Hi-Drive
Designing Automation

Deliverable D3.3 /

Description of vehicles

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Hi-Drive

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Executive summary

The Hi-Drive project is pushing automated driving further towards high-level automation. The feasibility of high-level automation is being tested in different conditions across Europe, from south to north, free from the earlier narrow Operational Design Domains (ODDs) characterising SAE L2-L3 automation. The main objective of Hi-Drive is to make driving automation robust and reliable by taking intelligent vehicle technology into conditions and scenarios that have neither been extensively tested nor demonstrated earlier in European and overseas traffic.

This deliverable, D3.3 *Description of vehicles*, describes the research vehicles involved in the Hi-Drive project. Besides simulations, questionnaires, literature, and other actors, physical vehicles provide a main source of data for analysis, assessment, and evaluation. Twenty vehicle owners (VOs) have prepared one or more vehicles for Hi-Drive. The information of this deliverable ends with the (imaginary) handover of vehicles to the subproject *Operations* (SP5), which will manage the driving and data collection. In SP5, vehicles will be driven by professionals, by ordinary drivers accompanied by safety drivers, and by ordinary drivers alone. The routes will include parking places, urban and city roads, motorways, and proving grounds.

The methodology describes how to collect information from the VOs in two templates for readiness and details. The VOs are project partners that develop and implement enablers for vehicles, test and drive the vehicles within the designed ODD, and later collect data for assessment and evaluation. Enablers are technological tools (software, hardware, methodology) that have the potential to enable new vehicle automated driving functions (ADFs) and/or upgrade existing vehicle ADFs towards an extension of the ODD.

First a visual summary is given, followed by statistics on the 37 vehicles involved in the project and on the human-machine interface (HMI) with which some of the vehicles are equipped. HMI examples are shown where they differ from series HMIs or where they are an integral part of the enabler.

The vehicle description catalogue consists of 20 entries each providing an overview of the vehicle, sensor and sensor coverage, HMI, and data logger description. Each entry ends with a description of the enablers that are central to the ADFs of the vehicle. The amount of information per vehicle has been reduced, as the purpose of this deliverable is to describe the collection of the information. Individual vehicles reflect the best implementation of the intended enabler after simulations, feasibility studies, and prototype vehicles. The absence of benchmarking between VOs is a core principle of Hi-Drive, thus different partners are identified simply by their ID.

1 Hi-Drive – Addressing challenges toward the deployment of higher automation

Connected and Automated Driving (CAD) has become a megatrend in the digitalisation of society and the economy. CAD has the potential to drastically change transportation and generate far-reaching impacts. SAE L3 automated functions were piloted in Europe by the L3Pilot project in 2017–2021. Hi-Drive builds on the L3Pilot results (L3pilot, 2021) and advances the European state-of-the-art from SAE L3 'Conditional Automation' further up towards 'High Automation' by demonstrating in large-scale trials the robustness and reliability of CAD functions in demanding and error-prone conditions with special focus on:

- CAVs travelling in challenging conditions covering variable weather and traffic scenarios,
- connected and secure automation providing vehicles/their operators with information beyond the line of sight and on-board sensor capabilities,
- complex interaction with other road users in normal traffic, and
- factors influencing user preferences and reactions including comfort and trust and eventually, enabling viable business models for AD.

The project's ambition is to extend considerably the operational design domain (ODD) from the current situation, which frequently demands taking over control of the vehicle by a human driver. As experienced in the EU flagship pilot project L3Pilot, on the way from A to B a prototype AV will encounter a number of ODD factors leading to fragmented availability of the AD function. Hi-Drive addresses these key challenges, which are currently hindering the progress of vehicle automation. The concept builds on reaching a widespread and continuous ODD, where automation can operate for longer periods and where interoperability is assured across borders and brands. Hi-Drive strives to extend the ODD and reduce the frequency of TORs by selecting and implementing technology enablers leading to highly capable CAD functions, operating in diverse driving scenarios including, but not limited to, urban traffic and motorways. The removal of fragmentation in the ODD is expected to facilitate a gradual transition from conditional operation towards higher levels of automated driving.

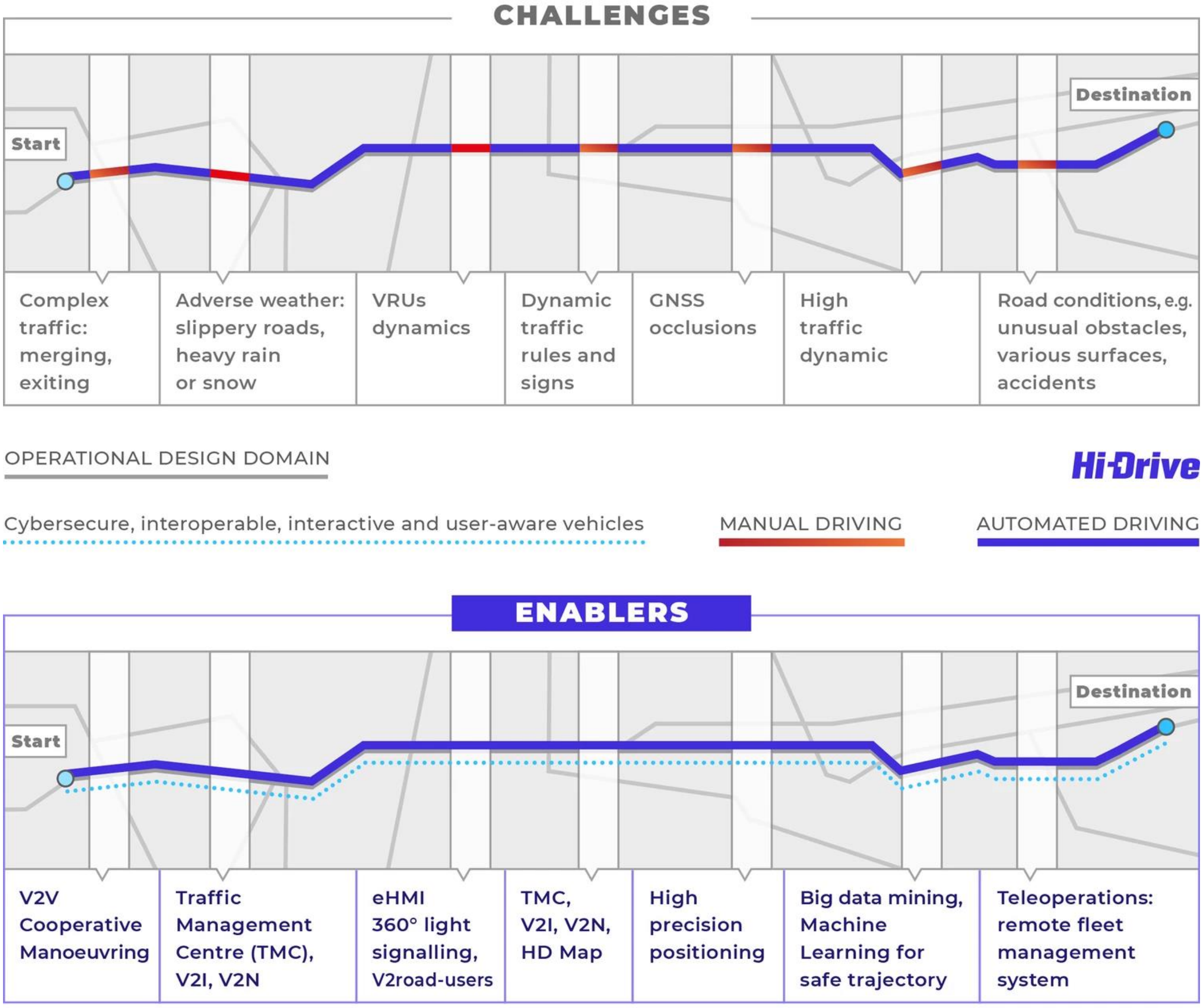


Figure 1.1: Hi-Drive addressing ODD defragmentation against challenges

The work started with the collection and description of the different ADFs, enabling technologies, and ODDs. Once the testable functions and use cases are defined, the research questions and hypotheses will be formulated, leading to specification of the data needed for evaluation, and then the actual recording of vehicle-driver behaviour. Testing will focus on eight evaluation areas: 1) Users; 2) AD performance; 3) Safety; 4) Efficiency; 5) Environment; 6) Mobility; 7) Transport system; and 8) Society. Furthermore, these assessments will serve as input to determine whether the socioeconomic benefits outweigh the costs. The project will also engage in a broad dialogue with stakeholders and the general public to promote the Hi-Drive results. Dissemination and communication will be boosted by a demonstration campaign to show the project's achievements.

Overall, Hi-Drive strives to create a deployment ecosystem by providing a platform for strategic collaboration. Accordingly, the work will include an EU-wide user education and driver-training campaign and a series of Codes of Practice (CoPs) for the development of ADFs and road-testing procedures. It will also lead outreach activities on standardisation, business innovation, extended networking with interested stakeholders, and coordinating parallel activities in Europe and overseas.

1.1 Background and concept

The scope of this deliverable is the outcome of Work Packages 3.4, 3.5, and 3.6 (Figure 1.2). The objective is the collection and presentation of information describing the vehicles involved in Hi-Drive. The VOs will equip the vehicles with actuators, sensors, and computing technology. The enablers will be implemented and integrated into the ADF, tested on proving grounds, urban roads, and motorways, and handed over to SP5 *Operations*, which will oversee driving in simulators and on urban roads and motorways.

The target of this deliverable is to provide an overview and status of the Hi-Drive fleet. Operating the fleet on public and closed roads and collecting data from hundreds of vehicle signals while driving within the nominal and extended ODD comprises an essential part of the data collected for analysis and evaluation.

This deliverable is the last of three vehicle-related reports, beginning with D3.1 *Use case definitions and ODD description*, which depicts the automated functions to be applied in the use cases. In the second report, D3.2 *Logging tools*, recommendation state-of-the-art tools are collected and commented on for a selection of data recorders that can handle several signal formats and fulfil methodological and automotive requirements.

A core condition of Hi-Drive, as a non-differentiation research project, is the absence of benchmarking. No comparison will be possible between the performance of different vehicle brands, and no link can be made between the data collected from a test vehicle of a certain brand and the contribution of the results derived from this data in the final assessment and evaluation of the effects of CAD on traffic and society.

The main objectives addressed by this work are as follows:

1. Ensure readiness of the enablers in the test vehicle. Enablers provide the enhancement allowing the CAD to extend the vehicle's ODD. The enablers need to be installed and connected in the test vehicle (Implementation).
2. Preparation of the vehicles. Series production vehicles are modified with additional sensors, changed actuator software (to extend limits, e.g., steering torque, low speed creep), datalogging, computing, harnesses, additional HMI, and control monitors (Preparation).

3. Pre-testing vehicles. The modified test vehicles are driven on test tracks and later within the intended ODD. The intended use cases are performed and the applicability of the enabler to the use case is ascertained. Having achieved the final objective, the test vehicles are ready for handover to SP5 *Operations*.

1.2 Interrelations with other SPs/WPs

For this work, which belongs within the Hi-Drive subproject *Vehicles* (SP3), interaction with other SPs is needed to ensure that the ADF owners are aware of the Hi-Drive data analysis targets (Subproject *Methodology*, SP4) and consequently that the vehicles are capable of generating the required data for evaluation studies in SP7 *Effects* and SP6 *Users* according to the data requirements, defined by SP4.

Following the ordered sequence of SPs, the following inputs/outputs from/to other SPs are processed/produced by SP3 as follows:

SP1 *Collaboration* looks at individual progress in the development of vehicle and enabler integration. It provides inter-project connectivity and is adaptable to changes in the partner workforce. It receives information on vehicle status and incurred efforts.

SP2 *Enablers* provides the enablers which, when integrated within the ADF of the vehicle, will enhance the ODD. It receives feedback on handling the enablers in the vehicles and makes recommendations on changes.

SP4 *Methodology* specifies the research questions and evaluation needs that are directly impacted by the capabilities of vehicles. Aligned with the requirements from SP7 *Evaluation*, experimental procedures are created along which our experiments with vehicles will be performed. It receives information on use cases and ADFs of vehicles.

SP5 *Operations* is where driving, execution of experiments on roads, tracks, and in simulators, and data collection at all our various experiment sites is centralised. It will receive an imaginary hand-over of tested vehicles as the last milestone of SP3.

SP6 *Users* receives the description of Hi-Drive in-vehicle ADFs, use cases, and test scenarios, from which user studies will be developed that act as a companion to the evaluation of collected vehicle data.

SP7 *Effects* receives the collected vehicle data in a common data format, drives the analysis of collected results through technical assessment and leads the socioeconomic evaluation.

SP8 *Outreach*, together with SP1 *Collaboration*, determines how the project is publicly presented, e.g., with vehicle showcases, to increase stakeholder and public awareness. It receives insight on the deployment needs of CAD vehicles (user training, limitations, and the non-intuitive concept of ODD).

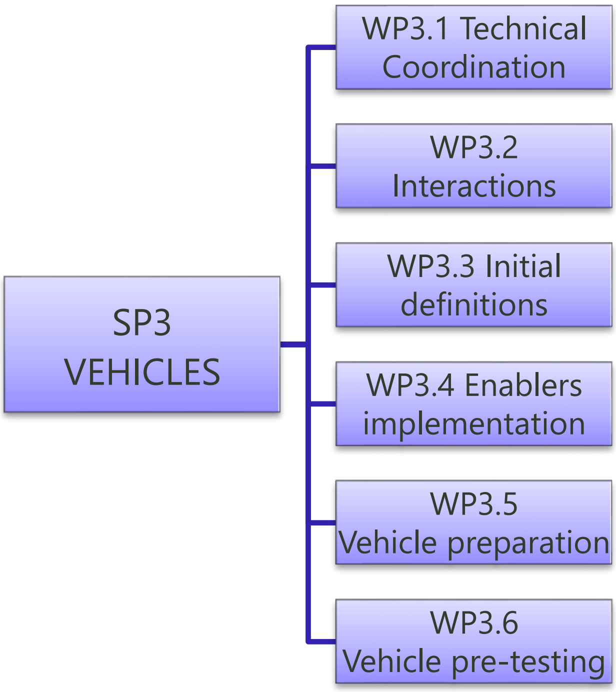


Figure 1.2: Work Breakdown structure

1.3 Structure of the deliverable

Deliverable 3.3 is structured as follows: Section 2 starts with the Methodology to collect and group the vehicle information on individual timing and content from the VOs. This is done using the two templates described in subsection 2.2.

Section 3 is the main catalogue and starts with an overview of the categories (Vehicle, HMI, external HMI) and statistics. It then presents individual information from each of the twenty VOs in the sections Overview of the vehicle, Sensor and sensor coverage, HMI, and Data logger description as required by the template on Vehicle description. As in other Hi-Drive deliverables, the name of the VO has been replaced by an ID.

Section 4 concludes the work.

2 Methodology

2.1 Background work

The description of a vehicle as part of the Hi-Drive fleet should provide information that is needed to deliver a status of tasks toward handover (e.g., in progress, ready) and information that is needed to characterise the contribution of the VO and their vehicles in a more general view for the later task of technical assessment of the data collected and delivered.

For describing the Hi-Drive vehicles and their readiness for operation, we decided to use two different templates. The first is used to track the vehicle status and see if every VO can deliver their vehicle on time. The second is used to describe the vehicles and show the link between the vehicle, ADS, and enabler. The next section will introduce the terminology used to define the vehicles, followed by the enabler groups and finally by the ADF type list.

2.1.1 Terminology

Table 2-1: Terminology

Source	D3.3 Glossary	
Hi-Drive glossary	Automated Driving System (ADS) [SAE (2021)]	The hardware and software that are collectively capable of performing the entire DDT on a sustained basis, regardless of whether it is limited to a specific operational design domain (ODD); this term is used specifically to describe a Level 3, 4, or 5 driving automation system.
	Automated Driving Function (ADF) [SAE (2021)]	A common feature addressed by a group of Automated Driving Systems. Example: Motorway ADF, Urban ADF NOTE: Similar ADFs share the same level of driving automation and quite similar ODDs. NOTE: ADF types considered in Hi-Drive are Motorway Chauffeur, Urban Chauffeur, Rural Chauffeur, and Parking Chauffeur.
	Automated Driving System feature (ADS)[SAE (2021)]	A Level automated driving system's design-specific functionality at a given level of driving automation within a particular ODD, if applicable.
	Driver [SAE (2021)]	A user who performs in real time part or all of the dynamic driving task (DDT) and/or DDT fallback for a particular vehicle. This definition of "driver" does not include a robotic test device designed to exercise steering, braking, and acceleration during certain dynamic test manoeuvres.

Source	D3.3 Glossary	
	Enabler	Technological tools (SW, HW, Methodology) that have the potential to enable new vehicle automated function/s and/or upgrade existing vehicle automated function/s. Examples: SW to be installed into vehicles to acquire data received from other vehicles, HW board to be installed into vehicles to connect to the 5G core network, Methodology: Threat Analysis and Risk Assessment

2.1.2 Naming of Enabler Groups

Enablers are a central topic in Hi-Drive. Together with the ADF they enable the extension of the vehicle's ODD. A total of 13 enablers have been identified. Most belong to the technology group (TECH) and one to Methodology and Tools. Each enabler theme is further sub-divided into individual instances (e.g., E.2.3.1.a to g) to denote the enabler realised by the VO in the ADF of their vehicle(s) (instances are not shown here).

Table 2-2: Hi-Drive Technology Enablers, Thematic and Groups

Hi-Drive Technology Enablers, Thematic and Groups	
VEHICLE COMMUNICATION	
E.2.3.1 V2V Vehicle-to-Vehicle Communication	TECH
E.2.3.2 V2I Vehicle-to-Infrastructure and Infrastructure-to-Vehicle Communication	TECH
E.2.3.3 Vehicle-to-Cloud (Edge and Core)	TECH
E.2.3.4 Vehicle Intention Communication	TECH
VEHICLE HIGH PRECISION POSITIONING & LOCALISATION	
E.2.4.1 Geo-referenced Cloud Services	TECH
E.2.4.2 Sensor Fusion for Localisation	TECH
E.2.4.3 Positioning Relying on Ranging Signals NOTE: in the E.2.4.3 GROUP, NO ENABLERS ARE AVAILABLE YET	TECH
VEHICLE COMMUNICATION CYBERSECURITY	
E.2.5.1 TARA Threat Analysis and Risk Assessment	METHOD
E.2.5.2 V2X Cyber-Risk Mitigation	TECH
VEHICLE MACHINE LEARNING	
E.2.6.1 CAD ML Toolkit	TOOLs
E.2.6.2 CAD ML Perception, Object Detection, and Classification	TECH

Hi-Drive Technology Enablers, Thematic and Groups	
E.2.6.3 CAD ML Decision Making	TECH
E.2.6.4 CAD ML Driver Monitoring	TECH

2.1.3 Use case clusters

As with the enablers, each VO delivered a description of several use cases (UCs) to WP3.3 *Initial definitions*. In deliverable D3.1 *Use case definition and description* all use cases have been collected and clustered.

