TCCS - Data Model_01_Approach

Author(s)	Benedikt Wenzel
Abstract	This document describes the scope, approach, and general methodology of Transversal CCS reg. Data Modelling.
Config Item	
Document ID	CCS_TMS Data Model/TCCS - Data Model_01_Approach#584159 TCCS - Data Model_01_Approach
Classification	Public
Status	In Approval by System Pillar
Version	1.1
Revision	584159
Last Change Date	14.05.2025
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Document History

0.1	31.03.2023	Benedikt Wenzel	Reviewed version (initial) (initial)
0.2	07.07.2023	Benedikt Wenzel	Reviewed version including Findings from Review 0.1
0.3	31.08.2023	Benedikt Wenzel	Reviewed version including Findings from Review 0.2
0.4	21.12.2023	Benedikt Wenzel	Reviewed version including Findings from Review 0.3
1.0	11.09.2024	Benedikt Wenzel	Approved version based on Review 0.4
1.1	10.05.2025	Benedikt Wenzel	Reviewed version including Change Request

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1 Purposee

This document describes the scope, approach, and general methodology of TCCS regarding data modelling. Since the overall data model is a central topic of this transversal subdomain, an emphasis is put on the mode of work and collaboration with the System Pillar Tasks/Domains and the Flagship Areas of the Innovation Pillar. In addition, the integration into ERA ontology is described.

2 References

TCCS - Data Model_01_ERA Ontology Extension

TCCS - Data Model_02_Methodology

TCCS - Data Model_02_Schema

3 Definitions

CCS/TMS Extended ERA Ontology (CCS/TMS Data Model)

The CCS/TMS Extended ERA Ontology and its derived CCS/TMS Data Model defines the harmonised data language for configuration, communication and diagnostics interfaces within ERJU System Pillar architecture. The Transversal CCS domain is responsible for the specification of the CCS/TMS Data Model in collaboration with

- the System Pillar domains, which apply the defined data structures in interface specifications
- the Innovation Pillar, which proves the applicability of the data model by demonstrators.

4 Summary

SPT2TS-123978 - The Transversal CCS Sub Domain 1 (SD1) of the ERJU System Pillar started its activities in December 2022. As part of the ERJU System Pillar, standardisation focuses on traffic/train CS, traffic management, or use cases such as diagnostics. Subsystems and interfaces are standardised within the System Pillar to implement functionality such as Train Protection or Automated Operation. The CCS/TMS data model builds the **base for harmonised configuration, communication and diagnostic**s over the interfaces as defined by ERJU System Pillar. **[** Open **]**

SPT2TS-123981 - The data model is not derived from existing legacy processes and artefacts but instead **is driven by functional system data needs**. The model shall enable digital solutions best adapted to provide configuration data of the required quality in the most efficient way. This functional-driven approach maximises the potential for a generic data model and harmonised rules, data formats, processes, and tools. **[** Open **]**

SPT2TS-123982 - TCCS avoids inventing new models but rather picks and recombines fragments from existing standards or data models to fit the functional and non-functional needs that are elicited within TCCS and by the other domains representing the data users. These requirements and analyses are sources or rationales for design decisions. The result of TCCS is a merged data model based on technical specifications, supporting the direct usage by the systems and the whole life cycle of data within the System Pillar architecture (incl. safe data publishing, activation or deactivation of data versions). **[** Open **]**

SPT2TS-123983 - The resulting SPT2TS-2040 - CCS/TMS Extended ERA Ontology (CCS/TMS Data Model) is controlled by the System Pillar TCCS SD1 to enable governance and stability. The latter shall support backwards compatibility and address the aspect of securing investments into toolchain developments or expensive modifications to processes. The migration to the "Single European Railway Area" (SERA) shall be supported by specific extensions to the interface model. **[** Open **]**

SPT2TS-123980 - Following the regulations, it has been decided by ERJU and ERA to **integrate the achievements of Transversal CCS with regard to CCS/TMS Data Model into the ERA ontology**. This connection to the binding railway ontology offers a comprehensive approach and long-term maintenance of the data model. Hence, investments into interface implementations or reliable tool chains (EN50716 compliant) based on the data model are secured. This also offers a profound and stable basis for digital end-to-end processes - from engineering, validation to data provisioning (for details see ~~SPT2TS-2053~~ - *Missing cross-reference*). **[** Open **]**

5 CCS/TMS Extension of ERA Ontology

SPT2TS-2052 - The CCS/TMS data language will be the base at least for ERJU specifications for communication interfaces, diagnostics and configuration. The CCS/TMS model specification is highly integrated into the System Pillar system engineering tool chain (Capella, Polarion,..).
Furthermore, the integration into the ERA Vocabulary as CCS/TMS extension is decided and performed for the purpose of legislation, long-term maintenance and semantical linking to further data models. Besides reusing semantic definitions and obtaining consistent use of terms within the railway domain, this approach also offers the possibility to benefit from existing links of other data models, which already are or will be connected with ERA vocabulary.

