeType R : 01 RST - Rolling stock kinematic gauge [4.2.3.1]	INFStructureGaugeType RSTKinematicGaugeType	01 RST - Rolling stock kinematic gauge [4.2.3.1]
2	01 RST - Mechanical and geometrical characteristics of wheels [4.2.3.5.2.2]	R LOC&PAS-TSI-1.4.2.3.5.2.2 4.2.3.5.2.2 Mechanical and geometrical characteristics of wheels	F in : INFRailheadProfileType F out : RSTWheelGeometryType R : 02 INF - Railhead profile for plain line [4.2.4.6]	INFRailheadProfileType RSTWheelGeometryType	02 INF - Railhead profile for plain line [4.2.4.6]
3	01 RST - Rolling stock kinematic gauge [4.2.3.1]	R LOC&PAS-TSI-1.4.2.3.1 4.2.3.1. Gauging	F in : INFStructureGaugeType F in : INFPlatformOffsetType F out : RSTKinematicGaugeType R : 01 INF - Structure gauge [4.2.3.1] R : 04 INF - Platform offset [4.2.9.3]	INFStructureGaugeType INFPlatformOffsetType RSTKinematicGaugeType	01 INF - Structure gauge [4.2.3.1] 04 INF - Platform offset [4.2.9.3]
4	01 TRK - Track Form		F out : TRKTrackFormType R : 01 TUN - TunnelProvisions	TRKTrackFormType	01 TUN - TunnelProvisions
5	02 INF - Railhead profile for plain line [4.2.4.6]	R TSI-INF-1.4.2.4.6 4.2.4.6 Railhead profile for plain line	F out : INFRailheadProfileType F in : RSTWheelGeometryType R : 01 RST - Mechanical and geometrical characteristics of wheels [4.2.3.5.2.2]	INFRailheadProfileType RSTWheelGeometryType	01 RST - Mechanical and geometrical characteristics of wheels [4.2.3.5.2.2]
6	04 INF - Platform offset [4.2.9.3]	R TSI-INF-1.4.2.9.3 4.2.9.3 Platform offset	F out : INFPlatformOffsetType F in : RSTKinematicGaugeType R : 01 RST - Rolling stock kinematic gauge [4.2.3.1]	INFPlatformOffsetType RSTKinematicGaugeType	01 RST - Rolling stock kinematic gauge [4.2.3.1]

DEFINE CONTRACT –SPECIFIC INTERFACE REQUIREMENTS

PROGRESS

- Motivation
- Background, Challenges & Objectives
- Model-Based Systems Integration Framework
- MBSI Framework Development
- MBSI Framework Use
- Summary & Conclusion

SUMMARY & CONCLUSION



BACKGROUND, CHALLENGES & OBJECTIVES

LARGE-SCALE PROJECTS: INDUSTRY TYPICAL CONTRACT BREAKDOWN STRUCTURE

Large-Scale Project
- Civil Works
  - At-Grade
  - Bridges
  - Tunnels
  - Utilities
- Facilities
  - Stations
  - Depots
  - Control Center
- Trainsets
  - Locomotives
  - Passenger Cars
  - Maintenance Vehicles
- Trackwork
  - Track
  - Special Trackwork
- Systems
  - Mechanical, Electrical
  - Traction Power
  - Communic., Train Control
  - SCADA
- Operations & Maintenance
  - Train Operator
  - Infrastructure Management

BACKGROUND, CHALLENGES & OBJECTIVES

LARGE-SCALE PROJECTS: INTERFACE MANAGEMENT REALITIES

How a French rail company spent £12bn on trains that are "too wide"

Apparently, it's the sort of thing that occurs when you separate the rail operators from train companies, so will probably be happening soon at a platform near you

TRAINS

STATIONS

'Unspeakable botch': Spain spends €258 million on trains that are too big for its tunnels

