TD 2.8: Virtually Coupled Train Sets

Moritz Schenker

22.10.2020, Brussels

This project has received funding from the European Union’s Horizon 2020
research and innovation programme under grant agreement No: 826141

Agenda

- Virtual Coupling – Goals and Vision
- System Concept (D6.1)
  - Functional Layer Structure
  - Main Functions and Two-Stage Implementation Approach
- Performance and Safety (D6.2)
  - Parameter Study
  - Relative Braking Distance vs. Absolute Braking Distance
- Project Outlook – Next Tasks
- Conclusions

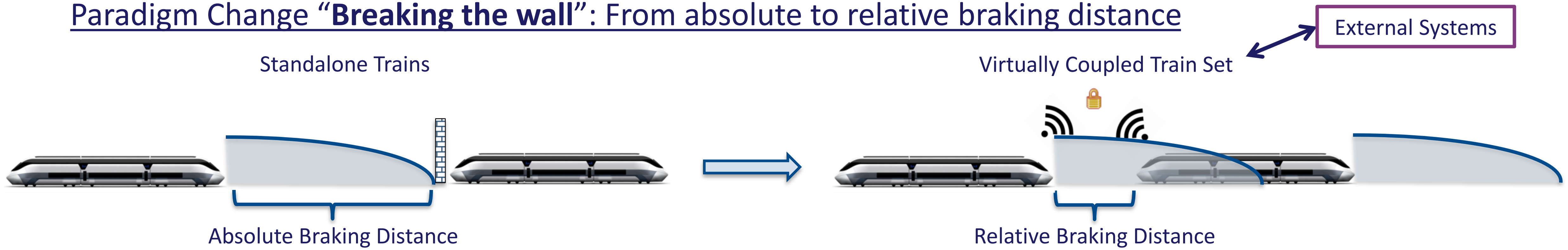
The Goals of Virtual Coupling

- Increase line **capacity** by reducing the headway
- Increase operational **flexibility** by ensuring **interoperability**
- Improve the **use of the existing station platforms** by utilization of several platform tracks
- Reduce **costs** by:
  - Adding on-board equipment and electronic systems instead of new tracks or heavy changes in the infrastructure
  - Reducing maintenance cost in relation with best use of the line

➢ **Increasing competitiveness with respect to road transportation**

Virtually Coupled Train Sets (VCTS) - The Concept

Paradigm Change "**Breaking the wall**": From absolute to relative braking distance

