This project has received funding from the ECSEL Joint Undertaking under grant agreement No 101007326.
This Joint Undertaking receives support from the European Union's
Horizon 2020 research and innovation programme and the ECSEL member states.

Automotive Intelligence for Connected Shared Mobility

Deliverable	Report on SC7 use cases, scenarios, KPIs and requirements		
Involved WPs	WP1	Deliverable type	Public
Project	*AI4CSM*	Grant Agreement Number	101007326
Deliverable File	D1.7	Last Modified	27.05.2022
Due Date	27.05.2022	Actual Submission Date	27.05.2022
Status	public	Version	v1.0
Contact Person	Vahid, Lorenz, Gerald	Organization	AIDI+ Solutions GmbH
Phone		E-Mail	vahid@aidigi.de

Document history			
V	**Date**	**Author**	**Description**
1.0	21.04.2022	AIDI	Initial Draft
1.1	30.04.2022	AIT, AVL, TUG	Added contributions w.r.t. SCD7.1
1.2	04.05.2022	AVL, TUG	Added contributions w.r.t. SCD7.1

Disclaimer

Table of contents

1 Executive/Publishable summary

This document is intended to give an overview of the Task 1.7 Requirements and specifications for Connectivity and Communications which is assigned to the Supply Chain 7 of the AI4CSM project. The task comprises the identification of technical and non-technical requirements and specification concerning the communication sub-systems in the project.

The aim of SC7 is to develop new processes, systems and methods for AI in case of production as a closed loop approach (AIDG). The Generation of Licences and New Area of Methods and tools for Agile Intelligent Shared and connected mobility. To leverage AI techniques, such as Reinforcement learning, together with standardized real-world data in order to build safe systems. Together with industrial partners, AIT will research on efficient approaches for increasing trustworthiness of AI-based systems.

The results are Results of research and prototypical development will feed into ISO/SAE21434, ISO26262, and related standards from the vehicle domain. Results will also contribute the ongoing standardisation activities in ISO regarding AI (JTC1/SC42).

Within T1.7 we followed a bottom-up approach to collect and compile T1.7 results and findings of each individual task member:

- Partners concentrated on their individual work package tasks and contributed to the chapter of D1.7 describing their work executed for T1.7.
- The task leader provided a template for requirement definition. Partners used the template to collect their requirements and compiled them into a separate document.
- Inputs where reworked and consolidated. Furthermore, partners discussed cooperation and requirements alignment in the status meetings of SC7.
- The task leader compiled and aggregated the developed requirements into this document and described the approach and achievements in T1.7.

The following chapter of this deliverable D1.7 is describing the scope of the document and is giving an introduction and overview. The main chapter in which all SC7 partners describe their contribution in detail follows it. Finally, a conclusions chapter sets the work in context to related AI4CSM tasks and summarizes on the impact and contributions to the work packages and supply chains. The annex of this deliverable includes a detailed list of developed technical and non-technical requirements for the two demonstrators together with corresponding SC7 demonstrator descriptions.

2 Non publishable information

All the information below is publishable.

3 Introduction & Scope

3.1 Purpose, vision and objectives

The **AI4CSM** project will **develop advanced electronic components and systems (ECS)** and architectures for future mass-market ECAS vehicles. This fuels the digital transformation in the automotive sector to support the mobility trends and accelerate the transition towards a sustainable ecosystem.

The **vision** of Connectivity and Cognitive Communication in AI4CSM is as follows. SC7 peruses an end-to-end approach that integrates independent hard- & software elements into a comprehensive platform that can improve functionality and decrease complexity, with focus on:

- Improved Methods for Rigorous AI Development: Automated, shared driving very heavily depends on full Level 5 automation that can only be achieved using AI methods in a safety critical environment. So without this technology reduction of ecological footprint, as requested by the Green Deal, seems impossible to reach.
- Application of Munich Agile Concept for the improvement of processes and methods for climate neutrality, zero pollution Europe, sustainable transport and circular economy.
- Increased the traffic flow in urban areas and easy accessibility to cities from peri-urban areas through the provision of automated shared mobility services and their seamless integration with other public transport system (multi-modal transport system, mobility as a service).

The vision of the AI4CSM for AI-based Green Shared Mobility is to create a virtual and simulation-based ecosystem platform where universal mobility enables everyone to live well without having to own a vehicle. SC7 is the central enabler for AI methods, tools and processes to make AI accountable, available, collaborative, explainable, fair, inclusive, reliable, resilient, safe, secure, trustworthy, and transparent and maintains privacy. AI4CSM is working to create a robust mobility backbone, complemented by modes such as autonomous shuttles, micro mobility, shared ride hailing, and active transportation. In the context of AI Based Simulation and Virtualization for Multimodal mobility for virtual Smart Cities, SC7 strives to achieve:

- New methods for Green Shared Connected Mobility
- New Tools for Green Shared Connected Mobility
- New Systems for Green Shared Connected Mobility
- Interoperability between the different Systems
- Application of different Standards for a Shared multimodal mobility Systems

With D1.7 (T1.7) Report on Requirements for Simulation of AI-shared mobility system as a digital twin (AIDG)[m12] - The report will outline the specified SC1 use cases together with the targeted scenarios and KPIs referring to defined baselines for MAGIC Approach. In addition, the report will describe the requirements for virtualisation and simulation for cloud- and edge-based environment perception and vehicle ADAS functionalities together with the communication in between all the required sensors. Research and demonstration for methods, tools and processes for a trustable AI-based connected shared mobility with focus of trustworthiness, simulation and virtualization.

Objectives: 3, 5, 6

Innovation:

- Automated cloud-based learning and scenario generation
- Standardized data exchange for digital twins

