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# *Automotive Intelligence for/at Connected Shared Mobility*

| **Deliverable** | ***Report on Requirements and specifications for the AI-based EV demonstrator*** | | |
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# Table of contents

# 1 Executive/ Publishable summary

This document is intended to describe the activities and results from Task 1.2 – "Requirements and specifications for the AI-based EV demonstrator". This task comprises activities and alignments of defining the requirements for the various demonstrators that will be integrated into the demonstrator vehicle of Supply Chain 2. These include an 800V SiC-based inverter, a PPU-equipped controller platform, a Time-of-Flight perception system and a communication gateway for vehicle-to-cloud communication. It also comprises algorithms for cognitive diagnostics using AI and prediction algorithms for energy consumption. The demonstrator vehicle itself, a Mercedes-Benz EQC adapted for higher charging power, is described as well.

# 2 Non publishable information

# 3 Introduction & Scope

## 3.1 Purpose and target group

This document describes the component-specific high-level requirements as derived from the vehicle-level requirements defined in Task 1.2 and in the AI4CSM project proposal. Therefore, it serves as a baseline for the subsequent work in WP2, 3 and 4, where these requirements will be broken down to a more detailed level. Fulfilling the requirements described in this document will ensure smooth integration into the target vehicle as well as achieve the objectives of the AI4CSM project in general.

Generally, this document is a report about the activities that have taken place within the scope of T1.2 and a summary of the achieved results. It is not seen as a complete compilation of the technical details. One reason for this is the nature of the technical data that has been shared, provided or created. For example, CAD data is best represented as a 3D model in a standardised file format. Another reason are data security aspects that do not allow the distribution of confidential or company internal data outside of a defined group of partners.

The guideline for all specification activities was is considering the demonstrator vehicle, a Mercedes-Benz EQC. This vehicle will be taken over from the 1000kmPLUS project, which has received funding from the European Union's Horizon 2020 Programme under Grant Agreement No. 824262. Resulting from the activities in this project, the vehicle's power network has been upgraded to 800V by installing a new 800V battery, drivetrain and the necessary HV auxiliary components. In order to minimise efforts, as many components and developments as possible are to be taken over from this vehicle, allowing to focus on the AI4CSM-specific technology. Another benefit is that many project partners from the 1000kmPLUS project are also participating in AI4CSM. Therefore, interfaces for data exchange and general knowledge of the vehicle environment are already well established in the working group.

## 3.2 Contributions of partners

The following table indicates the contributions of each partner. It is organised by chapters and provides an overview of each individual contribution in the document.

TABLE 1 – PARTNER CONTRIBUTIONS

| Chapter | Partner | Contribution |
|---|---|---|
| 4.1 | MBAG | Document creation, description of vehicle platform (Network, LV, Environmental specs) |
| 4.1 | AVL | Description of Thermal Control Strategy, LV architecture, environmental conditions |
| 4.4 | BUT | Description of Cognitive Diagnostic System |
| 4.5, 5.2, 5.3, 5.4 | EDI | Information about the 3D and 360° ToF Perception System demonstrator, how it goes beyond SoA and interacts with other WPs. |
| 4.2 | IFAG | Description of AURIX PPU platform |
| 4.7 | OTH | Description of the AI-based federated learning system for the prediction of the energy consumption of electric vehicles and of its use concerning energy-based route engines; requirements for demonstrator SCD2.1 |
| 3.2, 4.6, 5 | TTTAUTO | Requirement definition for integrating connectivity and communication technologies from SC5. Description of communication platform. |
| 4.2 | ZF | Description of 800V 250kW SiC inverter |

## 3.3 Relation to other activities in the project

The vehicle that serves as a demonstrator platform for Supply Chain 1 will include developments from the technology field of Supply Chains. In particular

- The power train, including the power train controller and the cognitive diagnostic system, will include developments from **Supply Chain 4**
- The 3D and 360° ToF Perception System originates from **Supply Chain 6**
- The V2C communication gateway is a contribution from **Supply Chain 5**

The requirements defined in this Task will be picked up in the following design phases within the respective Supply Chains. These will be a part of the overall specification of each development and ensure the compatibility for integration in the vehicle platform towards the end of the project.

The requirements will also serve as the foundation for Task 2.2 – "System level design for the AI-based EV demonstrator" of Work Package 2.

# 4 Description of the technical work

The demonstrator vehicle unites many developments from different supply chains. Therefore, this task focused on the actual integration of the diverse prototypes and systems into the vehicle, including

- Geometrical boundaries
- Electric interfaces
- Adaptions of the vehicle platform

Where possible, the base vehicle – including the alterations made in the 1000kmPLUS project – shall remain unchanged. This implies several generic requirements like the means of communication, the type, temperature and flow rate of the coolant (if needed), the power supply and environmental requirements like ambient temperature, vibration profile and protection class. For HV-components, compliance with HV-safety requirements and integration into the vehicle's HV power network is mandatory.

## 4.1 Vehicle platform (MBAG, AVL)

The vehicle platform itself is a Mercedes-Benz EQC400, available for public sale, although classified as a prototype car. It is a fully electric premium SUV. Its initial version features electric drivetrains on both front and rear axle, each drivetrain capable of delivering 150kW peak electrical power, thus resulting in a total system power of 300kW. The HV-battery is a 384-cell Li-Ion battery, containing energy of around 80kWh. Under NEDC-conditions, the EQC has a driving range of about 450km.


FIGURE 1 - MERCEDES-BENZ EQC400

During the 1000kmPLUS project, these aspects are being modified to enable higher efficiency and a higher charging rate in order to allow for long-range travel. This requires significant changes to the vehicle’s architecture and electric system. Most importantly, the system voltage is being increased from 400V to 800V in order to handle high charging powers. To provide the higher voltage and charging currents, the HV battery is being replaced by a new development. The same applies to the electric drivetrains, which are replaced by a single front axle drive with reduced power and higher efficiency. Since all HV components of the vehicle are rated for the 400V range, these have to be replaced as well.

Because many of the new components are taken from other developments, their integration into the vehicle’s control and communication structure needs to be taken into account. The initial approach is to adapt the communication definition of the devices wherever possible. However, the components are fixed and cannot be adapted in many cases. These devices are being controlled by means of a gateway device, routing the signals from the vehicle communication network to the new devices and vice versa.

The gateway also serves as a platform for altered control strategies and algorithms. For instance, the higher charging power requires a layout change of the vehicle’s coolant circuit, making the cooling control strategy obsolete as implemented in the base vehicle. Instead of adapting the control strategy on the old controller, which turns out to be very difficult to accomplish, the new control strategy is being implemented on the gateway. The actors and sensors of the coolant circuit are then directly connected to the gateway, which effectively replaces the controller for the coolant circuit.

From a technological standpoint, the communication architecture of the vehicle is based on the automotive CAN and LIN protocols, as they are commonly used throughout the industry. Transceivers and prototyping hardware are widely available for these networks, so integrating new components into the vehicle's network can be realised with minor efforts. MBAG is providing the necessary network descriptions to the partners as needed.

One of the most significant challenges for electronic components in passenger vehicles is the robustness regarding environmental conditions. Depending on their location in the vehicle, devices are exposed to extreme temperatures, mechanical stress (shocks and vibration), dust, humidity or even submersion in water, and corrosive or otherwise harmful media. The components need to be designed to a certain degree to withstand such environmental influences. For this purpose, MBAG is providing the appropriate demands as they are also used for serial developments. While it will certainly not be possible (and appropriate) to meet all of these demands, they will help achieve the aspired technology readiness levels.

Finally, the components will be supplied by the vehicle's electric power network. Due to the EV-architecture of the vehicle, it relies on a galvanically isolated DC/DC-converter, stabilised by a standard 12V automotive battery. The lack of an internal combustion engine ensures the absence of extreme voltage drops or peaks, e.g., when cranking the engine. However, components still need to be tolerant with regard to over- and undervoltages.

Due to the new thermal control strategy, new LV-wiring for the affected components must be implemented. As mentioned above, most thermal components are connected to the gateway instead of the original controller. Moreover, the new control strategy requires an additional valve that must be integrated in the new LV-wiring architecture and the new systems, like the AI-based near field 360° perception system and the V2C communication system. Since the new HV-inverter also has a new LV-connection, the cabling must be modified too. Before the LV layout adaptions can be designed, the relevant wiring section diagrams of the vehicle platform need to be evaluated. Afterwards, a new wiring diagram for this section is being implemented.