As a result of the integration, all further developments in the System Pillar regarding data models are reflected in ERA vocabulary. Official releases of the data model will always be derived from ERA vocabulary by an automatized process, as shown by the following process overview:

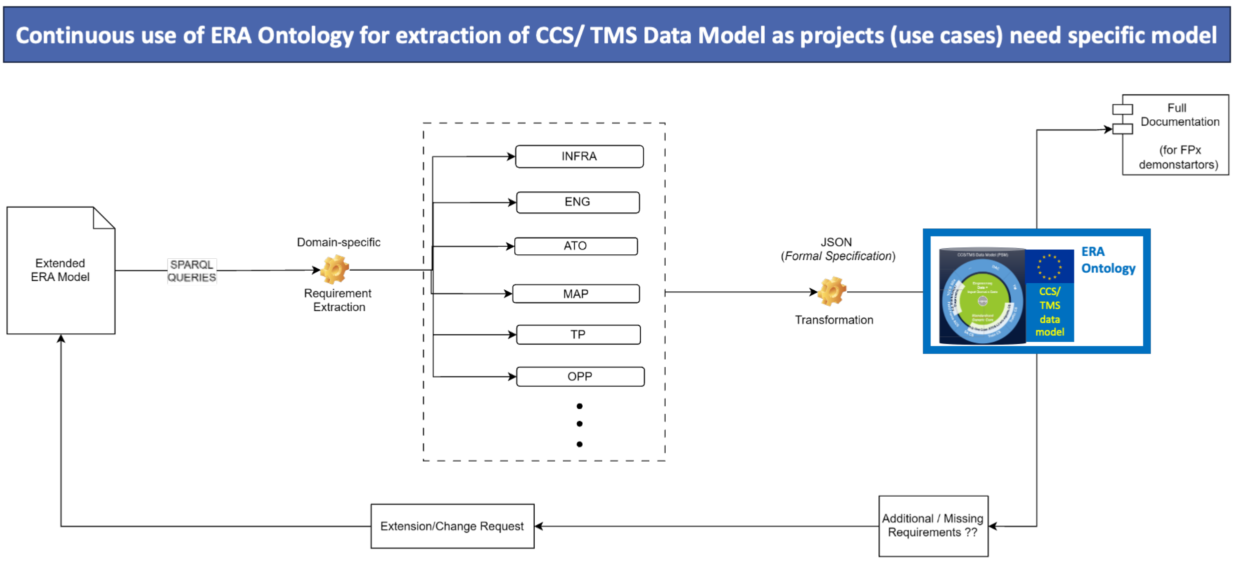


Figure 1 CCS/TMS Data Model derived from ERA Vocabulary to serve interface specification and demonstration needs

To support the specification process, the representation of the CCS/TMS data model in the toolchain of System Pillar (Polarion and Capella) is maintained by an automated toolchain, which keeps the connection to ERA vocabulary.

[Open **]**

SPT2TS-130685 - The **Extended ERA Ontology** is publicly accessible via the following GitLab repository:

https://gitlab.com/era-europa-eu/public/interoperable-data-programme/era-ontology/era-ontology/-/tree/ext-ccstms?ref_type=heads **[** Open **]**

SPT2TS-130686 - This ontology serves as a **single source of truth** for multiple railway digitalization initiatives, and is intended to support:

- Interoperable data exchange across systems;
- Precise modeling of railway infrastructure, assets, and operational scenarios;
- Querying and extraction of relevant domain-specific views (e.g., ETCS L2/3 use case for engineering and planning,

TMS/SCI-OP use case , etc) using metadata tagging;
- Conformance validation and semantic reasoning.

[Open **]**

SPT2TS-130683 - The Extended ERA Ontology was developed to unify and operationalize two complementary perspectives of the European railway system:

- The ERA RINF model, which offers a meso-level abstraction of railway infrastructure, emphasizing interoperability and regulatory compliance.
- The CCS/TMS specifications, which demand micro-level granularity for specific safety, control, engineering, and monitoring use-cases among others.

[Open **]**

SPT2TS-130684 - The primary purpose of the Extended Ontology is to:

- Enable semantic interoperability between diverse railway information systems.
- Bridge the abstraction gap between high-level regulatory data and low-level technical details.
- Facilitate data reuse and integration by providing a shared vocabulary and formal semantics.
- Allow targeted sub-ontology extraction via metadata-driven queries, reducing complexity and increasing relevance per use-case.
- Promote modular, standards-based development by leveraging existing ontologies (e.g., SKOS, Time Ontology, GeoSPARQL)

[Open **]**

Further details regarding the CCS/TMS extension of ERA ontology are defined in TCCS - Data Model_01_ERA Ontology Extension.

