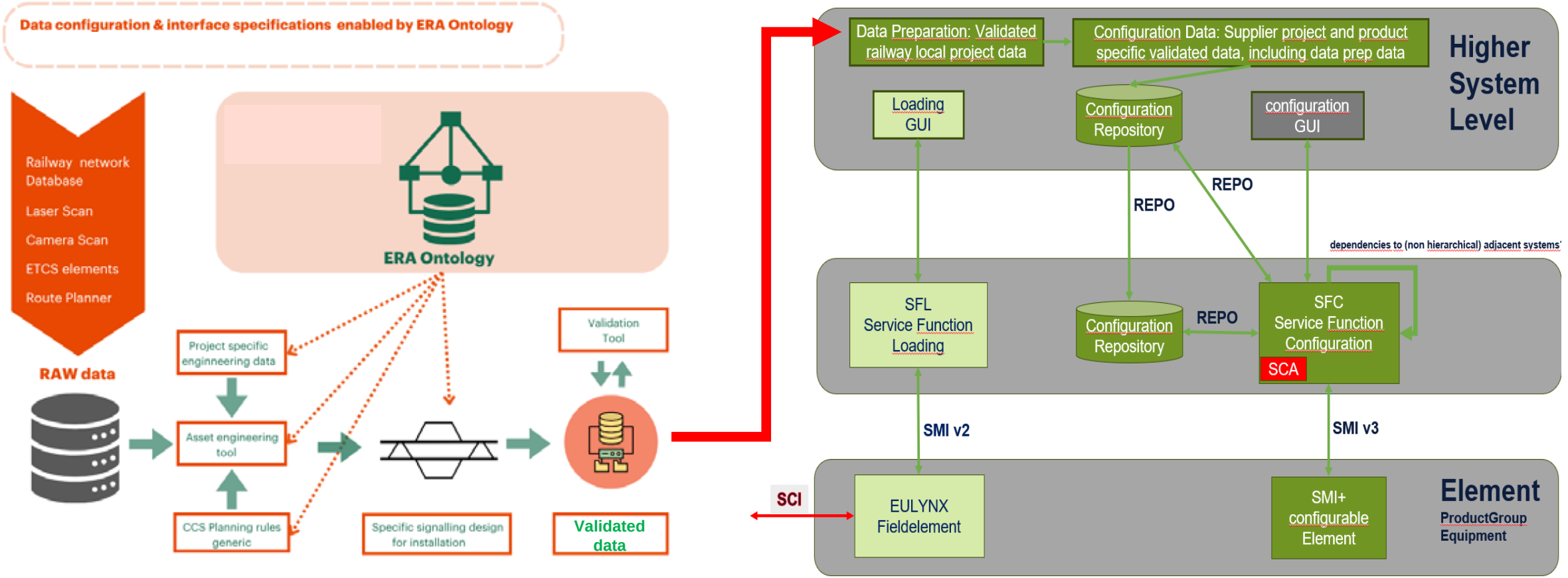
Towards a harmonised topology provision for CCS configuration with CCS TMS ERA ontology extension - Example: RBC

Europe's Rail

EU-RAIL System Pillar

ERA-ontology, extended by CCS/ TMS, enables the E2E data process from raw to config data

OBJECTIVE: *ERA-ontology* is basis and *single source of truth* for data preparation and *validation*. *Validated data* enable generating configuration data, stored in configuration repositories. *Service Function Configuration* ensures safe, reliable and interoperable operation of digital assets & trains



ERA-ontology extension allows ETCS L2 configuration for the full SP Target Architecture. As early proof-of-concept for ERA RDF 2025, the E2E process has been validated on ETCS L2 legacy product RBC.