Table 2-3: User case clusters formed in Hi-Drive user case catalogue

ADF type	UC clusters	VOs members
Motorway	Cooperative lane merging/exiting/overtaking	10
	Lane merging/exiting/interchange/lane changing	6
	Motorway driving (different challenging scenarios)	5
	AD system identifies challenging operational domain condition or recognises driver state	4
	Special or temporary road infra crossing	5
	Handling an event notification about an event in the range 0.5-2km ahead	5
Urban	Cooperative non-signalised intersection transit with early AD reaction to V2N	5
	Cooperative signalised intersection transit via V2I	5
	Cooperative urban driving (no intersections) – handling an event notification (about 0.2–2km ahead)	2
	Urban canyon driving	2
	Urban driving – straight segment	7
	Urban driving – non-signalised intersections	2
Rural	Driving on 2-directional rural road section	1
	Cooperative overtaking via V2V	1
	Arctic uninterrupted driving in specific conditions	2
Parking	Automated Valet Parking	3

2.2 Templates

2.2.1 Two types of templates

The two templates proposed are presented in Annex 1 (Progress tracking template) and Annex 2 (Vehicle definition template). The design logic for each of them is provided in the two sub-sections that follow, 2.2.2 and 2.2.3 respectively.

2.2.2 Progress tracking template information

In SP3 *Vehicles*, vehicles are being prepared for experiments in SP5 *Operations*. Pre-tests in SP5 concern the combined effects of vehicle, user, environment, and use case.

Once the enablers are working in the vehicles (**WP3.4**), we need to ensure that AD is working with the enablers (**WP3.5**) and that the necessary signals are present, processed, and converted, and that the vehicles are pre-tested (e.g., in a real or pseudo use case) (**WP3.6**) to ensure that data is sufficient for analysis checks by the analysis partner.

WP3.4 is responsible for the readiness of enablers in the test vehicles. Therefore, we need to track the test vehicle preparation process that leads to the test vehicles being ready for the implementation of the targeted enabler(s). Each VO needs to implement at least one enabler as described by SP2. Each VO may use their own enabler technology solutions (i.e., hardware), as long as they are compatible with those recommended by SP2. This hardware integration progress needs to be tracked as well. Finally, we need to track the completion of the test vehicles in the sense that the implemented enabler also works with the targeted ADF.

The progress-tracking table derived from the above work description is shown below.

Table 2-4: Enabler Implementation

Activity	Description	Planned completion date	Enabler ID 1: (e.g. E.1.1.1)	Enabler ID 2:	Comment	Last update on
Test vehicle is ready for implementation of enabler	Vehicle is available	<date>	<date>	<date>		<date>
Enabler HW integrated in vehicle	HW integrated	<date>	<date>	<date>		<date>
Enabler operational	SW integrated	<date>	<date>	<date>		<date>

Activity	Description	Planned completion date	Enabler ID 1: (e.g. E.1.1.1)	Enabler ID 2:	Comment	Last update on
in vehicle with ADF	This is after completion of vehicle preparation in WP3.5					

WP3.5 is responsible to ensure that the test vehicles are equipped with all hardware and software means required to perform the planned vehicle tests in SP5 *Operations*. Therefore, we need to track the completion of the test vehicle build, i.e., whether all required additional sensors and technical equipment, including data loggers, have been installed. It is also expected that test vehicle functionality is confirmed to ensure that the test vehicles are technically mature. In addition, adaptation of the ADF software modules to the new enabler inputs is required to implement the new ADFs and, therefore, needs to be tracked as well. All in all, progress tracking in WP3.5 ensures that all test vehicles are technically ready for the pre-testing phase in WP3.6.

The progress-tracking table derived from the above work description is shown below.

Table 2-5: Vehicle preparation

Activity	Description	Planned completion date	Actual completion date		Comment	Last update on
			Vehicle 1	Vehicle 2		
Vehicle technically ready	Sensors, actuators, computing, harnesses, and safety review are done. Technically mature.	*<date>*	*<date>*	*<date>*		*<date>*
ADF adapted to the vehicle	HW/SW installed	*<date>*	*<date>*	*<date>*		*<date>*
ADF tested and approved	Tested on public road or test track?	*<date>*	*<date>*	*<date>*		*<date>*
Logger installed and tested	All required signals are available for logging. Data can be recorded.	*<date>*	*<date>*	*<date>*		*<date>*

Activity	Description	Planned completion date	Actual completion date		Comment	Last update on
			Vehicle 1	Vehicle 2		
Vehicle approved for public roads		*<date>*	*<date>*	*<date>*		*<date>*
Signals in common data format	Signal input for CDF conversion delivers correct data (precision, ...)	*<date>*	*<date>*	*<date>*		*<date>*

WP3.6 is responsible to ensure that the adapted test vehicles are ready for hand-over to SP5 *Operations*. Therefore, test events need to take place to ensure interoperability between different ADFs of vehicles and different test sites. The test events are also intended to ensure the applicability of the use cases/scenarios defined by WP3.3 under real life conditions. To understand the progress made in the test events, it is necessary to track the status of data recording and conversion to a common data format (CDF) shared with all partners in the project. It is expected that full sets of baseline and treatment data are provided to the selected analysis partner from SP7 *Effects* to test the evaluation tool chain and the integrity of the provided data. Therefore, we need to track whether the analysis partner confirms that the CDF data is as expected.

The progress-tracking table derived from the work description is shown below.

Table 2-6: Vehicle pre-testing

Activity	Description	Planned completion date	Actual completion date		Comment	Last update on
			Vehicle 1	Vehicle 2		
Data recording	Vehicle provides meaningful data at operation site	*<date>*	*<date>*	*<date>*		*<date>*
Data conversion	Recorded data can be converted into CDF	*<date>*	*<date>*	*<date>*		*<date>*
Baseline data quality check	Analysis partner confirmed that	*<date>*	*<date>*	*<date>*		*<date>*

Activity	Description	Planned completion date	Actual completion date		Comment	Last update on
			Vehicle 1	Vehicle 2		
Treatment data quality check	CDF data is as expected	*<date>*	*<date>*	*<date>*		*<date>*
First test trips performed	A reasonable amount of data has been recorded that is suitable for testing analysis	*<date>*	*<date>*	*<date>*		*<date>*
Simple analysis performed	A reasonable amount of recorded data has been used for testing analysis by the analysis partner	*<date>*	*<date>*	*<date>*		*<date>*

The three progress-tracking tables above help us to observe and understand the vehicle preparation progress of the VOs across WP3.4, WP3.5, and WP3.6. In case there is a delay in a VO's plan, countermeasures can be discussed so that the test operations can be realigned.

2.2.3 Vehicle description template information

Most CAD test vehicles will be series production vehicles modified with additional sensors and technical equipment including data loggers and enablers.

We have constructed a template to describe the vehicles of each vehicle owner (VO). The template is in 10 parts.

The first part is the vehicle description summary (Table 2-7), which describes the number of vehicles, type of vehicle, how the vehicle operates with the enabler, and the enabler implemented in the vehicle. To select the enabler tech solution, we have summarised all the enablers in Table 2-2. All the use cases are listed in Table 2-3 as well, so that the VOs can easily fill in the last columns of Table 2-7.

Table 2-7: Vehicle description summary

ID	Count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)

The second part shows a picture of the adapted vehicle. All pictures will be displayed in the same section (see section 3.2.1).

In addition, we wanted to describe the sensors used by the ADF and by defining the technology, the function, and the interface (Table 2-8).

Table 2-8: Sensors for AD function(s)

Technology	Function	Hor. field of view	Interface
Outside camera			Ethernet
Inside camera			Ethernet
Radar			CAN
LiDAR			Ethernet
USS			N/A
GPS			Ethernet
IMU			Ethernet

We also ask each VO to illustrate their sensor coverage (Figure 2.1) to support the above description (Table 2-8).

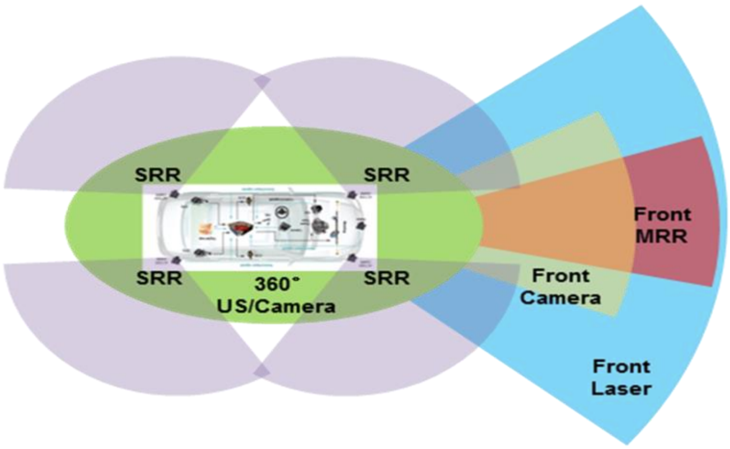


Figure 2.1: Sensor coverage example

In addition to the vehicle sensors, each VO integrates the ADF with an HMI already equipped in series on the vehicle or with a new HMI added for the specific purpose of providing more information to the driver. An HMI is provided to receive a request from the driver or to send ADF feedback to them. The HMI list is shown in Table 2-9.

Table 2-9: HMI description

Channel	Device	Main features
Visual		
Audio		
Commands		
MID (Meter)		
Multimedia		
HUD		
Haptic		

In addition to the table, we ask each VO to provide an example view of the HMI to give an idea of what the driver sees (Figure 2.2).

Figure 2.2: HMI example

Some VOs are using an external HMI to inform people in the vehicle's surroundings, so we decided to add this category also (Figure 2.3).

Figure 2.3: External HMI (eHMI)

In addition to this equipment, VOs might equip their vehicle with in-cabin equipment which may serve to monitor the driver's state of mind (happy, drowsy, …) and/or activity.

The data logger is a key element of the ADS. It allows to record raw data from sensors, from CAN signals, from sensors not necessarily used for the prototype, like Driver Monitoring Systems (DMS), and information coming from outside, like V2X. The logger can record at a low level (raw data) or at a higher level, such as object level. Depending on the need, some VOs might decide to record both, which leads to higher bandwidth and data storage requirements. The table below illustrates these differences (

Table 2-10: Data logger description).

Table 2-10: Data logger description

Raw data record	Yes / No
Fusion object level record	Yes / No
Embedded video labelling	Yes / No
Could the driver annotate events	Yes / No
Data volume per hour in terabytes	xxx TB/h

The purpose of Hi-Drive is defragmenting the ODD. This can be achieved with specific technology solutions, of which Hi-Drive has selected four (Communication, High precision positioning and localisation, Cybersecurity, and Machine learning). These technological solutions are summarised Table 2-2. Each VO is requested to describe how they will use their technological solution by filling in Table 2-11.

Table 2-11: Enabler description

Enabler Tech Solution (E.2.y.z) and brief motivation
E.2.x.y title Insert free text here: please explain/describe your enabler

3 Vehicle definition

3.1 Vehicle description summary and catalogue

This section contains descriptions of the Hi-Drive vehicles. The material is organised in two parts: Part I: Vehicle description summary, and Part II: Vehicle description catalogue.

The first section collects all the pictures depicting the vehicles, HMI, and eHMI used in Hi-Drive. The purpose is to show the current state-of-the-art of AD prototype vehicles used to operate ADFs on the road.

3.2 Vehicle description summary

3.2.1 Vehicles

Figure 3.1: Hi-Drive vehicles

In total 37 vehicles will be used in the project (Figure 3.1). Some vehicles will be used to send information to the AD vehicle (V2X), some will be used on open roads, and some will be used on test tracks for specific experiments. Figure 3.2 shows the locations of target operations.

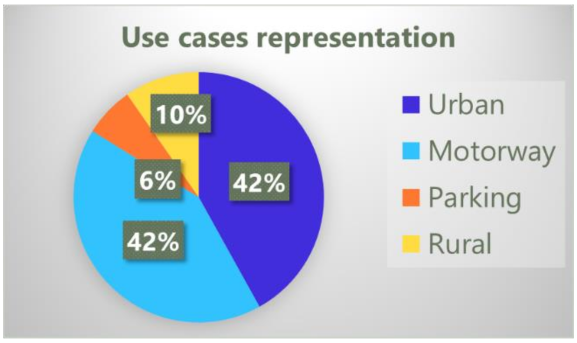


Figure 3.2: Use cases representation

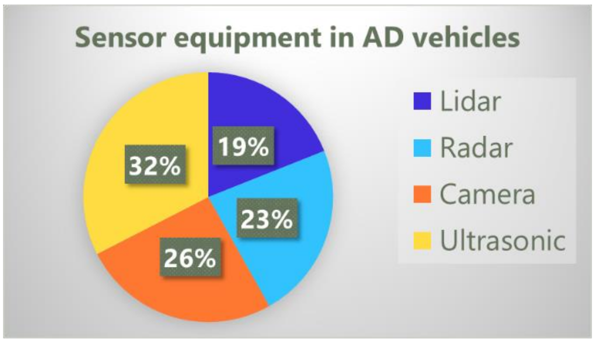


Figure 3.3: Sensor equipment in AD vehicles

Figure 3.3 shows the distribution of sensor types in the vehicle fleet present in Hi-Drive. In addition to the sensors installed on vehicles, all VOs have equipped their vehicles with an enabler (see Table 2-2). Figure 3.4 shows the distribution of enablers in the Hi-drive fleet.

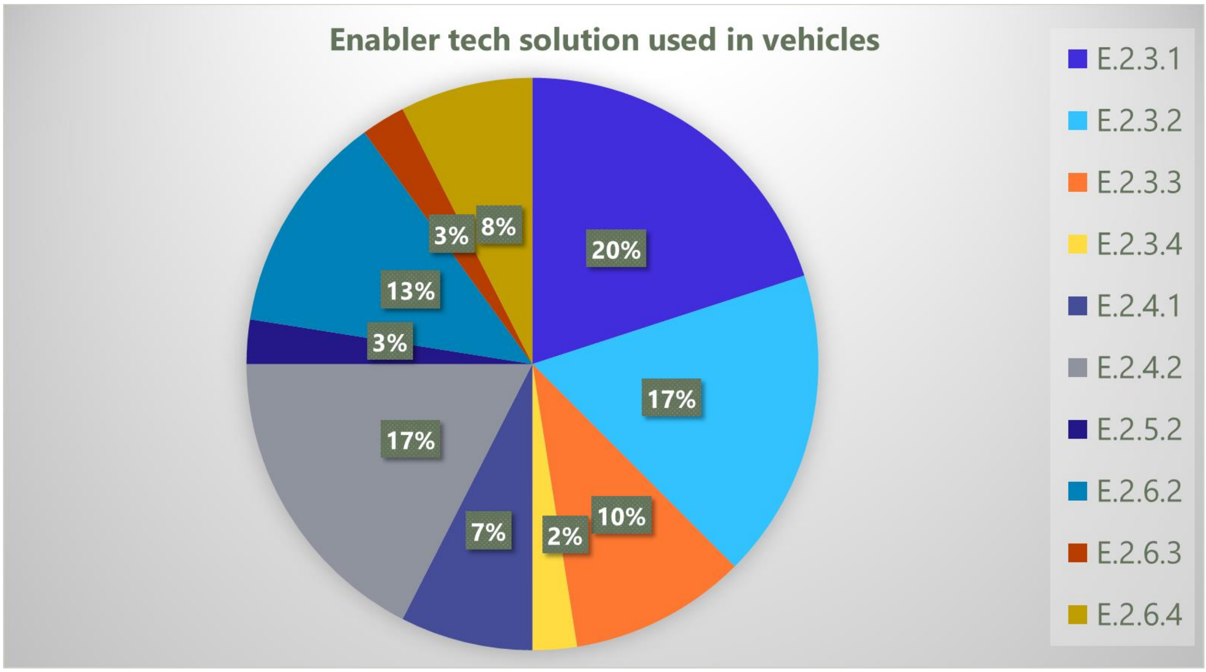


Figure 3.4: Enabler tech solution used in vehicles (Table 2-2)

Figure 3.5 shows the data volume per hour split per use case. Motorway is the most represented, with 6.56TB/h. The raw data collection depends on the number and type of sensors. Camera data collection without compression is the biggest data storage consumer (uncompressed data is needed for exact re-simulation). Access to videos is granted to the analysis partner only on a case-by-case basis to check driving situations that are unclear.

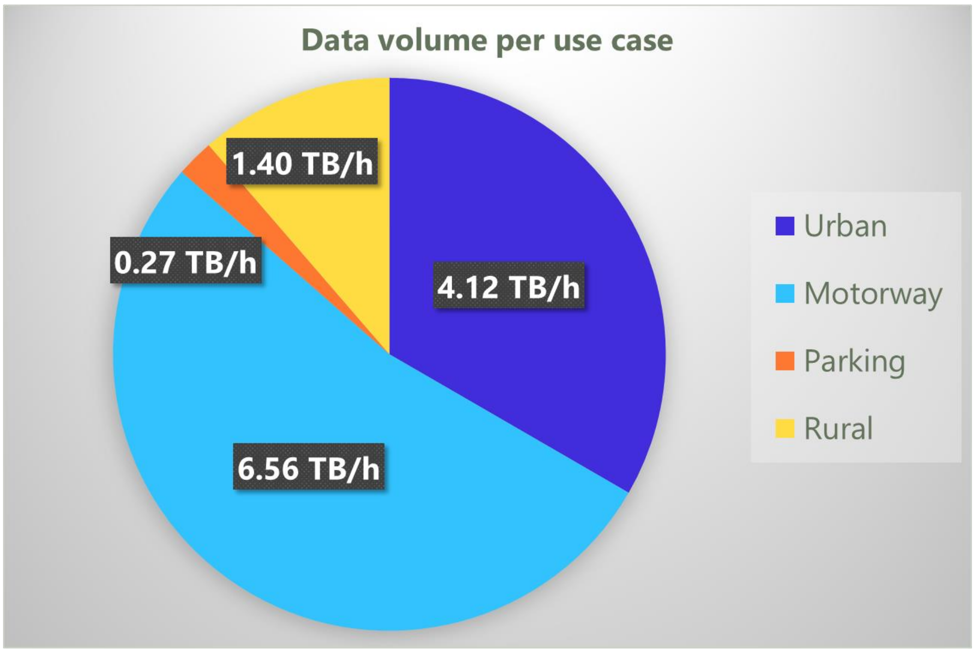


Figure 3.5: Data volume per use case

The variance in data volume is large as this information had been asked for overview and not for planning resources. At the beginning of data logging, it might be not clear which data is really needed (and a large volume is anticipated) or if only the data is reported, that will ultimately be used for e.g., CDF-conversion (lower volumes anticipated). Also, the concept or raw data is broad, and volumes can be measured directly at the sensor (raw data such as images, point clouds), after sensor internal pre-processing, or after the path and actuation planning (very different outcomes). Infrastructure, V2I, and V2V message are low volume.

