Development Platform for Safe and Efficient Drive

D5.2.1 Commercial Vehicle - Application definition design

Deliverable n.	D52.1 Commercial Vehicle - Application definition design		
Sub Project	SP5	Integration and Test	
Workpackage	WP5.2	Commercial Vehicle Applications	
Task n.	T5.2.1	Applications definition	
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File name	DESERVE_D521_ApplicationDefinitionDesign_v08.doc		
Status	Final		
Distribution	Public (PU)		
Issue date	20/10/2013	Creation date	13/05/2013
Project start and duration	1st of September, 2012 – 36 months		

ARTEMIS

REVISION AND HISTORY CHART

VER.	DATE	AUTHOR	REASON
0.1	13/05/2013	N. Pallaro (CRF)	Template
0.2	5/06/2013	E. Nordin (VOLVO)	Objectives
0.3	02/08/2013	V. Natterjee (VOLVO)	Details
0.4	12/10/2013	N. Pallaro (CRF)	Paragraph 1.4, 3.1, 3.2, 3.3 and 3.4
0.5	13/10/2013	E. Nordin (VOLVO)	Conclusions and executive summary. Section 1 and 2 update. Small adaption of section 3. Peer review version.
0.6	17/10/2013	M. Kunert (Bosch)	Bosch peer reviewof D52.1 v0.5
0.7	17/10/2013	Paul van Koningsbruggen (TECHNO)	Technolution peer review of D52.1 v0.5.
0.8	20/10/2013	E. Nordin (VOLVO)	Final version for submission.

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LIST OF ACRONYMS

ABBREVIATION	DESCRIPTION
AEB	Autonomous Emergency Braking
LDW	Lane Departure Warning
CWEB	Collision Warning and Emergency Braking
LCV	Light commercial vehicle
HCV	Heavy commercial vehicle
CC	Cruise Control
ACC	Adaptive Cruise Control
BLIS	Blind Spot Information System
TBD	To Be Defined
NAP	Not Applicable
SP	Sub Project
WP	Work Package
MIL	Model In the Loop
SIL	Software In the Loop
HIL	Hardware In the Loop

0. EXECUTIVE SUMMARY

The workpackage 52 "Commercial Vehicle Applications" of DESERVE project has two main objectives:

- Integration of DESERVE platform system and vehicle functions into commercial vehicle demonstrators, a heavy commercial vehicle from Volvo and a light commercial vehicle from CRF
- Laboratory and road testing to ensure the complete functionality of the platform and of the integrated functions before validation and verification.

In particular, more reliable software design and simulation (MIL, SIL , HIL) through the DEVERSE platform means less iterations needed from vehicle testing to code optimisation and so on, resulting in lower time and costs for the testing and validation phases.

The purpose of D52.1 deliverable (the first output of workpackage 5.2) is to define the ADAS applications that will be developed by the DESERVE partners and that will be integrated in the commercial vehicle demonstrators (Volvo, CRF).

From one side D52.1 contributes to impose the applicable requirements and constraints on the DESERVE platform characteristics and design, from the other the results of the analysis carried out in the requirement phase of DESERVE platform (D12.1 "Development Platform Requirements") allow for the definition of use cases.

D52.1 provides also the basic inputs to guide the development activities within other DESERVE subprojects, e.g:

- SP1 – Requirements and specification
- SP2 - ADAS Development Platform
- SP3 - Driver Behaviour / HMI
- SP4 - Test case functions

The present report defines in detail the reference applications, the target accident scenarios and the use cases that will be integrated in the demonstrators, giving a basis for later testing, validation and evaluation activities in DESERVE SP5 (Integration and test) and SP6 (Validation and evaluation).

In the course of the work in this WP52 further definitions, use cases and testing scenarios may be developed or modified. However, this deliverable, as already submitted, will not be updated accordingly, but these results will be documented in the final deliverable D52.2 Commercial vehicle functions integrated on prototypes.

1. INTRODUCTION

1.1 Objectives and scope of the document

This document is an outcome of workpackage 52 "Commercial Vehicle Applications". WP52 are dealing with initial application definition up to the integration and testing of the DESERVE platform and functions in the commercial vehicle demonstrators, a heavy commercial vehicle from Volvo and a light commercial vehicle from CRF.

The purpose of D52.1 deliverable is to define the ADAS applications that will be developed by the DESERVE partners and that will be integrated in the commercial vehicle demonstrators (Volvo, CRF).

From one side D52.1 contributes to impose the applicable requirements and constraints on the DESERVE platform characteristics and design, from the other the results of the analysis carried out in the requirement phase of DESERVE platform (D12.1 "Development Platform Requirements") allow for the definition of use cases.

D52.1 provides also the basic inputs to guide the development activities within other DESERVE subprojects, e.g:

- SP1 – Requirements and specification
- SP2 - ADAS Development Platform
- SP3 - Driver Behaviour / HMI
- SP4 - Test case functions

In the same way D51.1 (output of workpackage 51 "Passenger Car Applications") and D53.1 (output of workpackage 53 "Motorcycle Applications") define the applications to be integrated in the passenger cars (CRF, Daimler) and in the motorcycle (Ramboll) demonstrators. For this reason the same template has been used for all three reports, with some deviations from the template structure in D53.1 due to the specificity of the application.

1.2 Structure of the deliverable

In section 1 the document content and objectives are described. Also the template used for the application definition are described in section 1. In section 2 and 3 the commercial vehicle application in the Volvo and CRF commercial vehicle demonstrators and the vehicles themselves are defined, using the template described in section 1. The applications in the CRF demonstrator are described in section 3. Section 4 is dedicated for conclusions.

1.3 Application definition

The following driver assistance functions will be integrated and tested in DESERVE commercial vehicle demonstrators (see Table 1):

Table 1: Functions and commercial demonstrator vehicles in DESERVE.

Diver Assistant functions	Demonstrator vehicle	Responsible
ACC and CWEB	Heavy commercial vehicle	VOLVO

AEB pedestrian Driver Monitoring (Driver Drowsiness) Driver Intention	Light commercial vehicle	CRF

The draft application definition for these functions are documented using a template for a common application design for all demonstrators. The template used for the draft application definition is described in section 1.4.

The draft application definitions for the DESERVE commercial vehicle demonstrators from Volvo and CRF are then documented in subsequent sections, i.e. section 2 (Volvo) and section 3 (CRF).

1.4 Template definition

The template used for draft application definition consists of sections for reference application, accident scenario and use cases. The templates for these sections are described in Table 2, 3 and 4 below.

1.4.1 Reference application

The following template has been adopted to define the reference application; the description of each field is marked in grey.

Table 2: Reference application documentation template

ID: *The reference application is identified by the following nomenclature **aaa_bb**:* • *aaa=PCA (passenger car application), CVA (commercial vehicle application);* • *bb=acronym of driver assistance function.*	**Name:** *Name of the reference driver assistance function (acronym)*
Description of safety / comfort function: *Description of the addressed function*	
Driving Environment: *Definition of driving environment (urban, interurban, …)*	
Sensing / communication technologies: *List of the main sensors and communications technologies that can be used to implement the function*	
Demonstrator vehicle: *Selected vehicle model*	
Source: *Responsible of demonstrator vehicle*	

1.4.2 Target Scenario

The following template was adopted to define the target scenarios; the description of each field is marked in grey.

Table 3: Target scenario documentation template

Target scenario ID	*The target accident scenarios are identified by the following nomenclature* ***TAS_CVX_yy*** • *TAS = target accident scenario; TS = target scenario;* • *CVX=CV (Commercial vehicle), CVX=CVC (Commercial vehicle-to-Car), CVX=CVP (Commercial vehicle-to-Pedestrian);* • *yy= progressive number.*
Target scenario name	*Name of the target accident scenario*
Accident type	*Type of accident*
Description	*The narrative describes the flow of events at a detailed level, including the hypothesised causal mechanisms behind the crash taking into account driver-, vehicle- as well as environmental factors. When applicable, it may also contain approximate or boundary values on kinematic parameters such as speed, headway and time-to-collision. As the number of factors and parameters (e.g. road conditions, speed ranges, driver states etc.) that can be included is wide, the main rule is to only include the information that is relevant for explaining the causal mechanisms behind the accident.*
Sketch	*This refers to a pictorial representation that further illustrates the flow of events defined in the narrative in terms of vehicles' paths and kinematics.*
Sequence diagram	*The sequence diagram describes the sequence of events and key interactions between different actors (e.g. drivers, vehicles or road infrastructure elements) in a scenario over time.*
Source	*Partner who has defined/suggested the accident scenario*

1.4.3 Use Cases

The following template was adopted to define the Use Cases; the description of each field is marked in grey.

