UDRIVE

European Naturalistic Driving Study

DAS Technical Specification

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Written By	Xavier Augros (Volvo Group) Karsten Heinig (Volvo Group) Clément Val (CEESAR) Jonas Kurol (SAFER/ÅF) Johan Liden (SAFER/ÅF) Michael Palander (SAFER/ÅF)	03-05-2013
Checked by	Xavier Augros (Volvo Group)	12-08-2013
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1 Executive Summary

This document describes the technical requirements for the compelete data acquisition system (DAS) equipment used for EU project UDRIVE. The vision of this project, is to gather high quality driving environment and behavioral data. The DAS will be installed in diffent vehicles in Europe and the test period per vehicle will be about 20 months of data logging. All data from test vehicles will be stored in a central database. The test vehicles for the project are passenger cars, trucks and powered two wheelers (PTW).

The DAS equipment will record the test vehicles driving environment with interior and exterior cameras. It will also log CAN data, accelerometer sensor signal and GPS signals. Exterior cameras will focus on these areas: front view, including a smart camera able to analyse subject vehicle's environnement, rear view, sideviews and blindspots views. Interior cameras will focus on the driver, driver feet and driver face, and also collect information about cabin interior.

GSM network communication will be used by the data logger to send out status report and communicate with an internet based status web application.

2 Introduction

This report is part of SP2 (Data management), and integrated in WP2.1, in which the main goal is to derive technical requirements for data acquisition systems (DAS) from the research questions defined in SP1, survey the market for suitable systems and prepare the procedure for the purchase.
Based on the various experiences collected in the EuroFOT project by several UDRIVE partners, a few important decisions have already been made:

- One common data acquisition system (DAS) will be used for data collection. This common DAS will be tailored to the needs of the project, and allow for the necessary adaptations to fit to the different vehicle types (e. g. rugged sensors or cameras for PTW or similar.
- The collected data will initially be collected and pre-processed at three Local Data Centres (LDCs) and then delivered to the Central Data Centre (CDC). In addition, the LDCs are responsible for performing map matching (i.e., the addition of road and infrastructure attributes from digital maps).
- All videos and pre-processed data will be stored at a central data centre (CDC), so that all partners will have access to all collected data. The CDC will support data analysis, and, consequently, also store the results of processing, data annotation and analysis.
- To facilitate processing and analysis of the data, a common software toolset will be developed. This toolset will separate data management tasks from analysis tasks a hence will not impose requirements on data management on the analysts themselves. Instead, analysts can concentrate on developing and implementing algorithms, without having to deal with the low level architecture of the database and data storage.

This document describes the technical requirement for the compelete data acquisition system (DAS) equipment used within the project.

The document presents the technical specifications produced at the current state of the project. Every point can be discussed with the supplier under certain conditions fixed by project partners.

3 Context

UDRIVE is a large scale naturalistic driving observation, organised all over Europe as a collaborative project. Several hundreds of vehicles, including passenger cars, trucks and power two wheelers (PTW) will be instrumented in different operation sites. They will be driven by ordinary drivers, and the instrumented vehicles will be their own vehicles. Very rich data (including data from vehicle networks, several sensors and video cameras) will be recorded continuously and automatically while participating drivers are using their vehicles. Data will be collected on each operation site, then gathered in a central database which will be used to perform different kind of analysis on driving contexts and drivers' behaviour. These analysis will adress issues such as road safety and road transport's environmental impact.