3.2.2 Human-Machine Interface (HMI)

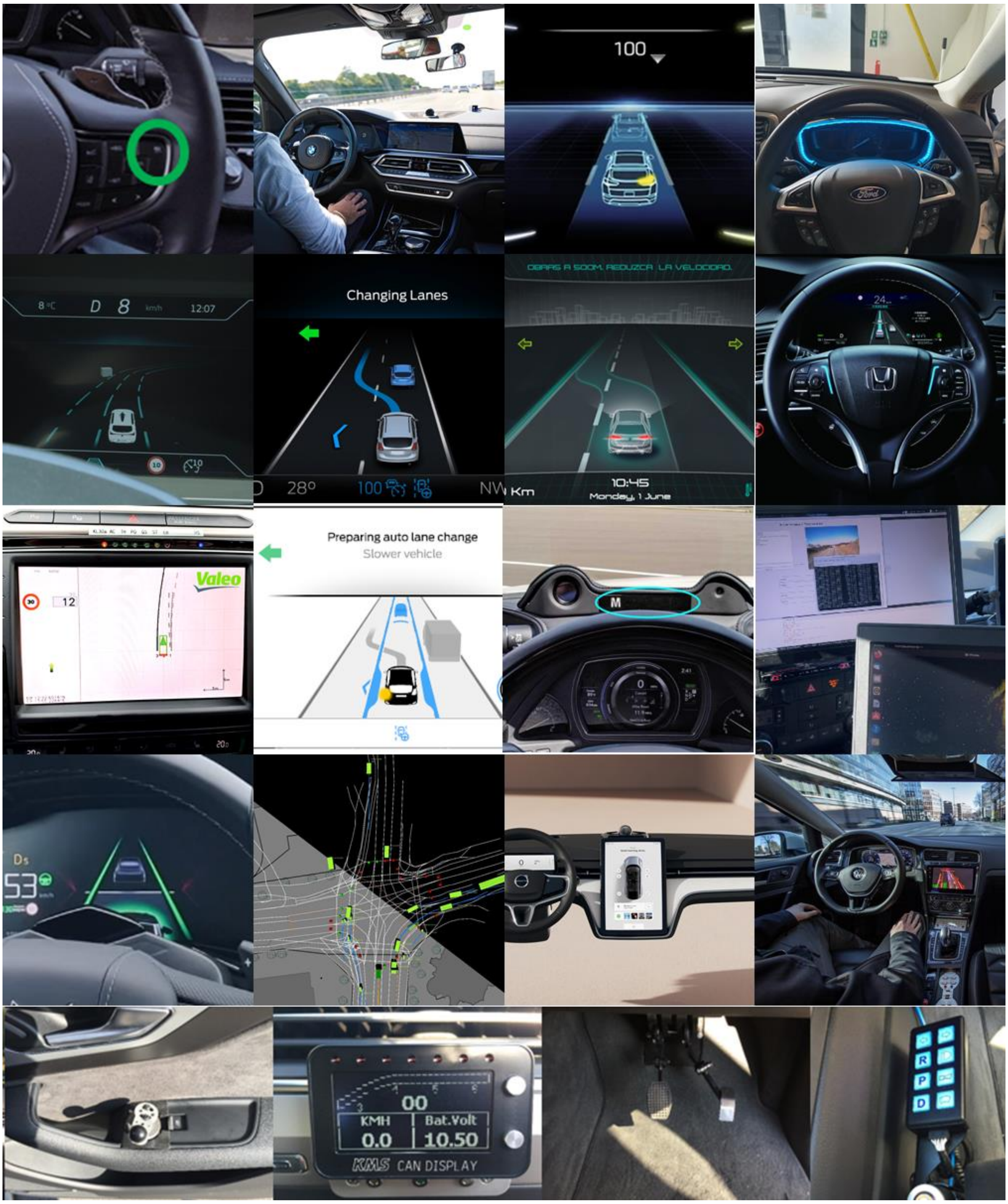


Figure 3.6: HMIs used in Hi-Drive

Almost all VOs are using the HMI present in series cars to inform the driver of the AD status and/or for the driver to take action. The information is presented on the meter or multimedia display. Usually, all actions are taken at the steering wheel. Figure 3.7 shows an example of the HMI types used in the Hi-Drive vehicle fleet. Some VOs are adding extra LED or bigger screens to demonstrate understanding of the ADF. Some VOs require an operator to monitor the ADS and inform the driver of a malfunction or future action taken by the ADS.

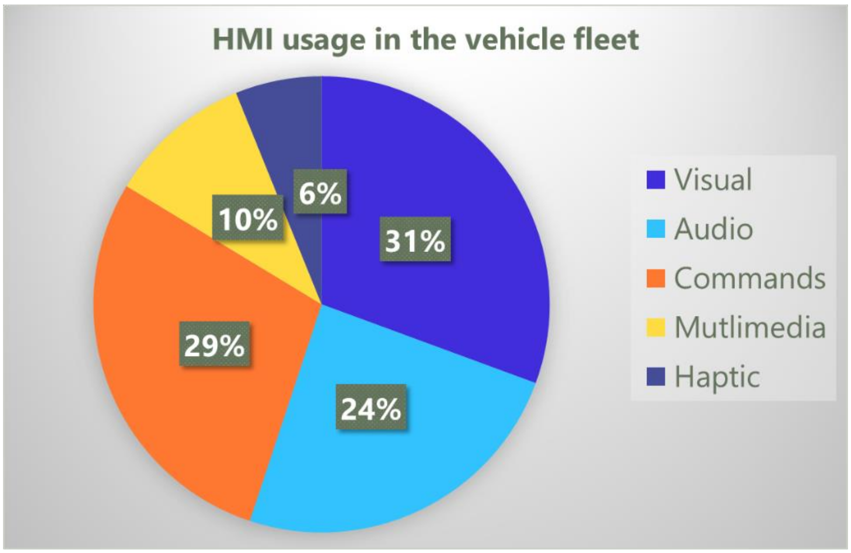


Figure 3.7: HMI usage in the vehicle fleet

3.2.3 External Human-Machine Interface (eHMI)

Figure 3.8: eHMIs considered for Hi-Drive

When the vehicle is driving in automated mode, the ADS must be able to transmit information to people both inside the vehicle (driver, operator) and in its vicinity. Figure 3.8 shows several examples of eHMIs used in Hi-Drive.

3.3 Vehicle description catalogue

In this section, we present a catalogue of the details delivered by all 20 VOs for their research vehicles, enablers, equipment, and intended use case. We apply the methodology described in section 2.2.3 to describe the number of vehicles, the enabler technology solution used, and the equipment installed in the test car. The tables were filled in by the VO in our web-based workflow tool and any missing parts completed upon request.

3.3.1 Vehicle owner ID 1

3.3.1.1 Vehicle description

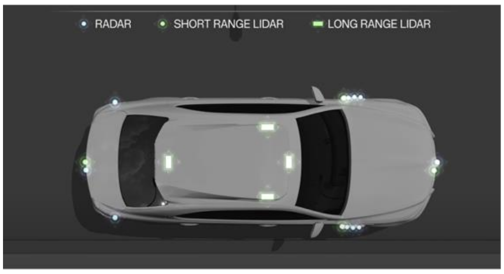
ID	Count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
1.1	1	Prototype	The vehicle can operate AD on its own. In that case the enabler is not used. The vehicle needs another vehicle to send/receive V2V information during the operation to evaluate AD with the enabler. A safety driver and an operator are required to operate the system.	Integration of the new enabler in the vehicle has been done at different levels. We had to integrate the hardware (connectivity and configuration) to add low-level software to integrate the hardware with the AD software. Once communication could be established, we had to integrate the new information (V2V) at different levels so that the planner and the decisions of	E.2.3.1	Urban

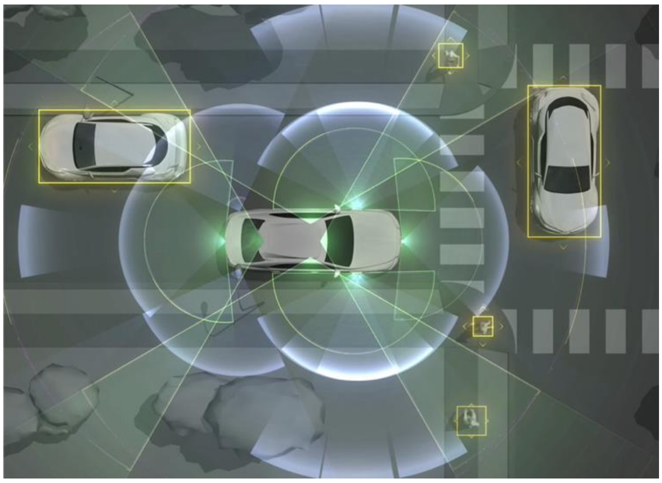
ID	Count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
				the AD would take into account this new type of data.		
1.2	1	Series vehicle equipped with ITS-G5	This vehicle provides information to the AD vehicle at the back	We had to integrate the hardware (connectivity and configuration) and write some software to send the required data.	E.2.3.1	Urban

3.3.1.2 Sensors for AD function(s)

Technology	Function	Hor. field of view	Interface
Outside camera	Lanes + objects + traffic signs	6*60°	Ethernet
Inside camera	Driver status		Ethernet
Radar	Objects	360°	CAN
LiDAR	Lanes + objects	360°	Ethernet
USS	Not used	N/A	N/A
GPS	Vehicle position	N/A	Ethernet
IMU	Vehicle position	N/A	Ethernet

3.3.1.3 Sensor coverage





3.3.1.4 HMI description

Channel	Device	Main features
Visual	LED	AD status
Audio	Buzzer OR speaker	TOR
Commands	Buttons	Turn on/off AD
MID (Meter)	N/A	
Multimedia	N/A	
HUD	N/A	
Haptic	N/A	

3.3.1.5 Data logger description

Raw data record	Yes
Fusion object level record	Yes
Embedded video labelling	No
Could the driver annotate events	Yes
Data volume per hour in terabytes	0.3TB/h

3.3.1.6 Enabler description

Enabler Tech Solution (E.2.y.z) and brief motivation
E.2.3.1: V2V Vehicle-to-Vehicle Communication Our enabler aims to implement both Cooperative Awareness Message (CAM) and Decentralised Environmental Notification Message (DENM) in an on-board unit based on ITS-G5 to improve AD vehicle safety & comfort. This will significantly increase the AD sensor range and extend its dataset.

3.3.2 Vehicle owner ID 2

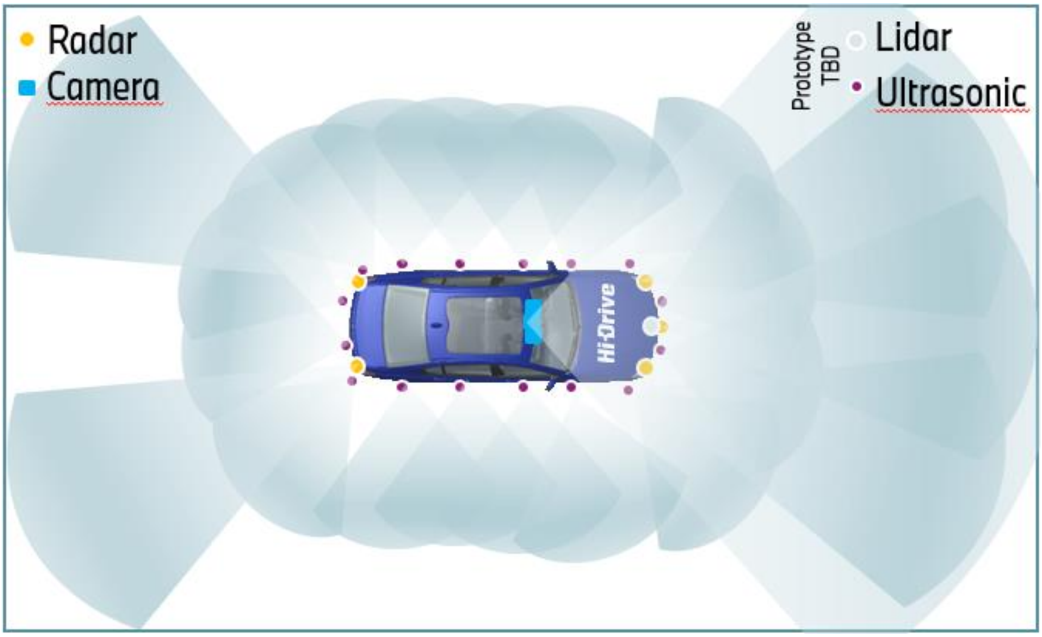
3.3.2.1 Vehicle description

ID	Count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
2.1	2	Vehicle with adapted display & operating concept (non-serial), technical components (non-serial steering wheel) and driving-school pedals on safety driver (passenger seat). Requirement to operate the vehicle with safety driver in co-driver seat (independent of enabler)	Measurement equipment and in-cabin cameras (for enabler driver monitoring) are installed.	Application of enabler in post-processing.	E.2.6.4	Motorway Urban
2.2	1	Prototype TBD	Measurement equipment and in-cabin cameras (for enabler driver monitoring) are installed.	Application of enabler in post-processing.	E.2.6.4	Motorway Urban

3.3.2.2 Sensor for AD function(s)

Technology	Function	Hor. field of view	Interface
Outside camera	Object, lane, and traffic sign detection	110°	Ethernet
Inside camera	Driver monitoring system	100°/55°	Ethernet
Radar	Object detection	16°/56°	CAN
LiDAR	N/A		Ethernet
USS	N/A		N/A
GPS	Vehicle position		Ethernet
IMU	Vehicle odometry		Ethernet

3.3.2.3 Sensor coverage



3.3.2.4 HMI description

Channel	Device	Main features
Visual	Instrument Cluster + LED stripes integrated in steering wheel	Representation of AD Function State + Mode transitions + Warnings
Audio	Speaker	Warnings, TOR
Commands	Buttons	ADF main controls
MID (Meter)	N/A	

Channel	Device	Main features
Multimedia	N/A	
HUD	N/A	
Haptic	Steering wheel	Warnings

3.3.2.5 In-cabin equipment other than HMI (e.g., driver monitoring)

The test vehicle contains a standard series-production radio/navigation unit. An additional laptop for the operator has been set up to monitor the AD system and hardware module states. This additional equipment is not part of the driver HMI (debugging and AD scenario control).

3.3.2.6 Data logger description

Raw data record	No
Fusion object level record	Yes
Embedded video labelling	No
Could the driver annotate events	Yes (safety driver)
Data volume per hour in terabytes	0.15 TB/h

3.3.2.7 Enabler description

Enabler Tech Solution (E.2.y.z) and brief motivation
E.2.6.4 Conformal prediction in driver monitoring systems Safety of the intended functionality (SOTIF): A better understanding of occurrence likelihoods will help decide which driver activities can be allowed and when an intervention is needed. This information is crucial, e.g., for take-over situations. Furthermore, increased precision of driver status detection can impact the number of issued take-overs and may extend or shorten ADF availability, improving performance within and perhaps extending the ODD. User experience/comfort: Improved driver monitoring will also enable appropriate reaction to the driver’s attention to driving or to side activities, increasing user experience by enabling tailored driver information to their current situation.

3.3.3 Vehicle owner ID 3

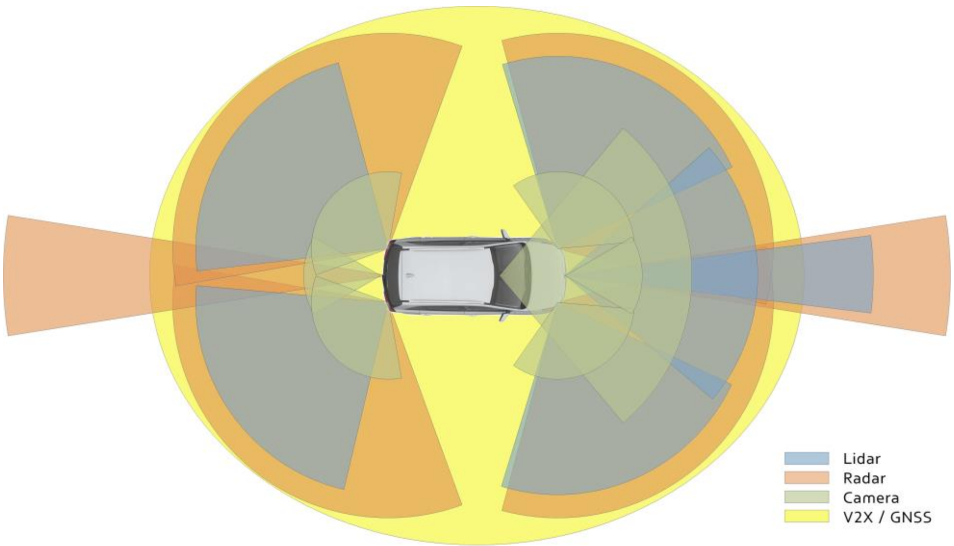
3.3.3.1 Vehicle description

ID	Count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
3.1	1	Prototype	The vehicle can drive automated on its own (enabled/disabled by the safety driver). For the support of Hi-Drive use cases, the vehicle requires another vehicle or the infrastructure to send/receive V2V information during the operation to evaluate AD with the enabler. A safety driver and an operator (safety co-driver) are required to operate the system.	Integration of the new enabler in the vehicle has been done at different levels. Additional hardware modules (connectivity, sensors, processing units) have been installed inside the test vehicle. Software modules have been developed and will run on the additional processing units to add a low-level vehicle control to enable the AD functions. Additional software modules to process HD map data and for communication with other vehicles and the infrastructure have been added so that the planner and the decisions of the AD take into account these additional data sources.	E.2.3.1 E.2.3.2 E.2.3.3 E.2.4.2	Urban, Motorway

3.3.3.2 Sensors for AD function(s)

Technology	Function	Hor. field of view	Interface
Outside cameras	Object detection & logging of test scenarios (test analysis)	60° (front/back) and 120° (corners), dedicated front view camera for scenario recording	GMSL
Inside cameras	Logging of test scenarios (test analysis)		Ethernet
Radar	Object detection and vehicle localisation	120°	CAN
LiDAR	Object detection and vehicle localisation	80° and 15° (front long range)	Ethernet
USS	Installed but not part of enabler/ADF (automated parking assist)		CAN / LIN
GPS	Localisation and ground truth	360°	Ethernet
IMU	Localisation, positioning, path and trajectory planning, etc.	360°	Ethernet
V2X (OBU)	Cooperative sensing, cooperative merging Extension of object detection	360°	Ethernet

3.3.3.3 Sensor coverage



3.3.3.4 HMI description

A dedicated HMI research is not part of our enablers (HMI development is out of scope), but the test vehicle will be equipped with a prototypic HMI to support the driver/user of the test vehicle.