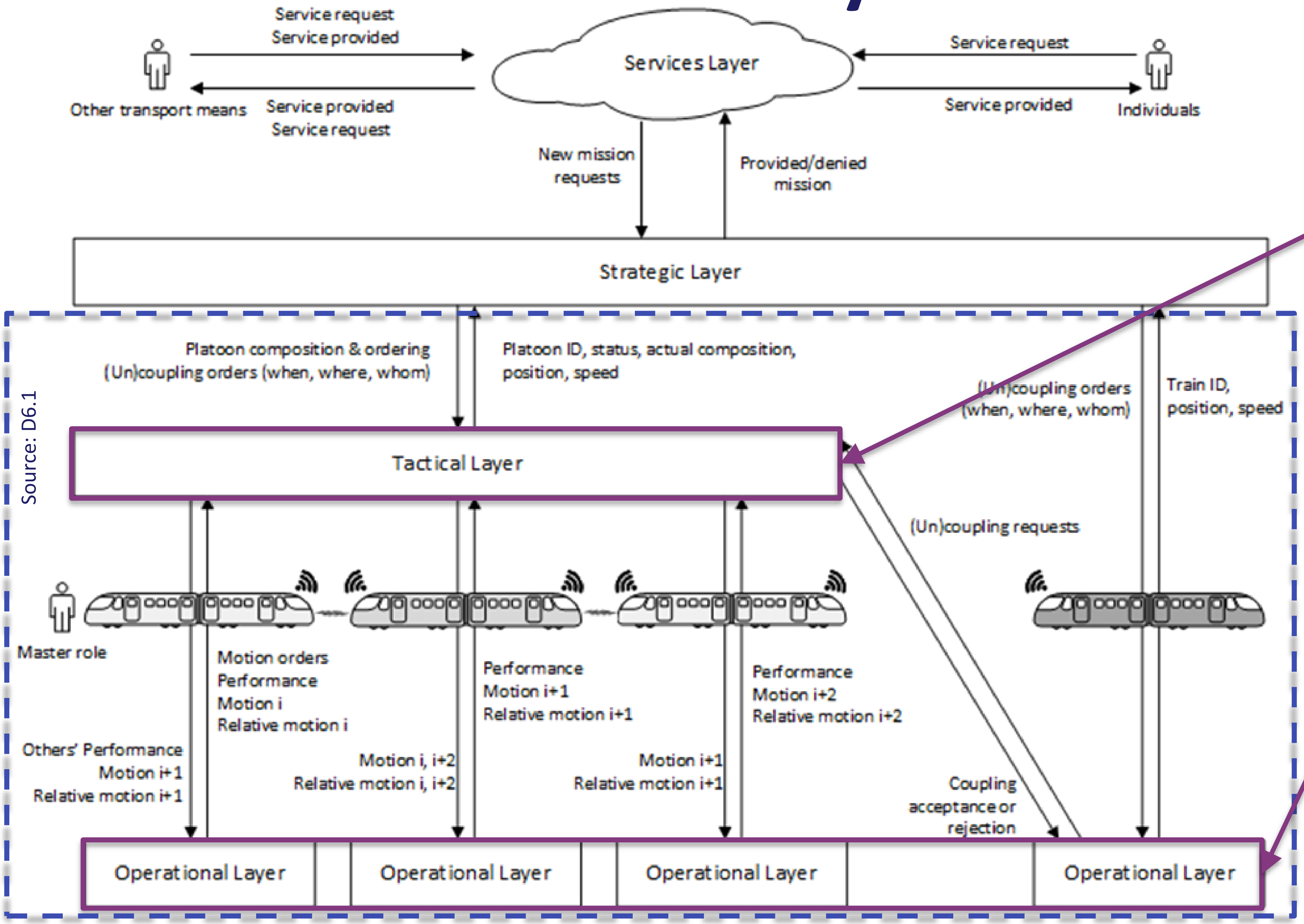


Utilization of safe **platoon and consist management** for two or more consists of any train type:

- Real-time distance, speed and acceleration supervision through **on-board sensors**
- Permanent **T2T-communication** of current train dynamics, trajectories and braking capabilities to enable **cooperative movement**
- Safe distance **control** with traction/braking control units
- To the external systems the VCTS is seen as one train that follows the rules of the underlying signaling system.

➢ New Elements in VCTS System: **Sensors, Controls, T2T-Communication, Platoon Management**

VCTS – Functional Layer Structure



Functional VCTS Implementation

Tactical Layer: Platoon Management

The tactical layer is in charge of coordinating the movement of the trains composing the platoon from the instance a joining request is received until the platoon is dissolved, including unexpected events and degraded modes.

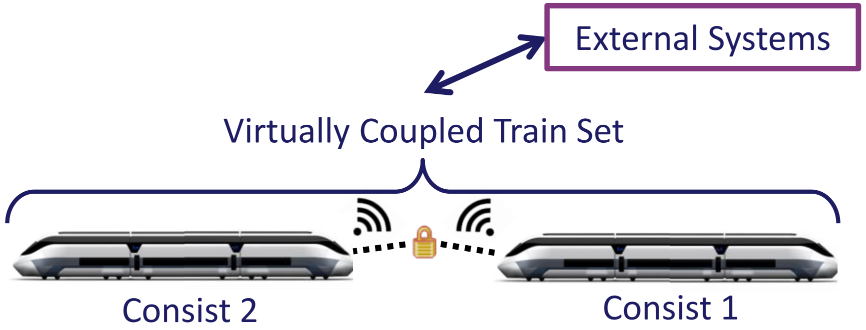
→ On-the-fly manoeuvres (possibility to optimise with respect to time/energy/…)

Operational Layer: T2T-Communication, Sensors, Controls

The operational layer manages the local movement of each train assuring that commands established by the tactical layer are safely executed.

