Hi-Drive
Designing Automation

Deliverable D3.2 /

Logging tool recommendations

Version: 1.0 Draft

Dissemination level: PU

Lead contractor: FEV.io GmbH

Due date: 31.05.2022

Version date: 16.12.2022

This project has received funding from the
European Union's Horizon 2020 research and innovation
programme under grant agreement No 101006664.

Hi-Drive

Document information

Authors

Luxen Michael – FEV.io GmbH

Kremer Markus – FEV.io GmbH

Jörg Kottig – FEV.io GmbH

Christian Frohn – FEV.io GmbH

Coordinator

Aria Etemad

Volkswagen AG

Berliner Ring 2

38440 Wolfsburg

Germany

Phone: +49-5361-9-13654

Email: aria.etemad@volkswagen.de

Project funding

Horizon 2020

DT-ART-06-2020 – Large-scale, cross-border demonstration of connected and highly automated driving functions for passenger cars

Contract number 101006664

www.Hi-Drive.eu

Legal Disclaimer

Table of contents

List of figures

List of tables

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.

This deliverable, D3.2 *Logging tool recommendations,* addresses a variety of research questions formulated in the project methodology and later via a concrete signal list defined for the evaluation needs. Even broader logging needs were further considered when making recommendations for data loggers. These were (i) the needs of legal entities: given information must be made available for research related to digitalisation, automation, networking, and accident research; (ii) the technical needs of vehicle owners (VOs): e.g., to provide maintenance information for sensors, develop new functions, and validate existing functions and prove reliability; and (iii) the analytical needs of VOs and research on the impact of automated driving as part of the Hi-Drive project.

Several reference data loggers were defined and recommended which met the aforementioned needs. VOs are free to choose their preferred logger, which does not necessarily have to be one of the reference ones. This flexibility of choice was deemed necessary, as early discussions showed that the VOs had vastly different automated driving function architectures for which a universal logger would not be suitable. This also enables the VOs to continue using their existing raw data management tools.

In the Hi-Drive field experiments, all the information has to be logged, which leads to control decisions for the automated driving functions (ADFs) and monitor all relevant internal data exchanges between all control units within the vehicle so that the collected data can be used for analysis, validation, and re-simulation purposes. Bearing this in mind, the logging requirements were defined already at the beginning of the project, ending up as a formalised signal list with feedback from all VOs as an iterative process.

A detailed analysis of logging needs was carried out. A variety of use cases were addressed in order to extend the ODD for automated vehicles (AVs) by means of, for example, V2X (vehicle-to-everything) communication and enhanced positioning. V2X communication is an essential condition for extending the ODD of AVs. V2X communication logging needs were analysed with respect to the use case of V2V for manoeuvre coordination (highway on-ramp merging), which is similar overall to many other use cases in the project.

All these use cases have different logging needs to evaluate the Key Performance Indicators (KPIs) related to the extension of the ODD. For logging needs, the topics for relevant data logging are described, but the specific logging of VOs' needs are individual and could not be

addressed individually. Most of the specific logging needs, however, can easily be covered with the loggers presented in this deliverable, with perhaps some minor extensions in the hardware or software of the logging systems.

A questionnaire was used to determine the technical data logger needs of the individual VOs. Based on this information, a study was carried out to find which data loggers are available on the market and are capable of meeting the requirements of the project. Then, all feasible data loggers were tested under the same test conditions. The test vehicle was always driving the same selected test tracks in Aachen, Germany, and its surroundings. Important aspects of testing included, among other things, the usability of a data logger and data handling. For the objective evaluation of the individual ADAS/AD data loggers, an evaluation matrix was created with various evaluation criteria based on which logger was individually assessed.

Each vehicle manufacturer, and even each department within the company, has different requirements for recording and collecting data for further use. All of the analysed data loggers can support the VOs in re-using logged raw data from the vehicles. The VOs themselves need to decide where to put their focus and the next steps that they wish to take with the collected data.

1 Introduction

1.1 Hi-Drive - Addressing challenges toward the deployment of higher automation

Hi-Drive addresses a number of key challenges that currently hinder progress in the development of vehicle automation. The main goal of the project is to focus on testing and demonstrating automated driving (AD) by improving intelligent vehicle technologies to cover a large set of traffic environments, which is not currently achievable.

Hi-Drive enables testing of a variety of functionalities, from motorway chauffeur to urban chauffeur, in diverse scenarios with heterogeneous driving cultures across Europe. In particular, the Hi-Drive trials will consider European TEN-T corridors and urban nodes in large and medium cities, with specific attention to demanding, error-prone, conditions. The project's ambition is to extend the operational design domain (ODD) compared to the current situation, which frequently demands interventions from the human driver. Therefore, the project concept builds on achieving a widespread and continuous ODD, where automation can operate for longer periods of time and interoperability across borders and brands is ensured. The project also investigates the factors that influence user behaviour and acceptance and the needs of other road users interacting with these vehicles. Reducing fragmentation of the ODD is expected to give rise to a gradual transition from conditional operation to higher levels of AD. With these goals in mind, Hi-Drive associates formed a consortium of 41 European partners with a wide range of interests and capabilities, covering the key areas that impact users and the transport system and enhance societal benefits. The project intends to contribute towards market deployment of automated systems by 2030. All this cannot be achieved by testing only. Accordingly, the work also includes outreach activities on business innovation and standardisation, plus extended networking with interested stakeholders, coordinating parallel activities in Europe and overseas.

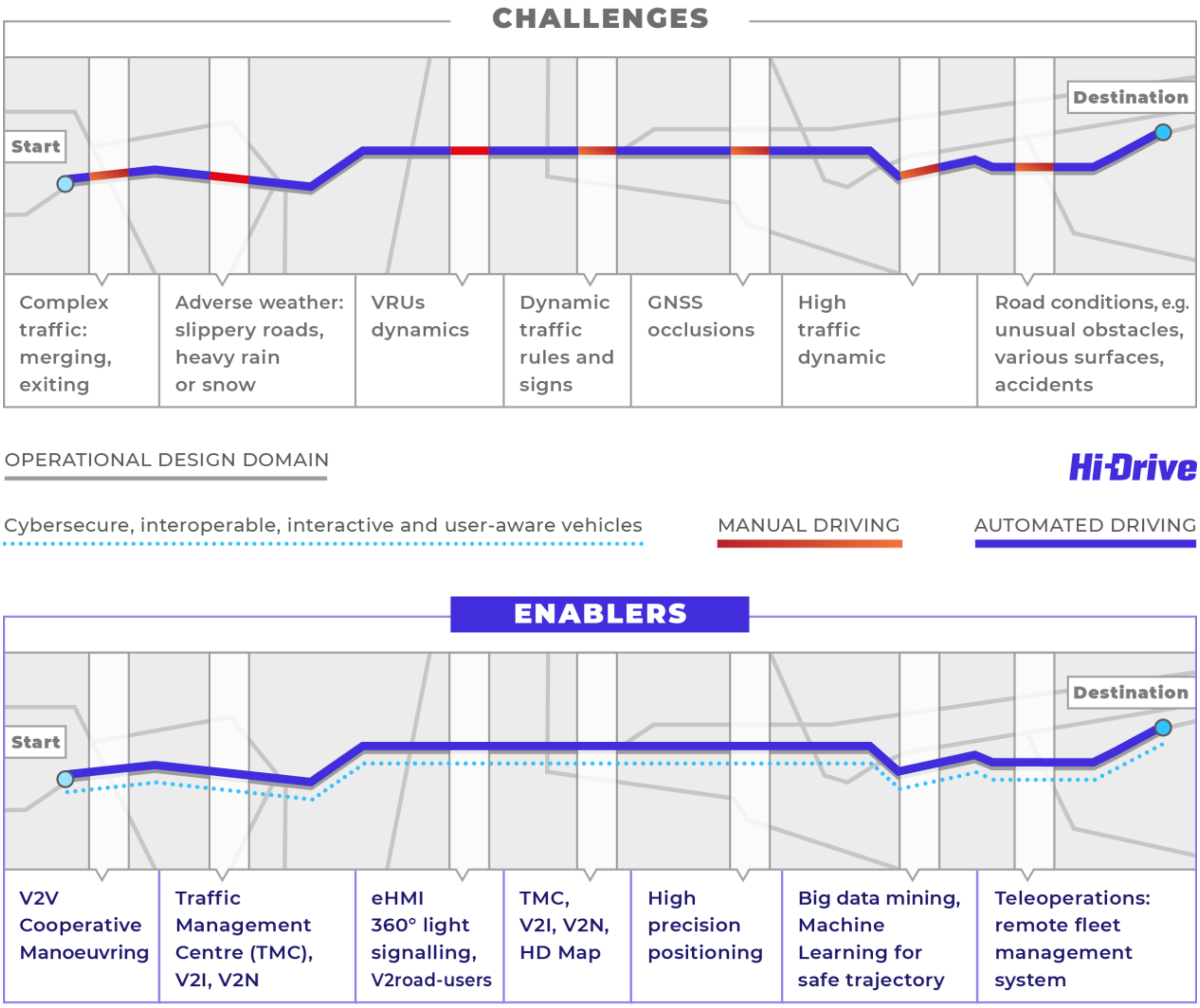

Figure 1.1: Hi-Drive addressing ODD defragmentation against challenges

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, research questions and hypotheses are formulated leading to the specification of data needed for evaluation and then 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 serve as input to determine whether the socioeconomic benefits outweigh the costs. The project also engages in a broad dialogue with stakeholders and the general public to publicise the Hi-Drive results. Dissemination and communication are supported by a demonstration campaign to showcase the project achievements. Overall, Hi-Drive strives to create a deployment ecosystem by providing a platform for strategic collaboration. Accordingly, the work includes 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. In addition, Hi-Drive leads activities on standardisation, business innovation, and extended networking with interested stakeholders, and coordinates parallel activities in Europe and overseas.

1.2 Objectives

The scope of Deliverable 3.2 *Logging tool recommendations* is to adopt the data collection needs via a signal list as defined in D4.2 *Data for Evaluation* and to inquire about extra needs for data from vehicle and other experiment owners. With the knowledge of size, structure, and frequency of data, a survey of data loggers should be compiled and annotated into a manageable list. Finally, a recommendation for suitable data loggers is provided

1.3 Logging needs for automated driving

Regarding AD, there is a broad variety of needs for logging the different signals in automated vehicles. First of all is the need mandated by legal entities. On European level, regulation on the need for an Event Data Recorder (EDR) is under preparation. The following is an example from German law:

In Germany, the federal government introduced an amendment of the StVG (**St**raßen**v**erkehrs**g**esetz = road traffic act) and the compulsory insurance act in 2021. As part of these amendments on AD, it was already stated that certain information in automated vehicles needs to be logged and made available to the Kraftfahrt-Bundesamt for research on traffic-related common good purposes, in particular for digitalisation, automation, and networking as well as accident research.

Within §1g (Data processing) the detailed list of data to be logged is as follows:

Table 1.1: StVG §1g Data processing (1)

No	Kind of data
1	Vehicle identification number
2	GPS Position of vehicle (e.g., latest date 08.02.2021)
3	Amount and time for using activation and deactivation of AD functions
4	Amount and time of release of alternative driving manoeuvres
5	System monitoring data including data for software version
6	Environmental and weather data
7	Networking parameters such as transmission latency and available bandwidth
8	Name of activated and deactivated passive and active safety systems, data on the status of these safety systems, as well as the entity that triggered the safety system
9	Longitudinal and lateral vehicle acceleration

No	Kind of data
10	Vehicle speed
11	Status of lighting equipment
12	Power supply of the AD vehicle
13	Commands and information sent externally to the motor vehicle

The data pursuant to paragraph 1 are to be stored on the following occasions:

1. In the event of interventions by the technical supervisor

2. In conflict scenarios, especially accidents and near-accident scenarios

3. In the event of an unscheduled lane change or swerving

4. In the event of disruptions during operations.

Next to these legal requirements and logging needs, the OEM (Original Equipment Manufacturer) may also have technical needs, e.g., to provide maintenance information for sensors, develop new functions with the help of collected data, and validate existing functions and prove reliability.

The third category is the analytical needs of the OEMs and the research. This is about collecting data to gain insights into AD and manual driving and possibly re-simulating and studying the performance of the AD system with parameter changes in the algorithms, and as part of a larger scientific framework, studying the impact of AD, which is part of the Hi-Drive project.

Several reference loggers will be defined in this deliverable that meet the aforementioned requirements.

VOs are free to choose their preferred logger, which does not necessarily have to be one of the reference ones. This flexibility of choice was deemed necessary as early discussions showed that the VOs had vastly different ADF architectures for which a universal logger would not be suited. This also enables the VOs to continue using their existing raw data management tools.

