FP5 TRANS4M-R

Transforming Europe's Rail Freight

Preliminary concepts and specifications for a self-propeled wagon

Disclaimer

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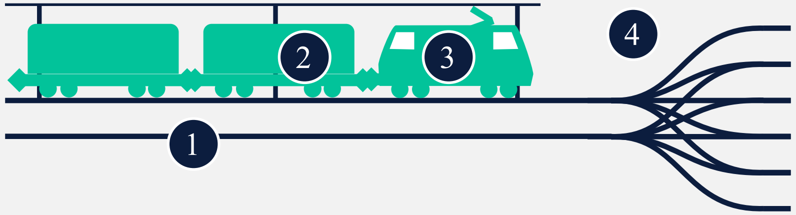
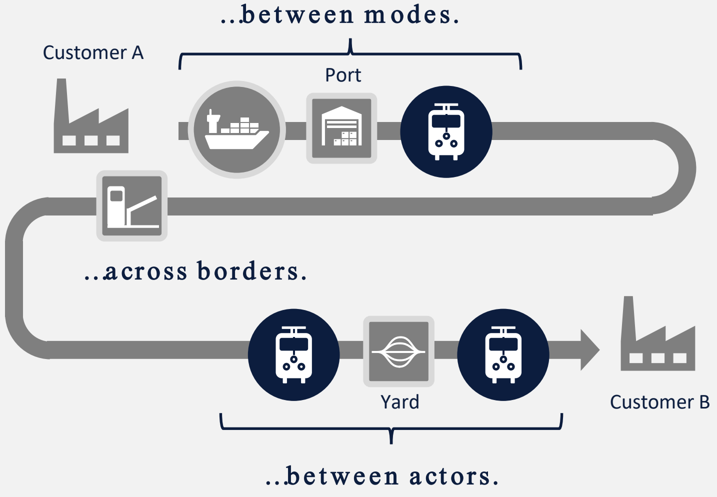
Three clusters enable „Transforming Europe's rail freight"

1 Full Digital Freight Train Operations (FDFTO)



1. Digital Automated Coupler (Typ 4+5+Hybrid)
2. Energy and Communication (400V + Train integrity)
3. Train functions (e.g. automated brake test)
4. Automated Yard Operations

2 Seamless Rail Freight...



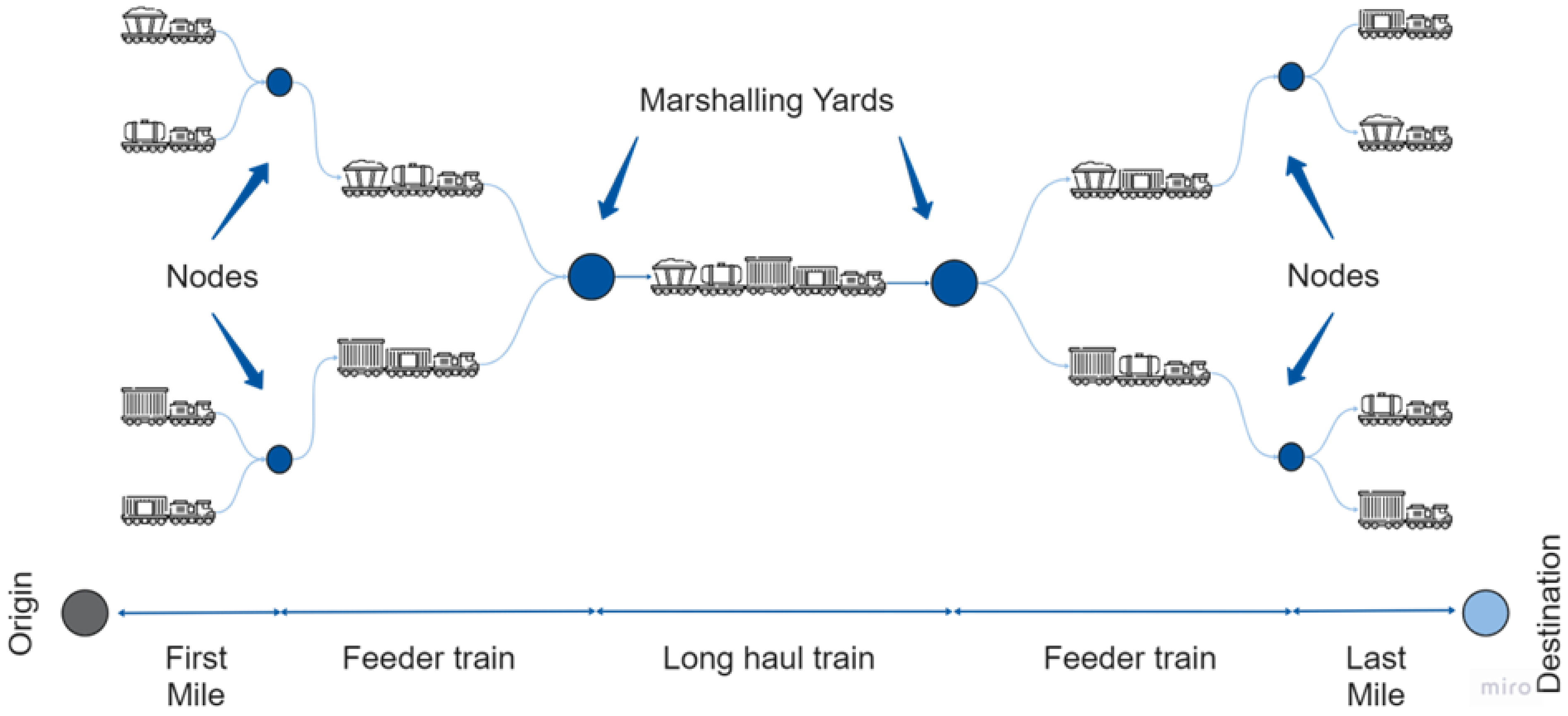
- Seamless planning and dispatching
- Intermodal integration and prediction

3 Innovative Freight Assets

- Hydrogen transport container
- Self-Propelled Wagon
- Energy effciency strategy for freight

Self propelled wagon

Production network in single-wagon load transport (example Germany)



Why do we need Self Propelled Wagon?