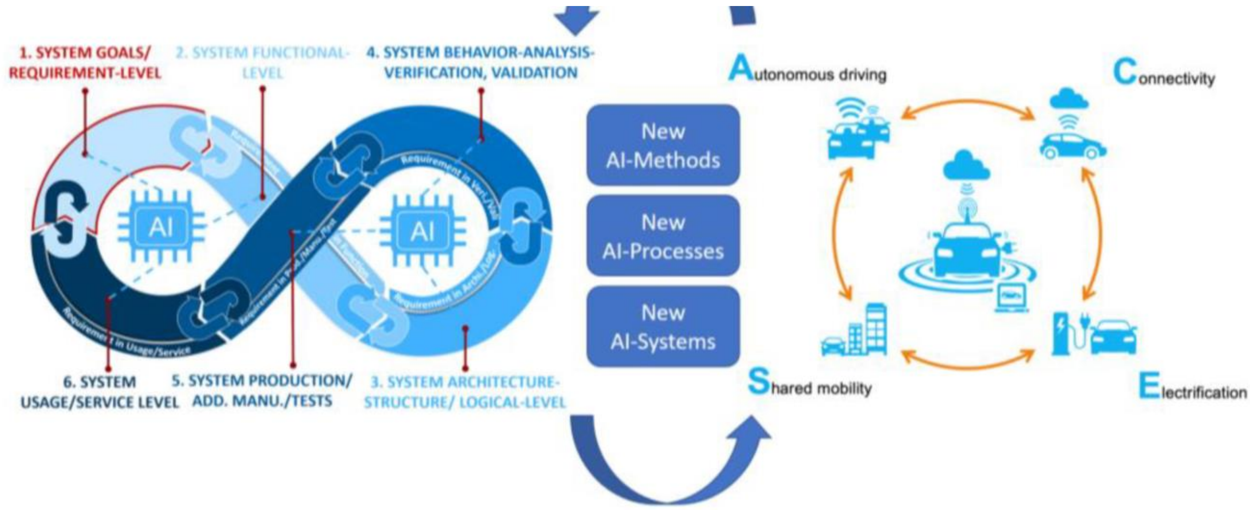

FIGURE 1: SC7 BIG PICTURE

3.2 Contributions of partners

Individual partner summarized their contributions in following table and provided detailed contributions in the referenced chapters.

TABLE 1 OVERVIEW PARTNER CONTRIBUTIONS

Chapter	Partner	Contribution
1, 2, 3, 4.3, 0	AIDG	Deliverable structure and draft outline, demonstrator SCD 7.1 description, requirements for demonstrator SCD 7.2 and SD7.3, conclusion section
0	AVL	Demonstrator SCD7.1 description, requirements for demonstrator SCD7.1
4.2	AIT	Demonstrator SCD7.1 description, requirements for demonstrator SCD7.1
4.2	TUG	Demonstrator SCD7.1 description, requirements for demonstrator SCD7.1
4.2	TTTech	Demonstrator SCD7.2 description, requirements for demonstrator SCD7.2
4.2	AIDG	Demonstrator SCD7.3 description, requirements for demonstrator SCD7.3

3.3 Relation to other activities in the project

As technology provider, supply chain 7 is for the integration of the Green Deal, Standardization, Certification and the ethical aspects related mainly to the output enabler in the project. In particular SC7 will provide SC1 with functionalities concerning communication architectures and approaches for car-2-car, and car-2-infrastructure communication. These will be achieved by providing and integrating technologies as WP5 activity. Figure 2 also highlights the relation to SC8 where AIT is predominantly active in linking the supply chain activities to existing initiatives in Standardization to foster the exploitation in this area.

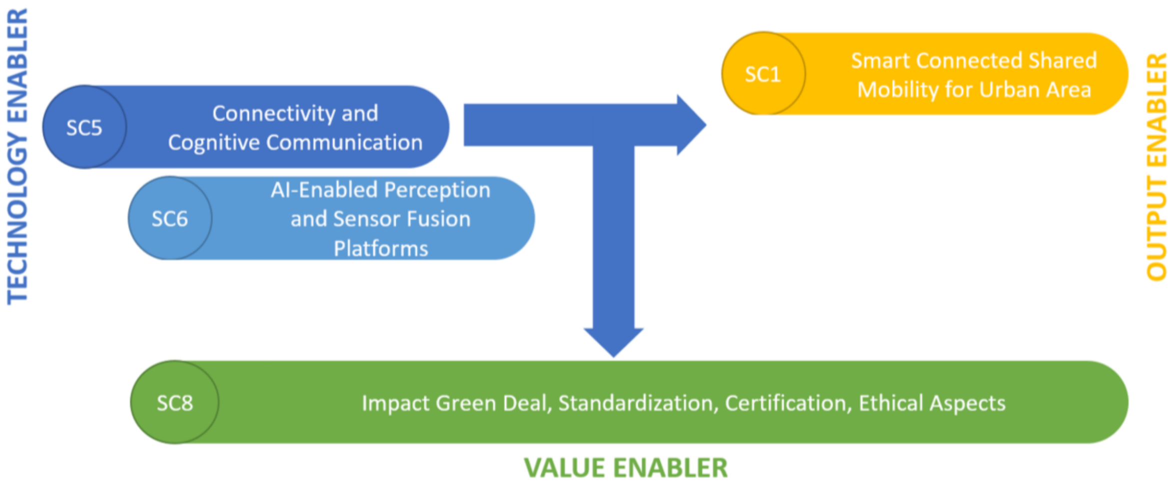

FIGURE 2: OVERVIEW SC7 INTERCONNECTIONS

Therefore, this supply chain will collaborate with the following supply chains in the following aspects:

- Showcasing of communication and connectivity functionalities into the demonstrator SC1 - **SCD 1.2** of supply chain "Smart Connected Shared Mobility for Urban Area".
- Alignment of interfaces for connectivity solutions with **SC2** and **SC3** during the sub-system design phase of AI4CSM.
- Close and bidirectional exchange with **SC8** concerning Standardization activities and inclusion of Green-Deal principles whenever possible into the development and design within SC7.

3.3.1 Output from these results

The results of task 1.7 are requirements of the components subsystems and specifications of the demonstrators SCD 7.1 and SCD 7.2 and 7.3. Objectives

The results and aim of this SC 7 is to use AI for digital twins, learning, scene interpretation and manipulation, data analysis as well to push today's limits while running AI at the edge. We want to reduce the amount of programming through visualization and simulation that is necessary today to automate and test automated driving vehicles. We want to use digital twins based on real world data as well as digitally enhanced real-world data to enable a more software orientated training of automated driving functions. We want to be able to build whole systems and systems of systems that are standardized or open source to exchange data for testing ne AI algorithms and methods, respectively. And we also want to be able to simulate the effects of multimodality on the traffic systems with a very precise representation of individual cities, ref to:

- Development of interoperability as well as standardization between the different systems: This aspect contains the details for a standardized data transfer incl. the necessary file formats to transfer data from real world driving to the cloud and to enable a subsequent data processing. This real-world data should be suitable to formats like OpenDrive.
- Development of virtualization tools for AI processing at the edge: The benefits of virtualization are progressing more and more from today's servers, PCs and smartphones into the car. With more powerful in car processing capabilities the use and application of virtualized AI based functions with timing and latency constrains are clearly shall be explored.

- Development of AI supported real world data virtualization (digital twins): Build automated and AI enhanced virtualized models of the surrounding that a vehicle passes to use the real world data for cloud based training as well as cloud based optimization strategies (multi-modal traffic solutions and improve traffic flow).
- Develop AI tools with multiple agents with observer elements for improved cooperation: Intensify the cooperation between multiple traffic partners through novel multiple agent AI techniques in order to improve the possibilities of connected automated driving as well as to improve the applicability of online learning.

