This project has received funding from the ECSEL Joint Undertaking under grant agreement No 877539.
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ArchitectECA2030

Trustable architectures with acceptable residual risk for the electric, connected and automated cars

Deliverable	***Report on requirements and targets for fault detection in acquisition and perception***		
Deliverable File	***D1.1***		
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Contact Person	Richard Kelley	**Organisation**	UNEV
Phone	___	**E-Mail**	rkelley@unr.edu

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V0.2		TUDR	Input SSC1
V0.4		VIF	Input SSC2
V0.99		Cristina De Luca	Review
V0.99.1	07.06.21	UNEV	Merging previous drafts for final review and submission
V0.99.2	16.07.2021	IFAG	Review layout
V0.99.3	23.08.2021	VW	Add content for demo 1.4
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1 Executive/ Publishable summary

When investigating ECAs, three phases of a journey can be identified in chronological order. The journey begins with a charging process, followed by the journey from the starting point to the end point. The journey ends again at a charging point where another charging process is initiated. Considering these phases from a safety perspective several challenges are observable for perception systems.

First, a robust charging, to get ready for the trip with your ECA is curial. Wireless charging systems must be able to determine any objects near the system that could potentially cause unsafe conditions at any time during charging operation and to take appropriate action by alerting the operator or powering down when needed. Therefore, such systems require a working foreign object detection (FOD) system. After charging a safe and robust travel in different disturbing environments (ODDs) with and challenging localization areas (e.g., urban canyons) is needed. To do this, an ECA needs to perceive and understand its surrounding environment. After a safe travel, a trip finishes with an arrival at target location and recharging at charging point for following trip.

These challenges are represented in four specific demonstrators for the supply chain.

- Demonstrator 1: Foreign object detection within a wireless charger (TUDR)
- Demonstrator 2: Robust operation of EPS in disturbing environments (VIF)
- Demonstrator 3: Robust virtual perception systems (VIF)
- Demonstrator 4: Road segmentation using 2D a camera (VW)

This deliverable defines the requirements for all demonstrators in Supply Chain 1.

Keywords: perception, safe travel, fault detection, robust virtual perception, wireless charger

2 Introduction & Scope

2.1 Purpose and target group

Within this deliverable, the demonstrators investigated in Supply Chain 1 “Failure modes, fault detection and residual risk in acquisition and perception systems” are elaborated and explained in detail. This document summarizes the activities that members of Supply Chain 1 will undertake under the umbrella of the ArchitectECA2030 project.

This document will be useful to anyone interested in the high-level vision and plans of the demonstrators related to Supply Chain 1. The document will also be useful to project evaluators at the end of the project period of performance.

2.2 Contributions of partners

The partners in Supply Chain 1 contributed in a number of ways, from the start of the project through to the current project month. Supply Chain 1 held regular meetings in which the demonstrators below were discussed, developed, and refined. Specific contributions of partners, both for the demonstrators and for this document, can be found in Table 1 below.

TABLE 1: CONTRIBUTIONS OF PARTNERS

Chapter	Partner	Contribution
	UNEV	Document organization and structure
7	VW	Requirements for a perception system that automatically segments 2D image sequences to estimate lane markings and lateral vehicle position.
	DATA	
	IFAT	
5	TUDR	Requirements for a system to detect metallic and/or magnetic foreign objects within the operating area of wireless power transfer systems for charging the traction battery of automated vehicles.
6	VIF	Requirements for a perception system that operates in degraded environmental conditions, and for a virtual sensor system.
	IFAG	Minor

2.3 Relation to other activities in the project

The D1.1 to D1.4 can be considered as a fundamental block for the definition of the ArchitectECA2030 requirements' rules.

In these Deliverables, on the basis of the different demonstrators in the SCs, are illustrated the fundamentals for the definition of residual risk in connectivity systems, the requirements and targets for fault detection in acquisition and perception and in actuators and propulsion systems, last but not least the requirements and targets of reliability and safety at system level.

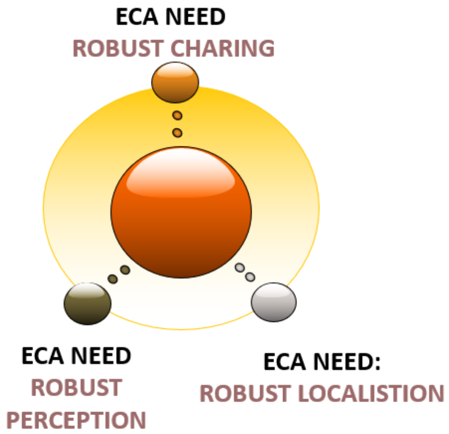
Obviously, the Deliverables are linked to all subsequent tasks in the different WPs, needed to fulfil the defined requirements based on the demonstrators. This deliverable targets SC1 "Failure modes, fault detection and residual risk in acquisition and perception systems" and provides output to the subsequent tasks allocated in the following WPs.

2.4 Main objectives and key targets overview

The relation is to the main objectives and key targets is described in the following sections for each demonstrator separately.

3 Supply Chain 1 Overview and Demonstrators

Error! Reference source not found. shows the needs which motivated the definition of the three demonstrators of Supply Chain 1.



After being charged an ECA needs to perceive the surrounding environment to drive safely to its intended target locations. It also needs to understand its location in a robust manner. Based on these needs three different demonstrators were formulated. These are:

- Demonstrator 1: Foreign object detection within a wireless charger (TUDR)
- Demonstrator 2: Robust operation of EPS in disturbing environments (VIF)
- Demonstrator 3: Robust virtual perception systems (VIF)
- Demonstrator 4: Road segmentation using 2D a camera (VW)

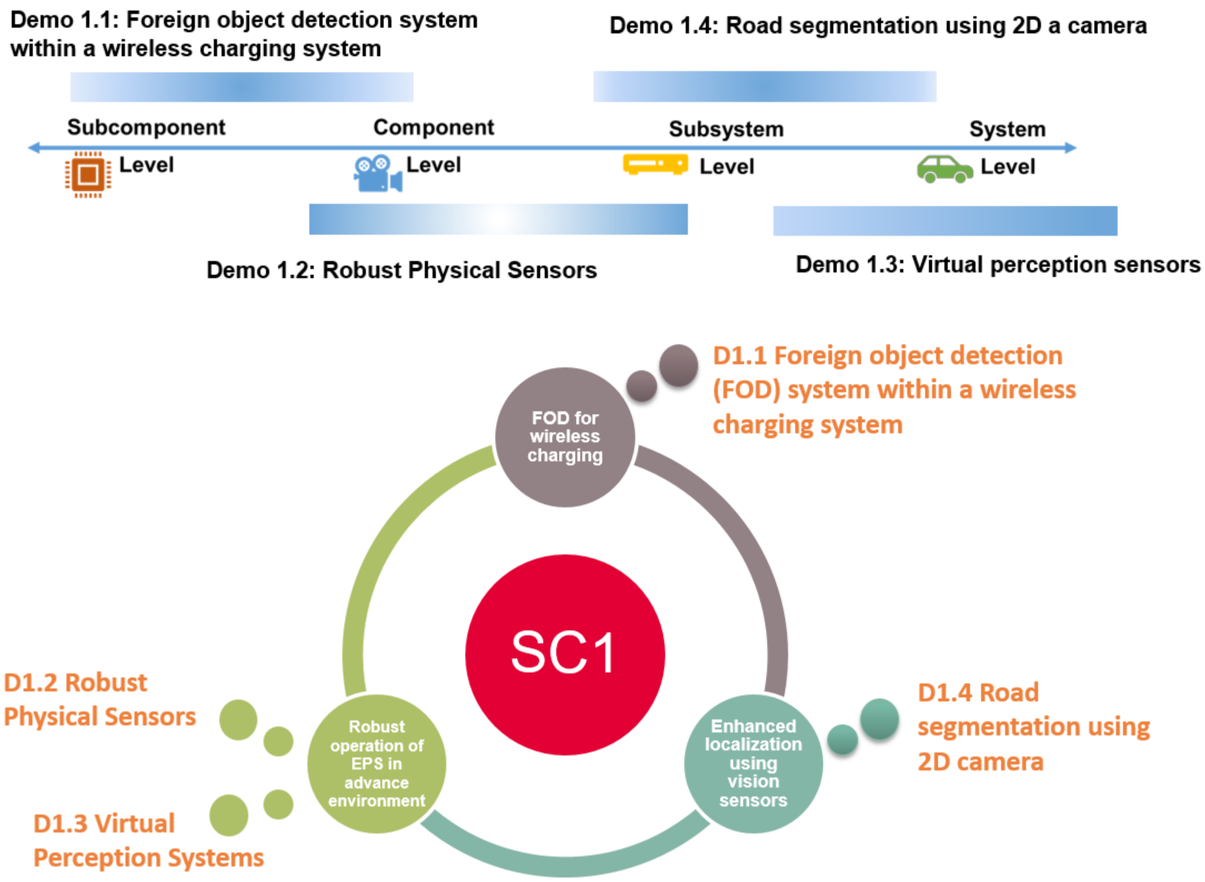


FIGURE 1. SUPPLY CHAIN 1 AND DEMONSTRATOR STRUCTURE

Figure 1 shows summarizes the respective demonstrators. Supply Chain 1 will have 4 demonstrators, which are listed in Table 2.