6 TCCS Data Scope

SPT2TS-2037 - A harmonised digital CCS/TMS system requires a shared data language applied at all relevant interfaces with similar exchange items. Furthermore, it requires comprehensive configuration data for implementing systems according to the System Pillar architecture (i.e. radio-based ETCS only). With the
SPT2TS-2040 - CCS/TMS Extended ERA Ontology (CCS/TMS Data Model)
the System Pillar provides a data structure for standardised engineering and to align a data structure for standardised interface specifications within CCS including CCS-TMS. This data structure shall be suitable across all relevant use cases of the System Pillar such as engineering and communication for traffic control or automated train operation.

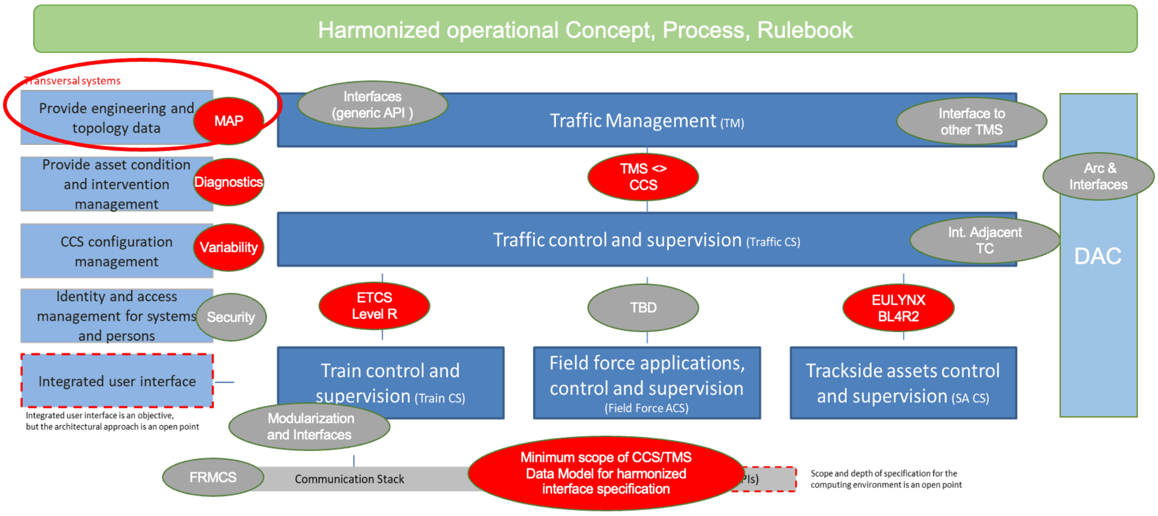


Figure 2 Interfaces between domains and minimum scope of CCS/TMS data model

The Data Model and interface specification must be comprehensive for SERA and therefore sufficiently detailed (not on a high conceptual level), at least on the Functional Interface Specifications (FIS) level within the System Pillar architecture. The development must be according to SEMP. The modelling approach is selected to support these goals.

While the TCCS domain is located in Task 2 of the System Pillar, it offers the inclusion of other tasks with the same and consistently applied CCS/TMS Data Model, as it is already applied for the interface between Task 2 and Task 3 TM.

[Open **]**

SPT2TS-129336 - The TCCS configuration Process covers only the distribution of static configuration data through the configuration interface as defined in the Data Terms for CONEMP, including SPT2TS-127779 - Configuration Data and SPT2TS-127775 - Software Configuration Data. The dynamic or semi-dynamic data, in addition to operational data, are out of the scope of the TCCS Configuration Process and are considered to be fully distributed through the communication (SCI) interfaces.
The only dynamic data considered in the TCCS scope is the diagnostic data collected from the assets.