2 Methods for the analysis of different ADAS/AD logger systems

2.1 Aspects of logging

This chapter describes in more detail the various aspects that were applied in the market analysis and identification of suitable ADAS/AD logger systems for the needs of the Hi-Drive project.

AD (prototype) vehicles have several requirements for logging data within the vehicles, as mentioned in chapter 1.2.

For the developers of these vehicles, it is important to understand in detail the situations that they are dealing with. Therefore, they need to log all the information leading to control decisions by the ADF and monitor all relevant internal data exchanges between all control units within the vehicle, so that the collected data can be used for validation and/or for re-simulation purposes.

The data flow begins with raw data logging by each VO. Within Hi-Drive, all VOs are required to integrate loggers into their vehicles in such a way that the setup meets the logging requirements as defined in D4.2 *Data for Evaluation*.

2.2 Logging needs for Hi-Drive

2.2.1 List of signals for logging

At the beginning of the Hi-Drive project, the logging requirements were developed in WP4.4 and then presented to all VOs as a pseudo-signal list. The list was formalised into a proper signal (non-pseudo) list with feedback from all VOs using an iterative process. Commonly occurring signals were selected with the help of the VOs as candidates for each logging requirement as a first draft. This draft list was then evaluated by the VOs, improved based on their feedback and incorporated into a more complete list. If a signal that could not be provided by most VOs was found, another suitable signal value was identified which could be provided by all VOs. The signal list was determined and defined in D4.2 *Data for Evaluation*. See Annex 1 for the full list.

2.2.2 Hi-Drive V2X Use cases with different logging needs

The Hi-Drive project deals with a variety of use cases, all of which aim to enhance the ODD of automated vehicles, for example using V2X communication and enhanced positioning. All of these use cases have different logging needs to evaluate the KPIs related to the extension of the ODD. For all these logging needs, the topics for relevant data logging are described, but the VO-specific logging needs are very individual and cannot be addressed individually. Most of the specific logging needs are easily covered by the mentioned loggers within D3.2 with perhaps some minor extensions to the hardware or software of these logging systems.

2.2.3 Evaluation of data logger needs of each vehicle owner

Evaluation of the data logger needs of each VO began in the preceding project, L3Pilot [35]. At the start of L3Pilot, a detailed questionnaire “L3Pilot, SP5 *Tools,* Detailed Questionnaire” was shared with all VOs.

The questionnaire was used to determine the technical data logger needs of the individual VOs. Based on this information, a study was carried out to find which data loggers are available on the market and capable of meeting the requirements of the Hi-Drive project.

The questionnaire feedback is summarised in Table 2.1. The ‘min’ and ‘max’ columns indicate the minimum and maximum logger requirements given by the VOs.

Table 2.1: Questionnaire and feedback from vehicle owners

Questions	Min	Max
If commercial tool is used, what is the commercial name?	Vector Tools, intempora RT-Maps, VIGEM or internal development	
Which sensor data (e.g. camera, radar, LiDAR, …) and/or network communications (CAN, FlexRay, …) can be acquired (with the existing tool)?	Network communication (CAN, FlexRay, Ethernet)	
	Video data (Ethernet, USB, FPD) logging	
	Radar	
	LiDAR	
	USS, IHM, vehicle sensors	
How many interfaces need to be logged?		
CAN (if CAN, please specify baud rate for each CAN)	6x CAN-FD	8x CAN-FD
	2x CAN @125kbps	10x CAN HS @ 1Mbps
		7x CAN @ 500kbps
Ethernet	1x Ethernet	4x Ethernet @ 1Gbps
		4x Ethernet @ 100Mbps
		22x Ethernet => to clarify
FlexRay	1 FlexRay @10Mbps	4 FlexRay @10Mbps
LVDS	2 x LVDS	2 x LVDS
USB	1x USB => to clarify 2.0 or 3.0	6x USB 3.0
Other Interfaces? Which and how many?	Keyboard, screen, mouse	
	3,5 mm audio input (microphone)	
	>14 FAKRA	
Is remote control/management needed?	No	Remote management (location, status)
How long should the logger be able to log the data? Minimum and maximum number of hours.	2 hours	70 hours

Questions	Min	Max
How much logger stop time for data transfer is allowed?	5 minutes (HDD Swap)	6 hours
What should be the recording rate (sampling frequency) for analogue and digital?	10 Hz	5 kHz
		up to 4Gbps (digital)
LVDS	2 x LVDS	2 x LVDS
USB	1x USB => to clarify 2.0 or 3.0	6x USB 3.0
Other interfaces? Which and how many?	Keyboard, screen, mouse	
	3,5 mm audio input (microphone)	
	>14 FAKRA	
Is remote control/management needed?	No	Remote management (location, status)
How long should the logger be able to log the data? Minimum and maximum number of hours.	2 hours	70 hours
How much logger stop time for data transfer is allowed?	5 minutes (HDD Swap)	6 hours
What should be the recording rate (sampling frequency) for analogue and digital?	10 Hz	5 kHz
		up to 4Gbps (digital)
LVDS	2 x LVDS	2 x LVDS
USB	1x USB => to clarify 2.0 or 3.0	6x USB 3.0
Other interfaces? Which and how many?	Keyboard, screen, mouse	
	3,5 mm audio input (microphone)	
	>14 FAKRA	
Is remote control/management needed?	No	Remote management (location, status)
How long should the logger be able to log the data? Minimum and maximum number of hours.	2 hours	70 hours
How much logger stop time for data transfer is allowed?	5 minutes (HDD Swap)	6 hours
What should be the recording rate (sampling frequency) for analogue and digital?	10 Hz	5 kHz
		up to 4Gbps (digital)

2.2.4 Data logger hardware installation

As part of the "Smart Vehicle" competence centre, FEV owns a small fleet of smart vehicle demonstrators which have also been used for data logging evaluation within the Hi-Drive project. One of these vehicles is shown in Figure 2.1.

Figure 2.1: Vehicle used for evaluation of data logging systems

Most of the data logger components were installed in the trunk of the vehicle. The ones used to control the logger (e.g., remote control button or monitor and mouse) were mounted on the windscreen or in the front passenger compartment.

2.2.5 Harmonised test tracks for comparable test conditions

All data loggers were tested under the same test conditions. The test vehicle was always driving the same selected test tracks in Aachen, Germany, and its surroundings (7km, 13.2km, 19km, 114km) as described in Annex 3.

The test tracks were selected according to different criteria to include relevant urban, interurban, and motorway elements to ensure a wide range of differentiation.

Naturally, weather conditions could not be set identically for all test drives.

2.2.6 Usability of a data logger

The user friendliness of a data logger solution is very important, as the effort required to use the system should be as minimal as possible. The best solution is a configurable system that can be used by any driver (trained or untrained) without user interaction. Various criteria were considered for the evaluation of a suitable data logger system. Among other things, emphasis was placed on minimising the time and effort required for the initial setup of the system. This included the question of whether the data logger could be set up at a standard working place where it could be put into operation without having to take it to its final installation location (e.g., vehicle trunk).

Furthermore, attention was paid to the delivered user manual or available online documentation for initial setup of the data logger. The possibilities of the hardware and software configuration should be clearly described here. Also of great interest is how intuitively the user interface of the hardware (remote control) and software is implemented. Questions for assessment included the following:

- Is it necessary to start the measurement manually at the data logger itself (e.g., by pressing a button)?
- Can the measurement be started or stopped by configurable triggers (e.g., CAN signal, remote control button)?
- Is it possible to install the data logger in the vehicle without any user interaction (e.g., automatic start/stop by IGN ON/OFF or any trigger condition)?

2.2.7 Data handling

Data handling of the logger is another important point for the daily work of data acquisition and the subsequent analysis and evaluation, since the amount of data from video logging is likely to be very large. The data format plays an important role here. If it is a standardised data format, further analysis and evaluation is more likely to be possible with a variety of software products than if it is a proprietary solution from the data logger provider.

This quickly raises some questions, such as:

- In what (file) format is the logging data stored?
- What export options in other data formats (e.g., CAN .asc, Video .avi/.mp4) are available for third-party software?
- What analysis options are available with the supplied software?
- How easy is the data exchange (e.g., USB-HDD, removable SSD, copy station) between the data logger and the vehicle owner's database to minimise the vehicle standstill time?
- How fast is the data transfer (e.g., GbE, 10GbE, USB3, Firewire) from the data logger to the data centre/cloud storage?

2.3 Connectivity logging for Hi-Drive

2.3.1 Two logging approaches

This chapter describes the logging needs with respect to highway on-ramp merging with V2X communication, which overall is similar to many other use cases within the Hi-Drive project.

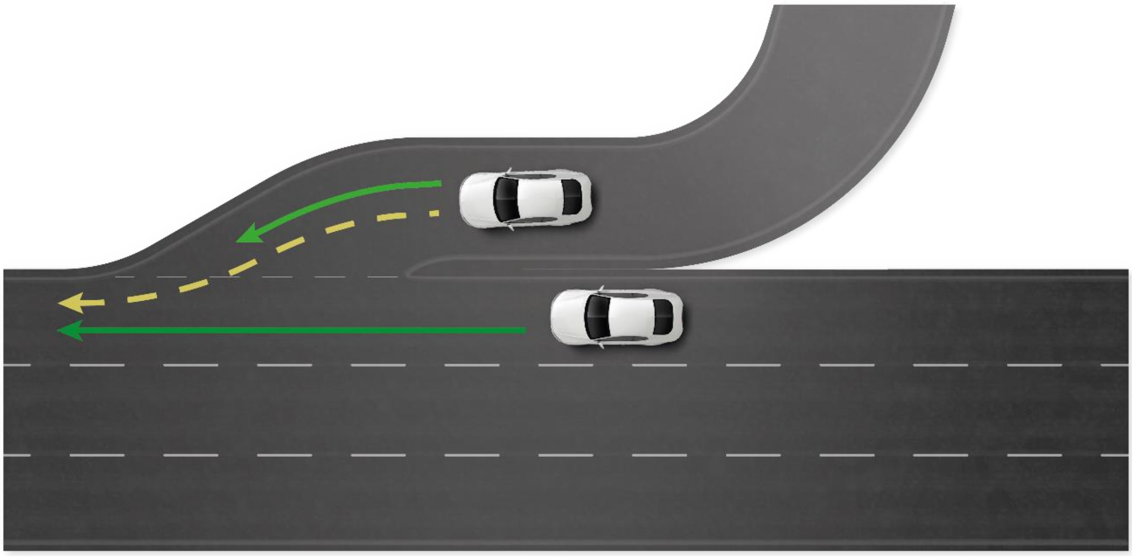

Figure 2.2: Highway on-ramp scenario for a connected ADAS use case (Hi-Drive project)

Calculation of KPIs to evaluate the success rate of the use case requires logging of only a few signals, such as

- V2X data transmissions for the Manoeuvre Coordination Message (MCM) type including the message content
- Transmission timestamps

This use case does not incorporate any signals regarding Bluetooth, cellular network, or Wi-Fi connectivity interfaces. Each V2X system only has accurate information about its own sent V2X messages; for the received V2X messages this information is not available. For example, the latency of a V2X message transmission can be calculated as the difference between the timestamp of sending the message (only known at the V2X sender) and the timestamp of reception of the message (only known at the V2X receiver). Similarly, most of the connectivity related signals listed in Table A1.1 need to be derived from multiple V2X logs of the involved V2X systems.

In the following sections, two basic approaches with their advantages and disadvantages for V2X logging data are described. The first approach uses the onboard V2X unit installed in the vehicle for logging, whereas the second approach describes a setup including an additional 3rd Party V2X system that can listen to and log V2X data transferred between the vehicles over the V2X radio interfaces.

2.3.2 V2X logging using the onboard V2X unit

Most available onboard V2X units also provide V2X logging capabilities by default. All sent and received V2X messages of these V2X units are typically logged in the well-known packet capture (PCAP) [31] file format, which can be processed by multiple tools for analysis and evaluation purposes. The PCAP file format can store each received or transmitted V2X message together with its timestamp. This information is typically recorded to the internal persistent memory of the onboard V2X unit provided by an SD card.

Distributed logging systems require time synchronisation to be able to relate logging data from the different systems to each other. There are two common options for time synchronisation:

- GNSS based: The global navigation satellite system is used as a common time reference. The time synchronisation resolution can be improved by means of a 1PPS (Pulse Per Second) signal.
- NTP based: The Networking Time Protocol (NTP) offers services to synchronise distributed, networked systems.