OPERATORS

TUNNELS

BACKGROUND, CHALLENGES & OBJECTIVES

OBJECTIVES: PREDICTABLE, REPEATABLE PROCESS, CONVENIENT, INTEROPERABLE

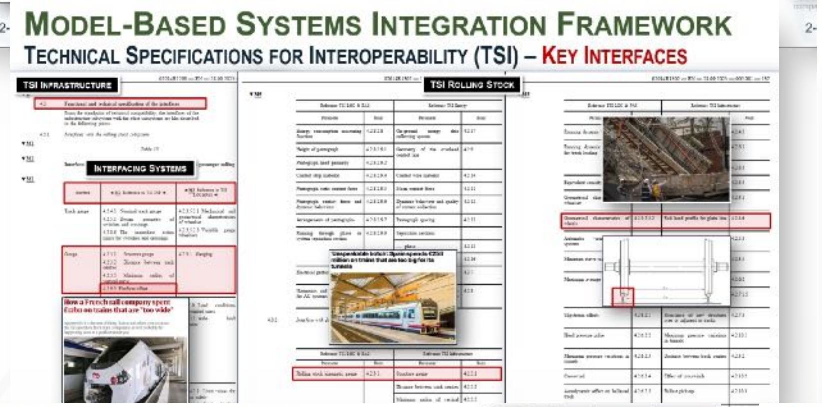
CMMI Level 1: Initial
- Unpredictable Processes, relying on SME Expertise (or Lack Thereof)

CMMI Level 2: Managed
- Repeatable Processes w/in Project

CMMI Level 3: Defined
- Repeatable Processes w/in Organization
- Project Tailors Processes from Organizational Standards

Additional Objectives
- Convenience: Ready (Easy) to Use
- Interoperable: Compatible w/ Future Contracts

CONCLUSION



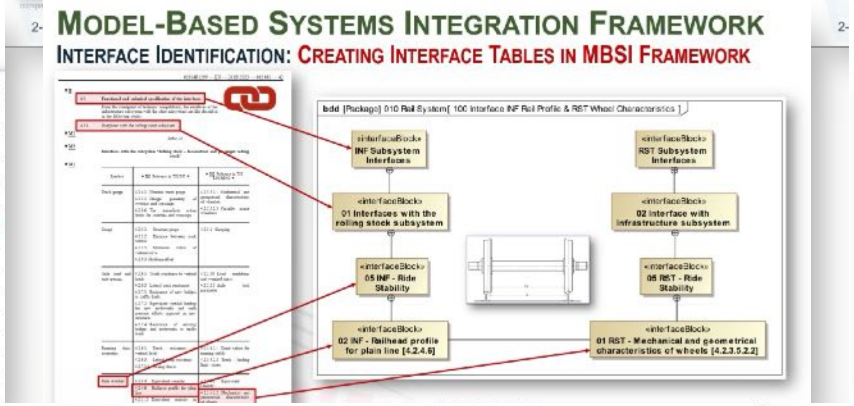
MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

TECHNICAL SPECIFICATIONS FOR INTEROPERABILITY (TSI) – KEY INTERFACES

TSI INFRASTRUCTURE

INTERFACING SYSTEMS

TSI ROLLING STOCK



MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

INTERFACE IDENTIFICATION: CREATING INTERFACE TABLES IN MBSI FRAMEWORK

bdd [Package] 010 Rail System[100 Interface INF Rail Profile & RST Wheel Characteristics]