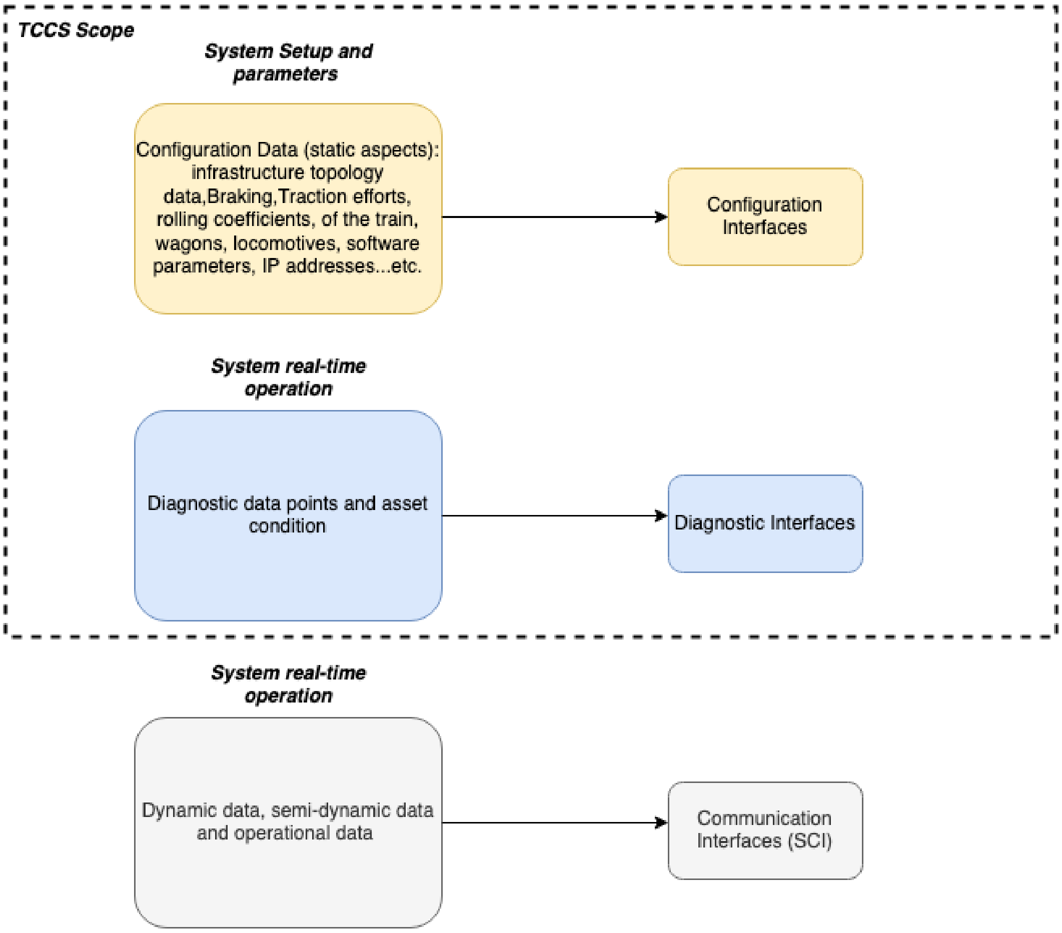


Figure 3 TCCS data scope

[Open **]**

The rationale for this scoping:

Separation for different purposes and frequencies

The configuration data is usually less frequent and needed during system setup or reconfiguration, while dynamic/semi-dynamic data are more frequently exchanged and usually during system operation and runtime, which results in more high-performance requirements for the distribution interface, especially for safety-critical systems.

Synchronization

By separating the channel for static data and dynamic data, we avoid concurrent communication of runtime data and the associated synchronization problems, especially in the safety-critical system.

Migration/backwards compatibility

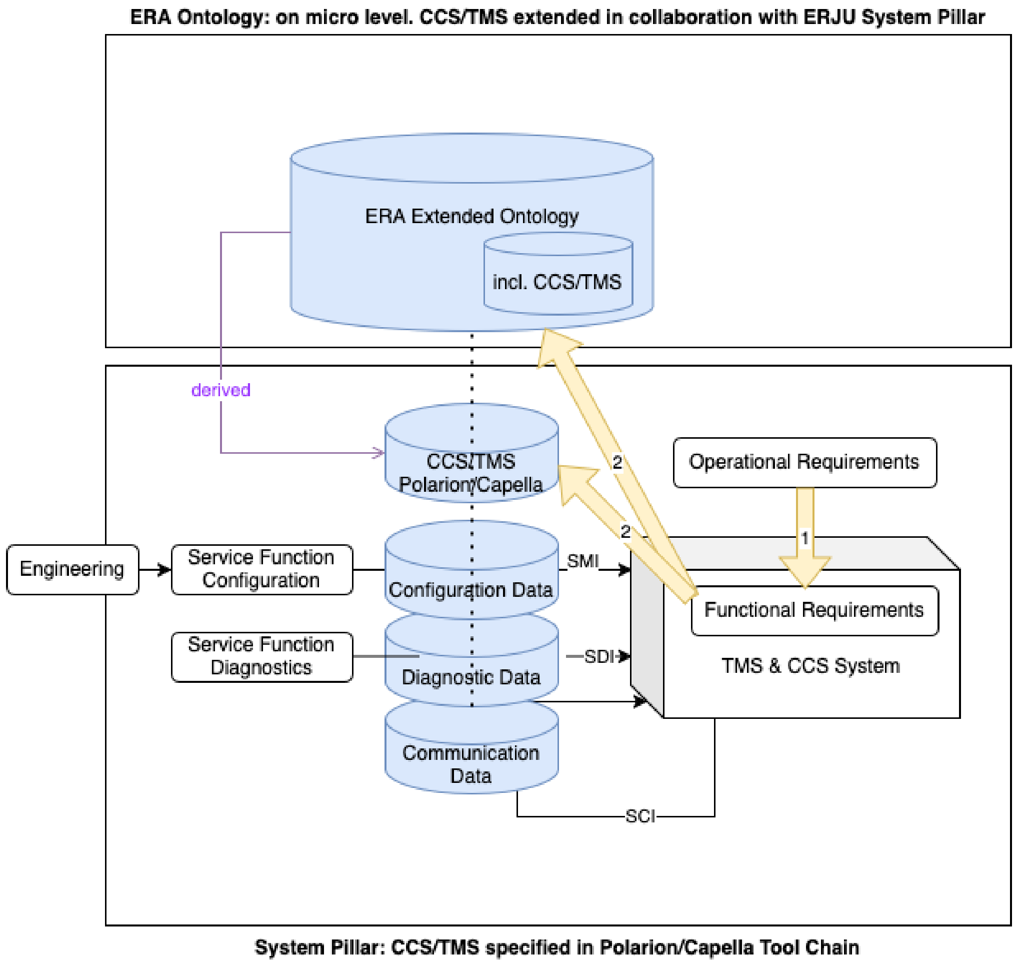
Today, all dynamic data are communicated over the SCI interfaces. For example, some train data is already part of SCI, e.g. for ATO. Also a similar approach for the Trackside asset/ EULYNX subsystem where the dynamic data is communicated over SCI interfaces.