In previous FEV publications, it has already been shown that GNSS-based time synchronisation with 1PPS can be suitable for testing and validating ADAS functionalities in a distributed system setup [30].

The resulting PCAP file of the onboard V2X unit can be copied to the main logger system after the use case has been executed. Alternatively, it would also be possible to continuously stream chunks of the PCAP file to the main logger system while running the use case via an Ethernet connection. The streaming approach would increase the robustness of the logging solution in case of unexpected V2X system failures or faults, but it would also result in an increased load on the communication medium.

Based on the previous descriptions, the V2X logging setup depicted in Figure 2.3 is recommended. The main vehicle logger is time-synchronised using GNSS with a 1PPS signal and it offers an NTP service so that the V2X onboard unit can synchronise its own time to the main vehicle logger. This ensures that the correct timestamps are recorded within the PCAP file.

The main advantage of using a V2X onboard unit for logging is that V2X logging data is a by-product of the overall V2X setup, which is required anyway for the highway on-ramp merging use case. No additional hardware is required, and only some configuration efforts need to be considered for the implementation of this V2X logging approach. In contrast to the solution described in the next section, the data logged by the V2X onboard unit is also very accurate, as it reflects the real V2X timing and transmission characteristics that are present within the V2X onboard unit.

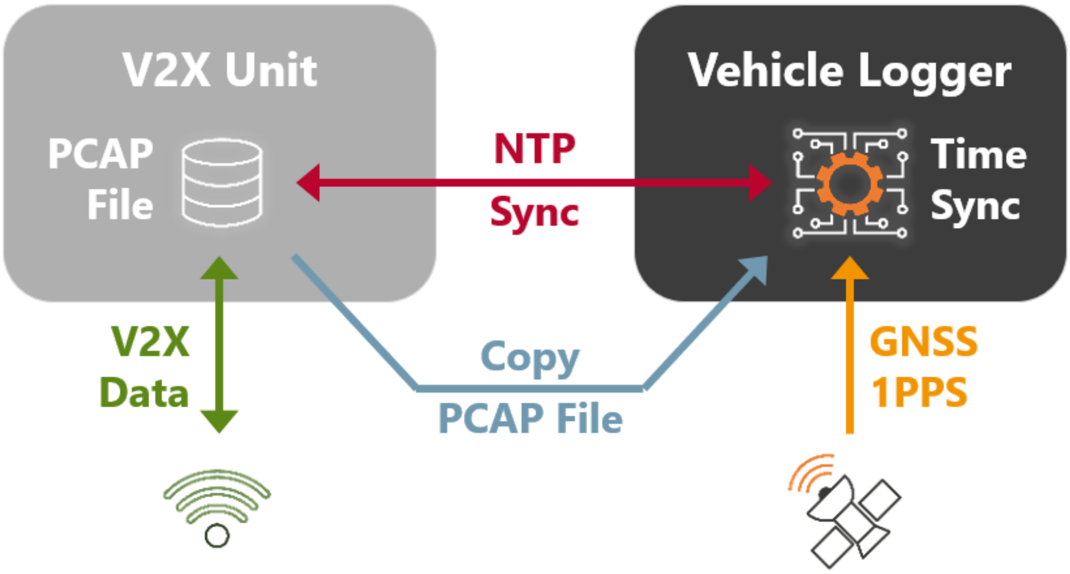

Figure 2.3: V2X logging setup using a V2X onboard unit

2.3.3 V2X logging using additional V2X systems

Alternatively, other than the logging solution described in the previous section (which is logging the V2X transmissions from inside the V2X onboard unit), V2X messages can also be logged from additional radio interfaces among the V2X onboard units installed in the vehicles.

To ensure interoperability, there are currently two major organisations that certify V2X products regarding their V2X standard conformance. These are OmniAir [32] and the Global Certification Forum (GCF) [33].

The only V2X "Sniffer" that is currently OmniAir certified is the V2X "Sniffer Software and Decoder" from S.E.A. GmbH and National Instruments (NI), called SEA 3610 [34].

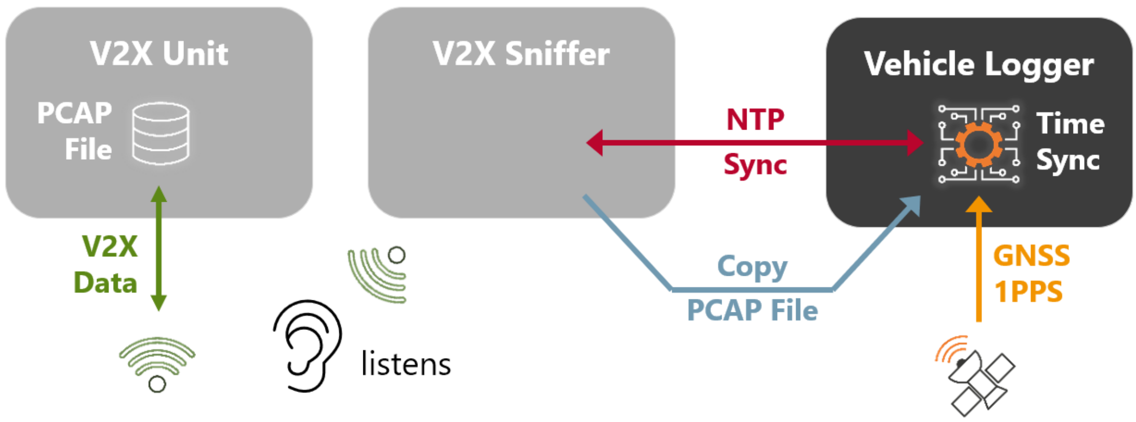

Figure 2.4: V2X logging setup using a 3rd Party Radio Sniffer

The solution from S.E.A. and NI offers the possibility of recording the monitored V2X messages and saving them in PCAP file format. Time synchronisation via NTP is also supported. Thus, the setup with this 3rd Party logger can be realised in a very similar setup as described in section 2.3.2: Data logging in PCAP file format, time synchronisation via NTP, and data exchange either in one go at the end of the use case execution or streamed continuously during execution (see illustration in Figure 2.4).

The advantage of the V2X sniffer solution compared to direct logging on the involved V2X onboard units would be the centralised approach, which scales up more easily as the number of onboard units increases. A disadvantage of this approach may be that the V2X traffic recorded by the sniffer does not exactly correspond to the V2X timing and transmission characteristics of the corresponding V2X onboard unit. Because the V2X transmissions are wireless radio transmissions, it cannot be guaranteed that the 3rd party system would receive exactly the same wireless transmissions at exactly the same time as the corresponding V2X onboard unit, even if these two systems are located right next to each other.

2.4 Analysed ADAS/AD logger systems

Data recording and logging is one of the most important tasks forming the basis for a whole range of other tasks in the field of AVs for ADAS/AD development. To name just a few important ones, these would be data analysis, data visualisation, and replay in MiL/SiL/HiL environments.

2.4.1 ADAS/AD data logger market research overview

Based on the signal list mentioned in chapter 2.2.1, a market analysis was initiated to find the most suitable ADAS/AD data logger solution as a recommendation for the VOs running the different use cases, with their enablers in mind. This task may sound like a simple undertaking at first, but it was a complex challenge due to the wide variety of requirements for hardware interfaces and support for existing software toolchains (some of which are proprietary in-house solutions). The result of the market research is summarised in the overview presented and discussed in section 3, particularly Table 3.1. The already known ADAS/AD data loggers were supplemented by other new, updated loggers or next-generation loggers with new, improved functions or more computing power.

2.4.2 Data logger evaluation criteria

For objective evaluation of the individual ADAS/AD data loggers, an evaluation matrix was created with various evaluation criteria based on which logger was individually assessed.

Due to the different requirements, these were grouped according to the following sections:

Environment

Power consumption and quiescent current are one of the most important factors, as is robustness to voltage drops or temperature in the section *Environmen*t.

Signals including analogue/digital inputs or outputs

Physical interfaces such as LIN, CAN(-FD), and Ethernet, as well as wireless interfaces such as Bluetooth, mobile cellular networks, and Wi-Fi, are subordinate to the *Signals* category. Since the status of an analogue or digital input or output is sometimes still needed, these logging requirements are also included in this section.

Logging

Logging time capacity and configurability belong to this section, as does the functionality for setting 10 Hz logging.

Configurability and Controllability

Simple user guidance, a wide range of configuration options, and easy operation on the one hand and, for example, status information on correct operation, data storage, and detectability of errors on the other, belong here.

Installation and Maintenance

The data logger should be as compact as possible, as AD computer equipment is already bulky. Loggers consisting of more than one device (e.g., data acquisition and logging) are difficult to integrate (e.g., fixtures, additional wiring harness). The size of the ADAS/AD loggers and the effort to maintain and integrate them into the vehicle under test (VUT) are the main issues here.

Storage and data handling

Storing the data on local (e.g., SSD) storage modules of the data logger and transferring the logged data, for example to cloud storage or local data centres, can be very cost- and time intensive, which is why they received special attention.

In view of a complete assessment, the following evaluation criteria matrix was used to evaluate the data logger that best meets the needs of each VO:

Table 2.2: Evaluation criteria and assessment factors for the assessment matrix

Evaluation criteria	Assessment factor	Comment
Bluetooth	3%	Remote control of system
Cellular network	3%	Remote control/access of system
V2X	6%	Logging of V2X communication
Configurability (e.g. resolution, compression) of camera interfaces	5%	
Configuration of system	3%	
Costs	5%	
Dark current	3%	
Data format (logging files)	3%	
Data storage size SSD/HDD	2%	
Dimension	2%	
Integration time	2%	
Log data transfer possibilities	2%	
Logging time capability/configurability	2%	
No. of analogue inputs	4%	
No. of CAN(-FD) interfaces	5%	
No. of digital inputs	4%	
No. of Ethernet interfaces	5%	
No. of FlexRay interfaces	5%	

Evaluation criteria	Assessment factor	Comment
No. of USB interfaces	5%	
Power consumption	5%	
Quiescent current	2%	
Remote control management	2%	
Startup/shutdown functionality	4%	
Time for log data transfer	5%	
Timestamping 10Hz	2%	
User interaction	2%	User status information and remote control (e.g. switches for trigger or en-/disable system)
Weight	5%	
Wi-Fi	4%	Remote control/access of system

3 ADAS/AD data logger recommendations

A summary of all data loggers identified and investigated in the market analysis based on the logging needs and evaluation criteria matrix summarised in Table 2.2 is shown in Table 3.1:

Table 3.1: ADAS/AD data logger overview

Supplier	Hardware	Software	URL
b-plus	BRICK CORE COMplus BRICK2	Aveto framework	BRICKplus (b-plus.com)
DEWEsoft	S-BOX	DEWEsoft X	SIRIUS® (Dewesoft)
dSPACE	Autera	RTMaps	AUTERA - dSPACE
Elektrobit	Data logger Low/Mid/High variant	ADTF	Automated driving validation (Elektrobit)
Intrepid	neoVI ION RAD-MARS	Vehicle Spy X	Products (Intrepid)
IPEtronik/Caetec	Arcos 1.5 ETHOS	IPEmotion	Datenlogger (IPEtronik)
NI (National Instruments)	NI PXI platform	Data Record AD	ADAS/AD logging (NI)
Racelogic	VBOX series	VBOX TestSuite	VBOX ADAS solutions (Racelogic)
Siemens	b-plus BRICK	Aveto framework / Simcenter SCAPTOR	ADAS Data Collection (Siemens)
TTTech	PM-200	TTX-DataLogger	PM-200 (TTTech Auto)
Vigem	CCA9002 / 9003 / 9010 CCA7010 compact	Vigem Tools/Framework	High-End Data Logging (ViGEM)
Xylon	logiRecorder 3.2	logiRecorder Dashboard	logiRECORDER 3.2 – (Xylon)
Zuragon	Vicanlog PRO Vicanlog PRO+	ViCANdo	ViCANdo (Zuragon)

Available data loggers were subjected to extensive analysis of their installation and its practicability, and of their user friendliness especially in terms of operation and use. Another important aspect here was data handling related to data carrier handling and connectivity to external storage solutions (data centre, cloud) as well as the duration of data transmission and thus the data throughput. An in-depth on-site analysis could not be carried out for all data loggers, as their availability was not always guaranteed. For these, suitability was ensured by means of data sheets, operating instructions, and further technical discussions with the manufacturers.

