Efficient and affordable Zero Emission logistics through
NEXT generation **E**lectric **TRUCK**s

HORIZON Innovation Actions ¦ Project Number: 101056740

D2.2
System Definition and Specification

Co-funded by the European Union

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Quality Control

	Name	Organisation	Date
Peer review 1	Miriam Azurmendi and Ibon Cerro	JEMA ENERGY, S.A	15/02/2023
Peer review 2	Daan van Rooij and Jorden van der Hoogt	CENEX NL	07/03/2023

Version history

Version	Date	Author	Summary of changes
0.1	27/01/2023	AVL	First draft of document structure
1.0	27/04/2023	AVL	Final Document with review changes and new template

Legal disclaimer

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ABBREVIATIONS AND ACRONYMS

Abbreviation	Meaning
BMS	Battery Management System
EHW	Electrical Hardware
EV	Electrical Vehicle
FMU	Functional Mock-up Unit
HVAC	Heating, Ventilation and Air Conditioning
HW	Hardware
IoT	Internet of Things
RQ	Requirements
SW	Software
TCO	Total Cost of Ownership
TCN	Technical Customer Needs
TSA	Technical Specification Application
TSS	Technical System Specification
VCU	Vehicle Control Unit
VTMS	Vehicle Thermal Management System

EXECUTIVE SUMMARY

NextETRUCK aims to address different optimization challenges regarding tomorrow's urban and suburban logistics for medium-duty vehicles into a systems approach that is reliable, strongly integrated, affordable, and flexible enough to be re-applied to different applications via dedicated tools/methods.

The overarching objective of the NextETRUCK project is to play a pioneering role in the decarbonization of vehicle fleets, by demonstrating next-generation e-mobility concepts consisting of holistic, innovative, affordable, competitive and synergetic zero-emission vehicles and ecosystems for tomorrow's medium freight haulage, while aiming significant leap of knowledge at component, vehicle, fleet, infrastructure and ecosystem levels, via innovations at e-powertrain components and architectures, smart charging infrastructure and management, improved thermal design of the cabin, fleet management systems with IoT and digital tools.

Within this deliverable, a system definition provides the basis to decompose the requirements for the vehicles and the charge and fleet management including the related cloud functions. For each implementation (e.g. vehicle) a definition of the composition needs to be done to fulfil these requirements. The set of definitions of the system elements in the use cases contains the main definition of the selected (existing or developed) elements (e.g. for vehicle platform and cabin), powertrain related system elements (e.g. propulsion system, energy storage, thermal management system, auxiliaries), and connectivity devices.

The developed element definition framework includes a library of relevant components for EVs. The models of the different individual components and sub-systems are defined according to the different physical properties. These powertrain component models are scalable regarding power and/or energy capacity level. Moreover, thanks to interface standardization, the powertrain components can be easily integrated to form EV models. The developed element definition framework plays a significant role in the development of the modular multi-level system interactions strategy in Task 2.4, and the following tasks. Furthermore, it will be used to verify the potential energy reduction and Total Cost of Ownership (TCO) reduction of the electric multimodal distribution truck in WP3.

1 INTRODUCTION

1.1 About NextETRUCK

NextETRUCK is a 3-year Horizon Europe project that develops ZEV concepts tailored for regional medium freight haulage, running from 1 July 2022 until 31 December 2025.
The project aims at playing a pioneering role in the decarbonisation of vehicle fleets, demonstrating next-generation e-mobility concepts. It also contributes to the development of zero-emission vehicles and ecosystems that are holistic, innovative, affordable, competitive, and synergetic.

NextETRUCK is expected to build concepts tailored for regional medium freight haulage with at least a 10% increase in energy efficiency compared to existing highest-end benchmark electric vehicles. In addition, it shall prepare concept and infrastructure demonstrators for fast charging and offer new business models to increase end-user acceptance and foster the market uptake of the project solutions.

The project's consortium consists of 19 partners from 8 countries: The Netherlands, Belgium, Germany, Spain, Greece, Australia, Turkey, United Kingdom[1]. The project's coordinator is TNO (Netherlands Organization for Applied Scientific Research). NextETRUCK shall conduct demonstrations in Istanbul, Barcelona, and Utrecht.

1.2 Task 2.2 introduction

This report contains the requirements and specific system definitions based on the use cases, missions and overall vehicle definitions described in task 2.1 ("Use case, mission and overall vehicle definition"). The requirements are derived and documented, enabling the exact system definition of each vehicle. Additionally, a plan for the setup and creation of digital twins with the focus on energy management is presented.

1.3 Purpose of the deliverable

This deliverable provides the requirements and specific system definitions for the specific vehicles. The outcome is a viable input for the definition of the digital twins and detailed specifications of the sub-systems.

Who	Role
VUB	Powertrain elements (e.g. BMS – inverter – powertrain energy manager
ABB (Panion)	Off vehicle charger systems, charge management platform

[1] The UK participants in this project are co-funded by the UK.

TEC	Interfaces and communication between the main system elements.
CERTH	Off-board connectivity, cloud services, backend
AIT	Requirements definition of the HVAC system and vehicle cabin
FORD	Vehicle level specification will be deceased to component and sub-system level requirements.
AVL-AT	Cybersecurity and Road safety requirements. Definition of the several Vehicle digital twin levels according to the several needs. Mainly by having in mind either pure data driven multi-dimensional meta models and/or semi-physical surrogate models
IRIZAR	Base vehicle and chassis definitions, Powertrain elements (e.g. BMS – inverter – Powertrain energy manager….)
TEVVA	Base vehicle and chassis definitions, Powertrain elements (e.g. BMS – inverter – powertrain energy manager)
DATIK	Connectivity and IoT system
AVL-THD	Requirements for thermal management system definition and VTMS/HVAC control.
NNG	Traffic Flow Information & Routing including uncertainty: define what is needed for the project

Table 1: Partner contribution in the task.

1.4 Structure of the deliverable and its relationship with other work packages/deliverables

Figure 1 presents the overall work packages in NextETRUCK with interactions.

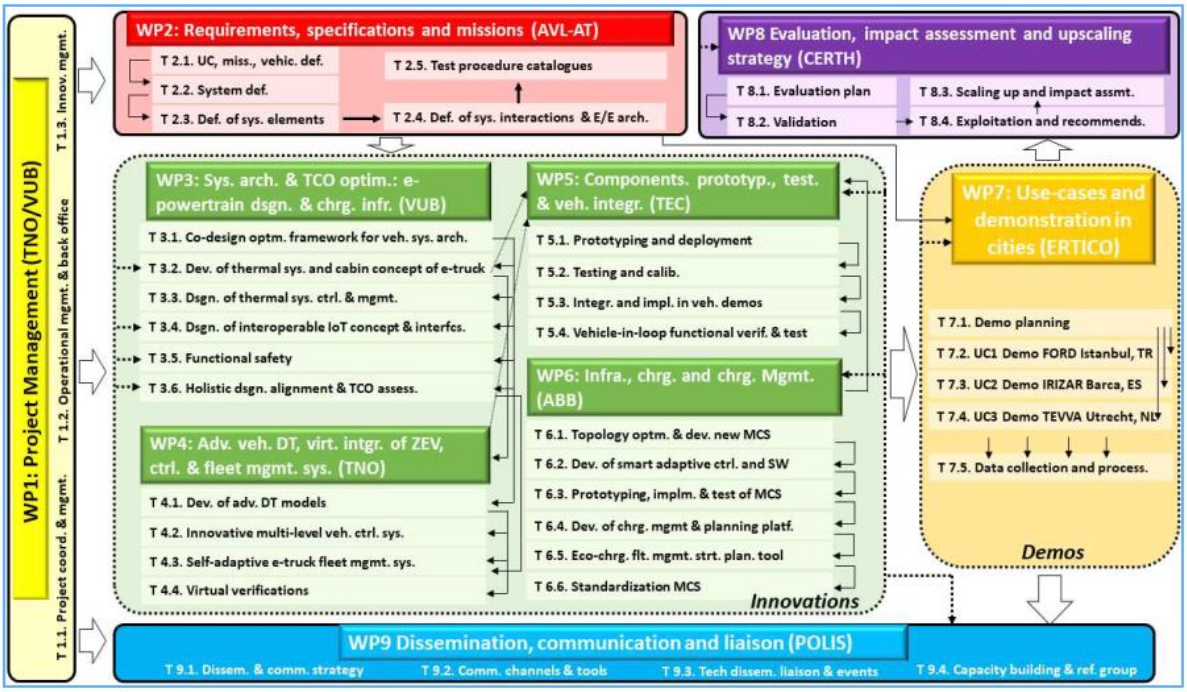

Figure 1: WP structure, allocated tasks and the relationships between the tasks.

Figure 2 presents the relation between this delivery and the digital twins in WP3 and WP4.

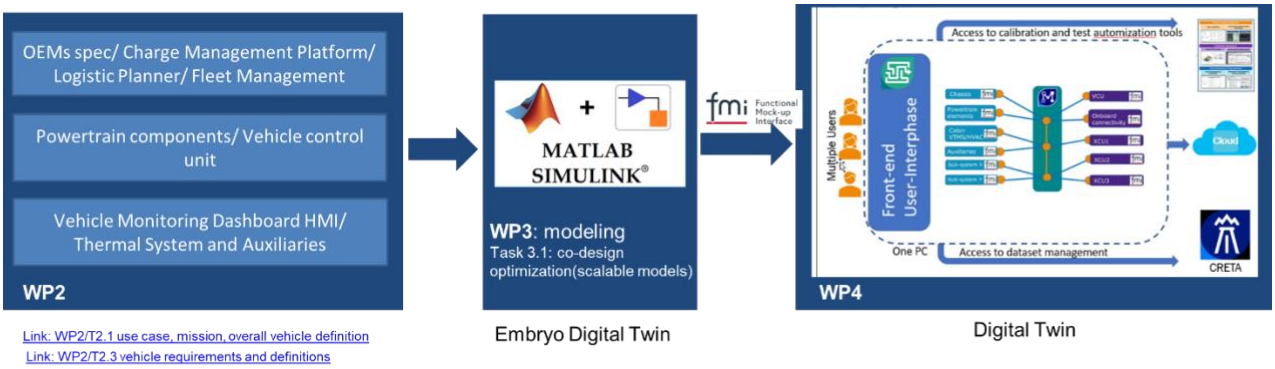

Figure 2: Inputs/Outputs of this deliverable.

To handle the technical complexity of a product under development, it is needed to classify requirements (RQs) and specifications according to which part of the product is described. Therefore, AVL uses a level structure approach where each level consists of specific architecture elements (System Structure Nodes). For products with respect to the automotive domain the levels (with increasing degree of detail) as defined in Figure 3 from Application down to software (SW) System/ Electrical Hardware (EHW) and hardware (HW) parts shall be used.

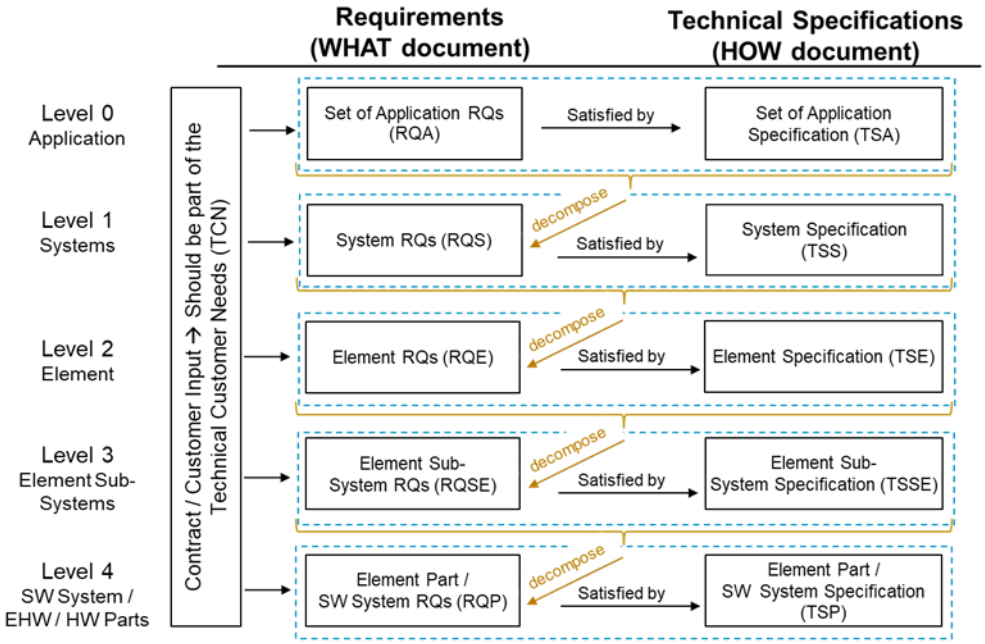

Figure 3: Process level structure.

The process flow in Figure 3 described serves to structure the complex system requirements and to define specification tasks. AVL uses a special toolchain to improve traceability and change management. The "Life Cycle Management" tool is able to support requirement definitions and creates with export filters readable documentation in pdf format.

The "NextETRUCK" EU project with its System definitions is already integrated in the AVL tool chain as requirement and specification items. The specific worksteps in Task 2.2 are shown in Figure 4 starting with the Excel from Task 2.1 and ending with the information to the partners in the Annexes of this report.

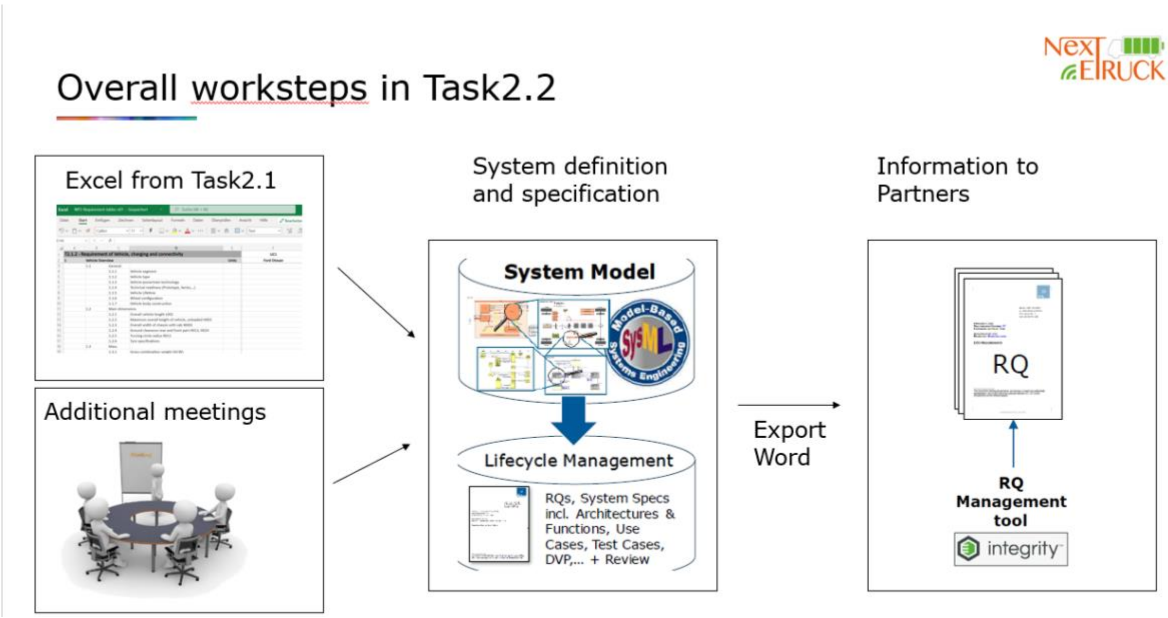

Figure 4: Overall work steps in Task 2.2

1.5 Main changes from previous version

This is the first submission of this deliverable.

2 NEXTETRUCK STAKEHOLDER REQUIREMENTS

The Stakeholder requirements contain the overall targets and requirements deduced from the WP2 - T2.1 Mission and Use case description template filled out by the partners (See [1]).

The stakeholder requirements are then decomposed to the lower level set of requirements as shown in Figure 3.

The stakeholder requirements are presented in **Annex1**.

The documentation in **Annex1** is a living document showing the status at the end of January 2023.

3 NEXTETRUCK VEHICLE TARGETS AND REQUIREMENTS (LEVEL 0)

The stakeholder requirements are decomposed to the vehicle targets and requirements (Level 0) as shown in Figure 3. The vehicle targets and requirements are presented in **Annex2**.

The documentation in **Annex2** is a living document showing the status at the end of January 2023.

4 NEXTETRUCK VEHICLE SPECIFICATION

Based on the vehicle requirements, the current status (end of January 2023) of the vehicle specification is documented in **Annex3**.

The documentation in **Annex3** is a living document showing the status at the end of January 2023.

5 NEXTETRUCK VEHICLE SPECIFICATION

Based on the requirements and vehicle specifications, the specific use cases for vehicle operation are defined and documented in **Annex4**.

The documentation in **Annex4** is a living document showing the status at the end of January 2023.

6 PLAN FOR THE SETUP AND CREATION OF DIGITAL TWINS

The use of digital twins plays a central part in the NextETRUCK project. The digital twins are used to perform rapid impact assessment of the new powertrain architectures that are realized by the developed technologies and innovations through the project.

The AVL proposal for a generic digital twin setup was accepted by all partners. The proposal enables all partners to deliver sub-system models and virtual control units for a common digital twin as shown in figure 5.

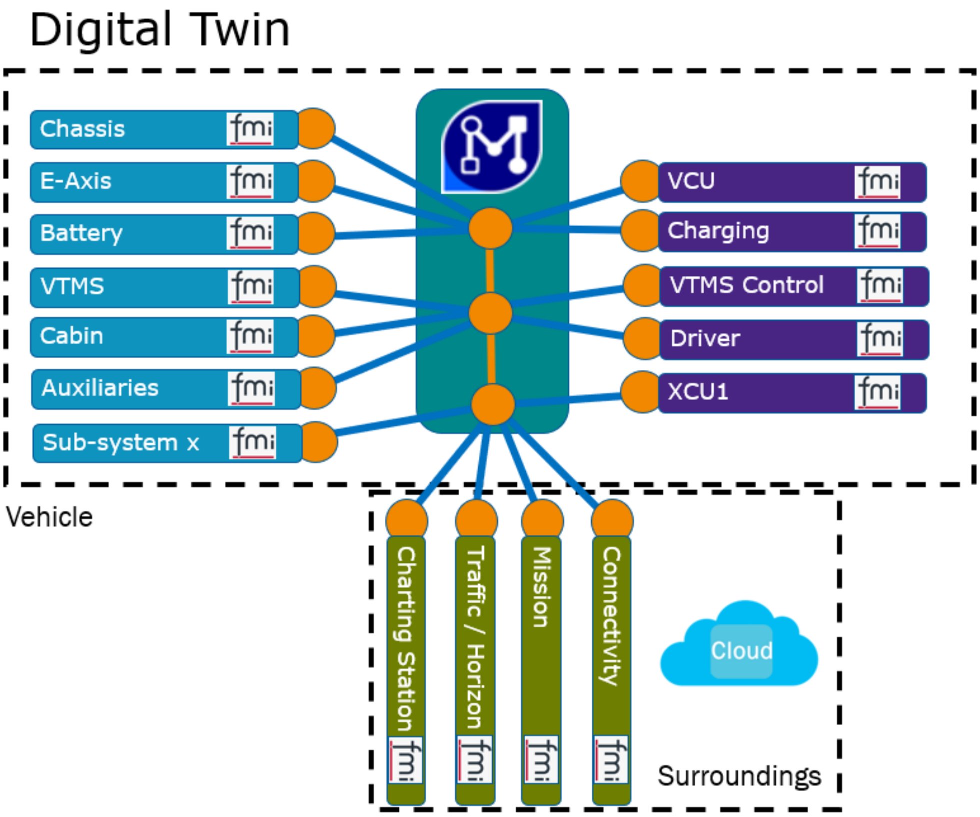

Figure 5: Example of AVL digital twin setup.

The digital twin contains the following major components:

<u>Vehicle sub-system plant models:</u>

Examples of major sub-systems in the vehicle are the E-Axis, Battery and Vehicle thermal management system (VTMS). The sub-systems can be modelled in commercially available software tools such as AVL CruiseM, MATLAB, etc.

<u>Virtual control units:</u>

Examples of virtual control units are the vehicle control unit (VCU), charging control or VTMS controls. The virtual control units can be programmed in MATLAB.

<u>Surrounding models:</u>

Examples of the surroundings are the charging station, route and traffic information and connectivity. The surroundings models can be modelled in commercially available software tools such as AVL CruiseM, MATLAB, etc.

All models and control units are compilated to the "Functional Mock-up Interface (FMI) standard". Using the software AVL ModelConnect, all models and control units are coupled to a full vehicle simulation platform.

AVL offers the partners to deliver sub-system models and control units compiled as functional Mock-up units (FMU) as shown in Figure 6. AVL will then prepare digital twins and give access to the partners via an online platform or free licenses.

