16th Modelica & fmi Conference

Europe's Rail

FP1 MOTIONAL
European Rail Network and Mobility Management

Flagship Project 1:

Mobility Management in a multimodal environment & digital enablers

Aspects and Ideas for the FMI-based Modeling of Railway Digital Twins

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The Project Background

- Europe‘s Rail is a joint undertaking, i.e. a public-private partnership for rail research & innovation
  - Established in 2021 under Horizon Europe, 8 Flagship Projects ≈ 600 Mio€ total budget

Founding Members



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  - Established in 2021 under Horizon Europe, 8 Flagship Projects ≈ 600 Mio€ total budget
- The Flagship projects are linked, e.g.

Sustainable Rail Systems

High efficiency
Low weight
High performance
Virtual homologation

Asset Management

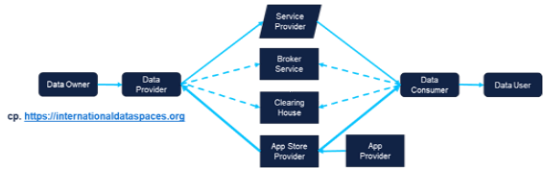
Monitor infrastructure & vehicle
Predict maintenance
Improve operation

Automatic Train Operation

Reduce brake distances
Virtual coupling
Increase infrastructure capacity

Use cases

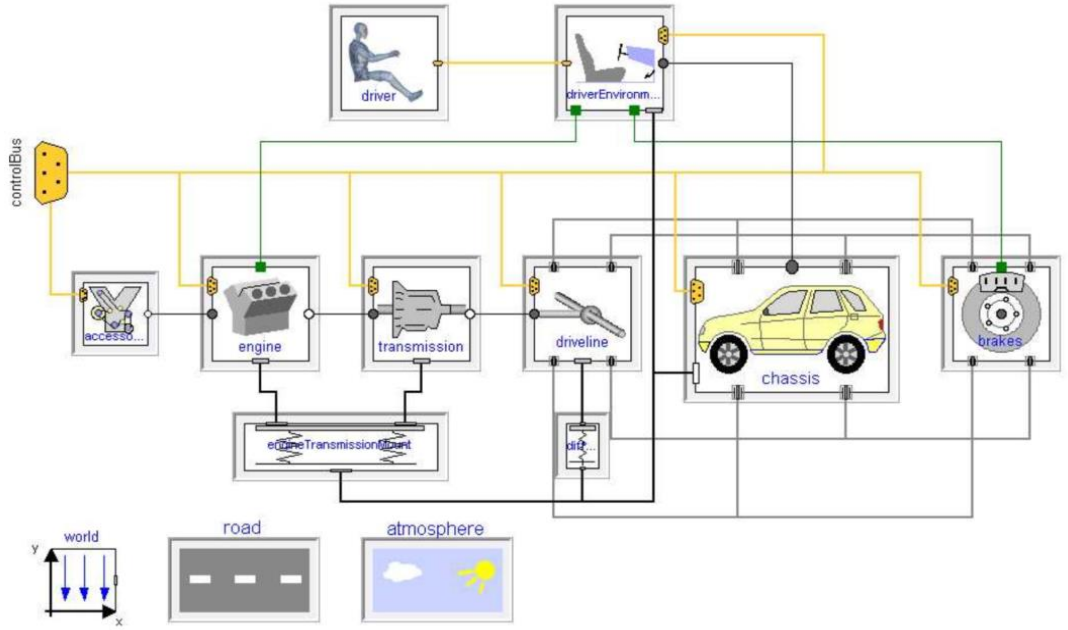
Digital Twin Federated Dataspaces



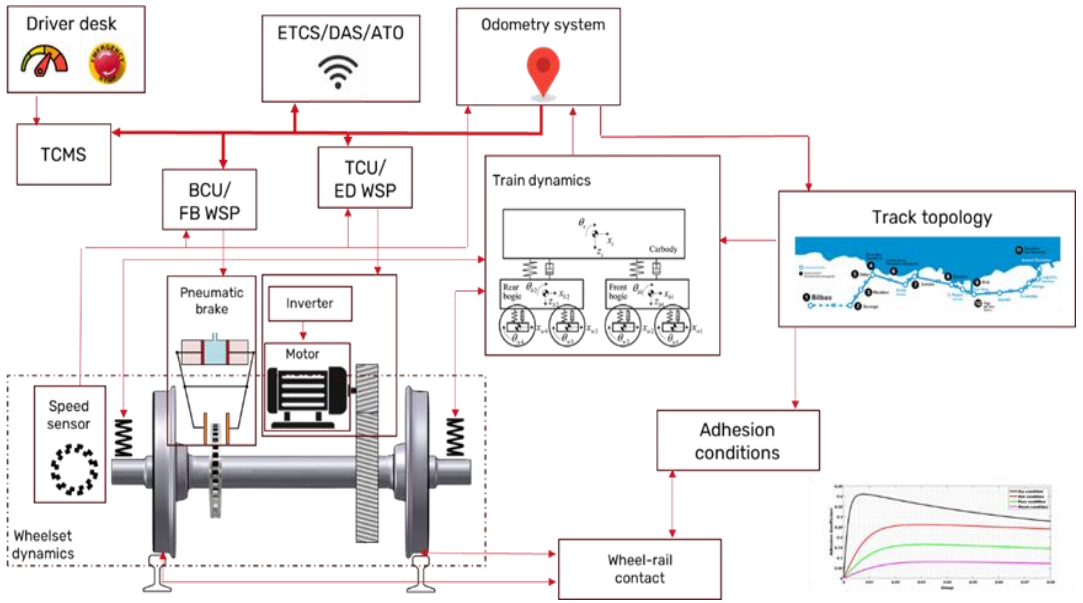


Demands, approach and challenges

- Demands
  - Organize **modularity, interoperablitity & composability** of high-order digital twin assemblies
    - Support digital twin work in other Flagship projects
  - fmi Functional Mock-Up Interface
  - TRL 5 until 2026, TRL 6 until 2028
- Approach: define minimal component models, compose reference architectures, specify interfaces
-



cp. **Vehicle Interface Library, 2006**



Courtesy of CAF

Demands, approach and challenges

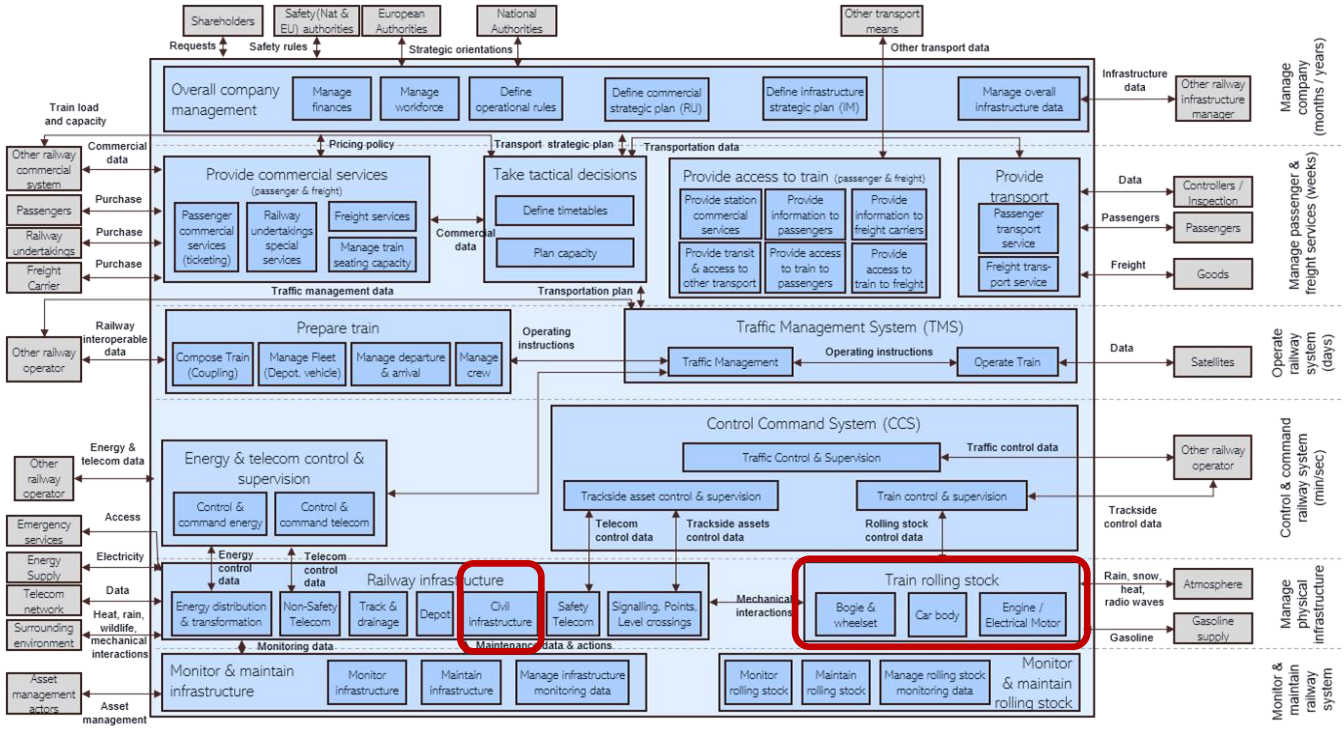
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  - Digital twins may differ in many aspects.