Europe's Rail

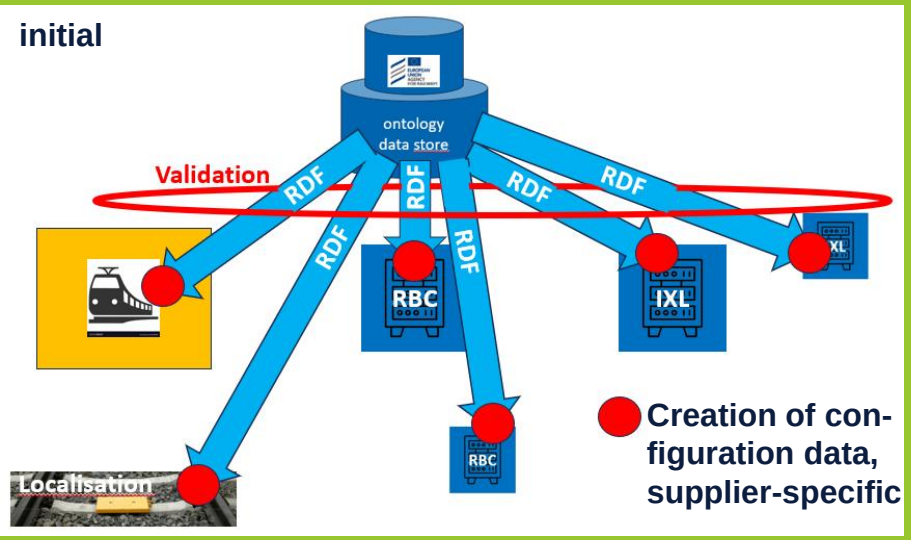
1 RBC CONFIGURATION

2 RBC OPERATION

Example RBC

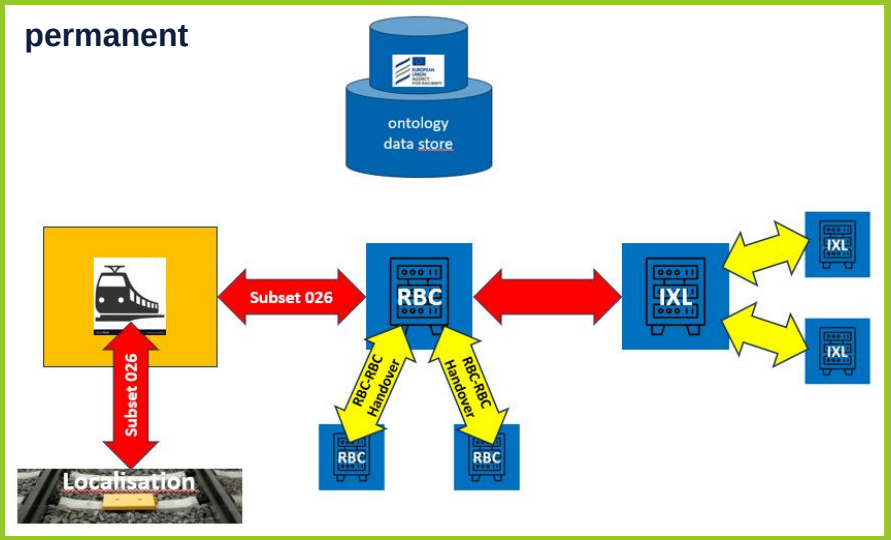
1

initial



2

permanent



GENERIC:
MODEL, METHOD, TOOLING

Single source of truth

ETCS-only specifications

System Pillar

- Safety analysis
- Operational rules
- Engineering rules
- Functional model

TSI, EN (IEC), Sector specifications

Standardised validation

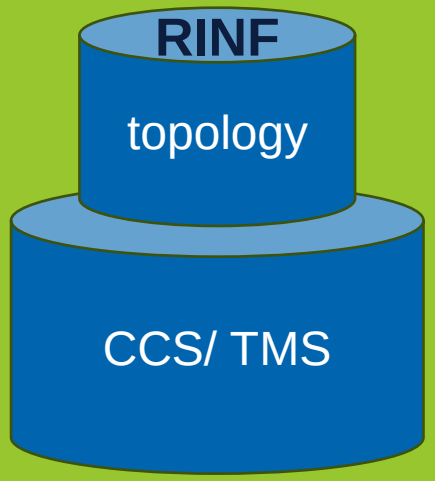
W3C: standardized *RDF*
- Querying: *SPARQL*
- Constraint validation: *SHACL*

ERJU:
- data validation method & tooling
- Functional specification models
- Service Functions Config&Diag