Channel	Device	Main features
Visual	Cluster display (instrument panel)	System status, AD on/off, visualisation of surrounding objects and vehicle functions (merging, transition of control, minimum risk manoeuvre)
Audio	Speaker (instrument panel)	Alarm and confirmation of vehicle actions
Commands	Paddles behind steering wheel	Transition of control (request and confirmation)
MID (Meter)	N/A	N/A
Multimedia	Radio/navigation system	N/A (not part of dedicated HMI)
HUD	N/A	N/A
Haptic	N/A	N/A

3.3.3.5 In-cabin equipment other than HMI (e.g., driver monitoring)

The test vehicle contains a standard series-production radio/navigation unit. Additional displays for the co-safety driver and operator have been mounted to monitor the AD system and hardware module states. These additional displays are not part of the driver HMI (debugging and AD scenario control).

3.3.3.6 Data logger description

Raw data record	Yes (partially)
Fusion object level record	Yes
Embedded video labelling	Yes
Could the driver annotate events	Yes (safety co-driver)
Data volume per hour in terabytes	0.5 TB/h

3.3.3.7 Enabler description

Enabler Tech Solution (E.2.y.z) and brief motivation
E.2.3.1 V2V for cooperative manoeuvring Cooperative motorway chauffeur with merging support via V2V enabler, either on-ramp vehicle interacting with vehicle on the main motorway or vehicle on main motorway interacting with vehicle on the on-ramp. Traffic safety is a result of the explicit V2V coordination of actions between cooperative highly automated vehicles. Knowing about each other's "plans" and "intentions" would allow the receiving vehicles to know in advance how to react (e.g., safely and smoothly slow down when a vehicle ahead notifies the intention to merge onto the ego-lane), but also to keep less conservative time gaps to the surrounding cooperative vehicles.
E.2.3.2 I2V for road hazard notification and road signage Cooperative motorway chauffeur with early AD reaction to I2V hazard notifications and reaction to I2V dynamic road signage. Increased safety and comfort are a consequence of the time advance with which vehicles become aware of hazardous events and road signs as well as their explicit and unambiguous description, which can help with one's own planning and control decisions.
E.2.3.3 V2N for cooperative sensing Urban chauffeur with support for non-signalised intersections (early AD reaction to V2N cooperative sensing information). Increased safety and comfort are a consequence of the time advance with which vehicles become aware of the presence and descriptions of objects that could be relevant for one's own planning and control decisions.
E.2.3.3 N2V for road hazard notification and road signage Cooperative motorway chauffeur with early AD reaction to N2V hazard notifications and N2V dynamic road signage notifications. Increased safety and comfort are a consequence of the time advance with which vehicles become aware of hazardous events and road signs as well as their explicit and unambiguous description, which can help with one's own planning and control decisions.
E.2.4.2 Sensor fusion for localisation Fusion of multiple positioning sources to improve vehicle positioning (precision and robustness). Extended capabilities of the vehicle to understand where it is (localisation) with lane-level accuracy should prevent fragmentation of the ODD due to wrong road association or unreliable map matching and lead to safer decisions in terms of trajectory planning.

3.3.4 Vehicle owner ID 4

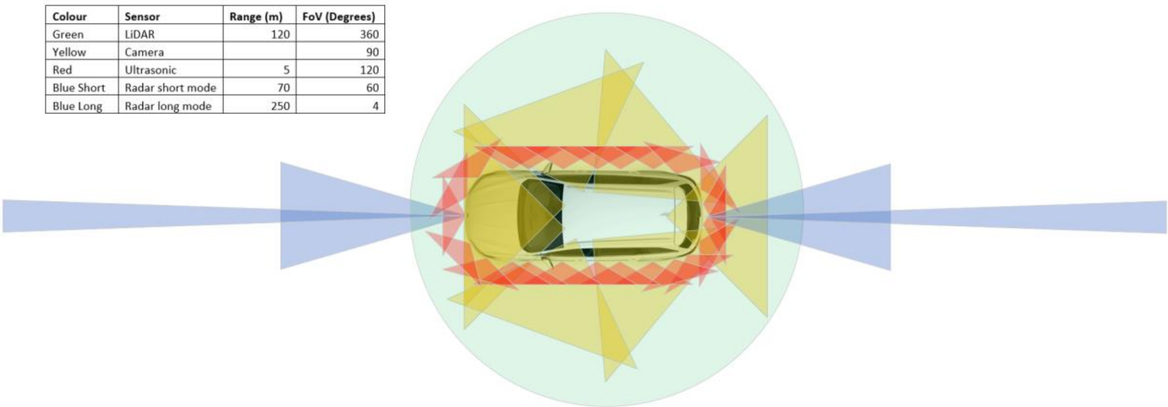
3.3.4.1 Vehicle description

ID	Count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
4.1	1	Prototype	The vehicle can operate the ADF on its own. In this case, the enabler is not used. To enhance the ADF using the enablers, the vehicle requires the infrastructure systems (sensing, detection algorithms, and communications) to be operational. A safety driver and an operator are required to run the vehicle and supporting systems.	Requires V2X communication between the infrastructure and vehicle. The ADF needs to be modified to allow for input of the additional information from the infrastructure.	E.2.3.3 E.2.6.2	Urban Motorway

3.3.4.2 Sensors for AD function(s)

Technology	Function	Hor. field of view	Interface
Outside camera	Objects	7*90	Ethernet
Inside camera			N/A
Radar	Objects	60 and 4 for different configurations	CAN
LiDAR	Objects and localisation	360	Ethernet
USS	N/A	N/A	N/A
GPS	Vehicle position	N/A	Ethernet
IMU	Vehicle position	N/A	Ethernet

3.3.4.3 Sensor coverage



Colour	Sensor	Range (m)	FoV (Degrees)
Green	LiDAR	120	360
Yellow	Camera		90
Red	Ultrasonic	5	120
Blue Short	Radar short mode	70	60
Blue Long	Radar long mode	250	4

3.3.4.4 HMI description

Channel	Device	Main features
Visual	LED	ADF status, searching for gap at junctions
Audio	Speaker	ADF ending
Commands	Buttons	
MID (Meter)	N/A	N/A
Multimedia	PC screen for equipment operator	ADF control and visual representation of what the car is seeing and doing
HUD	N/A	N/A
Haptic	N/A	N/A

3.3.4.5 Data logger description

Raw data record	Yes
Fusion object level record	Yes
Embedded video labelling	No
Could the driver annotate events	Unsure, yes if required
Data volume per hour in terabytes	Approximately 3 TB/h

3.3.4.6 Enabler description

Enabler Tech Solution (E.2.y.z) and brief motivation
E.2.3.3 - V2N for cooperative sensing **E.2.6.2 - 3D cooperative object detection** Infrastructure sensing at a complex junction communicated via V2N to provide additional information to the vehicle

3.3.5 Vehicle owner ID 5

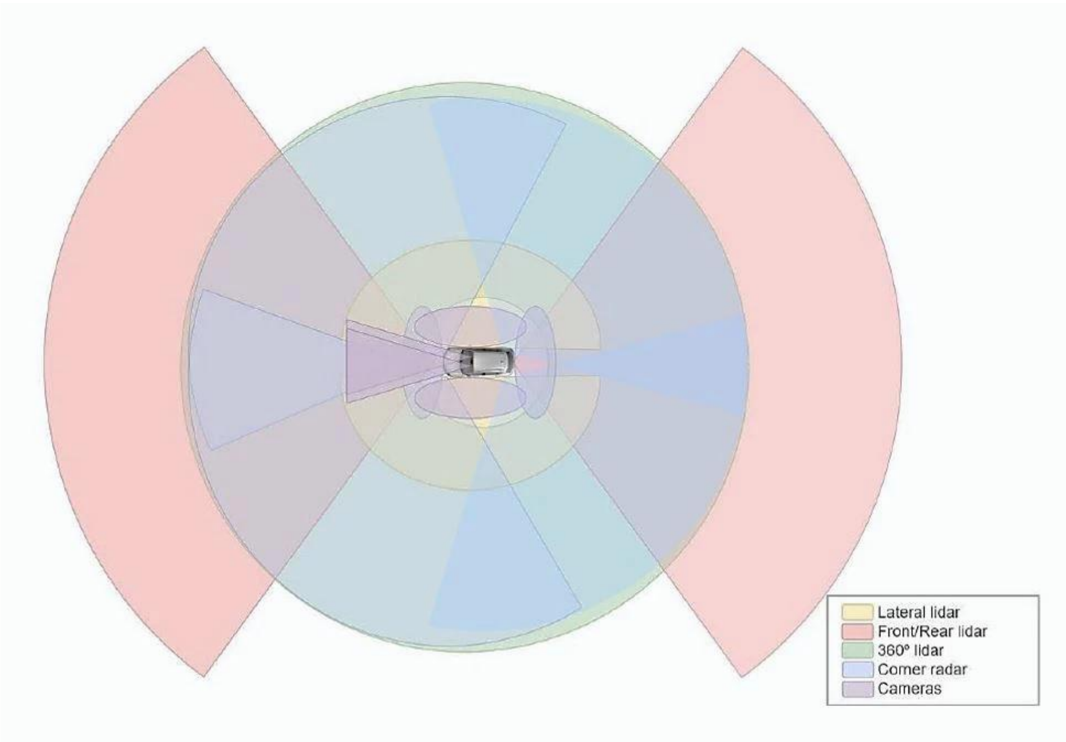
3.3.5.1 Vehicle description

ID	Count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
5.1	1	Prototype	AD functionality is enabled by a button placed on the steering wheel. A safety driver is a must to enable/disable AD functionality and operate the vehicle. The vehicle is also ready to connect to infrastructure (V2X). It can mainly receive SPATEM/MAPEM messages with traffic lights.	The vehicle is currently equipped with all necessary HW units to carry out UCs (LiDAR, cameras, radar, communication unit OBU for ITS-G5 and LTE, GPS, ...) SW updates are being done to integrate the 3 enablers in the different computers. HD map updates and signal adaptations for CDF are being prepared.	E.2.3.2 E.2.4.2	Urban

3.3.5.2 Sensors for AD function(s)

Technology	Function	Hor. field of view	Interface
Outside camera	Object detection for vehicle localisation & logging of usability/function tests	Parking: 360° Front: 120° & 60°	Ethernet
Inside camera	Not integrated in the enabler	109°	Ethernet
Radar	Not integrated in the enabler	N/A	N/A
LiDAR	Object detection for vehicle localisation	Front & Rear: 145° Side: 180° Roof: 360°	Ethernet
USS	Not integrated in the enabler	N/A	N/A
GPS	Vehicle localisation	-	Ethernet
IMU	Vehicle localisation and trajectory planning	-	Ethernet

3.3.5.3 Sensor coverage



3.3.5.4 HMI description

Channel	Device	Main features
Visual	Instrument cluster	Series information (speed, time, fuel level, blinker…), AD availability, set speed, TOR message, map, objects in vehicle's trajectory
Audio	Instrument cluster	Gong for TOR, MRM manoeuvres
Commands	Steering wheel buttons	Start AD, set speed, set distance to car ahead
MID (Meter)	N/A	N/A
Multimedia	N/A	N/A
HUD	N/A	N/A
Haptic	N/A	N/A

3.3.5.5 In-cabin equipment other than HMI (e.g., Driver monitoring)

The vehicle has a driver monitoring camera available, but it will not be used in use cases.

3.3.5.6 Data logger description

Raw data record	Yes
Fusion object level record	Yes
Embedded video labelling	No
Could the driver annotate events	No
Data volume per hour in terabytes	1.2 TB/h

3.3.5.7 Enabler description

Enabler Tech Solution (E.2.y.z) and brief motivation
E.2.3.2 I2V/N2V GLOSA The main objective of the enabler is to achieve automated, fluid driving (L3) in urban and interurban scenarios, where, through communication with a series of traffic lights (GLOSA), the vehicle's speed is set to optimise traffic flow and avoid having to stop at intersections. Thanks to I2V/N2V communication, it will be possible to know the status and phase of the traffic lights on the route, and the vehicle will calculate the optimal target speed to drive smoothly and avoid stopping as much as possible. It is hoped to avoid stopping in the middle of an intersection if the traffic does not allow crossing it, or to stop before a pedestrian crossing if the traffic light changes to red.

Enabler Tech Solution (E.2.y.z) and brief motivation
The aim is to use the signal phase and timing of traffic lights to accelerate or brake comfortably and safely, and to influence the traffic flow in a positive (in terms of efficiency) way. For this enabler, short-range ITS-G5 communication technology will be used. Long-range technology will be used via a server communication using 4G. **E.2.4.2 Sensor fusion for localisation** The main objectives of the enabler are to create a more robust positioning system able to operate in GNSS-challenged urban scenarios. Correction of a vehicle's lateral error in the driving lane is based on correlation between map data and in-vehicle sensors. In each use case, a camera-based line detection system will be used along with HD maps to pinpoint the outdoor location on some roads with low GNSS coverage, allowing the ADF to continue uninterrupted when transitioning from areas with low GNSS coverage and vice versa. **E.2.4.2 Seamless positioning for slow-speed manoeuvres in varying conditions** This enabler is mainly meant to enhance positioning of the AD vehicle by providing continuous and seamless positioning in various scenarios, where the system is able to operate in GNSS-challenged urban areas. LiDAR obstacle maps will be used for this enabler, providing outdoor location on some roads with low GNSS coverage, to allow continuing with an ADF function when transitioning from areas with low GNSS coverage and vice versa.

3.3.6 Vehicle owner ID 6

3.3.6.1 Vehicle description

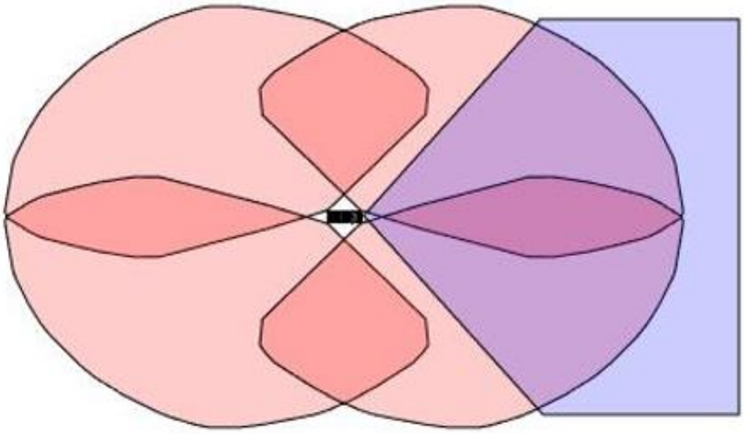
ID	Count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
6.1	1	Series vehicle equipped in L3Pilot and upgraded. Uses four fish-eye cameras for free space	Operator outside. Remote safety switch. The ADF can operate in private parking spaces and include park-in, park-out	Full sensor set, LiDAR as ground truth	E.2.4.2 Sensor fusion	Parking
6.2	1	Series vehicle. Uses ITS-G5 DSRC for traffic light communication. 5G on board but not committed	Professional driver and data engineer for operation and annotation.	Full sensor set., no LiDAR. Communication equipment for G5.	E.2.3.2 V2I	Urban Green Light Assist

ID	Count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
6.3	2	Series vehicle with mostly series sensor set	Professional driver and data engineer. The ADF has automated lateral and longitudinal control on highways with certified status (AD possible)	Full sensor set, but no LiDAR. An AD map is required for navigation.	E.2.4.2 Sensor fusion	Motorway: Navigation guided

3.3.6.2 Sensors for AD function(s)

Technology	Function	Hor. field of view	Interface
Outside camera	Free space support, lane detection, collision warning	360° when flattened and stitched	Proprietary, Ethernet
Inside camera	Driver monitoring		Ethernet
Radar	Four corner SR, one LR		CAN
LiDAR	Ground truth	360°	Ethernet
USS	Close-up protection for parking		CAN
GPS	dGPS, GPS		Ethernet, internal
IMU	Series		Ethernet

3.3.6.3 Sensor coverage



3.3.6.4 HMI description

Channel	Device	Main features
Visual	TBD	HMI to be decided. Existing info is meant for the feature developer
Audio		
Commands	Steering wheel	AD (with enabler) on/off. Steering wheel buttons for ACC will switch the feature
MID (Meter)		
Multimedia		
HUD		
Haptic		

3.3.6.5 In-cabin equipment other than HMI (e.g., driver monitoring)

One car has the series driver-monitoring camera.

3.3.6.6 Data logger description

Raw data record	Yes
Fusion object level record	Yes
Embedded video labelling	No
Could the driver annotate events	Yes
Data volume per hour in terabytes	(Data 12 + Video 120) 0.132 TB/h

3.3.6.7 Enabler description

Enabler Tech Solution (E.2.y.z) and brief motivation
E.2.3.2 V2I Vehicle-to-Infrastructure and Infrastructure-to-Vehicle Communication Traffic light phases need to be known to adapt early vehicle speed to red/green light. A challenge is the non-standardised dialect of traffic light communication. **E.2.4.2 Sensor Fusion for Localisation** Seamless positioning for slow-speed manoeuvres with landmarks. Needed to get a meaningful location for valet parking for retrieval of parking location. For navigation-guided AD, a meaningful location is needed to align the AD map and vehicle position for motorway interchange manoeuvres.