For the operation of the demonstrator, the environmental conditions of the 1000kmPlus project were applied. This ensures reliable operation of the powertrain and sufficient thermal system performance within the specified ambient conditions. Newly installed systems need to meet these requirements, Table 2 gives an overview of the most relevant values.

| | |
|---|---|
| Coolant temperature for unlimited operation | -25°C to 65°C |
| Ambient temperature for unlimited operation, based on thermal system specification | -20°C to 40°C |
| Environmental qualification | None, due to demonstrator purposes only |
| Noise vibration harshness (NVH) | No specification, with the understanding that the noise produced, should be harmless |
| IP protection class | IP6K9K |
| Max. Altitude | 4000m above sea level |

TABLE 2 - ENVIRONMENTAL CONDITIONS

## 4.2 800V 250kW 3-Phase Silicon-Carbide Inverter (ZF)

### 4.2.1 Description

The existing power inverter of the vehicle platform will be replaced with an 800V 250kW 3-phase power inverter based on Silicon-Carbine (SiC) power modules. The main goal of this inverter is to serve as a hardware demonstration platform both for the new AURIX 3G with Parallel Processing Unit (PPU), as well as advanced control and diagnostic algorithms to be evaluated at the vehicle level.

A base version of the inverter is already available, whose CAD design can be seen in Figure 2, left. It is based on SiC power transistors, which offer higher efficiency and a better thermal performance than Silicon (Si) devices. The inverter can provide 250 kW of peak power, with 200 kW of continuous power, with a PWM switching frequency of 16 kHz and 530 Arms output current. From the vehicle side, an 800 V (HV) as well as a 12 V (LV) power supplies are needed, as well as two CAN interfaces.

Modifications are needed to accommodate the needs of this project. The most extensive task is a complete redesign of the control board containing all components connected to the LV power network. This design change principally arises from using the AURIX 3G microcontroller; in addition, new processing electronics are needed to deal with the periphery coming from the vehicle, such as the rotor position sensor of the electric motor.

It may be necessary to modify the housing, mounting points, and cooling or electrical interfaces in parallel. A first integration analysis has been performed, as shown in Figure 2, right, where it has been confirmed that the inverter can be integrated into the demonstrator vehicle. However, an adaption for the mounting points may be needed. Additionally, the cooling system must be analysed in detail to define possible changes to the cooling circuit on the inverter side. Finally, a new CAN matrix will have to be determined based on the vehicle and integrated SW needs.

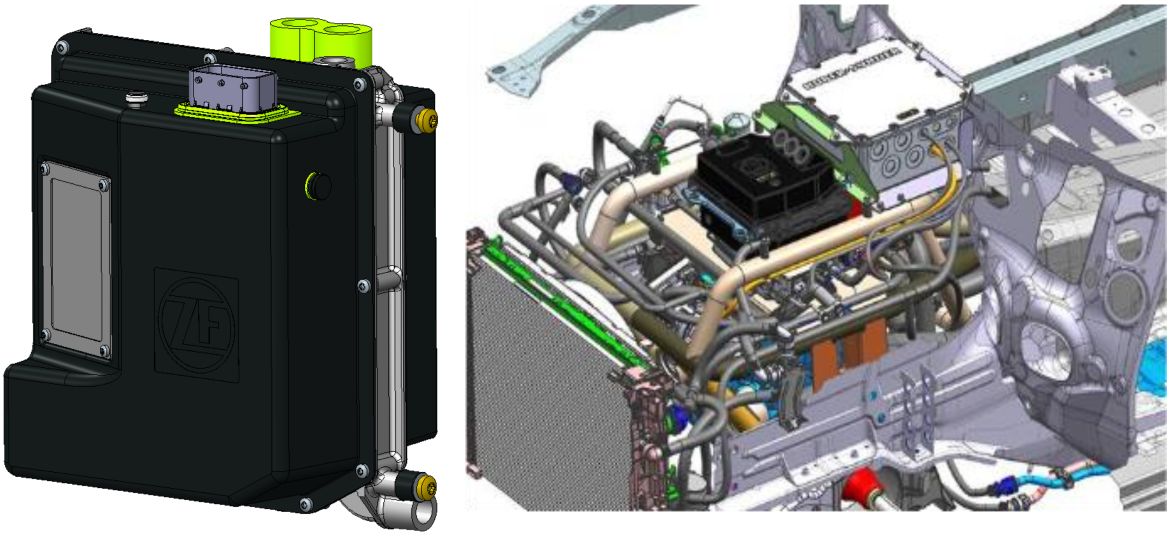


FIGURE 2 - 800V SIC INVERTER; LEFT: CAD MODEL; RIGHT: INTEGRATION INTO VEHICLE CAD MODEL

### 4.2.2 List of requirements

*ID:* AI4CSM_WP1_SCD2.1_26

*Name:* HV supply

*Description:* The power inverter must be provided with an 800 V voltage supply from the vehicle

*Rationale:* defined by Hardware platform

*Metrics:* yes/no

*Owner:* AVL/MBAG, ZF

*ID:* AI4CSM_WP1_SCD2.1_27

*Name:* HV AC output

*Description:* The inverter 3-phase AC output must be connected to a 3-phase permanent-magnet electric motor

*Rationale:* defined by Hardware platform

*Metrics:* yes/no

*Owner:* AVL/MBAG, ZF

*ID:* AI4CSM_WP1_SCD2.1_28

*Name:* HV connectors

*Description:* The HV connection for DC and AC is realized with HV cable lugs, as well as blueglobe cable glands from PFLITSCH

*Rationale:* defined by Hardware platform

*Metrics:* yes/no

*Owner:* AVL/MBAG, ZF

*ID:* AI4CSM_WP1_SCD2.1_29

*Name:* LV supply

*Description:* The inverter will be provided with a 12V voltage supply from the vehicle

*Rationale:* defined by Hardware platform

*Metrics:* yes/no

*Owner:* AVL/MBAG, ZF

*ID:* AI4CSM_WP1_SCD2.1_30

*Name:* CAN Communication

*Description:* Two standard CAN communication interfaces must be implemented. The first is used for normal communication between vehicle and power inverter. The second is used for flashing and calibration.

*Rationale:* defined by Hardware platform

*Metrics:* yes/no

*Owner:* ZF, AVL/MBAG

*ID:* AI4CSM_WP1_SCD2.1_31

*Name:* Control board

*Description:* The inverter must include a dedicated control board containing all necessary HW components to realize the motor control function, sensor monitoring, communication with the vehicle, and internal power supply

*Rationale:* defined by Hardware platform

*Metrics:* yes/no

*Owner:* ZF

*ID:* AI4CSM_WP1_SCD2.1_32

*Name:* Microcontroller

*Description:* Infineon Aurix 3G TC49X is to be used

*Rationale:* CPU platform must be defined in advance to allow for software development

*Metrics:* yes/no

*Owner:* ZF

*ID:* AI4CSM_WP1_SCD2.1_33

*Name:* Gate-driver board

*Description:* The inverter must include a gate-driver board providing the necessary voltages and currents to safely drive the SiC power semiconductors

*Rationale:* defined by Hardware platform

*Metrics:* yes/no

*Owner:* ZF

*ID:* AI4CSM_WP1_SCD2.1_34

*Name:* DC voltage measurement

*Description:* The DC-link voltage must be measured and provided to the microcontroller

*Rationale:* Voltage measurements on HV side are a HV-safety feature

*Metrics:* +/- 1% (min. +/-1,5V) within 10% to 90% of maximum

*Owner:* ZF

*ID:* AI4CSM_WP1_SCD2.1_35

*Name:* AC phase current measurement

*Description:* The AC phase currents of all phases must be measured and provided to the microcontroller

*Rationale:* Required for space vector motor control

*Metrics:* +/- 1% (min. +/- 1A) within 10% to 90% of maximum range

*Owner:* ZF

*ID:* AI4CSM_WP1_SCD2.1_36

*Name:* Temperature measurements

*Description:* The temperature of the internal components of the power inverter must be measured and provided to the microcontroller

*Rationale:* Self-monitoring and enabling of derating functionality

*Metrics:* Derating not below T_coolant = 65°C

*Owner:* ZF

*ID:* AI4CSM_WP1_SCD2.1_37

*Name:* Liquid cooling system

*Description:* The power inverter must be cooled by a liquid cooling system, whose coolant and pressure must be provided by the vehicle.