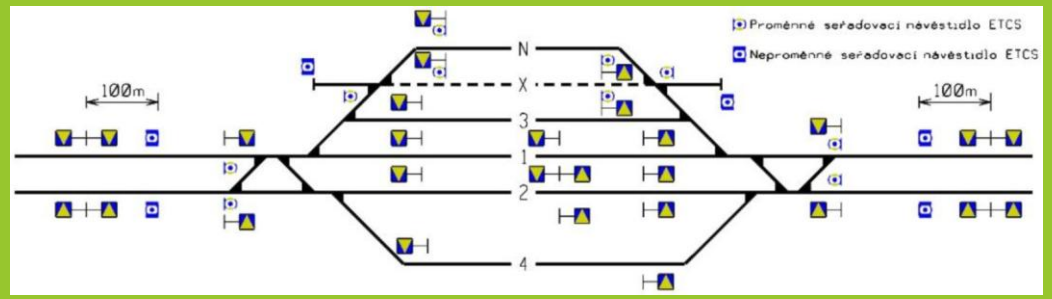
SPECIFIC:
PROJECT DATA

Example RBC

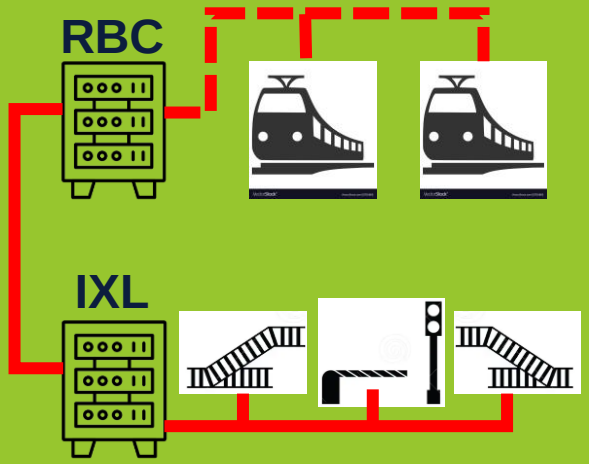
Ontology data store



ETCS-only asset



Configuration subjects



USE CASE:
RBC CONFIGURATION

Example RBC

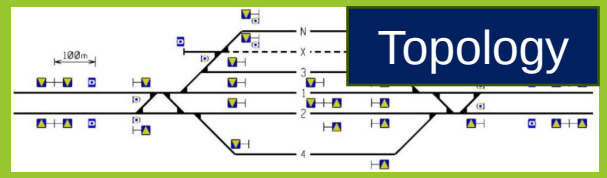
Scheibenberg data

RDF
Micro-level track data

Micro-level CCS/ TMS data

Planning & engineering

ETCS-only engineering



Topology

Track geometry

Marker boards

Static speed profile

Distances

Balise groups

Kinematic parameters

Validation

Configuration subjects

RBC

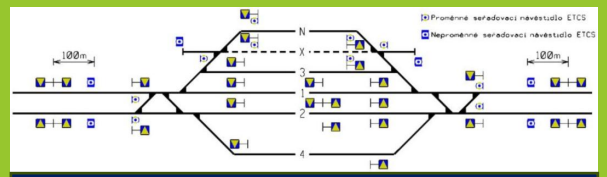
Configuration

IXL

HOW WE CONFIGURED VARIOUS RBC

Example RBC

Scheibenberg track data in RDF



Digital asset engineering

Validated Scheibenberg CCS data in RDF

Configuration of

- **Balises**
- **Interlocking**
- **Object Controler**
- **OBU (train)**
- **RBC (radio block)**
- **User interfaces**

Enablers

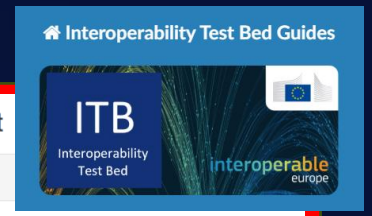
Ontology (CCS/ TMS)

ETCS-only engineering rules

Functional specification models

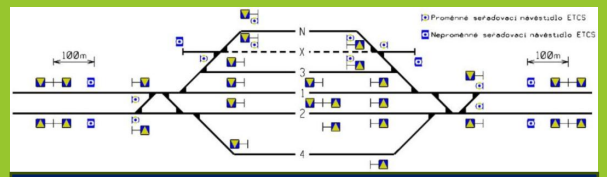
Validation tools

Europe's Rail



Example RBC

Scheibenberg track data in RDF



Digital asset engineering

Validated Scheibenberg CCS data in RDF

Configuration of

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Enablers

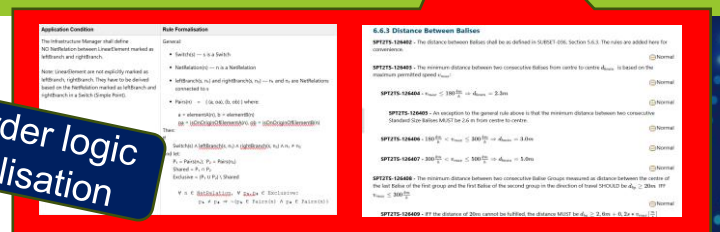
EUROPEAN UNION AGENCY FOR RAILWAYS

Ontology (CCS/ TMS)