Table 4: Use cases documentation template

Function	*Name of the reference driver assistance function (acronym)*
Demonstrator	Passenger car *(responsible)*
Reference scenario ID	*ID of the reference accident scenario*
ACCIDENT SCENARIO* description	

Scenario pictogram	*This refers to a pictorial representation that further illustrates the flow of events defined in the narrative in terms of vehicles' paths and kinematics.*	
Background attributes	**Area type**	*Urban, interurban, …*
	Road segment	*Intersection, merge, split, roundabout, …*
	Environmental conditions	*Lighting, weather*
	Speed range	*Speed*
Participant 1 attributes	**Type of participant**	*Participants description (how many, who, characteristics, etc.)*
	Start of position	*Position at the beginning*
	Manoeuvre	*Kind of manoeuvre*
Participant 2 attributes	**Type of participant**	*Participants description (how many, who, characteristics, etc.)*
	Start of position	*Position at the beginning*
	Manoeuvre	*Kind of manoeuvre*
USE CASE description		
Use case ID	*The use cases are identified by the following nomenclature* ***UCx_TAS_CX_yy*** • *UC = use cases;* • *x=progressive number;* • *TAS=target accident scenario; TS = target scenario;* • *CVX=C (Commercial vehicle), CVX=CVC (Commercial vehicle-to-Car), CVX=CP (Commercial vehicle-to-Pedestrian);* *yy= progressive number.*	
Use case name	*Name of the use case*	
Functional description	*Functional description of driver assistance function.*	
Event 1 (main flow)	*Story description: participants, manoeuvre, safety system behaviour, system-driver interaction, driver reaction.*	
Event 2	*Story description: participants, manoeuvre, safety system behaviour, system-driver interaction, driver reaction.*	
Sensing attributes	**Type of sensor**	*Lidar, radar, camera, ….*
	Detection range	*Detection range*
	Field of view	*Field of view*
Communication attributes	**Technology**	*Technology*
Function attributes	**Actions**	*Actions (warning, mitigation, avoidance,…)*
	HMI	*Selected HMI for the addressed function*

2. COMMERCIAL VEHICLE APPLICATION – VOLVO

2.1 Reference application

ID: CVA_ACC	**Name: Adaptive Cruise Control (ACC)**

Description of safety / comfort function:

The main system function of Adaptive Cruise Control is to control vehicle speed adaptively to a forward vehicle by using information about: (1) ranging to forward vehicles, (2) the motion of the subject (ACC equipped) vehicle and (3) driver commands. Based upon the information acquired, the controller (identified as "ACC control strategy" in figure 2.1) sends commands to actuators for executing its longitudinal control strategy and it also sends status information to the driver.

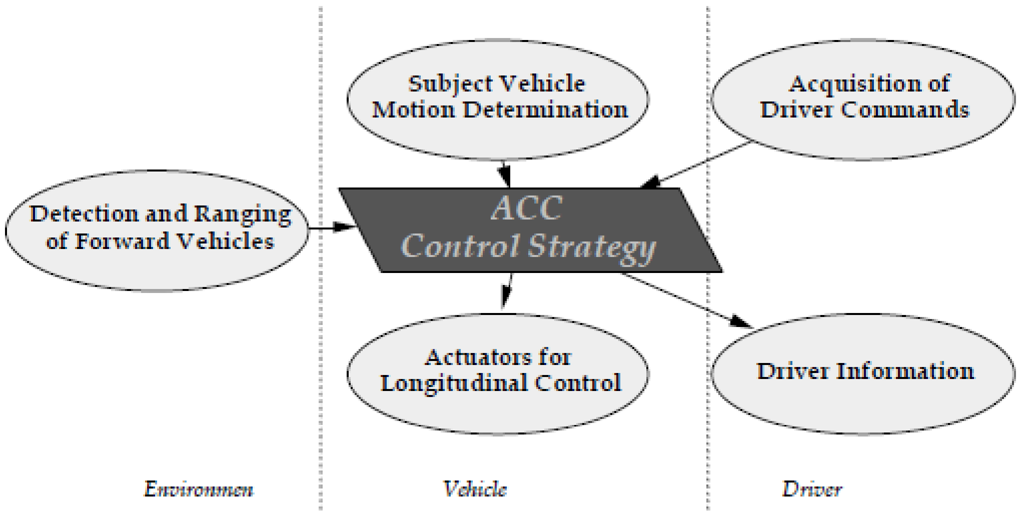


Figure 1: Functional ACC elements

The goal of ACC is a partial automation of the longitudinal vehicle control and the reduction of the workload for the driver with the aim to support and relieve the driver in a convenient manner.

Driving Environment: Highway roads (roads where non-motorized vehicles and pedestrians are prohibited) under free-flowing traffic conditions

Sensing / communication technologies:

Detection of target vehicle that are ahead on the road can be performed with some of the following standard sensor technologies or combinations:

- Specific Detection Sensor
- Ranging sensor concepts
- Higher level Functionality

Demonstrator vehicle: Volvo Heavy Commercial Vehicle

Source: VOLVO

ID: CVA_CWEB	**Name: Collision Warning & Emergency braking (CWEB)**

Description of safety / comfort function:

The main system function of a CWEB function is to warn the driver when the ego vehicle encounters the situation when a forward vehicle in the subject's trajectory becomes a potential hazard. This is done by using information about: (1) the range to forward vehicles, (2) the time to a potential collision, (3) the grade of warning provided to the driver. When sensors detect a potential collision it doesn't take immediate action to avoid it. Once the sensing system has detected that the collision has become inevitable regardless of braking or steering actions then emergency braking is automatically applied to avoid collision.

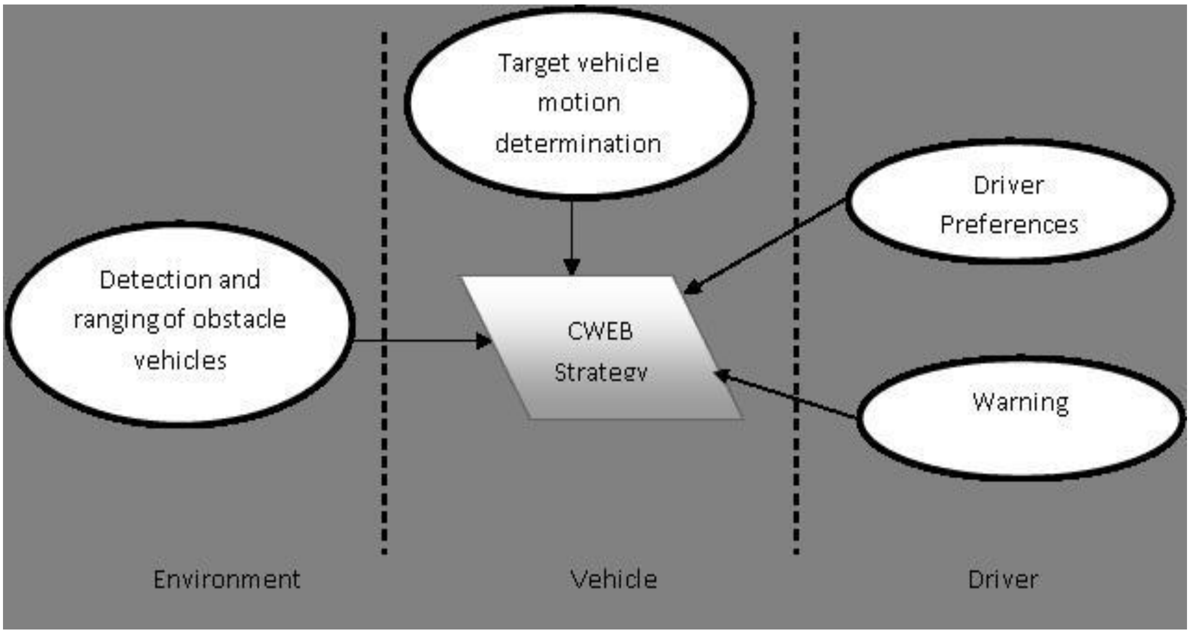


Figure 2: Functional CWEB elements

Driving Environment: Highway roads (roads where non-motorized vehicles and pedestrians are prohibited) under free-flowing traffic conditions

Sensing / communication technologies:

Detection of target vehicle that lie ahead on the road can be performed with some of the following standard sensor technologies or combinations:

- Specific Detection Sensor
- Ranging sensor concepts
- Higher level Functionality