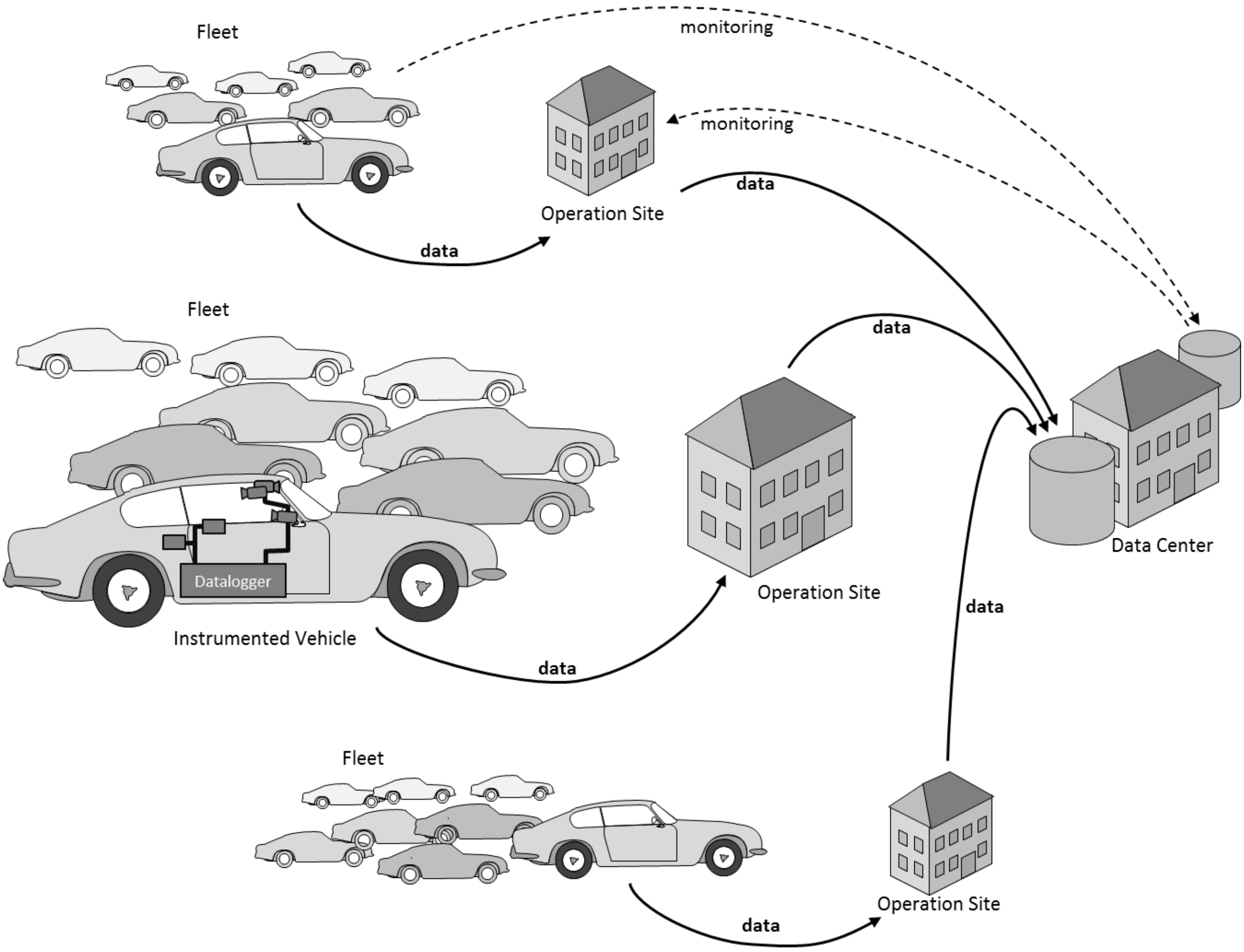

Figure 1: UDRIVE data collection scheme

Due to the large amount of data to be collected, it will be manually picked up at Operation Sites (harddrive exchange), and sent to a Data Center. Each vehicle will also be connected remotely to the data center, to allow continuous monitoring, through a web interface, of data logging and quality.
This document lists technical requirements for the Data Acquisition System (DAS) to be installed in the different vehicles, and the associated software. After selection of the DAS provider, and delivery of DAS prototypes, adaptation of DAS to each selected vehicle will be performed by project partners. This will lead to additionnal requirements (e.g. cable length) for the manufacturing of vehicle-specific DAS installation kits, which have to be made by the supplier.

4 System under consideration

The DAS will be used to collect information about driver behaviour and reactions in naturalistic driving scenarios, in passenger cars, trucks and powered two wheelers.

- Four to eight cameras will be used for recording video, both of the interior and of the exterior of the vehicle.
- Two CAN buses are estimated to be recorded in passenger cars and trucks. Some installations might require more CAN buses (maximum 4), and it is uncertain whether CAN is available on the selected powered two wheelers.
- All non-PTW vehicles will be equipped with a camera with object tracking functionality (computer vision).
- The operation of the DAS should be controlled by means of an editable configuration file and surveillance of the fleet by an online monitoring system.