*Rationale:* as defined by Hardware platform

*Metrics:* Tmax = 65°C, Flow rate = 10lpm

*Owner:* ZF, AVL/MBAG

*ID:* AI4CSM_WP1_SCD2.1_38

*Name:* Safe states

*Description:* The power inverter must enter a safe-state if conditions which may lead to an uncontrolled torque are detected

*Rationale:* Avoidance of unwanted or uncontrolled torque generation is mandatory from functional safety perspective

*Metrics:* Assessment

*Owner:* MBAG

*ID:* AI4CSM_WP1_SCD2.1_39

*Name:* HV safety design

*Description:* The power inverter must be designed in such a way that the risk to persons and components due to HV faults is minimized

*Rationale:* HV safety is mandatory for safe testbench and vehicle operation

*Metrics:* Assessment

*Owner:* MBAG

*ID:* AI4CSM_WP1_SCD2.1_40

*Name:* HV safety functions

*Description:* The power inverter must have safety functions that minimize the risk to persons and components due to HV faults

*Rationale:* HV safety is mandatory for safe testbench and vehicle operation

*Metrics:* Function test

*Owner:* MBAG

## 4.3 AURIX PPU Platform (IFAG)

### 4.3.1 Description

**Aurix Microcontroller, AI-based Functionality and Parallel Processing**

Infineon will strengthen its automotive semiconductor product offerings with next-generation Aurix TC4x microcontrollers (MCUs) addressing eMobility, ADAS, automotive E/E architectures and artificial intelligence (AI) applications. The MCU will include a parallel processing unit (PPU), a SIMD vector digital signal processor (DSP) targeting AI topologies. This will include use cases such as real-time control and radar post processing. Targeting automotive applications, including the demand for functional integration in domain and zone-based E/E architectures, the Aurix TC4x supports both eMobility and automated driving through safety systems.

SOTA (Software Over the Air) provides a fast and secure car-to-cloud connection, enabling updates in the field, plus diagnosis and analysis during vehicle usage. The MCUs support high-speed communication interfaces like 5 Gbit Ethernet and PCI Express (PCIe) along with interfaces such as CAN-XL and 10BASE T1S Ethernet. This increased network throughput and connectivity gives customers the performance and flexibility needed to implement enhanced E/E architectures. The new Aurix architecture is based on smart accelerators, which provide real-time performance and high networking throughput.

With the growing vehicle complexity and the enablement of AI implementations, significant focus has been placed on the Aurix ecosystem to ensure fast time-to-market and ease of use. To achieve this goal, Infineon is collaborating with IP core solution provider Synopsys to accelerate software development for the TC4x MCU. Using the Virtualizer Development Kit (VDK) enables software developers to shrink the product design cycles. DesignWare ARC MetaWare Toolkit provides compilers, debuggers, libraries, and a simulator needed to develop software for the integrated PPU.

Building advanced automotive systems to address stringent safety functionality requires implementing AI technology. Infineon provides tools to develop AI-driven functionality for applications such as powertrain and ADAS processing that meet safety, performance, and power-efficiency requirements. Additional IFAG partner offerings like MATLAB support will be available for the auto-code generation to enable rapid prototyping.

**Key features of the AURIX TC4x will be a performance** up to 500 MHz with virtualisation support, up to 25 MB on-chip Flash, and zero downtime SOTA support with A/B swap partitioning and external memory interface. Cybersecurity modules meet the ISO 21434 standard. A PPU, powered by a Synopsys DesignWare ARC EV processor, enables AI-based functional safety up to ASIL-D. Further features will be a Data Routing Engine for communication and data handling, scalable communication interfaces with 5 Gbps Ethernet, and PCIe. Communication standards like 10BASE T1S Ethernet and CAN-XL will also be covered as safety requirements up to ASIL-D according to the ISO26262 2018 Standard.

**Parallel Processing Unit (PPU)**

The new Aurix MCU will include a parallel processing unit (PPU), a SIMD vector digital signal processor (DSP) targeting AI topologies. It will offer fully programmable parallel processing capabilities and include a 32-bit scalar processing unit and a 512-bit wide vector DSP unit that will process 8-bit, 16-bit, or 32-bit vector elements. An overview of the functional architecture of the PPU is shown in the following figure.

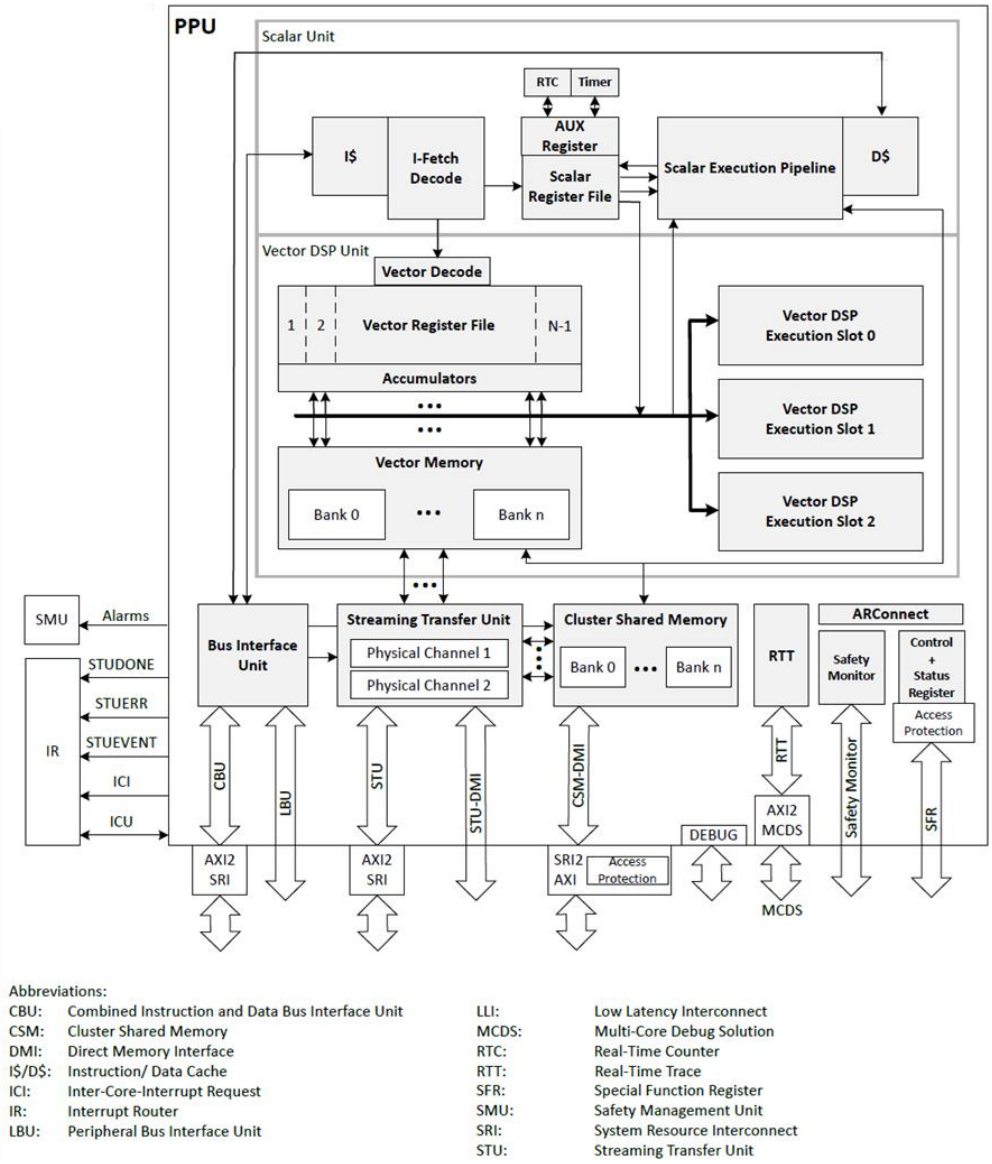


FIGURE 3 - PPU FUNCTIONAL BLOCK DIAGRAM (SOURCE: INFINEON)

The scalar unit fetches and decodes instructions. Instruction fetch requests go through the PPU internal bus fabric before being forwarded either to the CSM memory region or towards the Combined Instruction and Data Fetch Interface (CBU). Data fetch requests from the scalar core also go through the internal bus fabric, before being forwarded towards the CBU interface.

The Vector DSP unit is closely integrated within the scalar core. Vector instructions are forwarded towards the Vector DSP unit where they are executed in one out of three execution slots. Vector instructions typically operate on vectors in the vector register file, while movement of vectors to and from memory is done with vector load and store instructions between the vector register file and the vector memory (VMEM). Some vector instructions can return a scalar value that is written to a scalar register in the register file of the scalar unit.

Data transfers between VMEM, CSM, and PPU external memories are handled by the Streaming Transfer Unit (STU). The STU can be programmed by the scalar core through auxiliary registers and also from an external master through the STU-DMI interface. The Cluster Shared Memory (CSM) provides high capacity, high throughput memory shared by all cores. It can be used for instructions and data, cacheable and non-cacheable. External masters can access the CSM using the CSM-DMI interface.