Self-contained systems with minimum dependencies

Modern architectures avoid dependencies by self-contained systems, ensuring high availability and reliability during operation.

7 Data Model follows Function

SPT2TS-130734 - As shown in the figure below, the data structures of CCS/TMS are built from functional requirements of the systems . The functional requirements are derived from the operational requirements allocated to CCS and TMS systems. The resulting data structures are added to ERA Extended Ontology and mirrowed to Polarion/Capella specifcation documents, which define the configuration, diagnostics, and communication interfaces and the communicating systems.



[Open]

Figure 4 :CCS/TMS Data Model as ERA Extended Ontology follows functional needs

7.1 Functional-driven Harmonization of Configuration Data

SPT2TS-123984 - Today, Engineering Data-related processes are too often paper/drawing-based, manual activities, inefficient, and not state-of-the-art – compared to the available technical possibilities. Subsystem-specific, propriety formats characterise the Domain Data. Consequently, standardised digital toolchains in the field of CCS engineering are not yet established in the railway domain.
As with national BIM plans by infrastructure managers, a proper digitisation strategy also relies on the standardisation of interfaces within this process to support coordination, data exchange, and close collaboration within the project. The standardisation is also a consequence of the SERA objectives and call for a harmonised solution. **[** Content to be approved **]**

SPT2TS-123985 - The data structures developed in national contexts are a first step towards this digitised process flow. The international standardisation of data formats, rules, and processes improves the business case and ROI due to scale. Higher development costs related to safety, such as CCS, increase the need for a standardised environment with the semi-automated, digitised engineering process, i.e. planning, validation or transformation functions. Today, several initiatives provide interface data formats, such as EULYNX Data Prep, railML, RSM, RCA, IFC-rail, Linx4Rail, and X2R4-PSM. These partially overlapping standards complicate the decision process of IMs or other parties to invest and build toolchains following long-term roadmaps. Also, the coexistence of several data standards in parallel for the same use case is not acceptable for safety, functional or economic reasons if a new, standardized architecture, as intended by the System Pillar, is developed. ERJU System Pillar shall improve the situation by harmonising the input information required from engineering or infrastructure data inputs to operate the System Pillar systems within their area of operation. As it will be shown in the following chapters, the decisions will be driven by the functional needs of the consumers, though the technical and economic feasibility is equally essential for the System Pillar design process. **[** Content to be approved **]**

SPT2TS-130733 - The results of this function-driven configuration data specification is specified and approved with Polarion and Capella tool chain of the System Pillar according to SEMP. **[** Open **]**

7.2 Functional-driven Harmonization of Communication Data

SPT2TS-130731 - To enable harmonised data structures for communication interfaces, the functional exchanges are analyzed regarding their data needs and also checked against the variable data model classes of CCS/TMS. This process requires an intense collaboration between Transversal CCS and the domains specificing the systems and interfaces applying the data. It is expected that this process can start on any System Level of Architecture Process, though it is on a conceptual characteristics until System Analysis. The process is documented in Capella/Polarion as specified by the SEMP. **[** Open **]**

7.3 Functional-driven Harmonization of Diagnostic Data

SPT2TS-130732 - Diagnostic data as specificied by Transversal CCS in collaboration with the domains repsonsible for the CCS/TMS systems will also be derived from functional needs. As a result, the structures of the same CCS/TMS data model are used and extended. The process is documented in Capella/Polarion as specified by the SEMP. **[** Open **]**

8 Annex

8.1 Assumptions regarding SP Target Architecture

Regarding the overall System Pillar architecture, the following assumptions relevant to SD1 are made:

SPT2TS-2034 - Increased configurability

- The systems (as designed by domains like Traffic CS) will offer generic functionality with parameterisation, so Software and configuration are separated.
- The systems will offer flexible data loading and configuration regarding Topology and Asset Data.