The DAS will be installed in the best possible location in the vehicle (e. g. spare wheel compartment on passenger cars and luggage compartment on trucks) and cables will be routed to cameras, power supply, CAN bus connectors etc. For car and trucks, all equipment will be installed inside the vehicle including the GPS and mobile network antennas.

Cameras will be located differently depending on the type of vehicles they are going to be installed in. Installations will differ significantly between trucks, passenger cars and PTW.

Passenger cars will most likely have a cluster of cameras, mounted close to the rear view mirror, containing the front and cabin camera and probably the smart camera (see section “Sensors”). One additional interior view will show the drivers feet/ right foot. Another camera might be foreseen to record the drivers face, located either in the above mentioned camera cluster or in a separate location optimised for this view. An additional view will show the blind spot opposite the driver side, or potentially both sides. A rear view camera is considered.

Trucks will have a slightly different set up for cameras. Front camera and the smart camera will likely be integrated in a cluster to be mounted on the upper or lower middle of the windscreen. Left and right blind spot view are realised by one or two cameras mounted accordingly close to the A-pillars in the vehicles, facing outwards and backwards. A camera aiming at the drivers face will be located accordingly. The driver’s right foot will be recorded in the same way as in the passenger cars. A rear view camera is not considered to be feasible for trucks, as it requires work intensive cable routing from the cabin to the rear end of the chassis of the vehicle. Additionally, in the case of tractor units with semitrailers or rigid units with trailers, no useful recording could be provided.

PTWs will be most likely limited to a front camera, a face camera, two side view cameras and potentially rear view camera.

4.1 Overall requirments

4.1.1 Environmental constraints

4.1.1.1 Certification

The data logger **must** be European e-marked and CE-marked.

4.1.1.2 Hardware

The DAS needs to be compatible with as unobstrusive installation as possible, in a wide variety of vehicles (from PTW to trucks). The complete DAS **must** also provide reliable, automatic data collection, for years, in a wide variety of driving and climatic conditions.

- Temperature range: -20°C to 55°C
- Cable harness
    - All cables **must** have a protection cover.
    - Soldering **must not** be needed during installation.
    - Connectors **must** be automotive grade connector and not much larger than cable itself in order to ease the installation.
- Resistant to long duration vibrations in normal operational use and survive an impact up to 50G long enough to complete data logging.

4.1.1.3 EMC

All DAS equipment **must** be compliment with all aftermarket standard rules and fulfil the European Standard: Directive 2004/108/EC (http://ec.europa.eu/enterprise/policies/european-standards/harmonised-standards/electromagnetic-compatibility/index_en.htm)

4.1.2 Power management

- The DAS will be continuously connected to a raw, unfiltered power supply, and its operation will be driven by the vehicle's ignition key signal.
- The DAS **must** support being powered from both +12V (passenger cars, PTWs) and +24V (trucks) electrical systems, also during engine crank.
- The supplier **must** guarantee that the DAS will work properly when powered by the electrical system in a passenger car, a truck or a PTW.
- The DAS **must not** consume **any** current in off mode.
- The DAS, including external sensors, **must** correctly support any kind of ignition on/off cycles (including very quick successive changes) and engine stall, maintaining consistency between data from different sources in any scenario.
- User-definable ignition on/off delays **must** be available to fine tune the DAS behaviour in different situations:
    - The DAS starts booting after ignition is *on* since *on delay*
    - It properly terminates logging (see 4.2.3 below), then is shut down after ignition has been *off* since more than *off delay*.
- There **must** be a mechanism (e.g. watchdog) that guarantees that the DAS always is unconditionally shut down when ignition is turned off since a certain time. The watchdog timeout **should** be user definable. A typical value would be 10 minutes.

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- The DAS **must** shut down automatically if the vehicle battery voltage falls below a certain limit. The threshold level **must** be configurable in software or in the configuration file for the DAS.
- The supplier **must** ensure that DAS' power consumption does not affect the vehicle working. The following values are given as an indicatve basis:
    - No more than 5A at 12V for cars,
    - No more than 3A at 24V for trucks,
    - No more than 4A at 12V for PTWs.