Supply chain links:

- Interface alignment with technology enabler supply chains:
  - SC4: Robust Propulsion System for Shared Connected Mobility
  - SC6: AI-Enabled Perception and Sensor Fusion Platforms

Description of demonstrators

SCD 7.1: Enriched virtual models based on standardized real-world data (lead: AVL)

This demo showcases the virtualization of real-world driving data from the car until the validation. The work starts from the system level design for a raw data collection back end. Therefore, AVL will develop the requirements for the data centre to handle the collected data in real world driving and will implement the specification of the required inputs to virtualize data from real world driving. Based on this the system level design for a raw data collection back end and the subsequent data virtualization will be designed. This includes a new application to modify the converted data to enhance criticality and reuse collected data for system validation. AVL, AIT and TUG will work on this topic and will also take care to standardize the requirements regarding data collection, data formats and system design to ensure reliable systems and connected verification and validation approaches.

SCD 7.2: Virtualized time and latency critical AI processes on the in-car computing platform (lead: TTTech)

To ensure security of highly automated driving functions virtualization is one of the key tools that is currently used. Virtualization can also be used for AI processes. This demonstrator shall showcase the virtualization of AI processes and methods on the in-car computing platform. Thereby special emphasis will be put on the timing and latency constrains that are needed to perform automated driving functions. This demonstrator will research the architectural design and the SW methods that are necessary to enable the hosting, management, and orchestration of virtualized AI applications on the in-vehicle control system.

SCD 7.3: AI based simulation and virtualization for multimodal mobility for virtual Smart Cities (lead: AIDG)

The goal is to make a multimodal shared mobility simulation model including passenger cars, busses and e-bikes. In particular, the following visualization and simulation techniques are in the focus of interest:

- Functional Framework: Generic integration of the vehicle functions as well as their parameterization and versioning as well as parameterization of the 3D environment with. The framework will be used to record signals and characteristic values for quantitative evaluation of multimodal traffic solutions as well as to optimize traffic flow.

- Virtual models: The models used include highly accurate vehicle dynamics model as well as the models for the simulation of the surrounding traffic and its detection by sensors.
- Animation: For visualization and qualitative evaluation of simulations, but also for detailed sensor simulation.

4 Requirement collection process and methodology

The methodology followed in SC7 combines a top-down and a bottom-up approach, this means the two demonstrators within SC7 were defined first top-down the outcome and structure addressing the SC vision and objectives accordingly. To showcase the targeted SC7 objectives all requirements are then referred to the individual demonstrators and corresponding use cases including use case specific KPIs which are used to measure the success.

Task	Nr	***Name***	***Description***	***Rationale***	***Owner***
SCD7.2	1	Data requirements must be defined	Data requirements must be defined	for UC Implementation and Validation	AI Digi+
SCD7.2	2	The environmental data must be in a format suitable for editors/simulators.	Development of a smart 3D city model for the virtual validation of autonomous driving functions.	for UC Implementation and Validation	AI Digi+
SCD7.2	3	The data must provide high accurate data. (cm-range)	Data requirements	for UC Implementation and Validation	AI Digi+
SCD7.2	4	The data in the considered area must be complete.	The environmental data must be in a format suitable for editors/simulators.	for UC Implementation and Validation	AI Digi+
SCD7.2	4	The used data has to provide correct information.	The data must provide high accurate data. (cm-range)	for UC Implementation and Validation	AI Digi+
SCD7.2	5	The data has to include different levels of detail (min. 2 Levels).	The data in the considered area must be complete.	for UC Implementation and Validation	AI Digi+
SCD7.2	6	System requirements of involved author systems in the process.	The used data has to provide correct information.	for UC Implementation and Validation	AI Digi+

SCD7.3	6	Simulation Software Requirements.	The data has to include different levels of detail (min. 2 Levels).	for UC Implementation and Validation	AI Digi+
SCD7.3	7	Development of methods to transfer real world driving data into a virtual environment to enhance criticality of scenarios for validation of AD functions.	System requirements of involved author systems in the process.	for UC Implementation and Validation	AI Digi+
SCD7.3	8	The data should be collected in a meaningful way, i.e., unrelevant data should not be collected.	Simulation Software Requirements.	for UC Implementation and Validation	AVL
SCD7.1	9	Main Objective (Level 1)	Development of methods to transfer real world driving data into a virtual environment to enhance criticality of scenarios for validation of AD functions.	for UC Implementation and Validation	AVL
SCD7.1	10	Data Collection (Level 3)	The data should be collected in a meaningful way, i.e., unrelevant data should not be collected.	for UC Implementation and Validation	AVL
SCD7.1	11	Data Collection Triggering (Level 3)	The data collection process can be triggered by specified trigger actions.	for UC Implementation and Validation	AVL
SCD7.1	12	Data Collection Buffer (Level 3)	If not currently collecting data, the data should be stored in a buffer in case a trigger event happens.	for UC Implementation and Validation	AVL
SCD7.1	13	Data Format (Level 3)	The data must be in a format suitable for editors/simulation.	for UC Implementation and Validation	AVL
SCD7.1	14	Data Accuracy (Level 3)	The data must be accurate to reproduce the driving scenario in the virtual	for UC Implementation and Validation	AVL

			environment in a realistic way.		
SCD7.1	15	Data Correctness (Level 3)	The data should be checked regarding plausibility.	for UC Implementation and Validation	AVL
SCD7.1	16	Simulation Files (Level 3)	The resulting simulation files must be in a open source format.	for UC Implementation and Validation	AVL
SCD7.1	17	User Operability (Level2)	The User should be able to use the developed system, i.e., transfer real world data into a simulation environment and enhance the criticality without expert knowledge.	for UC Implementation and Validation	
SCD7.1	18	Systems Reliability (Level 3)	The developed methods should be able to generate 10 critical scenarios out of the collected data.	for UC Implementation and Validation	AVL
SCD7.1	19	System Efficacy (Level 3)	The developed methods should be able to generate critical scenarios in a reasonable amount of time.	for UC Implementation and Validation	TUG
SCD7.1	20	Properties of the critical scenarios generation algorithm available (Level 3)	Formalize the properties of the algorithm in detail, including termination condition, correctness, completeness and runtime expectations.	for UC Implementation and Validation	TUG
SCD7.1	21	Critical scenarios generation algorithm fulfills all properties (Level 3)	Use of testing for showing that critical scenarios generation algorithm conforms to all properties.	for UC Implementation and Validation	TUG
SCD7.1	22	Test Oracle Correctness (Level 3)	The oracle offers the right verdict for all test inputs.	for UC Implementation and Validation	TUG
SCD7.1	23	Test Oracle Completness (Level 3)	The oracle can offer a verdict (pass/fail/inconclusive) for any test input.	for UC Implementation and Validation	AIT