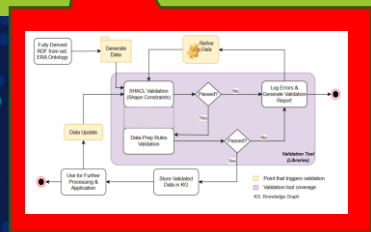
ETCS-only engineering rules

Functional specification models

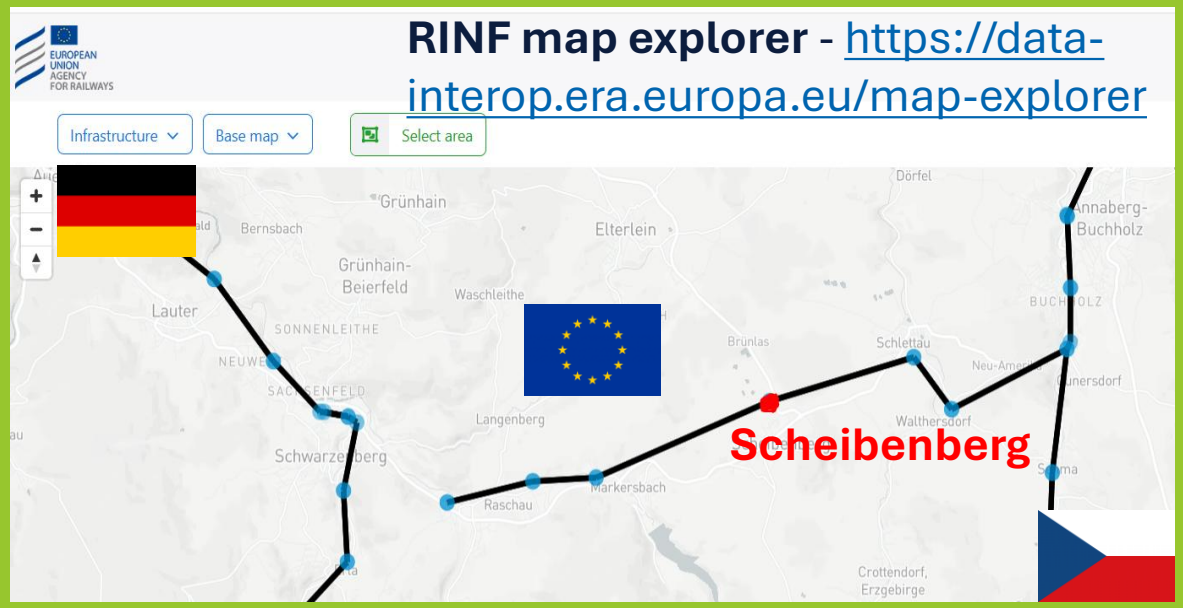
Validation tools



First order logic (formalisation



IT ALL STARTS WITH ERA ONTOLOGY



RINF map explorer - https://data-interop.era.europa.eu/map-explorer

```
era:d5ea256a-c2dc-478e-a3d4-201716c315b0 a era:CantPoint ;
    era:appliedCant "95.0"^^xsd:double ;
    era:elementGeometryPos "5646210.0"^^xsd:double .

<http://data.europa.eu/949/functionalInfrastructure/nationalLines/DE/6624>
  a <http://data.europa.eu/949/NationalRailwayLine> ;
  rdfs:label "6624" ;
  era:inCountry <http://publications.europa.eu/resource/authority/country/DEU> .

<http://data.europa.eu/949/functionalInfrastructure/lineReferences/6624_%2B10.648>
  a era:LineReference ;
  rdfs:label "+10.648 6624" ;
  era:kilometer 1.064800e+1 ;
  era:lineNationalId <http://data.europa.eu/949/functionalInfrastructure/nationalLines/DE/6624> .

<http://data.europa.eu/949/functionalInfrastructure/operationalPoints/7dc5db0ef6ff8a3c81d25eb54a367810c98b8ff1>
  a era:OperationalPoint ;
  rdfs:label "Scheibenberg" ;
  geo:location <http://data.europa.eu/949/locations/%2B12.911064/50.547598> ;
  era:inCountry <http://publications.europa.eu/resource/authority/country/DEU> ;
  era:opName "Scheibenberg" ;
  era:opType <http://data.europa.eu/949/concepts/op-types/rinf/70> ;
  era:uopid "DE00DSG" ;
  era:platforms ( era:144C54EA-70F8-4432-A44D-B53226E2B1F4 ) ;
  era:validityEndDate "2025-12-31"^^xsd:date ;
  era:validityStartDate "2025-01-01"^^xsd:date ;
  era:canonicalURI <http://data.europa.eu/949/functionalInfrastructure/operationalPoints/DE00DSG> ;
  era:hashSource "DE/DE00DSG/70/2025-01-01_2025-12-31" ;
  era:hasAbstraction <http://data.europa.eu/949/topology/netElements/DE00DSG> ;
  era:track <http://data.europa.eu/949/functionalInfrastructure/tracks/7beed3c835f37013d73c995f2ea6d5600a75d9d2> ;
  ogcgs:hasGeometry <http://data.europa.eu/949/locations/%2B12.911064/50.547598> ;
  era:lineReference <http://data.europa.eu/949/functionalInfrastructure/lineReferences/6624_%2B10.648> ;
<http://data.europa.eu/949/functionalInfrastructure/contactLineSystems/6624_DE00DSCL_single-track_DE00DSG_not%20electrified>
  a era:ContactLineSystem ;
  rdfs:label "not electrified" ;
  era:notApplicable era:maxCurrentStandstillPantograph, era:maxTrainCurrent, era:hasRegenerativeBrake, era:energySupplySystem, era:conditionalRegenerativeBrake ;
  era:contactLineSystemType <http://data.europa.eu/949/concepts/contact-line-systems/rinf/40> .

<http://data.europa.eu/949/functionalInfrastructure/load-capabilities/6624_DE00DSCL_single-track_DE00DSG_40-50>
  a era:LoadCapability ;
  rdfs:label "C2 50 " ;
  era:loadCapabilityLineCategory <http://data.europa.eu/949/concepts/load-capability-line-categories/rinf/40> ;
  era:loadCapabilitySpeed 50 .

<http://data.europa.eu/949/functionalInfrastructure/tracks/a3b023921765ee689fc2ce5bf64b43d93c7b9b31>
  a era:Track ;
  rdfs:label "single-track" ;
  era:validityEndDate "2025-12-31"^^xsd:date ;
  era:validityStartDate "2025-01-01"^^xsd:date ;
  era:canonicalURI <http://data.europa.eu/949/functionalInfrastructure/tracks/6624_DE00DSG_single-track_DE0DMAR> ;
  era:hashSource "6624_DE00DSG_DE0DMAR/2025-01-01_2025-12-31/single-track/2025-01-01_2025-12-31" ;
  era:trackLoadCapability <http://data.europa.eu/949/functionalInfrastructure/load-capabilities/6624_DE00DSG_single-track_DE0DMAR_40-50> ;
  era:magneticBraking <http://data.europa.eu/949/concepts/magnetic-braking/rinf/40> ;
  era:eddyCurrentBraking <http://data.europa.eu/949/concepts/eddy-current-braking/rinf/50> ;
  era:hasTSITrainDetection false ;
  era:trainDetectionSystem <http://data.europa.eu/949/functionalInfrastructure/trainDetectionSystems/6624_DE00DSG_single-track_DE0DMAR_Achs z%C3%A4hler> ;
  era:tenClassification <http://data.europa.eu/949/concepts/ten-classifications/rinf/40> ;
  era:maximumTemperature 40 ;
  era:minimumTemperature -25 ;
  era:temperatureRange <http://data.europa.eu/949/concepts/temperature-ranges/rinf/10> ;
  era:tsiSwitchCrossing true ;
  era:hasAbstraction <http://data.europa.eu/949/topology/netElements/6624_DE00DSG_single-track_DE0DMAR> ;
  era:trackDirection <http://data.europa.eu/949/concepts/track-running-directions/rinf/30> ;
  era:trackId "single-track" ;
  era:hasSevereWeatherConditions false ;
  era:railInclination <http://data.europa.eu/949/concepts/rail-inclinations/rinf/40> ;
  era:isQuietRoute false ;
  era:wheelSetGauge <http://data.europa.eu/949/concepts/nominal-track-gauges/rinf/30> ;
  era:minimumWheelDiameter 330 ;
  era:minimumHorizontalRadius 195 ;
  era:maximumPermittedSpeed 50 ;
  era:maximumBrakingDistance 400 ;
```