TABLE 2: DEMONSTRATOR OVERVIEW OF SUPPLY CHAIN 1

SC1	Demonstrator #.#	Title
Acquisition and perception	Demo 1.1	FOD for wireless charging TITLE: Foreign object detection (FOD) system within a wireless charging system
Acquisition and perception	Demo 1.2	Robust operation of EPS in advance environment TITLE: Robust Physical Sensors
Acquisition and perception	Demo 1.3	Robust operation of EPS in advance environment TITLE: Virtual Perception Systems
Acquisition and perception	Demo 1.4	Enhanced localization using vision sensors TITLE: Road segmentation using 2D camera

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4 System level view

The demonstrators investigated in the supply chain are all to be found on a subsystem level of the overall vehicle (as shown in Figure 2).

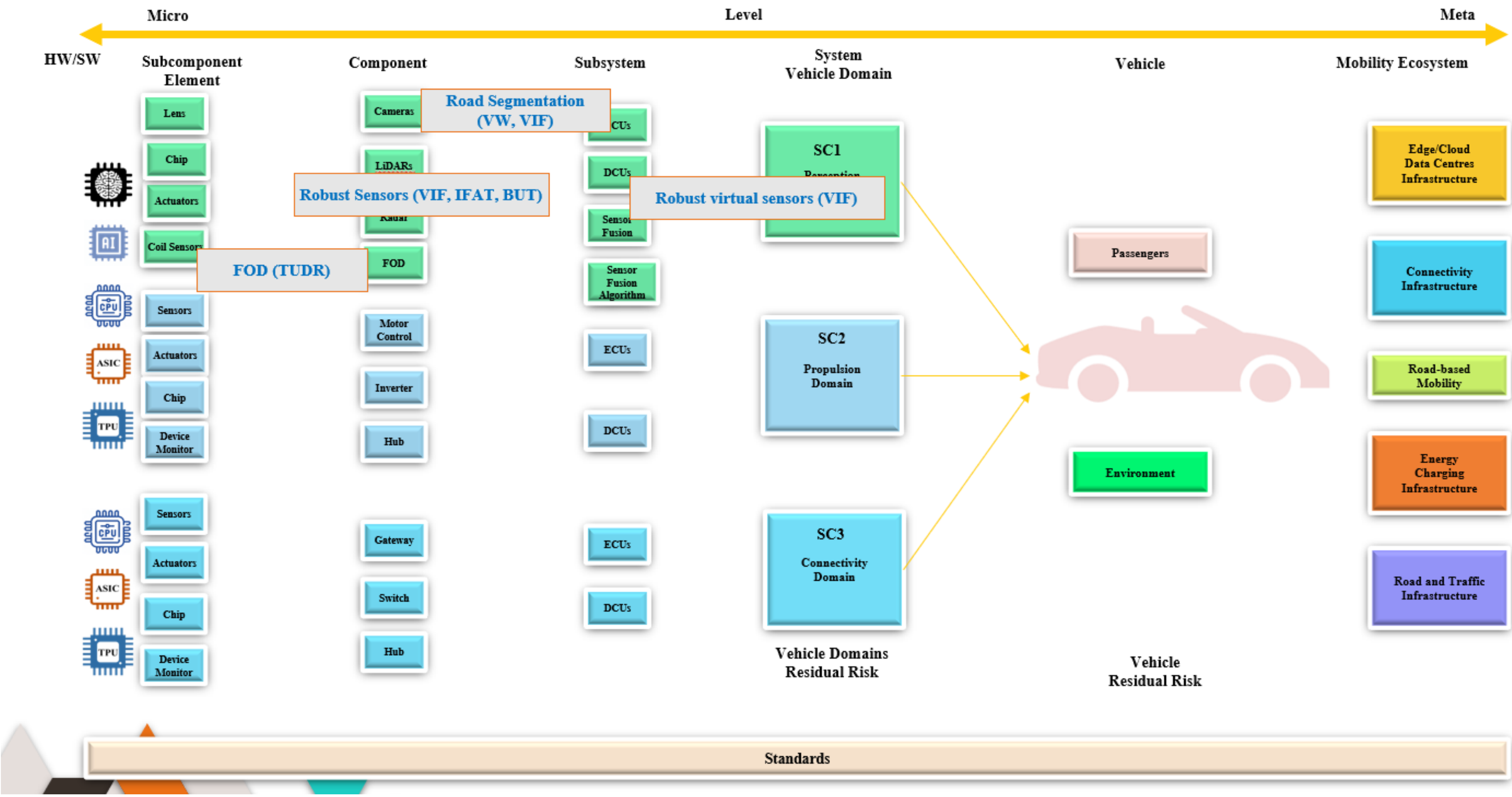

FIGURE 2: ALLOCATION OF DEMONSTRATORS TO VEHICLE LEVELS

The following chapters provide detailed insight on the requirements per demonstrator.

5 Demonstrator 1.1: Foreign object detection system within a wireless charging system

This demonstrator focuses on the interactions between wireless charging systems and metallic and/or magnetic objects that are not part of the system. During the charging process of the traction battery, energy is transferred to the vehicle via a magnetic field. Due to the magnetic flux between **the ground assembly** (GA) coil under the vehicle and the **vehicle assembly** (VA) coil, such a foreign object can get very hot.

If the foreign object lies directly on the surface of the GA, one of the possible consequences of the heating is a damage to the surface of the GA. In the worst case, this can lead to faults that are relevant to safety, such as a possible contact with an electrically conductive part in the GA. Other possible consequences include burns of human body parts when touching such a highly heated foreign object or the ignition of such a foreign object under the vehicle. Therefore, wireless charging systems must be able to detect foreign objects in close proximity to the system at any time during the charging operation and take appropriate action by alerting the operator or powering down if necessary. The subsystem responsible for this task is called a foreign object detection (FOD) system.

An FOD system must be able to detect foreign objects and prevent overheating. According to the standard SAE J2954, the FOD system is part of the safety process and one of the main functional elements of the charging system.

In the literature, a very wide repertoire of different ways to detect foreign objects in wireless charging systems is described. A good overview of the different methods is given in [Xia et al, 2020] and [Jeong et al, 2015]. This project will investigate passive inductive sensors as described in [Verghese et al, 2013], [Jang et al, 2016], [Rim et al, 2017], [Jeong et al, 2018], and [Verghese et al, 2020].

5.1 Target goals and achievements

If there is a risk of overheating and/or ignition of foreign objects, a wireless charging system needs a suitable and working FOD system. For this purpose, for example, the standard SAE J2954 defines test procedures that can be used during the development and production of the charging system to evaluate the performance of the FOD system that is used. However, a FOD system should be designed in such a way that its functionality can also be tested at runtime. Tests at runtime must be able to cope with two uncertainties: a possible malfunction of the FOD system and the possible presence or absence of a foreign object during the test.

The demonstrator is intended to show the characteristics of typical sensors for foreign object detection. Different variants of passive inductive difference sensors will be used, which represent the current state of the art and are described in literature and patents. Not only the test case given in the standard SAE J2954 shall be considered, where a test object is placed directly on the surface of the GA at the location of the highest magnetic flux, but also the influence of the test objects on the sensors shall be investigated at different positions on the surface of the GA and in the space between the GA and the VA. Furthermore, the influence of typical environmental conditions, such as rain, snow or ice, shall be modeled.

Furthermore, test procedures will be proposed that can be used during the entire operating life of the charging system to test the functionality of the FOD system.