The ADAS/AD logger recommendations again differ significantly in terms of various aspects such as size, features, and purchase price. Each VO has very different requirements based on the individual use cases, vehicle interface requirements, and established toolchains. For this reason, Table 3.2: above ranges from the "simple" ADAS/AD data logger without a re-simulation feature, few IVN interfaces, and low data storage capacities/speeds to high-end and high-priced ADAS/AD data logger systems with the largest currently possible storage capacity and IVN interfaces, including integration into existing HiL systems for the purpose of re-simulation. This should provide the best possible and most suitable logger system for every application and VO. Raw data logging was not on the list of requirements for a recommended data logger, although a few are also suitable for this application due to their processing power and data throughput.

Of the 13 loggers, five could be recommended for the VOs involved in the Hi-Drive project. The loggers *not* recommended were, for example, more suitable for stationary logging, too complex for continuous data logging, or too feature-rich/expensive.

The data logger recommendations in Table 3.2: for the Hi-Drive project cannot cover all applications, which is why each individual application must be examined in detail according to its needs.

Likewise, not including a logging system in the recommendation list says nothing about the quality or performance of the device in general.

It is not mandatory to use these loggers. Most VOs already have their preferred logging system as part of their ADF development activities; they are free to use them, provided they meet the logging and signal list requirements.

Table 3.2: Alphabetically sorted summary of the ADAS/AD data logger recommendations

Supplier	Hardware	Software
b-plus	BRICK CORE COMplus, BRICK2	Zuragon ViCANdo, Vector CANape
dSpace	Autera	RTMaps
Vigem	CCA9002/3, CCA9010, CCA 7010 compact	Vigem Tools/Framework
TTTech	B200	
NI (National Instruments)	NI PXI platform	Data Record AD

4 Conclusions and outlook for further usage of logged data

4.1 Validation with the help of logged data

As detailed in Chapters 1 and 2, each vehicle manufacturer and even each department within the companies has different requirements for recording and collecting data for further use.

All of the analysed data loggers can of course support the VOs in reusing the logged raw data from the vehicles. All VOs themselves need to decide where to put their focus and the next steps they wish to take with the collected data. If ambiguous situations occur during the test drives, the data can be processed and used for re-simulating the scenario that occurred. If the VO only wants to store the data to prove that they have developed and tested their AD functions correctly, or if the data is also used for training artificial intelligence (AI) functions for new generations of AD functions and vehicles, this is possible with most of the logger systems and their recording capabilities. All loggers presented here can meet these requirements; the data processing and preparation for further use must then be done by the VOs and is a task not to be underestimated.

4.2 Constraints

In this overview, data loggers were collected from 13 suppliers with several variants of devices with the common property of being standalone data loggers. These and other suppliers also provide devices that log data (only) in connection with a controlling computer. During development, the separation of signal conversion (e.g., CAN to computer input via USB port) and storing is often used for rapid prototyping, as data are directly stored where they are easily visualised, transferred to data centres, and re-simulated. For the field testing, however, once the initial development work is concluded, a robust (standalone) solution for testing is needed that does not require expert knowledge to combine data from different sources. An example is a test driver who does not need to start logging right away and ejects a filled data container from the data logger at the end of a tiring day of tests. Preparatory work to prepare a cable harness, programming, and testing can be extensive until the needed (and distributed) data sources are directed and time-synchronised to one data logger. Extensive work might also be incurred in postprocessing, which is needed for the data to fit to legacy software (e.g., written for validation). This explains why, for example, a product development department, with teams distributed across an automotive organisation, is reluctant to consider new data loggers and formats because of the need to reprogram existing tools.

4.3 Lessons learned

Comparing systems is a task with several dimensions. The complexity (e.g., depth of understanding of the system under test, looking through different marketing terms to find the same specifications, and the variety of test situations) should be adequate to the intended use of the comparison: Here we addressed data logging in vehicles during a period of one year in a research environment, with vehicles under setup and operation from the VO in Hi-Drive. The signal list and signal formats provided a requirement that changed during the task but in the end did not lead to new requirements for the data logger. The depth of recording extra information of V2X communication has been limited to signals available at the receiving end of the vehicle to avoid including telco-operators in providing additional connection-related data. As with any complex task that is not routinely performed, planning is important. Methodology, preparation, and availability of the test vehicle, procurement, understanding and installation of the logger, data collection, and postprocessing need to be understood, and time-bound excessive instrument costs could be avoided by the provision of device samples during the testing period.

List of abbreviations and acronyms

Abbreviation	Meaning
ABS	Antilock Braking System
AD	Automated Driving
ADAS	Advanced Driver Assistance Systems
ADF	Automated Driving Function
AIO	Analogue Input/Output
AV	Automated Vehicles
CAD	Connected and Automated Driving
CAN(-FD)	Controller Area Network (Flexible Datarate)
CoP	Code of Practice
CPU	Central Processing Unit
CSI	Camera Serial Interface
DIO	Digital Input/Output
DM	Derived Measures
ECU	Electronic Control Unit
FPD-Link	Flat Panel Display – Link
FPGA	Field Programmable Gate Array
GMSL	Gigabit Multimedia Serial Link
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GPU	Graphics Processing Unit
GUI	Graphical User Interface
HiL	Hardware in the Loop
HMI	Human-Machine Interface
IOT	Internet of things
IVN	In-vehicle network
HDD	Hard disk drive
KPI	Key Performance Indicator
LiDAR	Light detection and ranging
LIN	Local Interconnect Network
LTE	Long Term Evolution

Abbreviation	Meaning
LVDS	Low Voltage Differential Signalling
MiL	Model in the Loop
NVMe	Non-Volatile Memory express
OABR	Open Alliance BroadR-Reach
ODD	Operational Design Domain
OS	Operating System
OEM	Original Equipment Manufacturer (e.g., vehicle manufacturer)
PI	Performance Indicator
PCI	Peripheral Component Interconnect
PXI	PCI eXtensions for Instrumentation
RAM	Random Access Memory
SAE	Society of Automotive Engineers
SATA	Serial AT (Advanced Technology) Attachment
SDV	Software Defined Vehicles
SiL	Software in the Loop
SoC	System on a Chip
SSD	Solid State Drive
StVG	**St**raßen**v**erkehrs**g**esetz (road traffic law)
TOR	Take-Over Request
UMTS	Universal Mobile Telecommunications System
USB	Universal Serial Bus
VO	Vehicle Owner
V2I	Vehicle to infrastructure
V2N	Vehicle to network
V2V	Vehicle to vehicle
V2X	Vehicle to everything (communication)
VRU	Vulnerable road user
VUT	Vehicle under test
WiFi	Wireless Fidelity
WLAN	Wireless Local Area Network

Annex 1 Signal list

The minimum set of signals as described in 2.2.1 and required for all vehicle owners is summarised in Table A1.1.

Table A1.1: Hi-Drive signal list

No.	Signal	Signal Group	Description	Unit
1	ID of transmitting object	Connectivity	ID of communicating object	Number
2	Latency	Connectivity	Time difference between sent and received information	ms
3	Packet loss	Connectivity	Number of actual received packages divided by number of sent packages	%
4	Active gear	Driver input	Current driven gear	Number
5	Brake pedal position	Driver input	Position of brake pedal, % of range	%
6	Brake pedal pressure	Driver input	Brake system pressure, % of min/max range to normalise the signal	%
7	Safety driver intervention	Driver input	Indicates any intervention by safety feature (take-over, steering, braking, accelerating)	[1/0] or Categories
8	Steering wheel angle	Driver input	Steering wheel angle	Rad
9	Throttle pedal position	Driver input	Position of throttle pedal, % of range	%
10	GNSS position latitude	Ego vehicle kinematics	GNSS longitudinal position	WGS 84
11	GNSS position longitude	Ego vehicle kinematics	GNSS lateral position	WGS 84
12	GNSS quality	Ego vehicle kinematics	GNSS quality	TBD
13	Heading angle (vehicle)	Ego vehicle kinematics	Heading of ego vehicle (axis)	Rad
14	Lateral acceleration	Ego vehicle kinematics	Lateral acceleration (Y-axis, measured in CoG)	m/s^2

No.	Signal	Signal Group	Description	Unit
15	Lateral speed in lane	Ego vehicle kinematics	Lateral speed relative to lane marking	m/s
16	Longitudinal acceleration	Ego vehicle kinematics	Longitudinal acceleration (X-axis, measured in CoG)	m/s^2
17	Odometer	Ego vehicle kinematics	Vehicle odometer reading	km
18	Position in lane	Ego vehicle kinematics	Lateral position in lane (measured to centre of vehicle)	m
19	Velocity	Ego vehicle kinematics	Velocity of ego vehicle as reported by the ABS/wheel sensing module	m/s
20	X-position	Ego vehicle kinematics	Relative x-position (longitudinal position) of ego vehicle towards the start of the scenario/trip	m
21	Yaw rate	Ego vehicle kinematics	Yaw rate of vehicle	rad/s
22	Y-position	Ego vehicle kinematics	Relative y-position (lateral position) of ego vehicle towards the start of the scenario/trip	%
23	Lighting condition	Environment	Ambient light level at location of ego vehicle. Requires signal from light sensor. Measured as the natural log of the raw value (because the range is huge)	ln(lux) / Categories
24	Rain sensor	Environment	Rain sensor signal	Categories
25	Road condition	Environment	Current road condition at location of ego vehicle	Categories
26	Temperature	Environment	External ambient temperature at location of ego vehicle	°C
27	Weather information	Environment	Current weather at location of ego vehicle (requires information from rain sensor, wipers)	Categories
28	Age (Subject)	Experiment information	Only for non-professional drivers	Categories or Number
29	Country	Experiment information	Country of test site	Categories

No.	Signal	Signal Group	Description	Unit
30	Participant ID	Experiment information	Unique ID for each driver; important to map answers in the questionnaire	ID
31	Driving scenario	Experiment information	Current detected driving scenario	Categories
32	Gender	Experiment information	Only for non-professional drivers	Categories
33	Number of trials/runs per driver	Experiment information	Number of trials/runs a test person has already conducted	Number
34	Role of driver	Experiment information	Role of test person during test	Categories
35	Purpose of experiment	Experiment information	Purpose of experiment	Categories
36	Questionnaire status	Experiment information	Describing if and when questionnaires are conducted	Categories
37	Seat position	Experiment information	Seat position of test person during test	Categories
38	Status "unusual things"	Experiment information	Flag to mark test in which something went wrong and to indicate tests that should not be considered for the assessment	[0/1]
39	Status Practice Drive	Experiment information	Status of current test drive – Practice drives should not be considered for the analysis	[0/1]
40	Test scenario	Experiment information	Currently tested scenario	Categories
41	Trial or test run number	Experiment information	Number of test runs/trials in experiment	Number
42	Type test person	Experiment information	Type of test person	Categories
43	Use case	Experiment information	Currently tested Hi-Drive use case	Categories
44	Traffic light status	Infrastructure detection	Status of external traffic light	Categories
45	Infrastructure detection – in XY	Infrastructure detection	Determine that the vehicle is currently in a certain infrastructure situation – which situation is relevant depends on	[1/0]

No.	Signal	Signal Group	Description	Unit
			the ADF and enabler (XY: intersection, construction site, tunnel, motorway entry, passing a motorway entry)	
46	Infrastructure detection – in ODD	Infrastructure detection	Detection that the infrastructure related ODD condition is fulfilled	[1/0]
47	Distance to XY	Infrastructure detection	Distance from the current location of the ego vehicle to the start of an infrastructure condition (XY: intersection, construction site, tunnel, end of lane, motorway entry, passing a motorway entry)	m
48	Video (driver)	Other	Video feed of driver	-
49	Video (front)	Other	Video feed from front-facing camera	-
50	Lane marking type	Road	Type of lane markings	Categories
51	Lane width	Road	Width of lane in which the ego vehicle is currently driving	m
52	Number of lanes	Road	Number of lanes at current location of ego vehicle in driving directions	[-]
53	Road type	Road	Road type according to Hi-Drive classification, to be discussed	Categories
54	Speed limit	Road	Speed limit at current location of ego vehicle	m/s
55	Driver angle head n/ Head tracking	Status driver	Heading position (yaw, roll & pitch angle)	Categories | Orientation on 3 axes
56	Driver attention	Status driver	Status driver attention	Categories
57	Status Hands-on-wheel Detection	Status driver	Status hand of detection	Categories
58	Crash detection	System status	Status crash	[1/0]