SCD7.1	24	Simulation Software	The use of open source software for simulation	for UC Implementation and Validation	AIT
SCD7.1	25	Format	Use of open formats like OpenDRIVE , OpenSCENARIO, etc. or other such wide-spread standards whenever possible	for UC Implementation and Validation	AIT
SCD7.1	26	Level of Detail	defining a (possibly small) set of very concrete use case scenarios – what exactly is being simulated, for example left turn at an intersection with multiple vehicles and pedestrians crossing	for UC Implementation and Validation	
SCD7.2	27	Hardware availability	AI/ML accelerators available for setup the demonstrator equipment	for UC Implementation and Validation	TTTAUTO
SCD7.2	28	SW driver available for improvement	Open source driver available for utilizing in the development of virtualization methods	for UC Implementation and Validation	TTTAUTO
SCD7.2	29	SW API from HW vendor sufficient	Features necessary to abstract the TPU/GPU resources in the abstraction layer	for UC Implementation and Validation	TTTAUTO

Figure 3: Overview SC7 Development of Requirements

4.1 Demonstrator specification

SC7 defines three specific demonstrators to address the targeted objectives and evaluate the selected KPIs:

SCD 7.1: Enriched virtual models based on standardized real-world data (lead: AVL)

This demo showcases the virtualization of real-world driving data from the car until the validation. The work starts from the system level design for a raw data collection back end. Therefore, AVL will develop the requirements for the data centre to handle the collected data in real world driving and will implement the specification of the required inputs to virtualize data from real world driving. Based on this the system level design for a raw data collection back end and the subsequent data virtualization will be designed. This includes a new application to modify the converted data to enhance criticality and reuse collected data for system validation. AVL, AIT and TUG will work on this topic and will also take care to standardize the requirements regarding data collection, data formats and system design to ensure reliable systems and connected verification and validation approaches.

SCD 7.2: Virtualized time and latency critical AI processes on the in-car computing platform (lead: TTTech)

The goal of this demonstrator is to showcase the results achieved by developing an architectural design and the SW methods that are necessary to enable the hosting, management, and orchestration of virtualized AI applications on the in-vehicle control system. Virtualization of hardware, in general, adds latency to the access time and thereby increases the processing time of a request as a whole. The activities in this demonstrator will access the consequences of such a virtualization effort with respect to timing and latency to evaluate the effect on AI/ML workloads on the in-car computing platform.

SCD 7.3: AI based simulation and virtualization for multimodal mobility for virtual Smart Cities (lead: AIDG)

The goal is to make a multimodal shared mobility simulation model including passenger cars, busses and e-bikes. In particular, the following visualization and simulation techniques are in the focus of interest:

4.2 SCD 7.1 - Enriched virtual models based on standardized real-world data (lead: AVL)

In this demonstrator, the partners AVL, AIT and TUG, show how to bridge the gap from collecting real-world data to trustworthy autonomous driving based on AI-controllers. It should be noted that SCD7.1 collaborates and is connected with SC1 and the demonstrator SCD1.1. With this, the overall goal is to integrate the results developed within SCD7.1 also to the demonstrator in SC1-SCD1.1.

To accomplish the goal of creating enriched virtual models, as a first step real-world data is collected based on data specifications that ensure that the required inputs for virtualization are available. After data pre-processing in the developed data center, we obtain the prerequisites for the conversion to a virtual testcase. As a next step this testcase will be converted to a suitable format, preferably to a Scenic or a MetaDrive scenario, which will allow us to train an AI-based controller for a concrete safety-critical scenario. We will shape the reward for the Reinforcement Learning control task, in order to learn a safe controller for autonomous driving. To achieve this, we will use formal specifications to specify our set of safe controller behaviors. Based on this formal specification, we synthesize our reward strategy for Reinforcement Learning and learn a controller for autonomous driving using a dedicated training environment, such as MetaDrive. In addition to that, we will utilize a monitoring system to evaluate and validate the developed methods and approaches.

In the following sections we give an overview about the key building blocks of the demonstrator, some evaluation metrics, and a description of the demonstrator platform as well as an outlook on the test plan.

4.2.1 Key building blocks

This chapter describes the key building blocks within the SCD7.1 demonstrator dealing with enriched virtual models based on real-world data.

4.2.1.1 Specification of AI4CSM building blocks

Fehler! Verweisquelle konnte nicht gefunden werden.3 gives and overview of the key building blocks of the SCD 7.1. The blocks show the different parts of the demonstrator starting with the real-world data collection and the virtualization. Followed by the conversion part and the training through reinforcement learning. The final step is represented by the evaluation and validation block.

Parts of the building blocks are developed separately and integrated during the progress of the supply chain in close alignment of all partners. Dedicated integration and evaluation events are planned in year two and three of AI4CSM and are also connected to SC1.

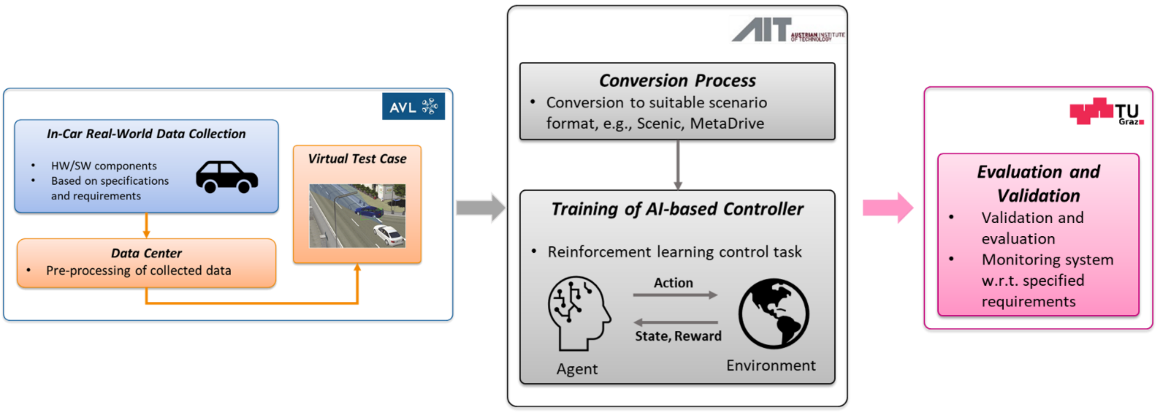

FIGURE 3: OVERVIEW OF THE KEY BUILDING BLOCKS.