Demonstrator vehicle: Volvo Heavy Commercial Vehicle

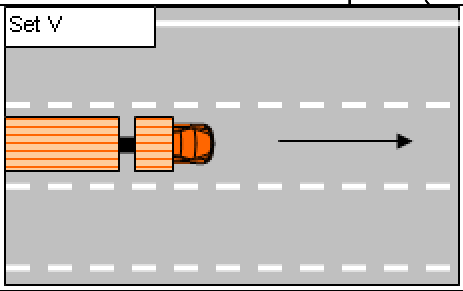
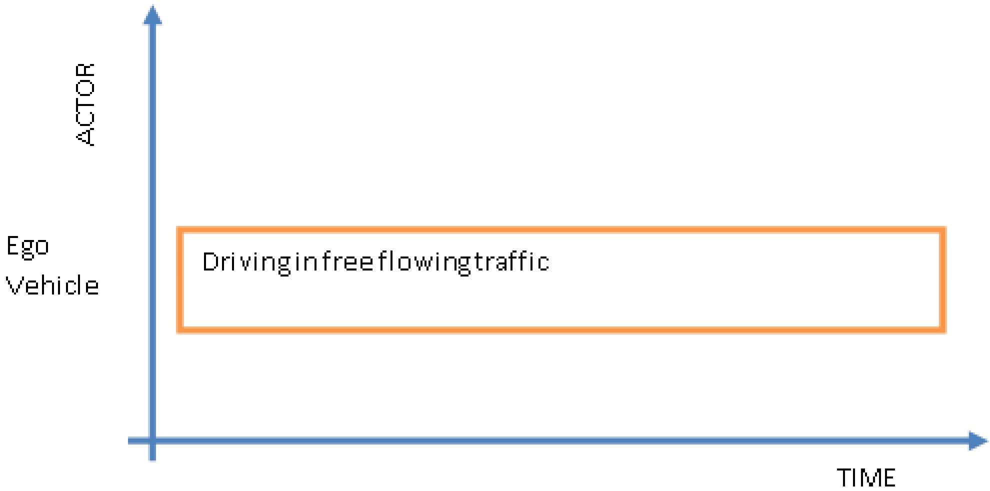
Source: VOLVO

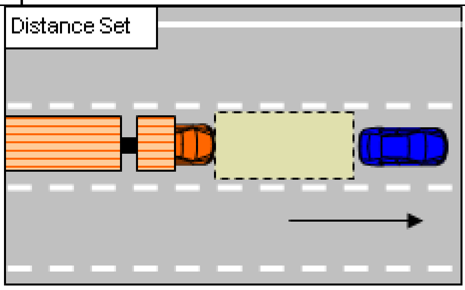
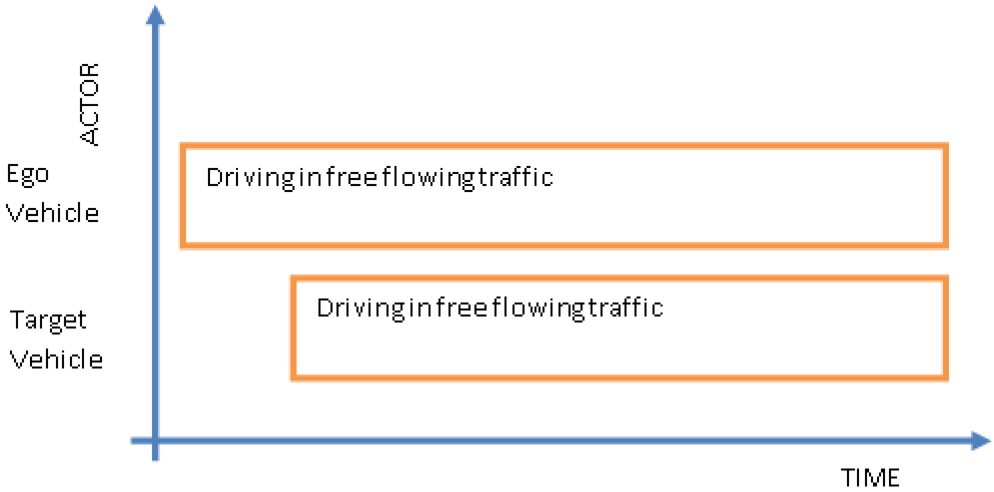
2.2 Target scenario

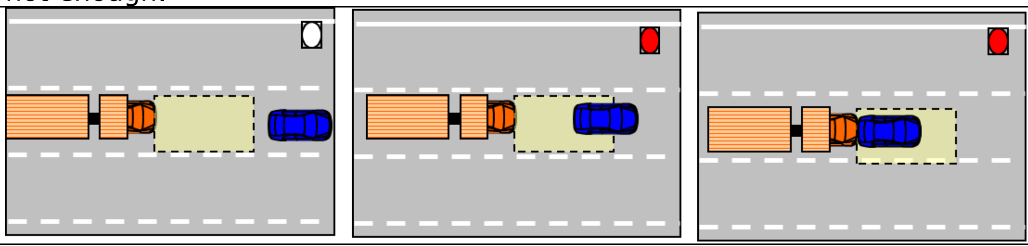
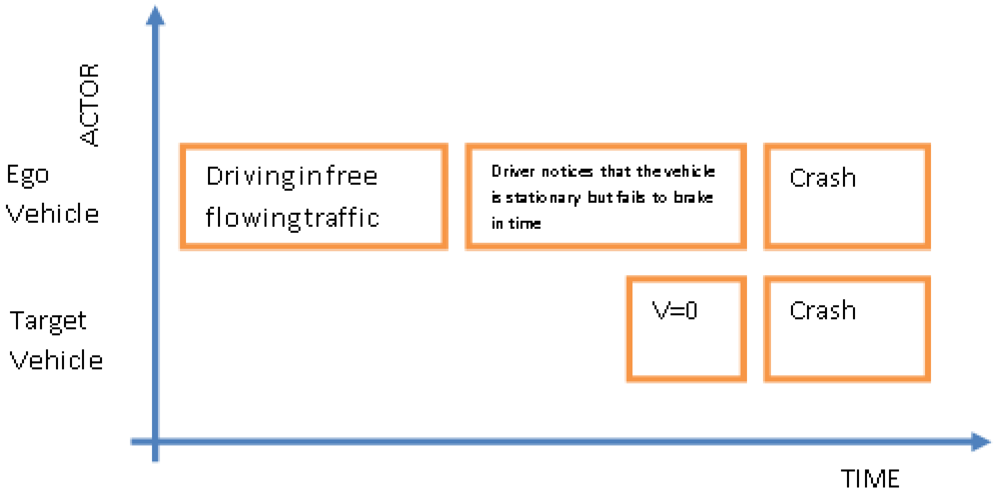
Target scenario definition consists of a precise formulation of the problem situation to be addressed by the applications to be developed. The targeted scenarios for the Volvo commercial vehicle demonstrator are described in Table 5.

Table 5: Target scenarios for Volvo Heavy Commercial Vehicle

Accident type	Function	Target scenario	Type of vehicle
NAP	ACC	TS_CV_1: Speed control	Heavy Commercial Vehicle
		TS_CVC_2: Gap control	
CV-to-C: Rear-end collision	CWEB	TAS_CVC_3: Rear-End Collision Avoidance	Heavy Commercial Vehicle

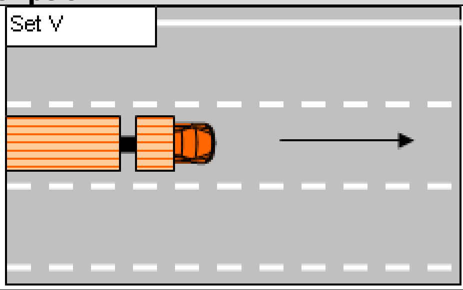
Target scenario ID	TS_CV_1
Target scenario name	Speed Control
Accident type	*NAP*
Description	While the vehicle is in free flowing traffic the speed of the vehicle is controlled to be at a set speed (Driver sets the speed).
Sketch	
Sequence diagram	
Source	VOLVO

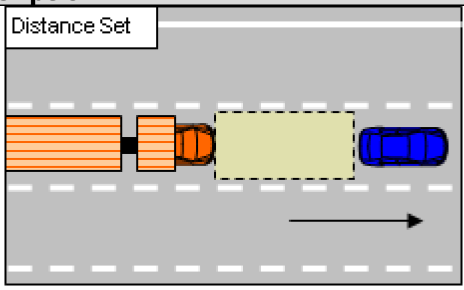
Target scenario ID	TS_CVC_2
Target scenario name	Gap Control
Accident type	*NAP*
Description	While the ego vehicle is in free flowing traffic a safe distance between the ego vehicle and the vehicle directly in front is maintained by controlling the speed of the vehicle to the forward vehicle for a constant time-gap.
Sketch	
Sequence diagram	
Source	VOLVO