No.	Signal	Signal Group	Description	Unit
59	Enabler interacting with ADF	System status	Describes whether the technical enabler is interacting with the ADF while the ADF is operational	[0/1]
60	Enabler status	System status	Status of enabler; name of enabler	Categories
61	Status ABS Active	System status	Whether the ABS system is intervening	[1/0]
62	Status ACC	System status	Status ACC	Categories
63	Status ADF	System status	Status ADF	Categories
64	Status AEB	System status	Status AEB	Categories
65	Status Brake Light	System status	Whether brake lights of ego vehicle are on or off	[1/0]
66	Status ESC Active	System status	Whether electronic stability control/traction control system is intervening	[1/0]
67	Status Horn	System status	Status horn	[1/0]
68	Status Within ODD	System status	Whether ego vehicle is/isn't in the ODD of the ADF	[1/0]
69	Status Lane Keeping	System status	Status lane keeping	Categories
70	Status ADF Level ≤2	System status	Whether any ADF level ≤2 is active	Categories
71	Status MRM	System status	Status minimal risk manoeuvre	[1/0]
72	Status Take-over Request Active	System status	Whether a TOR to return control to the driver is active	[1/0]
73	Status Turn Indicator	System status	Status turn indicator	[1/0]
74	Status Windscreen Wipers	System status	Status windscreen wiper	[1/0]
75	Time since start	Time	Time since start of trip/run/experiment	s
76	UTC Time	Time	UTC timestamp since epoch	ms
77	Object lane assignment	Traffic object (all)	Lane assignment of object x	Categories

No.	Signal	Signal Group	Description	Unit
78	Longitudinal acceleration object	Traffic object (all)	Longitudinal acceleration of another vehicle	m/s^2
79	Object class	Traffic object (all)	Classification of object type	Categories
80	Object ID	Traffic object (all)	ID of object x (should be constant during driving scenario)	[-]
81	Object source tag	Traffic object (all)	Tag showing if the detection of object x is based on one or multiple sensor sources (incl. V2X)	Categories
82	Relative lateral velocity to ego	Traffic object (all)	Relative y-velocity to object x (lateral direction) measured from ego vehicle	m/s
83	Relative velocity speed to ego	Traffic object (all)	Relative x-velocity to object x (longitudinal direction) measured from ego vehicle	m/s
84	Relative position to ego x	Traffic object (all)	Relative x-distance to object x (longitudinal direction) measured from ego vehicle	m
85	Relative position to ego y	Traffic object (all)	Relative y-distance to object x (lateral direction) measured from ego vehicle	m
86	Distance to lead vehicle	Traffic object (Lead vehicle)	Longitudinal distance to lead vehicle	m
87	Lateral acceleration lead vehicle	Traffic object (Lead vehicle)	Longitudinal acceleration of lateral object	m/s^2
88	Longitudinal acceleration lead vehicle	Traffic object (Lead vehicle)	Longitudinal acceleration of lead object	m/s^2
89	Velocity lead vehicle	Traffic object (Lead vehicle)	Absolute velocity of lead vehicle	m/s
90	Time gap to lead vehicle	Traffic object (Lead vehicle)	Time gap from ego vehicle to lead vehicle	s

Annex 2 ADAS/AD data logger technical specifications

a. b-plus – BRICK CORE COMplus with b-plus Aveto framework

The b-plus BRICK COMplus data logging system is based on an Intel Core i7 processor running on either Windows 10 IOT or Linux OS. It supports a wide range of different interfaces, including the standard ones such as CAN(-FD), FlexRay, and Automotive Ethernet (100Base-T1), as well as WLAN 802.11 a/b/g/n, GPS or LTE/UMTS. The BRICK COMplus system is scalable if a higher throughput than 16Gbit/s or higher interface count is required. The storage module BRICK STORAGEplus [1] can support up to 32TB.

Figure A2.1: b-plus BRICK CORE COMplus [2]

The AVETO.app recorder is the web-based interface from b-plus for configuring, setting up, and monitoring BRICK data logging systems with a focus on high bandwidth for raw sensor data and associated vehicle communication bus systems such as CAN(-FD) or Automotive Ethernet (100 Base-T1).

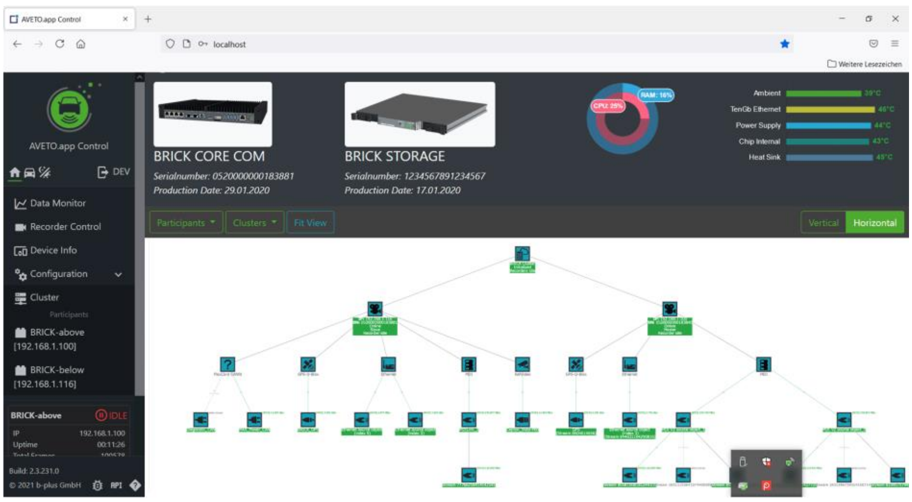

Figure A2.2: b-plus AVETO.app Recorder [3]

AVETO.app Visualisation is the visualisation backend to the recorded data to display the sensor data from all types of sensors such as camera, radar, or LiDAR as well as the associated vehicle buses.

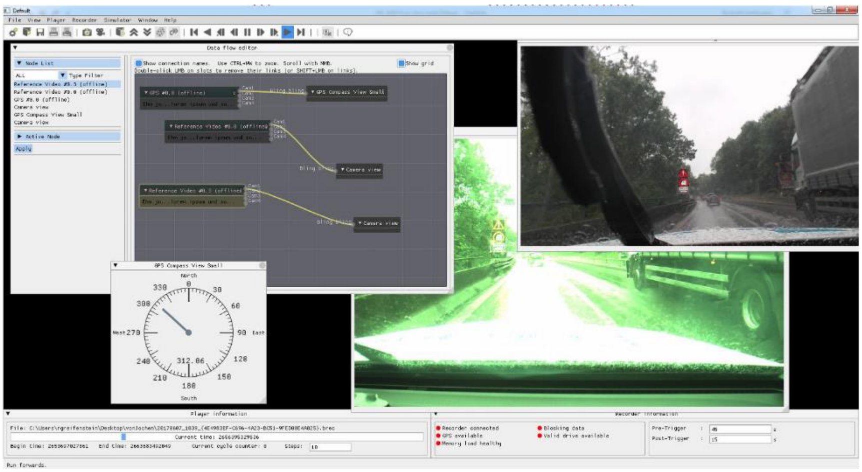

Figure A2.3: b-plus AVETO.app Developer – Visualising multi-sensor data [4]

b. DEWESoft – SBOX

The DEWEsoft SBOX data acquisition system is based on an Intel Core processor (up to i7) on Windows OS. The DEWEsoft SIRIUS series is highly configurable for different (sensor) interfaces based on AIO/DIO. CAN(-FD) and FlexRay is supported by using interfaces from e.g., Vector Informatik (e.g., VN1600 / VN7600 series) connected via USB.

Figure A2.4: DEWESoft SBOX [5]

DEWESoft X is the interface to the SBOX for testing, measuring, and monitoring. Data recording, signal processing, and visualisation of the recorded data are among its features.

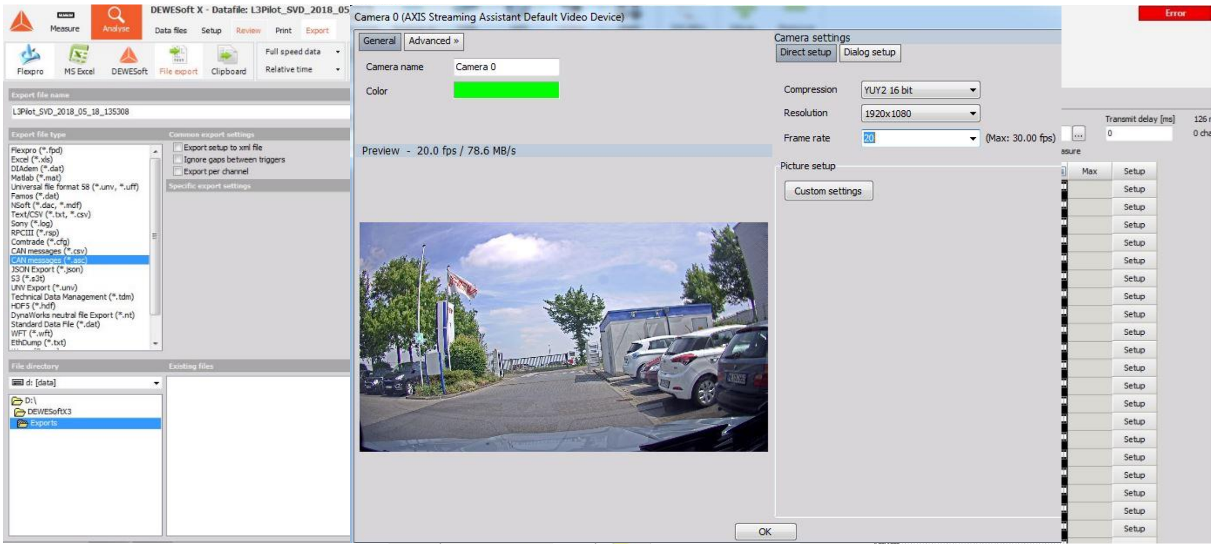

Figure A2.5: DEWESoft X [6]

c. dSpace Autera with RTMaps

The dSpace Autera system is equipped with an Intel Xeon CPU with 12 cores (12 x 2.0 Hz) and 32GB RAM as standard (up to 512GB optional). It supports a wide range of hardware interfaces to capture all types of vehicle communication interfaces such as CAN(-FD), Ethernet, camera raw data like GMSL II, FPD-Link III or CSI II. Hardware accelerators such as GPUs from e.g., NVIDIA are supported as well as hot-swappable AUTERA SSD. The data acquisition bandwidth can reach up to 50 Gbit/s

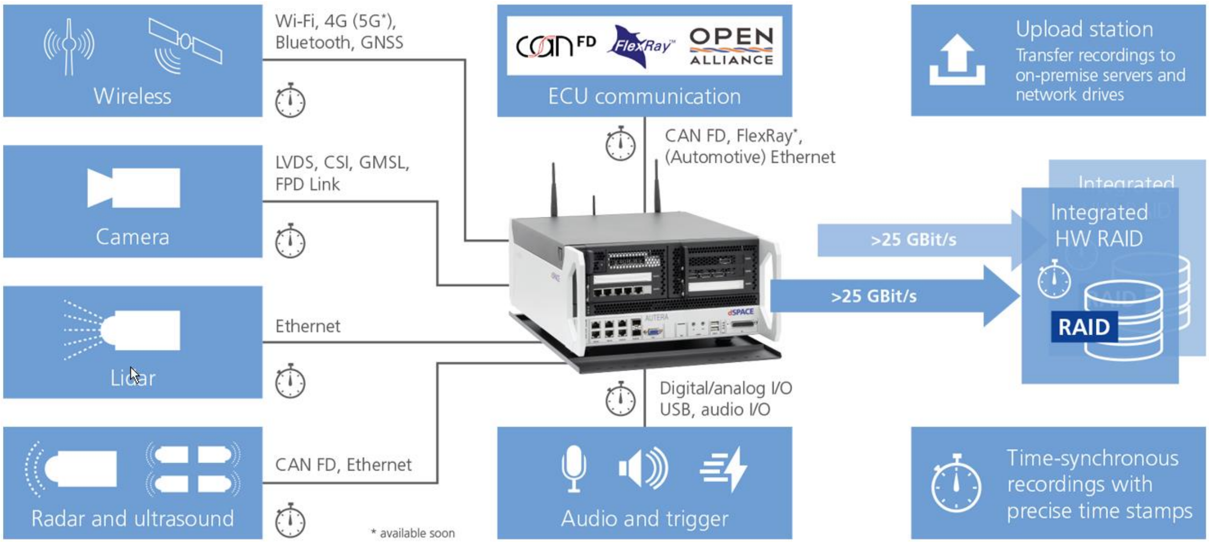

Figure A2.6: dSPace Autera [7]

RTMaps is a multi-sensor real-time application for the development and validation of the environment for such applications, especially in the field of ADAS/AD. The main features are recording, synchronisation, and playback of time-stamped data from different sensors and vehicle buses.