The Real Time Trace Unit (RTT) is used to trace the program flow of the PPU processor. The configuration is done by the scalar core through auxiliary registers. For debugging a memory mapped APB debug port can be used to access all internal core registers for debugging purpose. The ARConnect block is a collection of system functions, such as a global timer and interrupt distribution unit. To access safety relevant information of the PPU, the Safety Monitor interface can be used to access the diagnosis registers. The control and status information register interface (SFR) allows application software to configure basic PPU options (for example run or halt control) and to read the current processor status.

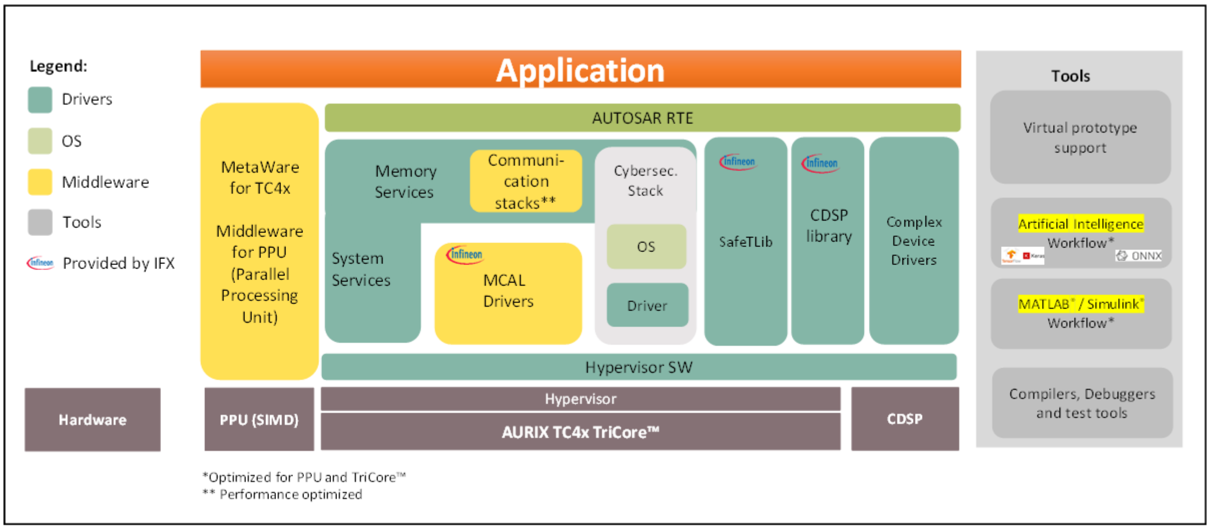


FIGURE 4 - AURIX TC4X SOFTWARE ECOSYSTEM (SOURCE: INFINEON)

The PPU will deliver the following features: A vector architecture that combines scalar and vector instructions in one instruction bundle. 32-bit scalar processing capabilities (Scalar Unit) with double precision Floating Point support and integrated timer modules. Vector processing capabilities (several vector DSP units) which includes a 512-bit wide Single Instruction Multiple Data (SIMD) processing, support for Vector Floating Point processing, and floating-point math acceleration. Additional features are many-bank L1 vector memory with scatter/gather functionality, integrated Streaming Transfer Unit (DMA capabilities) with multiple physical channels, multi-banked L2 Cluster Shared Memory, low latency peripheral interface towards timers and converters, interrupt and exception handling from various sources, configuration and Status Reporting Interface, and support for low power features. Besides the scalar processing units, the PPU includes other components such as a Streaming Transfer Unit (STU), a Cluster Shared Memory (CSM), an Interrupt Unit (IU) as part of a scalar unit, ARConnect, and Real Time Trace Unit. The PPU internal bus fabric is used for connections between the scalar processing unit, system components, and PPU external memories.

### 4.3.2 List of requirements

*ID:* AI4CSM_WP1_SCD2.1_41

*Name:* System Integration

*Description:* The safety controller shall support all current (CAN, HSSL, Flexray etc) and projected (Ethernet) automotive communication interfaces

 

*Rationale:* The safety controller must communicate with other hardware elements in both the local system and the rest of the vehicle

*Metrics:* verifiable support for communication interfaces

*Owner:* IFAG ATV MC

*ID:* AI4CSM_WP1_SCD2.1_42

*Name:* Traction inverter application

*Description:* The MCU shall be able to support automotive traction inverter applications

*Rationale:* Needed to support automotive traction inverter applications

*Metrics:* verfiable support of traction inverter failures via discrete test cases

*Owner:* IFAG ATV MC

*ID:* AI4CSM_WP1_SCD2.1_43

*Name:* PPU support for AI algorithms

*Description:* The MCU shall support a parallel processing unit for optimized execution of AI algorithms

*Rationale:* Needed to support PPU for execution of AI algorithms

*Metrics:* verifiable PPU support for executing AI algorithms

*Owner:* IFAG ATV MC

*ID:* AI4CSM_WP1_SCD2.1_44

*Name:* Processing, data integrity, communication

*Description:* The MCU shall provide mechanisms to ensure reliable processing, internal data integrity and communication

*Rationale:* Needed to ensure reliable processing, internal data integrity and communication

*Metrics:* verifiable and measurable processing, integrity and communication capabilities

*Owner:* IFAG ATV MC

*ID:* AI4CSM_WP1_SCD2.1_45

*Name:* Voltage, temperature, timing supervision

*Description:* The MCU shall provide voltage, temperature and timing supervision (watchdogs)

*Rationale:* Needed to provide voltage, temperature and timing supervision (watchdogs)

*Metrics:* verifiable and measurable voltage, temperature and timing values

*Owner:* IFAG ATV MC

*ID:* AI4CSM_WP1_SCD2.1_46

*Name:* Temperature range profiles

*Description:* The MCU shall support automotive temperature range profiles

*Rationale:* Needed to support automotive temperature range profiles

*Metrics:* verifiable temperature range profiles

*Owner:* IFAG ATV MC

## 4.4 Cognitive Diagnostic System (BUT)

### 4.4.1 Description

Fault detection and the diagnostic system will use artificial neural networks (ANNs) if advantageous. ANNs must be fast enough to detect severe faults as fast as possible. For this reason, the integration of ANNs into a power inverter appears to be the optimal solution. All measured motor parameters are presented in the microcontroller. Direct processing in the microcontroller can significantly reduce fault detection time because communication delays will be significantly reduced. On the other hand, ANN inference on the microcontroller is computationally demanding. Thanks to the new generation of AURIX microcontroller with the parallel processing unit, the implementation of a properly designed ANNs directly into the inverter control unit should be feasible.

Power inverter faults can be visible in current and voltage waveforms. Feature extraction can be performed by a specialised part of the software or by the ANN. It will use one-dimensional convolutional layers to extract features from current and voltage waveforms. The waveforms will be connected to the first input. In this case, voltage and current waveforms will be oversampled to satisfy the input dimension of the ANN. Extracted features will be combined inside the ANN with other measured features from the second input.

The diagnostic system should be able to detect internal winding faults as well as power inverter faults. For this reason, a high amount of data that can be used to train ANNs is required. These data cannot be measured on the real motor because only fraction of assumed faults can be emulated on the real machine. For this reason, training and validation data for the ANN will be prepared in simulations using the innovative motor model which respects real motor winding arrangements. Simulations provide sufficient data sets with all assumed faults. The diagnostic system should be able to detect internal winding faults as well as power inverter faults.

The ANN will be trained in TensorFlow using the float32 data type. AURIX supports single-precision numbers, and the ANN can be relatively simply implemented into the AURIX core. The implementation into the parallel processing unit should significantly decrease the inference time of the ANN or allows to use of more complex ANNs. Inference time can also be reduced usiintquantisation type quantisationype.

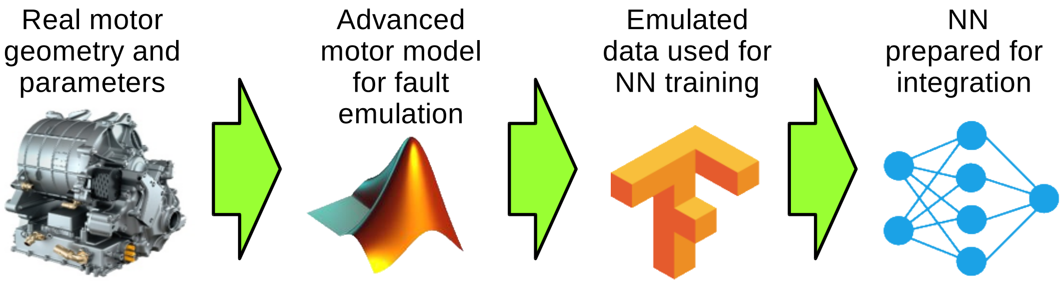


FIGURE 5 - WORKFLOW FOR ANN PREPARATION

In addition to the pure electrical-based diagnostics of the components of the propulsion system, which is usually based directly on measurements of position, current and voltage waveforms as a straightforward procedure to detect faults in the electric system, there can also be implemented diagnostics based on analysis of mechanical manifestations in the propulsion. Diagnostics utilising a measurement of dynamic mechanical quantities could be able to enhance cognitive functions of the overall diagnostic system when some indications of typical electrical faults can be registered earlier or can confirm indications reported by diagnostics relying only on electrical quantities with greater confidence. Such diagnostics utilises monitoring of symptoms over a more extended period of time, and links between symptoms (features) and the specific fault is typically a multidimensional space. Therefore, it is very difficult to determine these dependencies using analytical or simple model-based methods, so there is a significant potential of the application of machine learning approaches utilising ANNs and inference mechanisms. Moreover, ANNs can help extend electrical-based diagnostics and easily combine it with mechanical-based diagnostics to provide a more reliable diagnostic system as developing the common analytical model utilizing both electrical and mechanical information is almost impossible.