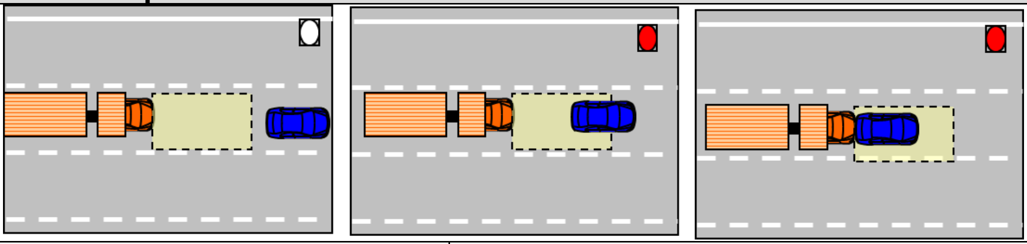
Target scenario ID	TAS_CVC_3
Target scenario name	Collision avoidance
Accident type	Rear-end collision
Description	While the ego vehicle is in free flowing traffic a safe distance between the ego vehicle and the vehicle directly in front is maintained by controlling the speed of the vehicle to the forward vehicle for a constant time-gap. While this ego vehicle approaches a stationary/slow driving vehicle a collision warning and eventually an emergency braking is applied in case the driver doesn't react himself or if the driver's steering and braking efforts are not enough.
Sketch	
Sequence diagram	
Source	VOLVO

2.3 Use cases

Use case definition consists of a description of how an application is intended to interact with the driver in a particular target accident scenario in order to prevent the accident. The targeted use cases for the Volvo commercial vehicle demonstrator are described below.

Function	ACC	
Demonstrator	Volvo Heavy Commercial Vehicle	
Reference scenario ID	TS_CV_1	
ACCIDENT SCENARIO description		
Scenario pictogram		
Background attributes	**Area type**	Highway
	Road segment	Straight Road
	Environmental conditions	Sunny Good Weather
	Speed range	
Participant 1 attributes	**Type of participant**	Commercial Vehicle (Ego Vehicle)
	Start of position	Free-flowing traffic in highways
	Manoeuvre	Straight, no overtaking, Driver controls steering
Participant 2 attributes	**Type of participant**	NAP
	Start of position	NAP
	Manoeuvre	NAP
USE CASE description		
Use case ID	UC1_TS_CV_1	
Use case name	Cruise control following set speed	
Functional description	While the vehicle is in free flowing traffic the speed of the vehicle is controlled to be at a set speed (Driver sets the speed).	
Event 1 (main flow)	The ego vehicle is in free flowing traffic while the speed of the vehicle is set to 70 kph and the CC system maintains the speed of the vehicle at the set speed	
Event 2		
Sensing attributes	**Type of sensor**	RADAR, CAMERA
	Detection range	TBD
	Field of view	TBD
Communication attributes	**Technology**	NAP
Function attributes	**Actions**	Vehicle motion control
	HMI	Display of the speed set

<table>
<tr><td>Function</td><td colspan="2">ACC</td></tr>
<tr><td>Demonstrator</td><td colspan="2">Volvo Heavy Commercial Vehicle</td></tr>
<tr><td>Reference scenario ID</td><td colspan="2">TS_CVC_2</td></tr>
<tr><td colspan="3">ACCIDENT SCENARIO description</td></tr>
<tr><td>Scenario pictogram</td><td colspan="2">
</td></tr>
<tr><td rowspan="4">Background attributes</td><td>Area type</td><td>Highway</td></tr>
<tr><td>Road segment</td><td>Straight Road</td></tr>
<tr><td>Environmental conditions</td><td>Sunny
Good Weather</td></tr>
<tr><td>Speed range</td><td></td></tr>
<tr><td rowspan="3">Participant 1 attributes</td><td>Type of participant</td><td>Commercial Vehicle (Ego Vehicle)</td></tr>
<tr><td>Start of position</td><td>Free-flowing traffic in highways</td></tr>
<tr><td>Manoeuvre</td><td>Driving Straight, no overtaking, Driver controls steering</td></tr>
<tr><td rowspan="3">Participant 2 attributes</td><td>Type of participant</td><td>Passenger car</td></tr>
<tr><td>Start of position</td><td>In front of the ego vehicle</td></tr>
<tr><td>Manoeuvre</td><td>Driving straight</td></tr>
<tr><td colspan="3">USE CASE description</td></tr>
<tr><td>Use case ID</td><td colspan="2">UC2_TS_CVC_2</td></tr>
<tr><td>Use case name</td><td colspan="2">Adaptive cruise control following gap control</td></tr>
<tr><td>Functional description</td><td colspan="2">While the ego vehicle is in free flowing traffic a safe distance between the ego vehicle and the vehicle directly in front is maintained by controlling the speed of the vehicle to the forward vehicle for a constant time-gap.</td></tr>
<tr><td>Event 1 (main flow)</td><td colspan="2">The ego vehicle is in free flowing traffic while the speed of the vehicle is set to 70kph and the ACC system maintains the speed of the vehicle by maintaining a constant time-gap to the vehicle in front based on a safe distance.</td></tr>
<tr><td>Event 2</td><td colspan="2"></td></tr>
<tr><td rowspan="3">Sensing attributes</td><td>Type of sensor</td><td>RADAR, CAMERA</td></tr>
<tr><td>Detection range</td><td>TBD</td></tr>
<tr><td>Field of view</td><td>TBD</td></tr>
<tr><td>Communication attributes</td><td>Technology</td><td>NAP</td></tr>
<tr><td rowspan="2">Function attributes</td><td>Actions</td><td>Vehicle motion control</td></tr>
<tr><td>HMI</td><td>Display of the speed set</td></tr>
</table>

Function	ACC with CWEB	
Demonstrator	Volvo Heavy Commercial Vehicle	
Reference scenario ID	TAS_CVC_3	
ACCIDENT SCENARIO description		
Scenario pictogram		
Background attributes	**Area type**	Highway
	Road segment	Straight Road
	Environmental conditions	Sunny Good Weather
	Speed range	
Participant 1 attributes	**Type of participant**	Commercial Vehicle (Ego Vehicle)
	Start of position	Free-flowing traffic in highways
	Manoeuvre	Driving Straight, no overtaking, Driver controls steering
Participant 2 attributes	**Type of participant**	Passenger car
	Start of position	In front of the ego vehicle
	Manoeuvre	Driving straight, moderate deceleration (-1m/s) until complete stop
USE CASE description		
Use case ID	UC3_ TAS_CVC_3	
Use case name	Emergency braking due to slow/stationary vehicle ahead.	
Functional description	While the ego vehicle is in free flowing traffic a safe distance between the ego vehicle and the vehicle directly in front is maintained by controlling the speed of the vehicle to the forward vehicle for a constant time-gap. While this ego vehicle approaches a stationary/slow driving vehicle a collision warning and eventually an emergency braking is applied in case the driver react himself or if the driver's steering and braking efforts are not enough.	
Event 1 (main flow)	The ego vehicle is in free flowing traffic while the speed of the vehicle is set to 70kph and the ACC system maintains the speed of the vehicle by maintaining a constant time-gap to the vehicle in front based on a safe distance.	
Event 2	The target vehicle starts decelerating at 1m/s until it reaches a complete stop. The ACC-CWEB system realizes the change in situation and gives a collision warning and it automatically assists in emergency braking if an impact is imminent.	
Sensing attributes	**Type of sensor**	RADAR, CAMERA
	Detection range	TBD
	Field of view	TBD
Communication attributes	**Technology**	NAP
Function attributes	**Actions**	Warning and vehicle motion control
	HMI	Display of the speed set, Collision Warning.