cp. 8D-model: Stark et al., 2019

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- Approach: define minimal component models, compose reference architectures, specify interfaces
- Challenges:
  - Digital twins may differ in many aspects.
  - Simulation of railway vehicles is
    - more complex w.r.t. modelling,
    - more computational demanding,
    - less robust in FMU co-simulations,
    - highly interrelated to high level system architecture.



cp. LINX4Rail

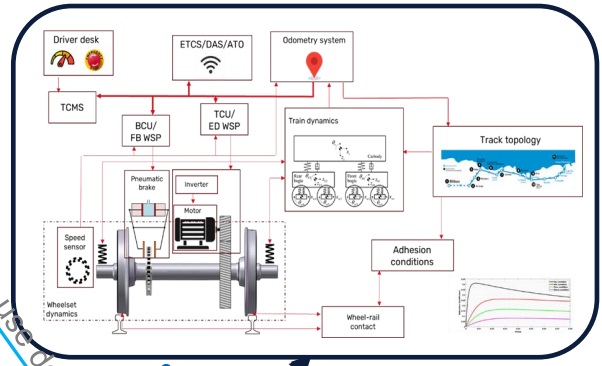
The Digital Twin: conceptual view

Service Provider
Broker Service
Clearing House
App Store Provider
App Provider
Data Owner
Data Provider
Data Consumer
Data User

cp. https://internationaldataspaces.org

use data & data apps

use data



Functional Mock-Up Interface

cp. https://fmi-standard.org/

Proprietary instances

Proprietary instances

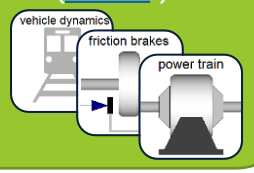
cp. Vehicle Interface Library, 2006

Railway Dynamics Library, 2019

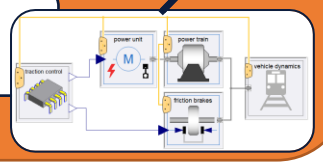
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GitLab

DT support environment
repository with minimal models (FMUs)



DT design time environment
library with minimal FMU assemblies
exemplary algorithms
test data



DT runtime environment

- On-premises
  e.g. Matlab, OpenModelica..
- Cloud / SaaS
  e.g. AVL Model.Connect
  DLR Multi-Agent-Simulator, ..
- On-the-edge / embedded
  e.g. sensor data aggregation
  in the vehicle, IoT

Executive Summary on Use Cases

Use case name	Technical Criteria	Strategic Criteria	Interactions
ERTMS DT	HIL-environment in operation, high complexity	CCS	FP2 WP 22, 34/35 FP6 WP7
Pre-assessment of ATO Set-ups	Extension to ERTMS DT Open simulation environment	ATO up to GoA4	FP2 WP 5-11
DT on Graph Database	Graph database	Maintenance optimization	FP3 WP7
Braking/Traction DT Virtual Certification	Vehicle subsystems from different suppliers, Co-simulation	Virtual vertification Standarization committees	FP2 WP 34/35 FP4 WP 16/17
Point Machine	Classic approach	Fault diagnosis	FP3 WP14/15 SP Diagnostics
Fault Diagnosis	Simpack, multi-sensor/-purpose approach, scientifically ambigious with strong consortium	Diagnosis & maintenance	FP3 WP10/11 SP Diagnostics
Station	BIM	Asset management	FP3 WP 14/15
Bridge	BIM	Asset management	FP3 WP 12/13
HVAC	Thermodynamics	Failure & maintenance Eco-friendliness	FP3 WP 5/6 FP4 WP 18/19