4.2 Data logger specification

The main unit of the DAS is the data logger. This section is dedicated to its description.

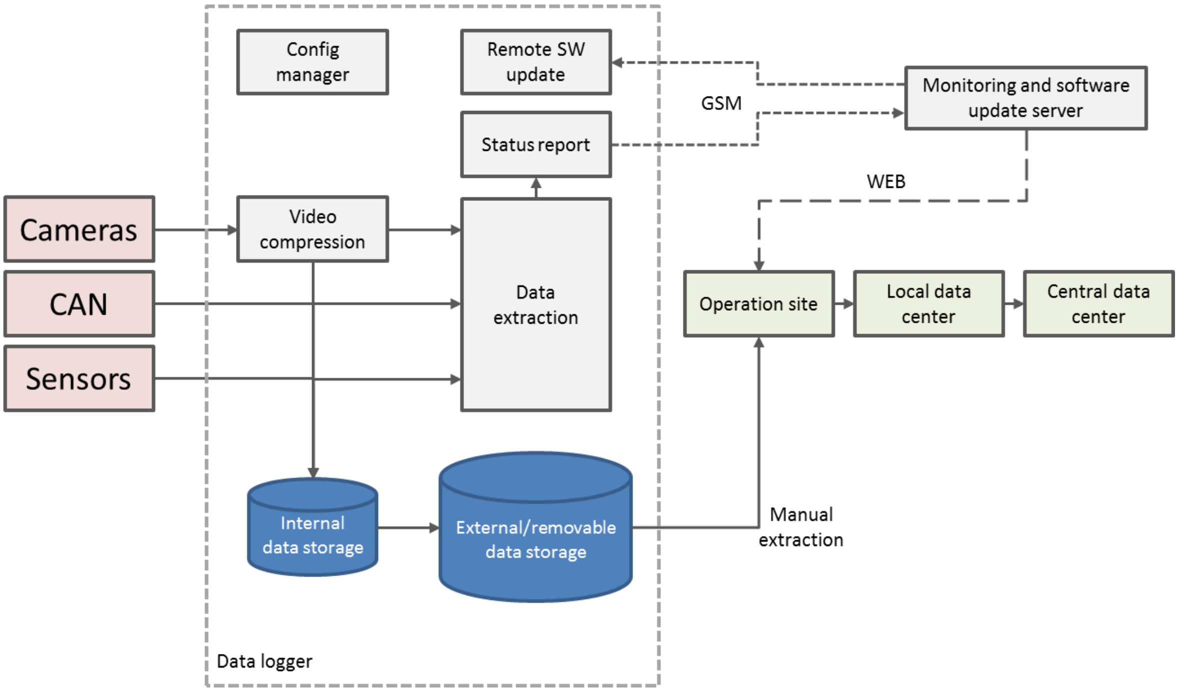

Figure 2: The figure above illustrate the DAS and its sub parts (this structure is open to discussion)

4.2.1 Hardware description

- Data logger **must** be included in a compartment depending on the kind of vehicle:
  - for cars, data logger will be placed either on the spare wheel compartment or in the trunk;
  - for trucks, data logger will be placed on the compartment in the top of the cab;
  - for PTWs, a top case to be set behind the driver and including data logger **must** be provided.
- Data logger **should** be the same for each vehicle
- Data logger **must not** exceed this size : 240 x 360 x 120 (mm)

4.2.2 Configuration and update management

The datalogger has different functionalities which are implemented in its firmware, and some of them are user-configurable.

- All configurable parameters **must** be gathered in a single configuration file.
- It **must** be possible to change the configuration file with a simple procedure when physical access to the datalogger is possible, or remotely using remote update service (see 4.2.5 below).
- It **must** also be possible to upgrade the firmware with a simple procedure when physical access to the datalogger is possible, or remotely using remote update service.