To be able to perform diagnostics based on the measurement of mechanical manifestations of the system (typically in the e-motor, or in special cases, also in the inverter), there should be available an additional sensor specifically measuring mechanical motion (e.g., mechanical vibrations or air-borne noise in an audible or ultrasonic range) and such type of sensor is not usually present in the existing propulsion systems in the cars. Therefore, the availability of such a sensor in the propulsion system and its interconnection to the diagnostic subsystem possibly implemented and running directly in the inverter controller is necessary. Furthermore, the sensor capturing dynamic mechanical quantities should be placed in the location and positioned in such a way that it can be able to capture sufficient data and therefore provide the output signal rich enough to calculate the required feature(s) serving as an input to the diagnostic system. Specifically in the case of measurement of mechanical vibrations, the placement of the sensor is critical to be able to obtain a relevant signal for subsequent analysis, a calculation of significant features which can indicate a specific type of fault.

### 4.4.2 List of requirements

*ID:* AI4CSM_WP1_SCD2.1_47

*Name:* Fault detection data aquisition

*Description:* Measured motor data should be sent into the diagnostic system with the same frequency as into the control algorithm.

*Rationale:* The diagnostic system must be able to monitor motor currents and voltages.

*Metrics:* The fault is detected from current and voltage waveforms and from other measured parameters.

*Owner:* BUT

*ID:* AI4CSM_WP1_SCD2.1_48

*Name:* Short-circuit detection

*Description:* System should be able to detect winding short-circuit.

*Rationale:* Winding short-circuit can cause overheating of the machine. Fast detection can reduce additional damage.

*Metrics:* Short-circuit should be detected in time under 30 ms for speeds of 20-100 %.

*Owner:* BUT

*ID:* AI4CSM_WP1_SCD2.1_49

*Name:* Fault feedback processing

*Description:* The system should be able to react to the detected fault.

*Rationale:* The control algorithm should be aware of the fault, the information can also be visualized.

*Metrics:* Control algorithm or visualization will react to emulated fault.

*Owner:* BUT

*ID:* AI4CSM_WP1_SCD2.1_50

*Name:* Preprocessing in microcontroller

*Description:* One microcontroller core should be dedicated for the implementation of the neural network preprocessing algorithm.

*Rationale:* Measured data must be oversampled to fit neural network input dimensions.

*Metrics:* The neural network will be able to detect the fault in provided data.

*Owner:* BUT

*ID:* AI4CSM_WP1_SCD2.1_51

*Name:* Short inference time

*Description:* Inference time should be less than 5 ms to provide fast fault detection.

*Rationale:* Inference time must by be short enough to detect the fault in time.

*Metrics:* Measured inference time must be less than 5 ms.

*Owner:* BUT

*ID:* AI4CSM_WP1_SCD2.1_52

*Name:* Mechanical based diagnostics

*Description:* Specific sensor measuring appropriate mechanical quantity should be available in the system.

*Rationale:* In case of diagnostics utilizing also mechanical manifestations such process information is necessary. No such sensor is usually present in the existing propulsion system.

*Metrics:* Availability of suitable sensor (vibration, acoustic, ultrasonic) in the system and connected to the diagnostic system (implemented and running in the inverter controller).

*Owner:* BUT

*ID:* AI4CSM_WP1_SCD2.1_53

*Name:* Additional sensor for diagnostics (placement)

*Description:* Additional sensor must be placed in the location or position where sufficient features related to analysed fault can be captured.

*Rationale:* Sensor should provide sufficient information for subsequent fault detection, especially in case of mechanical quantities measurement.

*Metrics:* Output from the sensor will provide sufficient signal for calculation of required feature(s) as an input to the diagnostic system.

*Owner:* BUT

## 4.5 3D and 360° ToF Perception System (EDI)

### 4.5.1 Description

The perception system developed by EDI is planned to use an array of at least six 3D time of flight (ToF) sensors enhanced by AI algorithms for surrounding object recognition. Some of the required AI functions are designated to be implemented on IFAG's safety-oriented AURIX® 3G platform to reduce system cost and power consumption.

Figure 6 depicts the preliminary architecture variants of the demonstrator. The left-hand variant assumes registration and stitching to occur first, and AI processing second. The right-hand variant has a changed order in the pipeline with AI-based processing first, followed by registration and an output merge afterwards. Both approaches have advantages and disadvantages on a software level but have a relatively low impact on hardware integration aspects.

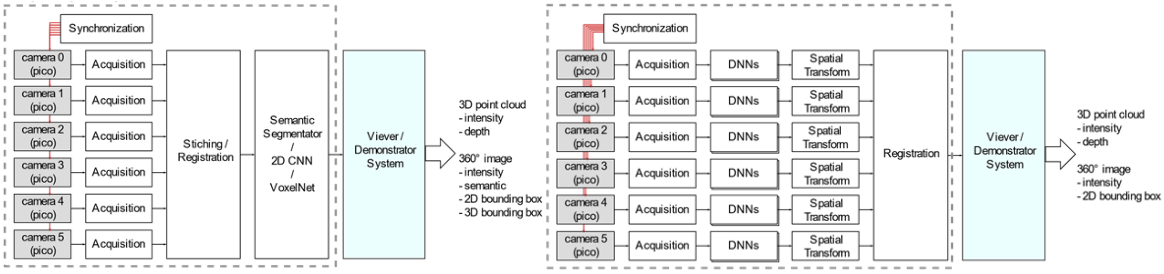


FIGURE 6 - PRELIMINARY 3D PERCEPTION FUNCTIONAL ARCHITECTURE.

The EDI connected and automated driving (CAD) platform (based on Kia Soul EV) will be used as a basis for research, development, deployment and initial tests of the proposed perception system (based on 3D ToF sensors (see Figure 7)). The platform is currently equipped with a high-performance computing unit for processing data from multiple sensors (lidars, radars, cameras) and can be adapted for ToF sensors. The ToF sensors by *PMD Tech* have a field of view of 100x85 degrees (HxV), a measurement range of 0.5 - 6 m, use a USB3.0 interface for power and data transmission and consumes up to 4.5W of power.

FIGURE 7 - EDI CAD PLATFORM (LEFT) AND *PICO MONSTAR* TOF SENSOR BY PMD TECH (RIGHT).

The preliminary layout of the ToF sensor array is presented in Figure 8. In this schema, the sensors on the sides of the vehicle have been rotated away from each other for increased overlap around the front- and backward-facing sensors and reduced blind spots around the vehicle.

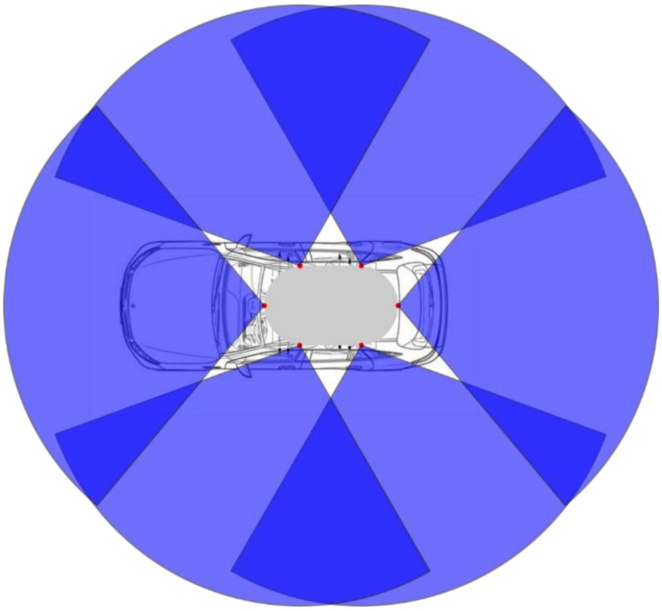

FIGURE 8 - ROOF PLATFORM TOF SENSOR LAYOUT PLAN.