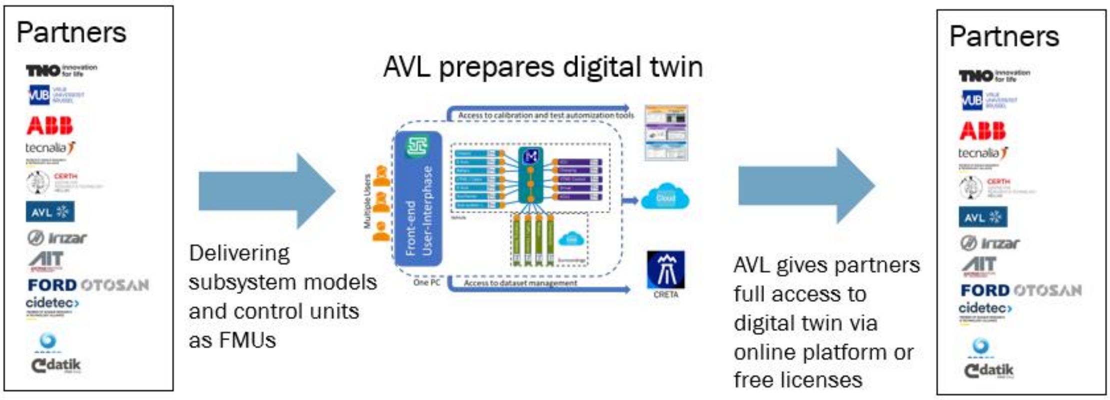

Figure 6: Example of AVL digital twin setup with partner access.

7 CONCLUSION

The requirements and specific system definitions have been presented in detail in this report and are an important input for future activities with the digital twins. Due to the dynamic of the project, the requirements and specific system definitions are expected to be a "living document" with future changes.

AVL intends to continue the update of the requirements and specific system definitions and automatically feed the information into the digital twins as shown in figure 7.

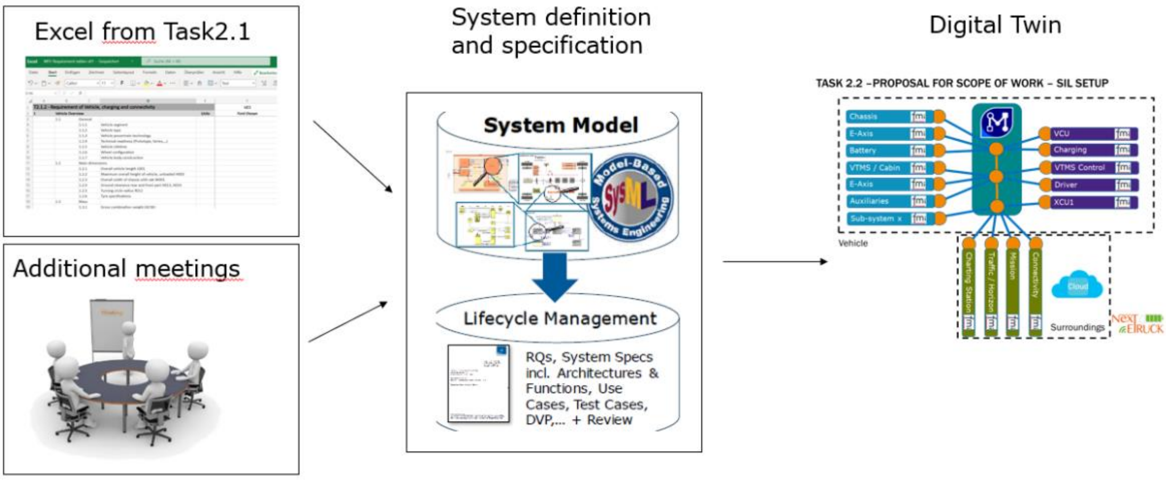

Figure 7: AVL vision.

8 REFERENCES

1. NextETRUCK-T2.1-UC-v06.docx
2. OMG Systems Modeling Language (OMG SysML™), TutoriaAuthor (2000), Sanford Friedenthal, Alan Moore, Rick Steiner

9 LIST OF ANNEXES

9.1 Annex 1: NextETRUCK stakeholder requirements

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PROJECT: DFE2189: NextETruck

REPORT: NextETruck Stakeholder Requirements

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NextETRUCK Stakeholder Requirements

Reference

Number	Name	Date
[1]	WP2-Requirement-tables-v01.xlsx	12.12.2022
[2]	NextETRUCK-T2.1-UC-v05.docx	12.12.2022
[3]	NextETRUCK-T2.1-overview.docx	12.12.2022

Use Case 1 (Istanbul) – Distribution Logistics

This use case aims to give the first steps in upgrading the truck fleet in Istanbul from diesel-based powertrain to electric powertrain. The modular system architecture will be made generically applicable to varying mission profiles and truck types in terms of powertrain, control and charging.
One demonstrator truck from Ford Otosan will be fully operational on-road in Turkey with the internal facilities and addressing the following targets:

- Zero emissions in the urban and intercity area with the same service and performance as the current vehicles equipped with internal combustion engine;
- Functionality equal to or better than the conventional vehicle in any of its urban applications: greater acceleration, better braking, automatic control and electronic regulation;
- Zero emission drive in city operation for heavy commercial vehicle;
- Vehicle level efficiency optimization based on the simulation; intelligent thermal management strategy reducing load and energy usage for climate control and battery cooling;
- Noise and emission reduction in city;
- Improved cycle efficiency compared to diesel and first gen electric truck applications;
- DC charge for opportunity charging;
- Tailored eco-routing strategies.
- Fleet level efficiency; closed loop vehicle communication, via the cloud, with the intelligent fleet management system to enable real-time mission, vehicle load and charge planning.

Use Case oriented innovations of NextETruck

Specific needs	Operating cost reduction with efficiency EV drive train.
System level solutions	Efficiency improvement with right sizing enabled by digital twins. Novel thermal management solutions.
Vehicle level solutions	Connectivity, weight reduction, new vehicle control software
Fleet level solutions	Charge and fleet management integration

1. Use Case Objectives

Objective	10% improvement in overall efficiency
Baseline	0,95 kWh/km energy consumption
Target	0,86 kWh/km energy consumption

2. Use Case Objectives

Objective	Demonstrate at least 200 km average daily operation in real conditions
Baseline	Not Available
Target	Real world testing with 200 km daily mileage

3. Use Case Objectives

Objective	(Between Eskisehir and Golcuk plants: 198 km) over a period of at least 6 months

4. Use Case Objectives

Objective	Synergies with shorter range/lower payloads urban and suburban applications in the municipal waste collection or construction activities, can be included;
Baseline	Not Available
Target	Analytical assessment of other duty cycles will be done with digital twins developed under the leadership of TNO

5. Use Case Objectives

Objective	Development of lightweight chassis and integration of electric powertrain components
Baseline	Chassis design based on ICE powertrain.
Target	Lightweight and modular chassis based on electrical

Use Case description related to missions

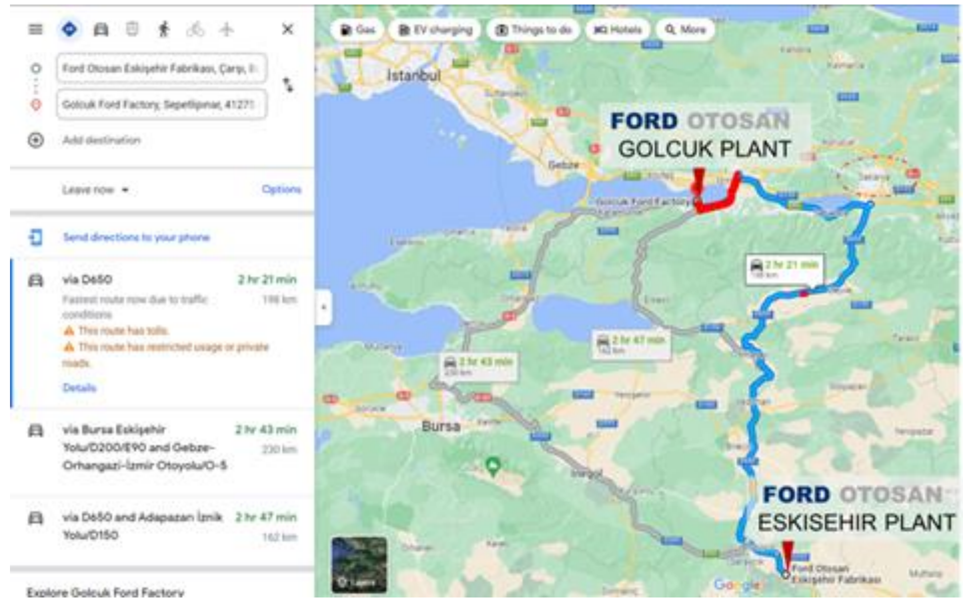
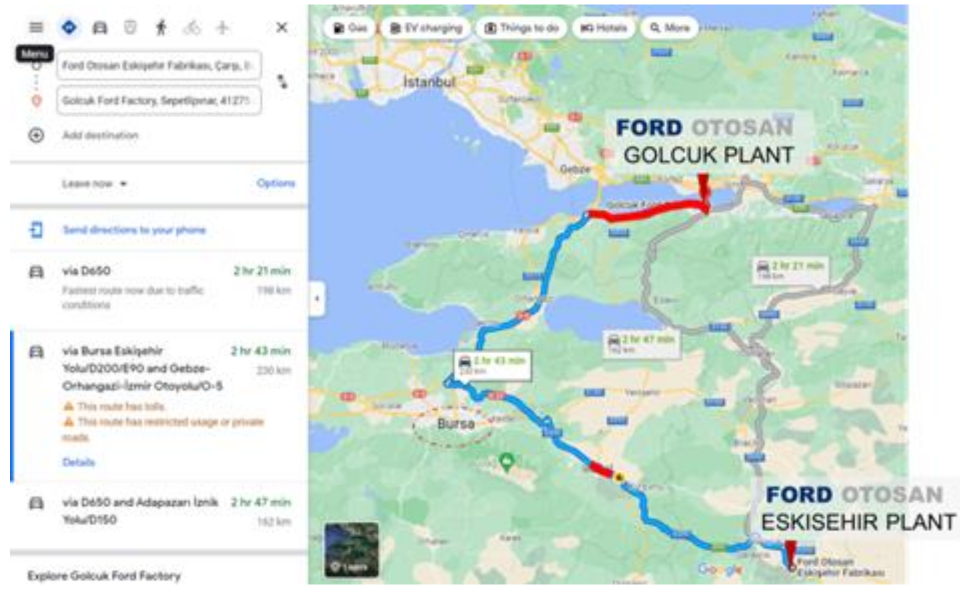
Mission description

Demonstrate at least 200 km average daily operation between Eskisehir and Golcuk plants where we can demonstrate intercity and urban transport scenarios. This mission represents 100% of ICE truck usage.

Addressed challenges	Development of lightweight and modular electrical born platform for N3 type trucks that is not in the current product portfolio of ford trucks.

Charging requirements	DC overnight charging is required for every cycle

Charge management	Cloud-based software solution for charge planning and shifts scheduling. PANION solution collects data from the available telemetry providers and on-site chargers to calculate the charge opportunity windows and prepare most suitable charging plans with awareness of additional external constraints and insights like electricity prices, or available power capacity. Then the software supervises execution of the charge plan and aligns dynamically it in case of any changes. In this particular case, PANION will provide a solution that will optimize the charge times and introduce charge planning allowing the truck to perform more operations than with just an overnight charging approach. This will lead to reduced TCO for a comparable base case by reducing infrastructure cost (less trucks and chargers needed for same amount of trips) and energy cost (in case of time variable energy cost).

Use Case Route Options 1	
Use Case Route Options 2	

Use Case 2 (Barcelona)

Barcelona is the capital and the most populous city of Catalonia, and the second largest city in Spain, with a population of 1.6 million, climbing to 4.2 million for the metropolitan area. The main transport challenges facing Barcelona include protection of the historical city centre, which does not lend well to motorised transport; a high proportion of electric powered vehicles dedicated for urban logistics; and city services could reduce pollutants and noise levels in the city centre and suburban towns. The use case concerns to develop a new vehicle architecture with high flexibility on the vehicle architecture that could be adapted and used in different applications such as a refuse truck or as a delivery truck in distribution in urban and regional logistics.

This use-case will demonstrate the integration of developed vehicle in a fleet of waste collection vehicles / vehicle park in Barcelona, Spain. One ZEV (pilot truck) will be fully operational on road in Barcelona

(6 months operation) integrated into FCC´s waste collection fleet. This will also demonstrate the smart and fast charging system and its fleet charging management system. This will also demonstrate the smart IoT system and it connectivity providing more services e.g. predictive maintenance, road safety guidelines (real-time), and connected fleet management with accurate range estimation. The targets of this use-case are summarized as follows:

- Zero emissions in the urban area with the same service and performance as the current vehicles equipped with a heat engine;
- Noise emissions at the lowest technically possible limit, with special importance on starts, braking and in the use of bodywork;
- Functionality equal to or better than the conventional vehicle in any of its urban applications: greater acceleration, better braking, automatic control and electronic regulation
- Through the low cabin, facilitate and improve frequent access to the cabin by operators. Currently, they must descend from a very high level and accidents are frequent;
- Full integration of the body and cabin assembly exterior shapes; important aesthetic and aerodynamic improvement. This will be also investigated by the means of Digital Twin for potential improvement;
- Very significant improvement in the maintenance and accessibility of components for maintenance activities in workshops due to the modular design of the components and their integration into the new vehicle. Reduced maintenance costs;
- Durability and recyclability of components: The lifespan is extended and the vehicles can be recycled, supporting the transformation to the circular economy model.
- Integration into the cabin of the general control for the equipment and the bodywork
- Efficient charging and management with fast charging capability for optimized fleet management.
- Reduced cost through maintenance and equivalent fuel consumption

1. Use Case Objectives

Objective	10% improvement in overall efficiency
Baseline	1 kWh/km energy consumption (only chassis consumption considered)
Target	Up to 0.85 kWh/km energy consumption with efficient powertrain, thermal management and HVAC incl. vehicle cabin

2. Use Case Objectives

Objective	Vehicle components sizing through use case assessment (digital twin)
Baseline	Conventional design tool
Target	Fully digital twin for the demo vehicle for design optimization for right sizing.

3. Use Case Objectives

Objective	90% Payload capacity:
Baseline	16-ton truck with limited range and overnight charging
Target	16-ton e-truck with 90% payload capacity via - lightweight approach

	- improved body structure - New modular HV-Battery implementation with enhanced BTMS

4. Use Case Objectives

Objective	Development and integration of next gen. WBG-based power electronics (traction, auxiliaries, charger)
Baseline	Powertrain based on Si IGBT technology
Target	Using SiC technology in the powertrain and charging systems

5. Use Case Objectives

Objective	Develop and validate tools for zero tailpipe emission vehicles integration in fleets (and mixed fleets) for efficient assignment of tasks Scalability through digital twin demonstration and connectivity approach for fleet management (tracking, mission profiles, charge management, maintenance management based on internal diagnosis)
Baseline	Limited connectivity and standard fleet manager
Target	charging and predictive management system (as Connected Predictive control). Fleet management tool for up-scaling

6. Use Case Objectives

Objective	Digital twin
Baseline	Some models with low fidelity of some components
Target	Fully digital twin for the demo vehicle for design optimization for right sizing

7. Use Case Objectives

Objective	Fast Charging / opportunity charging
Baseline	Standard charging with 150 kW
Target	Fast charging with up to 1MW (up to 3 simultaneous vehicles in charge)

8. Use Case Objectives

Objective	200km electric range scalability demonstration
Baseline	Baseline with NMC 170kWh for a range of 100-150km, and it is commonly charged overnight.
Target	Target with NMC > 200kWh onboard with modular units for high adaptability vs application. >200km range

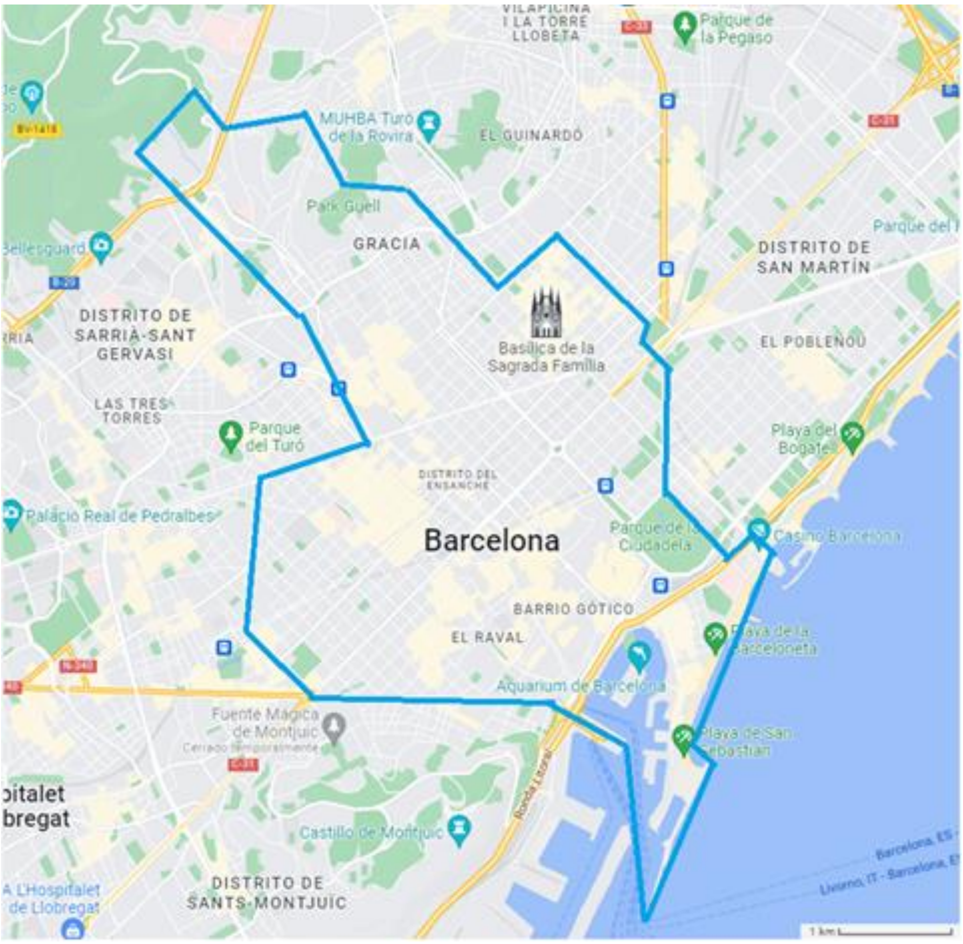
Use Case description related to missions

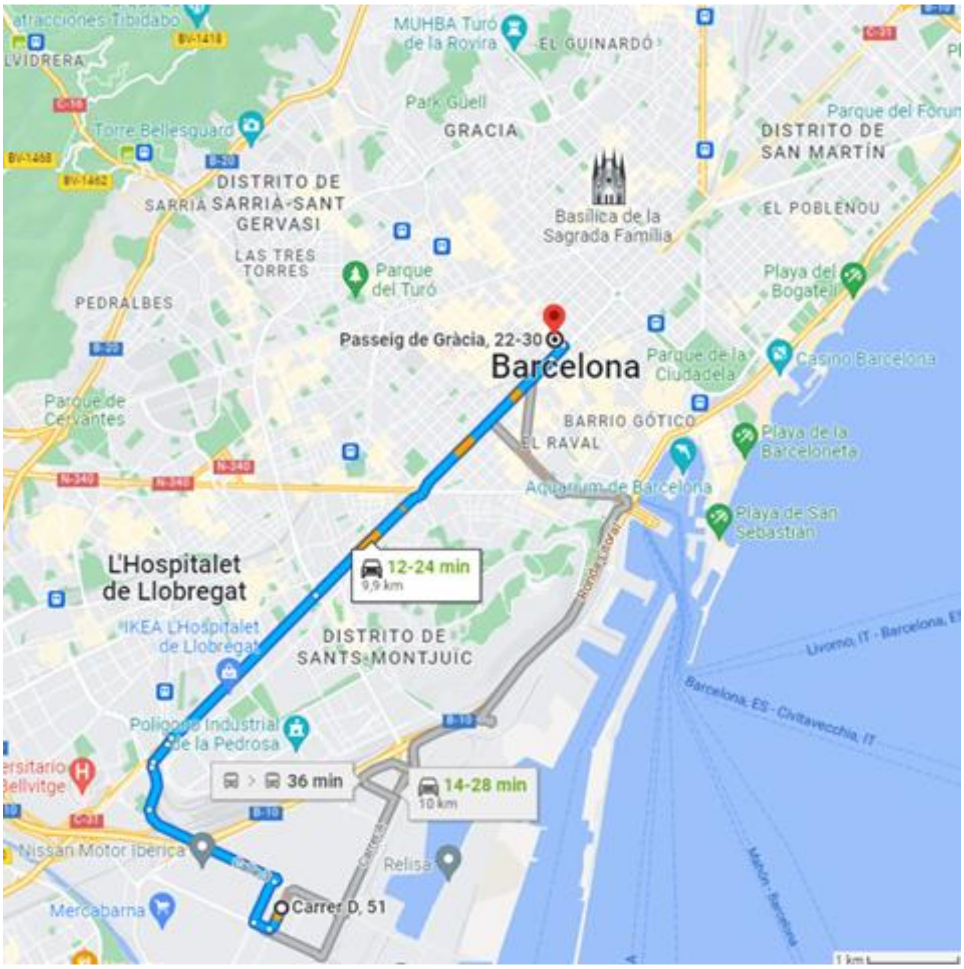
Mission description
Large dimension waste collection (furniture, electronic devices, etc.). IT is not a repetitive route, it's based on demand. It could be that the route doesn't reach 200km, this will have to be discussed with the vehicle operator.