4.2.3 Logging

- The datalogger **must** continuously log data from CAN, Video, Digital Inputs (DI), GPS and sensors, such as 3-axis inertial unit and smart camera (see 4.3.2). External sensors may be interfaced using some CAN ports of the datalogger. Interfacing is done by the DAS supplier.
- The datalogger must be configurable to external sensors

- Logging of all data sources **must** start as soon as possible after datalogger is booted. Total boot time plus logging start-up **must** be less than a minute for CAN, Video, DI and sensors.
- Logging **must** be properly terminated before datalogger is shut down.
- Even in the case of very short power-on/power-off cycles (depending on ignition command, see above), proper logging cycles **must** be created and terminated. No data corruption or incoherence **should** result from any pattern in power-on/power-off cycles.
- In the event where the DAS is powered again (ignition is *on* again since *on delay*) while terminating a logging cycle, the logging cycle **must** be properly terminated, and a new cycle **must** start after that.

4.2.3.1 Logging dating

The several data sources connected to the datalogger, will provide two types of data: numerical data (coming from CAN or other inputs, and integrated sensors) and multichannel digital video.

- All data sources, including video, **must** be timestamped according to a common time base, starting at 0 at the beginning of each logging cycle.
- Dating of a data sample or of a video frame **must** correspond to the initial acquisition of the information by the datalogger hardware. It **must** not correspond to any later event (e.g. end of compression of video frame).
- There **must** be no resampling of any data.
- For each logging cycle, logging's start timestamp, corresponding to 0 in the logging time base **must** be stored as a UTC time coming from the datalogger's system clock.
- The datalogger's system clock **must** be precisely adjusted using the GPS time as soon as it is available.
- The supplier **should** provide information about the average latency and jitter for each signal source from datalogger's peripherals which are included in the DAS (e.g. : smart camera and inertial measurement unit)
- Synchronization inaccuracy between different numerical signal sources (CAN, DI, Sensors) **must** not be larger than 500µs.
- Synchronization inaccuracy of video data with numerical data and between video channels **must** not be larger than 25ms.

4.2.3.2 CAN logging

Four CAN buses **must** be available to collect and transmit CAN data

- Each CAN bus **must** be user-configurable:
  - Physical deactivation of CAN emission.
  - Bus speed.
  - Filters (ability to collect all CAN traffic, or filter per frame).
- The DAS is expected to be able to store all data from four CAN buses at the following estimated rates:
  - CAN 1: Busload 80% @ 500 kbit/sec.
  - CAN 2: Busload 80% @ 125 kbit/sec.
  - CAN 3: Busload 80% @ 500 kbit/sec.
  - CAN 4: Busload 80% @ 500 kbit/sec.
- The DAS **must** store the full content of selected frames, unaltered and undecoded, along to its timestamp on the logging cycle timebase.The DAS **should** have functionality to send out CAN frames or information, including routing frames from one bus to another. This functionality **should** allow the following behaviors:
  a. Unaltered, immediate transmission of a list of selected frames from one port to another.
  b. Immediate transmission of selected frames to another port, with different identifiers.
  c. Real-time use of acquired frames' content and transmission of user defined CAN frames, incorporating information from acquired frames.
  d. Transmission of user defined CAN frames either at reception of CAN frame on one port or on a regular, user-defined basis.
  e. It **must** be possible to use simple mathematic operators to combine different information in CAN frames to be emitted.

The suggested way of implementing these behaviors is to provide an API offering the following high-level functionalities, and allowing easy user-developpement of small real time applications manipulating CAN data while logging:

- Callback on arrival of selected CAN frame, with frame content as input.
- Callback on timer (generated at *t1* after boot, and continuously repeated after *t2*).
- Method for storing/updating data in global space.
- Method for reading data in global space.
- Method for emitting CAN frame.
- Method for reading status of logging (e.g. access to current time on the time-base).

Reliability of the CAN functionality is considered the most important aspect of the datalogger. As at least one CAN port will be connected to one of the vehicle's CAN network, any malfunction could have disastrous effect, for which the supplier would be liable.

4.2.3.3 Video logging

Depending on vehicle, the data logger **must** support four to eight miniature cameras. The requirements of the data logger are the following:

- The datalogger **must** be capable of acquiring and storing video data at a rate of 25 Hz or more.
- The datalogger **must** allow selecting different frame rates, resolution and compression/quality ratio for different video channels.