5.2 Demonstrator structure

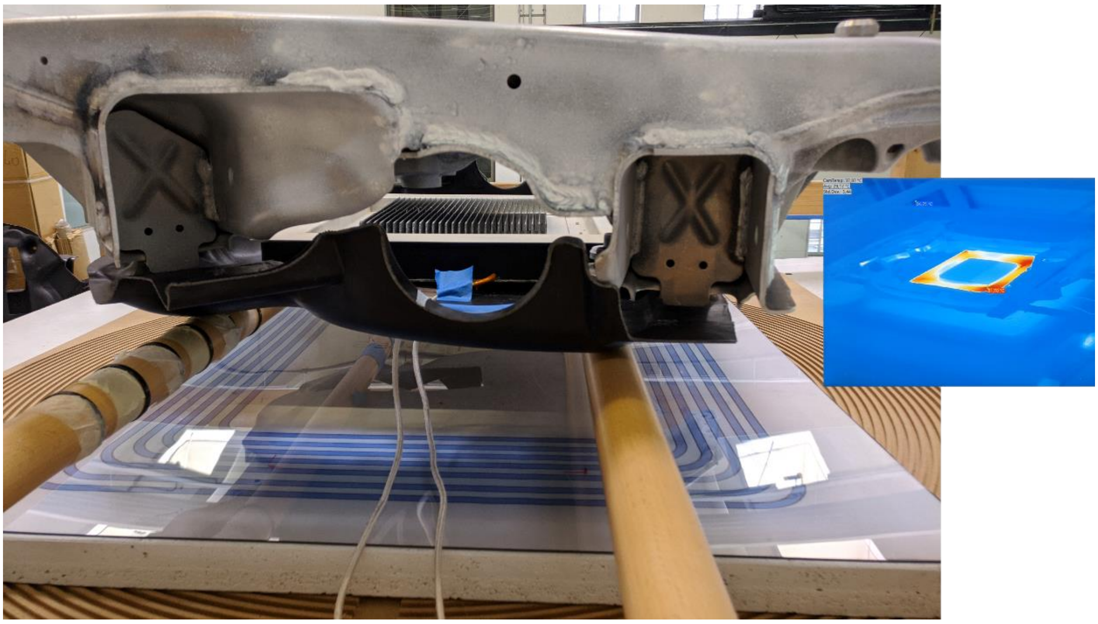

FIGURE 3: TEST BED WITH GA- AND VA-COIL OF THE CHARGING SYSTEM AS WELL AS PARTS OF THE REAL VEHICLE (SOURCE: TU DRESDEN/ILK)

The demonstrator consists of several measurement setups for the wireless charging test bed shown in **Error! Reference source not found.** and available at the Institute for Lightweight Engineering and Polymer Technology (ILK) at TU Dresden (TUDR). Here, the most important constraints for the charging system a non-metallic and non-magnetic environment and an energy source and sink for at least 11 kVA are given.

5.3 Demonstrator description

The demonstrator's frame component is a wireless charging system capable of charging a 400 V traction battery with a power level of up to 10 kW. The demonstrator is designed to represent the following scenarios:

1. Foreign objects placed on the surface of the **ground assembly** (GA) in absence of the **vehicle assembly** (VA)
2. Foreign objects placed on the surface of the GA in presence of the VA
3. Foreign objects placed somewhere in the operating area of the charging system
4. Consideration of environmental conditions, like rainwater and ice

The sensors of the FOD system are positioned directly above the GA coil on a carrier plate, as specified in the standard SAE J2954 (Figure 4). This makes measurements with and without VA feasible.

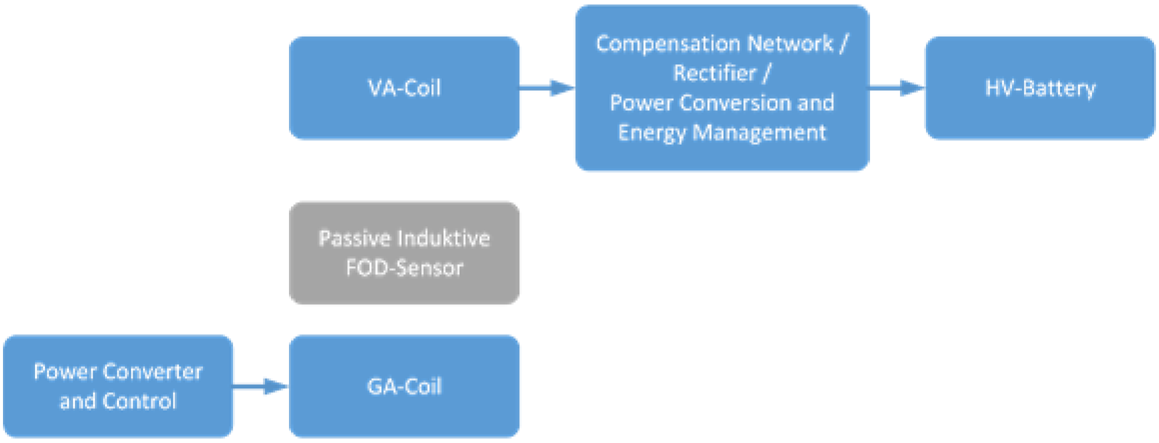

FIGURE 4: FOD-SENSOR WITHIN A WIRELESS CHARGING SYSTEM

With the help of the demonstrator it is intended to:

- Characterize the magnetic field of the charging system with and without VA
- Describe the behavior of the standardized test objects within the magnetic field, and
- Determine the properties of the sensors used as examples in different operating situations.

The measured data are analyzed and form the basis of the simulation of the FOD system (Figure 5).

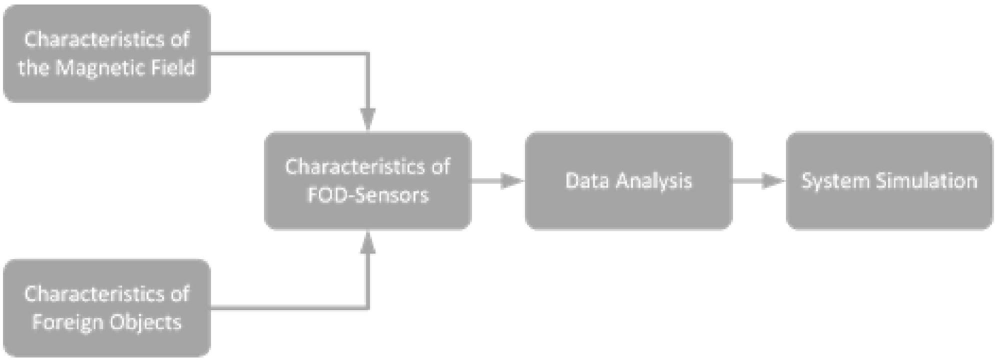

FIGURE 5: FUNCTIONAL BLOCKS OF THE DEMONSTRATION

To round off the content of the demonstrator, test procedures are proposed that can be used to automatically test the functionality of the FOD system during the operational lifetime of the wireless charger.

5.4 Residual Risks

As defined in the standard ISO 26262-1:2018, residual risk is the risk that remains after safety measures have been deployed. Risk, for its part, is defined as the combination of the probability of occurrence of a harm and the severity of that harm.

The standard SAE J2954 defines the following safety requirements regarding metallic foreign objects:

- Objects shall not be above touch hazard temperature when a person is able to touch that object.
- Any damage to the GA surface shall not create a safety hazard.
- Objects shall not cause ignition

Furthermore, the standard defines a list of objects to be used for testing FOD systems.

Based on these definitions, the severity of potential damage can be inferred from the behavior of the test objects in the magnetic field of a wireless charging system. The usage of a FOD system represents a safety measure in the sense of the ISO 26262 standard to reduce the risk posed by metallic and/or magnetic foreign objects in the charging system. Thus, the remaining risk posed by foreign objects in a wireless charging system with foreign object detection represents the residual risk

5.5 Demonstrator relations to the main objectives and key targets

The demonstrator is intended to characterize selected example sensors that can be used in FOD systems. Not only the positions defined in the standard for test objects will be used, but the foreign objects will be positioned at several locations in the entire operating range of the charging system. In addition, the influence of typical and potentially adverse environmental conditions is to be investigated. The obtained results should allow a better understanding of the appropriateness of the sensors for practical applications. The objectives are therefore in the areas of design optimization, identification of residual risk, and increasing user acceptance.

5.5.1 Objectives

O1 – Continuous robust design optimization for each part in the ECS value chain: The characterization of the sensors in the immediate vicinity of a wireless charging system incorporates many of the practically relevant influences and, together with the modelling and simulation of the FOD system, allows to draw conclusions about the interrelationships of the working mechanisms and thus better adapted sensors.

O3 – Identification and management of residual risks over the entire ECS value chain: The characterization of the standardized test objects within the magnetic field of a wireless charging system and the performance analysis of the selected sensors in detecting these objects allow conclusions to be drawn about the efficiency of the FOD system and, consequently, about the residual risk.

O4 – End-user acceptance by trustworthy ECS value chain: Optimized sensors and automatic functionality tests during the entire operating life of the FOD system increase the reliability of the charging system and thereby contribute to higher end-user acceptance.

5.5.2 Key targets

KT1 – Architectures, components, sub-systems enabling virtual development and validation (monitoring device, failure risk): The description of interrelationships and dependencies between subcomponents of a wireless charging system and the simulation of foreign object detection form the basis for future virtual development and validation.

KT2 – Methods and tools to validate the models used in virtual validation (lifetime monitoring, residual risk, methods, and tools): Data from measurements in real-world environments can be used to verify models used for virtual validation of systems

5.6 Homologation framework mapping

The demonstrator will be used to show how well the selected sensors are suitable for detecting metallic and/or magnetic foreign objects within wireless charging systems. With the detection of such objects, the danger posed by them when they heat up in the magnetic field can be reduced or even eliminated. This reduces the risk associated with the operation of wireless charging systems. In addition, test methods intended to ensure the functionality of the FOD system during operation of the charging system will be described. This will on the one hand ensure that a wireless charging system can be operated safely and on the other hand that the charging system is only used when the safety component is working.

5.7 Non-functional requirements, KPIs, and measures

In the standard SAE J2954, it is assumed that the test objects are located directly on the surface of the ground assembly at the positions where the largest magnetic fluxes occur. In practice, however, foreign objects should also be detected at other positions on the surface of the ground assembly and above the ground assembly. Foreign object detection is one of the safety components of the wireless charging system and should therefore function reliably throughout the entire operating life. To ensure this and to be able to test it automatically, appropriate runtime tests have to be provided.