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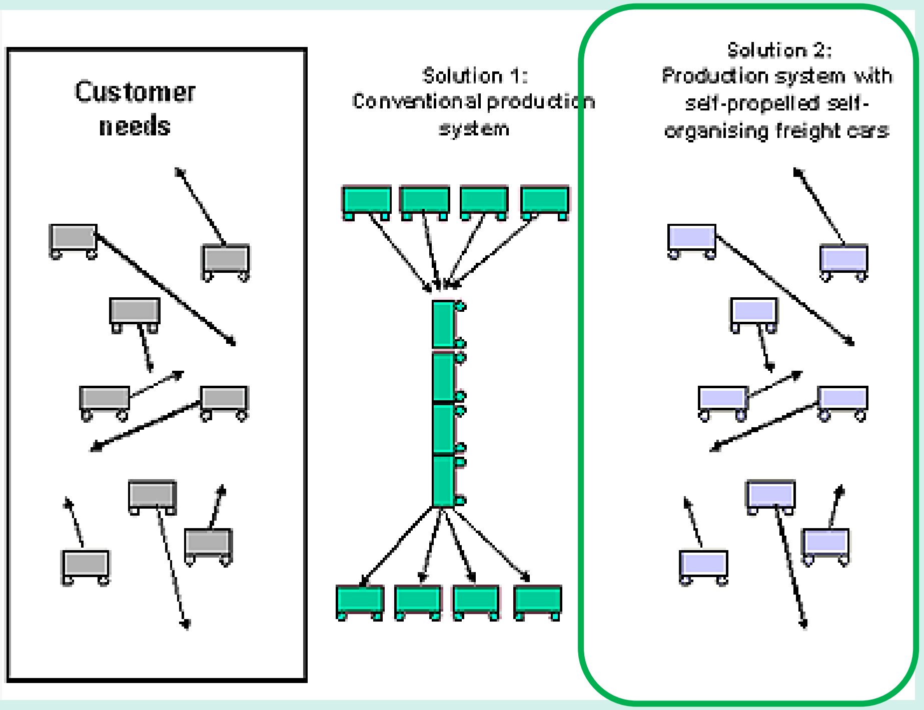
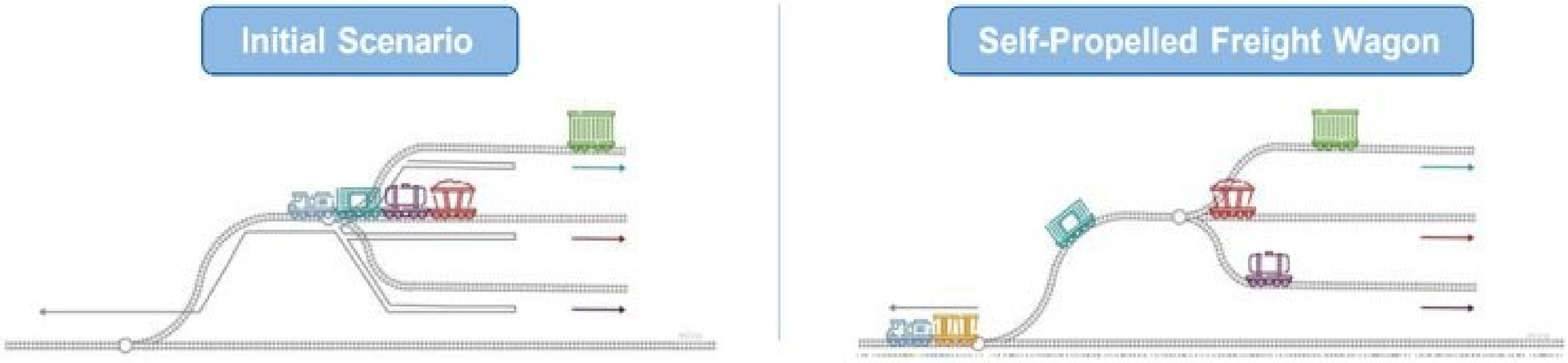
What has changed since 1996?

- Digitalization and monitoring
- Positioning technologies
- Digital Automatic Coupler
- Efficient motors and controls

Ref.- State of the art Frederich Lege 1996
UIC 2002





Self propelled wagon

Who has tried already?

→ Commercial initiatives end to end (e.g. Intramotev, Parallel)

→ Commercial references for enclosed areas (e.g. HIAROM)

Intramotev "ReVolt"