- It **must** be possible to record up to D1 resolution (720×480px) for each channel.
- The DAS **must** compress video data with state-of-the-art codecs, so that 8 channels of video at 360×240px resolution, monochrome, 25Hz fits within 1 GB per hour. Mpeg4 / h.264 encoding is recommended.

4.2.3.4 Digital inputs

- At least 4 Digitals Inputs **must** be installed.
- Each state changes **must** be recorded.

4.2.4 Storage and data pickup

- All data **must** be encrypted for security reasons with a standard and open encryption (e.g. PGP or AES).
- Storage devices health **must** be monitored by the datalogger. Using S.M.A.R.T is suggested.
- The datalogger **must** support two types of storage:
    - Internal, industrial grade storage, supporting very high level of vibrations and allowing collection of at least one hundred hours of driving. A 120 GB SSD drive is suggested.
    - External or removable storage of large capacity. A 1 TB mechanical hard drive is suggested.
- Accessing storage **must** require the use of a lock
- During a logging cycle, the data **must** be recorded on the internal storage. The internal storage will be the only support used to collect data on PTW.
- When the external or removable storage is present and in good health, the data which has been acquired on the internal storage **must** be transferred to this storage. An LED **must** indicate when data transfer is being done.
- Powering-off the DAS while some data is transferred **must not** lead to any data corruption. Transfer **must** resume when powering on again.
- Data which has been properly transferred from the internal to the external/removable storage **must** be deleted. A suggested way of performing the transfer is to rely on proven tools (e.g. rsync).

These requirements allow implementing the following use cases, which are necessary in the UDRIVE project:

1. On PTWs:
    a. Only the internal storage is used while driving.
    b. Data pickup consists of :
        i. adding the external/removable storage
        ii. powering on
        iii. waiting for transfer completion (including deletion of data from internal storage)
        iv. powering off
        v. removing of the external/removable storage
2. On trucks and passenger cars:
    a. The external/removable storage is continuously connected/inserted. This allows collecting large amount of data before data pick-up.
    b. Data pickup consists of replacing the external/removable storage by an empty one.

4.2.5 Diagnostic and remote update service and monitoring

It **must** be possible to monitor the DAS operation with a remote diagnostic system. Hence, the datalogger will be connected to a central server and will regularly send status reports, which will be used to assess the DAS health and plan corrective actions when they are necessary. This connection will also allow remote update of the datalogger's internal software.

- The data logger **must** communicate with a remote server via mobile communication (GSM).
- International roaming activation **must** be configurable.
- The datalogger **must** generate a report corresponding to each logging cycle (see 4.2.3 above), either at the end of the logging cycle, or at the beginning of the next logging cycle.
- This status report **must** contain the following information, for each logging cycle:
  - Trip info:
    - Trip id
    - Start/stop date
    - Foreach data source (on CAN : per channel, per frame) : number of lines of data. i.e. for CAN : number of collected frames per frame ID, for GPS : number of NMEA frames…
    - List of files corresponding to the Trip, including their size.
  - Phone card status (e.g. paycard balance, phone number).
  - Log of all the warning and errors raised during the cycle, including full Error Message and Timestamp. When the warning or error relate to a specific acquisition source (GPS, CAN, Video…), the corresponding source **must** be clearly specified.
  - Storage status: List of installed partitions with size, free space, health, max/min/average temperature.
  - Software Components Installed: List of file with version, config version
- This status report **should** also contain excerpt of data (static snapshots for selected cameras views) of configurable length and frequency (e.g. 1 minutes of logging while driving of each hour of logging).
- Available status reports **must** be transferred to server as soon as connectivity allows.
- The data logger **must** automatically check for new software or configuration file during start up. If there is, the new software will be downloaded and updated in data logger.
- It **must** also be possible to connect a screen and a keyboard to the data logger for use during installation or for support.

4.3 External units

The external units of the DAS are the camera modules, sensor modules and CAN interface module. All requirements are listed here.