2.4 Platform modules

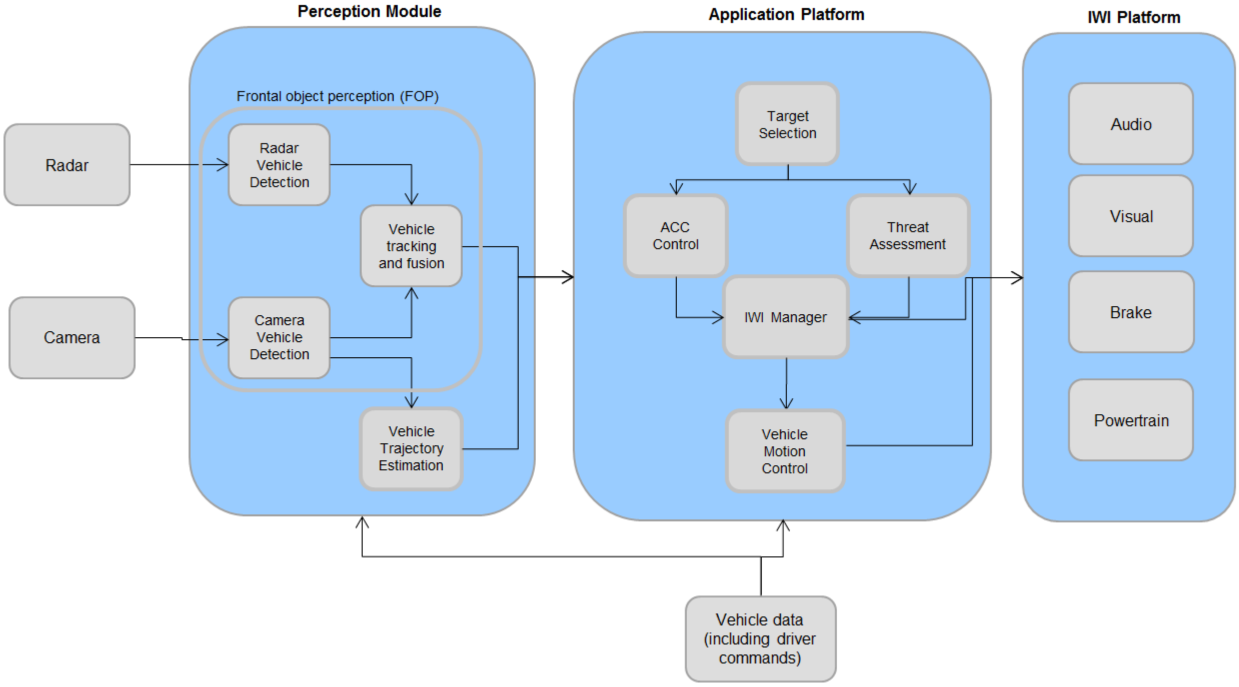


Figure 3: Functional block diagram for Volvo target applications

The functional block diagram, shown in Figure 3, describes the main modules of the software architecture implementing the following functions on the Volvo HCV demonstrator:

- Adaptive cruise control
- Collision Warning and Emergency Braking

The Perception Platform is composed of the following submodules:

- Frontal Object Perception; The objective of the module is to detect every relevant obstacle in the front area of the ego vehicle including stationary and moving objects and provide information about these objects (e.g. detection confidence value, ID, position, static/moving flag, moving direction, velocity, acceleration and estimated object size). Sensor data fusion and advanced filtering techniques should be taken into account in order to obtain a more reliable perception result and provide additional information not directly observed from sensor. The sensors connected to this module is a long range radar and front looking cameras.
- Vehicle Trajectory Estimation; This module deals with the forecast of the trajectory currently followed by the driver in terms of future ego-vehicle positions and speed profile.

The Application Module is composed of the following submodules:

- Target Selection; Determine which vehicle is the most relevant target vehicle (based on the data received from the Perception Platform) related to the current and predicted driving situation for the addressed safety function. The relevance of the target is dependent on its trajectory in comparison to that of the egovehicle.

- ACC Control: This module is a cruise control system with enhanced functionality that helps the driver to keep a safe distance to other traffic ahead and alerts the driver if manual intervention is required.
- Threat Assessment: Assess and classify the longitudinal and lateral risks associated to the current situation. As a result it provides specific measures like TTC (time-to-collision) and TLC (time-to-lane-crossing). It also calculates the threat for a new alternative trajectory.

IWI Manager: This module is based on Information, Warning and Intervention manager. The Information Manager deals with the information to be provided to the driver. The Warning Manager analyses the results of the Threat Assessment and the Driving Strategy modules and makes the final decision about when to issue a warning and when to suppress warnings. The Intervention Manager analyses the results of the Threat Assessment and the driving strategy modules and makes the final decision about when to issue an intervention and when to suppress interventions.

- Vehicle Motion Control; This component determines in case of an intervention or in automatic mode the desired longitudinal acceleration and steering wheel torques requests based on the results of the components trajectory planning and control. If a braking action is needed it controls the correct amount of braking to ensure that the vehicle is braked safe, i.e. avoids a collision as well as maintaining the stability of the complete vehicle during braking.

The IWI Platform consists of modules for Information, Warning and Intervention e.g. audio, visual, brake and powertrain in the Volvo Heavy Commercial Vehicle.

3. COMMERCIAL VEHICLE APPLICATION – CRF

3.1 Reference application

ID: CVA_AEBint	**Name:** Autonomous Emergency Braking Interurban (AEBint)

Description of safety / comfort function:

Many accidents are caused by late braking and/or braking with insufficient brake pedal force. A driver may brake too late for several reasons: he is distracted or inattentive; visibility is poor, for instance when driving towards a low sun; or a situation may be very difficult to predict because the driver ahead is braking unexpectedly. Most people are not used to dealing with such critical situations and do not apply enough braking force to avoid a crash.

The first step towards more safety is therefore to support the driver to avoid these kinds of accidents or, at least, to reduce their severity. The key functionalities of AEB systems are summarized in the same safety name:

- the system acts independently of the driver to avoid or mitigate the accident (**autonomous**);
- the system will intervene only in a critical situation (**emergency**);
- the system tries to avoid the accident by applying the brakes (**braking**).

AEB systems improve safety in two ways: firstly, they help to avoid accidents by identifying critical situations early and warning the driver; and secondly they reduce the severity of crashes which cannot be avoided by lowering the speed of collision and, in some cases, by preparing the vehicle and restraint systems for impact.

If a potential collision is detected, AEB systems generally (though not exclusively) first try to avoid the impact by warning the driver that action is needed. If no action is taken and a collision is still expected, the system will then apply the brakes. Some systems apply full braking force, others an elevated level. Either way, the intention is to reduce the speed with which the collision takes place. Some systems deactivate as soon as they detect avoidance action being taken by the driver.

Figure 4: AEB Interurban, slower lead vehicle

Driving Environment: interurban, motorways

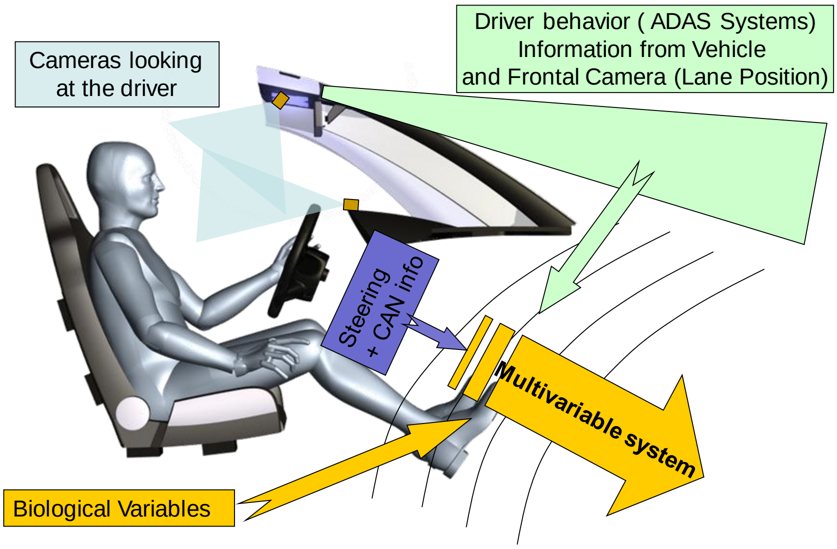
Sensing and communication technologies:
Frontal obstacle detection can be performed with some of the following forward looking sensor technologies or combinations:

- Long range radar
- Long range radar + mono-camera (sensor fusion)
- Long range radar + stereo-camera (sensor fusion)

Vehicle data (travel speed and trajectory)

Demonstrator vehicle: CRF Light Commercial Vehicle

Source: CRF

ID: CVA_DM_DDr	**Name:** Driver Monitoring: Driver Drowsiness (DM_DDr)
Description of safety / comfort function: Driver's limitations are very often related to his physiological and psychological states. Several factors negatively influence the optimum pilot state: ▪ driver's alertness can be reduced due to a lower vigilance, fatigue or sleepiness; ▪ driver's task-oriented attentiveness can be reduced due to distraction produced by internal or external attractors or executing additional non driving tasks. Safety enhancement is pursued supporting the driver to avoid or to reduce the decay of his state. A **drowsiness detection system** warns drivers to prevent them falling asleep momentarily whilst driving by e.g. visual (messages, telltales …), acoustic (voice) or haptic feedback. The system will prompt the driver to take an action (steering or braking) before it is too late.  **Figure 5: Driver status monitoring concept**	
Driving Environment: interurban, motorways	
Sensing and communication technologies: Interior camera (observation of the driver face for eye gaze, head pose, eyelid motion) Interior camera (observation of the driver thorax for respiratory signal) Bioimpedance grid sensors (sets of conductive textiles located on the steering wheel and seat for respiratory signal) Vehicle data (speed...) and vehicle lane position (LDW)	
Demonstrator vehicle: CRF Light Commercial Vehicle	
Source: FICOSA, CONTI	

ID: CVA_DI_OLC	**Name:** Driver Intention: Overtaking / Lane Changes (DI_OLC)

Description of safety / comfort function:

ADAS systems, during normal driving, might be perceived as annoying by the drivers. The LDW warns when the left or right lane is overtaken if the blinker is not used: however, blinkers are used only half the time before a lane change and, therefore, the LDW might warn the driver in situations in which he/she is in full control of the vehicle (for example, during an overtaking without blinker activated), causing a nuisance to the driver. On the other hand, the BLIS warns the driver with a blinking light when a vehicle is passing in the blind spot. However, the warning is received either the driver is keeping the lane, either the driver is planning to overtake.