Addressed challenges	90% ICE truck payload with a range >200km

Charging requirements	DC overnight charging

Charge management	Cloud-based software solution for charge planning and shifts scheduling. PANION solution collects data from the available telemetry providers and on-site chargers to calculate the charge opportunity windows and prepare most suitable charging plans with awareness of additional external constraints and insights like electricity prices, or available power capacity. Then the software supervises execution of the charge plan and aligns dynamically it in case of any changes. PANION software can support this use case by direct, live supervision of the operations during shift and calculation of appropriate charging plans in real time, to ensure vehicle operability during the next shift. The main benefit will be the intensification of the operations in difficult to predict conditions and thus lowering the cost of ownership for a particular electric vehicle

Use Case route Option 1	

Use Case route Option 2	

Use Case 3 (Utrecht) – Distribution Logistics

The use case is a "back to base" logistics vehicle operating in the city of Utrecht, Netherlands. Such vehicles operate on a single 8-hour shift per day with the vehicle returning to the depot each night. Vehicle operators need to provide flexible solutions to customers, particularly in the area of express transport, where efficient mission planning and last mile monitoring is crucial.

Utrecht is the fourth largest city of the Netherlands with a population of approximately 358,000 and operates a Low Emission Zone which currently restricts diesel lorries to Euro 4 minimum (Euro 6 minimum from 2022). From 2025 only zero emissions vehicles will be allowed to enter the city for delivery purposes and therefore the availability of ZEV logistics solution with capable range, and at least equivalent total cost of ownership, is important for logistics companies who wish to continue operating.

1. Use Case Objectives

Objective	200km demonstrated range; upgraded battery, higher power and energy density cell chemistry. High fidelity cell/module/pack model for predictive performance and lifetime assessment. Adaptive battery control strategy with over the air (OTA) software update and control capability for SoC management, preconditioning, energy management. Adaptive powertrain control / eco-driving strategy development
Baseline	120kWh LFP pack - baseline
Target	240kWh pack packaged within existing real estate through energy/power density improvement

2. Use Case Objectives

Objective	10% efficiency improvement; optimized battery thermal model, reduced thermal load on heating and cooling systems, waste heat recovery from HV/e-powertrain components. Model based thermal management strategy; Switched reluctance traction motor; high efficiency across wider speed range compared to existing motor technology (no permanent magnets)
	7.5t e-truck – baseline
Target	10% reduction in kWh/km and HVAC energy usage

3. Use Case Objectives

Objective	Load capacity; not less than 90% of current vehicle. Weight optimization from battery chemistry upgrade and light-weight enclosure
Baseline	7.5t diesel truck – baseline

Target	8t e-truck > 90% payload

4. Use Case Objectives

Objective	Digital twin; Model Based System Engineering approach; use of simulation to guide component and sub-system optimization. Virtual verification and validation techniques; SiL, HiL and ViL for assurance prior to customer deployment. Cloud connected VCU to provide real-time vehicle level data for validation and optimization of digital twin model.
Baseline	Partial / non inter-operable sub-system models available (low fidelity)
Target	High fidelity models of battery (cell to pack), cabin/HVAC. Fully interoperable vehicle level digital twin; correlated through demo phase

5. Use Case Objectives

Objective	Advanced fleet management tools; mission profiling, load management, charge management, vehicle diagnostics and battery prognostics capability via digital twin. Scalable model to demonstrate TCO opportunity based on duty cycle. Operator guidance system through integrated HMI and connected VCU
Baseline	Basic telematics and fleet management capability – still in development, limited functionality
Target	Fully functional customer solution; validated through demonstration phase

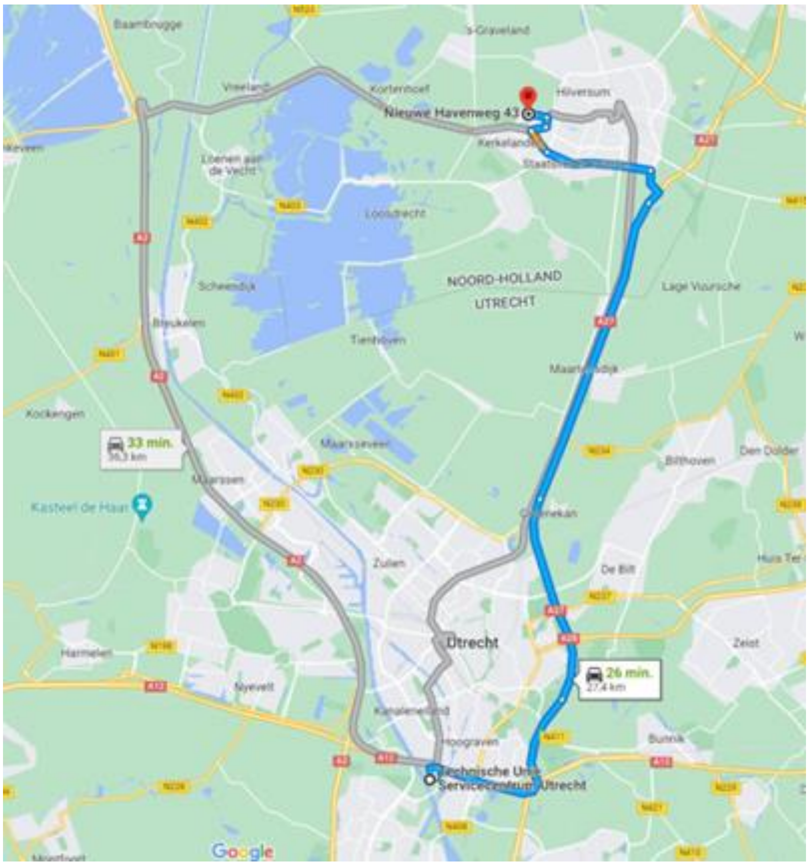
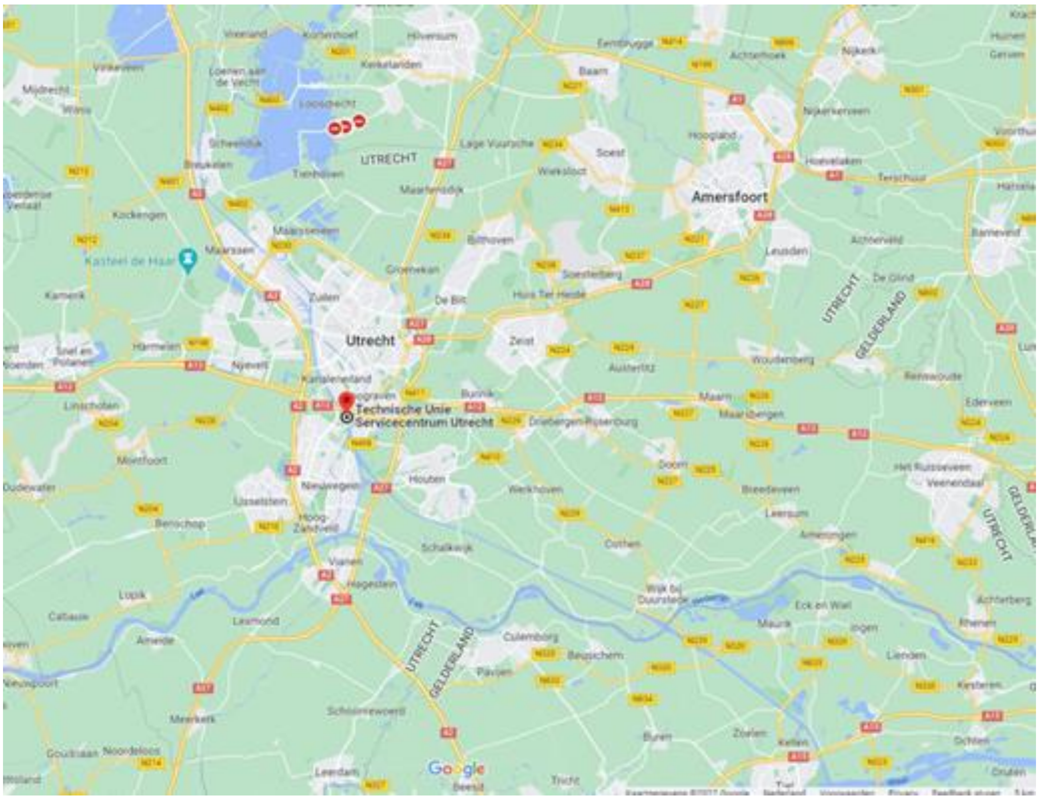
Use Case description related to missions

Mission description

Large dimension waste collection (furniture, electronic devices, etc.). IT is not a repetitive route, it's based on demand. It could be that the route doesn't reach 200km, this will have to be discussed with the vehicle operator.

Charging requirements	A/C charging required in first instance as truck returns to base each night

Charge management	Cloud-based software solution for charge planning and shifts scheduling. PANION solution collects data from the available telemetry providers and on-site chargers to calculate the charge opportunity windows and prepare most suitable charging plans with awareness of additional external constraints and insights like electricity prices, or available power capacity. Then the software supervises execution of the charge plan and aligns dynamically it in case of any changes, according to the truck end user's needs and priorities (still to be gathered). This use case will be supported by PANION solution by providing detailed and dynamically adjusted charging plans for the depot to ensure each of the vehicles will be charged in the most optimal way for his next operation window. With this approach, a cost optimization coming from less chargers needed than with an unmanaged approach in the depot will be available. The main benefit will be the intensification of the operations in difficult to predict conditions and thus lowering the cost of ownership for a particular electric vehicle

Use Case route Option 1 Bulk stock and order deliveries from Utrecht depot to Hilversum branch office	
Use Case route Option 2 Return to Utrecht and delivery of volume customer orders in the Utrecht vicinity	

9.2 Annex 2: NextETRUCK targets and requirements

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PROJECT: DFE2189: NextETRUCK

REPORT: NextETRUCK Vehicle Targets and Requirements

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ANNEX 2 TABLE OF CONTENTS

Introduction

Definitions & Abbreviations

GCM	Gross Combination Mass
HV	High Voltage
ESP	Electronic Stability Program
HVAC	High Voltage Air Conditioning

References

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Remarks on the Document

Remarks: Env. Operating Conditions

If not otherwise stated, all performance requirements in this document shall be tested under the following **normal environmental operating conditions**:

- Ambient temperature range: 0°C to +35°C
- Ambient altitude range: 0 m to 300 m
- Road conditions: straight, dry (high traction surface > 0.85), asphalt, city/ highway
- Road gradient: flat (gradient < +/- 0.5 %)
- Load conditions: Gross Combination Mass (GCM), Trailer included.

Remarks: System Operating Conditions

If not otherwise stated, all performance requirements in this document shall be tested under the following **normal system operation conditions**:

- All component temperatures within normal operation conditions
- No derating (power reduction) of e-drive/ HV battery/ charging system
- HV battery charging state > 50%
- No intervention from driver assistance system or ESP active
- Cabin cooling (HVAC) or heating is not active
- Low voltage load is caused by supply of propulsion system (no lights, no further comfort active)
- No diagnosis event from a component or the powertrain is active
- No functional safety event from a component or the powertrain is active

Vehicle Overview

Three OEM partner are involved in this project for focusing to bring highly efficiencies medium weight range distribution vehicle to the market. All partner have already battery electric vehicle in their portfolio. As targets were defined to integrate high technologies in their vehicle portfolio in order to build up prototype vehicles which achieve high efficiency requests.

General

The vehicle shall be an N3 (vehicle type) for urban delivery use case and with a 4x2 axle configuration.

Standards & Regulations

Standards: Brake System

The vehicle brake system shall be in compliance with UN ECE R13

Standards: EMC

The vehicle shall be in compliance with UN ECE R10 (Electro Magnetic Compatibility)

Standards: Electric Safety

All electrical equipment in the vehicle shall be in compliance with UN ECE R 100 (Electric Safety)

Standards: Functional Safety

The vehicle shall be in compliance with ISO 26262-2018

Note: The standard ISO 26262-2018 is not relevant for the OEM IRIZAR in terms of prototype vehicles. IRIZAR are responsible for prototype applications

Standards: Electric Vehicle Safety

The vehicle shall be in compliance with GTR No. 20 (Global Technical Regulation No. 20 - Electric Vehicle Safety)

Note: The standard GTR No. 20 is not relevant for the OEM IRIZAR in terms of prototype vehicles. IRIZAR are responsible for prototype applications

Energy Consumption

Vehicle Driving Range

The vehicle shall have a range of 250 km in Golcuk - Eskisehir Cycle in route option 1.

Vehicle Driving Range

The vehicle shall have a range of 250 km in Golcuk - Eskisehir Cycle in route option 2.

Vehicle Driving Range

The vehicle shall have a range at least of 200 km in Barcelona area (Gracia or Cicutat Vella) - target south area.

Vehicle Driving Range

The vehicle shall have a range at least of 200 km in Utrecht depot - Hilversum branch office and back

Performance

Boost time

Starting from an e-motor temperature of tbd °C, the peak power time shall be ≥ tbd s at maximum peak power.

Gradeability

High Speed Gradeability

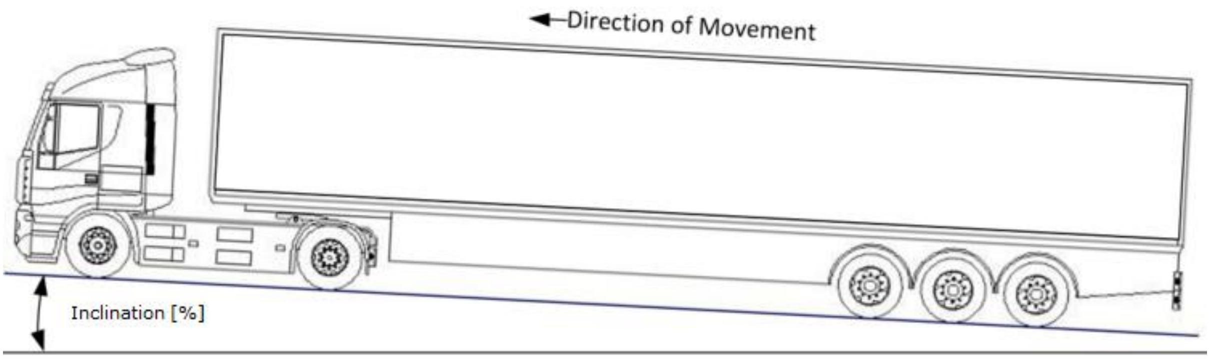
The vehicle shall be able to drive a gradeability of ≥ 4% at 80 km/h for TBD min.

Low Speed Gradeability

The vehicle shall be able to drive a gradeability of ≥ 7% at 30 km/h for ≥ 20 min, including initial environmental condition of cabin temperature of 22 °C, battery temperature of 30 °C and humidity 40 % and a solar load in the cabin of 1.0 kW/m².

Medium Speed Gradeability

The vehicle shall be able to drive a gradeability of ≥ 4.2 % at 50 km/h for ≥ 20 min, including initial environmental condition of cabin temperature of 22 °C, battery temperature of 30 °C and humidity 40 % and a solar load in the cabin of 1.0 kW/m².



Drive Away Gradeability Peak

For drive away at 0km/h with peak torque the maximum gradeability shall be > 30%

Reverse Gradeability

The vehicle shall be able to start driving reverse at a gradeability of 30% with peak power.

Acceleration

Performance: Full Acceleration

Under normal conditions the vehicle shall be able to accelerate from 0 km/h to 85 km/h in ≤ 25.8 s. (Fully loaded vehicle, Peak power considered)

Maximum Velocity

Performance: Max Speed

Under normal conditions at GCM, the maximum vehicle velocity shall be ≥ 90 km/h. This shall be possible with continuous power for ≥ TBD min.

Performance: Overspeeding

In overspeeding conditions, the vehicle velocity shall not exceed 110 km/h

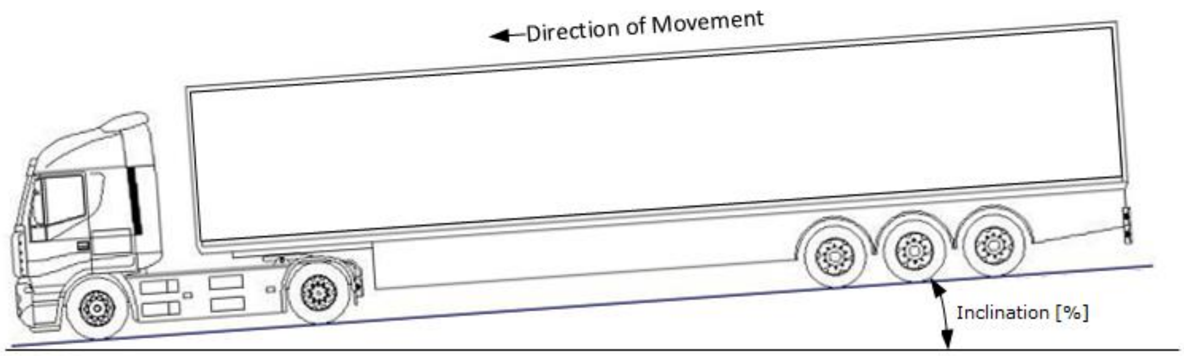
Performance: Reverse driving

Maximum reverse velocity shall be TBD km/h

Vehicle Durability Braking

Durability Brake

At a 6% downhill slope the vehicle must be able to keep a speed of 30 km/h for 6 km.



Thermal Requirement

Cool Down

The vehicle shall be able to cool down the cabin from an initial temperature of 70 °C to 22 °C within 30 minutes at an ambient temperature of 40 °C, a humidity of 40% and a solar load of 1000 W/m².

Environmental Requirements

Ambient Temperature Range

The vehicle shall be operable in an ambient temperature range of -40 °C to 70 °C.

Altitude

The vehicle shall be operable at an altitude up to 2000 m

Safety

Standard and Norms

Functional safety into a vehicle must comply with ISO 21434, UN R155 and UN R156.

Required Information

Required information for the development functional safety applications is the complete control flow and parts that are changeable for the next generation of vehicles.

Vehicle Driver Interface

Driver Interface Features

The following signals from the driver shall be relayed to the control system of the powertrain:

- Positive propulsion power request (Acceleration)
- Negative propulsion power request (Recuperation)
- Intended driving direction (Forward/Reverse)
- Electrical power charge request (Charge)

Cloud Interface

Optimized Energy Consumption Strategy

The following signals from the optimizer via cloud shall be relayed to the control system of the powertrain:

- Optimized velocity profile including traffic information (rush hour, traffic light, speed limits,)
- Optimized energy consumption including recovering (Recuperation)
- Optimized timing of charge request provided by a charge management which consider fleet activities.

Standard Cyber Security

Cyber security for data exchange in into vehicle must comply with ISO 21434, UN R155 and UN R156.

Needed information for developing cyber security application are the totally controls flow and parts which are changeable for the next vehicle generation.

Required Security Concept

A cyber security concept is to be developed. A functional description is required for this.

Cryptographic Encryption

The Vehicle should be connected to the OEM backend via a secure and trusted connection. This connection should be realized via a mobile connection 4/5G and should use modern cryptographic standards.

A HTTPS TLS 1.3 connection should be used. No other service should be reachable from the internet.

The backend should only accept TLS 1.3 and strong ciphers. The Backend and the Telecommunication Unit should have separate TARAs/Risk Assessment and be analyzed accordingly.

9.3 Annex 3: NextETRUCK vehicle specification

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PROJECT: DFE2189: NextETRUCK

REPORT: NextETRUCK Vehicle Specification

Author	Approved	Approved
Gölzner Stefan		

Datum: 2/2/23 7:00 PM
Document State: Final

ANNEX 3 TABLE OF CONTENTS

VEHICLE SPECIFICATION

Introduction

Definitions & Abbreviations

State of Specifications:
All specifications in this document are classified with individual states. These states describe the maturity of the specifications. The following states with the individual meanings are valid and are taken into consideration:

IN WORK: Content of specification may change without notice. Specification is not to be taken into consideration for review/ realization by stakeholder/ supplier.
REVIEW: Specification under AVL internal review process. Specification is not to be taken into consideration for review/ realization by stakeholder/ supplier. Specification may be commented by stakeholder/ supplier.
EXTERNAL REVIEW: AVL internal review process completed. Specification is ready for review process with stakeholder/ supplier. Official feedback is expected from stakeholder/ supplier.
APPROVED: Specification is accepted by stakeholder/ supplier for realization. Specification shall not change without according notification/ change process.