4.3.1 Cameras

The set of cameras will consist of four to maximum eight cameras both exterior and interior to the vehicle. Cameras will be used to record videos and some may take snapshots. Due to price and data size constraints all cameras will be similar and have a minimun resolution of 420TVL. Black&White and Colour cameras will be used. In passenger cars and trucks, cameras will be installed inside the vehicle. For PTW the installation will be in a rear top case and on handlebar.

- Cameras for PTWs **must** be IP65.
- Except for PTWs cameras , the lenses **must** be modifiable in order to change the focal distance.
- No preference for technology (analog or firewire).
- Cameras **must** be unobstrusive inside cars and trucks.
- Cables jam **must** be avoided. The number of cables **must** be limited (e.g: the camera cluster, combination of several cameras, including video signal and power supply in a single, thin cable)
- Infrared lighting **must** be integrated with cameras filming interior, and use the same cable as corresponding cameras for power supply.
- There **should** be a switch to allow disabling cameras (by who? Installer, OS or driver?).
- Cameras **must** be switched on at each start-up by default.
- For installation and troubleshooting, it **must** be possible to get a live visualization of the camera's video signals.

4.3.2 Sensors

4.3.2.1 Smart cam

The smartcam is a device which is able to detect objects in front of subject vehicle (SV) by use of computer vision. This camera is required for cars and trucks and **should** be placed in the cameras cluster nearby the rear-looking mirror.

The output signal is CAN.

The smart camera **must** measure:

- Distance to each lane marking (right and left)
- Quality indicator per side of distance to lane marking
- Road curvature
- Time to lane crossing
- Cars, trucks and PTW dectection and differentiation
- Pedestrians and bicycles dectection and differentiation
- Object width
- Object position (in 2D), relative to instrumented vehicle
- Object speed relative to SV
- Object ID (allowing tracking an object from sample to sample)
- Can detect and read several kind of road signs - please list supported road signs
- Detection of road signs from all countries in continental Europe
- Current speed limit

4.3.2.2 Accelerometer/gyroscope

A 3-axis inertial unit (gyroscope and accelerometer) **must** be included in the DAS. A suggested solution is to use one of the CAN ports from the datalogger to connect a CAN enabled sensor. The range of sensitivity **must** cover all possible on-road use (e.g. <6g) and **must** not be optimized for crash sensing.

4.3.2.3 GPS

- Positioning of the vehicle **must** be measured, using at least GPS.
- A minimum frequency of 1Hz is required. 10Hz is desired.
- Full GPS frames (e.g. NMEA) **must** be logged, along with the logging Timestamp.
- Quality data from the GPS **must** be stored, i.e. GDOP as well as number of sattelites.
- The GPS and GSM antennas **must** be integrated in the same antenna, with magnetic support.

4.3.2.4 Speech detection for cars and trucks

Possibly, a speech detection function **should** be installed inside trucks and cars passengers compartment. The DAS **should** record and store a signal allowing identifying if someone is speaking inside the vehicle. No actual discussion **must** be recorded and stored for privacy reasons. For example just the sound envelope could be stored.

4.3.2.5 Additionnal for PTW

A sensor measuring the speed in an accurate and frequent way **must** be installed. This sensor **should** be based on counting of wheel revolution and able to resists to PTW mechanical constrains such as vibration, speed, etc.

4.4 Software

In addition to the hardware and internal firmware, the supplier **must** provide additional software, necessary to use and interact with the datalogger. This software is listed below.

4.4.1 Remote monitoring

- The base functionality of the server side, to collect status from hundreds of dataloggers and send firmware update to them, **must** be provided by the DAS supplier.
- Both source code and binaries **must** be provided by the supplier. The server platform which will be used is not determined yet, but will be communicated to the supplier as soon as possible.

4.4.2 Data decoding

- The supplier **must** provide software for unpacking, decryption of data files, and synchronization of different data sources. This **should** be delivered as a Windows DLL or similar (depending on the chosen platform) and provide the data and video in a directly usable format with appropriate time stamping.
- The resulting format will be a MATLAB file (.mat) with a specific structure, which will be specified early in the project.
- CAN signals **must** be decoded using a Vektor .dbc files.
- A mechanism to allow remote (on-site) decoding of data while keeping those .dbc files private **should** be developped.