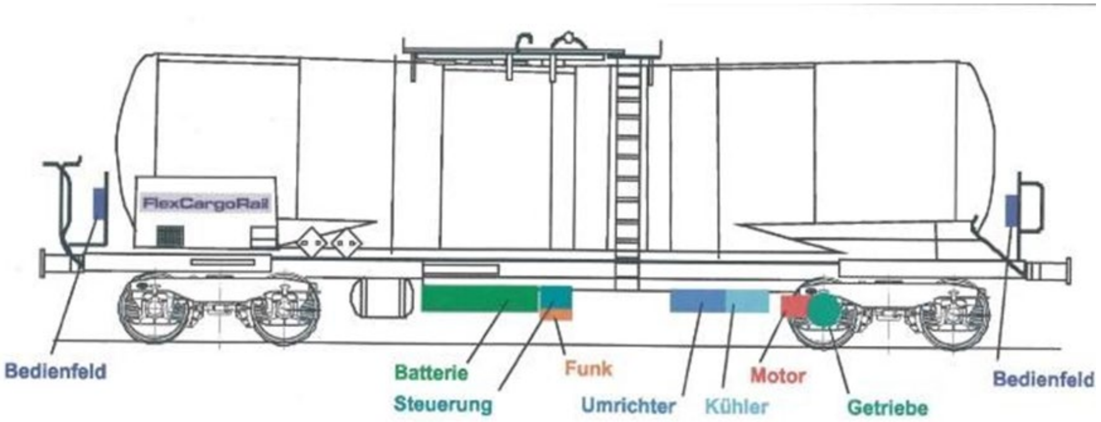
Parallel Systems

HIAROM

Self propelled wagon

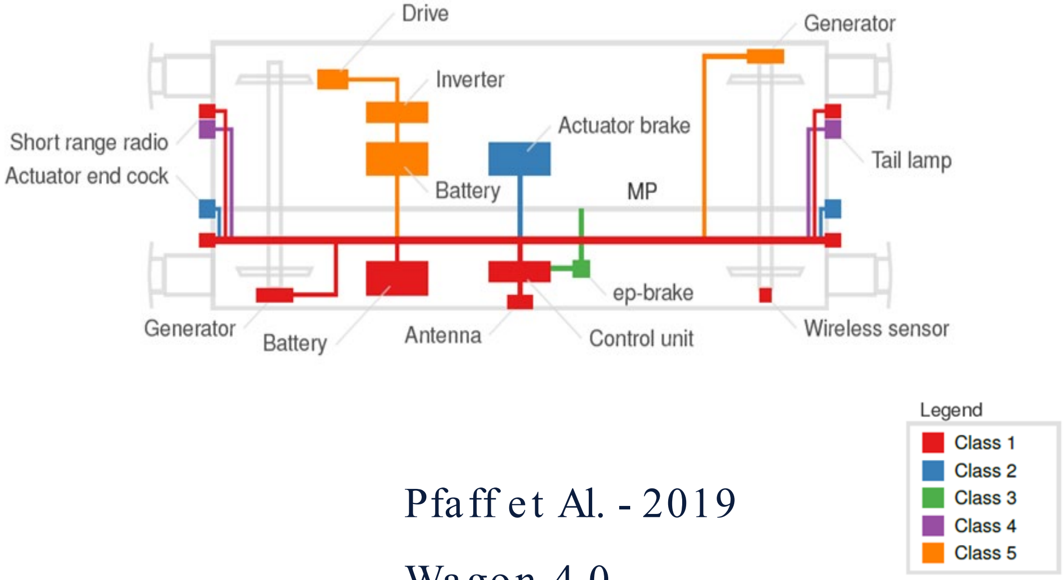
Who has studied and published on that topic?

→ Varied scientific approach on full system approach, subsystems and types of use cases



Baier et Al. - 2009

FlexcargoRail



Pfaff et Al. - 2019

Wagon 4.0

Europe's Rail

Self propelled wagon

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Workshop and survey to understand stakeholder needs

Potential for self-propelled freight wagon to revolutionize freight operations through increased efficiency, flexibility and sustainability

- Better understanding of the use cases prioritized and stakeholders' expectations
- Valuable ranges for the operations

Stakeholder Expectations
1. Last mile service from the mainline to the industrial area.
2. Self-loading and unloading.
3. Reduce the train time.
4. Reduce the need of feeder locomotives.
5. Reduce the need for shunting locomotives
6. Infrastructure way of thinking: Trains occupy tracks and they should move as much as possible.
7. Needs to be safe and reliable
8. Knowledge of the tracks (lack of energy), speed that you have to have going up a hill with a certain load
9. Cheap
10. Battery for the part of the track that don't have electricity

Question	Minimum	Maximum	Number of answers
Range Speed	15 km/h	120 km/h	7
Range gradient	4 ‰	25 ‰	4
Range distance with self-propulsion	1 km	More than 20 km	13
Distance track in the train formation between shunting operations	50 km	400 km	12
Time in which the wagons are uncoupled from the train set	1 h	168 h	8
Stationary time of the wagon at the destination	6 h	168 h	10
Number of start-up operations	3	12	11
Range curve radius	80 m	90 m	2
Permanently coupled wagon units	1	More than 5	11

Self-propelled wagon Use Cases

1. Private yard load automation (last mile)

2. Challenging tractive power and braking scenarios

3. Coordinating groups of self-propelled freight wagons

4. Autonomous loading and unloading

Self-propelled wagon Use Cases

1. Private yard load automation (last mile)

1. **Efficiency and cost reduction**: Self-propelled wagons streamline operations, reducing the need for shunting locomotives and manual labour
2. **Technical Feasibility**: Integrating traction motors, converters, batteries, and modified braking systems requires further analysis
3. **Energy Optimization**: Analyzing torque, power, and speed profiles to design efficient systems, including regenerative braking

2. Challenging tractive power and braking scenarios

1. **Parametric Study:** High-level analysis of battery-powered electric powertrains for self-propelled freight wagons, focusing on low-speed and high-power scenarios.
2. **Powertrain Conflict:** Identified conflict between last-mile delivery and traction support needs, suggesting a two-stage gearbox and mid-range powertrain as a solution.
3. **Case Study and Simulations**: Initial simulations in Sweden show potential benefits, with further analysis needed to explore operational benefits using existing motor and battery sizes

3. Coordinating groups of self-propelled freight wagons

1. **Efficiency Gains:** Concurrent shunting with self-propelled wagons reduced shunting time by 43% compared to sequential methods.
2. **Optimization and Limitations:** Centralized planning and evolutionary optimization minimized shunting duration, but scalability and real-world constraints need further research.
3. **Future Work:** Evaluate with larger fleets, develop alternative optimization methods, and integrate real-world constraints for practical deployment.

4. Autonomous loading and unloading

1. **Autonomous Yard Operations:** Investigated conditions for self-propelled wagons to autonomously enter, load/unload, and exit yards/terminals.
2. **Intermodal Focus:** Proposed constructing self-propelled wagons as intermodal due to feasibility of autonomous transshipment technology over non-containerized freight.
3. **Technology Survey:** Identified suitable technologies (AMCCT and SUM automatic loader) for autonomous loading/unloading, noting limitations of conventional gantry cranes.