Data used from RINF

FOR DEEPER DIVES

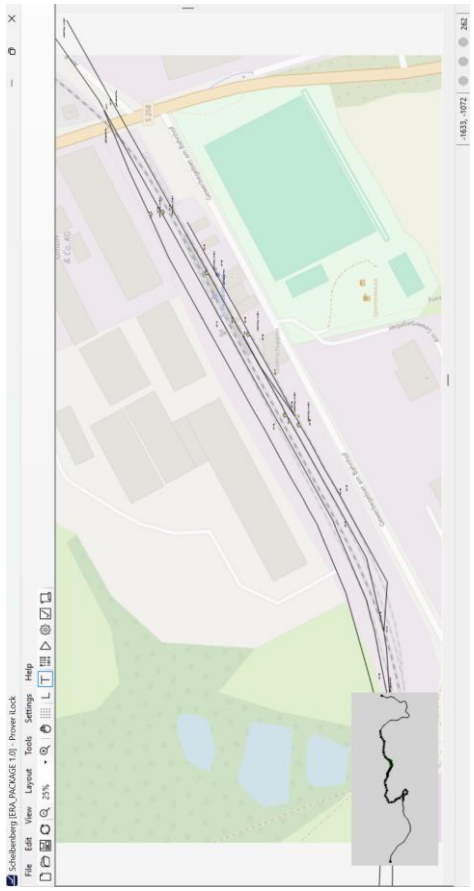
- **CCS/TMS ERA Ontology**
  GitLab – ERA Ontology (ext-ccstms branch)
- **HTML Documentation**
  Ext ERA Ontology Docs
- **RDF Dataset (Scheibenberg)**
  GitLab – RDF Data
- **Data Preparation Rules (Partially Formalized)**
  Polarion – Data Prep Rules
- **SHACL (Samples Based on Data Prep Rules)**
  GitHub – SHACL Samples

For Polarion read access please consult

Boryana.Tezgetarska@deutschebahn.com

PROOF BY SIMULATION 1

Validated Scheibenberg CCS data in RDF



Convert Scheibenberg CCS data to Prover iLock project

(using SPARQL queries)

Example: *"We want all the balise groups placed on a linear element"*

XML/ XSD

- Parse XML
- Loop over each bg : look for the subelement topological coordinates of each balise of a bg…
- **Not flexible**

RDF (TTL)

- Simple SPARQL request
- Operation on results
- Readable
- Flexible

```
PREFIX era: <http://data.europa.eu/949/>

SELECT
  (?bg AS ?id)
  (?nid AS ?nid_bg)
  (?bgOrient AS ?linkOrienta
  (?elem AS ?onLinearElement
  (?ofsAS ?offsetFromOrigin)
WHERE {
  ?bg a era:BaliseGroup .
  ?bg era:nid_bg ?nid .
  ?bg era:linkOrientationDir

  ?bg era:balises ?bal .
  ?bal era:topologicalCoordi
  ?coord era:onLinearElement
  ?coord era:offsetFromOrigi
}
GROUP BY ?bg
```

```
Prove:

  """
  Subset-026-3, §3.8.4: It shall be ensured that no overlapping movement authorities are issued for the
same track area.
  """

  SUB26_3_8_4 :=
      ALL ma1 (
      ALL ma2 (
      ~ma1=ma2 -> ~intersects(ma1, ma2)
    ));
```