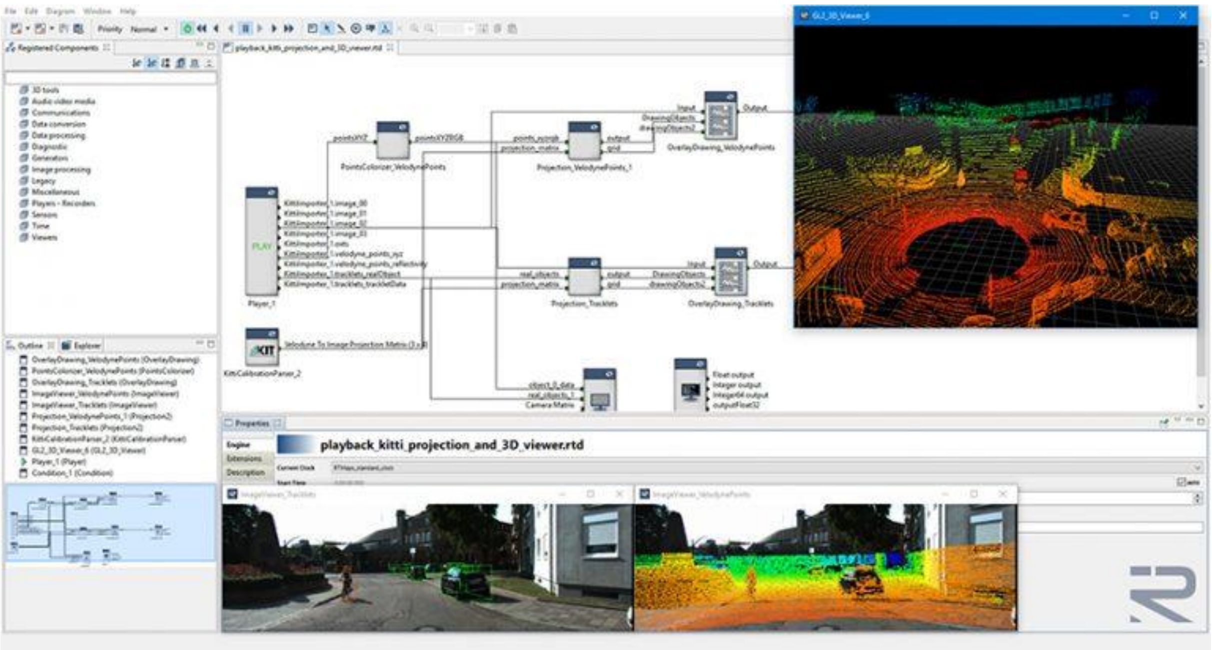

Figure A2.7: dSPace/INTEMPORA RTMaps [8], [9]

d. Elektrobit

Elektrobit's high-performance and scalable data logging solutions are used to collect sensor data and play them back in a simulated environment. The loggers can be equipped with NVMe storage up to 128 TB and up to 768 GB RAM, while the bandwidth can reach 12 Gbit/s.

Figure A2.8: Elektrobit data logger variants [10]

EB Assist supports the ADAS development and can be used for testing, visualising, validating, and building of ADAS and automated driving functions and systems.

Figure A2.9: Elektrobit EB Assist - Automated driving test & validation [11]

e. Intrepid Control Systems – RAD-Mars

The Intrepid Control Systems RAD-Mars data logging system runs on a proprietary operating system and stores the log data internally on SD cards (up to 12TB). The RAD-Mars supports various interfaces such as the standard interfaces for AIO/DIO or CAN(-FD), FlexRay, and TI FPD-Link III or Maxim GMSL. Additional interfaces for e.g., GPS, OABR, LIN can easily be extended within the Intrepid Control System hardware solutions, i.e., family neoVI or RAD.

Figure A2.10: intrepidCS RADMARS [12]

Figure A2.11: intrepidCS neoVI-ION [13]

Vehicle Spy Enterprise is a single tool that supports vehicle diagnostics as well as ECU simulation, data acquisition, automated testing, ECU memory calibration, and vehicle bus monitoring.

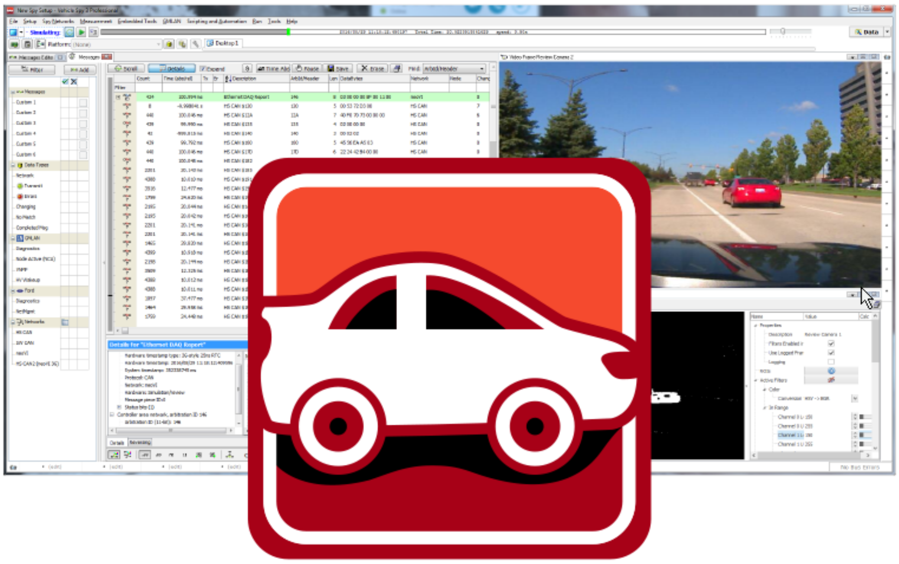

Figure A2.12: intrepidCS Vehicle Spy [14]

f. IPETRONIK/Caetec Arcos 1.5

IPETRONIK offers two different hardware solutions for ADAS/AD datalogging. One is the more scalable data logger solution ARCOS 1.5 and the other is the latest generation high-performance data logger ETHOS.

Figure A2.13: ARCOS 1.5 high scalable data logger for automotive networks [15]

Figure A2.14: ETHOS high performance data logger for ADAS/AD applications [16]

IPETRONIK supports a set of software solutions with the IPEmotion suite (IPEmotion PC, IPEmotion ME, and IPEmotion RT). The Mobile Edition IPEmotion ME offers the possibility to visualise live data or to control the data logger. The IPEmotion RT data logger software is based on Linux, while IPEmotion PC is used on Windows and offers the end user the option of data analysis.

Figure A2.15: IPEmotion PC software for all applications [17]

g. NI Data Record AD System

The Data Record System Autonomous Driving (Data Record System AD) is a PXI-based application system designed to capture, store, and analyse high-resolution data from in-vehicle sensors and networks. Two chassis with 10 or 18 slots are available, supporting a 2.8 GHz quad-core up to a 3.9 GHz eight-core Intel XEON CPU. The slot design makes the NI PXI system highly scalable to meet the needs of a wide range of ADAS/AD sensor and vehicle network data recording applications.

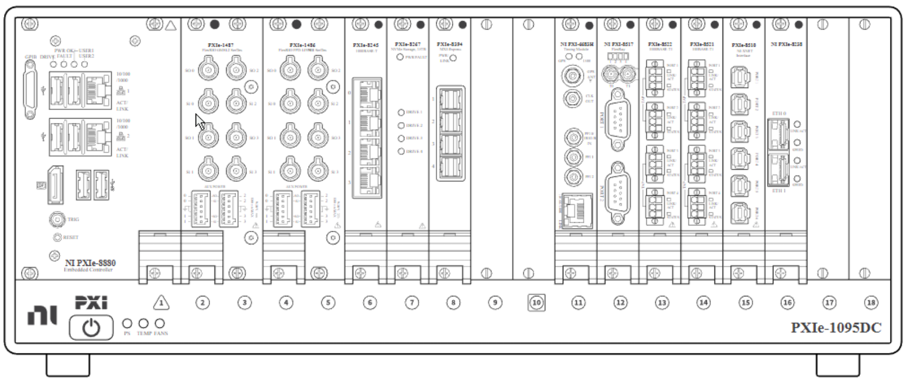

Figure A2.16: NI Data Record System - Hardware Configuration Example [18]

Data Record AD consists of a number of applications such as the Configuration Editor, the Visualization Editor, the User Interface, and the I/O plug-ins (Plug-in Creation Toolkit). Data Record AD itself is used as a data acquisition application and interface to the PXI system to record raw data from sensors and in-vehicle communication buses. In addition, a pre-labelling tool is available, and the data records can be used for playback and re-simulation.

Figure A2.17: NI Data Record System AD - Hardware and Software GUI [19]

h. Racelogic – Vbox series

The VBOX system provides a high-precision measurement system for the different tasks of ADAS testing & validation. Depending on the user's needs, a variety of individual components can be chosen from.

Figure A2.18: Racelogic VBOX solutions [20]

The VBOX Test Suite is Racelogic's user-friendly and intuitive data analysis software for recording and analysing data. Due to the large number of plug-ins, the software can be adapted to the relevant task.

Figure A2.19: Racelogic VBOX Test Suite [21]

i. TTTech – PM200

The TTTech PM200 data logging system runs on Linux OS and supports writing individual functions based on an extensive API using the Eclipse IDE. The PM200 supports different interfaces such as the standard interfaces for AIO/DIO or CAN(-FD), FlexRay, and OABR (PT-15B extension). The removable memory module can be exchanged for another, copying the data of the full module via a standardised SATA-III interface.

Figure A2.20: TTTech Auto PM-200 [22]

The TTX-DataLogger tool is used to configure all PM-2000 hardware interfaces, to convert from the proprietary ttl log files to various standard log file formats, and to analyse the ttl log files.

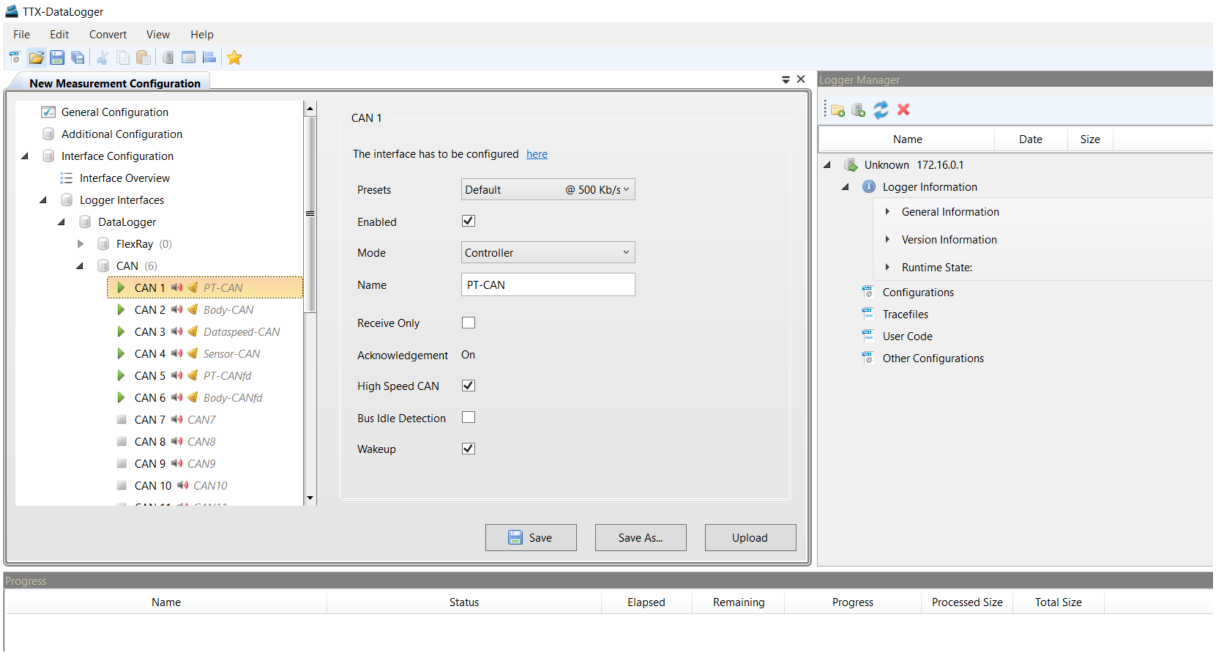

Figure A2.21: TTX-DataLogger tool screenshot – Configuration of PM-200 interfaces [Own figure]

j. Vector VP6400/7x00 Smart Logger Platform and CANape (log)

The VP6400 is suitable for simple ADAS applications running either CANape log or vMeasure log with a reduced feature set. The VP7400/7500 can be ordered with any Vector tool such as CANape that supports the full feature set for ADAS/AD applications. The number of supported hardware interfaces also differs and is significantly higher for the high-end VP7400/7500 hardware.