The technical setup will overlap between the sensor's field of view of up to 50 degrees, reducing blind spots around the vehicle. The system connected to the ToF sensors will have a high-speed interface with at least 1 Gbps throughput. It is expected that overall system power consumption will be less than 150W. A dedicated display will be mounted in the car to visualise relevant information to the driver.

### 4.5.2 List of requirements

*ID:* AI4CSM_WP1_SCD2.1_1

*Name:* ToF sensor integration

*Description:* The base vehicle shall have a platform (e.g. on the roof) with sufficient room for at least 6 ToF sensors.

*Rationale:* Necessary for 360 degree perception system integration.

*Metrics:* Demonstration setup on a physical cal

*Owner:* EDI

*ID:* AI4CSM_WP1_SCD2.1_2

*Name:* ToF sensor location

*Description:* The ToF sensor location on the vehicle must be chosen in such a way that the risk of unseen objects is minimized.

*Rationale:* Necessary for 360 degree perception system integration.

*Metrics:* Demonstration setup on a physical cal

*Owner:* EDI

*ID:* AI4CSM_WP1_SCD2.1_3

*Name:* ToF sensor overlap

*Description:* The ToF sensors must be placed in such a way that there is sufficient overlap between the sensor's field of view.

*Rationale:* To reduce blind spots around the vehicle.

*Metrics:* >50 degrees

*Owner:* EDI

*ID:* AI4CSM_WP1_SCD2.1_4

*Name:* Power supply

*Description:* Sufficient for Aurix-like data processing unit with at least 6 ToF sensors.

*Rationale:* Necessary for powering perception system.

*Metrics:* <150W

*Owner:* EDI

*ID:* AI4CSM_WP1_SCD2.1_5

*Name:* Display for data visualization

*Description:* The base vehicle shall have a sufficiently large display to visualize the merged output of at least 6 ToF sensors.

*Rationale:* Necessary information for driver.

*Metrics:* >10" display

*Owner:* Ssol

*ID:* AI4CSM_WP1_SCD2.1_6

*Name:* Bus system

*Description:* The system connected to the ToF sensors shall provide a high-speed interface with at least 1 Gbps throughput.

*Rationale:* Necessary for processing sensor array output data.

*Metrics:* >1Gbps

*Owner:* EDI

*ID:* AI4CSM_WP1_SCD2.1_7

*Name:* Independent power supply

*Description:* An independent power supply system should be deployed to ensure constant and stable power supply for the developed perception system (sensors, processing units, etc.).

*Rationale:* Necessary for the safety reasons

*Metrics:* Power supply system (battery, converters, rack, etc.) deployed and demonstrated on a physical car

*Owner:* EDI

## 4.6 V2C Communication Gateway (TTTAuto)

### 4.6.1 Description

The requirements for the in-vehicle communication architecture emerge from the trend toward a more centralised architecture, but also from the connectivity of the vehicles to the external networks. State-of-the-art in-vehicle networks include, e.g., CAN bus, FlexRay, LIN and Ethernet. Most of these technologies will remain due to legacy systems but also due to their cost-effectiveness. However, standard network design cannot fulfil the future requirements emerging from new applications such as autonomous driving, electrification and V2X connectivity. Future in-vehicle networks have to have high bandwidth (even in Gbit/s) but still guarantee hard real-time message exchange. In addition, these networks have to enable easier creation of redundant, or even fail-operational architectures, as well as enable easier creation of cybersecurity functionality. Such functionalities will be developed in SC5 on Communication and Connectivity, and it is planned to integrate and prototypically showcase selected modules in the SC2 demonstrator. TTTAUTO will contribute with a prototypical reference setup for the in-vehicle central computing platform (HW) and the corresponding software environment to showcase selected communication and connectivity services. The demonstration environment consists of the following components:

- Hardware platform (CPU's / hardware board)
- Platform software (board support package, operation system, networking stack, middleware and run-time environment)

Other than the processing platform, the rest of the in-vehicle communication architecture is formed by the controllers, the CAN transceivers, and the Ethernet switches. Figure 9 depicts a prototypical demonstration platform by TTTAUTO, designed for application development and evaluation of advanced driver assistance systems (ADAS). Together with the dedicated software framework, such a platform can be set up as a test environment to benchmark the communication gateway services in the demonstrator.

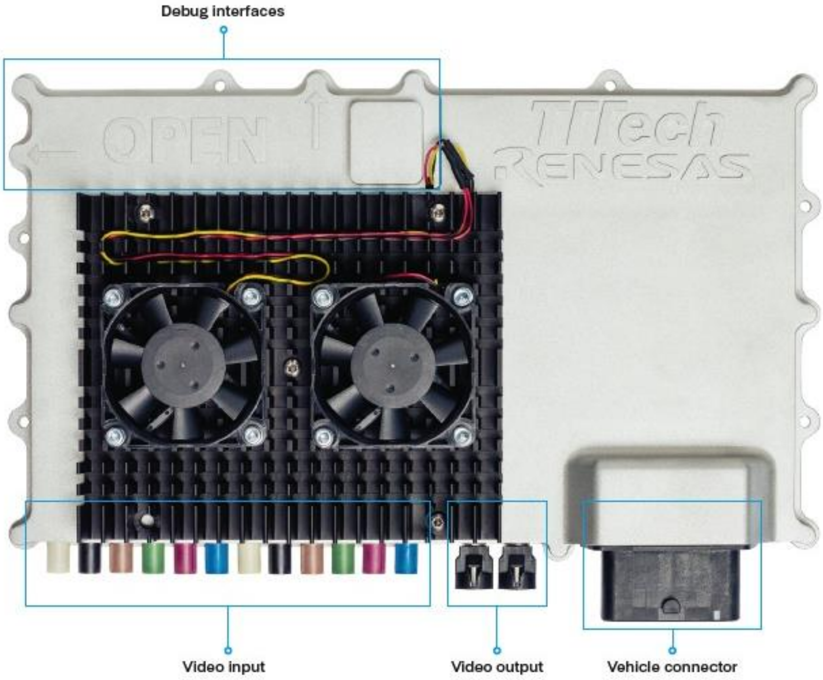


Figure 9 - Reference Design in-car computing and communication platform by TTTAUTO

### 4.6.2 List of requirements

*ID:* AI4CSM_WP1_SCD2.1_21

*Name:* Power Supply - Communication Platform

*Description:* The operating voltage range for the communication platform shall be within 9V to 16V (Vnom = 12V)

*Rationale:* The required power supply to ensure operational stability

*Metrics:* yes/no

*Owner:* TTTAUTO

*ID:* AI4CSM_WP1_SCD2.1_22

*Name:* Power Consumption - Communication Platform

*Description:* The max. foreseen power consumption shall be 5A.

*Rationale:* Max. current drawn by the hardware unit for system design.

*Metrics:* Measurement

*Owner:* TTTAUTO

*ID:* AI4CSM_WP1_SCD2.1_23

*Name:* Communication Interfaces

*Description:* The communication interfaces (Ethernet, CAN-FD, LIN, FlexRay, etc.) shall be aligned to match the selected hardware setup for the prototyical setup.

*Rationale:* The prototypical development board has limited interfaces to be utilized in the system design.

*Metrics:* yes/no

*Owner:* TTTAUTO

*ID:* AI4CSM_WP1_SCD2.1_24

*Name:* Environmental Conditions

*Description:* The operating temperature range shall be between -40°C to 85°C.

*Rationale:* The required operational temperatur range to ensure operational stability

*Metrics:* yes/no

*Owner:* TTTAUTO

*ID:* AI4CSM_WP1_SCD2.1_25

*Name:* Software Integration Framework

*Description:* The application developed for the communication with cloud services have to be compiled and compatible with SW framework on the in-car computing platform.

*Rationale:* The developed communication services and applications have to compatible with the SW middleware of the communication platform.

*Metrics:* Static Analysis of Development Environment

*Owner:* TTTAUTO

## 4.7 Prediction of energy consumption using federated learning (OTH)

### 4.7.1 Description

The OTH-AW intends to use AI and federated learning to make precise predictions of the energy consumption of electric vehicles under certain conditions.

Such a prediction of the power consumption is essential for routing services who try to find the most energy-efficient route for electric vehicles. The aim of such routing services is to be more energy-efficient compared to conventional speed optimised route engines and thus reduce carbon emissions and save energy. In SC1, an energy-optimized route engine for electric vehicles in urban areas is developed by the OTH-AW. SC2 will focus on the development of self-improving AI-based models for power consumption forecasts. These models will have an interface to the routing service developed in SC1. The AI models take speed, elevation profile, distance and further information from the routing server and return the calculated energy consumption for this setting. Thus the routing server gets enabled to calculate the most energy-efficient route. Figure 10 shows the comparison between an energy-optimized route and a time optimised route in the town of Amberg. The energy prediction model has to be accurate and fast at the same time to enable the fulfilment of the KPIs of the energy-optimized route engine.