Introductory Example

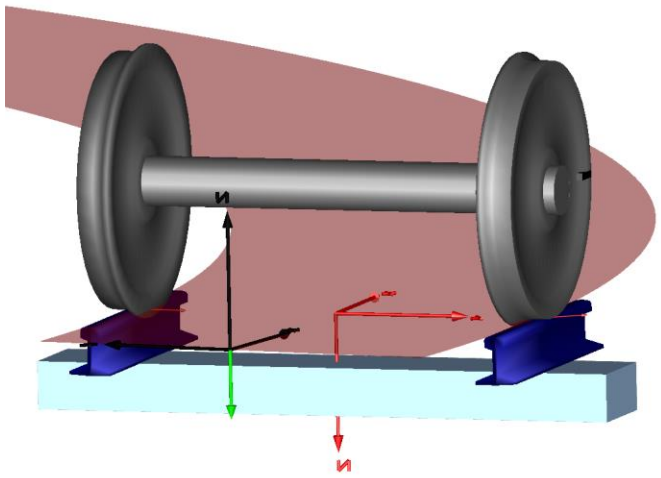
- **E**uropean**T**rain**C**ontrol**S**ystem Eurobalise
  - transmits telegrams to the train by magnetic induction
  - default: ID, geographic coordinates
  - optional: max. safe speed, warning on track conditions, monitoring of brake process, ….


see Eurobalise – Wikipedia CC BY-SA 3.0

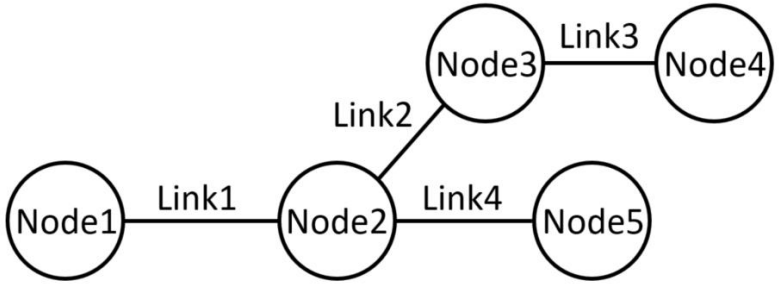
- Digital Twin use case
  - Real train runs along track and transmits received Eurobalises messages as data stream.
  - A virtual train runs along the track specified by design information and transmits virtual messages.
  - An algorithm
    - compares the data streams,
    - issues an alert to the infrastructure manager in case of any mismatch
- Note: Due to the current status of the project, the „real train runs“ are still done in simulation, only.

Modelling issues

- Vehicle-track interaction: the Modelica RailwayDynamics Library



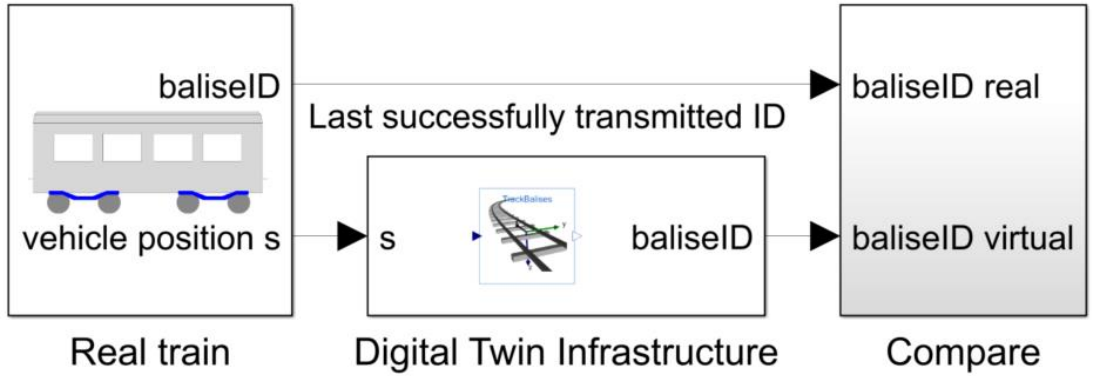
- Track input data: Motional WP provides ontology based methods to convert infrastructure data from country specific formats