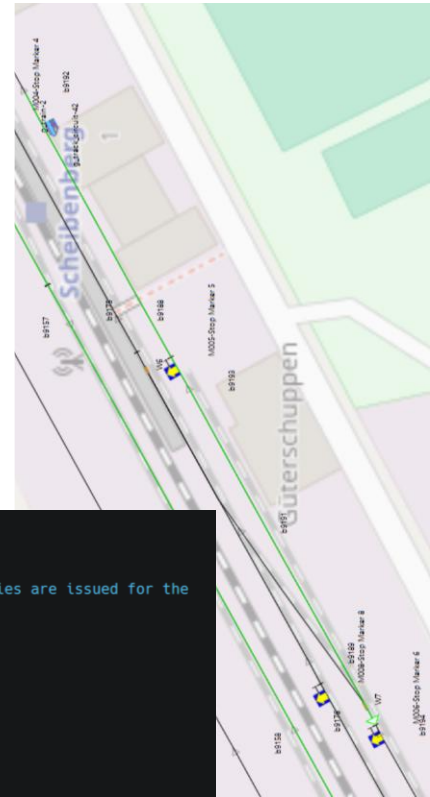
System Configuration:

- Interlocking configuration and logic
- RBC data prep:
  - Train paths
  - Distance metrics
  - …

Example RBC

Support for Additional Validation:
Engineering rules / Custom logic verification

Support for verification:
Simulation, formal verification of IXL+RBC safety properties



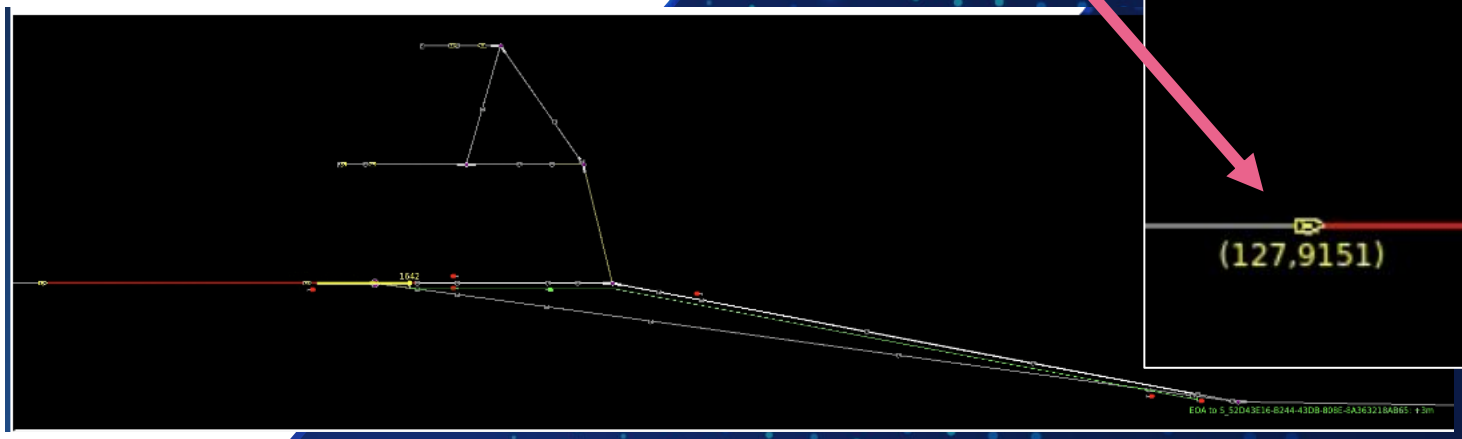
PROOF BY SIMULATION 2

CCS/TMS ERA ontology file for configuration of ETCS L2 in UNISIG Subset 026 compliant simulator

Example RBC

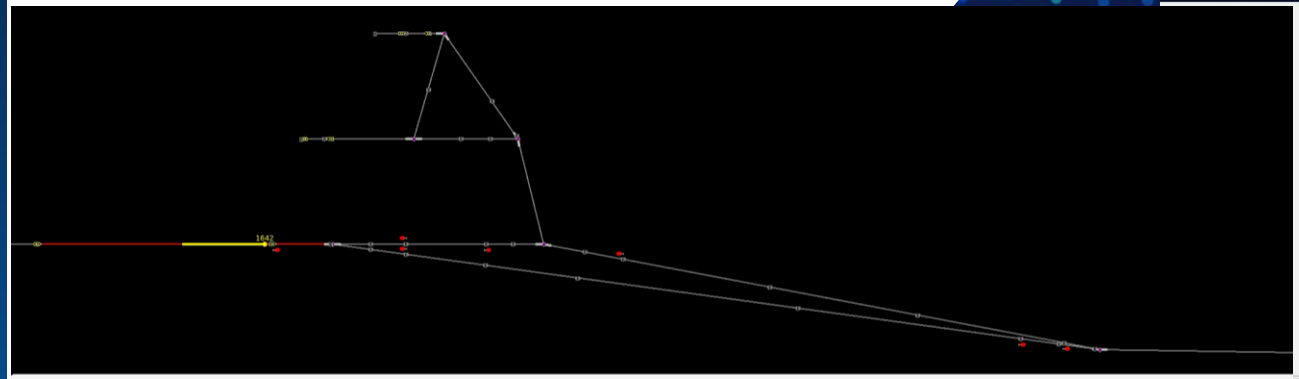
```
<rdf:Description rdf:about="http://data.europa.eu/949/776F3EC6-2ADC-442C-81C7-31E33E32C61B">
  <rdf:type rdf:resource="http://data.europa.eu/949/BaliseGroup"/>
  <era:balises rdf:resource="http://data.europa.eu/949/B1F75BD0-DF5F-44DC-BC30-910DDECF9515"/>
  <era:balises rdf:resource="http://data.europa.eu/949/E4D57C1E-C376-454A-9A7F-33C8F588459B"/>
  <era:bgFunction rdf:resource="http://data.europa.eu/949/concepts/balise-group-function/location"
  <era:linkOrientationDirection rdf:resource="http://data.europa.eu/949/concepts/orientations/same
  <era:m_version rdf:resource="http://data.europa.eu/949/concepts/etcs-m-versions/v2_1"/>
  <era:nid_bg rdf:datatype="http://www.w3.org/2001/XMLSchema#unsignedInt">9151</era:nid_bg>
  <era:nid_c rdf:datatype="http://www.w3.org/2001/XMLSchema#unsignedInt">127</era:nid_c>
  <era:q_link rdf:datatype="http://www.w3.org/2001/XMLSchema#boolean">true</era:q_link>
  <era:q_updown rdf:datatype="http://www.w3.org/2001/XMLSchema#boolean">true</era:q_updown>
</rdf:Description>
```