Further step towards higher safety and driver's acceptance of ADAS systems is therefore to predict the driver's intention in a suitable way.

A Driver Intention Detection System aims at warning the driver only when needed and at improving the safety function performance. A **Driver Intention for Overtaking / Lane change** manoeuvres can support many safety functions making more prompt and reliable the warning to the driver depending on the driver's intention. For instance in case of the AEB Interurban traffic scenario shown in Figure 6 the relative speed is high and the driver start a lane change manoeuvre a little bit in delay but the Driver Intention makes more robust the warning strategies and it avoids that the AEB intervenes warning the driver to take braking action during the lane change / overtaking manoeuvre.

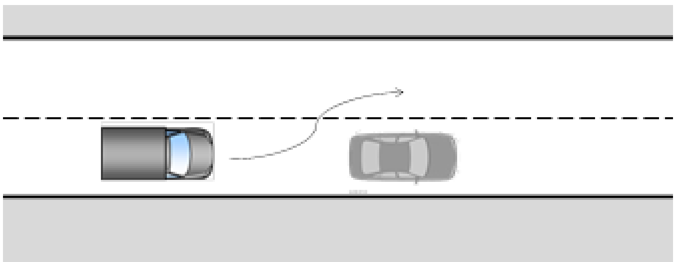


Figure 6: Overtaking manoeuvres in AEB Interurban scenario

Driving Environment: interurban, motorways

Sensing and communication technologies:

Camera (vehicle lane position)

Interior camera (observation of the driver face for eye gaze, head pose, eyelid motion)

Vehicle data (travel speed, vehicle trajectory-LDW, pitch angle, roll angle, steering wheel angle, turn indicator, pedal position …).

Demonstrator vehicle: CRF Light Commercial Vehicle

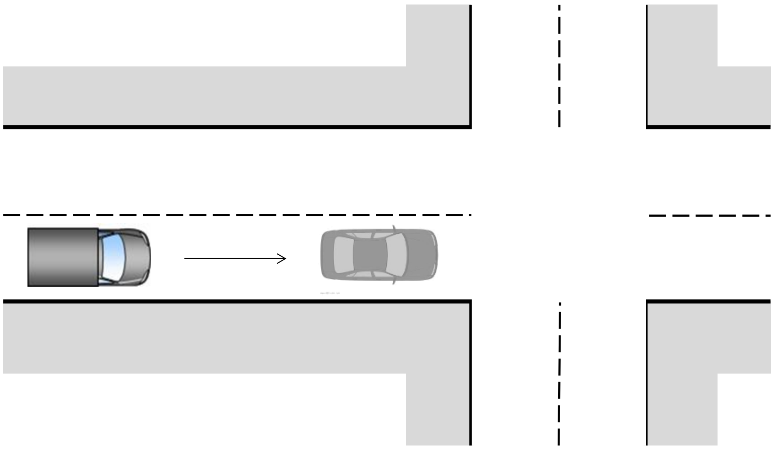
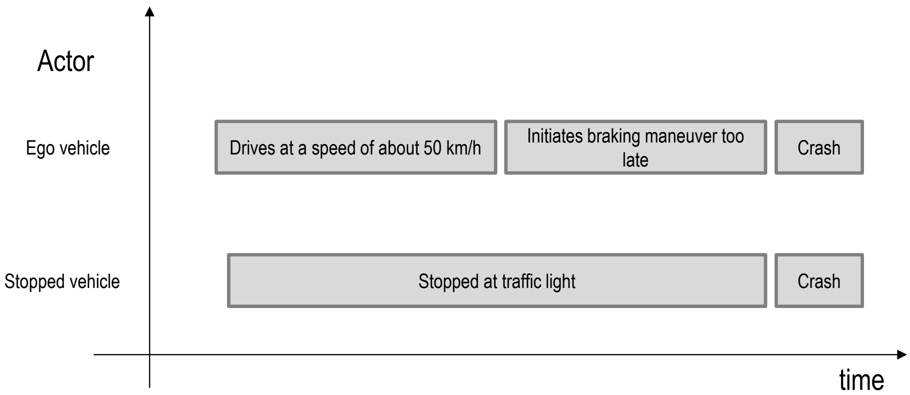
Source: ICOOR, CRF

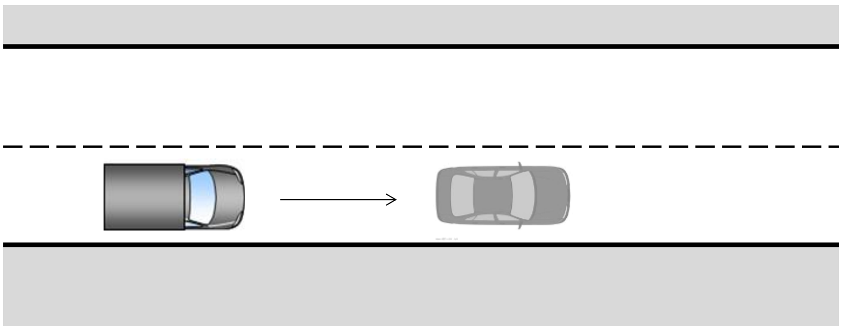
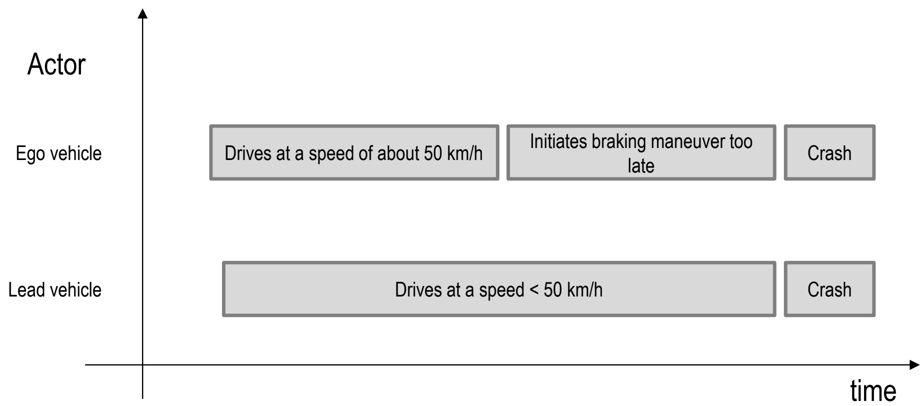
3.2 Target scenario

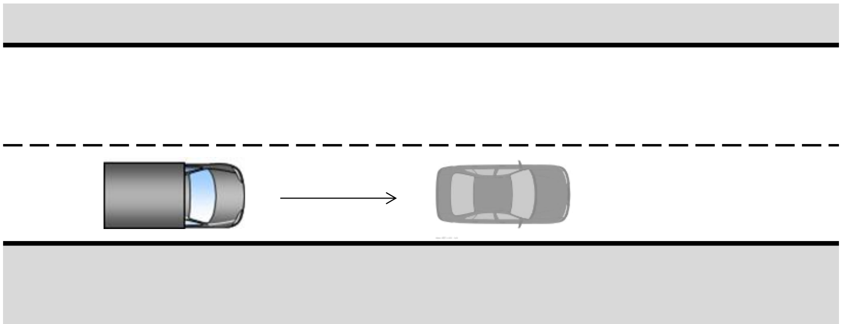
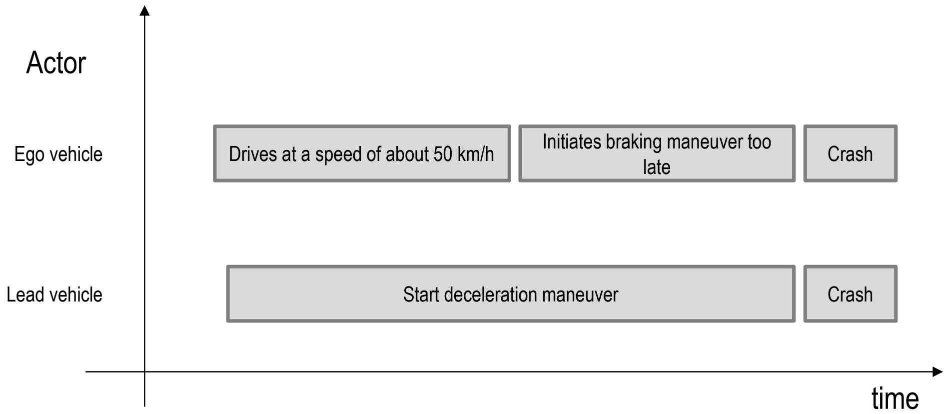
Target scenario definition consists of a precise formulation of the problem situation to be addressed by application to be developed. The targeted scenarios for the CRF commercial vehicle demonstrator are described in Table 6.