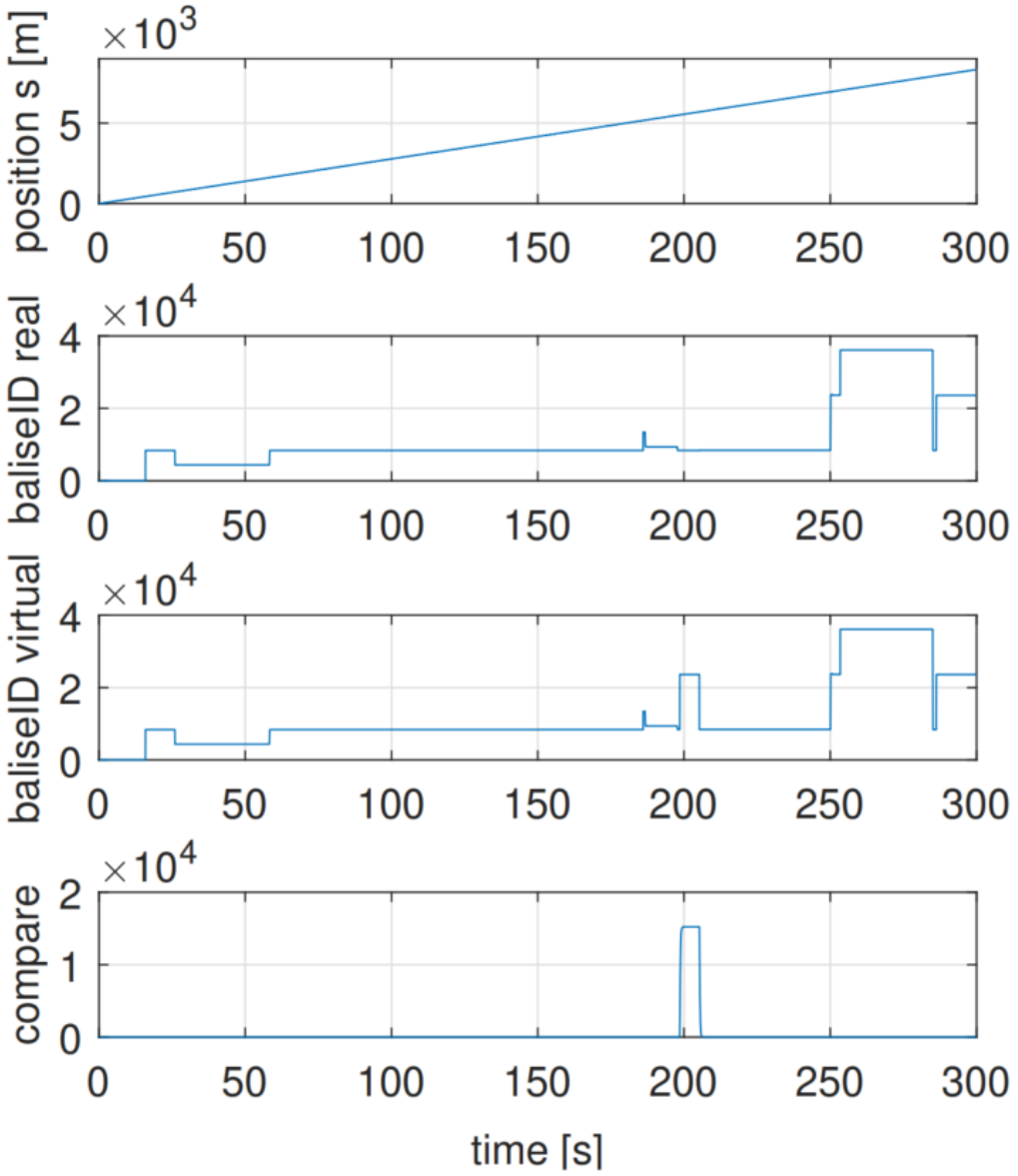



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