Within the SCD7.1, AVL contributes to the implementation and development of the infrastructure for in-car real-world data collection. In more detail AVL works on the definition of specifications and requirements for the data center as well as its implementation. This ensures that all necessary signals are collected which are needed for the pre-processing step in the data center and the conversion to a virtual test case.

AIT contributes by processing the output of the previous key building block, i.e., a virtual test case, and with its conversion to a suitable format like Scenic or MetaDrive. Furthermore, AIT contributes with the implementation of a reinforcement learning strategy for the training of an AI-based controller for autonomous driving.

TUG contributes to the demonstrator by the setup of the evaluation and validation building block which will integrate a monitoring system capable of evaluating the performance of the AI-based controller through the implementation of a test oracle.

4.2.2 Validation concept

4.2.2.1 Validation strategy and evaluation metrics

In order to validate our developed methods within the demonstrator SCD7.1, we will integrate the AI-based controller, which was trained through reinforcement learning, into a simulation environment, i.e., CARLA. Within the simulation environment, safety critical scenarios, based on the abstract scenario of building block one, are executed. During the simulation of such a safety critical scenario, the ego vehicle equipped with the respective AI-based controller for autonomous driving, will be monitored by the developed and integrated monitoring system (integration into the simulation environment) to evaluate the behavior of the used controller. As a last step the outputs of the monitoring system will be analyzed and evaluated to investigate the overall performance of the controller.

With respect to evaluation metrics, the goal is to execute different safety critical scenarios based on the collected real-world data in order to cover a range of possible occurring scenarios and to evaluate the developed approach on a wider range of situations that might occur during driving. In addition, each safety critical scenario itself will be simulated multiple times with the integrated controller. To evaluate the overall performance of the developed methods, the outcome of each simulation will be analyzed by the monitoring system with respect to the number of passed and failed tests.

4.2.3 Demonstrator platform

The results developed within SCD7.1 will be demonstrated within a simulation environment. To ensure a seamless connection and integration of the implemented methods within SCD7.1 it is planned to utilize the open-source simulator CARLA[1]. Within CARLA the virtual test case resulting from collected real-world driving data will be executed, as well as the AI-based controller and the monitoring system will be integrated.

CARLA is a state-of-the-art open-source simulation platform used for the development, training, and validation of autonomous driving systems. Within CARLA it is possible not only to specify different sensor suits but also change environmental conditions and control different aspects like static and dynamic actors to bring additional diversity into the safety critical scenarios which should be correctly handled by the AI-based controller.

4.2.3.1 Test plan for evaluation

The following paragraph gives an overview of the demonstrations planned within SC7 and over the duration of AI4CSM.

Demonstration Y1 - Test Definition and CARLA Setup
In Y1 all the partners in SCD7.1 work towards the definition of the requirements, specifications, building blocks, interfaces between them and the evaluation criteria for the demonstrator. By Y1 we define the technology stack to be used for the demonstrator and the concrete scenario to be demonstrated.

Demonstration Y2 - Preliminary Results – Simulation Monitoring in CARLA
Preliminary results are provided in terms of scenario implementation in CARLA, the AI-based learning of the controller and the integration of the developed tools. The reward shaping for Safe Reinforcement Learning Control Task is defined.

Demonstration Y3 – Complete Toolchain Demonstration
In Y3 the complete toolchain will be demonstrated starting with the real-world data collection in a data center, the simulation of the virtual scenario in CARLA, the integration and autonomous driving capability of the AI-based controller during the execution of critical scenarios as well as the monitoring system for evaluating the performance of the controller.

[1] Dosovitskiy, A., Ros, G., Codevilla, F., Lopez, A., & Koltun, V. (2017). CARLA: An Open Urban Driving Simulator. Proceedings of the 1st Annual Conference on Robot Learning, 1–16.

4.3 SCD 7.2 – Virtualized time and latency critical AI processes on the in-car computing platform (TTTAUTO)

Artificial intelligence or machine learning applications are inevitable when following current trends in highly automated driving. Future generations of electrical vehicles will automate more and more tasks and therefore AI/ML workloads are experiencing a significant interest with new use cases. As a consequence, in mission-critical applications the requirement for real-time data processing and low-latency response emerge to ensure that such concepts mature from being purely lab-based into potential marketable solutions. Since deep-learning methods relies heavily on data and computation of complex machine learning algorithms, the edge computing paradigm proclaims to move the applications towards the sensors close to where the data is generated. The amalgamation of both edge computing and AI gave birth to a new frontier: Edge AI.

However, the applicability of this paradigm to the automotive industry depends on technologies and methods that support a scalable, flexible computing platform with the ability to deploy AI/ML workloads for safety and efficiency critical applications. Current in-car computing platform with complex architectures and multiple ECUs do not support such seamless integration yet. The flexibility to decide where to execute AI/ML tasks improves machine performance, and results in more efficient resource utilization. Further efficiency improvements can be expected by implementing smart services, that rely on the data from future connected devices. TTTAUTO will investigate the architectures and methods for virtualizing special kind of hardware (TPUs) that are used for accelerating the execution of AI/ML workloads to enforce the required flexibility for use cases in the automotive domain.

The planned activities and the developed methods showcased in the supply will contribute to the following project objectives:

- **O2** – Develop scalable embedded intelligence for edge and edge/cloud operation
- **O6** – Build ECAS vehicles for Green Deal for future connected shared mobility

The following sections give an overview on the key building blocks of the demonstrator, an exemplary scenario description, associated key performance indicators (KPI) and an overview of the demonstrator platform as well as the planned validation plan.

4.3.1 Key building blocks

This chapter describes the key building blocks within the SCD7.2 demonstrator towards the virtualization of AI/ML workloads and its analysis with respect to latency.

4.3.1.1 Specification of AI4CSM building blocks

Virtualization of hardware adds an abstraction layer and complexity to the overall system in order to orchestrate and manage the shared resource among different applications. On the other hand such a capability provides an environment where the AI model is fully incapsulated with all the parameters that are needed. From the clients applications come inference requests and relevant data that should be used to run the current model on the connected AI/ML processor. Figure depicts an closed source solution provided by NVIDIA. It enables separating a single GPU into isolated instances. However, this feature only allows increased isolation between CUDA applications and not a higher degree of control of GPU resources. Consequently, this feature cannot be a basis for virtualization techniques, such as remote execution. NVIDIA keeps the implementation of these libraries proprietary. This significantly hinders the research on novel GPU virtualization techniques for which the interaction of applications with the GPU devices has to be manipulated.