TABLE 3: NFRS, KPIS AND MEASURES FOR DEMONSTRATOR 1.1 – FUNCTIONAL APPROPRIATENESS

NFR	Functional appropriateness
FR definition	Functional appropriateness of the sensor
KPI name	Degree of detectability at different positions at the surface of the GA coil
Description	At which positions relative to the GA coil can standardized test objects be detected?
Measure	Detectability at different positions
Type of measure	Quantitative (ratio)
Method of collection and measurement	Measurement $$X = \frac{A}{B}$$ A … Number of measurement points where the foreign object can be detected B … Number of all measurement points
Demonstrator target	
KPI for Verification and validation	Comparison between different sensor types

TABLE 4: NFRS, KPIS AND MEASURES FOR DEMONSTRATOR 1.1 – PERFORMANCE EFFICIENCY

NFR	Performance efficiency
FR definition	Performance efficiency of the sensor
KPI name	Degree of detectability at different distances to the surface of the GA coil
Description	At what distances from the surface of the GA can foreign objects be detected?
Measure	Detectability at different positions
Type of measure	Quantitative (ratio)
Method of collection and measurement	Measurement $$X = \frac{A}{B}$$ A … Number of measurement points where the foreign object can be detected B … Number of all measurement points

Demonstrator target KPI for Verification and validation	Comparison between different sensor types

TABLE 5: NFRS, KPIS AND MEASURES FOR DEMONSTRATOR 1.1 – TESTABILITY

NFR	Testability
FR definition	Testability of the foreign object detection subsystem during operation life
KPI name	Test function completeness
Description	How many of the proposed runtime tests can be realized for the selected sensor?
Measure	Test function completeness
Type of measure	Quantitative (ratio)
Method of collection and measurement	Measurement $$X = \frac{A}{B}$$ A … Number of feasible runtime tests B … Number of proposed runtime tests
Demonstrator target KPI for Verification and validation	Comparison between different sensor types

5.8 Functional requirements, KPIs, and measures

The passive inductive sensors are designed for differential or gradient measurements. Ideally, they should completely fade out the magnetic field of the wireless charging system and only detect changes in this magnetic field caused by foreign objects. This functionality should also be provided under the influence of typical environmental conditions, such as rain, snow or ice.

TABLE 6: FRS, KPIS AND MEASURES FOR DEMONSTRATOR 1.1 – SUPPRESSION OF THE INFLUENCE OF THE GA COIL

FR	Suppression of the influence of the GA coil
FR definition	Reliable suppression of the influence of the GA coil
KPI name	Suppression of the influence of the GA coil
Description	How well does the selected passive sensor fade out the impact of the magnetic field of the GA coil?
Measure	Output offset signal amplitudes of the sensors
Type of measure	Quantitative (offset signal amplitudes)
Method of collection and measurement	Measurement • Output offset signal amplitude of the sensor without any foreign object and without VA coil • Output offset signal amplitude of the sensor without any foreign object and different alignments of the VA coil
Demonstrator target KPI for Verification and validation	Comparison between different sensor types

TABLE 7: FRS, KPIS AND MEASURES FOR DEMONSTRATOR 1.1 – DETECTION OF THE STANDARDIZED TEST OBJECTS

FR	Detection of the standardized test objects
FR definition	Detection of metallic objects described as test objects in the standard SAE J2954 at positions with maximum magnetic flow
KPI name	Degree of detectability
Description	How well does the selected sensor detect the standardized test objects?
Measure	Detectability of standardized test objects
Type of measure	Quantitative (signal amplitude ratio)
Method of collection and measurement	Measurement $$X = \frac{A}{B}$$ A … Output signal amplitude of the sensor with specific test object B … Output offset signal amplitude of the sensor without test object
Demonstrator target KPI for Verification and validation	Comparison between different sensor types

TABLE 8: FRS, KPIS AND MEASURES FOR DEMONSTRATOR 1.1 – INFLUENCE OF ENVIRONMENTAL CONDITIONS

FR	Influence of environmental conditions
FR definition	Detection of metallic objects described as test objects in the standard SAE J2954 in combination with typical environmental conditions at positions with maximum magnetic flow
KPI name	Degree of detectability
Description	How well does the selected sensor detect the standardized test objects in combination with typical environmental conditions?
Measure	Detectability of standardized test objects
Type of measure	Quantitative (signal amplitude ratio)
Method of collection and measurement	Measurement $$X = \frac{A}{B}$$ A … Output signal amplitude of the sensor with specific test object and specific environmental condition B … Output offset signal amplitude of the sensor without test object
Demonstrator target KPI for Verification and validation	Comparison between different sensor types

5.9 Mapping to existing standards

The SAE J2954 standard evolved over several years from a Technical Information Report (TIR) published by SAE International in 2016. It defines acceptable criteria for interoperability, electromagnetic compatibility, electromagnetic fields, minimum performance, safety and testing for wireless power transfer for light-duty plug-in electric vehicles.

The detection of objects that may heat up to dangerous temperatures during power transfer is one of the safety functions of the wireless inductive charging system. To verify safety, the standard defines a test procedure for FOD systems, which in the current version is highly dependent on the implementation of the ground assembly coil and the FOD system. The demonstrator uses the test objects and temperature limits defined for this purpose to assess the efficiency of the FOD system and the risk.

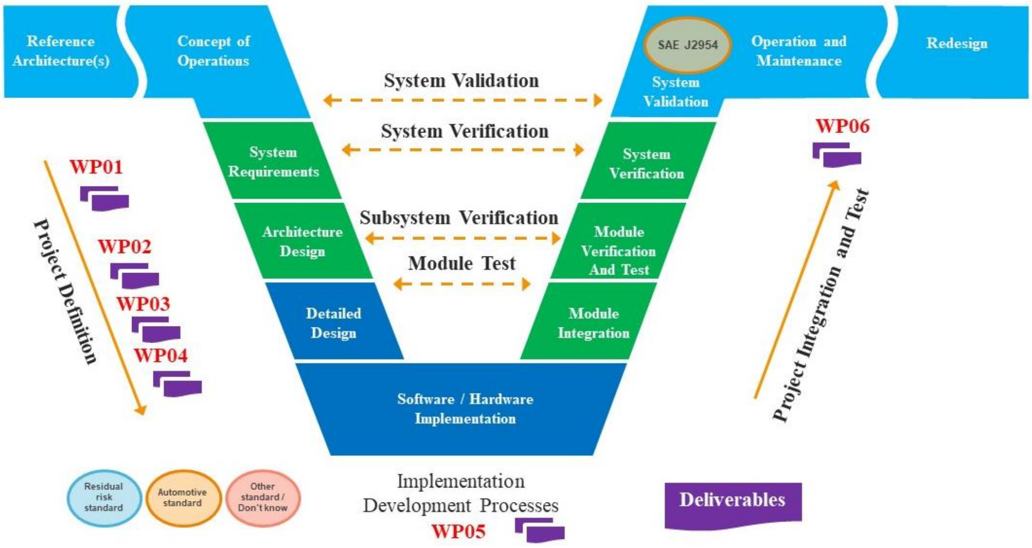

FIGURE 6. STANDARDS MAPPING V-MODEL ARCHITECHECA2030.

TABLE 9. MAPPING OF EXISTING STANDARDS FOR DEMONSTRATOR 1.1

Standard code	Standard title	Why relevant	How to use
SAE J2954:2020	Surface Vehicle – Wireless Power Transfer for Light-Duty Plug-in/Electric Vehicles and Alignment Methodology	Establish an industry-wide specification that defines acceptable criteria for interoperability, electromagnetic compatibility, EMF, minimum performance, safety, and testing for wireless power transfer (WPT) of light-duty plug-in electric vehicles. Addresses unidirectional charging, from grid to vehicle.	The standard defines objects and procedures for safety verification tests of wireless charging systems regarding the foreign object detection.

6 Demonstrator 1.2: Robust operation of EPS in adverse environments

6.1 Target goals and achievements

- Improve robustness of EPS against these influences/adverse conditions.
  - Fault Detection
  - Fail-Operational Design
  - Applying of existing and upcoming recommendations from standards ==> in exchange with SC5
- Definition of relevant sources for sensor failure
- Definition of KPIs to evaluate performance against sensor failure (baseline everything is shiny and work as intended
- Recommendation for Certification

6.2 Demonstrator description

These demonstrators focus on robust and reliable environmental perception systems. These are sensors and the corresponding data processes. First, the EPS works in an environment without disturbances. From this state the EPS is disturbed by weather or another anomaly. To ensure a safe and robust operation, the EPS needs to be capable on dealing with these disturbances and balance them out.