[Open **]**

SPT2TS-2035 - Increased data needs

- In the future, the consumers of topology, geometry, and further information will increase, e.g. localisation, IPM/Perception systems, management systems, information systems, and warning systems.

[Open **]**

SPT2TS-2036 - Support of CCS/TMS data model

- All system interfaces that transport Domain Data will support a common data structure and semantics as defined by the SPT2TS-2040 - CCS/TMS Extended ERA Ontology (CCS/TMS Data Model), incl. interface-specific quality constraints that must be met. However, use case-specific restrictions on the interfaces are expected, e.g. from file loading up to „on-the-wire“ transmission with binary protocols.

[Open **]**

SPT2TS-2033 - Generic engineering and data validation rules

- Standardised architecture, standardised engineering rules, and harmonised operational rules go together.
- Generic engineering rules enable standardised implementation and the economical automation of data generation, validation, and transformation.

[Open **]**

8.2 Constraints and applied Modelling Approach

8.2.1 Constraints

SPT2TS-123929 - As long as System Pillar Domains are in early development phases such as Operational or System Analysis, the possibilities for a collaborative interface design and approval based on the CCS/TMS Data Model are very limited. At the same time the parallel Innovation Pillar is expecting the CCS/TMS Data Model as a performant basis for their specifications and demonstrators.
TCCS defined a working mode compatible with the System Pillar's SEMP which supports the evolution of the other domains without missing the contributions to the Innovation Pillar as an important resource. **[**Content to be approved **]**

8.2.2 Top-Down and Bottom-Up

SPT2TS-123930 - Hence, TCCS has already provided the first releases to the Innovation Pillar to test the CCS/TMS Data Model in actual applications and ensure sufficient maturity before proceeding with standardisation. The feedback from the Innovation Pillar is continuously processed to improve the CCS/TMS Data Model, under permanent consideration of a standardised data structure for all use cases of the System Pillar. This process part is called "bottom-up" - since it starts with the requirements and feedback from the implementation and application of the CCS/TMS Data Model. In order to achieve standardisation within System Pillar, the "bottom-up" approach is combined with a parallel "top-down" approach of the System Pillar. During the starting phase, this process works with requirements derived from high-level objectives and assumptions regarding the needs of other domains. These needs are based on already well-defined use cases that remain stable (such as radio-based ETCS only, Trackside Assets, ATO GoA 2), prework from input documents coming from LinX4Rail, EULYNX, OCORA, RCA and others, and ongoing discussions with the System Pillar domains and Flagship Areas projects of the Innovation Pillar.
To sum it up, TCCS chose the following combination of principles for effective development and collaboration:

- **Top-down** development based on objectives, assumptions up to approved requirement specifications with other domains following the rules of System Pillar SEMP (System Engineering Management Plan)
- **Bottom-up** development based on practical experiences i.e. of demonstrators from Innovation Pillar, which is supported by the provided CCS/TMS Data Model formats for implementation (e.g. json, xml)

So, while the CCS/TMS Data Model might face pending domain approvals in the early stages, the **profound basis of the System Pillar foundation (LinX4Rail, RCA, EULYNX, OCORA) as well as the practical collaboration with the Innovation Pillar and other early adopters (ERA, PRIME, ...) allow quick and mature development of model increments** (see also development history in SPT2TS-122465 - CCS/TMS Data Model Revisions) **[** Content to be approved **]**

8.2.3 Functional-driven data model design

SPT2TS-123931 - Independently of the applied principle (top-down, bottom-up), the resulting CCS/TMS Data Model is always derived from functionality, which means each data structure shall be linked to a functional use case (e.g. gradient profile for ETCS supervision, infrastructure objects for radio based ETCS only asset engineering, ATO, localisation, ,..) and its constraints. Consequently, **each model part has a trace to the system functions or interfaces that use the defined structures**, enabling all advantages of model-based system design and ensuring the completeness and consistency of data structures. The impact of possible model adaptions can always be evaluated regarding affected functions, systems, and interfaces. Non-functional aspects can be inherited from the function to the linked data structures (e.g. accuracy of location data).
The principle of functional-driven is applied for all kinds of interfaces and along the complete data life cycle. Hence, the engineering data as input for planning, building and configuration will also be function-driven instead of process-driven. It is explicitly prevented to build up the data model based on (digital versions of) existing engineering/ preparation processes based on particular national IM or supplier-specific procedures or guidelines. The resulting CCS/TMS Data Model shall be minimal, while the structure for engineering and configuration should already be comprehensive for the actual communication during operation (e.g. the model contains lightweight, high-performant sampled geometry descriptions (e.g. ETCS, ATO,..), and very accurate, lossless track alignment model part is provided for first operational use cases requiring it).
The principle can be applied and documented with the Polarion tool (e.g. see example SPT2TS-122498 - Timing Point