Self propelled wagon Use Cases

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Use case goal:

1. Integrate traction motor, converter and batteries in an existing freight wagon
2. Modify the braking system to allow braking decoupled wagons

Aerial view of a private yard(Google Maps, 2023)

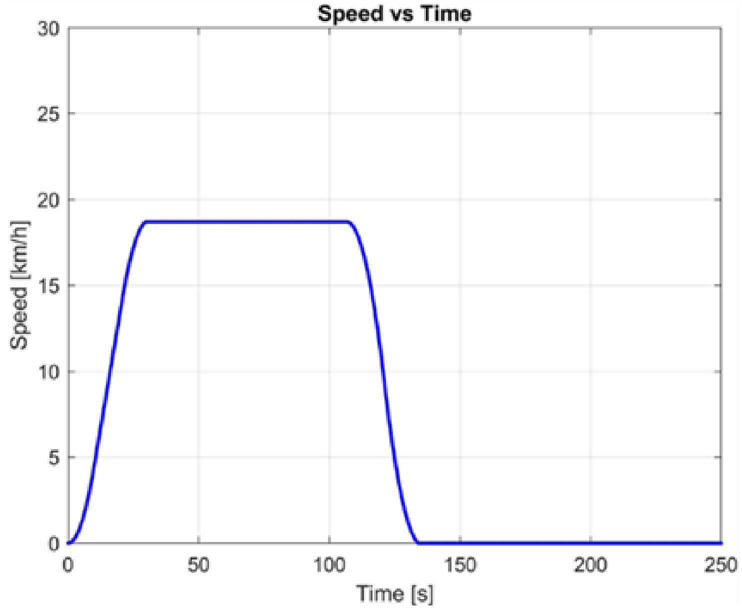
Use case leader: Ceit, Marco Satrustegui, Jonan Morales & Iñigo Adin
Use case contributor: Renfe, Alejandro Huergo

Self propelled wagon Use Cases

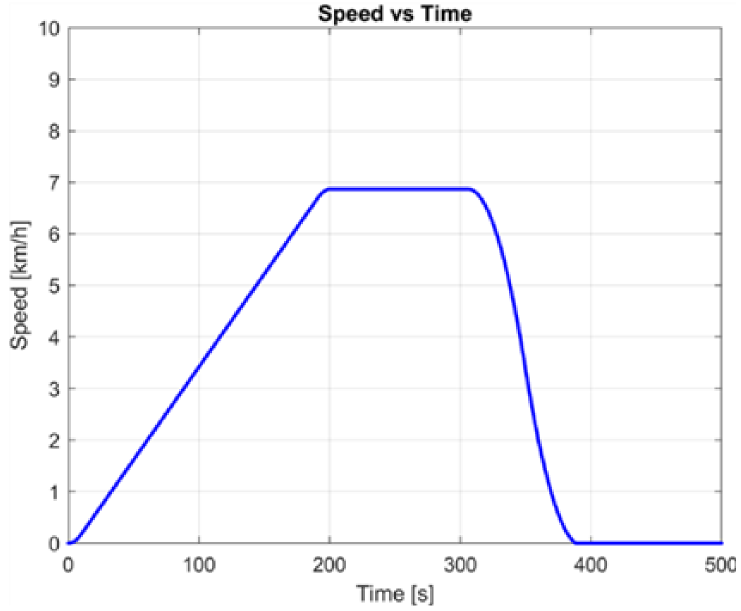
1. Private yard load automation (last mile)

Speed profiles for the self-propelled freight wagon

No load (10 tonnes)



Load (80 tonnes)



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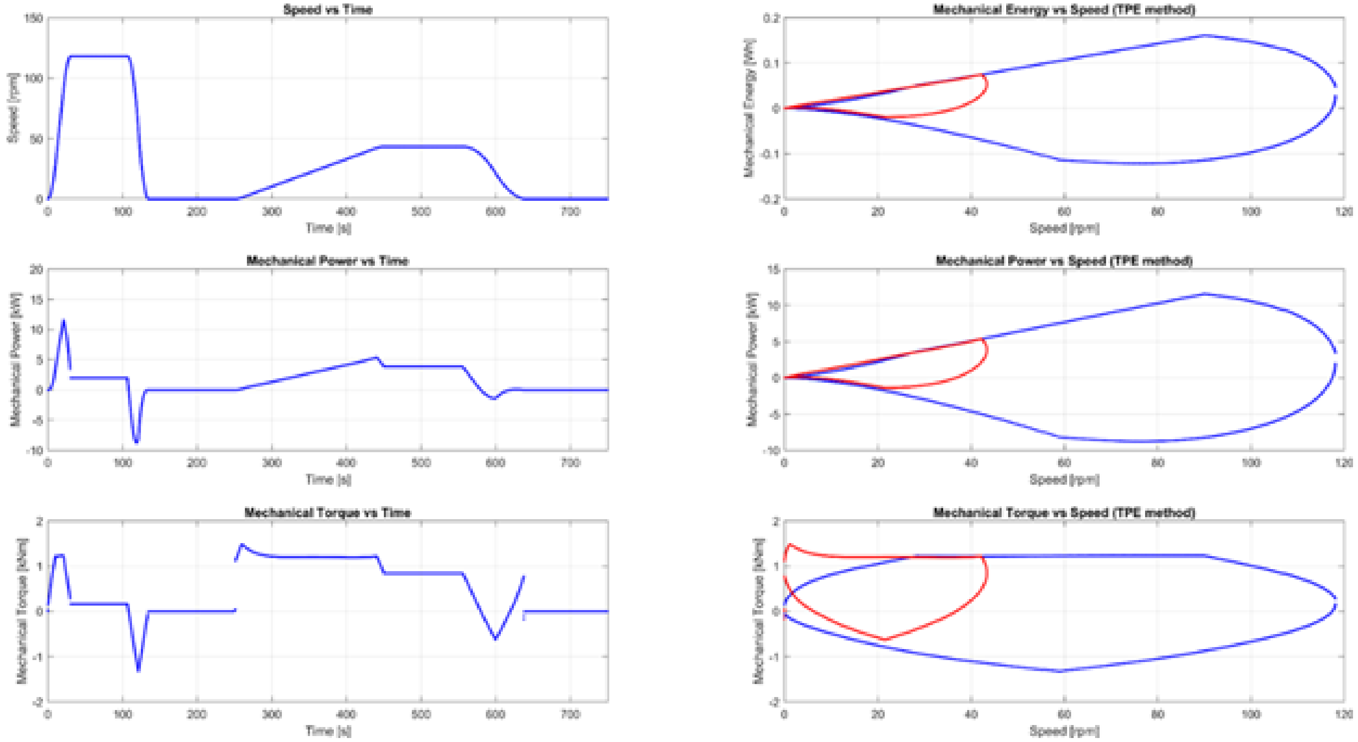
Self propelled wagon Use Cases