This document contains several graphical representations with the following convention:

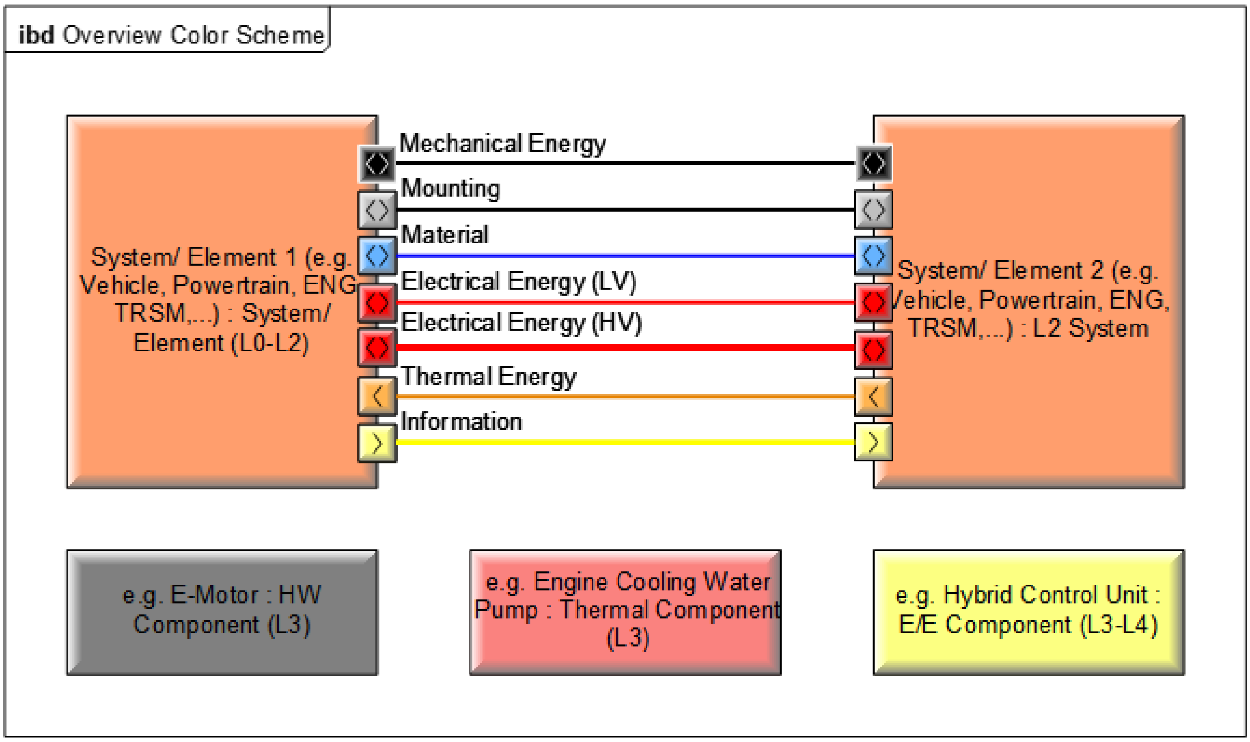

Figure 8 Component and structure related schemes:

Functional related schemes:

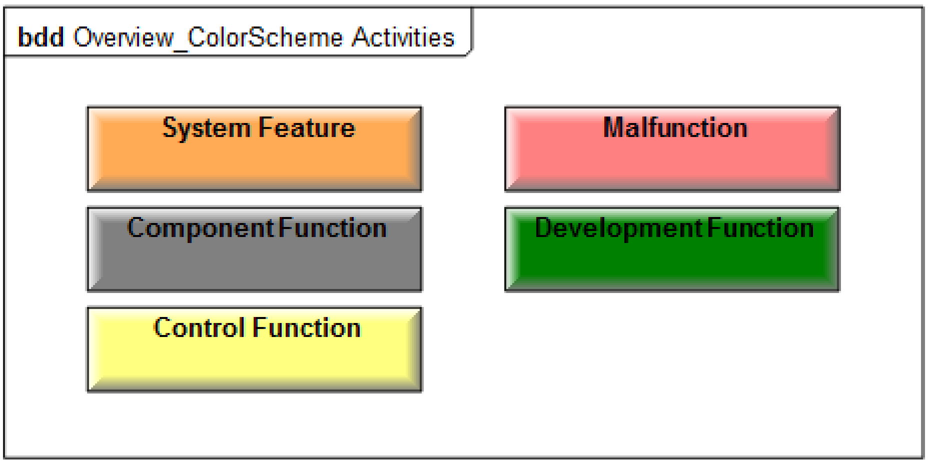

Figure 9 Functional related schemes:

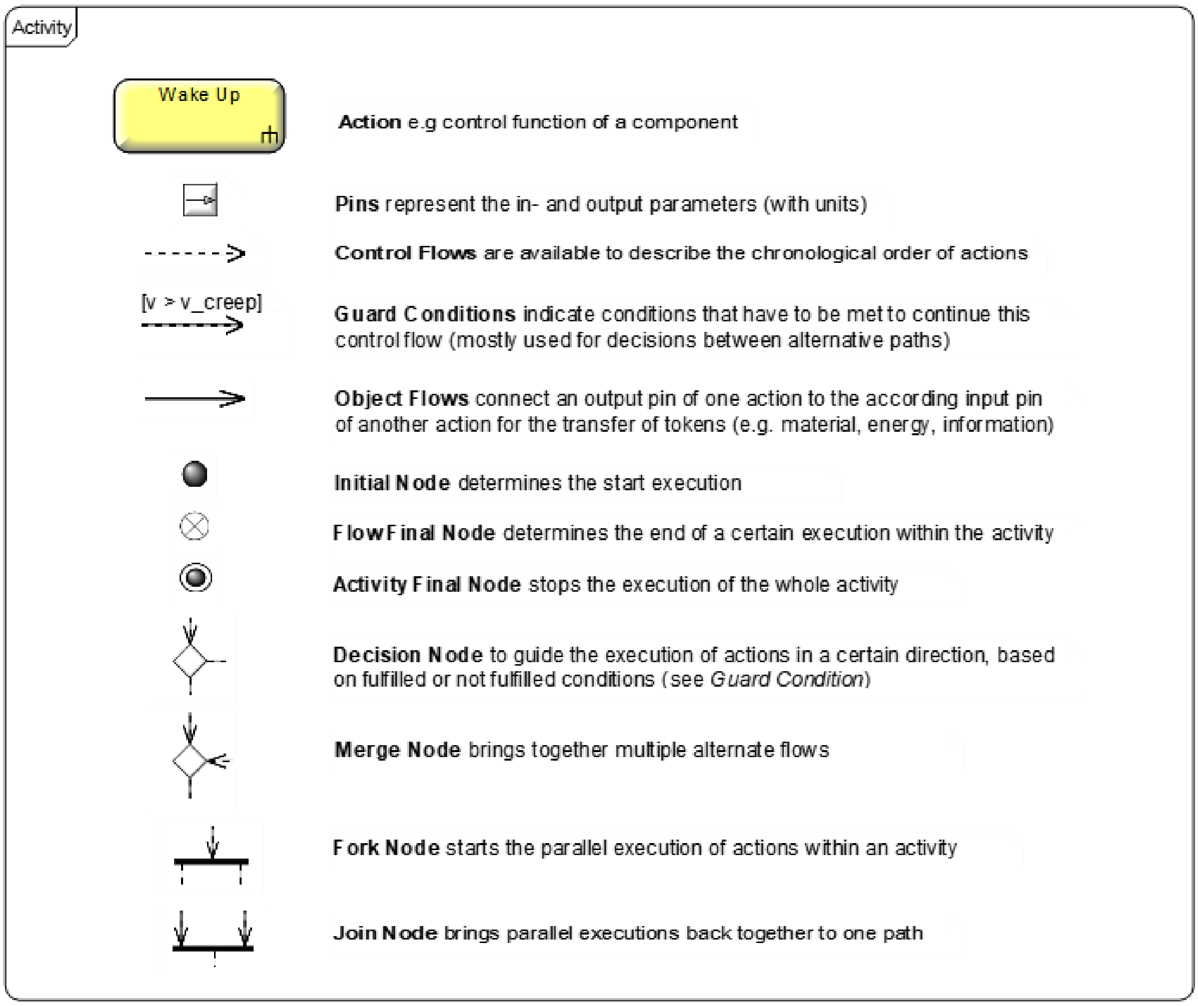

Figure 10 Activity symbols

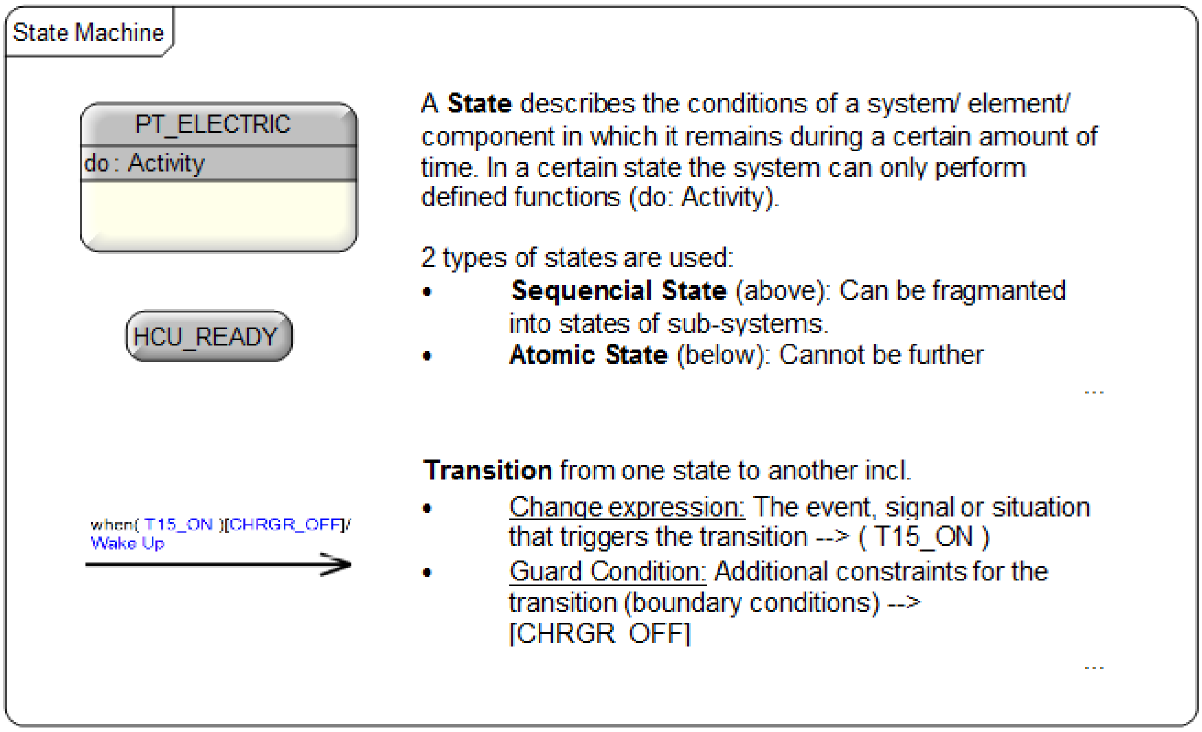

Figure 11 State Machine Symbols

In this document there will be used the following abbreviations:

TBD	To Be Defined
GCM	Gross Combination Mass
FA	Frontal Axle
RA	Rear Axle
HV	High Voltage
HMI	Human Machine Interface

Table 2 Abbreviations in Annex 3

References

Number	Name	Date
[1]	WP2-Requirement-tables-v01.xlsx	12.12.2022
[2]	NextETRUCK-T2.1-UC-v05.docx	12.12.2022
[3]	NextETRUCK-T2.1-overview.docx	12.12.2022

Table 3 References for Annex 3

General Project Information

Three OEM partners are involved in this project to bring highly efficiencies medium weight range distribution vehicle to the market. All partners have already battery electric vehicle in their portfolio. Targets were defined to integrate high technologies in their vehicle portfolio in order to build up prototype vehicles which achieve high efficiency requests.

 Figure 12 FORD OTOSAN	 Figure 13 IRIZAR	 Figure 14 TEVVA

Table 4 Vehicles

Ford Otosan

The general basic vehicle data are provided by the OEM linked to [1]:

Specification: 6196548

The general vehicle geometry data are as following:

Item	Unit	Value
Overall vehicle length	mm	Sensible information available
Total vehicle height	mm	Sensible information available
Total vehicle width	mm	Sensible information available
Tyre size	inch	Sensible information available 5
effective Front surface	m²	Sensible information available

Table 5 Geometric Data

Specification: 6196710

The vehicle mass data are as following:

Item	Unit	Value
Gross combination mass	kg	Sensible information available
Payload	kg	Sensible information available
Curb mass	kg	Sensible information available
Permissible front axle load	kg	Sensible information available 700

Permissible rear axle load	kg	Sensible information available

Table 6 Vehicle Mass

Specification: 6196712

The driving resistance parameter are as following:

Item	Unit	Value
Drag coefficient	1	Sensible information available
Rolling resistance coefficient	mm	Sensible information available

Table 7 Driving Resistance

IRIZAR

Specification: 6223008

The general vehicle geometry data are as following:

Item	Unit	Value
Overall vehicle length	mm	8 000
Total vehicle height	mm	3 600
Total vehicle width	mm	2 550
Tyre size		R22.5
effective Front surface	m^2	9.5

Table 8 Vehicle Geometry

Specification: 6223013

The vehicle mass data are as following:

Item	Unit	Value
Gross combination mass	kg	20 000
Payload	kg	7 000
Curb mass	kg	13 000

Permissible front axle load	kg	9 000
Permissible rear axle load	kg	13 400

Table 9 Vehicle Mass

Specification: 6223015

The driving resistance parameter are as following:

Item	Unit	Value
Drag coefficient	1	0.65
Rolling resistance coefficient	mm	0.008

Table 10 Driving Resistance

TEVVA

Specification: 6223049

The general vehicle geometry data are as following:

Item	Unit	Value
Overall vehicle length	mm	9337
Total vehicle height	mm	2 697+660
Total vehicle width	mm	2295
Tyre size		R19.5/285/70
effective Front surface	m^2	

Table 11 Geometry Data

Specification: 6223051

The vehicle mass data are as following:

Item	Unit	Value
Gross combination mass	kg	16 000
Payload	kg	9 285
Curb mass	kg	6 715

Permissible front axle load	kg	5 800
Permissible rear axle load	kg	10 900

Table 12 Vehicle Mass

Specification: 6223053

The driving resistance parameter are as following:

Item	**Unit**	**Value**
Drag coefficient	1	0.65
Rolling resistance coefficient	mm	0.009

Table 13 Driving Resistance

Vehicle System and Interface

Vehicle Architecture

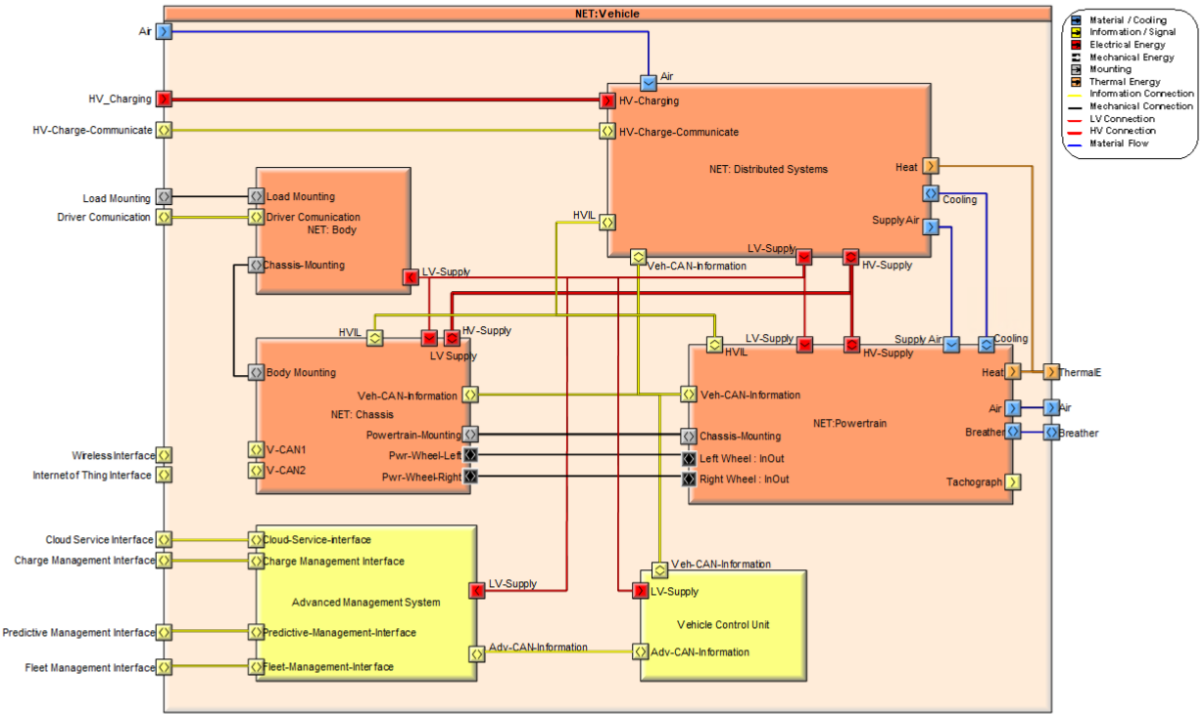

Figure 15 Vehicle Architecture

- The ***powertrain*** covers an energy storage device that supplies power consumers like the E-drive. The E-drive converts electrical power to rational power via gearbox to the wheels. The power is used for propulsion (wheel power, mechanical) and to power additional systems on the vehicle (auxiliary power, mechanical or electrical power with high or low voltage). Byproducts are heat.

  Also the powertrain receives cooling fluid for element cooling from distributed systems. Depending on actual powertrain architecture the powertrain possibly receives additional electrical power from external sources. The powertrain elements are mounted to the vehicle chassis.

  The powertrain element comprises of an E-drive system for rotational moving generation and a gearbox with a fixed gear ratio transfers the rotational energy to the wheels. The electrical / mechanical sub system is supplied by a HV battery system which is connected at the HV board net. The HV battery providing electrical energy to the electrical consumers for discharging and on the other hand receiving charging power to fill storage. For HV safety issues an isolation monitoring system is installed in the HV circuit which has an impact of system de-ratings.

- The vehicle ***chassis*** is the main structural system of the vehicle. It supports all loads onto the vehicle, transfers the power from the powertrain to the wheels and has to deliver the braking power. It is the connecting part between all vehicle systems. Also it has to suspend and dampen the loads from terrain inputs onto the vehicle to assure safe conditions for the driver.

- The vehicle ***body*** provides room for the driver and is the main "command center" of the vehicle. It has to provide an environment for the driver and the passengers that allows long driving without fatigue. To do so it takes power from the powertrain to power auxiliaries like infotainment and cabin air conditioning.

  - Display information to the driver like current driving vehicle states, show diagnostic information (warnings and critical faults).
  - Tachograph mainly for velocity indication and as a storage platform for driving data.
  - Thermal system to set required cabin temperature (heating and cooling).

- Vehicle ***distributed*** systems describe all systems, which cannot be allocated to one of the other systems. In this case the Distributed systems get electrical charging from the outside. The distributed systems also provide cooling to the powertrain.

- The ***vehicle control unit*** manages all relevant vehicle requests to control the electrical drivetrain to achieve required driving performance.

- ***Advanced management system*** is used to control the interaction to a cloud server system for exchanging vehicle data bi-directional in real time. Due to bi-directional data transfer a firewall system on both sides shall be installed for cyber securities to defend hackers entries. The advanced management system converts cloud structuring data to a readable vehicle information requirement.

Reuse Parts for Prototype Vehicle

The OEM has already developed a baseline vehicle and they intent an upgrade to the baseline vehicle to the next generation of NextETRUCK. The main component architecture shows reusable, to modify / new components.

- New system element added means that totally new requirements are necessary to create.
- Updated system elements mean update existing requirement.