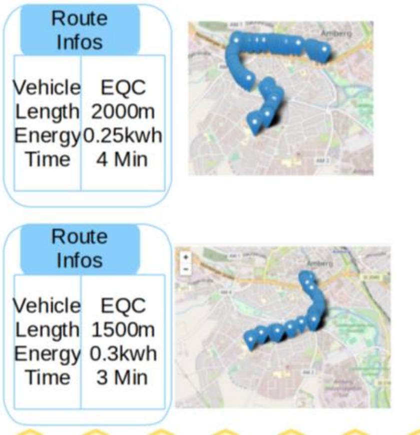


FIGURE 10 - EXAMPLE FOR ENERGY OPTIMIZED ROUTE AND COMPARISON

Data collected in vehicles will train local AI models in the edge. Training data is collected and saved during a vehicle is driving. This data includes, for example velocities, GPS positions, temperatures, the overall energy consumption of the vehicle and the energy consumption of auxiliary systems like heating or cooling systems. The OTH-AW will receive data sets from FHG that can be used for the training of AI models. The vehicle platform from MBAG must also provide interfaces, e.g., CAN, for gathering the required data. Additionally, external data sources are used to gather further information, such as weather data, traffic information and the elevation profile of the driving route. The training of the AI model in the edge should be done daily during the charging times of the vehicle. The reason for that is the increased power consumption during training which would result in a reduction of the vehicle's driving range if done during driving. The energy model is self-improving, the more data is collected during the driving of the vehicle, the more accurate the AI model will become. Enough storage space has to be provided in the edge to save the training data. The computing power of the edge platform has to be high enough to finish training during the charging time.

For further enhancement of the energy prediction, federated learning will be used. Federated learning means taking data collected by several different vehicles into account to develop a global generic energy prediction model and to further improve the local models by learning from the other vehicles' models. Federated learning can be implemented in a privacy-preserving way, sensible data does not leave the edge, and only model parameters are shared with the cloud. If it is still possible to draw conclusions from these parameters to the data points, appropriate security mechanisms have to be used. The federated learning system has to be able to cope with several challenges. First, the phases during which the different vehicles that participate in the federated learning system train their models and are available for contribution to the generic model differ. Second, the training data of the different vehicles is not independent and not identically distributed as not every vehicle is used in the same setting and with the same frequency. The federated learning system has to find a balanced solution for the generic model nevertheless.

The system structure is shown in Figure 11. The AI-based energy prediction that is needed for the energy-efficient routing should be done in the cloud to avoid high latencies caused by communication between the routing server and the energy model.

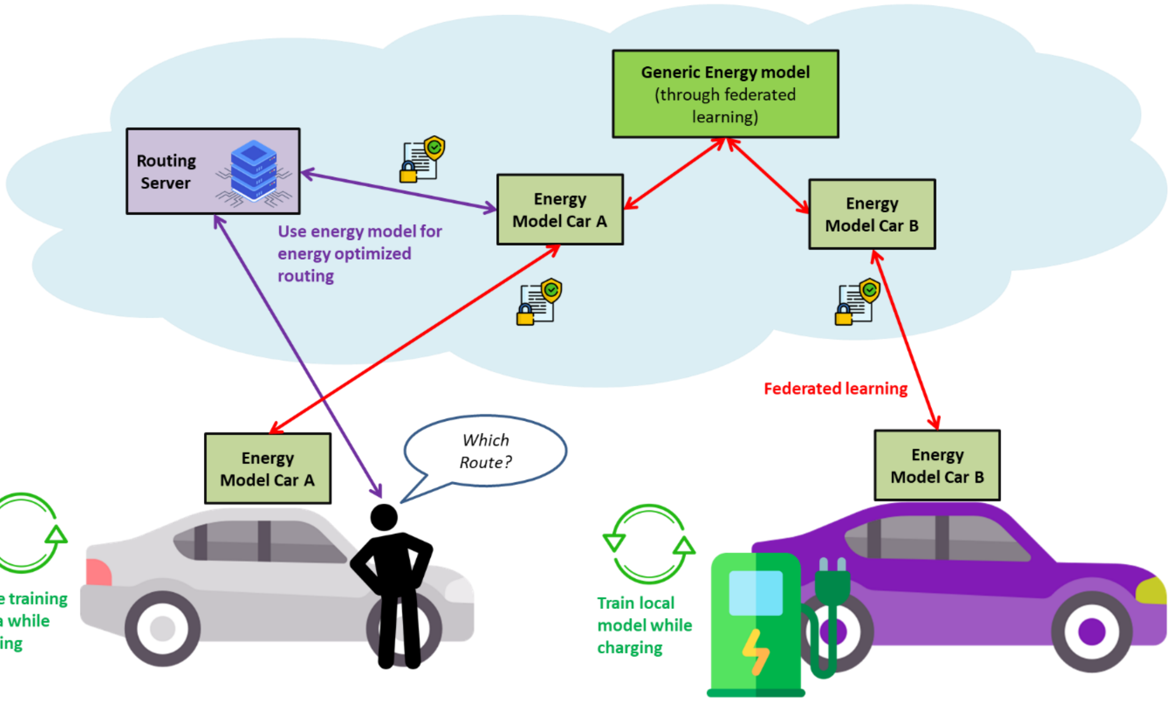


FIGURE 11 - SYSTEM STRUCTURE OF FEDERATED LEARNING SYSTEM FOR ENERGY CONSUMPTION PREDICTION

A cooperative edge/cloud approach will be used to build a self-improving energy model for electric vehicles and to use it for enhanced energy saving routing systems. (Project objective **O2**).

Currently investigated methods for explainable AI will be applied and evaluated on the AI model for energy prediction. (Project objective **O4**)

The solution, together with the routing engine developed in SC1, supports the green deal objectives for future connected and shared mobility. It helps to change the long-term decision-making that the driver or navigation system takes before and while a transportation request is handled towards the green deal objectives of more efficient, secure, and environment-friendly mobility (project objective **O6**).

### 4.7.2 List of requirements

*ID:* AI4CSM_WP1_SCD2.1_8

*Name:* Interface to EQC

*Description:* The interface to the EQC (e.g. CAN) should be able to provide the current gps position, state of charge, temperature (outside, inside, motor, battery), speed, acceleration, energy consumption (overall and comfort systems), driving mode and charging status (on/off). The interface should be able to do a query to a routing service in the cloud and receive a route to display on a screen.

*Rationale:* Data has to be provided to train an AI model which is used for energy prediction. There has to be the possibility to use these energy forecasts for energy-optimized routing to save energy and reduce carbon emissions.

*Metrics:* yes/no

*Owner:* OTH

*ID:* AI4CSM_WP1_SCD2.1_9

*Name:* External data sources

*Description:* In addition to the data which is gathered in the vehicle itself external data sources should be used for the training and execution of the AI model which predicts power consumption. This includes the following data sources: street network map by Open Street Map, weather data from openweathermap, height data via Valhalla, traffic information from an appropriate provider.

*Rationale:* The AI model needs external data sources to be able to learn about the environments impact on power consumption and thus make precise predictions for the energy that will be consumed in a certain setting.

*Metrics:* yes/no

*Owner:* OTH

*ID:* AI4CSM_WP1_SCD2.1_10

*Name:* Training data

*Description:* A sufficient and appropriate number of data sets including the relevant parameters (e.g. velocities, altitudes, energy consumption…) has to be provided to train the AI model that predicts power-consumption.

*Rationale:* A self-improving AI model that makes precise predictions for the energy that will be consumed in a certain setting must be developed to enable energy-efficient routing.

*Metrics:* yes/no

*Owner:* OTH

*ID:* AI4CSM_WP1_SCD2.1_11

*Name:* Regular sufficient network connection

*Description:* All vehicles must regularly, at least once per day, have a network connection which allows sending and receiving AI model updates.

*Rationale:* Necessary because otherwise a vehicle cannot contribute to and profit from federated learning, which is used to enhance the AI models used for energy prediction.

*Metrics:* < 24 h up-/download

*Owner:* OTH

*ID:* AI4CSM_WP1_SCD2.1_12

*Name:* Protection of sensible data

*Description:* The data which is sent to the cloud for federated learning must be privacy-preserving. It must not be possible to draw conclusions from the model parameters to the sensible data points or the model parameters must be protected by appropriate security mechanisms.

*Rationale:* Sensible data has to be protected from abusive use by third-persons.