1. Private yard load automation (last mile)

Torque, power and energy requirements for the traction system (loaded in red Munloaded in blue)



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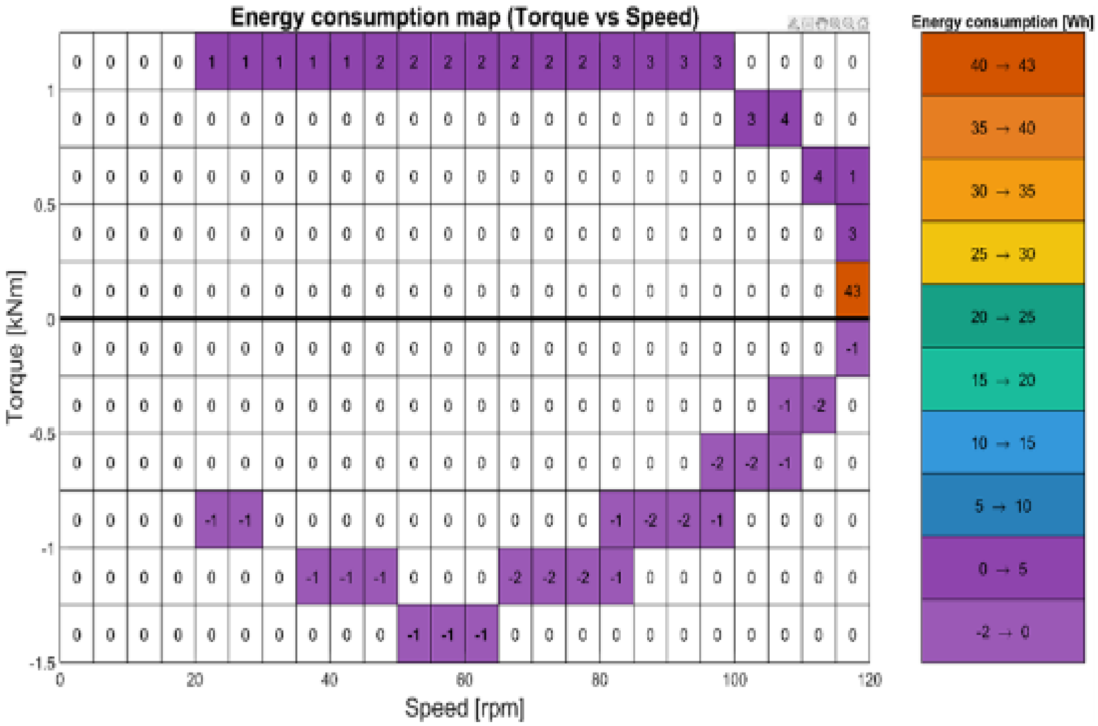
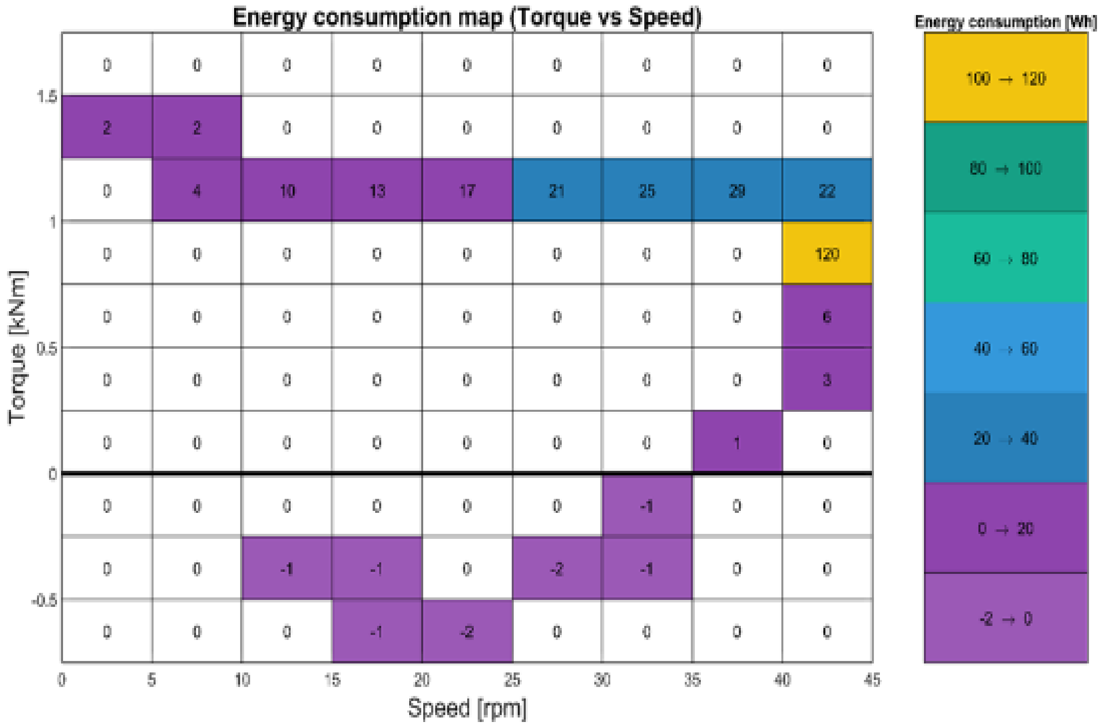
Self propelled wagon Use Cases