The computing platform is planned to be based on virtualisation approach and thus executing a type-1 hypervisor as well as workload manager to manage and execute virtual machines and containerized applications. To support the execution of containerized applications, the special services are running inside of a virtual machine (VM), which is managing every container and communicating through the virtual network provided by the system. In this design, the possibility to develop and deploy AI model as containers offers some advantages with respect to the creation and deployment of bare-metal applications:

1. faster development: containers can be installed inside an existing VM without problems and thus can easily be used without additional hardware.
2. easy reproducibility: containers can be configured through a text file that describes the execution environment, i.e., operating system, packages installed, environment variables set, volumes mounted, networks connected, etc. Using this file, the application source code and a running docker service, it is simple task to build the container image and run it.
3. less overhead for running small applications, since containers use the underlying kernel also as the kernel for the containers, each container is represented just by a process on the host machine (root VM).

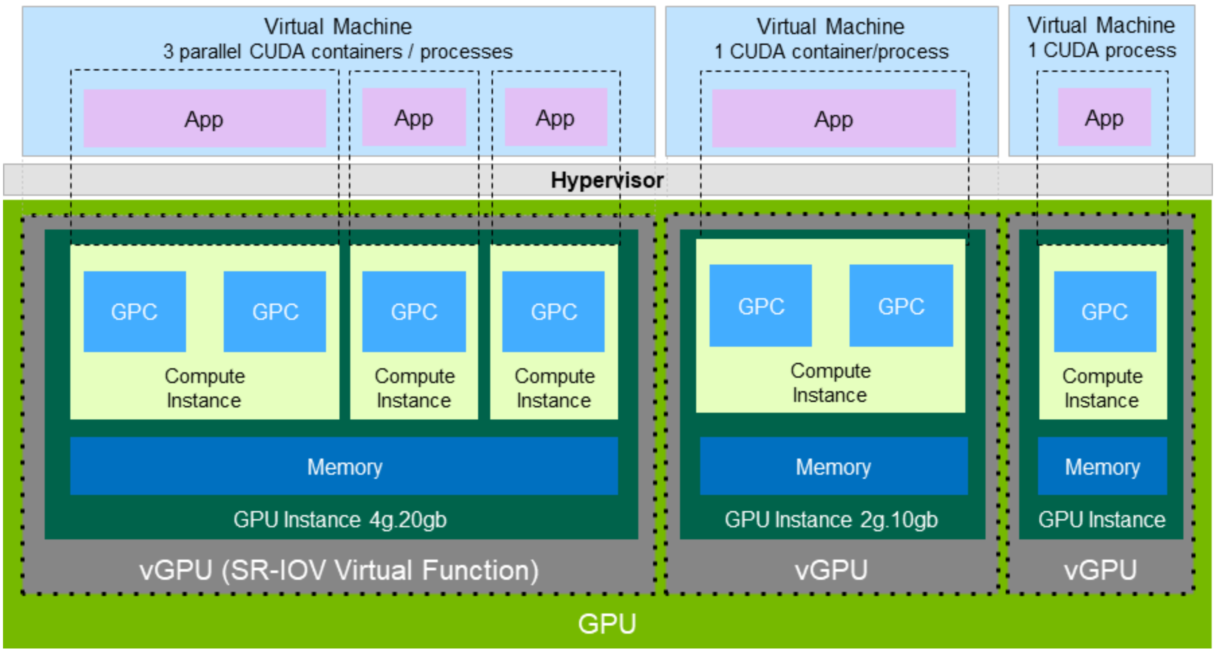

FIGURE 4: NVIDIA VIRTUAL GPU CONCEPT (CLOSED SOURCE SOLUTION).

4.3.2 Validation concept

4.3.2.1 Scenario specification

Virtualization of hardware, in general, adds latency to the access time and thereby increases the processing time of a request as a whole. Performance of non-virtualized hardware is often measured in the access latency or the request-processing time. Figure shows the difference between access latency and request time and illustrates the added latency when virtualization is introduced (yellow areas indicate additional delay). To assess the performance of virtualized hardware, these two metrics still must be considered, but a third is added to them: the processing time used up by the virtualization software, also referred to as virtualization overhead. This time can be estimated by first measuring the request-processing time of non-virtualized hardware and subtracting it from the virtualized version. Although, using this approach, no prediction can be made about the hardware-access time, it measures the complete virtualization overhead well.

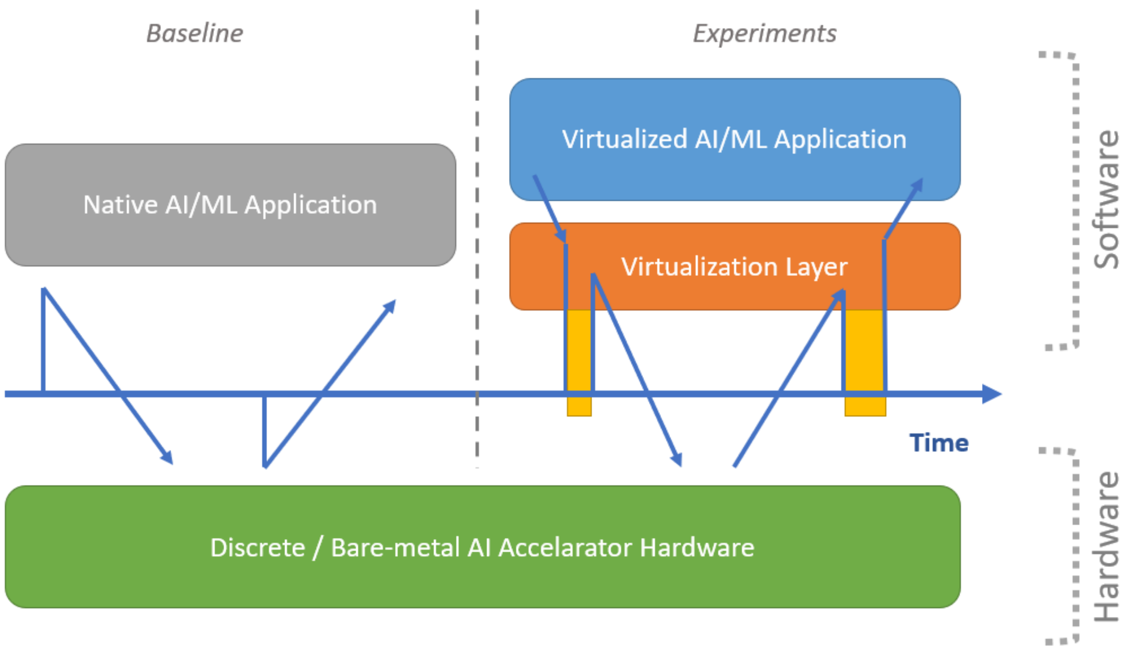

FIGURE 5: SIMPLIFIED SKETCH OF VALIDATION CONCEPT FOR THE SCD 7.2 DEMONSTRATOR

4.3.3 Demonstrator platform

The planned demonstrator platform is composed of the in-car computing platform by TTTAUTO in combination with additional external COTS edge TPU accelerators which will be tested for the described validation scenario in the previous paragraph. Both configurations, the non-virtualized and the virtualized, will be setup and benchmarked against each other considering the available integration interfaces (e.g., PCIe, etc.).