→ Regulation of headway with respect to safety limits and stability

VCTS Implementation – Stage 1



Replacement of mechanical coupler by virtual coupler: Builds upon the established procedure of portion working, i.e. joining and dividing trains during operation

Protect consists inside platoon from collision	▪ Executing safe distance **control** utilizing **sensors** and **communication** (full operational layer)
Virtual Coupling Set Up	▪ Coupling of identical vehicles in standstill as scheduled in timetable
Coupled Driving	▪ Basic platoon **management**, cooperative headway control manoeuvres (tactical layer)
Termination of Virtual Coupling	▪ Decoupling in standstill as scheduled in timetable
Interaction with external systems	▪ Similar to conventional operation, communication via lead consist for the whole platoon, basic interaction with interlocking (variable platoon length with gaps)

VCTS Implementation – Stage 2

Introduction of individual VCTS modules with additional functionalities

→ Smooth and efficient operation with on-the-fly manoeuvres – some examples:

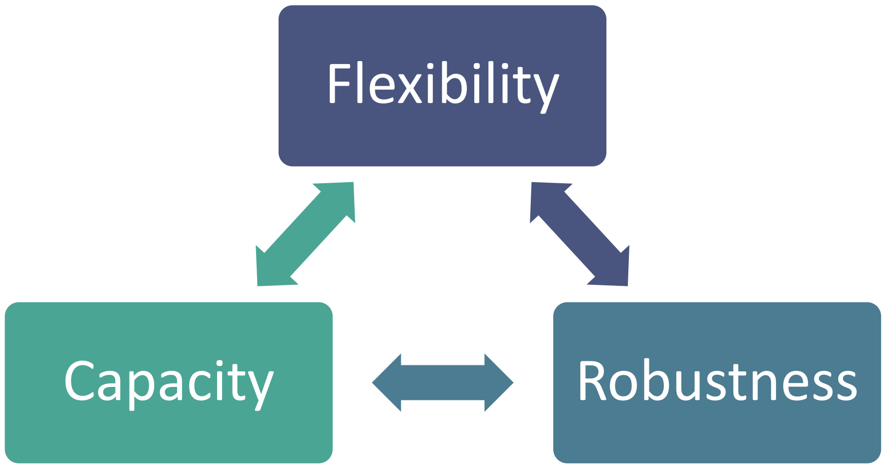
Protect consists inside platoon from collision	▪ Executing safe distance control utilizing sensors and communication (full operational layer) → unchanged from Stage 1
Virtual Coupling Set Up	▪ Coupling of identical vehicles in standstill as scheduled in timetable → Coupling of different vehicle types, coupling on-the-fly, unscheduled dynamic coupling
Coupled Driving	▪ Basic platoon management, cooperative headway control manoeuvres (tactical layer) → Calling at multiple platforms
Termination of Virtual Coupling	▪ Decoupling in standstill as scheduled in timetable → Decoupling on-the-fly, unscheduled dynamic decoupling
Interaction with external systems	▪ Similar to conventional operation → Interaction with TMS (e.g. to minimise delay by unscheduled coupling), switches and interlocking (advanced routing)

Agenda

- Virtual Coupling Goals and Vision
- Virtual Coupling System Concept (D6.1)
  - Functional Layer Structure
  - Main Functions and Two-Stage Implementation Approach
- Performance and Safety (D6.2)
  - Parameter Study
  - Relative Braking Distance vs. Absolute Braking Distance
- Project Outlook – Next Tasks
- Conclusions

VCTS – Performance and Safety

- VCTS has the potential to improve rail operations by combining benefits that usually contradict each other:
  - Capacity
  - Flexibility
  - Robustness
- For D6.2, we focussed on the capacity (S2R key performance indicator)
  - **Reduced coupling and decoupling time** (D6.2 studies: 10 - 40 % improvements for the IMPACT Scenarios High speed and Regional [2,3])
  - Paradigm shift from absolute to **relative braking distance (RBD)**



What is RBD? The required **distance between trains that guarantees safe braking** to standstill

→ **How large is the RBD?**

Relative Braking Distance – Parameter Study

In an ideal world, …

- without delays (communication, control and brake force application) and
- 100 % precision (measurement and control),