«interfaceBlock» INF Subsystem Interfaces

«interfaceBlock» 01 Interfaces with the rolling stock subsystem

«interfaceBlock» 05 INF - Ride Stability

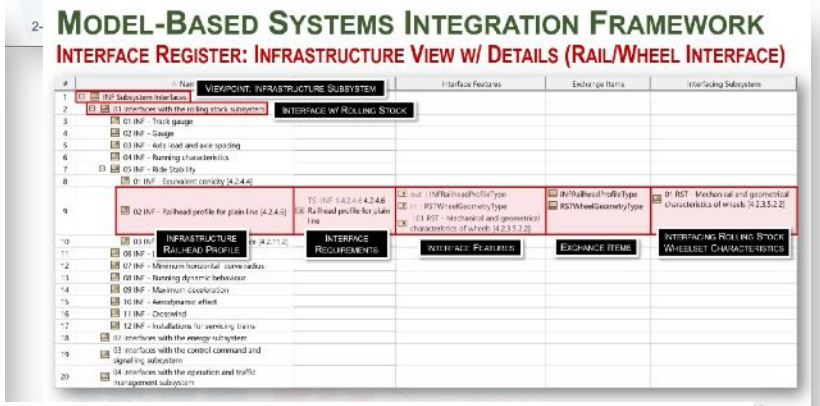
«interfaceBlock» 02 INF - Railhead profile for plain line [4.2.4.6]

«interfaceBlock» RST Subsystem Interfaces

«interfaceBlock» 02 Interface with infrastructure subsystem

«interfaceBlock» 06 RST - Ride Stability

«interfaceBlock» 01 RST - Mechanical and geometrical characteristics of wheels [4.2.3.5.2.2]



MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

INTERFACE REGISTER: INFRASTRUCTURE VIEW W/ DETAILS (RAIL/WHEEL INTERFACE)

VIEWPOINT: INFRASTRUCTURE SUBSYSTEM

INTERFACE W/ ROLLING STOCK

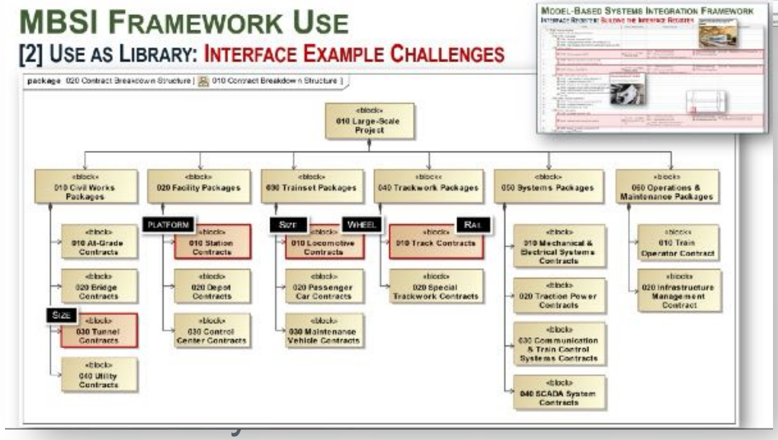
INFRASTRUCTURE RAILHEAD PROFILE

INTERFACE REQUIREMENTS

INTERFACE FEATURES

EXCHANGE ITEMS

INTERFACING ROLLING STOCK WHEELSET CHARACTERISTICS



MBSI FRAMEWORK USE

[2] USE AS LIBRARY: INTERFACE EXAMPLE CHALLENGES

package 020 Contract Breakdown Structure [010 Contract Breakdown Structure]

«block» 010 Large-Scale Project
- «block» 010 Civil Works Packages
  - «block» 010 At-Grade Contracts
  - «block» 020 Bridge Contracts
  - «block» 030 Tunnel Contracts
  - «block» 040 Utility Contracts
- «block» 020 Facility Packages
  - «block» 010 Station Contracts
  - «block» 020 Depot Contracts
  - «block» 030 Control Center Contracts
- «block» 030 Trainset Packages
  - «block» 010 Locomotive Contracts
  - «block» 020 Passenger Car Contracts
  - «block» 030 Maintenance Vehicle Contracts
- «block» 040 Trackwork Packages
  - «block» 010 Track Contracts
  - «block» 020 Special Trackwork Contracts
- «block» 050 Systems Packages
  - «block» 010 Mechanical & Electrical Systems Contracts
  - «block» 020 Traction Power Contracts
  - «block» 030 Communication & Train Control Systems Contracts
  - «block» 040 SCADA System Contracts
- «block» 060 Operations & Maintenance Packages
  - «block» 010 Train Operator Contract
  - «block» 020 Infrastructure Management Contract