(Demo Structure) as well as Capella or similar MBSE tools. **[** Content to be approved **]**

8.3 Expected Application within System and Innovation Pillar

SPT2TS-123933 - Based on the described scope and approach the CCS/TMS Data Model is expected to be applied to the following activities:

- System Pillar:
  - data structure for communication interface specifications, i.e. within CCS but also including CCS-TMS interface
  - data structure for maintenance interface specifications, i.e. for providing new versions of Configuration Data
  - data structure for diagnostic interface specifications
- Innovation Pillar:
  - data structure for Data Specifications and Implementation for different use cases and demonstrators, e.g. ATO, Moving Block, Localisation, e.g. FA2 WP13, WP27, WP45, WP21.
  - data structure for Engineering Data and process/ tool specifications and developments, e.g. FA1 WP 27
  - validation tooling for enabling the uptake of the CCS/TMS Data Model in all related projects of the Innovation Pillar FAs

No licensing model (i.e. for external usage) has been decided yet (e.g. European Union Public Licence EUPL, Version 1.2). **[** Open **]**

8.4 Consequences for the System Pillar Domain Design

SPT2TS-2039 - The SPT2TS-2040 - CCS/TMS Extended ERA Ontology (CCS/TMS Data Model) and life cycle aspects will impact interfaces, which must be specified by the System Pillar architecture and domains. To support domain-driven extensions and maintain control of the data model, the following working mode shall be applied from the SD1 perspective (see also ~~SPT2TS-1860~~ - *Missing cross-reference*).

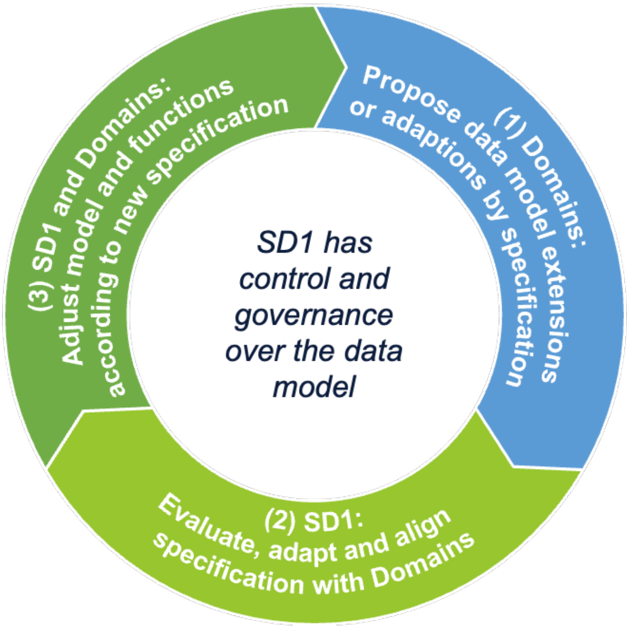


Figure 5 : Cycle of domain-driven data model extensions and collaboration with SD1

1. The domains specify the needs regarding data in a unified way. This includes structural aspects such as objects, attributes, relations, and quality criteria (e.g. accuracy, expected update frequency, time-criticality, safety-criticality)
2. The domains discuss the needs with SD1. During this process, the data model extensions are worked out and evaluated by SD1. Besides data structure, the alignment process could also include decisions regarding conflicting targets/quality criteria (e.g. high accuracy requirements vs. always updated data)
3. After that, SD1 and the domains adjust their specifications according to the result of the alignment process.

The above-mentioned cycle starts again for each evolution step (ensuring backward compatibility, i.e. for TSI increments). A similar procedure is proposed to collaborate with Flagship Areas of the Innovation Pillar. **[** Content to be approved **]**

8.5 Formal Specification and Schema Transformation

SPT2TS-2043 - To provide a model that is unambiguous and very close to implementation, the SD1 decided to use a formal, textual specification including meta-information such as semantics and linking to source data models. Based on the experiences in former modelling or implementation projects, a JSON notation has been selected and described as schema TCCS - Data Model_02_Schema. The data model itself is explained and documented in TCCS - Data Model_02_Methodology. The definitions of this document are automatically exported into technical schema files (e.g. XML/XSD, json,..) that can be used for the first implementation, demonstration and testing purposes to support a high grade of maturity even in early development stages. **[** Content to be approved **]**

The following excerpt from TCCS - Data Model_02_Methodology gives an impression of the chosen JSON notation (Example: Topology):

SPT2TS-1697 - Formal specification "Topology":

```
{
 "structs": [
 {
  "name": "TrackEdge",
  "info": "A track edge is an uninterrupted stretch of railway track, without divergence or convergence.",
  "belongsToSubPackage": "topology",
  "see": "http://ontorail.org/rsm12/Common/Topology/LinearElementWithLength",
```