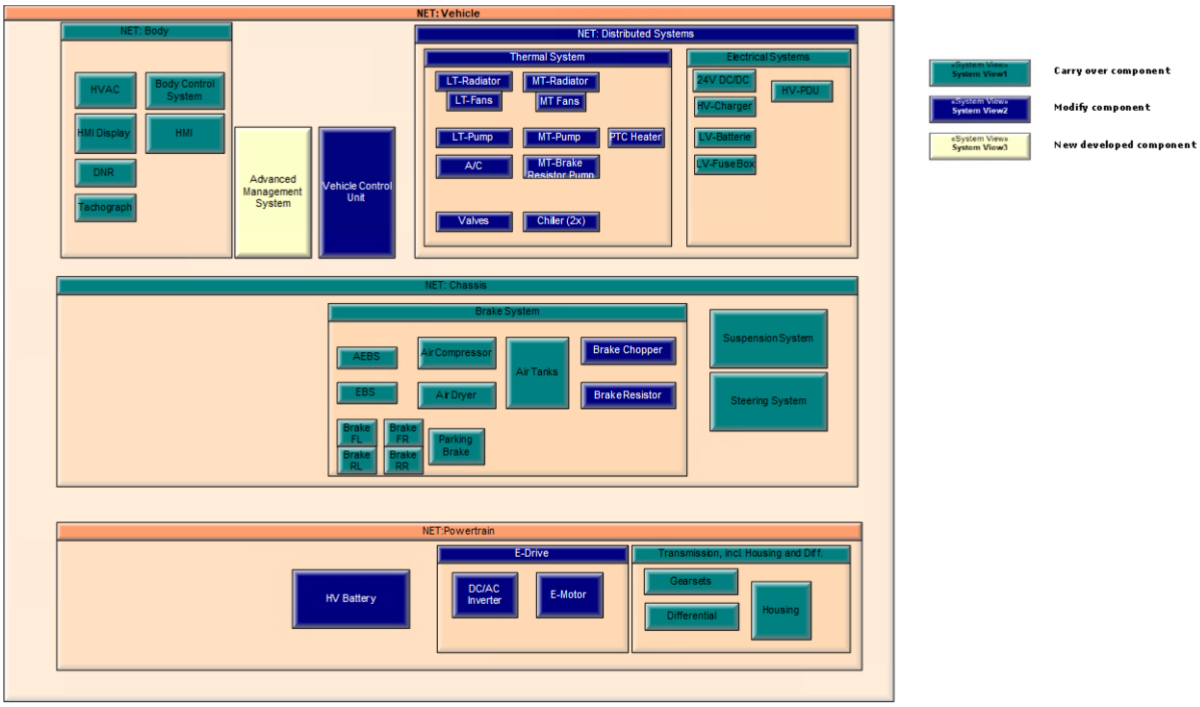

Figure 16 Reuse Vehicle System Parts

Vehicle Systems & Interfaces

The vehicle system is responsible for proper control of the generated torque from the E-drive to the wheels through the mechanical transmission based on automatic shift strategies. Depending on the present driving scenario, the actual driver's request and finally the actual fault(s), various safe states are conceivable (with different degradations of the vehicle system operation if required).

Powertrain Element

Powertrain Mechanical System

Specification: 6196562

The mechanical part of the drive train comprises of a central drive mounted at a transmission and a flanges rear axle. And the HV battery as energy storage element for the drive-train and auxiliary consumers is also included as a part of the powertrain.

The drive strategies also depend on the driver demand (driving direction, torque demand) from HMI or information received from external elements.

Specification: 6262439

The main performance properties of the e-drive system are given as:

Category	Property / Parameter	Unit	Value 1	Note
Lifecycle	Calendric Life	Years	TBD	
Performance	Max. Torque Motor/Generator in Boost	Nm	TBD	
	Peak Power Motor/Generator	kW	TBD	Limited by Inverter Software
	Continuous Power Motor/Generator	kW	TBD	
	Max. Speed Motor/Generator	rpm	TBD	
	Wheel Power @4%	kW	TBD	
	Wheel Speed @80 km/h	rpm	TBD	
	Wheel Power @7%	kW	TBD	
	Wheel Speed @30 km/h	rpm	TBD	
	Wheel Power @4.2%	kW	TBD	
	Wheel Speed @50 km/h	rpm	TBD	
	Speed Reverse Driving	rpm	-TBD	

Table 14 Main Performance Properties of the e-drive system

Specification: 6196337

(Ford Otosan): Traction Force Diagram based on defined requirements:

- E-motor peak power defined by requirement of 80 km/h @ 4% inclination
- Gear 1 ratio defined by driveaway at 30% inclination
- Gear 4 defined by max. vehicle velocity of 110 km/h and an e-motor max. speed of 9000 rpm (assumed by AVL)
- Gear 2 and gear 3 defined based on geometrical gear steps

Basic Data:

Vehicle parameter	Unit	Value
Vehicle application	-	Sensible information available
Vehicle weight	to	Sensible information available
Axle configuration	-	Sensible information available
Tire dimensions	-	Sensible information available
Tire radius	mm	Sensible information available
Frontal area (A)	m2	Sensible information available
Drag coefficient (Cw)	-	Sensible information available
Cross section (CwA)	m2	Sensible information available
Rolling resistance coefficient	%	Sensible information available

Table 15 Basic Vehicle Data

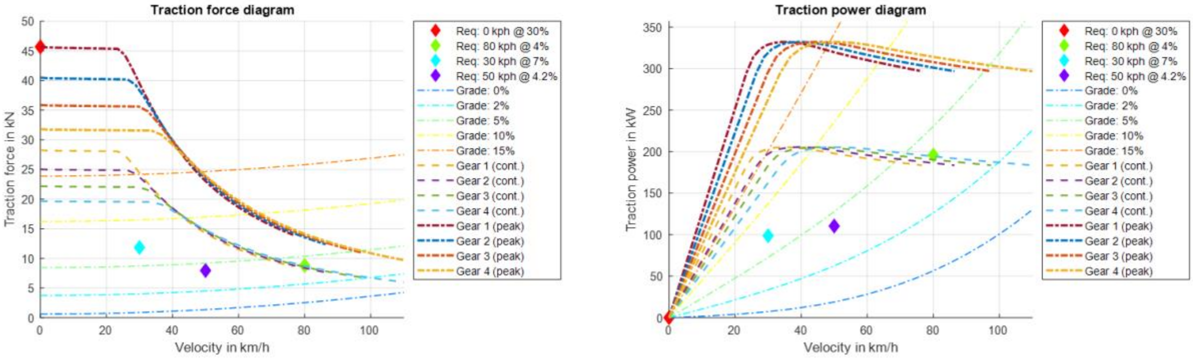

Figure 17 Traction Force Diagram

Assumed E-drive performance by AVL

Generic data	Unit	Value
EM cont. torque	Nm	665
EM cont. power	kW	214
EM peak torque	Nm	1 074
EM peak power (30 sec)	kW	346
EM max. speed	rpm	9000
Transmission efficiency	%	96

Table 16 Assumed E-drive Performance Data

Assumed E-drive performance by AVL

TM	Ratio
Gear 1	19.24
Gear 2	17.05
Gear 3	15.11
Gear 4	13.39

Table 17 Gear Ratios

Specification: 6196340

(TEVVA):Traction Force Diagram based on defined requirements:

- E-motor cont. power defined by requirement of 96 km/h @ 4% inclination
- Gear ratio defined by max. vehicle velocity of 96 km/h and an e-motor max. speed of 9000 rpm
- Selected gear ratio and assumed generic e-motor results in cont. traction force that fulfills driveaway at 25%

Basic Data:

Vehicle parameter	Unit	Value
Vehicle application	-	Heavy duty
Vehicle weight	to	8
Axle configuration	-	4x2
Tire dimensions	-	285/70R 19.5*
Tire radius	mm	434
Frontal area (A)	m2	10**
Drag coefficient (Cw)	-	0.5
Cross section (CwA)	m2	5
Rolling resistance coefficient	%	0.9

Table 18 Basic Vehicle Data

* Smaller tire option was used – other tire would change the resulting gear ratio

** Missing dates assumed by AVL

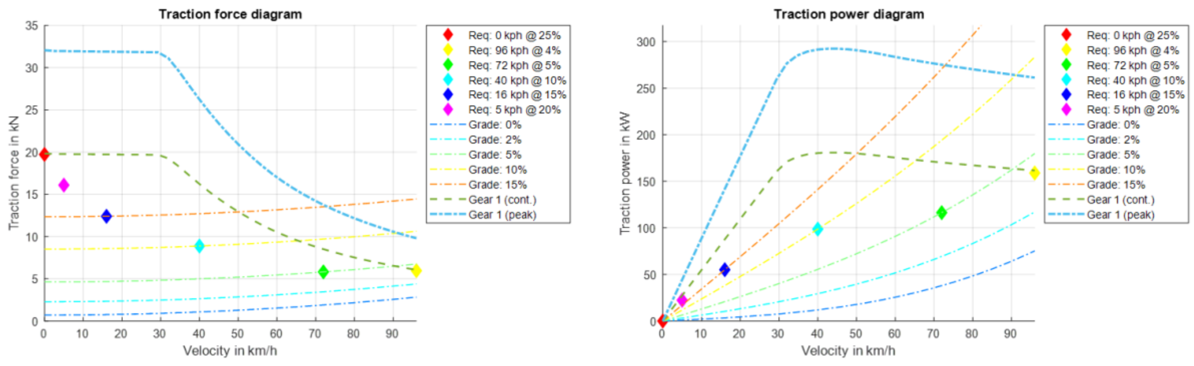

Figure 18 Traction Force Diagram

Assumed E-drive performance by AVL

Generic data	**Unit**	**Value**
EM cont. torque	Nm	585
EM cont. power	kW	188
EM peak torque	Nm	945
EM peak power (30 sec)	kW	305
EM max. speed	rpm	9000
Transmission efficiency	%	96

Table 19 E-Drive Performance

TM	**Ratio**
Gear 1	15.34

Table 20 Transmission Ratio

Powertrain Cooling System

The thermal components are part of the thermal system that's currently in the design phase, including architecture diagrams.

- HV battery
- E-drive

Specification: 6196308

The main properties of the cooling system are:

Specification	Value	Unit
Volume Flow	TBD	l/min
Inlet Temperature (@ Inverter)	TBD	°C
Inlet Temperature @400 kW Power (Inverter Outlet to Heat Exchanger)	TBD	°C
Inlet Temperature @480 kW Power (Inverter Outlet to Heat Exchanger)	TBD	°C
Outlet Temperature @400 kW Power (Inverter Outlet to Heat Exchanger)	TBD	°C
Outlet Temperature @480 kW Power (Inverter Outlet to Heat Exchanger)	TBD	°C
Pressure Drop from Inverter inlets to Heat Exchanger @50 l/min (2 Inverters in Parallel)	TBD	kPa
Coolant	Water / Glycol: 50/50	

Table 21 Main Properties of the Cooling System

Specification: 6196311

When driving in different driving conditions, the cooling system needs to cool down the following values:

- Max. Power for 3 Minutes: TBD kW
- Max. Power for 15 Minutes: TBD kW
- Max. Power for 25 Minutes: TBD kW

Powertrain E/E System

The E/E components are part of the HV / LV system that's currently in the design phase, including architecture diagrams.

- HV battery
- E-drive

Specification: 6196509

The main properties of the E/E System are:

Category	Property / Parameter	Unit	Value 1	Note
Voltage	Nominal Voltage	V	TBD	
	Minimum Voltage	V	TBD	
	Maximum Voltage	V	TBD	
Current	Maximum DC Current	A	TBD	
	Maximum Phase Current	A	TBD	

Table 22 Main Properties of the E/E System

Chassis

Tires and Wheels

Specification: 6196575

The vehicle is equipped with tires of the size R19.5

Static tire radius is assumed as TBD mm

Dynamic tire radius is assumed as TBDmm±2%

Tire width is assumed to be TBD mm

Specification: 6196424

The vehicle is equipped with twin tires at the rear

Specification: 6196390

Total weight of all 2 rear wheels and tires is considered as {{MTire}}kg.

Brakes

Specification: 6196560

The vehicle is equipped with disc brakes with integrated parking brake at the rear axle.

The service brake is pneumatically actuated.

The parking brake is integrated into the actuation cylinder.

Specification: 6196332

The vehicle is equipped with recuperative braking via the electric drive.

Specification: 6196325

To dissipate energy the vehicle is equipped with a system to convert electrical energy into heat. This system consists of a brake chopper and a set of brake resistors activated by the chopper.

Brake System Components

OEMs are obliged not to disclose sensitive data from their suppliers to third parties. For this reason, no component-specific data or interaction processes with other sub systems are known, also includes architecture diagrams.

- Air Compressor (carry over part)
- Brake chopper / Resistor

Steering System

Steering System Components

OEMs are obliged not to disclose sensitive data from their suppliers to third parties. For this reason, no component-specific data or interaction processes with other sub systems are known, also includes architecture diagrams.

- Steering pump (carry over part)

Body

OEMs are obliged not to disclose sensitive data from their suppliers to third parties. For this reason, no component-specific data or interaction processes with other sub systems are known, also includes architecture diagrams.

Distributed Systems

Thermal System

Most parts of the thermal system are currently in the design phase, also including architecture diagrams. If system architecture with detailed description of used component is available, the specification document should be updated.

Specification: 6196437

The thermal system consists out of 3 main subsystems:

- HT (High temperature) circuit for cabin and HV battery heating

- HT (High temperature) circuit for cooling of E-drive and EE components

- LT (Low temperature) circuit for cooling of HV battery

- Refrigerant circuit for cooling of cabin and HV battery at hot conditions

HV System

Specification: 6196419

The vehicle has a high voltage system with a nominal voltage of TBD V

Minimum HV Voltage is TBD V (Derating)

Maximum HV Voltage is TBD V (Derating)

LV System

Communications System

The exchange of information between the components are describe in a generic communication architecture based on the AVL development process. Each subsystem element such as "powertrain", "body", "chassis", "distributed system" is individually connected to the vehicle control unit via a communication bus system. Different colors are defined to make it easier to distinguish between the individual buses.

Specification: 6196346

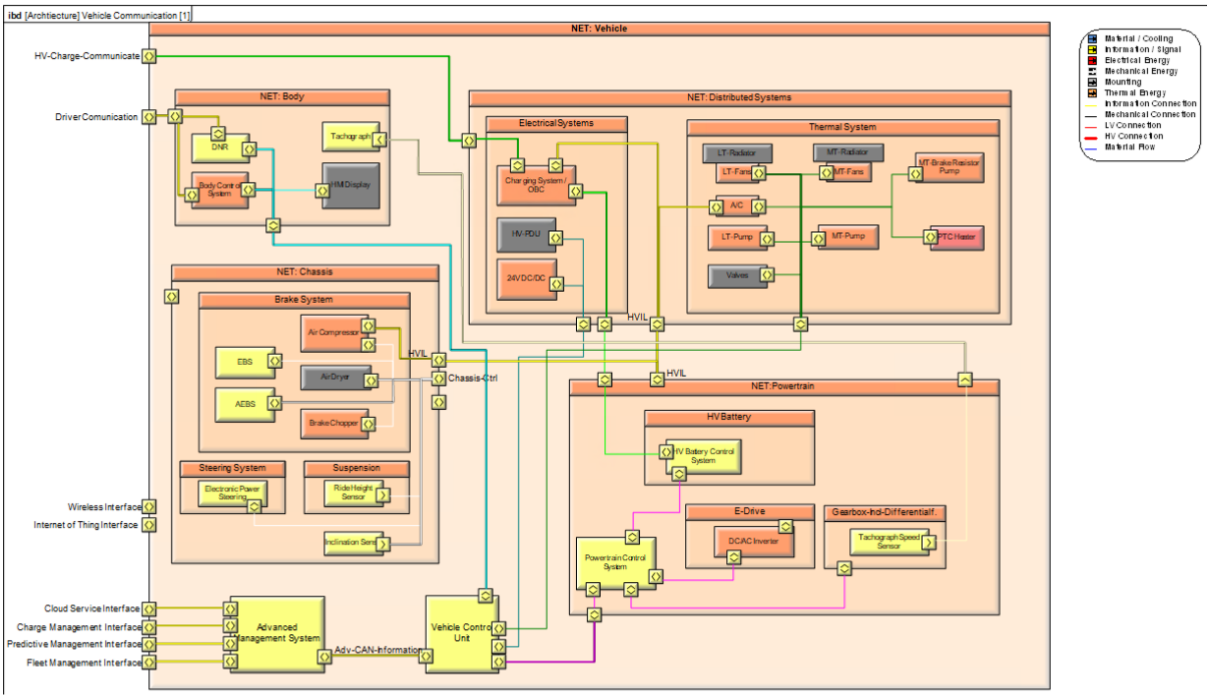

Figure 19 Overall Vehicle System Communication

Vehicle Features

The main focus is on increasing the efficiency, which primarily affects the drivetrain including the consumers. That leads to a pre-study work for basic driving features.

Vehicle State and Transitions

Normal Operation

Specification: 6263073

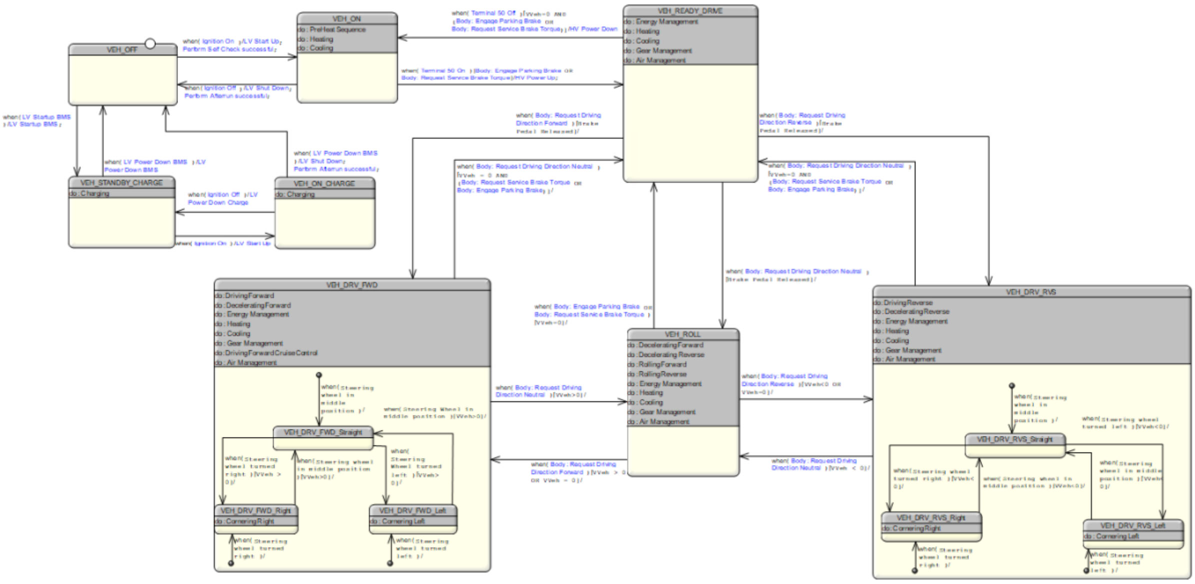

Figure 20 Vehicle State Machine

Specification: 6263077

The initial vehicle state is VEH_OFF (Vehicle off) This means that both, the LV System and the HV System of the vehicle are powered down.

When an external charger is connected to the vehicle, the vehicle state changes to "Standby Charge". (VEH_STANBY_CHARGE). To do so, all charging relevant LV components, especially the BMS and the internal charger have to be activated. Afterwards the HV-charging-loop between the internal charger and the battery has to be activated.

When now the ignition is turned on, the vehicle changes to the state "On, Charge" (VEH_ON_CHARGE). During the state transition the LV System is fully activated including the LV System of the Powertrain. Self checks and the use of the Infotainment system is possible in this state. If a driver tries to activate Terminal 50 (KL50) in this state, a warning shall be displayed to the driver to remove the charger, and the Powertrain HV-System shall remain powered down.

When the external charger is disconnected in this state, the vehicle state changes to "on" (VEH_ON). During the transition the HV charging loop is powered down, the charger is also powered down. This state can also be reached directly from VEH_OFF by turning on the ignition.

When Terminal 50 (KL50) is activated and at least one braking system (Parking brake or service brake) is engaged, the vehicle changes to the state "Ready to drive" (VEH_READY_DRIVE). During the state transition the HV System between the battery and the powertrain is fully activated. Changing back to. VEH_ON is possible by deactivating Terminal 15, only if the vehicle speed is verified to be 0km/h and again at least one braking system is activated.

By turning the Driving direction selector to "D" and releasing the brakes, the vehicle changes into the state VEH_DRV_FWD. This state is further described in specification item 3466907. Changing back to state VEH_READY_DRIVE requires the driver to select "N" on the driving direction selector. The state transition only occurs, if the vehicle velocity is 0 and at least one brake system is activated.

By turning the Driving direction selector to "R" and releasing the brakes, the vehicle changes into the state VEH_DRV_RVS. This state is further described in specification item 3466898. Changing back to state VEH_READY_DRIVE requires the driver to select "N" on the driving direction selector. The state transition only occurs, if the vehicle velocity is 0 and at least one brake system is activated.