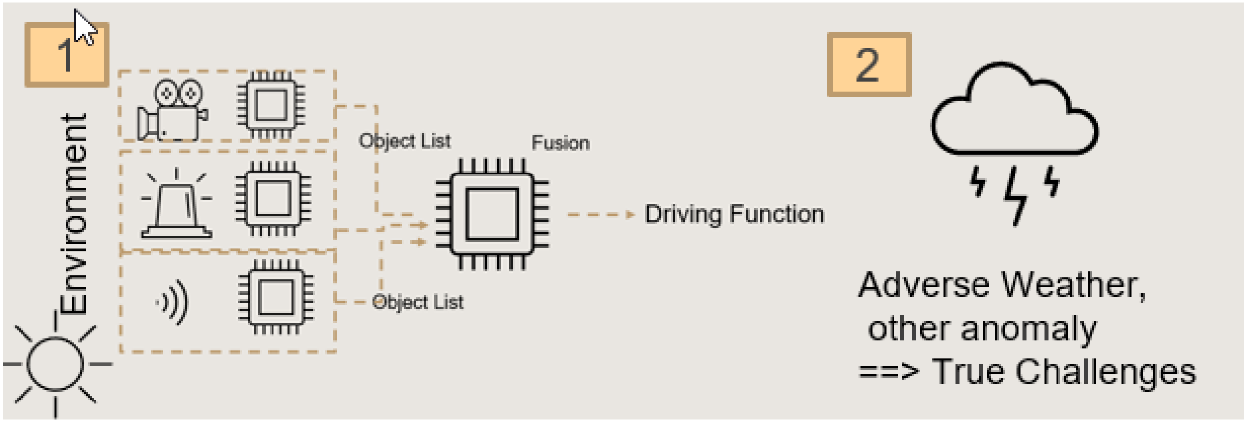

FIGURE 7: GRAPHICAL REPRESENTATION OF DEMONSTRATOR 3

In this demonstrator sensor fault detection of Radar and Lidar Sensors for different fault types will be investigated. SSC relations to the main objectives and key targets

6.2.1 Relation to main objectives of the project

O1 - Continuous robust design optimization for each part in the ECS value chain: This demonstrator supports this objective by delivering the basis for more robust sensors as one essential element in the ECS value chain. The perception part is the fundamental input to the whole sense plan act cycle. When planning and control builds on faulty perception input, safety critical situations may occur.

O3 - Identification and management of residual risks over the entire ECS value chain: This demonstrator supports this objective by investigating & delivering more reliable sensor technology.

With the ability to detect, identify and react on sensor faults, the inherent risk due to sensor failure can be reduced. This can also support a better understanding of residual risk.

O5 - Zero emissions, crashes, and congestions by ECA2030 vehicle: This demonstrator is an enabler for future safer ECA vehicles, thus paving the road to a vision zero. The perception part is the fundamental input to the whole sense plan act cycle. When planning and control builds on faulty perception input, safety critical situations may occur.

6.2.2 Relation to Key targets of the project

KT1 - Architectures, components, sub-systems enabling virtual development and validation (monitoring device, failure risk): This demonstrator supports this objective by delivering the basis for more robust sensors as one essential element in the ECS value chain. With the ability to detect, identify and react on sensor faults, the inherent risk due to sensor failure can be reduced. This demonstrator targets therefore, architectures and components as relevant element for monitoring.

KT2 - Methods and tools to validate the models used in virtual validation (lifetime monitoring, residual risk, methods, and tools): For this demonstrator, partners will collect data that is then used to validate models, thus supporting this target. The data is collected in lab-setup as well as in measurement campaigns on real road stretches.

KT3 - Metrics for quality assurance for ECS (mission-oriented qualification, residual risk): Within this supply chain, KPIs are defined for the corresponding demonstrators with relation to existing standards. Some of these KPIs may also be usable as metrics beyond the runtime of the project.

6.3 Residual Risks

Technical systems and components bear the risk of braking down or failing during operation. For understanding residual risk another term needs also to be introduced: Inherent risk. Inherent risk represents the extend of risk related to a technical system or a component of breaking down or failing without any risk control measures. Once risk control measures are applied, the inherent risk is reduced, and it is the residual risk remains.

For a LiDAR sensor, as example a target may not be hit by the LiDAR beams due to the vibration influence. A higher-level building block of the whole function requires the LiDAR data as input. A certain percentage of the emitted LiDAR beams are not returning to the receiver and therefore not represented in the input data provided to the driving function. The identification of vibration issues is the control measure where the change in the performance of the driving function is an indicator for the risk level. The deeper understanding of the (a) influence of adverse effects on the sensor data, and (B) on the whole driving function allows to give an estimate on the negative effects and the overall risk. This knowledge can then be utilized as indicator for residual risk.

6.4 Demonstrator 2 "Robust Physical Sensors"

Demonstrator should show the robustness of different sensor against faults

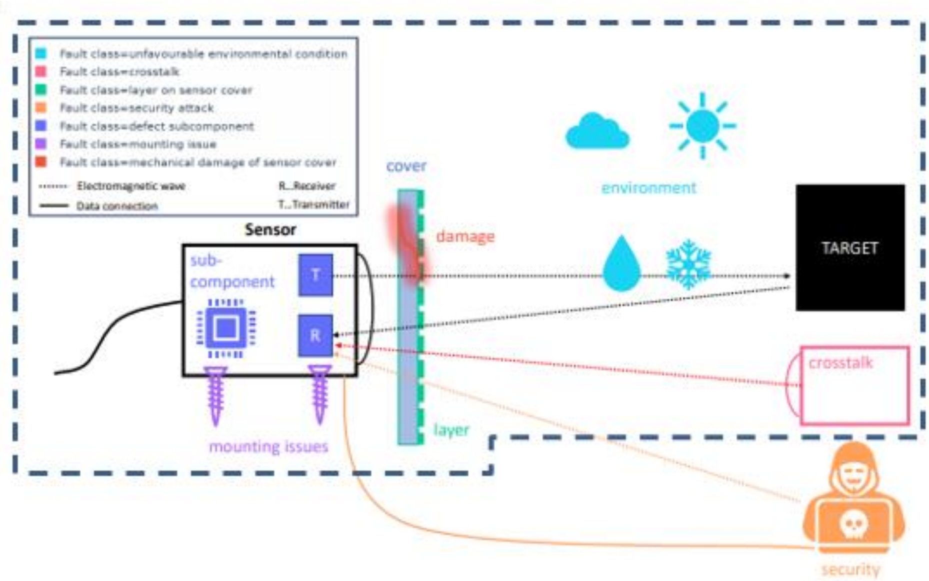

FIGURE 8: SENSOR FAUTL TYPES [GÖLLES T. ET AL., 2020]

Method

Development of a lab-testing environment for radar and Lidar Sensor measurement. In this lab environment, data Measurement (disturbed as well as non-disturbed) will be conducted. In a next step, an analysis of the data is to be conducted for the identification of patterns an adverse condition creates in sensor raw data. This is followed by the Development of fault detection methods for real sensors. Several types of fault classes exist. In several laboratory tests the robustness against different fault types will be shown. Figure 9 to Figure 11 show block diagrams for demonstrator set up (Radar and Lidar).