3.3.7 Vehicle owner ID 7

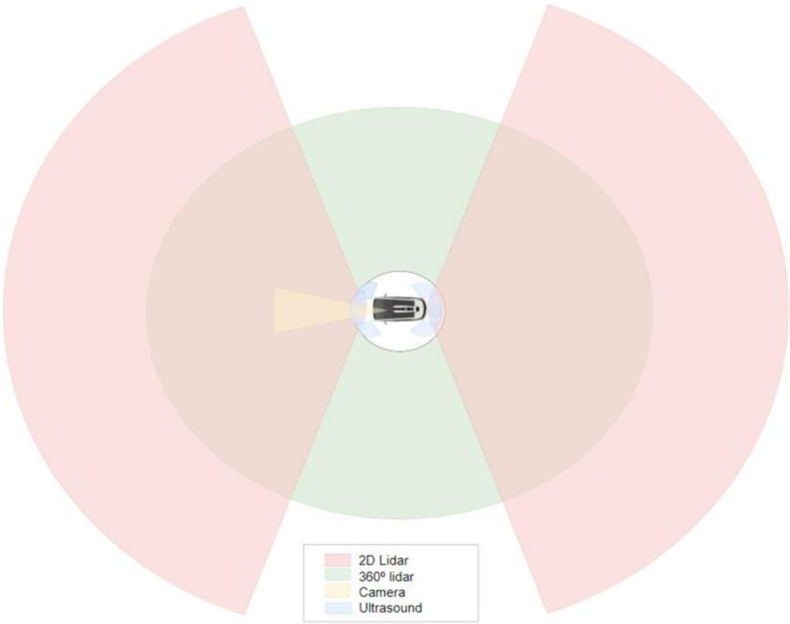
3.3.7.1 Vehicle description

ID	count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
7.1	1	Prototype			E.2.3.1, E.2.3.2, E.2.4.2, E.2.5.2, E.2.6.4	Motorway

3.3.7.2 Sensors for AD function(s)

Technology	Function	Hor. field of view	Interface
Outside camera	Object detection & logging of test scenarios (test analysis)	38º	Ethernet
Inside camera	Driver monitoring		Ethernet
Radar	N/A		N/A
LiDAR	Lanes + objects	360º	Ethernet
USS	N/A		N/A
GPS	Vehicle position		Ethernet
IMU	Vehicle position		Ethernet

3.3.7.3 Sensor coverage



3.3.7.4 HMI Description

Channel	Device	Main features
Visual	Digital instrument	Vehicle information, system status, alerts and warnings, system information, 3D context view
Audio	Speakers	Auditory information. Audio warnings and alerts for TOR
Commands	Steering wheel controls	Specific selection and activation function
MID (Metro)	N/A	N/A
Multimedia	Central touch screen	Navigation
Hud	N/A	N/A
Haptic	Seat vibration	TOR warning

3.3.7.5 External-HMI description (eHMI)

The vehicle is equipped with an eHMI based on a lighting source on the roof to communicate the AD status to other road users.

3.3.7.6 In-cabin equipment other than HMI (e.g., driver monitoring)

The car will be equipped with a driver monitoring system to determine the level of attention and readiness of the driver to take control during a TOR manoeuvre or during transition to a lower level of automation.

3.3.7.7 Data logger description

Raw data record	Yes
Fusion object level record	Yes
Embedded video labelling	No
Could the driver annotate events	No
Data volume per hour in terabytes	1.3 TB/h

3.3.7.8 Enabler description

Enabler Tech Solution (E.2.y.z) and brief motivation
E.2.3.1 Automated overtaking on motorway via the V2V connectivity enabler As the ego vehicle drives in automated mode on a motorway, it detects a vehicle ahead that is moving at a slower speed than itself. An automated overtaking manoeuvre must then be executed. However, as the ego vehicle's view is occluded by other vehicles, information about lane availability for the manoeuvre must be obtained from V2V connectivity. If the lane is available, the ego vehicle will perform an overtaking manoeuvre; if not, it will adapt its speed to the vehicle ahead. **E.2.3.2 and E.2.6.4 Hazard warning response on motorway via I2V connectivity and driver monitoring enablers** When the ego vehicle receives a hazard warning via I2V, it must react such that it can manage the situation and avoid stopping in the lane or braking hard, which would interfere with the traffic flow. When the hazard situation starts, if the driver monitoring system detects that the driver is inattentive, the ADF alerts the driver, through the HMI system, to pay attention to the road and intervene if necessary. If the I2V message concerns a change in weather conditions, the ego vehicle can check whether it is necessary to adapt its speed. If the I2V warning concerns roadworks ahead, the ego vehicle can decide whether to change lanes and adapt its speed to increase the safety of those in the vehicle and of other road users. **E.2.3.2 Taking a motorway off-ramp via the I2V connectivity enabler** The ego vehicle needs to take an off-ramp to continue the route and reach its destination. However, the junction geometry is difficult for the vehicle to manage on its own. A radar unit installed at the roadside monitors the environment and sends its data to an RSU (roadside unit), enabling the ego vehicle to enhance the information received through its own sensors and thus handle the situation successfully. **E.2.4.2 Keep driving within the lane on the motorway via sensor fusion for localisation as enabler** When the ego vehicle is driving on a motorway, the GPS signal may be depleted in tunnels, on bridges, or due to dense roadside vegetation, compromising the vehicle's positioning information and making it less safe for the passengers and other road users. In this case, sensor fusion can be used for localisation, avoiding deactivating the ADF until the GPS signal is fully recovered. **E.2.5.2 and E.2.6.4 Lane merging on motorway via cybersecurity concept, recommendations in V2X and driver monitoring as enablers** While the ego vehicle is merging onto a motorway, the cybersecurity system checks and analyses any threats received via I2V or V2V. Suitable countermeasures are implemented to counter a cyberattack and keep the ADF active. If the countermeasures prove ineffective and the driver monitoring system detects that the driver is attentive, a TOR is be executed; if the driver is not paying attention, an MRM (minimum risk manoeuvre) must be performed.

3.3.8 Vehicle owner ID 8

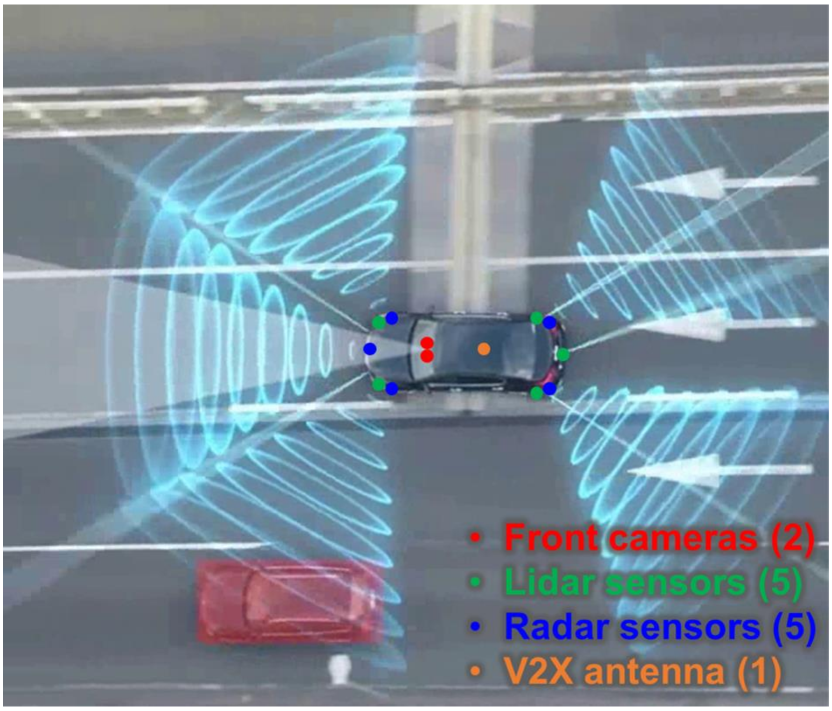
3.3.8.1 Vehicle description

ID	count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
8.1	2	Prototype	The vehicle needs to be operated in AD mode. Another vehicle equipped with a matching enabler from E.2.3.1 is required to coordinate manoeuvres. Testing requires a safety driver and an operator.	Integration and configuration of V2V HW. Integration of MCS communication protocol. Extension of vehicle-internal data communication for exchanging V2V information. Extension of AD SW on multiple levels to realise the target function.	E.2.3.1	Motorway

3.3.8.2 Sensors for AD function(s)

Technology	Function	Hor. field of view	Interface
Outside camera	Detection of lanes, objects, traffic signs	Front	Ethernet
Inside camera	Driver status	-	CAN
Radar	Object detection	360°	Ethernet
LiDAR	Object detection	360°	Ethernet
USS	Not used	N/A	N/A
GPS	Localisation	-	CAN
IMU	Localisation, positioning	-	CAN
V2X	Cooperative merging	-	Ethernet

3.3.8.3 Sensor coverage



3.3.8.4 HMI description

Channel	Device	Main features
Visual	Cluster display (instrument panel)	System status, surrounding object visualisation, TOC
Audio	Speaker (instrument panel)	Information, warning
Commands	Steering wheel buttons	AD (de)activation
MID (Meter)	N/A	N/A (not part of target function)
Multimedia	N/A	N/A (not part of target function)
HUD	N/A	N/A (not part of target function)
Haptic	Steering wheel vibration, seat belt tensioning	TOC

3.3.8.5 Data logger description

Raw data record	Partially
Fusion object level record	Yes
Embedded video labelling	No
Could the driver annotate events	Yes
Data volume per hour in terabytes	>0.5 TB/h

3.3.8.6 Enabler description

Enabler Tech Solution and brief motivation
E.2.3.1 V2V for manoeuvre coordination (highway on-ramp merging) Cooperative motorway chauffeur with merging support via V2V enabler, either on-ramp vehicle interacting with vehicle on the main motorway, or vehicle on the main motorway interacting with on-ramp vehicle. Traffic safety is a result of the explicit V2V coordination of actions between cooperative highly automated vehicles. Knowing about each other's "plans" and "intentions" would allow receiving vehicles to know in advance how to react (e.g., safely and smoothly slow down when a vehicle ahead notifies the intention to merge onto the ego lane), but also to keep less conservative time gaps from the surrounding cooperative vehicles.

3.3.9 Vehicle owner ID 9

3.3.9.1 Vehicle description

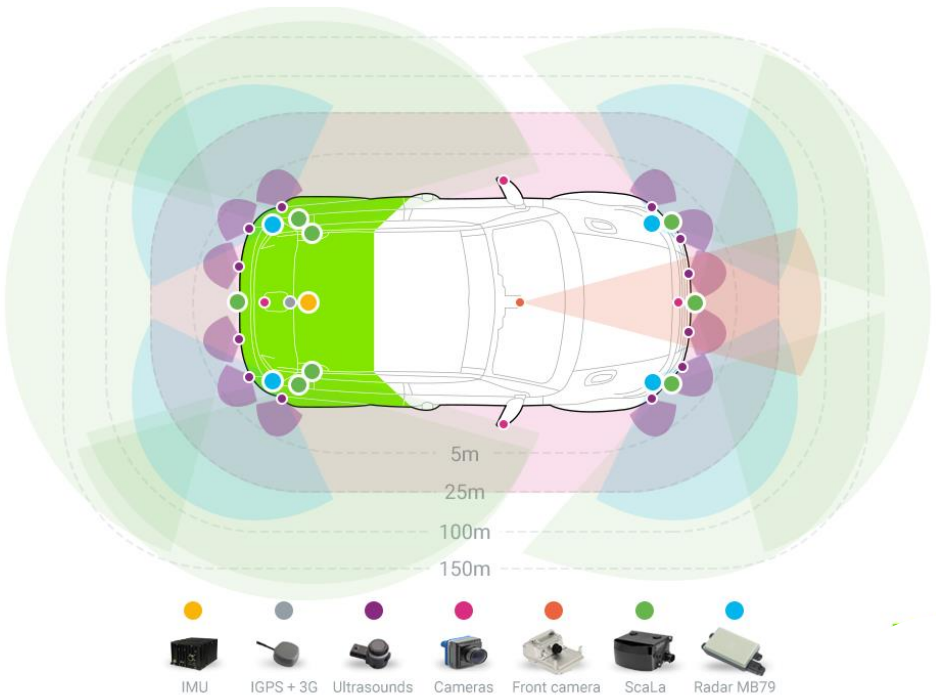
ID	Count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
9.1	1	Prototype	The vehicle is equipped with camera and LiDAR in addition to radar, GPS, and IMU to help with object detection and localisation. The vehicle can operate AD by its own without the	Hardware components (sensors and processors) are installed and integrated inside the vehicle. Software modules are under development and need to be	E.2.4.2 E.2.6.2	Motorway

ID	Count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
			dedicated Hi-Drive enablers. A safety driver and an operator are required to operate the system.	implemented inside the vehicle to be able to use the enabler.		

3.3.9.2 Sensors for AD function(s)

Technology	Function	Hor. field of view	Interface
Outside camera	Front camera: Lanes, object detection, recordings Cameras: object detection	60° 360°	CAN
Inside camera	N/A	N/A	N/A
Radar	Object detection	180°	CAN
LiDAR	Object detection	360°	Ethernet, BroadR Reach
USS	N/A	N/A	N/A
GPS	Vehicle localisation	N/A	Ethernet
IMU	Vehicle localisation	N/A	Ethernet and CAN

3.3.9.3 Sensor coverage



3.3.9.4 HMI description

Channel	Device	Main features
Visual	LED	Speed, position of car, speed restrictions, the track of driving, objects (pedestrian, vehicle, etc.)
Audio	Speaker	N/A
Commands	Long/Lat. ACC long switch	Car Control ON/OFF
MID (Meter)	N/A	N/A
Multimedia	N/A	N/A
HUD	N/A	N/A
Haptic	N/A	N/A

3.3.9.5 In cabin equipment other than HMI (e.g., Driver monitoring)

The destination vehicle has an additional display for the visualisation of the point cloud and monitoring of the AD systems. These displays are not part of the HMI.

3.3.9.6 Data logger description

Raw data record	Yes (LiDAR, camera)
Fusion object level record	Yes
Embedded video labelling	No
Could the driver annotate events	No
Data volume per hour in terabytes	0.13 TB/h

3.3.9.7 Enabler description

Enabler Tech Solution (E.2.y.z) and brief motivation
E.2.4.2 Sensor fusion for localisation **E.2.6.2 CAD ML perception, object detection and classification** The enabler will be based on camera and LiDAR sensors for providing a reliable and robust automated driving mode without GNSS support or communication to other infrastructure/vehicles. A typical use case for GNSS occlusion is a tunnel, piloting on a motorway. The targeting tunnel has a length of approximately 8km; with an average speed of 80km/h, the GNSS will not be available for more than 6 minutes. We are aiming to ensure an AD function of the ego vehicle in a highway construction area and enable an additional operational design domain (ODD) for complex traffic scenarios. The automated driving function of the ego type vehicle would provide a geometry identification and location of the construction areas on motorways.

3.3.10 Vehicle owner ID 10

3.3.10.1 Vehicle description

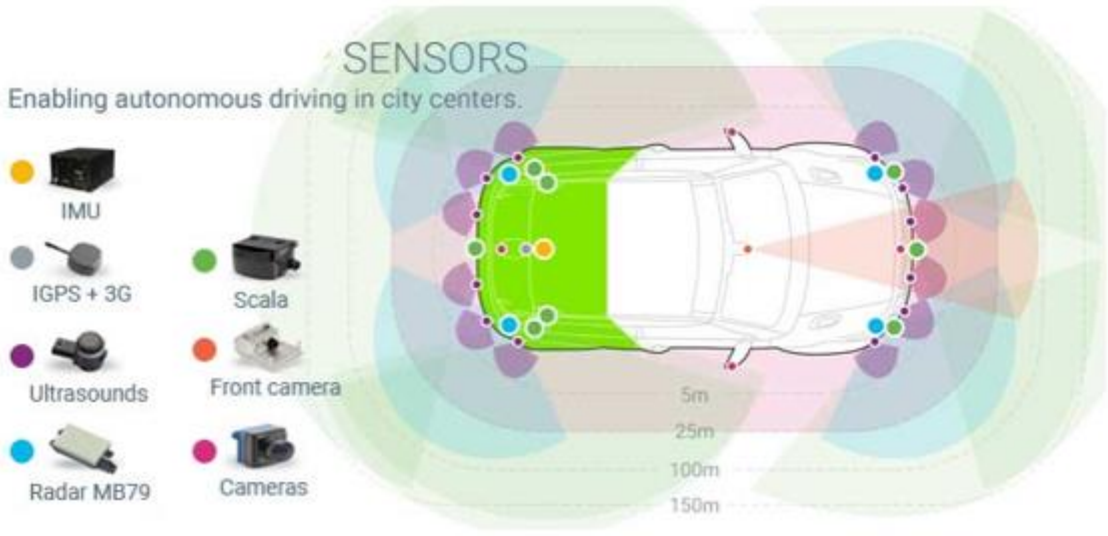
ID	count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
10.1	1	Prototype	The vehicle is equipped with cameras that help with object detection, including pedestrians. eHMIs will be activated by the	HW: Mechanical interface and electrical interface for control & supply SW: implementation of eHMI	E.2.3.4	Urban Parking

ID	count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
			ADS under predefined conditions to show messages to other road users. A safety driver and an operator are required to operate the system.	activation/deactivation rules		

3.3.10.2 Sensors for AD function(s)

Technology	Function	Hor. field of view	Interface
Outside camera	Front camera: Lanes, object detection (including pedestrians), recordings Cameras: Object detection	60° 360°	CAN
Inside camera	N/A	N/A	N/A
Radar	Object detection	180°	CAN
LiDAR	Object detection (including pedestrian)	360°	Ethernet, BroadR Reach
USS	N/A	N/A	N/A
GPS	Vehicle localisation	N/A	Ethernet
IMU	Vehicle localisation	N/A	Ethernet and CAN

3.3.10.3 Sensor coverage



3.3.10.4 HMI description

Channel	Device	Main features
Visual	LED	Speed, car position, speed restrictions, track of driving, objects (pedestrian, vehicle, etc.)
Audio	Speaker	N/A
Commands	Long/Lat. ACC long switch	Car Control ON/OFF
MID (Meter)	N/A	N/A
Multimedia	N/A	N/A
HUD	N/A	N/A
Haptic	N/A	N/A

3.3.10.5 External-HMI description (eHMI)

Two categories of eHMIs that correspond to the enablers will be implemented: Displays and Near Field Projectors.