Table 6: Target scenarios for CRF Light Commercial Vehicle

Accident type	Function	Target scenario	Type of vehicle
CV-to-C (CVC) rear: rear-end collision	AEB interurban	TAS_CVC_1: Rear-end collision due to stopped vehicle in front	Light commercial vehicle
		TAS_CVC_2: Rear-end collision due to slower vehicle in front	
		TAS_CVC_3: Rear-end collision due to decelerating vehicle in front	

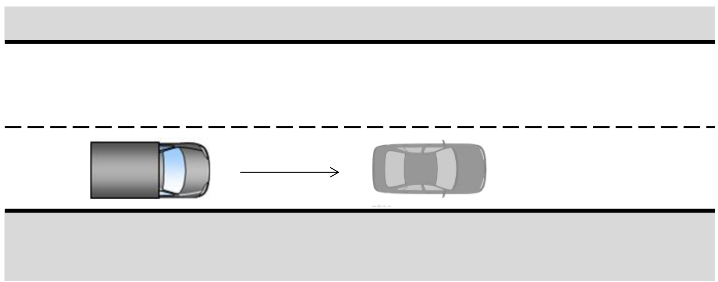
Target scenario ID	TAS_CVC_1
Target scenario name	Rear-end collision due to stopped vehicle in front
Accident type	Commercial Vehicle-to-Car rear: rear-end collision
Description	The ego commercial vehicle drives into lead stopped vehicle. The driver failed to recognise it at enough distance to perform avoidance manoeuvre in interurban driving condition.
Sketch	
Sequence diagram	
Source	CRF

Target scenario ID	TAS_CVC_2
Target scenario name	Rear-end collision due to slower vehicle in front
Accident type	Commercial Vehicle-to-Car rear: rear-end collision
Description	The ego commercial vehicle drives into lead slower vehicle. The driver failed to recognise it at enough distance to perform avoidance manoeuvre in interurban driving condition.
Sketch	
Sequence diagram	
Source	CRF

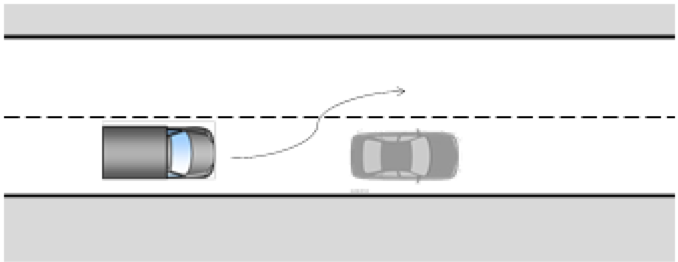
Target scenario ID	TAS_CVC_3
Target scenario name	Rear-end collision due decelerating vehicle in front
Accident type	Commercial Vehicle-to-Car rear: rear-end collision
Description	The ego commercial vehicle drives into lead decelerating vehicle. The driver failed to recognise it at enough distance to perform avoidance manoeuvre in interurban driving condition.
Sketch	
Sequence diagram	
Source	CRF

3.3 Use cases

Use case definition consists of a description of how an application is intended to interact with the driver in a particular target accident scenario in order to prevent the accident. The targeted use cases for the CRF commercial vehicle demonstrator are described below.

Function	AEB Interurban + Driver Monitoring System (Driver Drowsiness)	
Demonstrator	Light Commercial Vehicle (CRF)	
Reference scenario ID	TAS_CVC_3	
ACCIDENT SCENARIO description		
Scenario pictogram		
Background attributes	**Area type**	Interurban
	Road segment	Straight road
	Environmental conditions	Sunny Good weather
	Speed range	50 kph (ego vehicle) 10 kph < v < 50 kph (lead vehicle)
Participant 1 attributes	**Type of participant**	LCV (ego vehicle)
	Start of position	e.g. 100m from crash point
	Manoeuvre	Straight, no overtaking, constant speed 50 kph
Participant 2 attributes	**Type of participant**	Passenger car
	Start of position	e.g. 100m from potential crash point
	Manoeuvre	Straight with constant speed 50 kph (phase 1), then deceleration with target decelerations of 2 and 6m/s2 (phase 2)
USE CASE description		
Use case ID	UC1_TAS_CVC_3	
Use case name	Rear-end crash with decelerating lead vehicle due to lower driver's alertness	
Functional description	Autonomous Emergency Braking autonomous detects situations where the relative speed and distance between the host and target vehicles suggest that a collision is imminent. In such a situation, emergency braking can be automatically applied to avoid the collision or at least to mitigate its effects. Driver Monitoring System (Driver Drowsiness) warns drivers to prevent them falling asleep momentarily whilst driving by e.g. visual (messages, telltales …), acoustic (voice) or haptic feedback. The system will prompt the driver to take an action (steering or braking) before it is too late.	
Event 1 (main flow)	The ego vehicle driver is driving on an interurban road at a speed of about 50 kph following a lead vehicle at the same speed. Since the driver's alertness is low due to a long trip he notices too late that the vehicle in front of him is decelerating, thus the AEB system intervenes warning the driver and then, due to his slow reaction time, starting automatic braking.	

Event 2	The ego vehicle driver is driving on an interurban road at a speed of about 50 kph following a lead vehicle at the same speed. The driver's alertness is low due to his tiredness but the Driver Drowsiness System detect this status and warns the driver by HMI feedback. Few seconds later when the AEB system detects a risk of frontal collision with the decelerating lead vehicle and warns the driver to take an action, he has the necessary alertness to start braking and avoid crash.	
Sensing attributes	**Type of sensor**	1. Long range radar or Long range radar + mono-camera (sensor fusion) or Long range radar + stereo-camera (sensor fusion) 2. Front camera (LDW) 3. Interior camera 4. Bioimpedance grid sensors
	Detection range	TBD
	Field of view	TBD
Communication attributes	**Technology**	not used
Function attributes	**Actions**	Warning and braking (mitigation, avoidance)
	HMI	Visual, audio and haptic warning

Function	AEB Interurban + Driver Intention (Overtaking / Lane change)	
Demonstrator	Light Commercial Vehicle (CRF)	
Reference scenario ID	TAS_CVC_2	
ACCIDENT SCENARIO description		
Scenario pictogram		
Background attributes	**Area type**	Interurban
	Road segment	Straight road
	Environmental conditions	Sunny Good weather
	Speed range	50 kph < v < 80 kph (ego vehicle) 20 kph (lead vehicle)
Participant 1 attributes	**Type of participant**	LCV (ego vehicle)
	Start of position	e.g. 100m from potential crash point
	Manoeuvre	Straight, no overtaking, approach speed 80 kph (phase 1); lane change (phase 2)
Participant 2 attributes	**Type of participant**	Passenger car
	Start of position	e.g. 100m from potential crash point
	Manoeuvre	Straight with constant speed 20 kph
USE CASE description		
Use case ID	UC1_TAS_CVC_2	
Use case name	Rear-end crash with slower lead vehicle	
Functional description	Autonomous Emergency Braking autonomous detects situations where the relative speed and distance between the host and target vehicles suggest that a collision is imminent. In such a situation, emergency braking can be automatically applied to avoid the collision or at least to mitigate its effects. Driver Intention for Overtaking / Lane change manoeuvres warns the driver only when needed.	
Event 1 (main flow)	The ego vehicle driver is driving on an interurban road at a speed of about 80 kph following a lead vehicle at a lower speed of 20 kph. The relative speed is high and the driver starts a lane change manoeuvre a little bit in delay so the AEB system intervenes warning the driver to take action and then the warning is stopped as soon as the lane change / overtaking is under completion.	
Event 2	The ego vehicle driver is driving on an interurban road at a speed of about 80 kph following a lead vehicle at a lower speed of 20 kph. The relative speed is high and the driver start a lane change manoeuvre a little bit in delay but the Driver Intention makes more robust the warning strategies and it avoids that the AEB intervenes warning the driver to take braking action during the lane change / overtaking manoeuvre.	
Sensing attributes	**Type of sensor**	1. Long range radar or Long range radar + mono-camera (sensor fusion) or Long range radar + stereo-camera (sensor fusion)