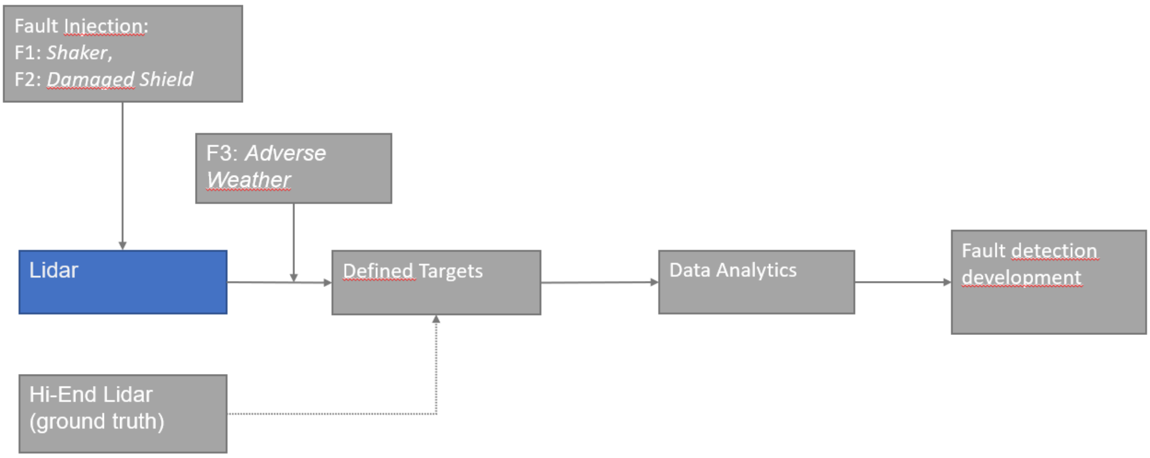

FIGURE 9: BLOCK DIAGRAM FOR LIDAR VIBRATION DEMONSTRATOR

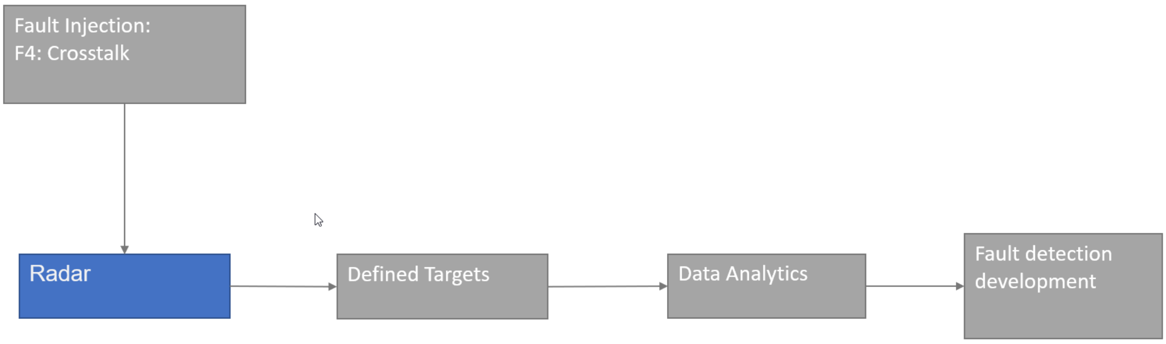

FIGURE 10 BLOCK DIAGRAM FOR LIDAR VIBRATION DEMONSTRATOR

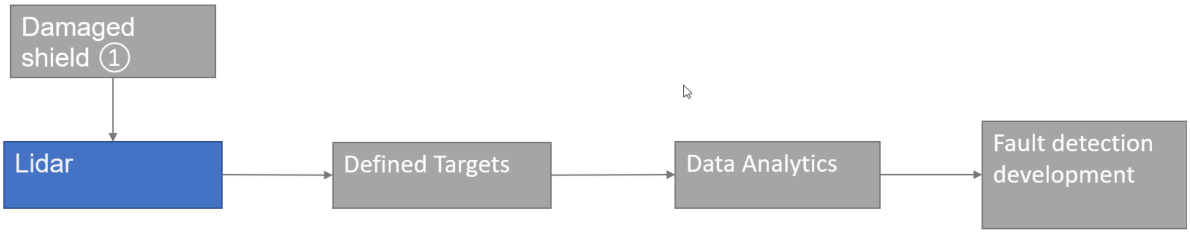

FIGURE 11: BLOCK DIAGRAM FOR LIDAR VIBRATION DEMONSTRATOR

6.4.1 Non-functional requirements, KPIs, and measures

NFR	Demonstration of Robust physical Sensors
FR definition	This demonstrator shall demonstrate robust physical sensors
KPI name	The functional requirements are fulfilled
Description	Does the system recognize the fault itself?
Measure	Pass-Fail Criteria
Type of measure	
Method of collection and measurement	Data Measurement in Lab Environment
Demonstrator target	Manual identification of patterns due to negative effects
KPI for Verification and validation	Baseline is fault-free data

NFR	Device Driver Abstraction
NFR definition	The data from the drift model are sent via a device driver to the application. .
KPI name	Microcontroller independent HW interface
Description	A device driver abstraction model is introduced enabling supplier independent MonDev functionality (to be standardized within SC5 later on)
Measure	Integration Test Case
Type of measure	Software

Method of collection and measurement	Software Test Case Implementation
Demonstrator target	MonDev Functionality is realized from the component level to the applications level.
KPI for Verification and validation	Transparency on MonDev

6.4.2 Functional requirements, KPIs, and measures

FR	Robust LiDAR Sensors
FR definition	This demonstrator shall detect sensor fault “vibration” & scratched shield
KPI name	Sensor fault pattern detected in data
Description	
Measure	Pass-Fail Criteria
Type of measure	Comparison Measurement with /without fault;
Method of collection and measurement	Data Measurement in Lab Environment
Demonstrator target	Manual identification of patterns due to negative effects
KPI for Verification and validation	Pattern could be found

FR	Robust RADAR Sensors
FR definition	This demonstrator shall detect sensor fault “Cross-Talk”
KPI name	Sensor fault pattern detected in data
Description	
Measure	Pass-Fail Criteria
Type of measure	Comparison Measurement with /without fault;
Method of collection and measurement	Data Measurement in Lab Environment
Demonstrator target	Manual identification of patterns due to negative effects
KPI for Verification and validation	Pattern could be found

FR	Eliminate Measurement Errors
FR definition	The Device driver is split into a Platform Independent High Level (HLDD) and Platform dependent Low level (LLDD) Part
KPI name	Platform independent I/F
Description	A device driver abstraction model is introduced enabling supplier independent MonDev functionality (to be standardized within SC5 later on)
Measure	Integration Test Case

Type of measure	Software
Method of collection and measurement	Software Test Case Implementation
Demonstrator target	MonDev Functionality is realized from the component level to the applications level.
KPI for Verification and validation	Transparency on MonDev

6.4.3 Mapping to existing standards

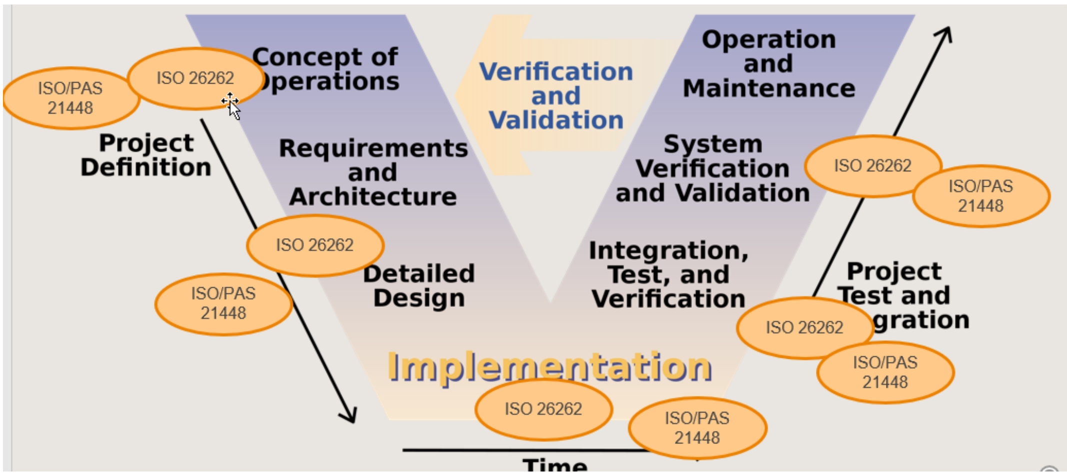

FIGURE 12. STANDARDS MAPPING V-MODEL ARCHITECHECA2030.

TABLE 10. MAPPING OF EXISTING STANDARDS FOR SC D2.1.

Standard code	Standard title	Why relevant	How to use
ISO 26262:2018	Functional Safety – Road Vehicles	ISO 26262 provides the baseline of automotive safety considerations	Demo 1 will use concepts of the standard to a reasonable extent
ISO PAS 21448	Safety of the intended functionality	ISO PAS Sotif extends the ISO 26262, where the original standard did not cover the needs of higher automated driving	Demo 1 will use concepts of the standard to a reasonable extent

7 Demonstrator 1.3 "Virtual Perception Systems"

This demonstrator focuses on robust and reliable virtual environmental perception systems for robust automated mobility. EPS are sensors and the corresponding data processes. Investigated in this demonstrator are sensors commonly used for automotive environment perception. Within this demonstrator various sensor models are demonstrated, that show a higher accuracy than current sensor models. In the end a sensor model will be demonstrated as block in a larger simulation framework.

7.1.1 Demonstrator description

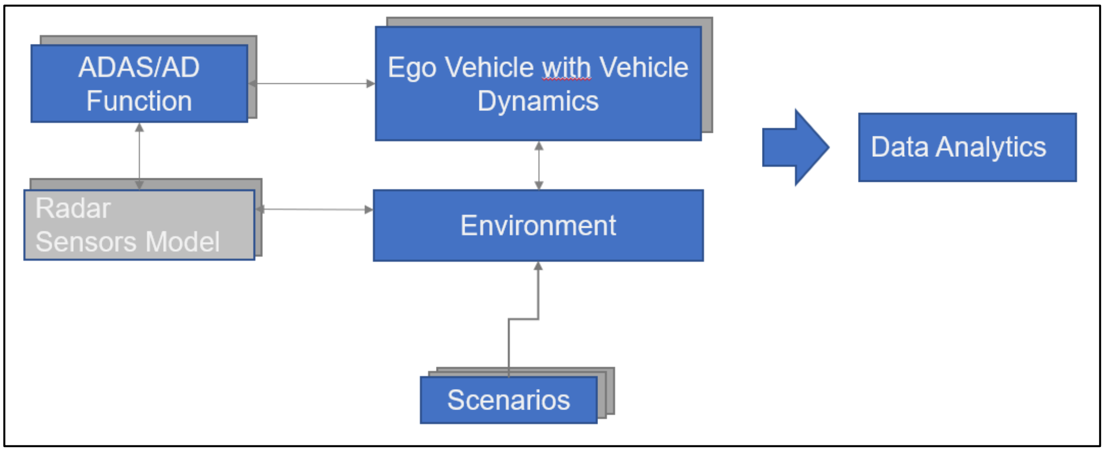

FIGURE 13 CONCEPTUAL ARCHITECTURE OF SIMULATION FRAMEWORK

In this demonstration an in-house developed sensor (Radar) model shall be integrated into an existing simulation framework. The existing simulation framework that includes a camera-based driving functionality (LKA and ACC).