Figure A2.22: Vector VP6450 based on CANape log or vMeasure log [23]

Figure A2.23: Vector VP7470 supports CANape or any Vector tool [23]

Vector CANape (log) with the additional option DA (Driver Assistance) is a powerful combination of the CANape calibration and measurement tool as an interface to the Vector Smart Logger family. A wide range of vehicle sensor data and bus systems can be recorded, visualised, and analysed (online & offline).

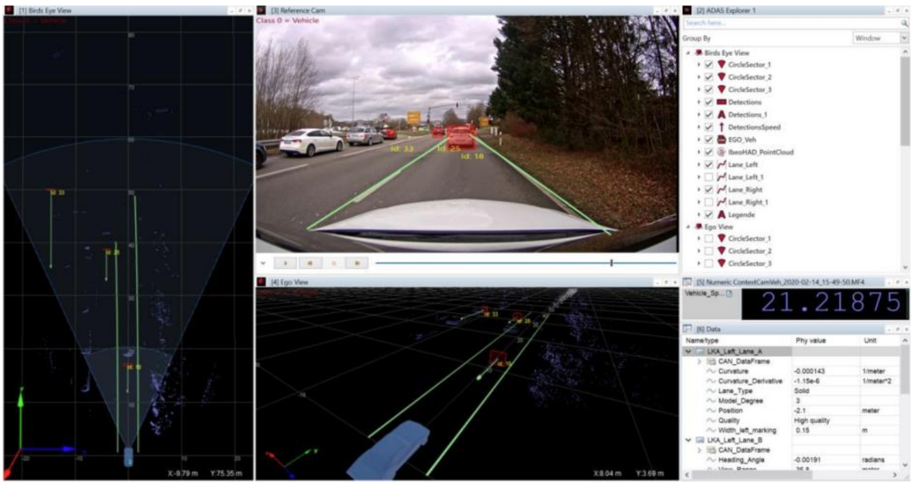

Figure A2.24: Vector CANape Option Driver Assistance [24]

k. ViGEM – CCA9002/3, CCA9010, CCA7010

The ViGEM CCA9002/3 data logging system is based on an Intel Core processor i7 running on Linux OS. The CCA9002 supports various interfaces such as the standard interfaces for AIO/DIO or CAN(-FD), FlexRay, LVDS, and OABR. The removable storage modules with a maximum capacity of 16TB can be exchanged for another one, while copying the data of the full one with the copy station CCA CS1. If the maximum data throughput of 6.4 Gbit/s of the

CCA9003 is not sufficient, the high performance CCA9010-100 can even achieve a data throughput of 25Gbit/s. At the other end is the more cost-effective CCA7010 compact, which can also realise a data throughput of up to 10Gbit/s.

Figure A2.25: ViGEM CCA9002/3 [25]

The ViGEM software suite (CCA Tools) ensures simple identification of the ViGEM units in the network (CCA Finder), as well as conversion of the recorded data (CCA Converter)

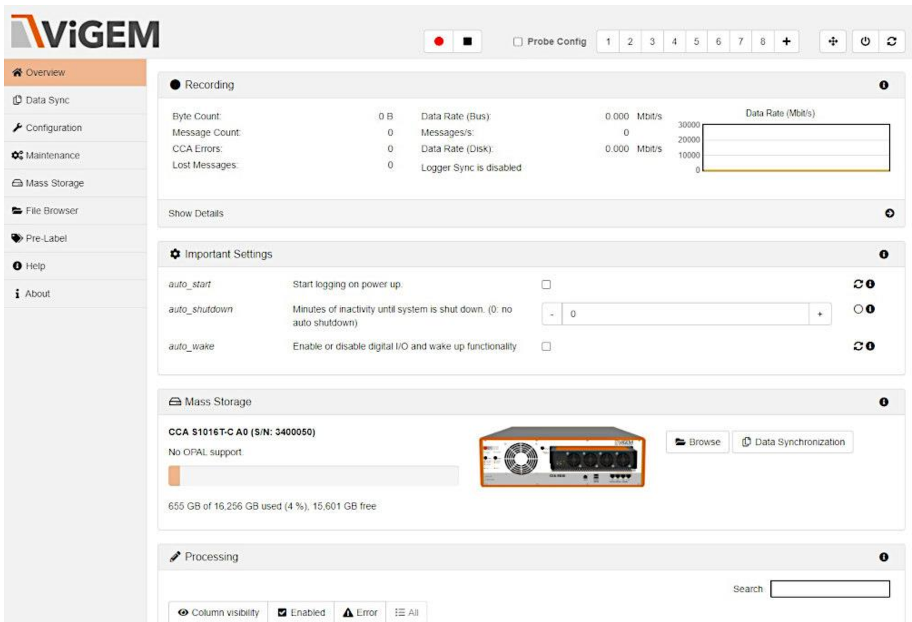

Figure A2.26: ViGEM software suite (CCA Tools) [26]

I. Xylon LogicBricks

The XYLON logiRECORDER 3.2 is designed as an Automotive HiL video logger and can be used for data recording and playback for e.g., HiL simulators and test applications. The logiRECORDER is powered by a Xilinx Zynq SoC and FPGA chipset, which supports a bandwidth of up to 12.8 Gbit/s, while data is stored on up to 32 TB of internal SSD memory. A 100ns timestamp is available for highly accurate data acquisition. The logiRECORDER is highly scalable by multi-unit stacking and supports a wide range of automotive interfaces for video, radar, LiDAR, and in-vehicle network logging.

Figure A2.27: Xylon logiRECORDER Video Data Logger for Automotive Applications [27]

On the one hand, the logiRecorder dashboard is used for the entire configuration of the logiRECORDER-connected interfaces and included features (e.g., video marking). On the other hand, it is used for offline analysis or playback of the data recordings.

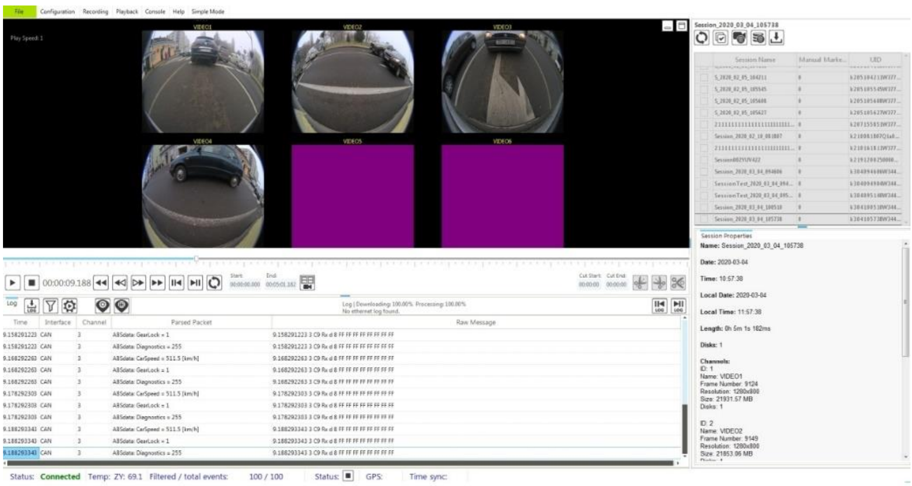

Figure A2.28: Xylon logiRECORDER Dashboard – Playback Tab [28]

m. Zuragon ViCANdo

Zuragon offers three different ADAS/AD data loggers. Starting with the entry-level fanless Vicanlog light, through the Vicanlog PRO to the high-end Vicanlog PRO+. Vicanlog PRO+ is a super-powerful and robust real-time AI computing machine specialised for AD purposes. Playback and analysis of the recordings in a HiL system is possible with all three.

Figure A2.29: Vicanlog PRO [29]

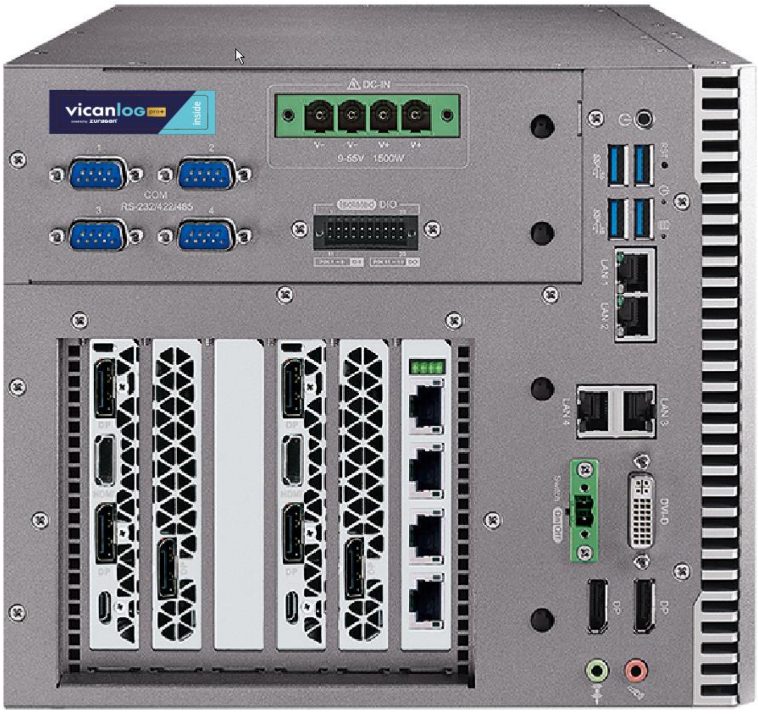

Figure A2.30: Vicanlog PRO+ [29]

ViCANdo is a suite of tools and is used as a general-purpose application for collecting data from multiple sensor sources and recording them in an individual memory. It is designed such that the recordings can easily be replayed and analysed online or offline. This retrospective analysis is also supported by other tools in the suite.

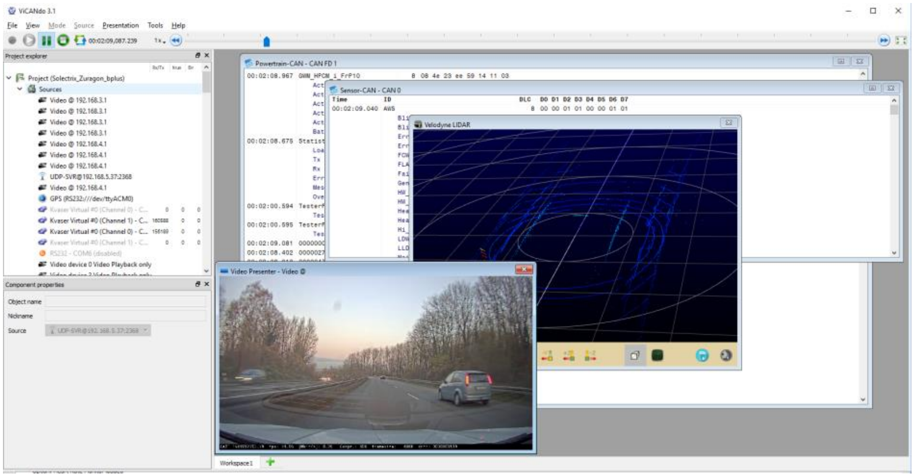

Figure A2.31: Zuragon ViCANdo – LiveView and post analysis of logging data [29]

Annex 3 Data logger evaluation test routes

The following figures show the test routes used for evaluation of the data loggers.

a. FEV-N (Neuenhofstr., 52078 Aachen, Germany) ⇔ CMP - Center for Mobile Propulsion (Forckenbeckstr., 52074 Aachen)

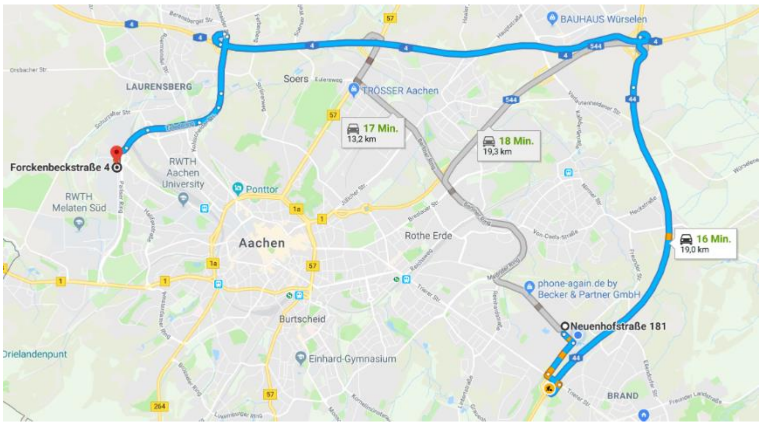

Figure A3.1: Test Route FEV-N ⇔ CMP

b. FEV-A (Konrad-Zuse-Str., 52477 Alsdorf, Germany) ⇔ FEV-N (Neuenhofstr., 52078 Aachen, Germany)