*Metrics:* yes/no

*Owner:* OTH

*ID:* AI4CSM_WP1_SCD2.1_13

*Name:* Interface to routing server

*Description:* The AI model takes speed, elevation profile, distance and further information from the routing server and returns the calculated energy consumption for this setting.

*Rationale:* The routing service needs the energy calculations done by the AI model to find the most energy efficient route.

*Metrics:* yes/no

*Owner:* OTH

*ID:* AI4CSM_WP1_SCD2.1_14

*Name:* Fast energy calculation

*Description:* The energy predictions by the AI model have to be fast to enable a low reaction time of energy based routing systems who use these calculations. A route of 30 minutes duration in an urban area has to be calculated in a tolerable duration by the routing engine.

*Rationale:* Long calculation durations for the energy optimized routing would decrease the user acceptance.

*Metrics:* yes/no

*Owner:* OTH

*ID:* AI4CSM_WP1_SCD2.1_15

*Name:* Energy calculation in the cloud

*Description:* The AI-based energy prediction that is needed for the energy efficient routing should be done in the cloud .

*Rationale:* If a routing service that is located in the cloud requires the predictions from an energy model that is located in the edge of an vehicle, the communication between these components results in potentially high latencies. This significantly increases the d

*Metrics:* yes/no

*Owner:* OTH

*ID:* AI4CSM_WP1_SCD2.1_16

*Name:* Accuracy of energy consumption model

*Description:* The energy consumption calculations which are done by an AI model are used as a basis for energy-efficient routing. Thus they have to be accurate enough to enable the fulfilment of the KPI's of the energy optimized route engine which is developed in SC1.

*Rationale:* Inaccuracies concerning the prediction of the power consumption lead to wrong results of the route generation. This causes a higher demand for energy and thus more carbon emissions which is the opposite of the project's goal. Furthermore miscalculations c

*Metrics:* yes/no

*Owner:* OTH

*ID:* AI4CSM_WP1_SCD2.1_17

*Name:* Federated learning with asynchronous availability of participants

*Description:* The federated learning system for enhancing the energy predictive AI models must be able to cope with asynchronous training and update periods of the different participating vehicles.

*Rationale:* It makes sense to postpone the task of training the AI model in the edge of an vehicle while this vehicle is in use. The reason for that is the increased power consumption during training which would otherwise result in a reduction of the vehicle's drivin

*Metrics:* yes/no

*Owner:* OTH

*ID:* AI4CSM_WP1_SCD2.1_18

*Name:* Balanced generic energy model

*Description:* The federated learning system should enable the creation of a self-improving generic AI model for energy predictions. This model has to be able to find a balanced solution also in case the data sets of the individual vehicles are not independent and not identically distributed.

*Rationale:* As not every vehicle is used in the same setting and with the same frequency the data sets that are used to train the AI models of the different vehicles will not be independent and not identically distributed.

*Metrics:* yes/no

*Owner:* OTH

*ID:* AI4CSM_WP1_SCD2.1_19

*Name:* AI Edge platform

*Description:* Training and executing the AI-model in the edge requires a platform with enough computing power and storage space.

*Rationale:* The training of the AI-model requires a lot of data sets, which are collected while the vehicle is driving.  They have to be stored until the training can be performed while the vehicle is charging. The computing power has to be high enough to finish trai

*Metrics:* yes/no

*Owner:* OTH

*ID:* AI4CSM_WP1_SCD2.1_20

*Name:* Post-hoc explanation of AI energy model

*Description:* Currently investigated methods for explainable AI will be applied and evaluated on the AI model for energy prediction.

*Rationale:* The prediction of the energy consumption is a critical feature because miscalculations could lead to situations in which the energy storage runs out before reaching the destination. Therefore the AI model needs to be explainable to be certified.

*Metrics:* yes/no

*Owner:* OTH

# 5 Conclusion

## 5.1 Contribution to overall picture

The results of Task 1.2 will make sure that the various demonstrators from the AI4CSM project will be fit for integration into the provided vehicle platform of Supply Chain 2. It will therefore allow for effective demonstration of these technologies in a real-world vehicle environment, contributing to the Technology Readiness Level (TRL) of each demonstrator.

## 5.2 Relation to the state-of-the-art and progress beyond it

| Partner/Topic | Description |
|---|---|
| **EDI** | The main role of different sensors[1] used in automotive is making driving safer and easier. A lot of current research goes into Surround View Systems[2,3] that can assist drivers to safely manoeuvre in different situations, where human perception is limited. In such systems the chosen sensors are often RGB cameras (or infrared for night vision), which don't provide depth information. The AI-based near-field, high resolution 360-degree perception system, based on 3D ToF imaging sensors, will make it possible to not only get visual data, but also semantically enhanced distance information of surroundings, thereby adding dynamic situational awareness to the vehicle. |
| **OTH** | **State-of-the-art:** Proprietary vehicle-type-dependent systems are used for energy prediction and range estimation of electric vehicles.<br>**Progress beyond:** Self-improving energy prediction models based on AI and federated learning are developed and validated using real-world vehicle data. |

## 5.3 Impacts to other WPs, Tasks and SCs

| Partner/Topic | Description |
|---|---|
| **EDI** | EDI will exploit the defined requirements from this deliverable for the guidance of the technical developments in WP3 and WP4, Task 3.4 "Components design for or AI-enabled perception and sensors fusion" and Task 4.5 "Embedded HW/SW and computing algorithms for perception and sensors fusion systems and platforms", integration tasks in WP5 - Task 5.2 "Integration of the AI-based EV demo vehicle" and tests/validation in WP6 Task 6.6 "Validation, verification and testing of AI-based perception systems and platform for ECAS vehicles". Additionally, the results will be exploited directly in SC2 "EV 2030 by AI inside". |
| **OTH** | The results of WP1 Task 1.2 build the basis for the upcoming tasks within WP2 dealing with the system level design and WP4 is responsible for the implementation of the proposed computing algorithms. The results are later integrated and verified within WP5 Task 5.2 and are verified within WP6 Task 6.2. The results of SC1 will later be used by SC2 in demonstrator SCD 1.3. |
| **TTTAUTO** | The results of WP1 Task 1.2 build the basis for the upcoming tasks within WP2 dealing with the system level design and WP4 is responsible for the implementation of the proposed |

[1]Biyao Wang, Yi Han, Di Tian, Tian Guan, "Sensor-Based Environmental Perception Technology for Intelligent Vehicles", Journal of Sensors, vol. 2021, Article ID 8199361, 14 pages, 2021. https://doi.org/10.1155/2021/8199361

[2]Al-Hami, M., Casas, R., El Salhi, S., Awwad, S., & Hussein, F. (2021). Real-Time Bird's Eye Surround View System: An Embedded Perspective. Applied Artificial Intelligence, 35(10), 765–781. doi:10.1080/08839514.2021.1935587

[3]https://www.nxp.com/applications/automotive/adas-and-highly-automated-driving/surround-view-:SURROUND-VIEW-PARK-ASSIST-SYSTEM

| | |
|---|---|
| | methods and concepts. TTTAUTO will build on the requirements in SC2 and map them to the development in SC5. Within SC5 selected modules and functions will be utilized in SC2. The findings are later integrated and verified within WP5 Task 5.2 and are verified within WP6 Task 6.2. |

## 5.4 Contribution to demonstration

| Partner/Topic | Description |
|---|---|
| **EDI** | Integration, testing and validation of the 3D perception system in the EDI connected and automated driving platform. |
| **MBAG** | Provision of vehicle platform as well as description of vehicle systems |
| **TTTAUTO** | Integration of selected functionalities into the demonstrator concerning communication and connectivity technologies. |

## 5.5 Other conclusions and lessons learned

| Partner/Topic | Description |
|---|---|
| **TTTAUTO** | The requirements defined in this document will be further analyzed and refined in WP2. Some of the requirements will need additional specification based on the use cases used in the demonstrator platform. |

# 6 References


[1] Biyao Wang, Yi Han, Di Tian, Tian Guan, "Sensor-Based Environmental Perception Technology for Intelligent Vehicles", Journal of Sensors, vol. 2021, Article ID 8199361, 14 pages, 2021. https://doi.org/10.1155/2021/8199361

[2] Al-Hami, M., Casas, R., El Salhi, S., Awwad, S., & Hussein, F. (2021). Real-Time Bird's Eye Surround View System: An Embedded Perspective. Applied Artificial Intelligence, 35(10), 765–781. doi:10.1080/08839514.2021.1935587

[3] https://www.nxp.com/applications/automotive/adas-and-highly-automated-driving/surround-view-:SURROUND-VIEW-PARK-ASSIST-SYSTEM

# List of figures

# List of tables

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