While the environment and vehicle dynamics are simulated in a car-maker environment, the actual driving function is a Matlab Block.

7.1.2 Relation to main objectives of the project

O1 - Continuous robust design optimization for each part in the ECS value chain: This demonstrator supports this objective by delivering the basis for more robust sensors as one essential element in the ECS value chain. The perception part is the fundamental input to the whole sense plan act cycle. When planning and control builds on faulty perception input, safety critical situations may occur.

O2 - Framework for safety validation of ECS value chain: This demonstrator supports this objective by delivering methods for virtual and physical safety evaluation of ECAs. This simulation framework helps to conduct virtual testing for tests not doable in physical environment. There it delivers a sub-component to a overarching framework.

O3 - Identification and management of residual risks over the entire ECS value chain: This demonstrator supports this objective by investigating & delivering more reliable sensor technology. With the ability to detect, identify and react on sensor faults, the inherent risk due to sensor failure can be reduced. This can also support a better understanding of residual risk.

7.1.3 Relation to Key targets of the project

KT1 - Architectures, components, sub-systems enabling virtual development and validation (monitoring device, failure risk): This demonstrator supports this key target by delivering virtual validation methods as simulation environment. This demonstrator includes relevant elements for an automated vehicle, planned as different building blocks. Therefore, the demonstrator supports architectures, sub-systems for virtual development and validation.

KT2 - Methods and tools to validate the models used in virtual validation (lifetime monitoring, residual risk, methods, and tools): For this demonstrator, partners will collect data that is then used to validate models, thus supporting this target. The data is collected in lab-setup as well as in measurement campaigns on real road stretches. Pipelines for tool validation will also be investigated.

KT3 - Metrics for quality assurance for ECS (mission-oriented qualification, residual risk): Within this supply chain, KPIs are defined for the corresponding demonstrators with relation to existing standards. Some of these KPIs will also be usable as metrics beyond the runtime of the project.

KT4 - Definition and understanding of test coverage (residual risk, design feedback, lifetime monitoring, aggregated risk): The applicability of different test methods (pure simulation, HiL, ViL) will be explored and supports the understanding of necessary test coverage for testing of environmental perception systems.

KT5 - Methods for shorter validation in respect to acceptable residual risk (methods): With the ability of assessing an acceptable residual risk for EPS a faster validation could be achieved.

7.1.4 Non-functional requirements, KPIs, and measures

NFR	Virtual robust sensors & perception in simulation
FR definition	This demonstrator shall demonstrate robust sensors & perception in simulation
KPI name	The functional requirements are fulfilled
Description	
Measure	Pass-Fail Criteria
Type of measure	
Method of collection and measurement	Simulation on Workstation
Demonstrator target	
KPI for Verification and validation	Baseline is fault-free data

NFR	Fault Propagation
FR definition	Simulation study on fault propagation in the AD system
KPI name	The functional requirements are fulfilled
Description	

Measure	Pass-Fail Criteria
Type of measure	
Method of collection and measurement	Data Measurement in Lab Environment
Demonstrator target	
KPI for Verification and validation	

7.1.5 Functional requirements, KPIs, and measures

FR	Fault Propagation
FR definition	The simulation framework shall consist of the following building blocks: sensor model, environment model, vehicle dynamics & automated driving function.
KPI name	Sensor model implemented
Description	
Measure	Pass-Fail Criteria
Type of measure	
Method of collection and measurement	Simulation on Workstation
Demonstrator target	
KPI for Verification and validation	Validation Data from Demonstrator Vehicle or Lab Environment

FR	Simulation use cases
FR definition	The simulation framework shall be able to simulate use cases relevant for virtual certification and validation (e.g. cut-ins).
KPI name	Simulation Framework Running
Description	
Measure	Pass-Fail Criteria
Type of measure	
Method of collection and measurement	Simulation on Workstation
Demonstrator target	
KPI for Verification and validation	Validation Data from Demonstrator Vehicle

FR	Sensor Fault Injection
FR definition	It shall be possible to inject sensor faults to sensor model or interface from sensor model
KPI name	Fault Injection in Framework running

Description	
Measure	Pass-Fail Criteria
Type of measure	
Method of collection and measurement	Simulation on Workstation
Demonstrator target	
KPI for Verification and validation	Validation Data from Demonstrator Vehicle

FR	Fault Propagation
FR definition	With the simulation framework the effect of sensor fault propagation shall be simulated and demonstrated for critical scenarios.
KPI name	Fault Propagation in Framework running
Description	
Measure	Pass-Fail Criteria
Type of measure	
Method of collection and measurement	Simulation on Workstation
Demonstrator target	
KPI for Verification and validation	Validation Data from Demonstrator Vehicle

FR	Virtual Monitoring Functionality
FR definition	The simulation framework shall enable a demonstration of a virtual monitoring functionality.
KPI name	Virtual Monitoring in Framework running
Description	
Measure	Pass-Fail Criteria
Type of measure	
Method of collection and measurement	Simulation on Workstation
Demonstrator target	
KPI for Verification and validation	Validation Data from Demonstrator Vehicle

FR	Input to SC4
FR definition	The simulation framework shall enable a pre-demonstration of the functional requirements from SC4 (VIF Demonstrator)
KPI name	Virtual Monitoring in Framework running
Description	

Measure	Pass-Fail Criteria
Type of measure	
Method of collection and measurement	Simulation on Workstation
Demonstrator target	
KPI for Verification and validation	Validation Data from Demonstrator Vehicle

7.1.6 Mapping to existing standards

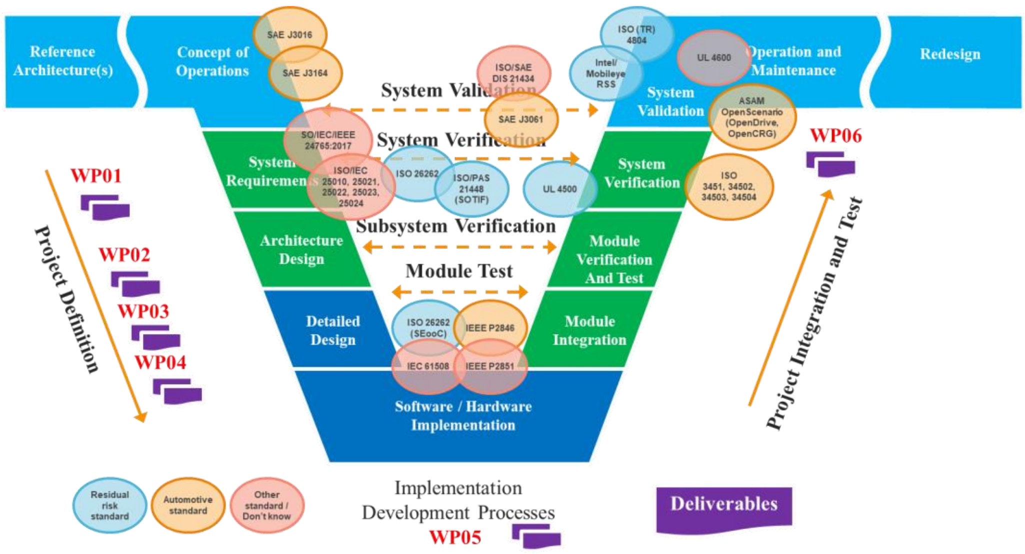

FIGURE 14. STANDARDS MAPPING V-MODEL ARCHITECHECA2030.

TABLE 11. MAPPING OF EXISTING STANDARDS FOR SC D2.2.

Standard code	Standard title	Why relevant	How to use
OpenDRIVE	ASAM OpenDRIVE v 1.6.1	Standard for description of static environment	Tbc. During implementation
OpenScenario	ASAM OpenSCENARIO v 1.1.0	Standard for description of dynamic elements	Tbc. During implementation

8 Demonstrator 1.4: Road segmentation using 2D camera

8.1 Target goals and achievements

Using a simple 2D camera, a function should be developed which segments the road (e.g. street, curb, lane markings, grass etc.). Specifically, the lateral (point of view of the driving vehicle) segmentation is of interest. Using the lateral segmentation, the given longitudinal position of the vehicle and a HD map, the lateral position of the car should be improved. The function should be fused with the longitudinal position and run on a vehicle on-board embedded device (e.g. the camera controller). The implementation will be demonstrator using a full-size vehicle from ViF. A 2D camera will be used to collect the data while driving and used as an input for the above-described function. The vehicle will be driven on a closed street.