Types of displays: front and rear

Types of projectors: extended turn indicator, projected ADS marker

3.3.10.6 Data logger description

Raw data record	Yes (LiDAR, camera)
Fusion object level record	Yes
Embedded video labelling	No
Could the driver annotate events	No
Data volume per hour in terabytes	0.13 TB/h

3.3.10.7 Enabler description

Enabler Tech Solution (E.2.y.z) and brief motivation
E.2.3.4: Display Mini LED displays for front and rear will be used to communicate to other road users. The front display messages will be targeted at pedestrians that cross the road or in a parking situation. The rear display messages will be targeted at the following driver of a manual car. **E.2.3.4: Projection** A projected turn indicator will be used to signal the vehicle's intention to a pedestrian in a parking environment. A projected ADS marker will be used to create a safety zone around the vehicle to gain a pedestrian's attention.

3.3.11 Vehicle owner ID 11

3.3.11.1 Vehicle description

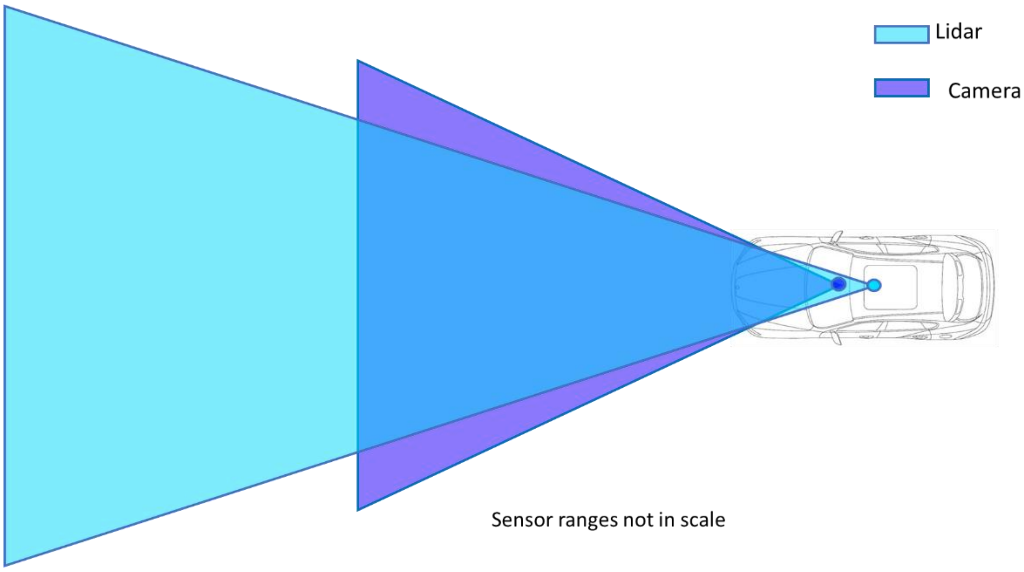
ID	Count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
11.1	1	Prototype vehicle, based on series	The vehicle can operate AD on its own, with the safety driver in the passenger seat. For the enabler with V2X, another vehicle is needed to send/receive V2V information during the operation to evaluate AD with the enabler. In addition, an operator can be required to operate the system.	HW components (sensors, V2X unit, processing ECUs and specific data-logger) are almost installed and integrated inside the vehicle (only LiDAR is missing). SW modules are under development and need to be implemented inside the vehicle to be able to use the enabler.	E.2.3.2 E.2.3.3 E.2.4.1 E.2.4.2 E.2.6.3 E.2.6.4	Motorway

3.3.11.2 Sensors for AD function(s)

Technology	Function	Hor. field of view	Interface
Automotive (external) camera	Detection of objects, lanes, traffic signs, and vehicle localisation	135°	CAN bus
Long Range Radar (Optional at present)	Object detection	120°	CAN bus
LiDAR	Vehicle localisation and ground truth	120°	IP/TCP
V2X radio	Vehicle position and extension of object detection	360°	CAN bus and IP/TCP

Technology	Function	Hor. field of view	Interface
HD-GNSS/IMU positioning solution	Vehicle position and odometry, as well as ground truth	N/A	IP/TCP
HD maps	Advanced positioning	N/A	IP/TCP
Internal camera (optional)	Driver's monitoring system (DMS)	(40-50)°	CAN bus and ETHERNET

3.3.11.3 Sensor coverage



3.3.11.4 Data logger description

Raw data record	Yes
Fusion object level record	Yes
Embedded video labelling	No
Synchronisation	All data are synchronised
Could the driver annotate events	Yes
Data volume per hour in terabytes	0.25TB/h

3.3.11.5 Enabler description

Enabler Tech Solution (E.2.y.z) and brief motivation
E.2.3.2 V2I hazard warning and dynamic signage at junctions and E.2.3.3 V2N dynamic road information for ODD adaptation
Cooperative motorway chauffeur with support via V2X enabler in critical situations, such as tunnel, missing lanes markings, roadworks, and other hazards. This can lead to preventive TORs, ADF deactivation, control speed adaptation, or lane change suggestion thanks to preventive knowledge of dynamic events.
E.2.4.1 Positioning based information service and E.2.4.2 Sensor fusion for localisation
The cooperative motorway chauffeur can deal with challenging areas of high-speed roads, thanks to advanced lane level positioning.
E.2.6.3 Driver Manoeuvre Intention Recognition (DMIR)
This enabler can lead to L1-2 driving modes on motorway (up to 130 km/h), in which a manoeuvre is proposed to the driver, based on her/his preferences/intentions. In addition, if the system detects a “risky intention”, it can warn the driver or even enhance the level of automation if the driver is detected as impaired (e.g., by the DMS).
E.2.6.4 Driver Distraction Detection (DDD)
L3 AD on motorway (up to 130 km/h), based on Highway-Chauffeur functionality (as developed by L3-Pilot project) can be enhanced by the use of the DDD enabler, since it can help in providing efficient TOR and ADF start-up.

3.3.12 Vehicle owner ID 12

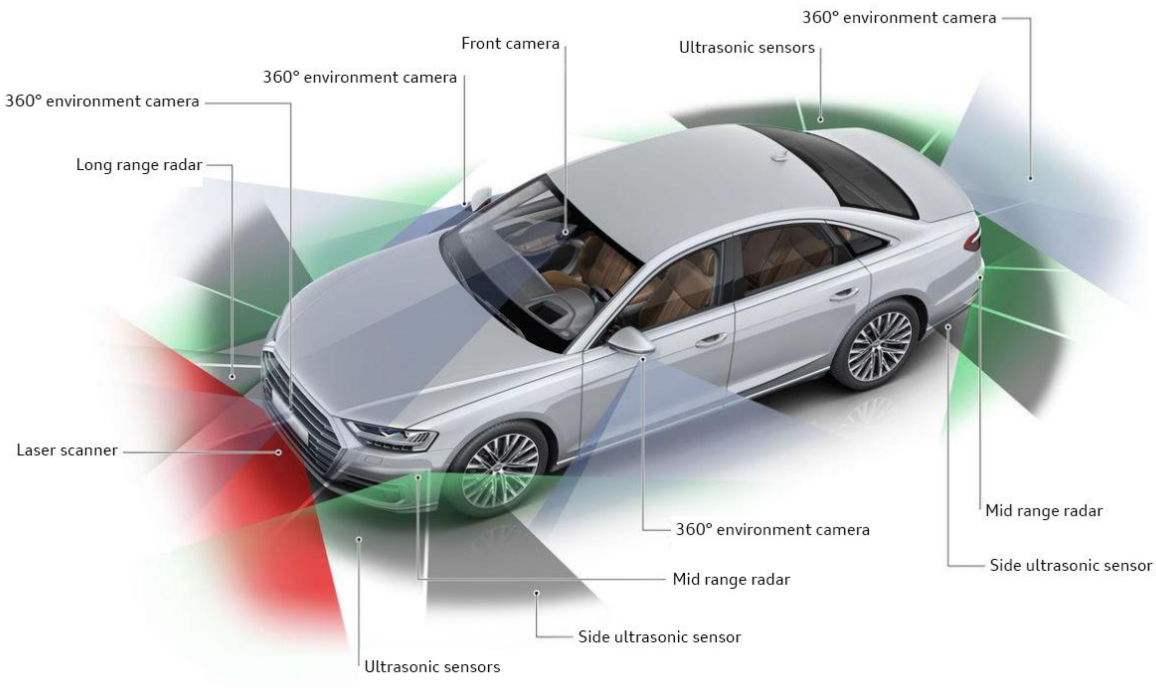
3.3.12.1 Vehicle description

ID	Count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
12.1	1	Prototype	Trained Driver	---	E.2.6.2	Urban
12.2	1	Prototype		---	No specific enabler for the HMI part (hazard warnings, eHMI)	Urban
12.3	1	Prototype (wizard of Oz)	Trained Driver on Wizard seat	---	No specific enabler	Urban, Motorway

3.3.12.2 Sensors for AD function(s)

Technology	Function	Hor. field of view	Interface
Outside camera	Object Detection (no video feed)	N/A	FlexRay
Inside camera	N/A	N/A	N/A
Radar	N/A	N/A	N/A
LiDAR	N/A	N/A	N/A
USS	N/A	N/A	N/A
GPS	N/A	N/A	N/A
IMU	N/A	N/A	N/A
Bus Data	Speed, braking pressure, steering wheel angle, …	N/A	FlexRay

3.3.12.3 Sensor coverage



3.3.12.4 HMI description

Channel	Device	Main features
Visual	Segmented taillights (red), potentially projectors around the vehicle	Hazard warnings in taillights
Audio	N/A	No plans to use this HMI
Commands	N/A	No plans to use this HMI
MID (Meter)	N/A	No plans to use this HMI
Multimedia	N/A	No plans to use this HMI
HUD	N/A	No plans to use this HMI
Haptic	N/A	No plans to use this HMI

3.3.12.5 External-HMI description (eHMI)

Taillights with integrated “displays” to show certain warning signals in the vehicle’s rear.

3.3.12.6 Data logger description

Raw data record	Yes
Fusion object level record	Yes
Embedded video labelling	No
Could the driver annotate events	No
Data volume per hour in terabytes	40 MB/h

3.3.12.7 Enabler description

Enabler Tech Solution (E.2.y.z) and brief motivation
E.2.6.2 Driver intention interpretation Interpret an algorithm for driver intention prediction (the current algorithm is based on neural networks) to propose a temporal behaviour of automated vehicles at pedestrian crossings. Therefore, we need to interpret the algorithm to know how it decides and what the clearest predictions are. These can be used to develop an automated vehicle's implicit communication in SP6.

3.3.13 Vehicle owner ID 13

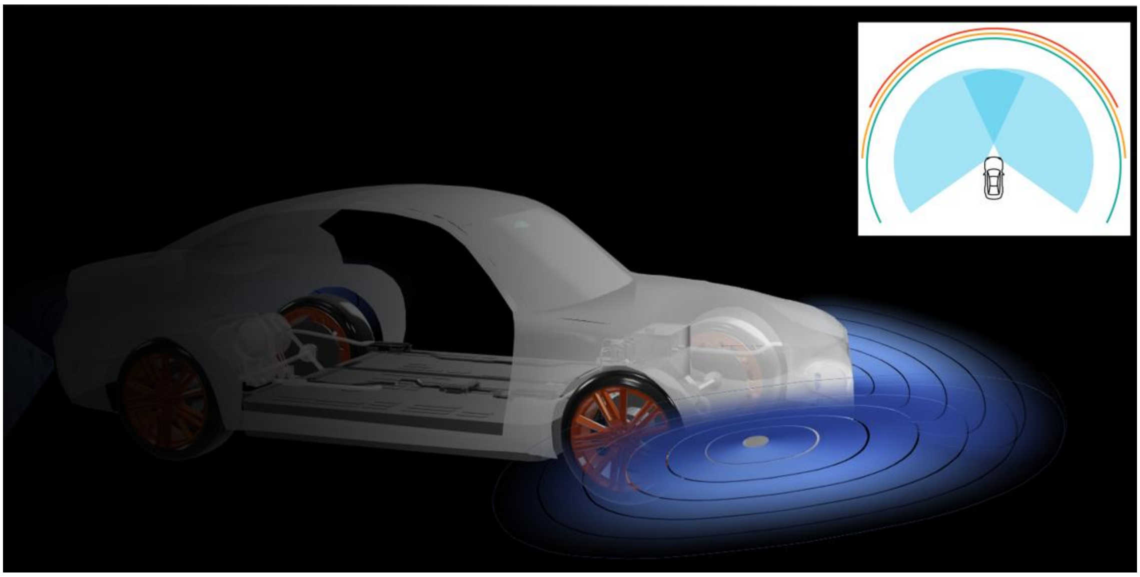
3.3.13.1 Vehicle description

ID	Count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
13.1	1	Prototype	The vehicle needs to be manually driven by a safety driver. An operator can be require to operate the system.	Hardware components (Radar, PC, GPS devices, Ground truthing devices, Gateways) has to be installed in the vehicle. Software integration and data logger on Linux operating system.	E.2.6.2	Motorway, Urban
13.2	1	Prototype	A safety driver is required to be on the driver seat of the vehicle. An operator can be required to operate the system.	Hardware components (Radar, PC, GPS devices, Ground truthing devices, Gateways) has to be installed in the vehicle. Software integration and data logger on Linux operating system.	E.2.6.2	Motorway, Urban

3.3.13.2 Sensors for AD function(s)

Technology	Function	Hor. field of view	Interface
Radar (x2 front)	Perception	75°	Ethernet
LiDAR	Reference, ground truth	360°	Ethernet
Outside camera	Reference, ground truth	360° (5 cameras)	USB
GPS + IMU	GPS location data	N/A	Ethernet
GPS 2	Sensor time sync	N/A	Serial port, Ethernet

3.3.13.3 Sensor coverage



3.3.13.4 Data logger description

Raw data record	Yes
Fusion object level record	Yes
Embedded video labelling	No
Could the driver annotate events	Yes
Data volume per hour in terabytes	0.1 TB/h

3.3.13.5 Enabler description

Enabler Tech Solution (E.2.y.z) and brief motivation
E.2.6.2 We will provide a perception algorithm, based on two (corner) radars in front to provide front free area estimation, instead of using only camera and LiDAR algorithms which are limited by weather and lighting conditions. This can be improved by using low-level radar data, which is a dense map of the energy reflected by the targets. This is not limited by illumination of the scene such as tunnel, construction, bridge, and hash weather conditions, which tend to lead to false detection with radar perception.

3.3.14 Vehicle owner ID 14

3.3.14.1 Vehicle description

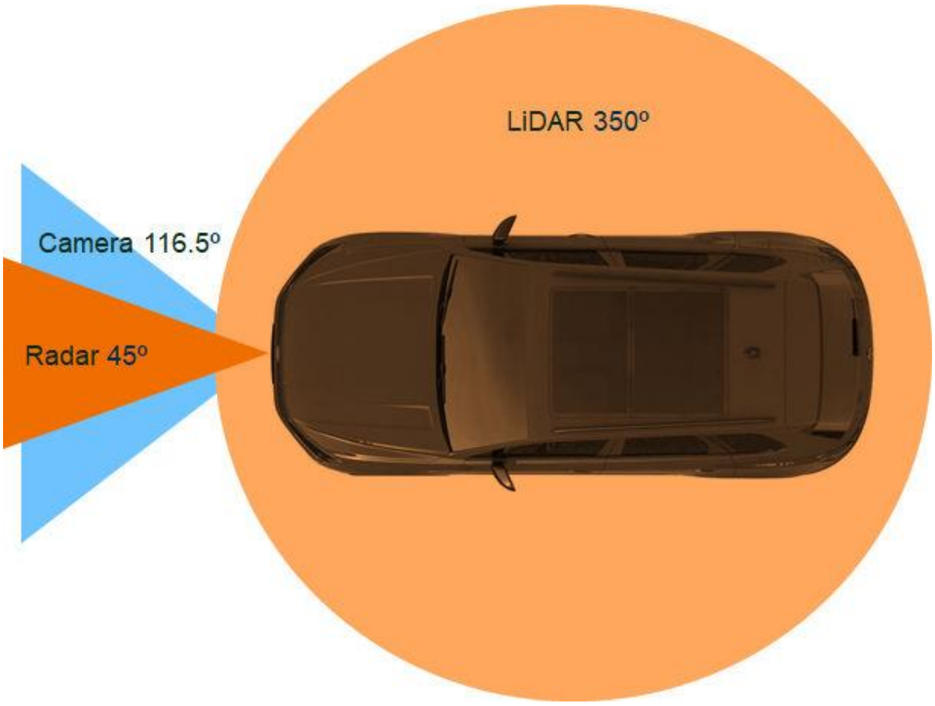
ID	Count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
14.1	1	Prototype	A safety operator is needed to drive in automated mode.	A Linux-based operation system is running the vehicle processing units. Ethernet and 5G/LTE connectivity is available to integrate the enablers	E.2.3.1 E.2.4.1	Rural

3.3.14.2 Sensors for AD function(s)

Technology	Function	Hor. field of view	Interface
Outside camera	Lane mark detection and visibility analysis	116.5º	Ethernet
Inside camera	N/A	N/A	N/A
Radar	Landmark and object detection	45º	CAN
LiDAR	Landmark and object detection. Visibility analysis	360º	Ethernet
USS	N/A	N/A	N/A

Technology	Function	Hor. field of view	Interface
GPS	Vehicle position	N/A	USB
IMU	Vehicle position	N/A	USB

3.3.14.3 Sensor coverage



3.3.14.4 HMI description

Channel	Device	Main features
Visual	Automotive display	Data recording interface. Vehicle information, system status, alerts and warnings, system information
Audio	N/A	N/A
Commands	Safety switch and brake pedal	Automated driving control and safety. State change between automated and manual driving
MID (Meter)	N/A	N/A
Multimedia	Central multimedia system	Navigation
HUD	N/A	N/A
Haptic	N/A	N/A

3.3.14.5 Data logger description

Raw data record	Yes
Fusion object level record	Yes
Embedded video labelling	Yes
Could the driver annotate events	Yes
Data volume per hour in terabytes	1TB/h

3.3.14.6 Enabler description

Enabler Tech Solution (E.2.y.z) and brief motivation
E.2.3.3, Predictive cellular network QoS and cloud-based notification service Enhancement of vehicle automated functions. When the vehicle is driving in automated mode on the road, cellular network data is collected and compared with cloud-based data. When approaching an area where cellular data could be lost or latency is increasing over the allowed values, the vehicle enables alternative methods (sensor-based detection) to compensate the loss, i.e., RTK GNSS accuracy. Vehicle can also update the current situation of the cellular network to the cloud-based service. **E.2.4.1 Positioning based information service** Hotspot Map is a geo information system that combines vehicle data with maps and external information. Specifically, relevant information from vehicles is assigned to the road segments on which they were recorded. Vehicle collects visibility data from landmarks i.e., traffic lights and light poles with vehicle sensor systems (LiDAR and RTK-GNSS). This landmark reference information is recorded in fluctuating weather and visibility conditions (clear weather, snowfall, rain). The information is processed and uploaded to Hotspot Map for each road section landmark. When approaching a road section, the test vehicle can download this reference data for in-vehicle sensor visibility analysis to estimate the possibility of proceeding with automated driving in case of adverse weather conditions.