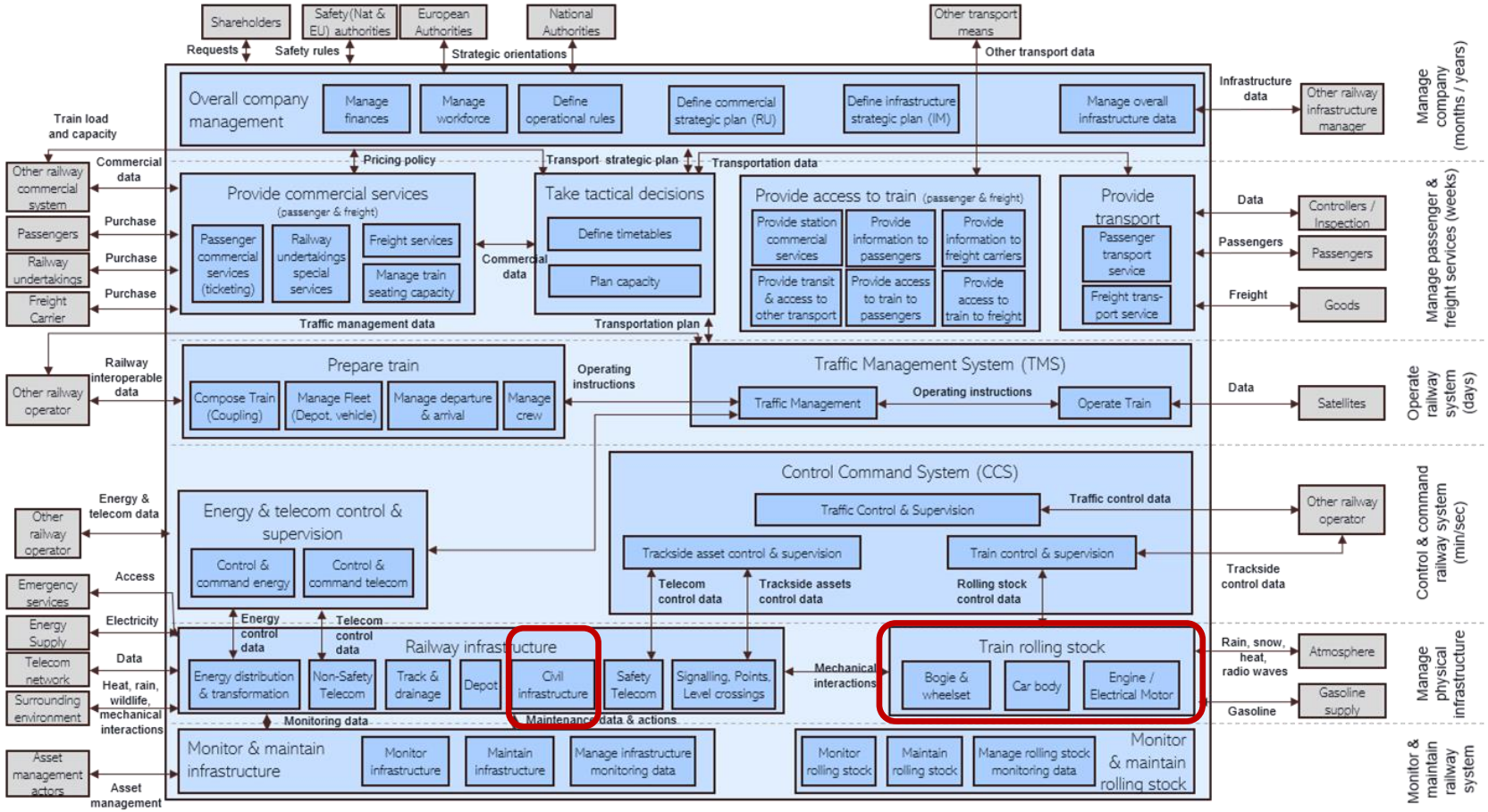
FMU Model Assembly and initial results