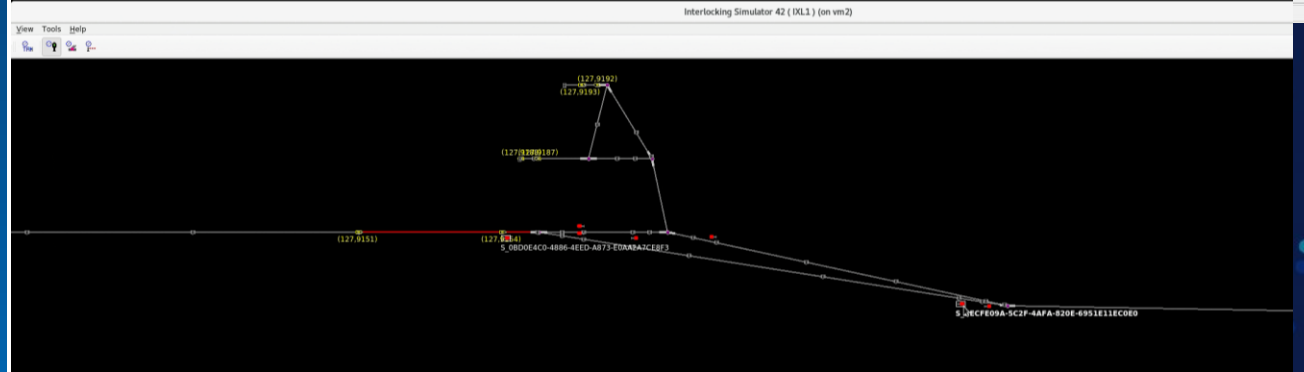
Use RDF for RBC configuration

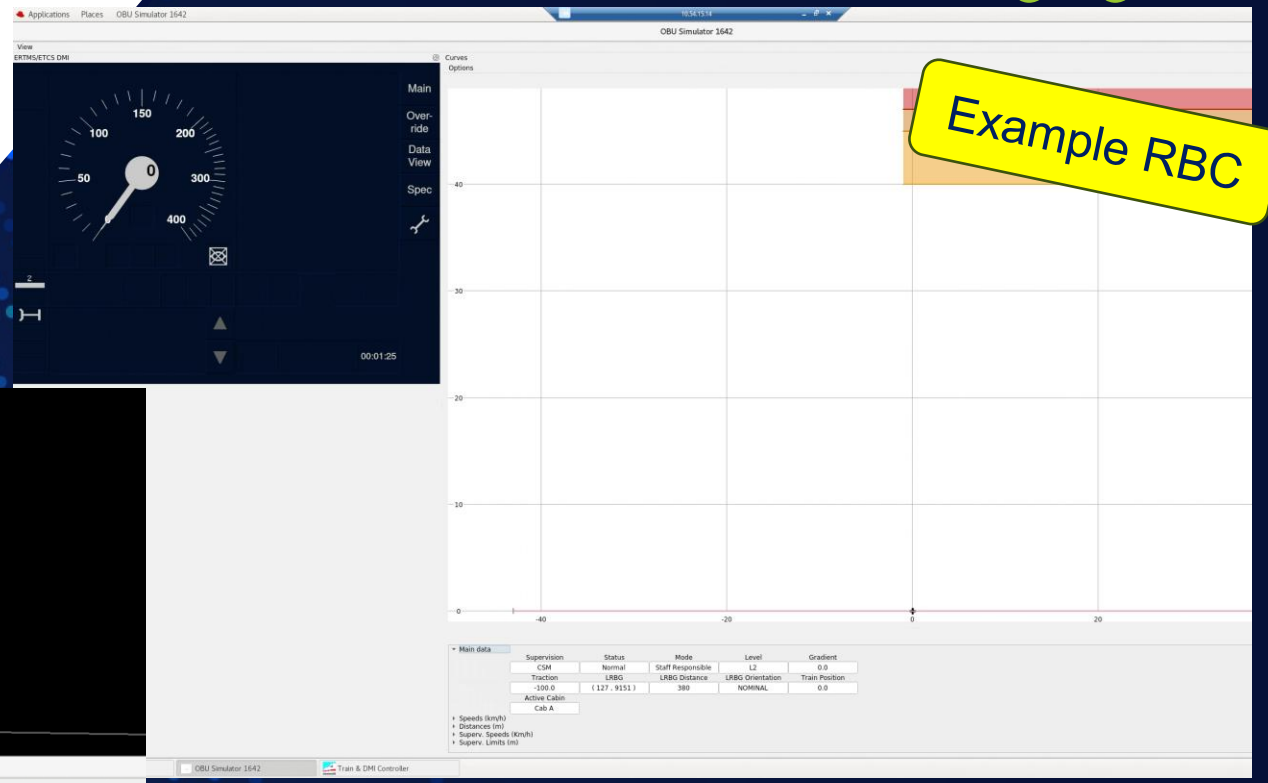


PROOF BY SIMULATION 2

CCS/TMS ERA ontology file for configuration of ETCS L2 in UNISIG Subset 026 compliant simulator



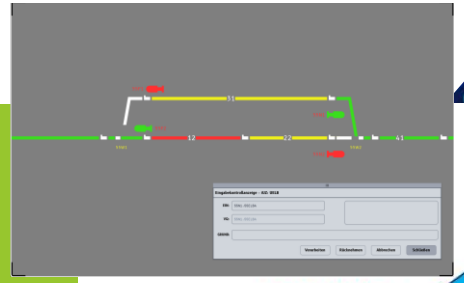


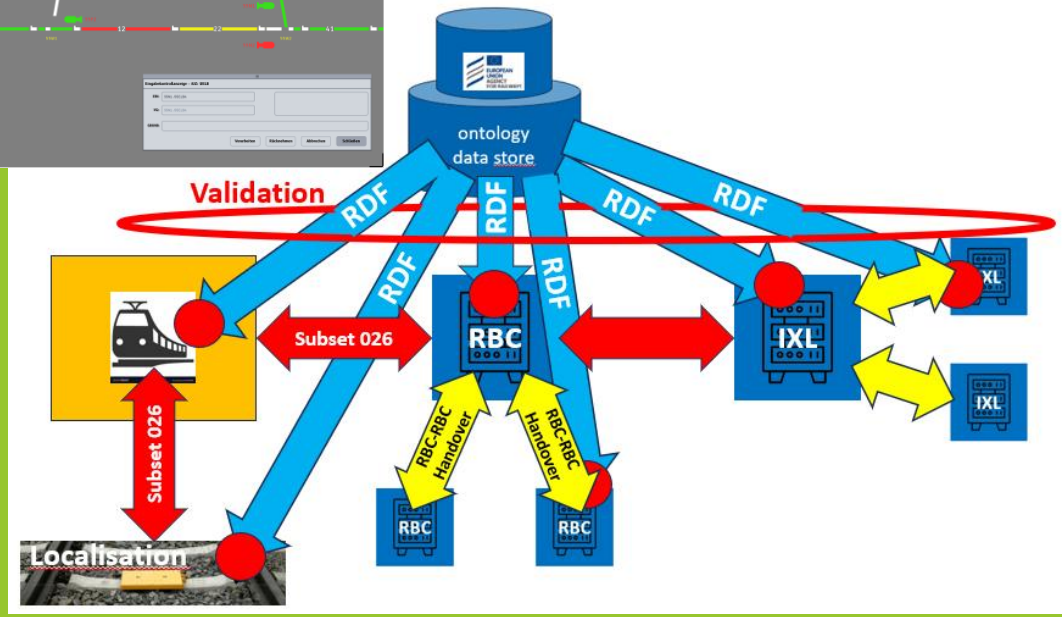


HOW WE COMPARE RBC PERFORMANCES

Example RBC

Reference Scheibenberg ETCS-only test train





Reference Scheibenberg ETCS-only test station

Keeping RBC interfacing sub-systems stable: Testing RBC communication with train where only RBC internal design determines the RBC performance (timing, operational constraints)

RECOMMENDATIONS

- **Massive prototyping**

Software developers have established models and tooling. Using ERA-ontology and applying the new process is a change requiring intense promotion. Convincing users is key for successful uptake of ERA-ontology. It requires massive prototyping to train users and attract early return of experience.

- **Validation method and tooling development**

Users need tools as a prerequisite for changing from established processes to the new EU process. Tooling development by EU-RAIL MOTIONAL is crucial for acceptance. Its development needs to be inclusive and interactive with System Pillar experts and users from start on.

- **Use ERA sample data “Scheibenberg”**

Data for testing is desired by developers and users. ERA has provided it. User feedback is required.

Thank you

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B1060, Brussels - Belgium

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