4.3.4 Test plan for evaluation

The following paragraph gives an overview of the demonstrations planned within SC7 and over the duration of AI4CSM.

Demonstration Y1: Evaluation concept definition and benchmark KPIs.
During the first year the SCD7.2 participants worked towards the definition of the requirements, specifications and concepts for benchmarking based on the evaluation criteria defined during this period. In addition, first attempts to design the sub-system level have been started.

Demonstration Y2: Preliminary Results on virtualized AI/ML workflows.

Y2 demonstrator will present preliminary results from implementing the concepts and methods in WP4 (Task 4.7). It is planned to evaluate and analyze the defined KPIs based on a sample AI/ML workflow in a lab environment.

Demonstration Y3: Final demonstration and performance evaluation.
At the end of the project the final demonstrator will showcase the developed concepts and evaluate the achieved performance compared to the baseline. The results will demonstrate the virtualization of an dedicated AI processes on the in-car computing platform utilizing special hardware accelerators.

4.4 SCD 7.3 – AI based simulation and virtualization for multimodal mobility for virtual Smart Cities

The vision of the 5.4 SCD 7.3 for AI-based Green Shared Mobility is to create a virtual and simulation-based ecosystem platform where universal mobility enables everyone to live well without having to own a vehicle. SC7 is the central enabler for AI methods, tools and processes to make AI accountable, available, collaborative, explainable, fair, inclusive, reliable, resilient, safe, secure, trustworthy, and transparent and maintains privacy. SCD 7.3 is working to create a robust mobility backbone, complemented by modes such as autonomous shuttles, micro mobility, shared ride hailing, and active transportation.

In the context of AI Based Simulation and Virtualization for Multimodal mobility for virtual Smart Cities, SC7 strives to achieve:

- New methods for Green Shared Connected Mobility
- New Tools for Green Shared Connected Mobility
- New Systems for Green Shared Connected Mobility
- interoperability between the different Systems

The planned activities and the developed methods showcased in the supply will contribute to the following project objectives:

- **O2** – New Methods and Tools and ProcessesDevelop scalable embedded intelligence for edge and edge/cloud operation

4.4.1 Key building blocks

4.4.1.1 Specification of AI4CSM building blocks

Figure depicts the key building blocks of the SCD 7.3, mentioning the different partner contributions and connections of the building blocks. The blocks show the different parts of the communication and connectivity solutions. This Key Building Blocks are:

- Adaptation of generic MAGIC models to serve as templates for the performance evaluation part within the frame of the decision support models for shared and connected mobility in field of research
- Evaluation of the suitability of the generic MAGIC models to simulation in research and laboratory environment.
- Proof of concept -MAGICFLOOP software prototypes of the proposed overall planning and management approaches.

- Test of the applicability of the approaches against real-life data from sample domains provided by an industrial partner.

The project results are used directly and indirectly in the form of close cooperation between the industrial and scientific partners in the consortium. Generation of Licences and New Area of Methods and tools for Agile Intelligent Shared and connected mobility concept based on EU Green Deal. When presenting the prospects of economic success and the connectivity, the exploitation of the results can be considered from an industrial perspective as well as from the perspective of the city. From the point of view of all participating companies (OEM and SME), the expected economic exploitation of the project results is beneficial in several ways. The know-how generated from the project will serve to expand competence and help regional companies to change from a focus on "mechanical engineering" to more interdisciplinary service and IT competence.

AIDG developed the Definition of a structure for the planning and control of a domain-oriented mobility network with different planning stages.

- Identification of relevant requirements alongside the different pillars of the project - Digital AI based shared mobility with the AI Lifecycle Management.
- Development and solving of associated decision models.
- Test of the applicability of the approaches with the help of the simulation models constructed.
- Adaptation of generic models to serve as templates for the performance evaluation part within the frame of the decision support models for shared and connected mobility
- Evaluation of the suitability of the generic models to simulation.

4.4.2 Demonstrator platform

This section gives a general description of the targeted demonstration platforms, which are applied in order to demonstrate the performance. The demonstrators will be carried out on the platform MAGIC LOOP.

The system goal/requirement level contains all customer needs and wants in relation to the product and its requirements. This means that the challenge in the early stages of product development is to understand the customer's needs and translate them into technical requirements. In product development and process optimisation, a requirement is an individually documented physical and functional need that a particular design, product or process must fulfil. It is most commonly used in a formal sense in systems engineering, software engineering or enterprise engineering. It is a statement that identifies a necessary attribute, capability, feature or quality of a system so that it has value and utility to a customer, organisation, internal user or other stakeholder. A specification can refer to an explicit set of requirements that must be met by a material, design, product or service. In the classical engineering approach, sets of requirements are used as input to the design phases of product development. Requirements are also an important input for the verification process, as tests should be traced back to specific requirements. Requirements show which elements and functions are necessary for the project in question. This is reflected in the waterfall model of the software life cycle. However, if iterative software development methods or agile methods are used, system requirements can be developed incrementally in parallel with design and implementation. The system functional level is a method for understanding the overall product and defining the structure and behaviour of a system. A system is structurally represented by the functional or structural relationships between the individual components or sub-functions in relation to the technical requirements. With the creation of a functional system architecture, it is possible to identify the different functions in the overall system. The technical system architecture of the MAGICLOOP approach describes a rough geometry, the design and concepts of the components, the kinematic models, the logical models and the modelling, the simulation tool used for the application example. It defines "how" the functional requirement is to be achieved - and there can be several ways to achieve these requirements. At the logical level, the realisation of the functions is modelled by the interaction of mechanical, electronic and software components. Different types of signals exchanged (e.g. control signals) as well as the type of persistent data. The analysis of the overall system behaviour based on relevant parameters can be displayed quickly and clearly. In everyday language, verification is the answer to the question: Is a correct product being developed? System verification generally means the proof of truth of statements. Applied to technical systems, it means checking whether the way something is realised corresponds to the specification. When checking the validity of a programme, one also speaks of programme verification. Verification is usually realised in a formal way. Validation, on the other hand, is the answer to the question: Is the right product being developed? In empirical social research, system validation originally meant checking the validity of a measurement method, i.e. the extent to which test results actually capture what the test is supposed to determine. Transferred to technical systems, this means checking whether the product is suitable for the intended purpose or achieves the desired value. Validation includes, for example, checking whether the description of an algorithm matches the problem to be solved. As a rule, it does not have to be carried out in a formal manner.