SIZE

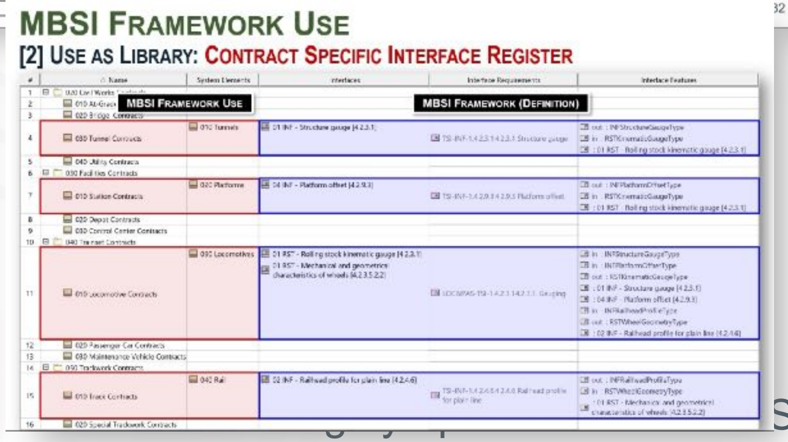
PLATFORM

SIZE

WHEEL

RAIL

MODEL-BASED SYSTEMS INTEGRATION FRAMEWORK

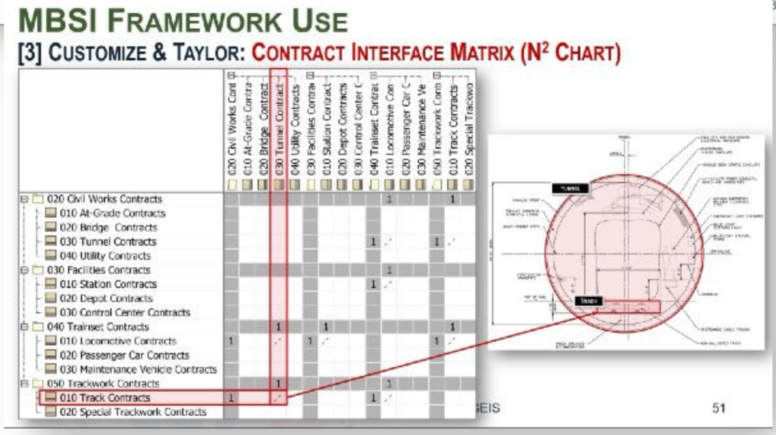


MBSI FRAMEWORK USE

[2] USE AS LIBRARY: CONTRACT SPECIFIC INTERFACE REGISTER

MBSI FRAMEWORK USE

MBSI FRAMEWORK (DEFINITION)



MBSI FRAMEWORK USE

[3] CUSTOMIZE & TAYLOR: CONTRACT INTERFACE MATRIX (N^2 CHART)

- 020 Civil Works Contracts
  - 010 At-Grade Contracts
  - 020 Bridge Contracts
  - 030 Tunnel Contracts
  - 040 Utility Contracts
- 030 Facilities Contracts
  - 010 Station Contracts
  - 020 Depot Contracts
  - 030 Control Center Contracts
- 040 Trainset Contracts
  - 010 Locomotive Contracts
  - 020 Passenger Car Contracts
  - 030 Maintenance Vehicle Contracts
- 050 Trackwork Contracts
  - 010 Track Contracts
  - 020 Special Trackwork Contracts

TUNNEL

TRACK

51

34th Annual **INCOSE**
international symposium

hybrid event

Dublin, Ireland
July 2 - 6, 2024

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