4.4.3 Video visualization

- A software component allowing simultaneous visualization of all the collected videochannels **must** be provided.
- Synchronization of all channels, and synchronization with numerical data, **must** be taken care off, so that delays between visualization of video and signals is within the accepted tolerance (see 4.2.3.1 above).
- The software **must** be a Windows executable, with a COM interface to allow piloting playback and get current playback timestamp in a separate software.
- Seek and play performance have to be excellent (i.e. no perceivable delay when playing, pausing, searching for a specific position in the different channels).
- The COM interface/API will be fully specified at the beginning of the project. It will contain:
    - Methods to initialize the component (setting of logging path, setting of relative position and size of different channels…)
    - Methods to get information about the video (e.g. duration, number of valid channels…)
    - Methods to pilot the playback (e.g. play/pause, seek to position…) and get information about it (current position)
    - Events to trigger actions while playing video (e.g. an 'OnPlay' event to be triggered every specified interval while video is playing), in order to refresh the interface of the signal visualization software.

4.4.4 Video access

- A component allowing access as a bitmap image, to a single frame from a video corresponding to a data acquisition timestamp **must** be provided. This will allow developpment of computer vision algorithms in post-processing of the collected data.

4.5 Installation requirements for vehicles

4.5.1 Camera focus view installation for external driving environment

Cameras focus presented in this section can be modified during the project.

Passenger cars:

- **Camera view area A:** Forward looking camera. Three cameras for cover the whole 180º view sight. Smart functionallity camera.
- **Camera view area B:** Right wide view side looking camera.
- **Camera view area C:** Left wide view side looking camera.
- **Camera view area D:** Wide view rear camera.

Trucks:

- **Camera view area A:** Forward looking camera. Three cameras for cover the whole 180º view sight. Smart functionallity camera.
- **Camera view area B:** Right wide view side looking camera.
- **Camera view area C:** Left wide view side looking camera.
- **Camera view area D:** Not possible. For tractors the trailer will be in the way and for rigid the installation will be difficult to solve.

PTWs:

- **Camera view area A:** Forward looking camera. Three cameras for cover the whole 180º view sight. Smart functionallity camera.

- **Camera view area B:** Right wide view side looking camera. Installation side on top box.
- **Camera view area C:** Left wide view side looking camera. Installation side on top box.
- **Camera view area D:** Wide view rear camera. Installation rear on top box.

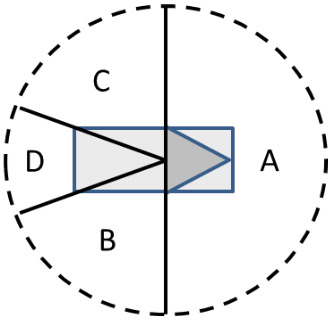

Figure 3: The figure above show external views of test vehicle

4.5.2 Camera focus view installation for interior driving environment

Focus for interior cameras installation views:

- Driver's hands and actions.
- Driver face.
- Driver feet.
- Wide view of interior driving environment.

5 List of abbreviations

3G: **3**:rd **G**eneration mobile communication
CAN: **C**ontroller **A**rea **N**etwork
DAS: **D**ata **A**cquisition **S**ystem
ECO: **ECO**nomy
FIFO: **F**irst **I**n **F**irst **O**ut
GPRS: **G**eneral **P**acket **R**adio **S**ervice
GPS: **G**lobal **P**ositioning **S**ystem
I/O: **I**n-**O**ut
ID: **ID**entyfication
LIN: **L**ocal **I**nterconnection **N**etwork
N/A: **N**ot **A**pplicable
PPS: **P**ulse **P**er **S**econd
POV : **P**rincipal **O**ther **V**ehicle
PTW : **P**owered **T**wo **W**heeler
RADAR: **RA**dio **D**etection **A**nd **R**angin
RAM: **R**andom **A**ccess **M**emory
SCE: **S**afety **C**ritical **E**vent
SUV: **SU**bject **V**ehicle
TBC: **T**o **B**e **C**onfirmed
TBD: **T**o **B**e **D**efined
TVL: **T**elevision **L**ines
UDRIVE: e**U**ropean naturalistic **D**riving and **R**iding for **I**nfrastructure and **V**ehicle safety and **E**nvironment

6 List of Figures