5 Conclusion

5.1 Contribution to overall picture

This deliverable provides requirements and specifications relevant for the design, integration, and verification of the communication and connectivity platform and methods to access data from the edge (e.g. cars, infrastructure) and the cloud (e.g. city-model) and fulfil fast, reliable, low-latency data connections in future shared mobility technologies. All specified requirements are linked to function blocks within the demonstrators to be able to track them during the development process efficiently and to avoid misunderstandings which partner is the specific owner of the requirements. All partner contributions are linked to individual demonstrators in the urban area. The developed software building bricks are continuously evaluated with KPIs in the field of safety, efficiency, and compliance with the Green-Deal. All defined KPIs are evaluated against a specified baseline. All specified requirements for the targeted SC7 technology bricks are synchronized with other technology enabler via this document, where the performance is evaluated on component and subsystem level before the integration on entire system level into the real-world demonstrators planned in SC1. To ensure consistent integration of the components, especially within the output enabler supply chain SC1 all interfaces to the other technology enabler SCs are clearly defined and synchronized during the requirements collection process.

5.2 Impacts to other WPs, Tasks and SCs

Table 2 briefly lists in which WP’s, tasks, and SC’s the outcome of task 1.7 will be used later in the project. The table is organized per partner or per topic.

TABLE 2: OVERVIEW OF WP, TASK AND SC INTERCONNECTIONS

Partner/Topic	Description
IFAG	
AIT	The requirements and specifications described in this deliverable will be passed to the consecutive tasks in WP2 (T2.7) for system-level design, WP4(T4.6) dealing with the implementation of algorithms, WP5 (T5.7) system integration and WP6 (6.7) responsible for validation and testing. In addition, the results of this deliverable are also strongly connected with SC1 and its demonstrator SCD1.1 and the respective tasks.
AVL	The requirements and specifications described in this deliverable will be passed to the consecutive tasks in WP2 (T2.7) for system-level design, WP4(T4.6) dealing with the implementation of algorithms, WP5 (T5.7) system integration and WP6 (6.7) responsible for validation and testing. In addition, the results of this deliverable are also strongly connected with SC1 and its demonstrator SCD1.1 and the respective tasks.
TUG	The requirements and specifications described in this deliverable will be passed to the consecutive tasks in WP2 (T2.7) for system-level design, WP4(T4.6) dealing with the implementation of algorithms, WP5 (T5.7) system integration and WP6 (6.7) responsible for validation and testing. In addition, the results of this deliverable are also strongly connected with SC1 and its demonstrator SCD1.1 and the respective tasks.
NXP	The requirements described in this deliverable will be considered in WP2 (T2.5) for system-level design, WP3 (T3.3) for embedded HW/SW for connectivity and communication, in WP4 (T4.4) for cross-protocol in-car communication architecture., in WP5 (T5.5) for system integration, and in WP6 (T6.5) for validation and testing
IMA	
FHG (HHI)	
TUD	The requirements described in D1.7 will guide WP2 (T2.5) for system-level design and WP4 (T4.4) for provisioning the communication and computation architecture in a novel, predictive way. Subsequently, in WP5 (T5.5), the system will be integrated, after which it will be validated and tested in WP6 (T6.5).
TTTAUTO	The results of WP1 Task 1.7 build the basis for the upcoming tasks within WP2 dealing with the system level design and WP4 responsible for the implementation of the proposed methods and concepts. The results are later integrated and verified within WP5 Task 5.7 and are verified within WP6 Task 6.7.
Requirements, scenarios, KPIs, demonstrators and evaluation plans.	Links to the other technology enabler SCs (SC4, SC6, SC7) are established to ensure consistent interfaces that are of particular interest during the integration of the developed components and subsystems. A dedicated link is established into SC1, which focus on the integration of SC7 modules into one of the SC1 demonstrators later in the project (WP5, WP6).

5.3 Contribution to demonstration

Table 3 briefly describes the relation between task 1.7 and the planned demonstrators. The table is organized per partner.

TABLE 3: OVERVIEW OF CONTRIBUTIONS TO DEMONSTRATORS

Partner/Topic	Description
IFAG	IFAG will focus on implementation of algorithms for secure external communication, with high data rates (5G) and bandwidth. The cloud fusion will be designed with fast and reliable wireless communication channels based on 28 GHz mmW technology.
AIT	Research on scenario-based methods for safety in autonomous driving AI-based controllers.
AVL	Demonstrate the collection of in-car collected real-world data and its processing in a data center in order to virtualize the collected data.
TUG	Demonstrate the integration of a monitoring system into the CARLA simulation environment responsible for evaluating the performance of AI-based autonomous driving controllers.
NXP	Demonstrate qualitative and quantitative results of safe and secure in-vehicle network. In addition, traffic captures will be obtained to document realistic in-vehicle traffic behaviour.
IMA	Embedded SW components for V2I communication platform - ID reader embedded SW, communication gateway, mobile application, and SW interfaces within the infrastructure. New computing AI algorithms will be embedded to enable new infrastructural services
FHG (HHI)	Interface specification of the developed onboard processing and baseband unit towards the 28GHz beamforming antenna from IFAG as well as the interface to the main domain controller (Brain). The onboard processing and baseband unit implements the 5G V2X connectivity in the mm-wave and sub-6 GHz bands (26/28 GHz and 3.7 GHz)
TUD	Demonstrate the availability and performance of a proactive and on-demand provisioning system for edge compute and other functionality. Traces of the behaviour of deployments and scaling will be recorded, together with the respective ingress (traffic and computational workload). The foundation for mapping of (specific) tasks to accelerators are laid herein.
AIDG	AIDG conducted an as-is analysis about the environment and status of data, systems and processes with a focus on the vehicle and will research the requirements based on the current Data transmission options and standards for vehicle-environment communication. The Platforms MAGIC are the baseline to be applied for the Simulation Use Case and researched actual status and identification of key problems in urban traffic. Conception of possible solutions and definition of a catalogue of measures for the urban framework.
TTTAUTO	The potential of methods for virtualizing AI computing resources in a middleware for automated driving will be investigated. The analysis will focus on a setup

	utilizing COTS hardware and the adapted SW framework to access the applicability concerning safety and latency requirements for decision making processes.

6 References

7 Appendices

The Appendix contains the consolidated requirements and the demonstrator descriptions. Content is publishable.

1. Demonstrator descriptions:
    a) AI4CSM SC7_1 Demonstrator
    b) AI4CSM SC7_2 Demonstrator
2. Key building block requirements:
    a) AI4CSM SC7 Requirements

List of figures

List of tables