1. Private yard load automation (last mile)

Energy consumption map for the traction system





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Self propelled wagon

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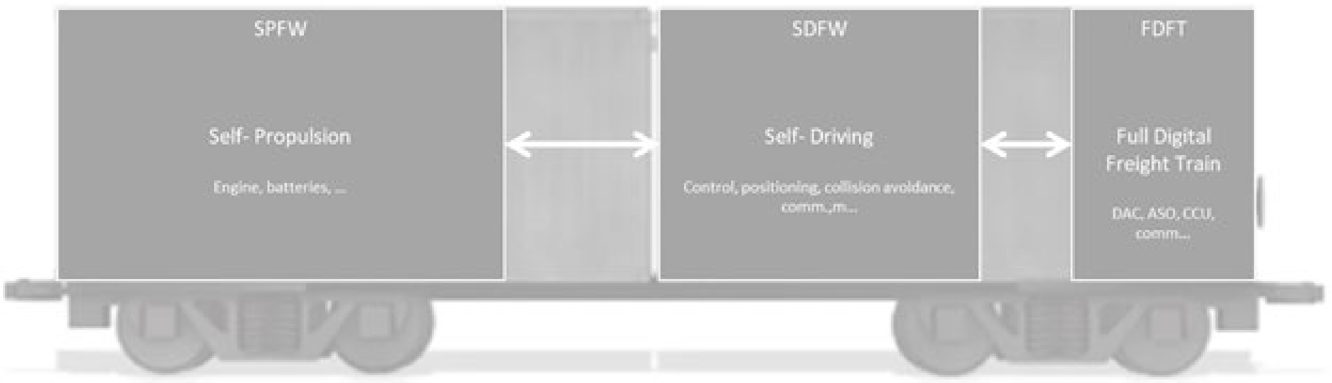
Full operational and integrated system



SDFW

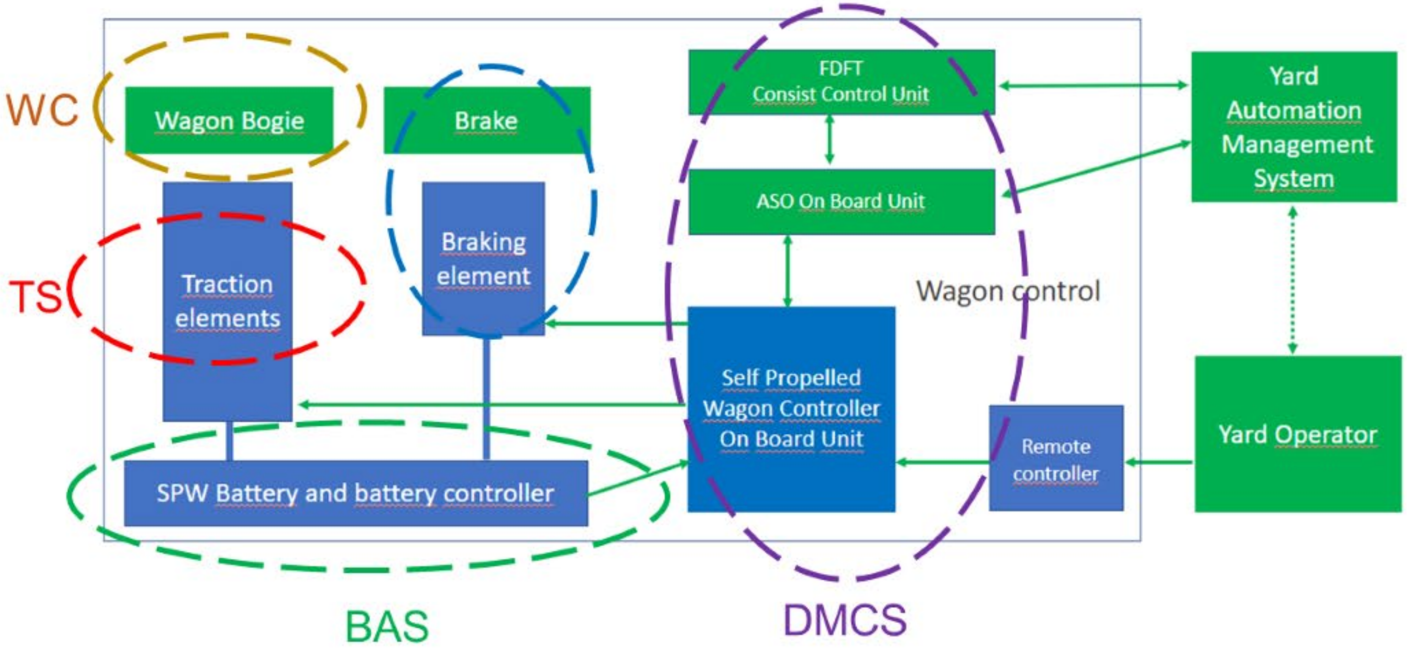
ASO: Autonomous Shunting Operation
CCU Consist Control Unit
FDFT: Full Digital Freight Train
OBU: On-Board Unit
SDFW: Self Driving Freight Wagon
SPFW: Self Propelled Freight Wagon
TMS: Traffic Management System
YMS: Yard Management System

FP2-R2DATO project WP48 T48.3 (work in progress)