3.3.15 Vehicle owner ID 15

3.3.15.1 Vehicle description

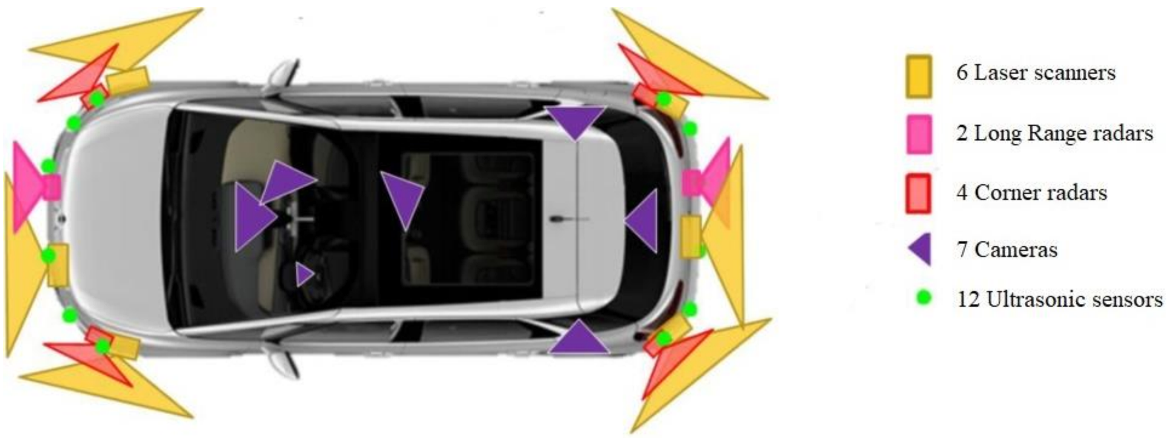
ID	Count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
15.1	1	Prototype	Professional safety driver in automated		E.2.3.3	Motorway

ID	Count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
			vehicle, used for data collection			
15.2	1	Prototype	Professional safety driver in automated vehicle, used for data collection		E.2.4.2	Motorway
15.3	1	Prototype	Professional safety driver in automated vehicle, used for data collection		E.2.4.2	Motorway
15.4	1	Prototype	Professional safety driver in automated vehicle, used for data collection		E.2.4.2	Motorway
15.5	1	Prototype	Professional safety driver in automated vehicle, used for data collection		E.2.4.1	Motorway
15.6	1	Prototype	Professional safety driver in automated vehicle, used for data collection		E.2.4.1	Motorway

3.3.15.2 Sensors for AD function(s)

Technology	Function	Hor. field of view	Interface
Outside camera	Context camera	360°	Ethernet
Inside camera	Context camera (pedals, steering wheel, face)		Ethernet
Radar	2 LR, 4 corners		Ethernet
LiDAR	1 Velodyne + 6 Ibeo + 1 Sick	360°	Ethernet & CAN
USS	Ultrasonic sensor		CAN
GPS	GPS		Serial port
IMU	Race logic, IMU 04		CAN

3.3.15.3 Sensor coverage

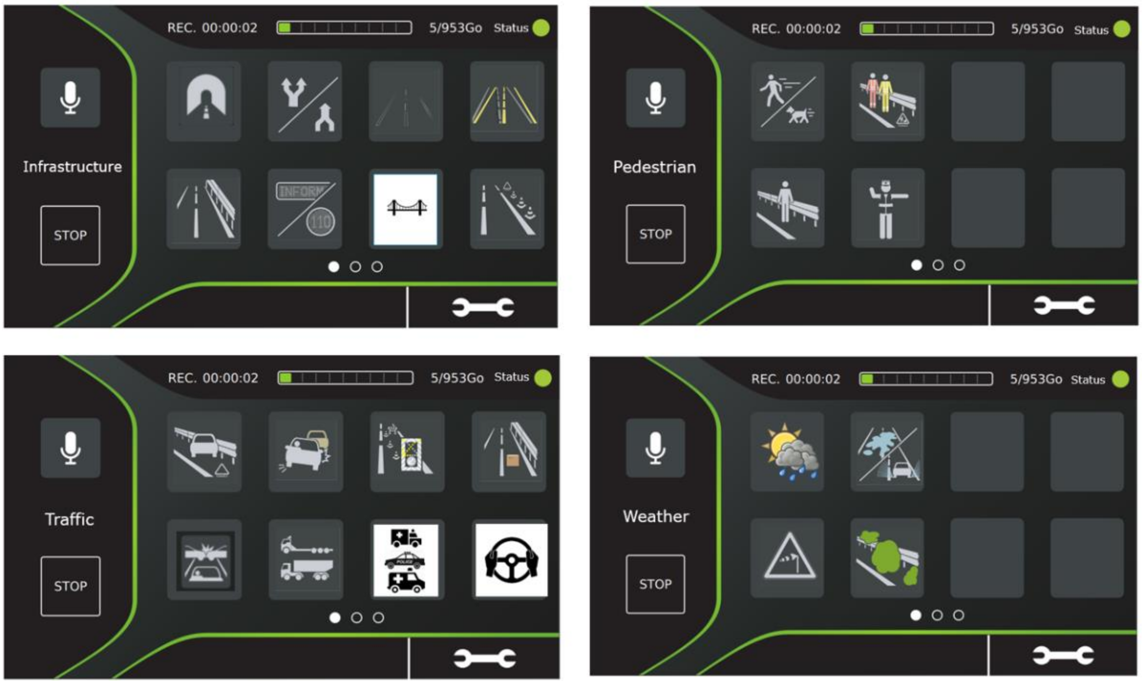


3.3.15.4 HMI description

Channel	Device	Main features
Visual	Lane on display, HMI from series vehicle	AD status
Audio	Beep	TOR
Commands	Steering wheel	Activate/deactivate AD function
MID (Meter)	N/A	N/A
Multimedia	N/A	N/A
HUD	N/A	N/A
Haptic	N/A	N/A

3.3.15.5 In-cabin equipment other than HMI (e.g., driver monitoring)

Annotation tablet



3.3.15.6 Data logger description

Raw data record	Yes
Fusion object level record	Yes
Embedded video labelling	No
Could the driver annotate events	Yes
Data volume per hour in terabytes	2.1 TB/h

3.3.15.7 Enabler description

Enabler Tech Solution (E.2.y.z) and brief motivation
E.2.3.3 V2N Field monitoring
Safety "Field monitoring" is part of SOTIF activity in the development of automated vehicles. It will contribute to the safety of the drive and the update of the scenario database for validation.
E.2.4.1 Forecasting in advance GNSS signal quality in challenging environments
This enabler will allow real-time navigation and fusion engine optimisation to improve performance and reliability, real-time GNSS optimised route planning to extend and confirm the ODD, and real-time GNSS coverage calculation for system-automated integrity monitoring.
E.2.4.2 Localisation and object detection in urban environment
Top-roof ground truth system for 360° field of view for scenario collection in an urban environment.

3.3.16 Vehicle owner ID 16

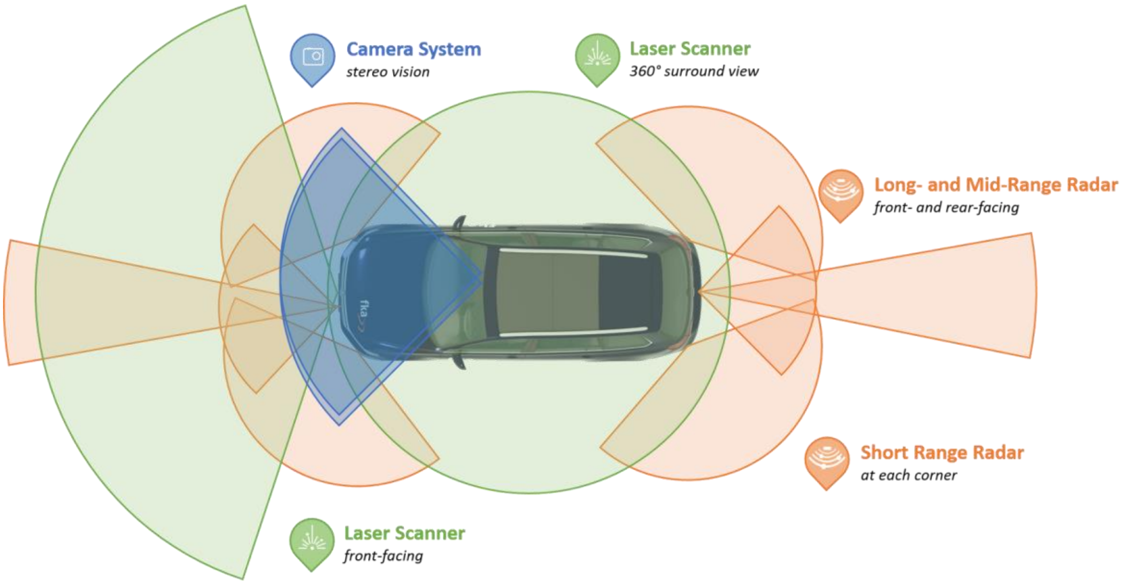
3.3.16.1 Vehicle description

ID	Count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
16.1	1	Prototype	Trained safety driver and operator to monitor driving function outputs	External HW	E.2.3.2	Urban

3.3.16.2 Sensors for AD function(s)

Technology	Function	Hor. field of view	Interface
Outside camera	Traffic light detection	360°	USB3.0
Inside camera	Object detection	55°	CAN/Ethernet
Radar	Object detection	360°	CAN
LiDAR	Object detection & localisation	360°	Ethernet
USS	N/A		N/A
GPS	Localisation		Ethernet
IMU	Localisation		Ethernet

3.3.16.3 Sensor coverage



3.3.16.4 HMI description

Channel	Device	Main features
Visual	Cluster	Safety driver information
Audio	Cluster	Safety driver information
Visual	Display	Passenger information

3.3.16.5 Data logger description

Raw data record	Yes
Fusion object level record	Yes
Embedded video labelling	No
Could the driver annotate events	No
Data volume per hour in terabytes	0.5 TB/h

3.3.16.6 Enabler description

Enabler Tech Solution (E.2.y.z) and brief motivation
E.2.3.2 V2I Vehicle-to-Infrastructure and Infrastructure-to-Vehicle Communication Using V2X Information from traffic lights for redundancy and traffic flow optimisation.

3.3.17 Vehicle owner ID 17

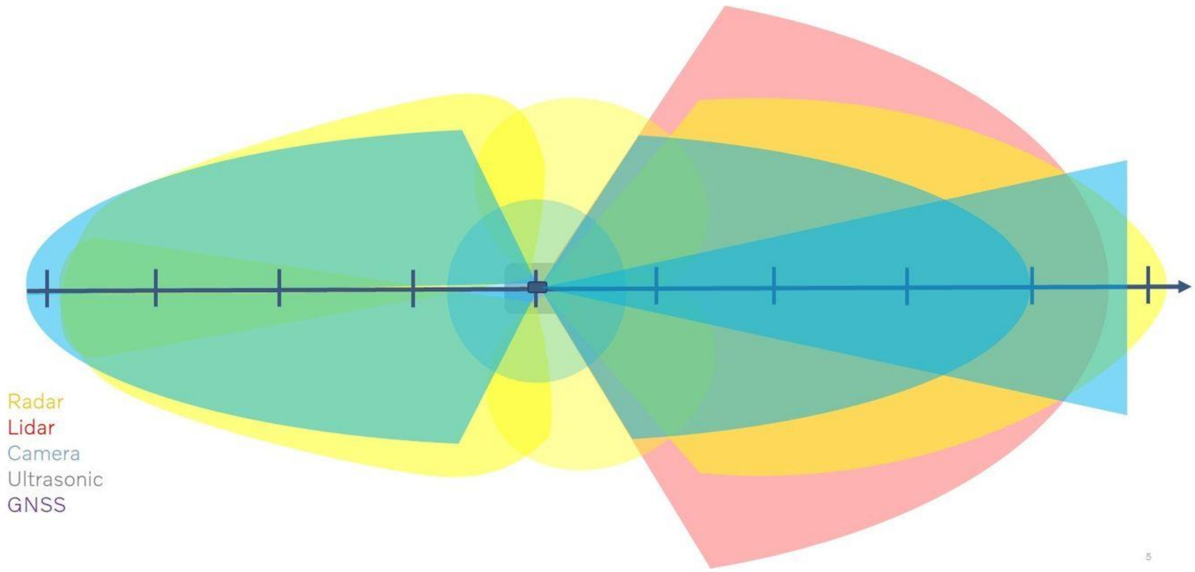
3.3.17.1 Vehicle description

ID	Count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
17.1	1	Prototype	The vehicle can be operated safely with a safety driver independent of the enabler in AD mode. Adaptations to operate the vehicle with the enabler will require participation of other actors in the scenario - sending/receiving V2X info.	Additional HW (OBU) to be installed in the vehicle. SW adaptations needed (trajectory planning, arbitration etc.)	E.2.3.1 E.2.3.2	Motorway/Urban Rural Urban
17.2	1	Prototype	The vehicle can be operated safely with a safety driver independent of the enabler. Adaptations to operate the vehicle with the enabler will require participation of other actors in the scenario – sending/receiving V2X info.	Additional HW (OBU) to be installed in the vehicle. SW adaptions needed (trajectory planning, arbitration etc.)	E.2.3.1 E.2.3.2	Motorway/Urban Rural Urban

3.3.17.2 Sensors for AD function(s)

Technology	Function	Hor. field of view	Interface
Outside camera	Objects	70°	GMSL/Ethernet
Radar	Objects	130°	CAN/Ethernet
LiDAR	Objects	100°	Ethernet
USS	Objects	-	CAN
GPS	Vehicle position	N/A	Ethernet
IMU	Vehicle position	N/A	CAN/Ethernet
V2X (OBU)	Cooperative sensing, cooperative merging, extension of non-line-of-sight sensing	360°	Ethernet

3.3.17.3 Sensor coverage



3.3.17.4 HMI description

Channel	Device	Main features
Visual	CSD/DIM	Warnings/Status
Audio	Speakers	Warnings/Status
Commands	Buttons	Activation/Deactivation
MID (Meter)	N/A	N/A
Multimedia	N/A	
HUD	N/A	
Haptic	Steering	Warnings

3.3.17.5 Data logger description

Raw data record	Yes
Fusion object level record	Yes
Embedded video labelling	No
Could the driver annotate events	Yes (Co Driver)
Data volume per hour in terabytes	0.1 TB/h

3.3.17.6 Enabler description

Enabler Tech Solution (E.2.y.z) and brief motivation
E.2.3.1: V2V for cooperative merging The target of this enabler is to implement V2V communications through a Manoeuvre Coordination Service (MCS) and Cooperative Awareness Message (CAM) dissemination through Open-Broadcast Software (OBS) based on ITS-G5 to accomplish cooperative lane merging on motorway entry. The cooperative lane-merging is accomplished by different vehicles at different automation levels (L3/L1) **E.2.3.1: V2V for cooperative sensing** The target of this enabler is to implement both Collective Perception Message (CPM) and CAM dissemination through OBS based on ITS-G5 to perform safe cooperative overtaking on rural roads via V2V. **E.2.3.2: V2I for ODD extension and defragmentation** The target of this enabler is to implement V2I through MAPEM/SPATEM based on ITS-G5 to accomplish efficient cooperative crossing at traffic intersections in urban environments, thereby enabling ODD extension and defragmentation for automated vehicles in urban environments.