If "N" is selected but no brake is engaged, the vehicle changes from each of the driving states as well as the "Ready drive" state into the rolling state (VEH_ROLL). A change from this state back into a driving state requires the selection of a driving direction which is identical to the current rolling direction. If the "wrong" driving direction is engaged, the vehicle displays a warning and torque requests in the wrong direction are not followed. If the brakes are engaged in this state and the vehicle reaches velocity 0 km/h state changes to "Ready Drive"

Specification: 6263079

In the state VEH_DRV_FWD, the vehicle is able to perform certain activities depending on the driver input.
- If the Driver presses the accelerator pedal, the vehicle performs the "Driving forward" activity, explained in specification item TBD.
- If the Driver presses the brake pedal while the speed is more than 0 km/h, the vehicle performs the activity "Decelerating forward, described in specification item TBD until the vehicle velocity is ~0km/h Depending on the steering wheel input, all of these activities can be combined with other activities:
- If the steering wheel is in the middle position, the vehicle will drive straight ahead. in the vehicle state VEH_DRV_FWD_Straight
- If the steering wheel is turned right, the driving activities will be combined with the activity "Cornering Right" in the vehicle state VEH_DRV_FWD_Right
- If the steering wheel is turned left, the driving activities will be combined with the activity "Cornering Left" in the vehicle state VEH_DRV_FWD_Left

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Specification: 6263083

In the state VEH_DRV_RVS, the vehicle is able to perform certain activities depending on the driver input.
- If the Driver presses the accelerator pedal, the vehicle performs the "Driving reverse" activity, explained in specification item TBD.
- If the Driver presses the brake pedal while the speed is less than -0.5 km/h, the vehicle performs the activity "Decelerating reverse", until the vehicle velocity is 0 kphkm/h. Depending on the steering wheel input, all of these activities can be combined with other activities:
- If the steering wheel is in the middle position, the vehicle will drive straight back in the vehicle state VEH_DRV_RVS_Straight
- If the steering wheel is turned right, the driving activities will be combined with the activity "Cornering Right" in the vehicle state VEH_DRV_RVS_Right
- If the steering wheel is turned left, the driving activities will be combined with the activity "Cornering Left" in the vehicle state VEH_DRV_RVS_Left

---

Vehicle Startup

Specification: 6271984

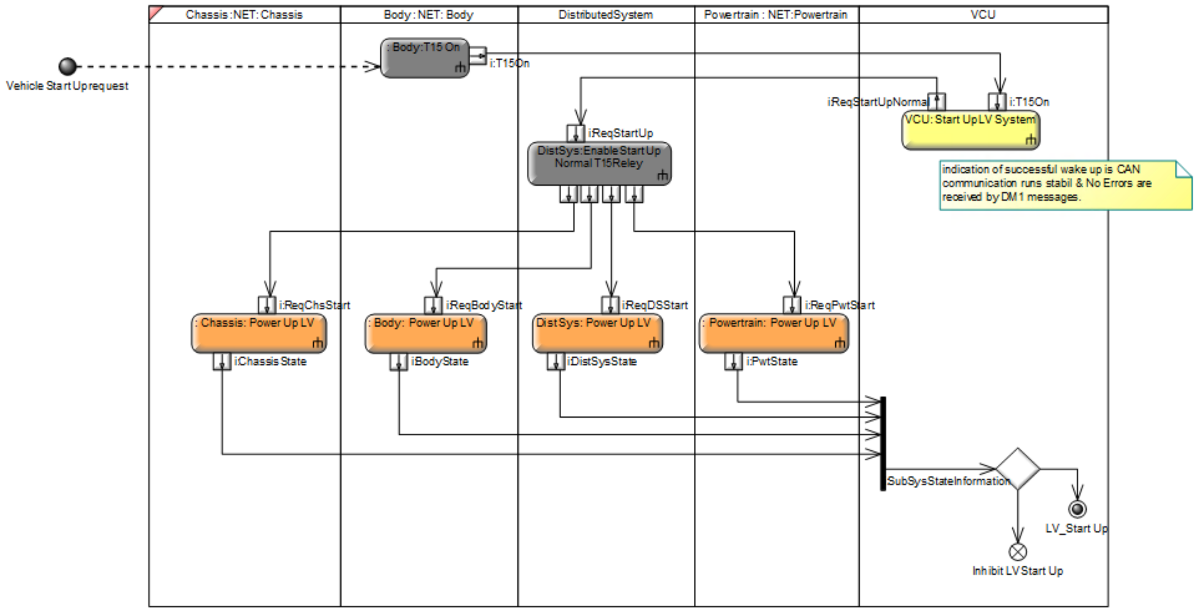

Figure 21 Vehicle Startup

Specification: 6271982

A LV Start Up is initiated when the driver turns the key into position 1 which activates the function "T15 On" in the Body. This "T15 On" function sends a signal to the VCU which executing the LV start up function. After successful boot up the VCU sends several Start-Up requests to all high level systems via Start Up relay like:

- Body
- Chassis
- Powertrain
- Distributed Systems
- VCU

After successful LV startup of each single system, each single system will send CAN message within a certain time slot back to the VCU. The VCU observe the CAN traffic which are indicating a successful startup of each single system. If no HV relevant error state are occur, then the LV system is successfully started up and the VCU sends the terminal 15 signal via CAN bus to all LV control system consumers and after the VCU trigger the state VEH_ON.

HV Power Up

Specification: 6271996

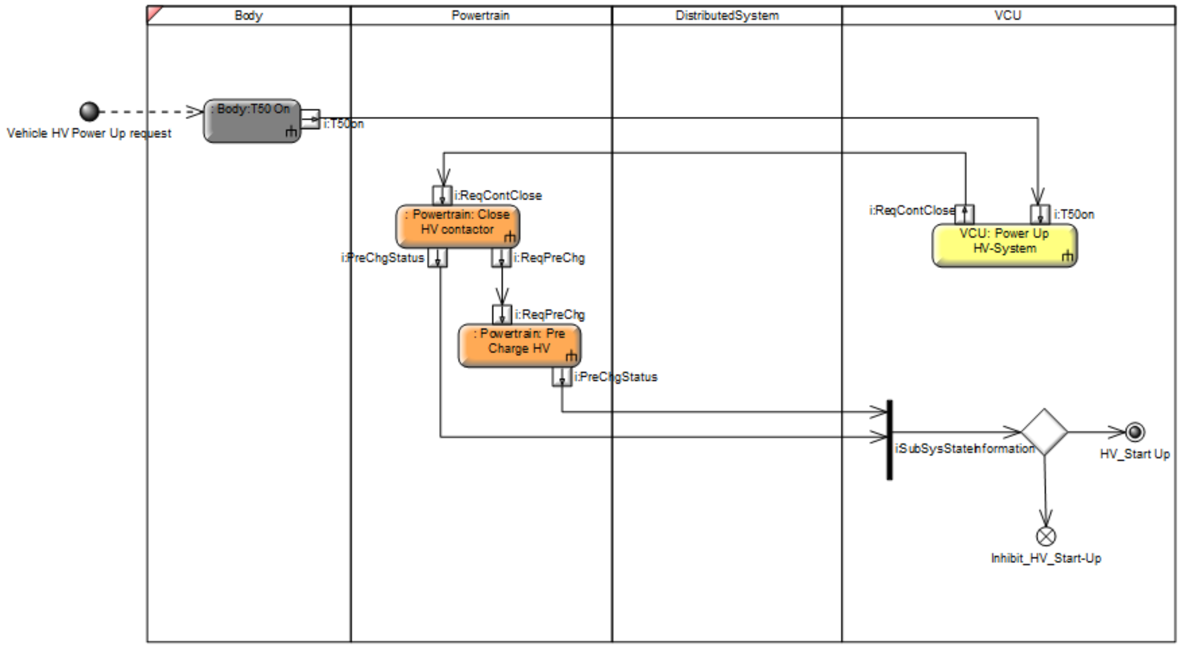

Figure 22 HV Power-up

Specification: 6271994

Terminal 50 is initiated if tow preconditions are fulfilled:

1. The terminal 50 on (press Start button) is operated which is precondition to enter the State "VEH_READY" (See transition diagram in specification item 6263073).

2. The brake pedal is pressed over the calibratable detection threshold or the parking brake is engaged.

HV start up is initiated when the driver turns the key into position 2 which activates the function "T50 On" in the body. This function send a signal to the VCU in order to send a request to the HV battery system to close the contactors. After finishing of pre charging the HV battery system sends the battery status back to the VCU which allows to entry in the state "VEH_READY".

HV Power Down

Specification: 6272043

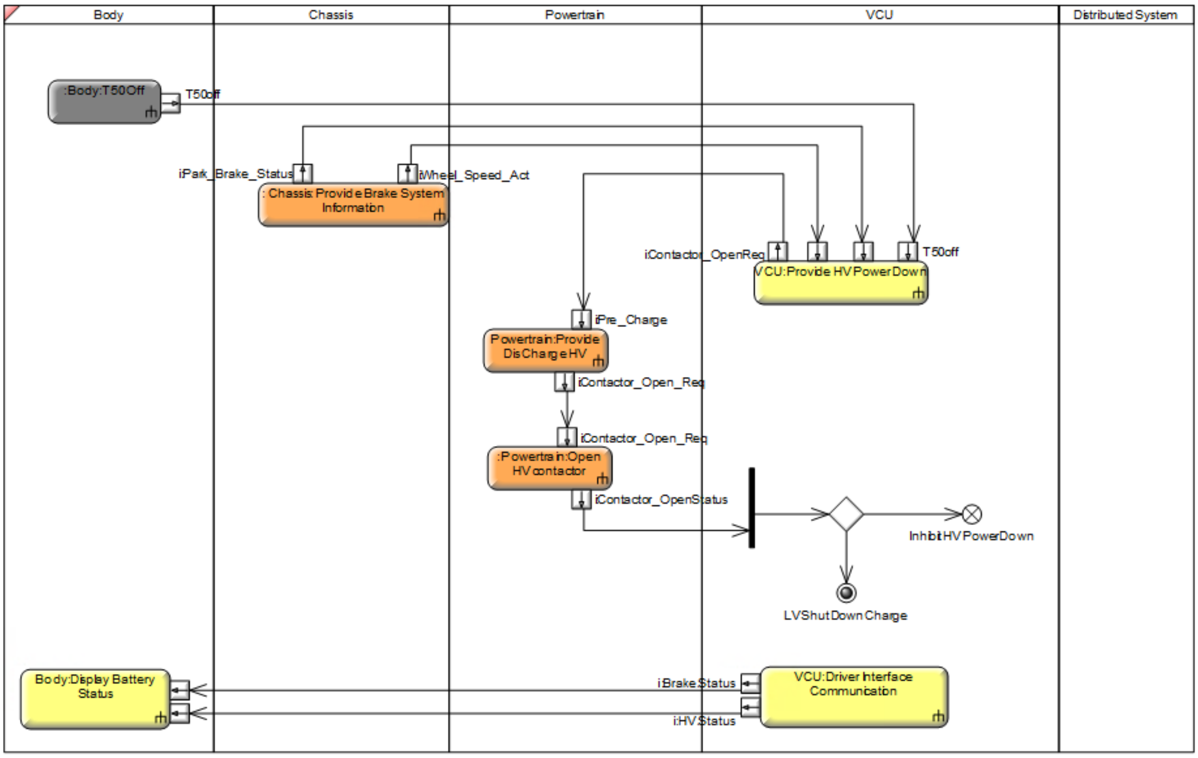

Figure 23 HV Power-down

Specification: 6272045

The vehicle power down is executed in standstill with initiated terminal 50 if three conditions are fulfilled:

1. Terminal 50 is Off (repress the start button) which is precondition to enter the state VEH_ON (See transition diagram in specification item 6263073).

2. The driving direction neutral (Selector in "N") is selected.

3. Parking brake is engaged.

The park brake status "engaged" and the vehicle velocity equal "0 km/h" both send signals to the VCU where the determination of the HV power down together with the terminal 50 deactivation finds place. VCU is responsible to send a signal which requests zero power for the HV consumers. The VCU observes the actual HV power. if the actual HV power is below a tolerance band then the VCU sends a signal for opening contactor to the HV battery system. After receiving contactor opening status from the HV battery system then the vehicle entry to state VEH_ON. Then the VCU is ready for initiating LV shutdown when terminal 15 Off is received.
The vehicle status of brake and HV send signals to a communication interface where the status is visualized.

LV Shut Down

Specification: 6278008

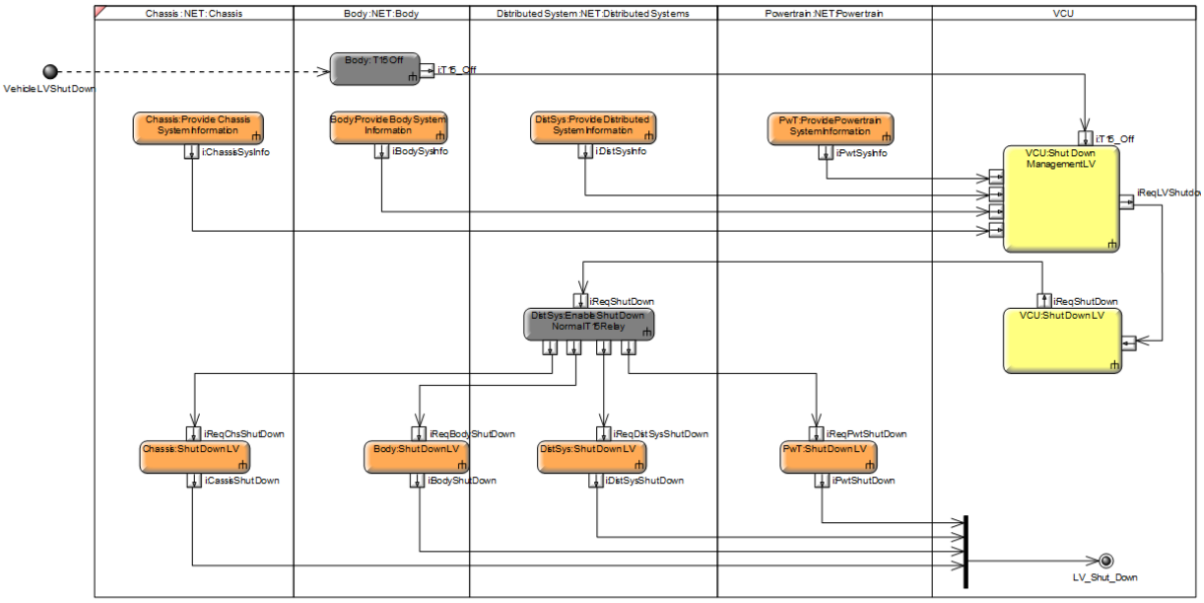

Figure 24 LV Shut-down

Specification: 6278010

The vehicle shut down is executed in standstill with initiated terminal 15 if three conditions are fulfilled:

1. Terminal 15 is Off (HMI to trigger Terminal 15 is not defined, yet) which is precondition to enter the state VEH_OFF (See transition diagram in specification item 6263073).

2. The driving direction neutral (Selector in "N") is selected.

3. Parking brake is engaged.

LV Shutdown is initiated when the driver turns the key into position 0 which activates the function "T15:Off" in the Body. This function sends a request to the VCU which activates the function "Trigger After run Sequence". This function sends an after run request to the Powertrain, Distributed Systems, Chassis and the Body. After these after run functions are finished the Systems send back this information to the VCU which then requests the function "Shut Down LV". This function then sends a request to trigger the Shutdown function for every single system.

Drive Forward

Specification: 6274854

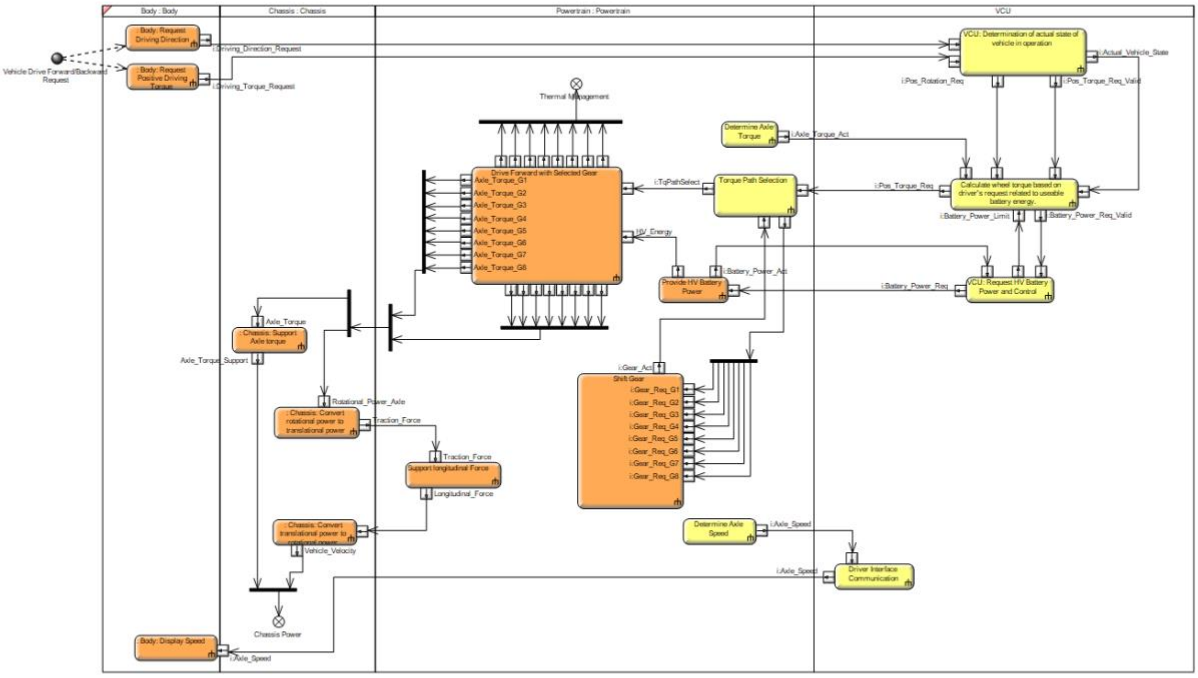

Figure 25 Drive Forward

Specification: 6274766

Driving forward is initiated if two preconditions are fulfilled:
1. The driving direction forward (Selector in "D") is selected, which is precondition to enter the state "VEH_DRV_FWD" (See transition diagram in specification item 6263073)
2. The accelerator pedal is pressed over the calibratable detection threshold

From the driving direction selection a signal for the requested driving direction is created and sent to the VCU. The accelerator pedal position is sent to the VCU and translated to a torque request via a calibratable map. After a function to determine the actual state of the vehicle in operation, which also sends a rotation direction request to the Powertrain, the VCU enters the feature "Calculate wheel torque". Outputs of this function is a torque direction request to the Powertrain and an energy request within the VCU. Using high voltage energy provided from a battery and a torque request from the feature "Torque Path Selection", the powertrain enters the features "Drive Forward with Selected Gear". Outputs of this features are a torque, which is transferred to the wheels and also supported by the suspension system, a rotational speed.

In the chassis the wheels convert the rotational input power into a translational power (vehicle velocity and longitudinal force). This force is once again supported by the powertrain and transferred onto the vehicle, which is then propelled forward.

The rotational speed of the "Drive Forward Gear N", "Drive Forward Gear 1" and "Drive Forward Gear 2" functions are converted into an output speed signal by the "Drive interface - Communication" feature and sent to the "Display speed" feature, which provides feedback to the driver.

In parallel, the uneven road conditions are an input into the powertrain. This triggers the "support vertical force" feature, where the road input is translated into vertical movement and vertical force. The chassis has to be able to accept this force, and allow the vertical movement to protect load and driver, while dampening the movement to make sure the vertical movement does not increase too much.

Drive Reverse

Specification: 6275652

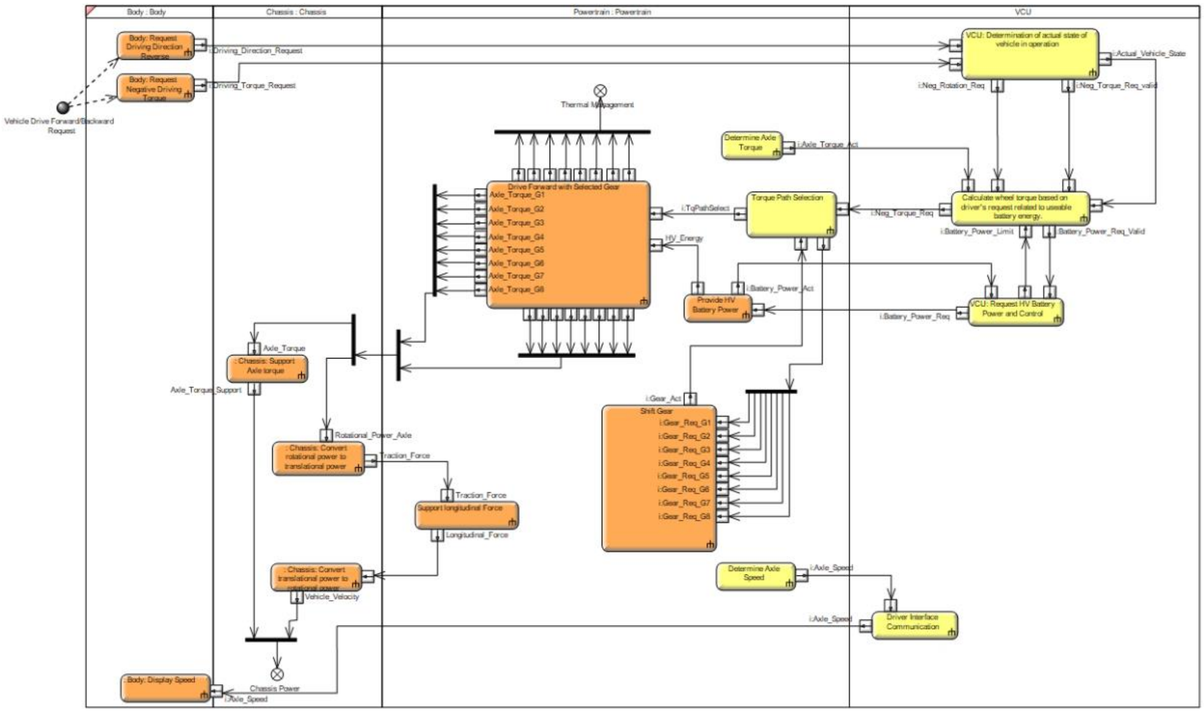

Figure 26 Drive Reverse

Specification: 6275627

Driving reverse is initiated if two preconditions are fulfilled:
1. The driving direction reverse (Selector in "R") is selected, which is precondition to enter the state "VEH_DRV_RVS" (See transition diagram in specification item 6263073)
2. The accelerator pedal is pressed over the calibratable detection threshold.