Self propelled wagon

Preliminary architecture

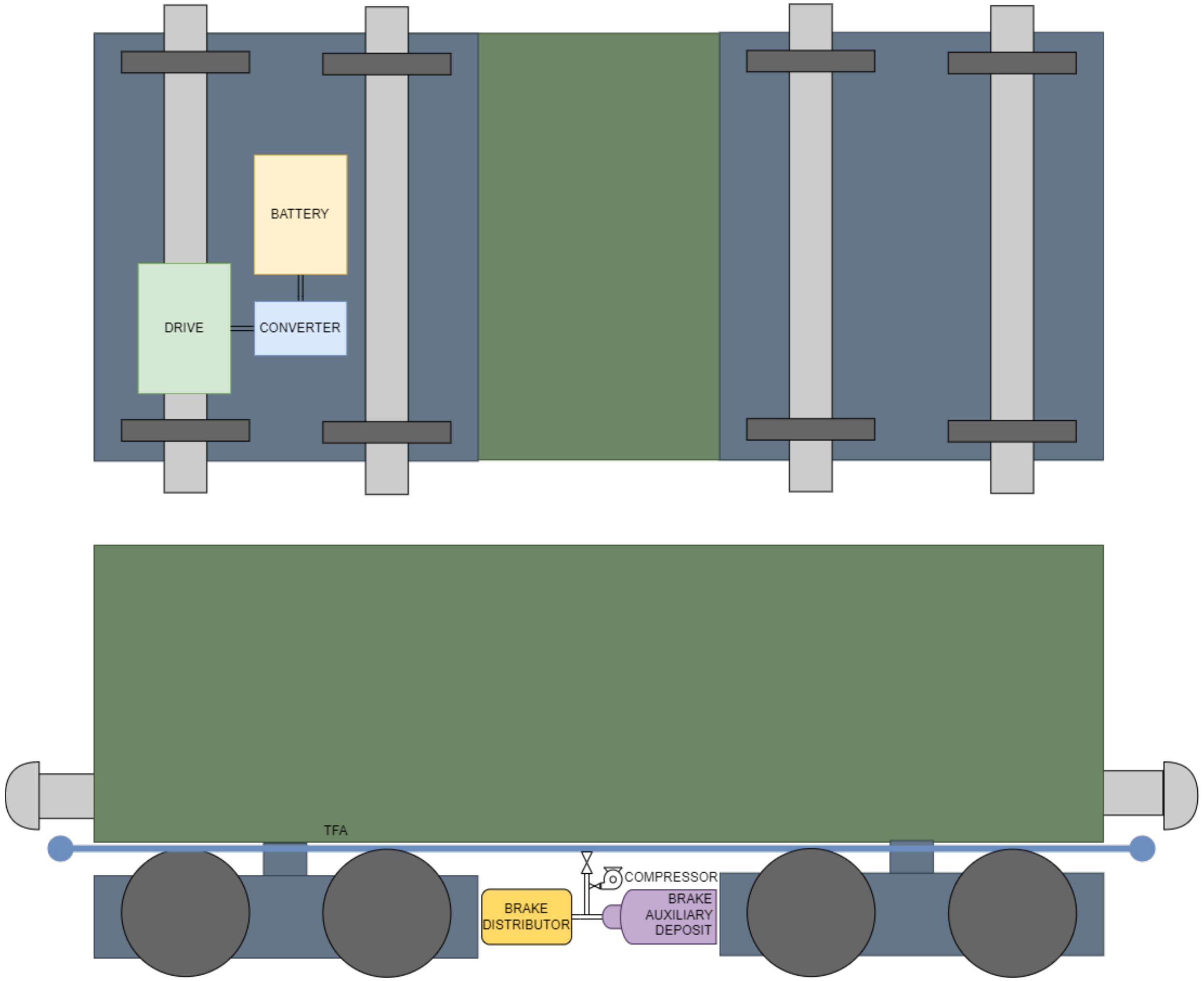
- Conceptual analysis on the impact of self-propelled objective on the digitalization of the freight trains (efficiency of the processes, calculation of the adequate traction units, IoT and traction integration with their interfaces, Infrastructure needs)
- Conceptual system specification and preliminary high level functional requirements (appendix)



Sub-systems of SPW	
Wagon construction + other sub-systems	WC
Traction system	TS
Braking system	BS
Battery system	BAS
Data management and control system	DMCS