Work on a demonstrator was started to test the methods, architectures, and scenarios with the partners. The demonstrator is to be tested with a simple 2D camera function that segments the road. Using the segmentation (see first results in figure), the given longitudinal position of the vehicle and an HD map, the lateral position of the vehicle should be used as a function to carry out the residual risk calculation. This enables the quantification of an accepted residual risk (accuracy of the position) under relevant scenarios such as the failure of electronic (sub) components of the system, e.g. camera. The following results have been achieved so far:

- Definition of suitable data sets and method completed
- First iteration of segmentation evolution completed
- Identified scenarios for failure modes of electronic components

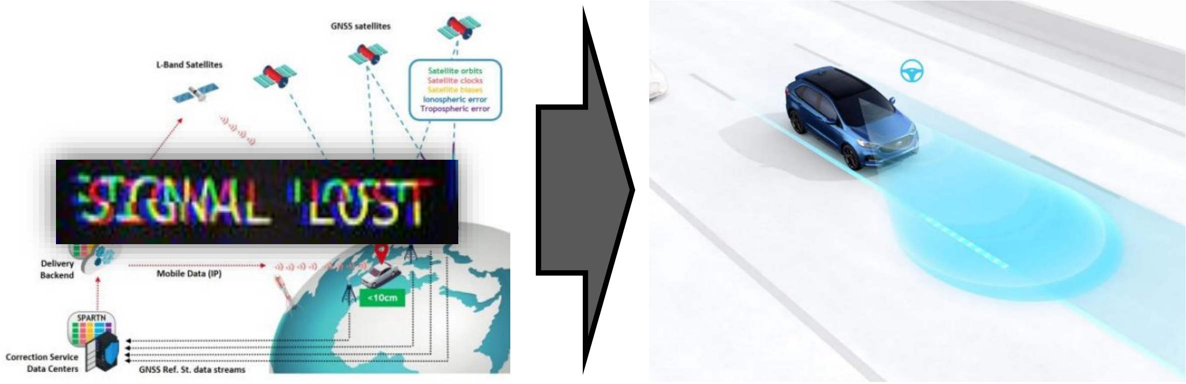

FIGURE 15: AI VISION-BASED FALL-BACK POSITIONING

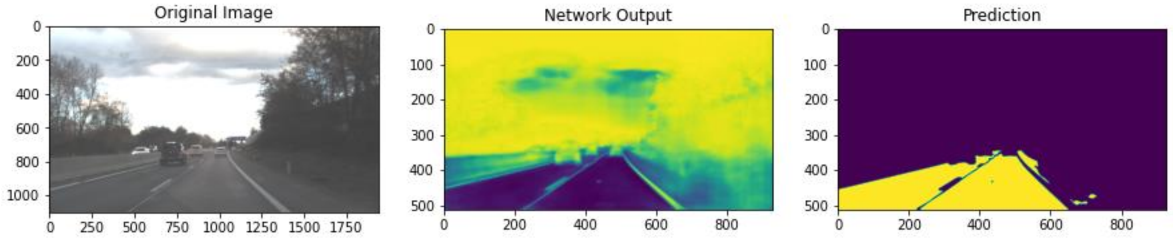

FIGURE 16: ROAD SEGMENTATION WITHOUT PIXEL FAILURE

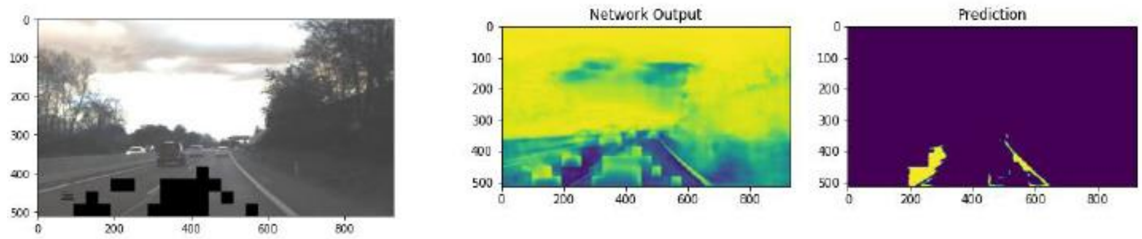

FIGURE 17: ROAD SEGMENTATION WITH 10% PIXEL FAILURE

8.2 SSC structure

A NN architecture should be used to segment the camera imagine. From the segmented image the lateral position should be calculate based on a known longitudinal position, a uncertain lateral position, vehicle heading and a HD map (this should be done using a more simple approach without ML).

8.3 SCC description

The precise vehicle location plays a major in car safety. Common localization sensors are GPS, IMU and odometer but these sensors suffer from significant errors depending on the environment (e.g. high buildings in the city, trees). Additional 3D sensors such as Lidars are expensive and therefore not always available. In case of no 3D sensors the usability of SLAM approaches is reduced. In these cases, also other perception systems like simple 2D cameras can help to increase localization in combination with a low-quality GPS signal.

8.4 Residual Risks

The residual risk for road segmentation model is evaluated by assigning each pixel of the input image a numerical value which describes its importance for the model to classify the segment which the pixel is part of as "road" or "not road". To derive that importance a XAI method called Heatmapping is applied on the model. In the next step we simulate the failure modes "dead pixels" or "dirt on lense" by blackening pixels of the input image. We incrementally blacken out those pixels of the input image which the segmentation prediction for class "road" will be most sensitive about, we assume those pixels are the "important" pixels derived from the Heatmapping. The doubling of the number of blackened pixels does not result in a doubling number of misclassified pixels but results in an even higher number. It becomes apparent that with an amount of 10% overall blackened pixels, the traffic lane boundaries cannot be derived from the predicted road segmentation.

8.5 SCC relations to the main objectives and key targets

8.5.1 Objectives

O1 - Continuous robust design optimization for each part in the ECS value chain:
Continues data loop optimization for connected vehicle with long-term improvement of the laterals position for autonomous vehicles.

O2 - Framework for safety validation of ECS value chain: Framework to evaluate vehicle images for the use for position systems and their risk.

O3 - Identification and management of residual risks over the entire ECS value chain: Contribution to the ECS value chain from individual vehicle perception until fleet positioning on a map.

8.5.2 Key targets

KT1 - Architectures, components, sub-systems enabling virtual development and validation (monitoring device, failure risk): Using simulated data the function can be tested and validated using virtual development.
KT2 - Methods and tools to validate the models used in virtual validation (lifetime monitoring, residual risk, methods, and tools): Using simulated data the function can be tested and validated using virtual development.

8.6 Non-functional requirements, KPIs, and measures

The method shall be robust against changes of the camera:

Functional appropriateness of the method:
The method shall be robust against system version changes of the camera.

Performance efficiency of the method:
At which quality (*SNR*) of the image can the lateral position be calculated?

The method shall be able to run on a given HW and be able to process the input images.

Analyzability of the runtime tests:
How many of the images can be used for the position estimation under the given boundary?
$X = A/B$
A … Number useful images, B … Number of all images collected

8.7 Functional requirements, KPIs, and measures

The method shall provide a precise estimated lateral position:

Quality of the position estimation:
How good is the lateral position estimation based on the input data?
$X = B - A$
A … Lateral position estimated, B … Ground Through Lateral Position

8.8 Mapping to existing standards

TABLE 12. MAPPING OF EXISTING STANDARDS FOR SC D1.4.

Standard code	Standard title	Why relevant	How to use

ISO 26262:2018	Functional Safety – Road Vehicles	ISO 26262 provides the baseline of automotive safety considerations	Demo 1 will use concepts of the standard to a reasonable extent
ISO PAS 21448	Safety of the intended functionality	ISO PAS Sotif extends the ISO 26262, where the original standard did not cover the needs of higher automated driving	Demo 1 will use concepts of the standard to a reasonable extent

9 SC1 /demonstrators' standards mapping summarized

TABLE 13. MAPPING OF EXISTING STANDARDS SUMMARIZED.

Standards vs Demonstrators	D1.1	D1.2	D1.3	D1.4
SAE J2954:2020	X			
ISO 26262:2018		X		x
ISO PAS 21448		X		x
OpenDRIVE			X	
OpenScenario			X	

10 Conclusion

10.1 Contribution to overall picture

The work carried out in Supply Chain 1 through the demonstrators listed above helps to clarify the risks to ECAs that occur as a result of perception systems on and around such vehicles. The work will also identify techniques that can be used to mitigate this risk and develop analytical and experimental tools to characterise and understand the residual risk that remains after mitigation. The demonstrators described above have been chosen with the aim of ultimately improving our ability to understand the residual risks associated with perception systems.

10.2 Relation to the state-of-the-art and progress beyond it

The work to be done will build on the state of the art and advance it. The details of this progress will be refined as the work is done.

10.3 Impacts to other WPs, Tasks and SCs

This work will impact Work Package 1 and Supply Chain 1, due to the interactions between WP1 and SC1. Specific details of these interactions are outlined above.

Due to the fact that perception systems tend to appear near the beginning of computational pipelines for controlling automated systems, it is likely that the demonstrators defined in this document will reveal potential points of interaction with other Work Packages and Supply Chains.

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12 List of figures

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