Outlook or why we are not running out of work

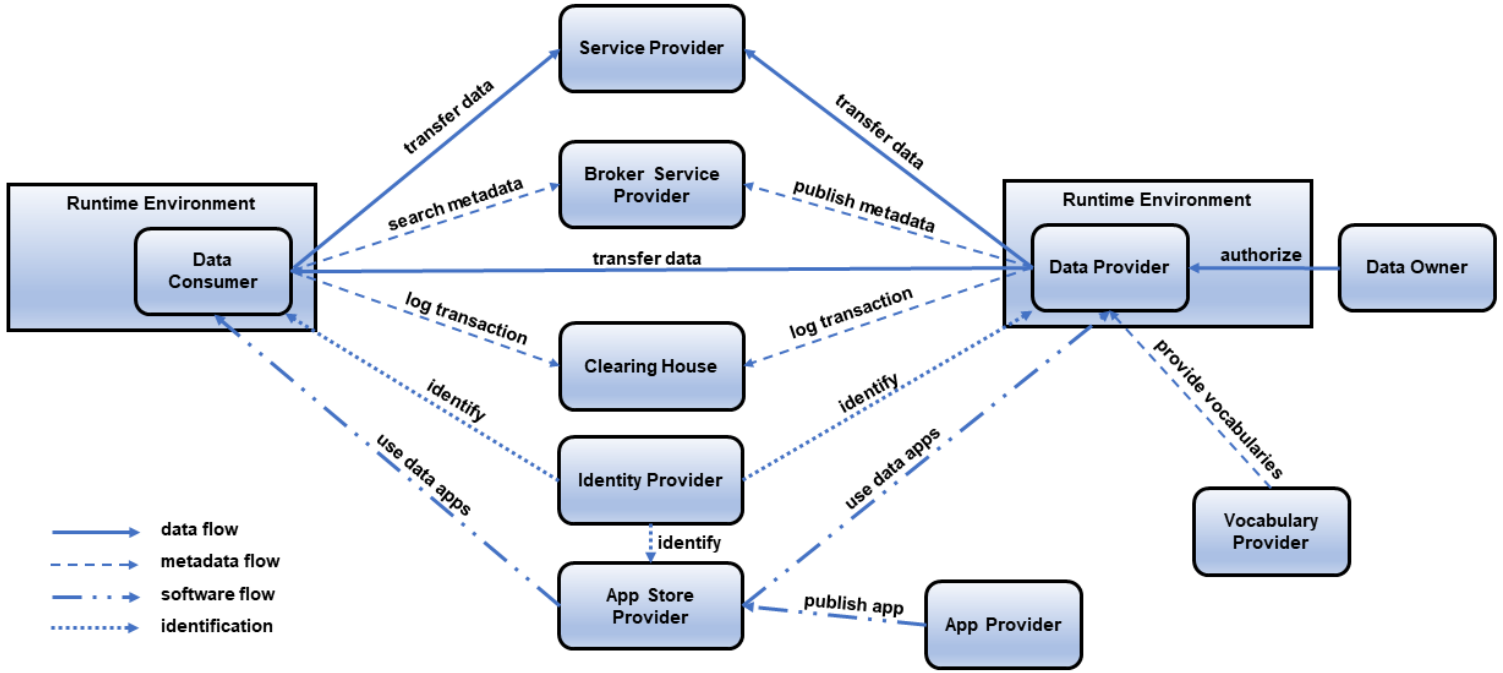
- Recall: support of modularity, interoperablity and composability is the objective
- Complexity of railway system architecture ⇒ cover additional domains



cp. LINX4Rail

Outlook or why we are not running out of work

- Recall: support of modularity, interoperablity and composability is the objective
- Complexity of railway system architecture ⇒ cover additional domains
- Raise TRL
- Realtime data exchange and exploitation
- Integration of (e.g. Digital Twin-based) services into Rail Data Space



cp. Bader et al., 2020

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- Complexity of railway system architecture ⇒ cover additional domains
- Raise TRL
- Realtime data exchange and exploitation
- Integration of (e.g. Digital Twin-based) services into Rail Data Space
- Consider AI modelling
- ….

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