Self propelled wagon

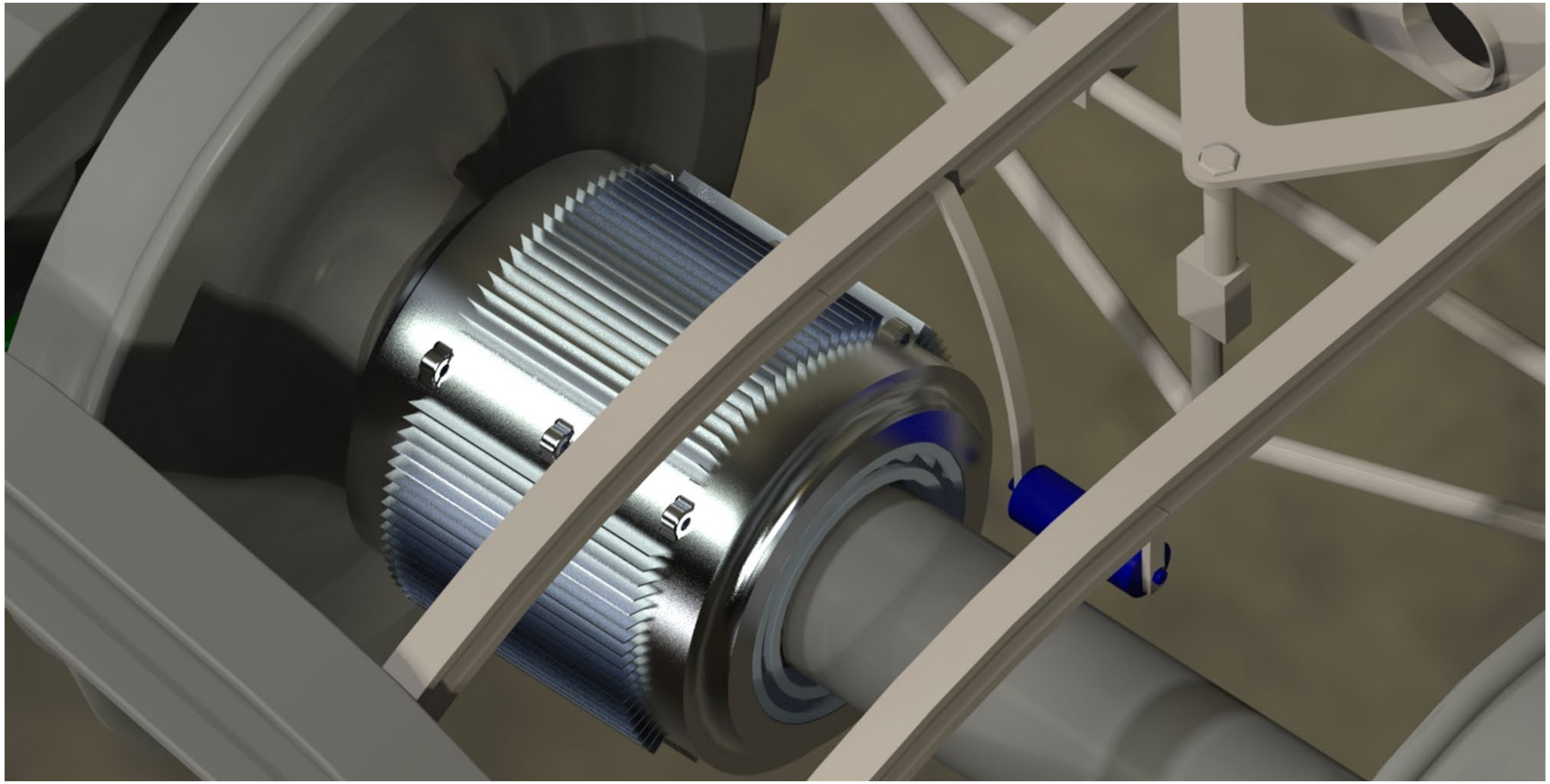
Preliminary architecture



Self propelled wagon

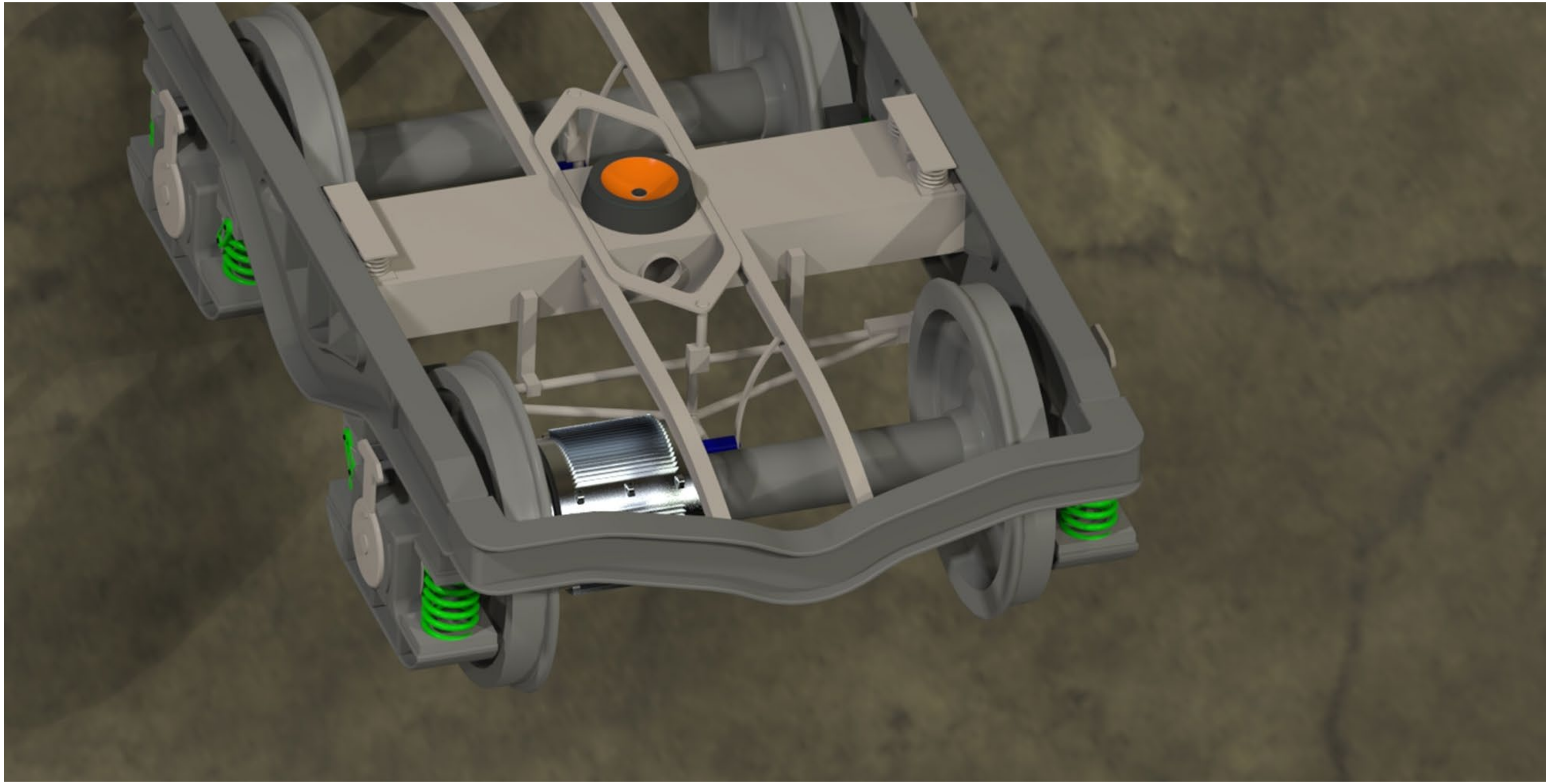
Future work on direct drive motor

- Axle-mounted permanent magnet motor
- Compatible with existing Y21 bogies, allowing retrofitting
- Up to 1500 Nm torque
- Up to 20 km/h



Self propelled wagon

Future work on direct drive motor



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