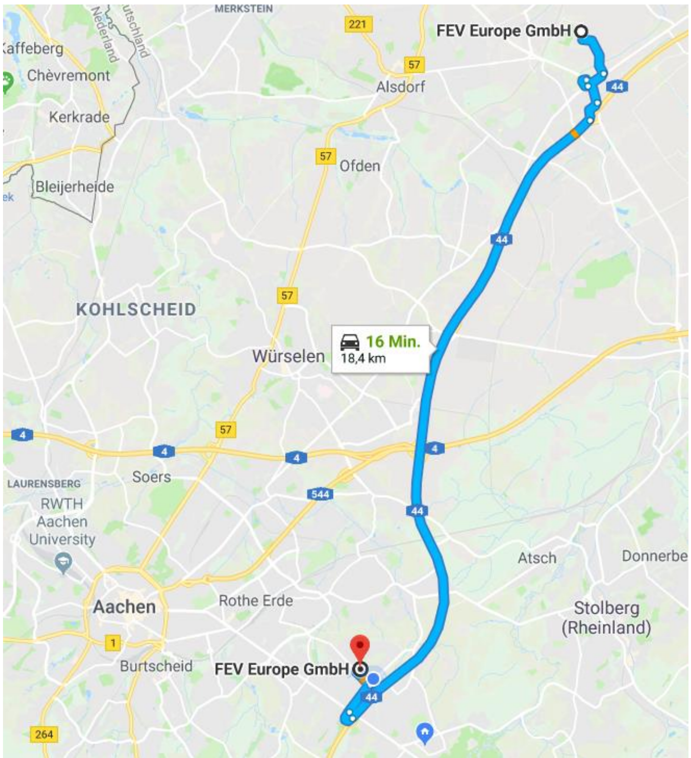

Figure A3.2: Test Route FEV-N ⇔ FEV-A

c. FEV-A (Konrad-Zuse-Str., 52477 Alsdorf, Germany) ⇔ ATC – Aldenhoven Testing Center (Industriepark Emil Mayrisch, 52457 Aldenhoven, Germany)

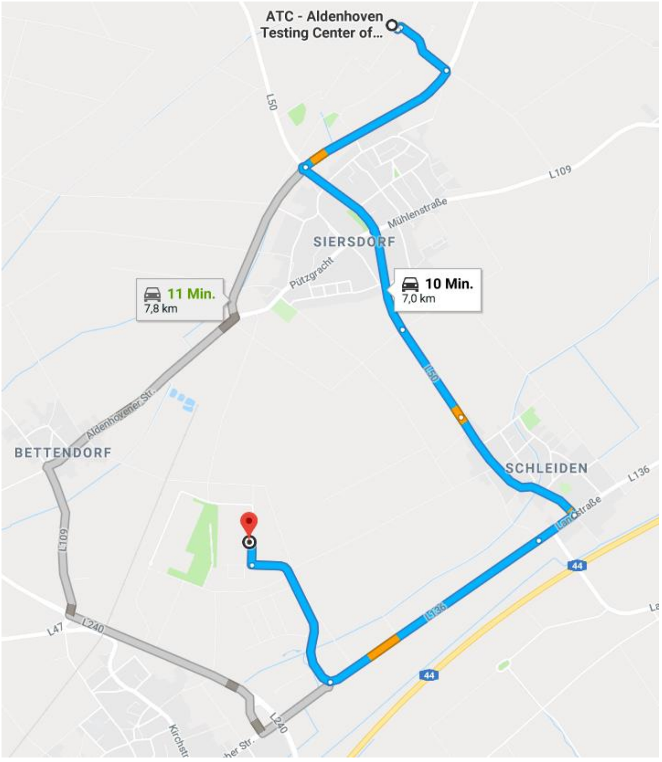

Figure A3.3: Test Route FEV-A ⇔ ATC

d. FEV-N (Neuenhofstr., 52078 Aachen, Germany) ⇔ A4 ⇔ A61 ⇔ A44 ⇔ FEV-N)

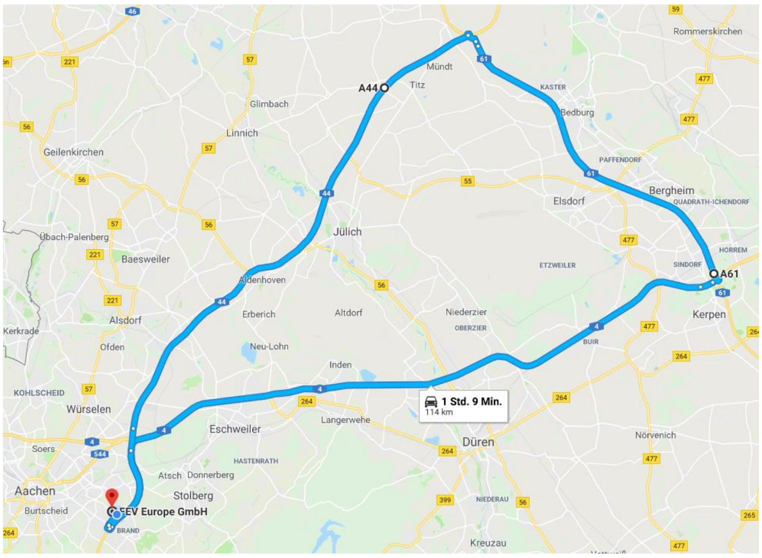

Figure A3.4: Test Route FEV-N ⇔ Motorway Triangle A44, A4, A61, A44

Annex 4 Summary and rating of the data logger evaluation

Table A4.2: Evaluation decision and rating matrix

Evaluation criteria	Assessment factor	b-plus with Aveto	b-plus with ViCANdo	b-plus with CANape	DEWEsoft	dSpace Autera	Intrepid	National Instruments	Logic bricks 3.2	TTTech	ViGEM
Bluetooth	3%	--	--	--	--	--	--	--	--	--	--
Cellular network	3%	+	+	+	--	+	--	+	+	--	--
V2X	6%	-	-	o	-	+	-	o	o	-	o
Configurability (e.g. resolution, compression) of camera interfaces	5%	+	++	++	o	+	o	+	+	++	++
Configuration of system	3%	+	+	+	++	+	+	+	+	+	+
Costs	5%	o	o	o	o	o	+	o	o	+	+
Dark current	3%	+	+	+	++	o	++	o	o	++	++
Data format	5%	--	++	++	+	-	++	+	++	++	++
Data storage size SSD/HDD	2%	++	++	++	++	++	+	++	++	+	o
Dimension	2%	o	o	o	+	o	++	o	o	++	+

Evaluation criteria	Assessment factor	b-plus with Aveto	b-plus with ViCANdo	b-plus with CANape	DEWEsoft	dSpace Autera	Intrepid	National Instruments	Logic bricks 3.2	TTTech	ViGEM
Integration time	2%	o	o	o	++	o	+	O	o	+	+
Log-data transfer possibilities	2%	++	++	++	++	++	-	++	+	-	+
Logging time capability / configurability	4%	++	++	++	++	++	+	++	+	+	+
No. of analogue inputs	5%	o	o	o	++	+	++	++	o	++	++
No. of CAN (-FD) interfaces	4%	++	++	++	o	++	++	++	++	++	++
No. of digital inputs	5%	+	+	+	++	+	++	++	o	++	++
No. of Ethernet interfaces	5%	++	++	++	o	++	o	++	++	+	++
No. of FlexRay interfaces	5%	++	++	++	o	++	++	++	+	++	++
No. of USB interfaces	5%	++	++	++	++	++	o	++	o	+	o
Power consumption	2%	o	o	o	o	o	++	o	o	++	+

Evaluation criteria	Assessment factor	b-plus with Aveto	b-plus with ViCANdo	b-plus with CANape	DEWEsoft	dSpace Autera	Intrepid	National Instruments	Logic bricks 3.2	TTTech	ViGEM
Remote control management	2%	+	++	+	++	+	o	+	o	o	++
Startup/Shutdown functionality	4%	o	o	+	++	+	++	+	+	++	++
Time for Log-data transfer	5%	++	++	++	++	++	-	++	+	-	+
Timestamping 10Hz	2%	o	++	++	++	+	o	++	+	o	++
User interaction	2%	o	+	++	++	+	+	o	+	+	+
Weight	5%	o	o	o	+	o	++	o	o	++	++
Wi-Fi	4%	++	++	++	+	+	--	++	+	+	--
Overall	100%	o	+	+	+	+	o	+	o	o	+

References

[1] https://www.b-plus.com/de/produkte/automotive/vehicle-data-harvesting/speicherloesungen/brick-storageplus [22.08.2022]

[2] https://www.b-plus.com/de/produkte/automotive/vehicle-data-harvesting/plattformen-fuer-datenaufzeichnung/brickplus [22.08.2022]

[3] https://www.b-plus.com/de/produkte/automotive/vehicle-data-harvesting/applikationssoftware/avetoapp-recorder [22.08.2022]

[4] https://www.b-plus.com/de/produkte/automotive/vehicle-data-harvesting/applikationssoftware/avetoapp-developer [22.08.2022]

[5] https://dewesoft.com/de/produkte/daq-systeme/sbox [18.08.2022]

[6] https://dewesoft.com/de/dewesoft-x-software [18.08.2022]

[7] https://www.dspace.com/de/gmb/home/products/hw/autera/interfaces.cfm [12.08.2022]

[8] https://www.dspace.com/de/gmb/home/products/sw/impsw/rtmaps.cfm [12.08.2022]

[9] https://intempora.com/products/rtmaps/ [12.08.2022]

[10] https://www.elektrobit.com/products/automated-driving/eb-assist/logger-solution/ [16.08.2022]

[11] https://www.elektrobit.com/products/automated-driving/eb-assist/logger-solution/ [16.08.2022]

[12] https://intrepidcs.com/products/autonomous-tools/rad-mars/ [19.08.2022]

[13] https://intrepidcs.com/products/vehicle-network-adapters/neovi-ion/ [19.08.2022]

[14] https://intrepidcs.com/products/software/vehicle-spy/ [19.08.2022]

[15] https://www.ipetronik.com/en/products-services/data-loggers/arcos-1-5-2.html [04.11.2022]

[16] https://www.ipetronik.com/en/products-services/data-loggers/ethos-2.html [04.11.2022]

[17] https://www.ipetronik.com/en/products-services/software-digitalization.html [04.11.2022]

[18] https://www.ni.com/docs/de-DE/bundle/data-record-system-ad/page/hardware-ref.html [24.08.2022]

[19] https://www.ni.com/de-de/solutions/transportation/adas-and-autonomous-driving-validation/adas-datalogger.html [24.08.2022]

[20] https://www.vboxautomotive.co.uk/index.php/en/applications/adas-safety [04.11.2022]

[21] https://www.vboxautomotive.co.uk/index.php/en/software-overvie [04.11.2022]

[22] https://www.tttech-auto.com/products/automotive-devices/testing-tools/pm-200-tttech-auto/ [01.09.2022]

[23] https://www.vector.com/int/en/products/products-a-z/hardware/vp6000-vp7000/ [04.11.2022]

[24] https://www.vector.com/us/en/products/products-a-z/software/canape/canape-option-driver-assistance/ [23.08.2022]

[25] https://vigem.de/de/content/produkte [26.08.2022]

[26] https://vigem.de/en/content/solutions#software [26.08.2022]

[27] https://xylon-lab.com/product/logirecorder/ [31.08.2022]

[28] https://xylon-lab.com/product/logirecorder-dashboard-2/ [31.08.2022]

[29] https://www.zuragon.com/vicando-suite#vicando [24.08.2022]

[30] Macke, D., Kottig, J., Christiaens, S. et al. Vernetzte Validierung von ADAS-Funktionen. ATZ Automobiltech Z 121, 36–41 (2019)

[31] https://datatracker.ietf.org/doc/id/draft-gharris-opsawg-pcap-00.html [25.10.2022]

[32] OmniAir – OmniAir – industry association promoting interoperability and certification in ITS, tolling, and connected vehicles.

[33] Ensuring C-V2X Product Compliance (globalcertificationforum.org)

[34] SEA 3610 V2X Sniffer Logger and Decoder – OmniAir

[35] L3Pilot Deliverable D1.7 Final Project Results. [Online] Available at: L3Pilot: Downloads [Accessed 15 12 2022].