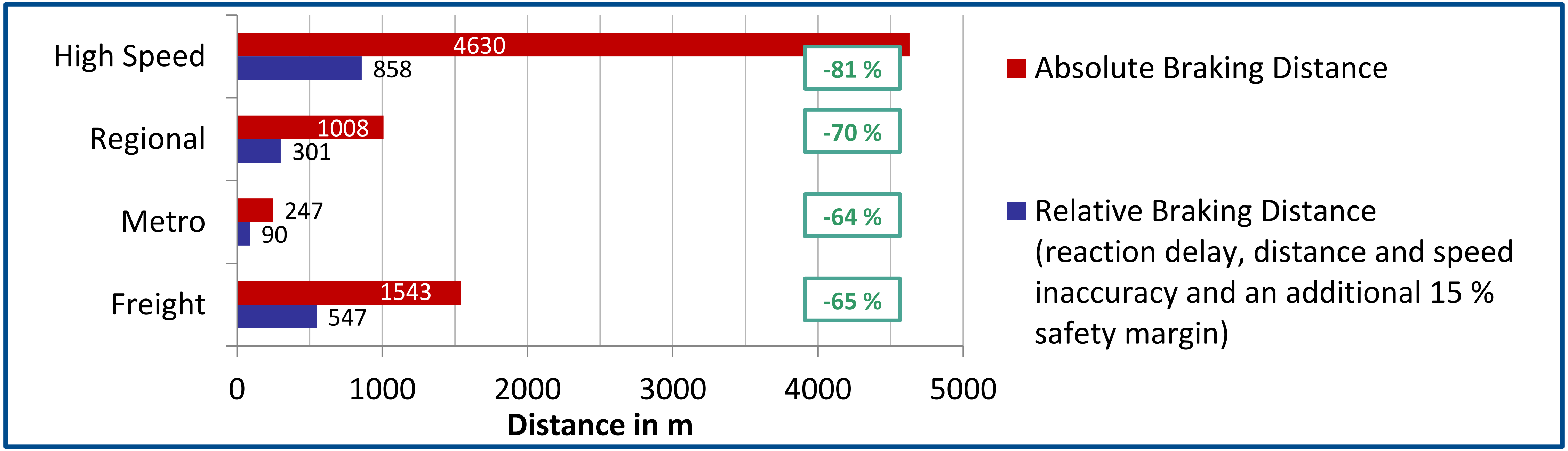
… RBD is zero.

➢ Both trains travel at the same speed and follow the same braking curve until standstill. Thus, the distance between both trains never changes.

But what happens to RBD in reality?

Factors of influence: Latencies, accuracy of speed/distance measurement, braking capabilities, speed level, …

Exemplary Comparison of Relative and Absolute Braking Distance



Assumptions and boundary conditions

Service [3]	a in m/s²	v_0 in km/h [3]	Δt_{RD} in s	Δs_{inacc} in m	Δv_{inacc} in km/h [4]
High Speed	-0.75	300	3	20	7.7
Regional	-0.75	140	3	15	4.3
Metro	-1.00	80	1.5	10	3.1
Freight	-0.25	100	8	15	3.5

Project Outlook – Next Tasks [5]:

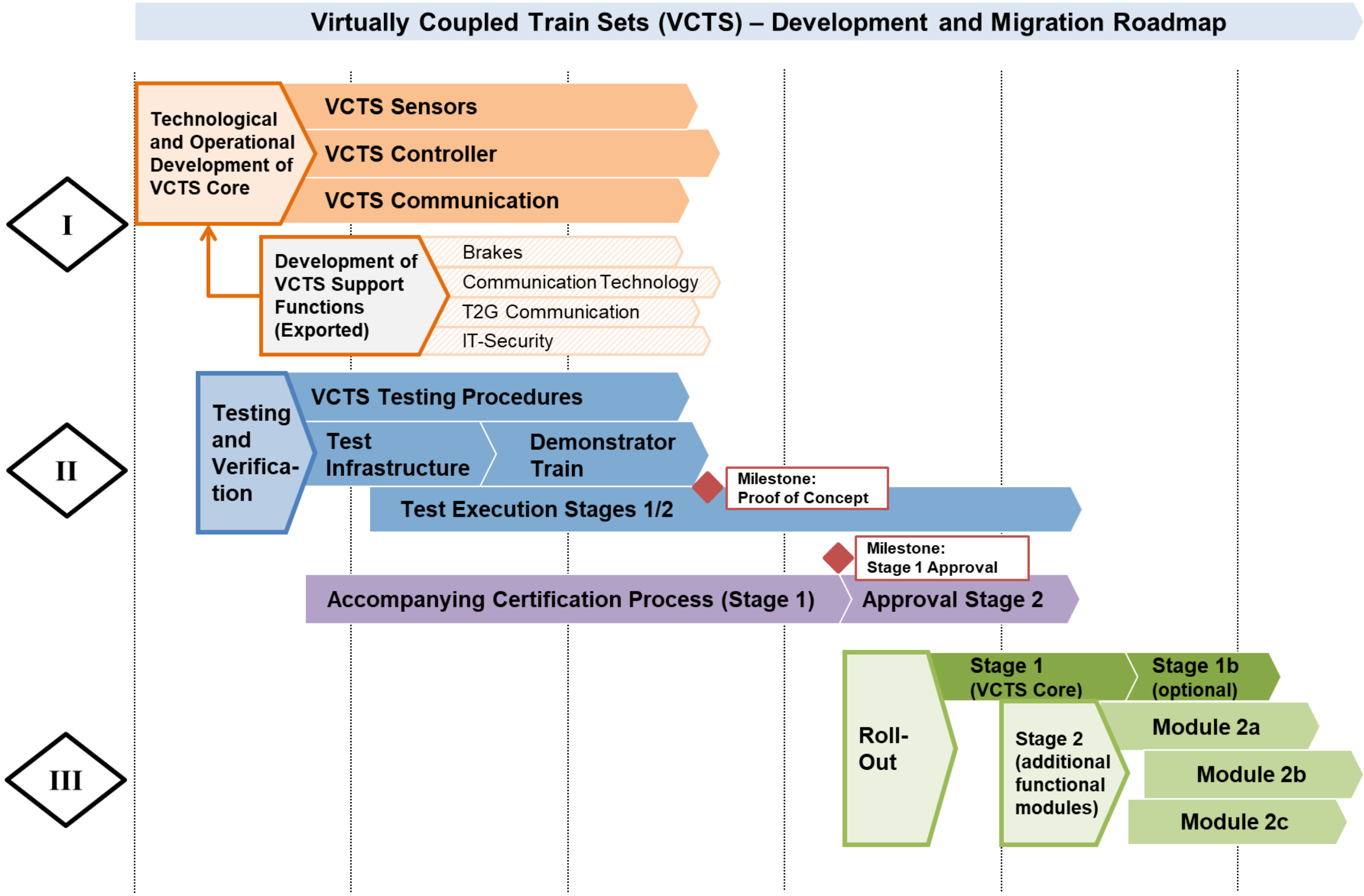
D7.1 – Technical Feasibility Analysis (ongoing)

- Identification of critical aspects in VCTS implementation concerning:
  - Technological and operational subsystems
  - General obstacles
- Mitigation measures
- Introduction strategy:
  - Proof of concept with a demonstrator
  - Enabling near-term implementation of Stage 1 with minimum complexity

D7.2/3 – System Requirement Specification

D7.4 – System Impact Analysis

D7.5 – Analysis of the Business Model



Preliminary illustration by DLR from draft of Deliverable 7.1

Conclusions

- VCTS can **increase capacity, flexibility and robustness** of a line without major infrastructural changes due to:
  - Decreased headway and coupling times
  - Efficient and dynamic manoeuvres
  - Interoperability by coupling between any train types
- A **safe** realisation of VCTS is possible with the right system design and control mechanisms.
- VCTS is not tailored to a single signalling system. Thus, it is fully compatible with the **Single European Rail Area** (SERA) framework.

➢ **VCTS – increasing competitiveness with respect to the road transportation by enabling more efficient freight and passengers transportation over the railway network.**

Thank you for your attention!

Contacts:

Moritz Schenker, M. Sc. | Research Associate

German Aerospace Center (DLR)

Institute of Vehicle Concepts | Vehicle Energy Concepts

moritz.schenker@dlr.de

Project Website: https://projects.shift2rail.org/s2r_ip2_n.aspx?p=X2RAIL-3

References

[1] X2Rail-3 (No 826141) - D6.1 - Virtual Train Coupling System Concept and Application Conditions - 2020, Canesi, S. (Lead Author), Deliverable.

[2] X2Rail-3 (No 826141) - D6.2 - Performance and Safety Analysis - 2020, Canesi, S. (Lead Author), Deliverable.

[3] IMPACT-1 (No 730816) - D4.1 - Reference Scenario - 2018, Deliverable.

[4] UNISIG - SUBSET-041 (v3.2.0) - ERTMS/ETCS - Performance Requirements for Interoperability - 2015.

[5] X2Rail-3 (No 826141) - IP/ITD/CCA - IP2/IP5 - 2018, Grant Agreement.