"attrs": [
{"intId": 1, "name": "id", "dataType": "string", "key": true, "info": "Identity of the track edge, needed for referencing"},
{"intId": 2, "name": "name", "dataType": "string", "info": "User-friendly name. Empty string, if equal to the id"},
{"intId": 3, "name": "length", "dataType": "uint32", "units": "m", "exp": -3,
"info": "Distance along the TrackEdge's 3D-alignment. Use zero if not defined."}
]
},
{
"name": "TrackEdgeLink",
"info": "Defines a relation between two track edges along which a train can run.",
"see": "http://ontorail.org/rsm12/Common/Topology/PositionedRelation",
"belongsToSubPackage": "topology",
"attrs": [
{ "intId": 1, "name": "id", "dataType": "string", "key": true, "info": "Identity for referencing, e.g. by points and crossings"},
{ "intId": 2, "name": "trackEdgeA", "reference": "TrackEdge", "info":"Connects to track edge A"},
{ "intId": 3, "name": "trackEdgeB", "reference": "TrackEdge", "info":"Connects to track edge B"},
{ "intId": 4, "name": "startOnA", "dataType": "boolean", "info": "True when linked to the start of track edge A, false when to the end"},
{ "intId": 5, "name": "startOnB", "dataType": "boolean", "info": "True when linked to the start of track edge B, false when to the end"}
]
},
{
"name": "TopoArea",
"info": "Defines a container for rail network topology",
"belongsToSubPackage": "topology",
"attrs": [
{"intId": 1, "name": "id", "dataType": "string", "key": true},
{"intId": 2, "name": "trackEdges", "composition": "TrackEdge", "multiplicity": "0..*", "sorted": true},
{"intId": 3, "name": "trackEdgeLinks", "composition": "TrackEdgeLink", "multiplicity": "0..*", "sorted": true}
]
}]
} **[Deleted]**

SPT2TS-2044 - The formal representation also allows automatic transformation into specific schemata for different applications (protobuf, xml/xsd, or further development/documentation (e.g. UML). The tools for transformations and resulting schemata will be provided as part of the next releases. **[** Content to be approved **]**

SPT2TS-1657 - The model is primarily documented, versioned and stored in Polarion. The model is exported with each release and parsed into the mentioned data schemata. These schemata allow unambiguous standardisation and fast integration into development tools or demonstrators with test data, i.e. Innovation Pillar. This practical usage of the model creates a short feedback loop so that a high level of maturity is quickly attained.

In addition, a translation into UML (e.g. plantUML, XMI) can be used for overall model visualisation, which is automatically created and always consistent with the model itself. The bridge to Capella (if available to Polarion) will be used to achieve a synchronised model view with the System Pillar architecture and all other domain stakeholders working with Capella.

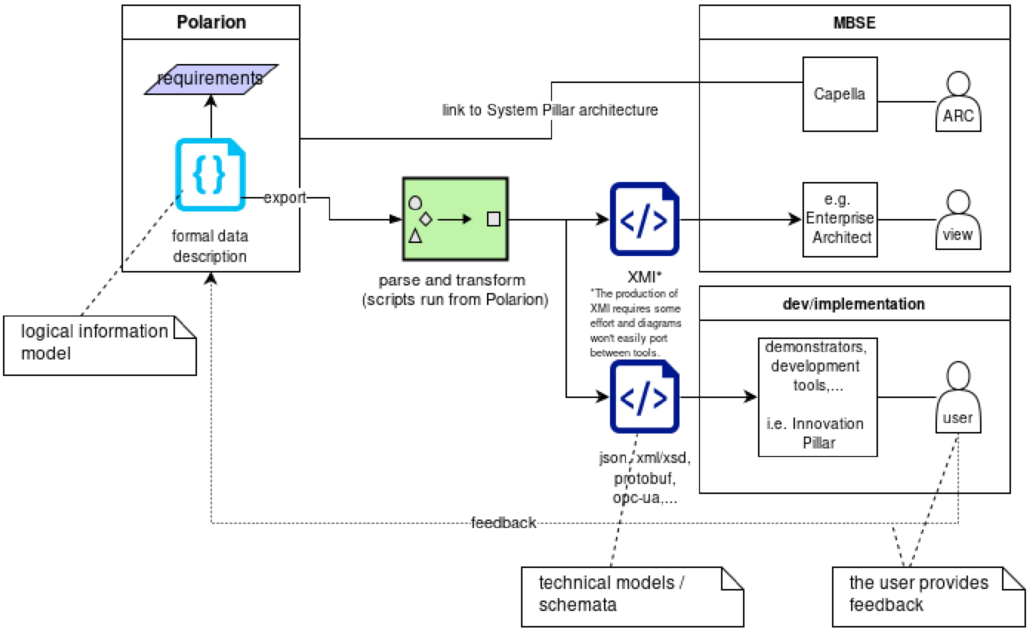


Figure 6: Handling the data model. The data model is a formal description of the object types and their relations. The ensuing technical information models are the schemata for transporting actual data over-the-wire or as files.

[Content to be approved]