The feature "Drive reverse" use an equivalent function flow as the feature "Drive forward" however the wheels rotate in the counter direction and also the axle torque. The following other feature works in the same way as "Drive forward".

Decelerating Forward

Specification: 6275789

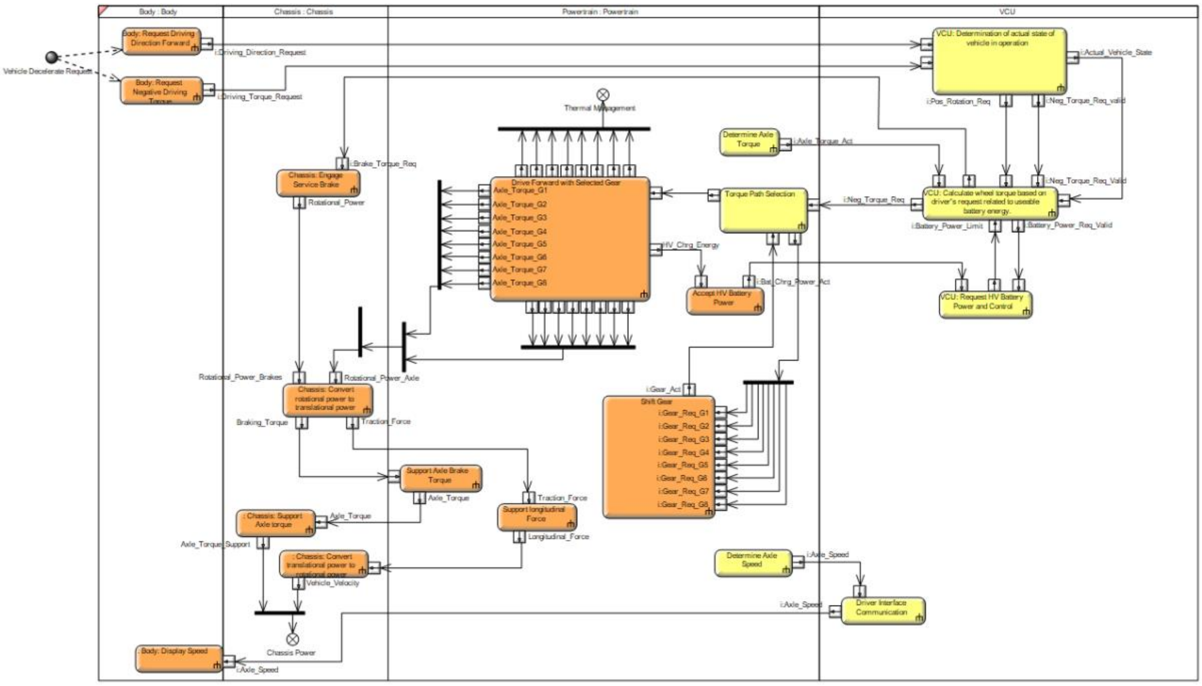

Figure 27 Decelerating Forward

Specification: 6275873

Decelerating forward is initiated if two preconditions are fulfilled:
1. The driving direction forward (Selector in "D") is selected, which is pre-condition to enter the state "VEH_DRV_FWD" (See transition diagram in specification item 6263073)
2. The brake pedal is pressed over the calibratable detection threshold

After a function in the VCU to determine the actual state of the vehicle in operation, which also sends a rotation direction request to the powertrain, the VCU enters the feature "Determination of Drive Torque Request". Outputs of this function is a torque direction request to the Powertrain and a braking energy request within the VCU. The VCU then determines an electrical recuperation power split between the HV Battery and the braking resistors provided by "Calculation Wheel Torque on Drivers Request". With the HV-Battery and/or Brake Resistors allowing high voltage energy, the powertrain enters the powertrain features "Drive Forward with Selected Gear", Outputs of these features are a recuperative torque, which is transferred from the wheels and also supported by the suspension system, a rotational speed and, as a waste product, thermal energy.

In the chassis the wheels convert the rotational input power into a translational power (vehicle velocity, longitudinal force and brake torque). This force is once again supported by the powertrain and transferred onto the vehicle, which is then slowing down.

The rotational speed of the "Drive Forward with Selected Gear" functions converted into an output speed signal by the "Drive interface - Communication" feature and sent to the "Display speed" feature, which provides feedback to the driver.

In parallel, the uneven road conditions are an input into the powertrain. This triggers the "support vertical force" feature, where the road input is translated into vertical movement and vertical force. The chassis has to be able to accept this force, and allow the vertical movement to protect load and driver, while dampening the movement to make sure the vertical movement does not increase too much.

Decelerating Reverse

Specification: 6277247

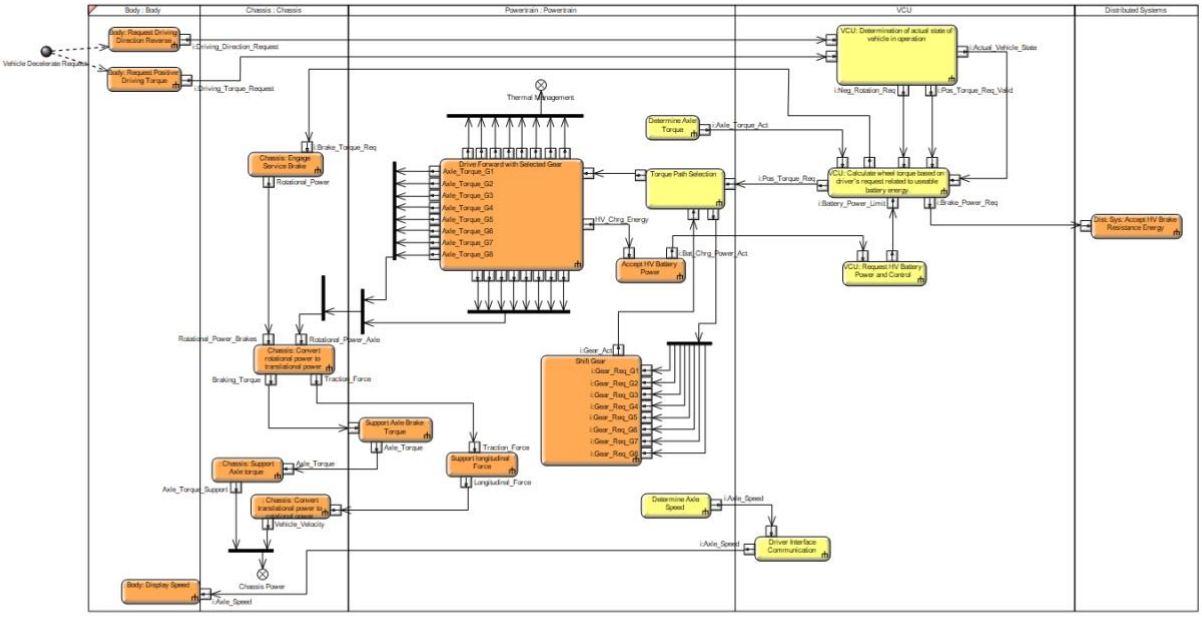

Figure 28 Decelerating Reverse

Specification: 6276802

Decelerating reverse is initiated if two preconditions are fulfilled:
1. The driving direction forward (Selector in "R") is selected, which is pre-condition to enter the state "VEH_DRV_RVS" (See transition diagram in specification item 6263073)
2. The brake pedal is pressed over the calibratable detection threshold

The feature "Drive reverse" use an equivalent function flow as the feature "Drive forward" however the wheels rotate in the counter direction and also the axle torque. The following other feature works in the same way as "Drive forward".

Turning Right

Specification: 6277338

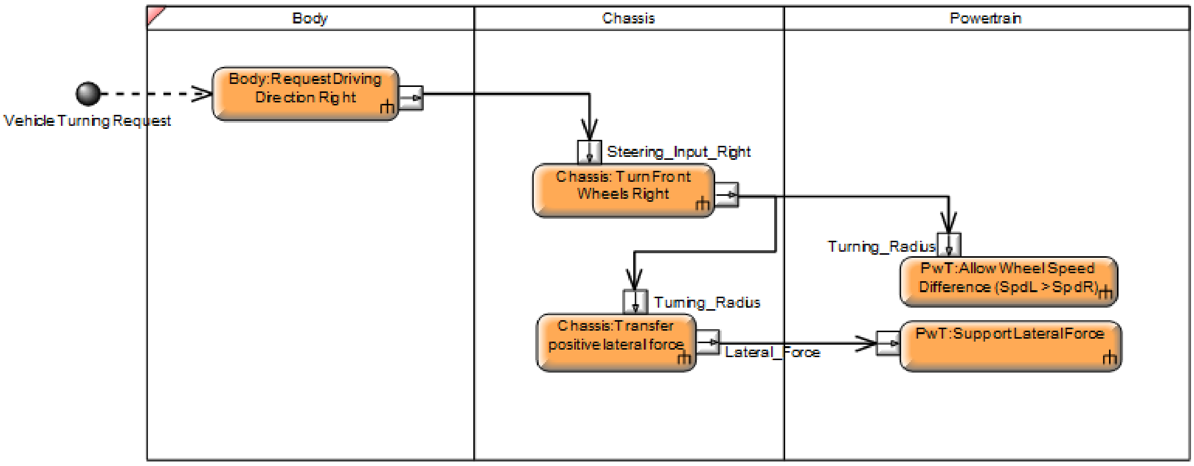

Figure 29 Turning Right

Specification: 6277340

1. The steering wheel is turned right by negative rotating direction, which is pre-condition to enter the state "VEH_DRV_FWD_Right" (See transition diagram in specification item 6263073)

2.The vehicle velocity > 0 km/h

Cornering right is initiated, by the driver turning the steering wheel right. This leads to the chassis turning the front wheels right. Assuming sufficient traction this pushes the vehicle into a turning radius. As the outer wheels have to run a bigger circle than the inner wheels, this leads to different wheel speeds also at the powertrain, which provides a function to allow this wheel speed difference.

The turning radius as well as the weight of the vehicle and the vehicle velocity create a lateral force on the chassis. This also has to be supported by the powertrain.

Turning Left

Specification: <u>6277346</u>

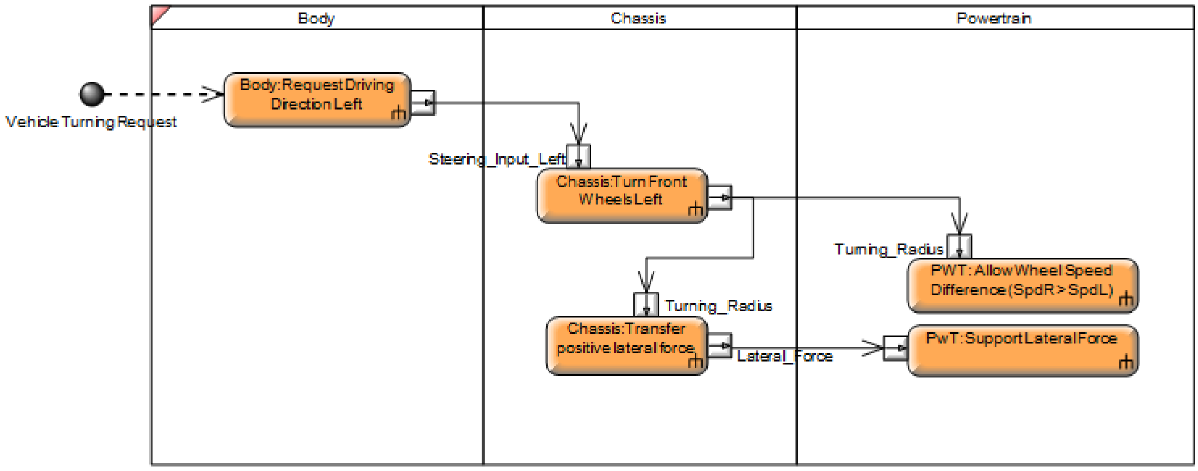

Figure 30 Turning Left

Specification: <u>6277344</u>

1. The steering wheel is turned left by positive rotating direction, which is pre-condition to enter the state "VEH_DRV_FWD_Left" (See transition diagram in specification item 6263073)

2.The vehicle velocity > 0 km/h

Cornering right is initiated, by the driver turning the steering wheel right. This leads to the chassis turning the front wheels left. Assuming sufficient traction this pushes the vehicle into a turning radius. As the outer wheels have to run a bigger circle than the inner wheels, this leads to different wheel speeds also at the powertrain, which provides a function to allow this wheel speed difference.

The turning radius as well as the weight of the vehicle and the vehicle velocity create a lateral force on the chassis. This also has to be supported by the powertrain.

Standstill Service Brake

Specification: 6280107

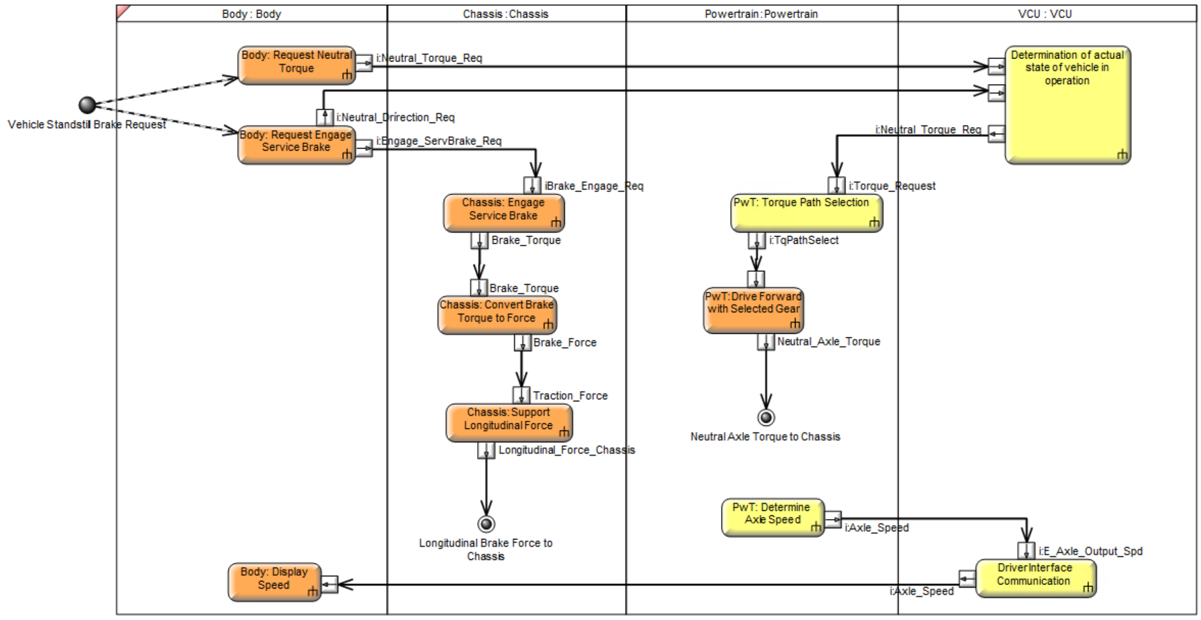

Figure 31 Standstill Service Brake

Specification: 6280109

Standstill with service brake engaged is initiated if two preconditions are fulfilled:
1. The driving direction neutral (Selector in "N") is selected, which is precondition to enter the state "VEH_READY_DRIVE" (See transition diagram in specification item 6263073)
2. The brake pedal is pressed

The driving direction "N" selection and the activation of the brake pedal both send a signal to VCU where a determination of the vehicle in operation finds place. After that a torque request of 0 Nm is sent to the Powertrain. As the vehicle is in the ready to drive state, although this is only used to keep the powertrain on stand-by. As the powertrain might still have increased temperature due to driving maneuvers before the standstill, also the thermal function is working.
In the chassis, the service brake creates brake torque, which is converted to a force. The torque as well as the force are dependent on the hill slope and the vehicle weight. The powertrain has to be able to support this force and transfer it to the chassis again.

Standstill Parking Brake

Specification: 6280125

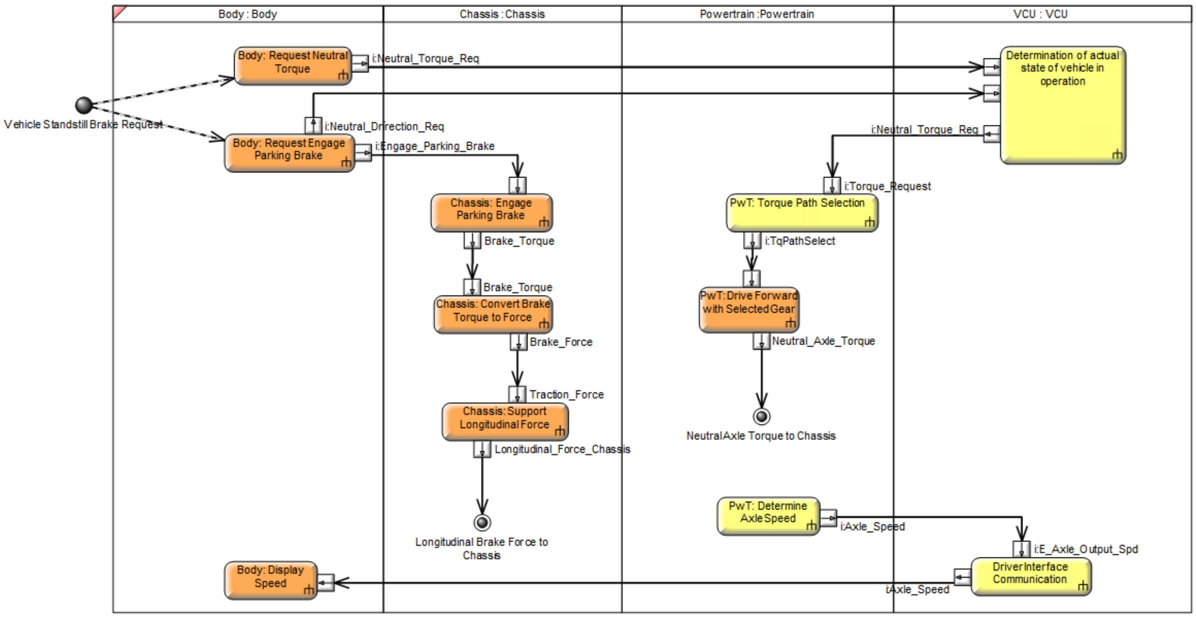

Figure 32 Standstill Parking Brake

Specification: 6280127

Standstill with parking brake engaged is initiated if two preconditions are fulfilled:
1. The driving direction neutral (Selector in "N") is selected, which is precondition to enter the state "VEH_READY_DRIVE" (See transition diagram in specification item 6263073)
2. The parking brake is active

The driving direction "N" selection and the activation of the parking brake both send a signal to VCU where a determination of the vehicle in operation finds place. After that a torque request of 0 Nm is sent to the Powertrain. As the vehicle is in the ready to drive state, although this is only used to keep the powertrain on stand-by. As the powertrain might still have increased temperature due to driving maneuvers before the standstill, also the thermal function is working.
In the chassis, the service brake creates brake torque, which is converted to a force. The torque as well as the force are dependent on the hill slope and the vehicle weight. The powertrain has to be able to support this force and transfer it to the chassis again.