		2. Front camera (vehicle lane position) 3. Interior camera
	Detection range	TBD
	Field of view	TBD
Communication attributes	**Technology**	not used
Function attributes	**Actions**	Warning and braking (mitigation, avoidance)
	HMI	Visual, audio and haptic warning

3.4 Platform modules

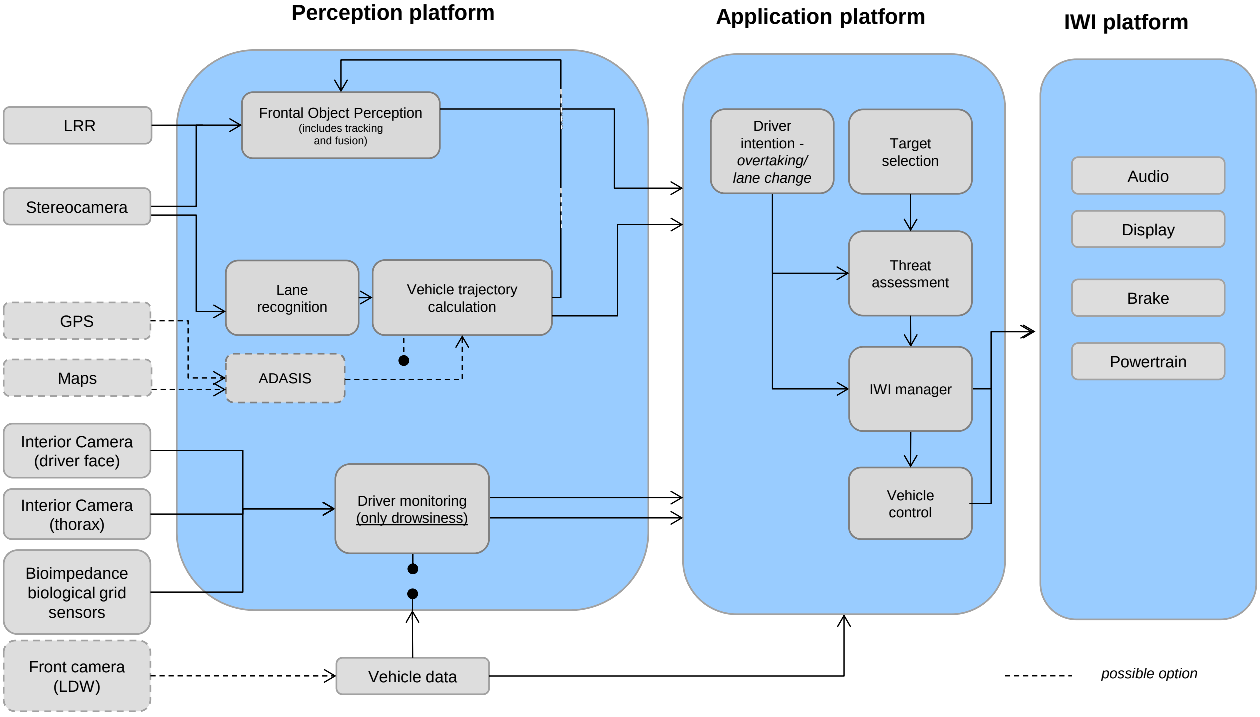


Figure 7: Functional block diagram for CRF target applications

The functional block diagram, shown in Figure 7, describes the main software modules of the software architecture implementing the following functions on the CRF LCV vehicle demonstrators:

- AEB Interurban
- Driver drowsiness
- Driver intention

The **AEB Inter-Urban** function includes both modules of Perception and Application platforms. The Frontal Object Perception module aims at detecting every relevant stationary and moving obstacle in front of the host vehicle. Advanced filtering techniques and data fusion are executed in order to extract additional information from the sensor data. The module receives as input the sensor signals (mid-range radar, stereo camera) and the data from the Vehicle Trajectory Calculation module. The output is based on a list of detected objects (stationary and moving) with the required attributes.
The Vehicle Trajectory Calculation module provides the trajectory of the host vehicle as a list of points. The aim is to predict the driver's intention few seconds in advance estimating the path of the host vehicle and its dynamics with respect to a given fused road geometry.
The Lane Recognition module evaluates the position and geometry of high-contrast lane markers of the host vehicle lane on the road. This module uses a stereo camera as sensor input. The ADASIS Horizon module allows to extract the host vehicle position data as well as the road segment attributes from the digital map.
The outputs of the former modules are sent to the Application platform. In particular, the Target Selection module determines which vehicle is the most relevant target obstacle related to the current and predicted driving situation. The priority of the target depends on its trajectory in comparison to that of the host vehicle.

The Threat Assessment module classifies and assesses the longitudinal and lateral risks associated to the current situation based on specific measures like TTC (time-to-collision) and TLC (time-to-lane-crossing). It also calculates the threat for a new alternative trajectory.
The IWI module is based on Information, Warning and Intervention manager. The Information Manager deals with the information to be provided to the driver. The Warning Manager analyses the results of the Threat Assessment and the Driving Strategy modules and makes the final decision about when to issue a warning and when to suppress it. The Intervention Manager analyses the results of the Threat Assessment and the Driving Strategy modules and makes the final decision about when to issue an intervention and when to suppress it. The Vehicle Control module determines in case of an intervention the desired longitudinal deceleration request based on the results of the components trajectory planning and control. If a braking action is needed it controls the correct amount of braking to ensure that the vehicle is braked safe.

The **Driver Monitoring Module**, designed by FICOSA and CONTI, [*4]* is placed in the Perception Platform and it is composed of the following submodules.
An Eye Gaze – Head pose module; an Eyelid Motion module, and the optional Image respiration extraction module. These modules use the video input from the camera. A specific module is dedicated to the Bioimpedance biological sensors.
An impairment detection algorithm using several parameters (like Steering wheel angle, LDW data, pedal actions and so on…) from the vehicle CAN is also implemented in the platform. Impairment level diagnostics module then elaborate the alarm signal with a confidence level
The eye gaze and head position data are sent to a distraction detection module, which elaborated them with other parameters from the vehicle CAN, like actions on radio and navigation system in order to infer a driver level of distraction sent to the application platform.
The data of eyelid movement are used by a specific drowsiness detection module; similarly another module elaborates the data from the biological sensor (or/and from the camera). Both supply their warning combined with a confidence level. These warnings and the ones form the impairment level diagnostics are used, combined with their confidence levels in the drowsiness detection fusion module to elaborate the data to send to the Application Platform.
In the Application Platform a **Driver Intention Detection Module**, designed by ICCOR and CRF, [*3]* makes use of the data from the distraction module, while threat assessment module, the IWI manager and vehicle control module will provide to take the appropriate actions through the Intervention-Warning-Information Controller.

The Driver Intention Detection module is placed in the Application Platform and it communicates with the IWI manager and with other modules of the application platform.
The main inputs from the perception platform are: CAN data (speed, indicators, pitch angle, roll angle, steering wheel angle, etc.), interior camera and external camera (lane position detection).
The output from the DIDM feeds the IWI manager providing information on the driver if he/she is going to perform a maneuver, for example by assigning a number to the maneuver undertaken by the driver (i.e.: 0 for lane following; 1 for left lane change; 2 for right lane change). Alternatively, it can provide the probability for each maneuver.

4. CONCLUSIONS

The definition of applications to be integrated in the commercial vehicle demonstrators have been documented. These are selected examples of ADAS functions targeted for the DESERVE platform, and will be used as basis for the test cases for the DESERVE development platform, specifically for testing, validation and evaluation within commercial vehicles demonstrators from Volvo and CRF. Targeted applications for passenger cars and motorcycles are documented in DESERVE deliverable D51.1 and D53.1 respectively, and together these documents (D51.1, D52.1 and D53.1) comprizes the applications definitions for the DESERVE demonstrator vehicles (passenger cars, commercial vehicles and motorcycles).

REFERENCES

[1] DESERVE consortium, *DEvelopment platform for Safe and Efficient dRiVE*, Technical Annex Part B, 31.01.2013[2] *D121 Development Platform Requirements*, DESERVE

[3] *D31.1 Standard driver model definition*, DESERVE

[4] *D32.1 General driver monitoring module definition*, DESERVE

[5] *D41.1 Warning functions solution design*, DESERVE

[6] *D42.1 Control functions solution design*, DESERVE

[7] *D43.1 VRU protection functions solution design*, DESERVE

[8] D51.1 Passenger car application definition design

[9] D52.2 Commercial vehicle functions integrated on prototypes

[10] D531 Motorcycle application definition design

[11] www.interactive-ip.eu

[12] ISO_DIS_15622 Transport information and control systems - Adaptive Cruise Control Systems — Performance requirements and test procedures