3.3.18 Vehicle owner ID 18

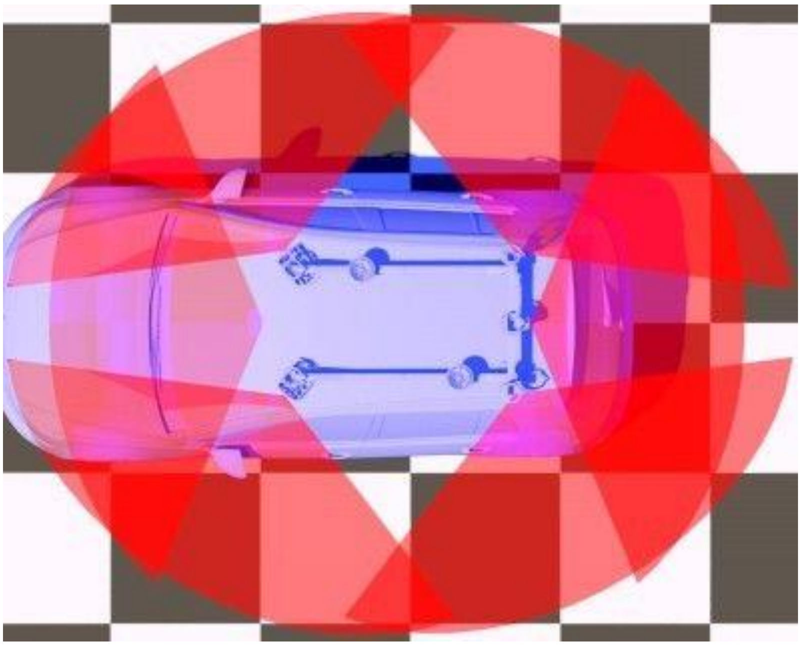
3.3.18.1 Vehicle description

ID	Count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
18.1	1	Modified series vehicle equipped with full sensor setup (cameras, LiDAR, radar) and computer HW	A professional safety driver is required to operate the vehicle. ADF can be activated by a two-hand switch and deactivated by intervention of the safety driver.	Sufficient network capacity and computer HW (GPUs) to transfer video streams and perform data processing with neural networks.	E.2.6.2	Urban

3.3.18.2 Sensors for AD function(s)

Technology	Function	Hor. field of view	Interface
Outside camera	Depth estimation, object detection	120°	GMSL
Radar	Not used	360°	
LiDAR	Reference measurements (dynamic and static objects)	360°	Ethernet
GPS	Vehicle position	N/A	Ethernet
IMU	Vehicle position	N/A	Ethernet

3.3.18.3 Sensor coverage



3.3.18.4 HMI description

Channel	Device	Main features
Visual	N/A	
Audio	N/A	
Commands	Buttons	Turn on/off AD
MID (Meter)	N/A	
Multimedia	N/A	
HUD	N/A	
Haptic	N/A	

3.3.18.5 Data logger description

Raw data record	Yes
Fusion object level record	Yes
Embedded video labelling	No
Could the driver annotate events	No
Data volume per hour in terabytes	0.24 TB/h

3.3.18.6 Enabler description

Enabler Tech Solution (E.2.y.z) and brief motivation
E.2.6.2 Camera-based object detection
Contour-precise object detection in the camera image to enable AD without LiDAR
E.2.6.2 Camera-based depth estimation
Pixelwise distance estimation in the camera image to enable AD without LiDAR
E.2.6.2 Camera-based motion estimation
Motion estimation of dynamic objects in the camera image to enable AD without LiDAR

3.3.19 Vehicle owner ID 19

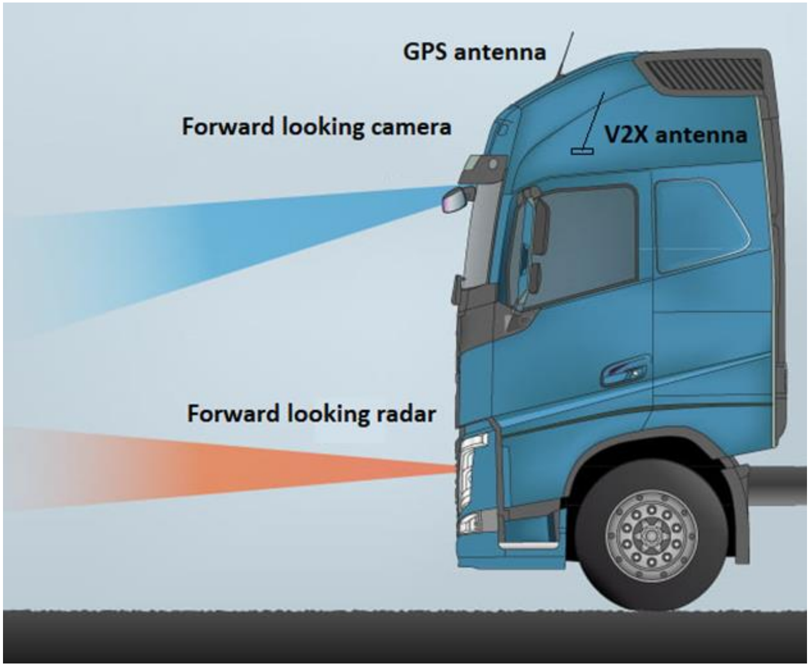
3.3.19.1 Vehicle description

ID	Count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
19.1	1	Series	The vehicle can be operated safely with a safety driver independent of the enabler.	Additional HW (OBUs, antennas, positioning devices etc.) to be installed in the test vehicle. SW adaptions needed (trajectory planning, V2X messaging, data logging etc.)	E.2.3.1 E.2.3.2	Motorway Rural Urban
19.2	1	Series	The test vehicle can be operated safely with a safety driver independent of the enabler.	Additional HW (OBUs, antennas, positioning devices etc) to be installed in the test vehicle. SW adaptions needed (trajectory planning, V2X messaging, data logging etc.)	E.2.3.1 E.2.3.2	Motorway Rural Urban

3.3.19.2 Sensors for AD function(s)

Technology	Function	Hor. field of view	Interface
Forward-looking camera	Object detection	46°	CAN
GPS	Positioning	N/A	CAN
Forward-looking radar	Object detection	Far range: + 9° 0.25 – 200 m Near range: + 28° 0.25 – 60 m	CAN
V2X	Non-line-of-sight sensing of surrounding vehicles	360°	Ethernet

3.3.19.3 Sensor coverage



3.3.19.4 Data logger description

Raw data record	Yes
Fusion object level record	No
Embedded video labelling	No
Could the driver annotate events	No
Data volume per hour in terabytes	0.3 TB/h

3.3.19.5 Enabler description

Enabler Tech Solution (E.2.y.z) and brief motivation
E.2.3.1 V2V for cooperative merging/sensing The target of this enabler is to implement V2V communications through Manoeuvre Coordination Service (MCS) and Cooperative Awareness Message (CAM) dissemination through OBS based on ITS-G5 to accomplish cooperative lane merging on motorway entry. The cooperative lane merging is accomplished by passenger cars and trucks at different automation levels (L3 cars and L1 trucks). The target of this enabler is to implement both Collective Perception Message (CPM) and Cooperative Awareness Message (CAM) dissemination via OBS based on ITS-G5 to perform safe cooperative overtaking on rural roads via V2V. **E.2.3.2 V2I for ODD extension and defragmentation** The target of this enabler is to implement V2I through MAPEM/SPATEM based on ITS-G5 to accomplish efficient cooperative crossing of traffic intersections in an urban environment, thereby enabling ODD extension and defragmentation of automated vehicles in an urban environment.

3.3.20 Vehicle owner ID 20

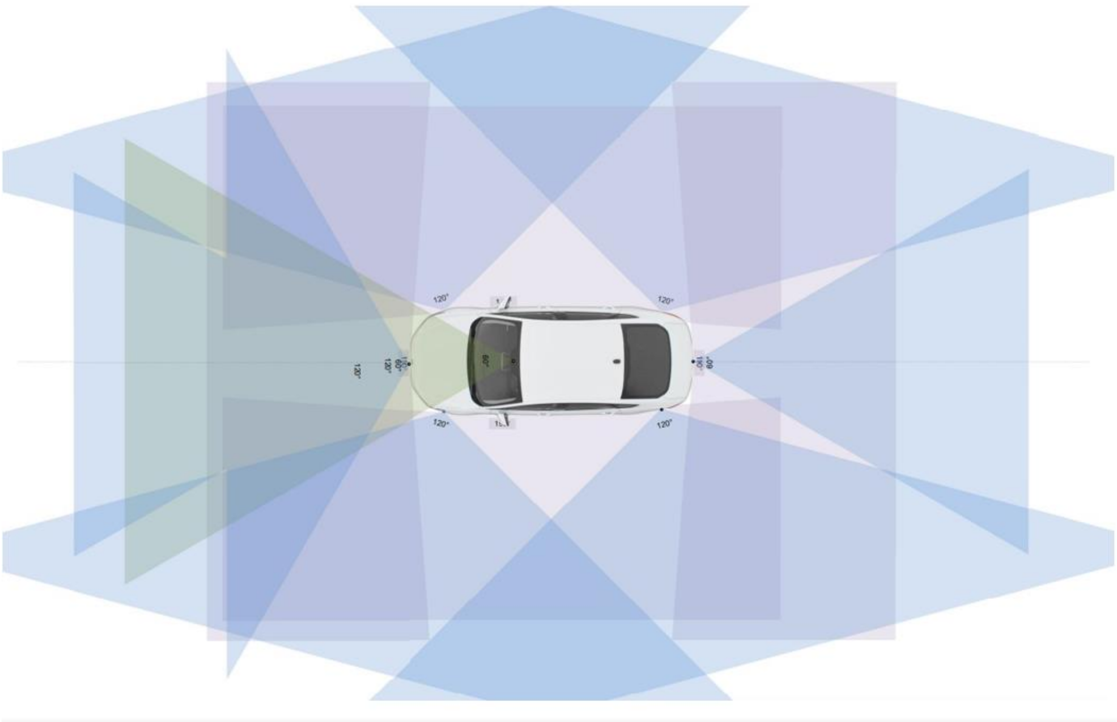
3.3.20.1 Vehicle description

ID	Count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, Table 2-3)
20.1	1	Ford Fusion US Version adapted with a data speed interface for accessing steering, acceleration, and braking interfaces. AD Function is our own developed driving function.	A safety driver and an operator (safety co-driver) are required to operate the system.	Enabler for Connectivity On Ramp function is implemented on the prototype controller and inside a Cohda Wireless box, adapted to support the On Ramp data communication exchange.	E.2.3.1	Motorway

3.3.20.2 Sensors for AD function(s)

Technology	Function	Hor. field of view	Interface
Outside surround view Camera	Object detection surround view nearfield and lane detection	190°	BroadR Reach (100 Mbit)
Front camera	Object and lane detection	38°	CAN
Long-range radar (surround view)	Object detection surround view further away	<120° (short range) <60° (long range)	BroadR Reach (100 Mbit)
Corner radar (surround view)	Object detection surround view nearby	150°	CAN-FD (2 MBit)
USS	Object detection nearby for short distance		N/A
dGPS	Map allocation		RS232 → USB

3.3.20.3 Sensor coverage



3.3.20.4 HMI description

Channel	Device	Main features
Visual	N/A	
Audio	N/A	
Commands	N/A	
MID (Meter)	N/A	
Multimedia	N/A	
HUD	N/A	
Haptic	N/A	

3.3.20.5 Data logger description

Raw data record	Yes
Fusion object level record	Yes
Embedded video labelling	No
Could the driver annotate events	No
Data volume per hour in terabytes	0.4 TB/h

3.3.20.6 Enabler description

Enabler Tech Solution (E.2.3.1) and brief motivation
E.2.3.1 Motorway chauffeur with support for negotiation of on-ramp sections The aim is to enhance highway driving by including on-ramp areas in the exchange of information between the on-ramping and the on-highway vehicle for a better merge-in possibility.

4 Conclusion

4.1 Summary

This deliverable describes the template for progress tracking and the template for vehicle description. The progress-tracking template was developed using three main categories to track the readiness of each VO, ensuring delivery of vehicles complete with their equipment to the operation phase. The vehicle description template has 11 categories. These categories are generic, allowing the VOs to fill in some of them in accordance with their plan (e.g., eHMI for external signals).

Thanks to the vehicle description template, we were able to collect information and get an image on the overall complexity of the AD prototype Hi-Drive fleet. We have shown 37 vehicles, split across four use cases, of which Urban (42%) and Motorway (42%) are the most represented. The vehicles are equipped with enablers, the two main ones being E.2.3.1 (V2V Vehicle-to-Vehicle Communication), with 20%, and E.2.3.2 (V2I Vehicle-to-Infrastructure and Infrastructure-to-Vehicle Communication), with 17%. In addition to the sensors and enablers, an ADS needs an HMI to receive requests and give feedback to users. The two principal HMIs that give feedback are visual, with 31%, and audio, with 24%.

The methodology described here with the given templates can also be applied to similar vehicle preparation projects. In addition to the progress-tracking tables, a regular update from VOs is required by written request or via meetings. During Hi-Drive we prefer to hold regular meetings to allow the VOs to explain their current status and especially the impact of any delays on the planned dates.

Given the dynamic situation in the development of AD functions and testing in Europe and overseas, changes are expected in realising the details of functions and their robustness.

4.2 Lessons learnt

The compilation of vehicle information from a wide range of stakeholders in a research project involving representatives of universities, research institutions, suppliers, and original equipment manufacturers (OEMs) is challenging, as the view on what exactly a vehicle consists of depends on the observer. Loosely speaking, for a university or research institution it is a workhorse for deriving the best algorithms with available hardware, for a supplier it means designing complex hardware and software, and for an OEM it means focusing on the update or generation of the next series vehicle model.

In designing the template, we changed and shortened the information content several times. Nevertheless, questions regarding a prototype/series vehicle could have been improved by defining the concept. All test vehicles are prototypes in various stages of build/rebuild, and all prototypes were initially series vehicles. One partner used a pre-production vehicle with a close-to-series software version and incurred tricky problems regarding compatibility with later vehicles having the series software. The older concept of prototype entailed deep modifications of the hardware for driving dynamics, test engines, etc.

If we compare the L3Pilot project and its (often newly equipped) vehicles, in Hi-Drive some vehicles are re-used and improved with new software. For few vehicles, the new series status of sensor, actuator, and HMI is such that the adaptation to Hi-Drive can rely on capable hardware that has improved in the last few years with the introduction of new models. For the test vehicle setup and development there is less clutter, smoother operation with series software (e.g., braking, steering) and, simply, a cleaner trunk.

As described in the final report for the L3Pilot project, the pandemic necessitated many virtual meetings. In 2021 and 2022, the rules for meeting, distancing, and travel were becoming less rigorous, and it is unclear if the “old” face-to-face meeting frequency will ever reach pre-pandemic levels. Many, but brief, online meetings were needed as replacement, and we missed the lively discussion and commitment of face-to-face meetings.

References

L3Pilot, (2022). Deliverable D1.7 Final Project Results. [Online] Available at: L3Pilot: Downloads [Accessed 15/12/2022].

SAE (2021). Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles. [Online] Available at: https://www.sae.org/standards/content/j3016_202104/ [Accessed 16/12/2022]

List of abbreviations and acronyms

Abbreviation	Meaning
AD	Automated Driving
ADF	Automated Driving Function
ADAS	Advanced Driver Assistance Systems
AV	Automated vehicles
CAD	Connected Automated Driving
CDF	Common Data Format
CoP	Code of Practice
DDT	Dynamic Driving Task
eHMI	External Human Machine Interface
HD Map	High-Definition Map
HMI	Human Machine Interface
HW	Hardware
OBU	On Board Unit
SP	Sub-Project
SW	Software
SDV	Software Defined Vehicles
TOR	Take Over Request
UC	Use Case
VO	Vehicle Owner
VRU	Vulnerable road users
WP	Work Package

Annex 1 Progress tracking template

Explanation

- Please adapt the number of enabler columns (WP3.4) and vehicle columns (WP3.5 and WP3.6) to your needs.
- Please make sure that the "Planned completion dates" are consistent with the operation dates (WP5.3)
- Cell colour should be:

Red: Not ready	Yellow: Ongoing, almost ready	Green: Completed	Grey: N/A

WP3.4 Enabler Implementation

Activity	Description	Planned completion date	Enabler ID 1 (e.g. E.1.1.1)	Enabler ID 2	Comment	Last update on
Test vehicle is ready for implementation of Enabler	Vehicle is available	*<date>*				*<date>*
Enabler HW integrated in vehicle	HW integrated	*<date>*				*<date>*
Enabler operational in vehicle with ADF	SW integrated This is after completion of vehicle preparation in WP3.5	*<date>*				*<date>*

WP3.5 Vehicle preparation

Activity	Description	Planned completion date	Actual completion date		Comments	Last update on
			Vehicle 1	Vehicle 2		
Vehicle technically ready	Sensors, actuators, computing, harnesses, and safety review are done. Technically mature!	*<date>*				*<date>*
ADF adapted to the vehicle	HW/SW installed	*<date>*				*<date>*
ADF tested and approved	Tested on public road or test track?	*<date>*				*<date>*
Logger installed and tested	All required signals are available for logging. Data can be recorded	*<date>*				*<date>*
Vehicle approved for public roads		*<date>*				*<date>*
Signals in common data format	Signal input for CDF conversion delivers correct data (precision, …)	*<date>*				*<date>*

WP3.6 Vehicle pre-testing

Activity	Description	Planned completion date	Actual completion date		Comment	Last update
			Vehicle 1	Vehicle 2		
Data recording	Vehicle provides meaningful data at operation site	<*date*>				<*date*>
Data conversion	Recorded data can be converted into CDF	<*date*>				<*date*>
Baseline data quality check	Analysis partner confirmed that CDF data is as expected	<*date*>				<*date*>
Treatment data quality check		<*date*>				<*date*>
First test trips performed	A reasonable amount of data has been recorded that is suitable for testing analysis	<*date*>				<*date*>
Simple analysis performed	A reasonable amount of recorded data has been used for testing analysis by analysis partner	<*date*>				<*date*>

Annex 2 Vehicle definition template

Vehicle description

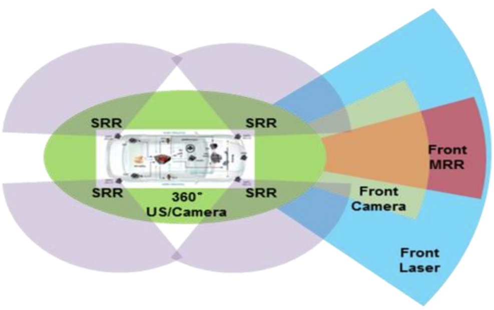
ID	Count	Prototype / Series	Requirements to operate the vehicle with the enabler	Requirements to integrate the enabler inside the vehicle platform	Enabler Tech Solution (E2.x.y, see Table 2-2)	Use case (Urban, Motorway, Rural, see Table 2-3)

Vehicle picture

Sensors for AD function(s)

Technology	Function	Hor. field of view	Interface
Outside camera			Ethernet
Inside camera			Ethernet
Radar			CAN
LiDAR			Ethernet
USS			N/A
GPS			Ethernet
IMU			Ethernet

Sensor coverage



HMI description

Channel	Device	Main features
Visual		
Audio		
Commands		
MID (Meter)		
Multimedia		
HUD		
Haptic		

HMI picture

External HMI description (eHMI)

Free text to insert here: please explain/describe your eHMI

External HMI picture

In-cabin equipment picture other than HMI (e.g., driver monitoring)

Free text to insert here: please explain/describe your in-cabin equipment

Data logger description

Raw data record	Yes / NO
Fusion object level record	Yes / NO
Embedded video labelling	Yes / NO
Could the driver annotate events	Yes / NO
Data volume per hour in terabytes	xxx TB/h

Enabler description

Enabler Tech Solution (E.2.y.z) and brief motivation
E.2.x.y title Free text to insert here: please explain/describe your enabler