Vehicle Connectivity Architecture

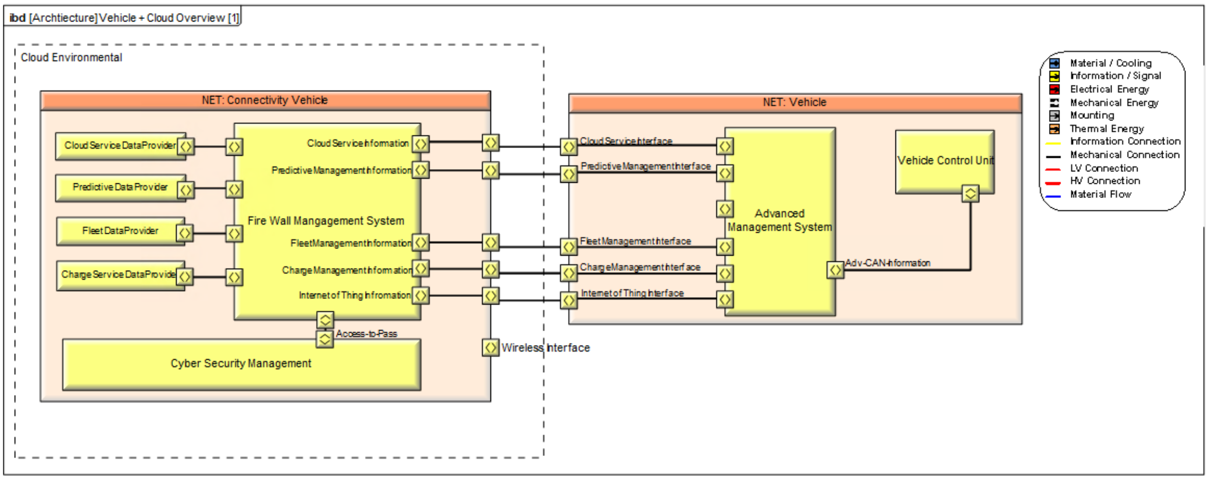

Figure 33 Vehicle Connectivity Architecture

9.4 Annex 4: NextETRUCK use case specification.

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PROJECT: DFE2189: NextETRUCK

REPORT: Use Cases Specification

Author	**Approved**	**Approved**
Gölzner Stefan		

Datum: 2/2/23 6:24 PM
Document State: Final

ANNEX 4 TABLE OF CONTENTS

Introduction

Disclaimer

The Use Cases in this document are used to build up a prototype vehicle for a distribution application within a medium weight class. The maturity level shall be at least A-Sample. The prototype vehicle is not suitable for Full vehicle or series development.

References

Number	Name	Date
[1]	WP2-Requirement-tables-v01.xlsx	12.12.2022
[2]	NextETRUCK-T2.1-UC-v05.docx	12.12.2022
[3]	NextETRUCK-T2.1-overview.docx	12.12.2022

Table 23 References Annex 4

Definitions & Abbreviations

State of Specifications:
All specifications in this document are classified with individual states. These states describe the maturity of the specifications. The following states with the individual meanings are valid and are taken into consideration:

IN WORK: Content of specification may change without notice. Specification is not to be taken into consideration for review/ realization by stakeholder/ supplier.
REVIEW: Specification under AVL internal review process. Specification is not to be taken into consideration for review/ realization by stakeholder/ supplier. Specification may be commented by stakeholder/ supplier.
EXTERNAL REVIEW: AVL internal review process completed. Specification is ready for review process with stakeholder/ supplier. Official feedback is expected from stakeholder/ supplier.
APPROVED: Specification is accepted by stakeholder/ supplier for realization. Specification shall not change without according notification/ change process.

In this document there will be used the following abbreviations:

TBD:	To Be Defined
GVM:	Gross Vehicle Mass
FA:	Frontal Axle
RA:	Rear Axle
HV:	High Voltage

Table 24 Abbreviations Annex 4

Diagram Explanation

Activity Diagram

Specification: 6176333

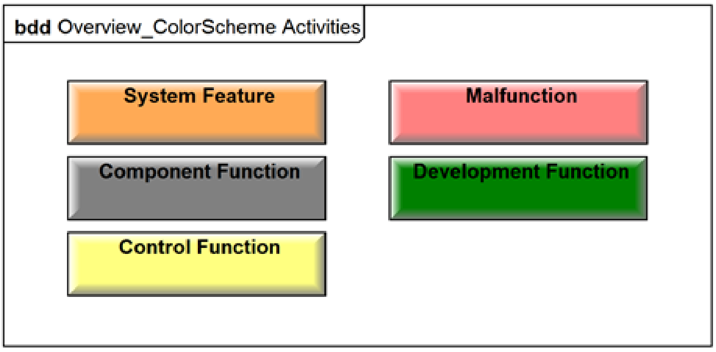

Figure 34 Activity Diagram

Specification: 6176341

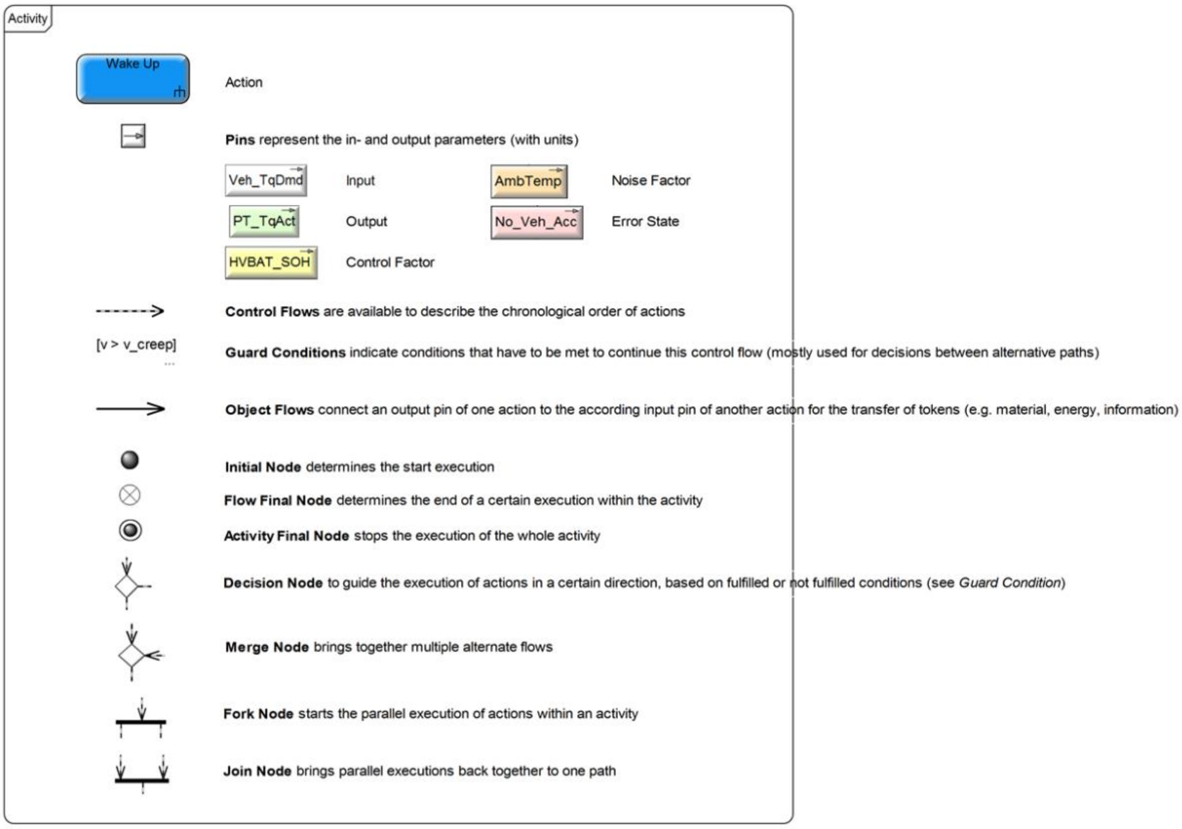

Figure 35 Activity Symbols

Use Case Diagram

Specification: 6176342

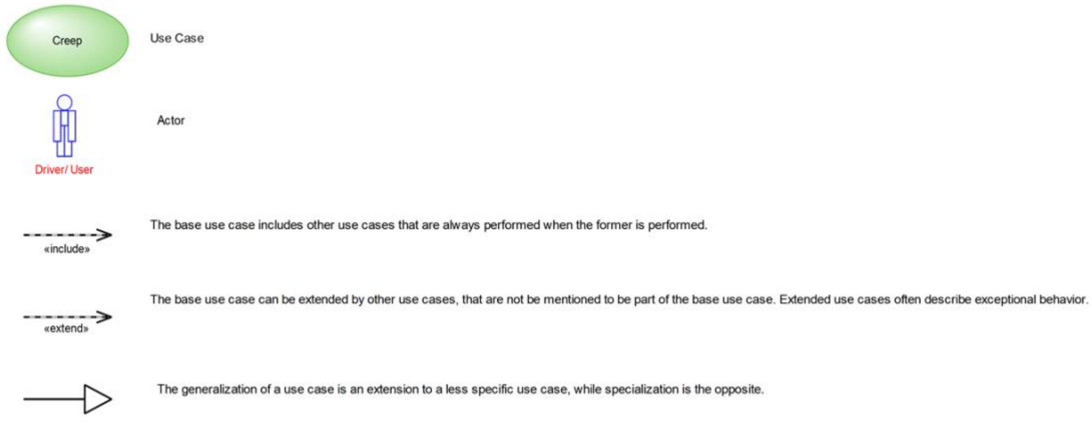

Figure 36 Use Case Diagram.

Use Cases

For the following use cases there are development targets defined. All use cases are covered with requirements and will subsequently be recognized in the course of the project:

Target Use Cases

Ford Otosan

Specification: 6177951

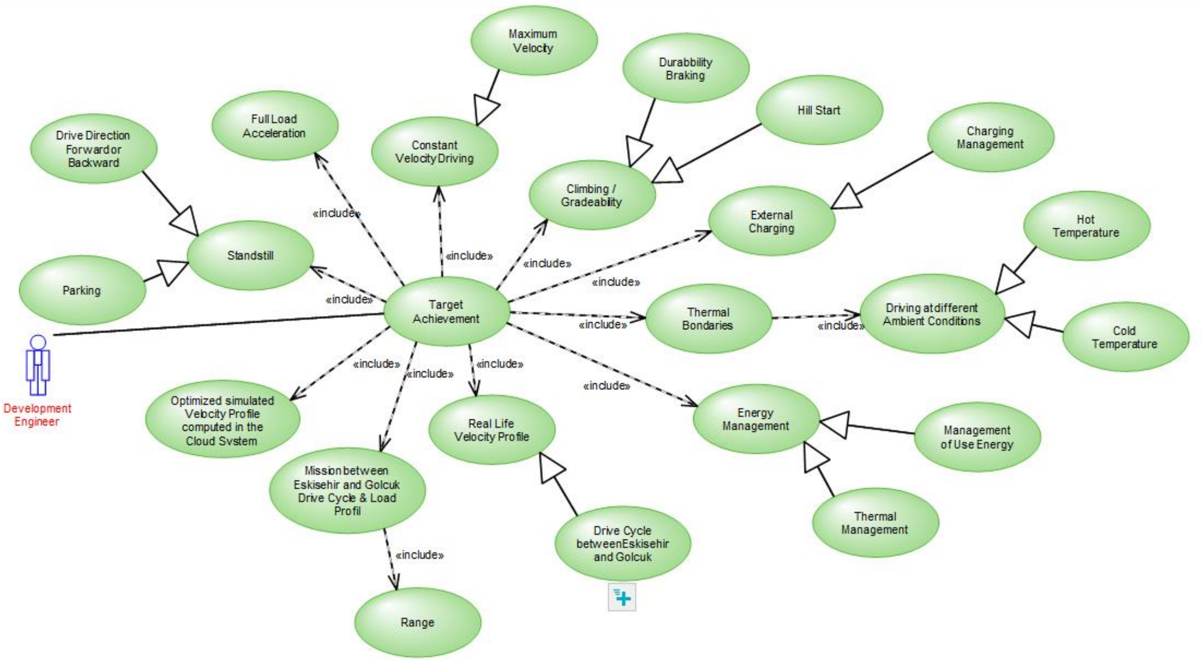

Figure 37 Target Achievement

Specification: 6178447

The Use Case "Standstill" describes the behavior of the vehicle at zero velocity. This includes the Use Case "Parking" and the Use Case "Drive Direction Forward or Backward".

Specification: 6178094

The Use Case "Full Load Acceleration" describes the behavior of the vehicle at max drive pedal. This is of importance for power dimensioning.

Specification: 6178058

The Use Case "Climbing/Gradeability" includes uphill and downhill driving for the vehicle including the use case "durability braking" and "hill start". This use case is used for power dimensioning for driving and recuperation.

Specification: 6178080

The Use Case "External Charging" describes the charging of the batteries from an external power source including the use case "Charging Management".

Specification: 6178082

The Use Case "Thermal boundaries" describes the driving behavior of the vehicle in extreme temperature scenarios. This is used to describe boundary conditions and vehicle power demands in the simulation.

Specification: 6178084

The Use Case "Energy Management" describes the active management of the different power sinks and sources in the vehicle to maximize range and/or comfort. This includes the thermal management as well as the management of the used energy

Specification: 6178515

The Use Case "Real Live Velocity Profile" describes the expected behavior of the vehicle speed in real service. This is used for dimensioning of recuperation power and battery size.

Specification: 6178520

The Use Case "Mission between Eskisehir and Golcuk Drive Cycle & Load Profile" is used to define the real world application of the vehicle. This also includes the range estimation.

IRIZAR

Specification: 6184706

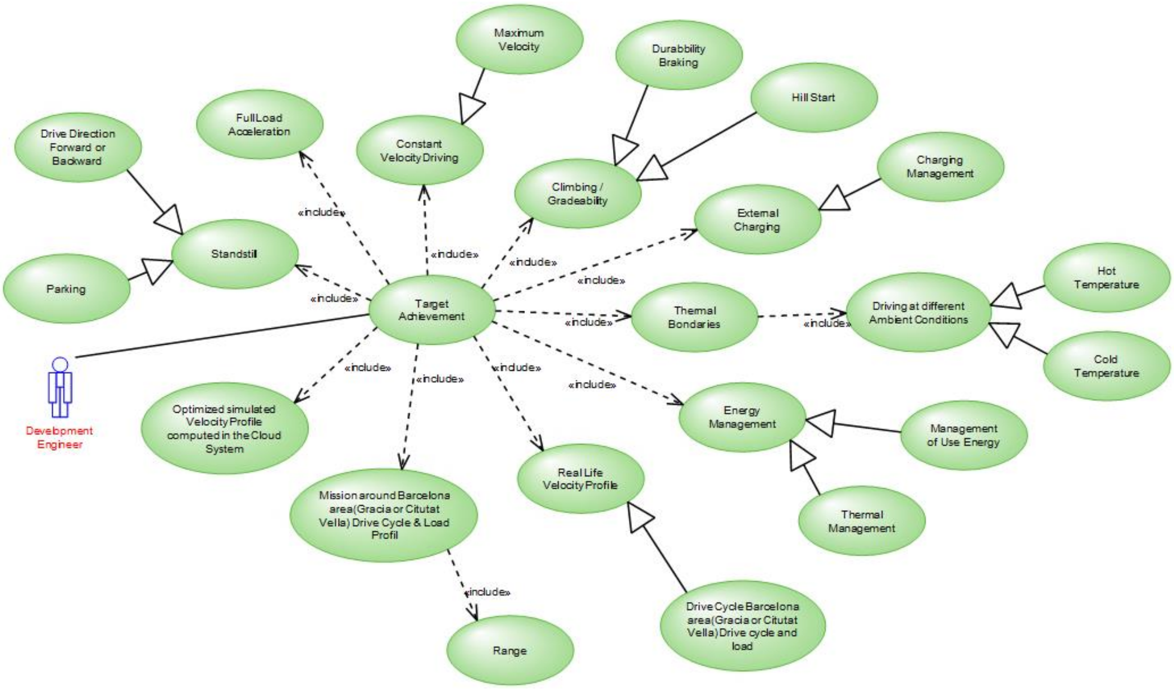

Figure 38 Target Achievement

Specification: 6184708

The Use Case "Standstill" describes the behavior of the vehicle at zero velocity. This includes the Use Case "Parking" and the Use Case "Drive Direction Forward or Backward".

Specification: 6184710

The Use Case "Full Load Acceleration" describes the behavior of the vehicle at max drive pedal. This is of importance for power dimensioning.

Specification: 6184712

The Use Case "Climbing/Gradeability" includes uphill and downhill driving for the vehicle including the use case "durability braking" and "hill start". This use case is used for power dimensioning for driving and recuperation.

Specification: 6184714

The Use Case "External Charging" describes the charging of the batteries from an external power source including the use case "Charging Management".

Specification: 6184716

The Use Case "Thermal boundaries" describes the driving behavior of the vehicle in extreme temperature scenarios. This is used to describe boundary conditions and vehicle power demands in the simulation.

Specification: 6184718

The Use Case "Energy Management" describes the active management of the different power sinks and sources in the vehicle to maximize range and/or comfort. This includes the thermal management as well as the management of the used energy

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Specification: 6184720

The Use Case "Real Live Velocity Profile" describes the expected behavior of the vehicle speed in real service. This is used for dimensioning of recuperation power and battery size.

Specification: 6184722

The Use Case "Mission between Barcelona (Gracia or Ciutat Vella) and south target area Drive Cycle & Load Profile" is used to define the real world application of the vehicle. This also includes the range estimation.

TEVVA

Specification: 6191319

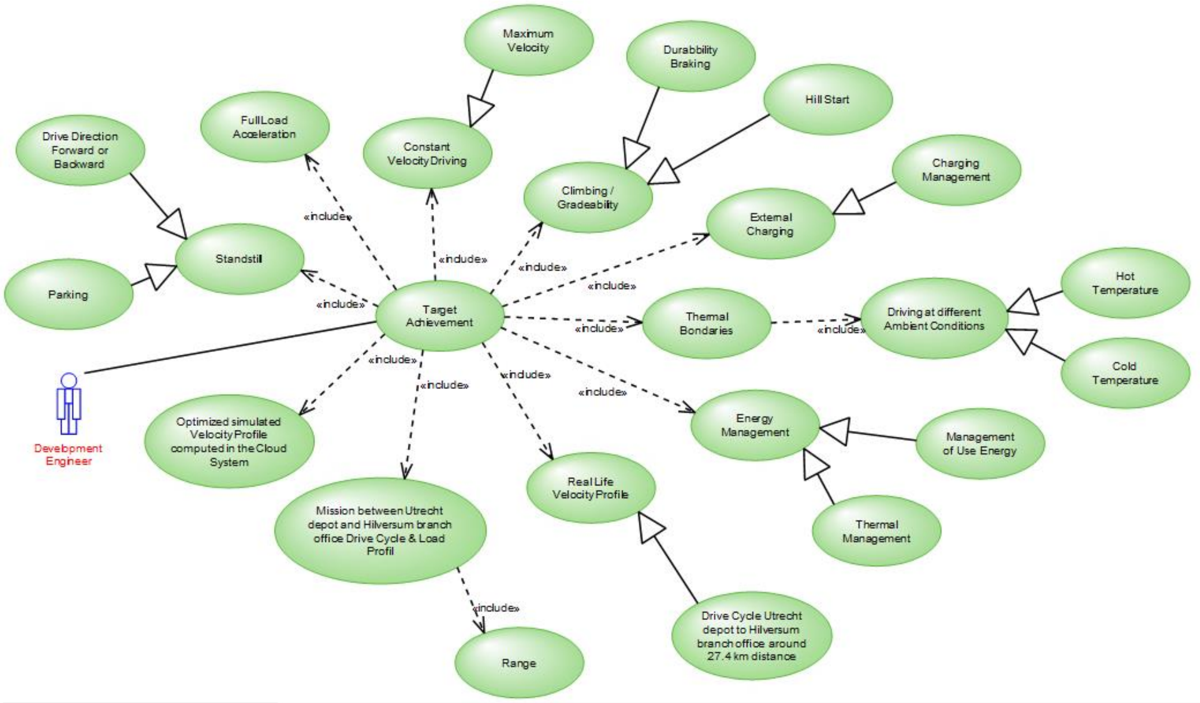

Figure 39 Target Achievement

Specification: 6191338

The Use Case "Standstill" describes the behavior of the vehicle at zero velocity. This includes the Use Case "Parking" and the Use Case "Drive Direction Forward or Backward".

Specification: 6191340

The Use Case "Full Load Acceleration" describes the behavior of the vehicle at max drive pedal. This is of importance for power dimensioning.

Specification: 6191342

The Use Case "Climbing/Gradeability" includes uphill and downhill driving for the vehicle including the use case "durability braking" and "hill start". This use case is used for power dimensioning for driving and recuperation.

Specification: 6191344

The Use Case "External Charging" describes the charging of the batteries from an external power source including the use case "Charging Management".

Specification: 6191346

The Use Case "Thermal boundaries" describes the driving behavior of the vehicle in extreme temperature scenarios. This is used to describe boundary conditions and vehicle power demands in the simulation.

Specification: 6191348

The Use Case "Energy Management" describes the active management of the different power sinks and sources in the vehicle to maximize range and/or comfort. This includes the thermal management as well as the management of the used energy

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Specification: 6191350

The Use Case "Real Live Velocity Profile" describes the expected behavior of the vehicle speed in real service. This is used for dimensioning of recuperation power and battery size.

Specification: 6191352

The Use Case "Mission between Utrecht depot and Hilversum branch office Drive Cycle & Load Profile" is used to define the real world application of the vehicle. This also includes the range estimation.

GPS based Route

Ford Otosan

Specification: 6179278

The route definition of vehicle service is described in the document [2]

IRIZAR

Specification: 6179286

The route definition of vehicle service is described in the document [2]

TEVVA

Specification: 6179288

The route definition of vehicle service ais described in the document [2]