Development Platform for Safe and Efficient Drive

Automated functions solution design

Deliverable n.	D44.1– Automated functions solution design		
Sub Project	SP4	Test case functions	
Workpackage	WP4.4	Automated Functions	
Tasks	T4.4.1	Requirement analysis and solution design	
Authors	Joshué Pérez Dave Marples Angel Cuevas Giulio Piccinini	INRIA Technolution CTAG ICOOR	
File name	D44.1_Automated functions solution design_14.0.docx		
Status	Final		
Distribution	Public (PU)		
Issue date	18/12/2013	Creation date	23/09/2013
Project start and duration	1st of September, 2012 – 36 months		

REVISION CHART AND HISTORY LOG

Ver	DATE	AUTHOR	REASON
1.0	2013-09-23	Joshué Pérez (INRIA)	Table of contents and structure of the document
2.0	2013-10-15	Giulio Piccinini (ICOOR)	Contributions in section 2
3.0	2013-11-14	Giulio Piccinini Caterina Calefato (ICOOR)	Contributions in section 2
3.5	2013-11-13	Joshué Pérez (INRIA)	Contribution in section 3, longitudinal controllers.
4.0	2013-11-13	Dave Marples (Technolution)	Introduction of concept of Candidate Manoeuvres
5.0	2013-11-15	Joshué Pérez (INRIA)	Restructuring of the document
6.0	2013-11-19	Dave Marples (Technolution)	Contributions in section 1
7.0	2013-11-21	Angel Cuevas (CTAG)	Table for the mapping of candidate Manoeuvres.
8.0	2013-11-25	Joshué Pérez (INRIA)	Contributions in section 1
9.0	2013-12-03	Joshué Pérez (INRIA)	Section 4 and conclusions
10.0	2013-12-05	Dave Marples (Technolution)	Contributions in section 3 and review
11.0	2013-12-06	Joshué Pérez (INRIA)	Final review
12.0	2013-12-06	Dave Marples (Technolution)	Final review
13.0	2013-12-16	Serge Boverie (Continental)	Peer-review.
14.0	2013-12-17	Nereo Pallaro (CRF)	Peer-review.
15.0	2013-12-18	Joshué Pérez (INRIA)	Final comments review.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ABBREVIATIONS

ABBREVIATION	DESCRIPTION
ACC	Adaptive Cruise Control
ADAS	Advanced Driver Assistance System
ALC	Adaptive Light Control
CAS	Collision Avoidance System
CCS	Cruise Control System
CSW	Curve Speed Warning
CWS	Collision Warning System
DPP	Dynamic Pass Predictor
EPS	Electric-Power-Assisted steering
FRLS-LR	Forward/Rearward looking system (long range)

HGV	Heavy Goods Vehicle
HMI	Human Machine Interface
ICC	Intelligent Cruise Control
i-PI	Intelligent Proportional– Integral controller
ITS	Intelligent Transportation Systems
LCA	Lane Change Assistance
LGV	Large Goods Vehicle
NVS	Night Vision System
OHDA	Over the Horizon Driver Advice
PA-C	Park Assistant – Car
PA-HGV	Park Assistant – Heavy Goods Vehicle
PI	Proportional– Integral controller
PP-C	Park Parallel Controllers
PSS	Pedestrian safety systems
PSV	Public Service Vehicle
RFID	Radio Frequency Identification
TRAM	Tramcar or electric street railways
TS&TLR	Traffic sign and traffic light recognition
VIO	Vehicle Interior Observation

EXECUTIVE SUMMARY

Automated functions for real scenarios have been increasing in last years in the automotive industry. Fully autonomous vehicles are becoming a reality due to recent advances in the perception, planning and control of Intelligent Transportations Systems [1]. Some research groups, projects and manufactures around the world (e.g.: VIAC [2], Google cars [3], Bosch Automated driving [4]) are technologically ready to provide fully autonomous driving. However, one of the most interesting problems is the arbitration between fully automated functions and driver control, considering the driver in the control loop –Driver only or assisted- (see D24.1 –SP2-[6]).

In this deliverable, a resume of the automated functions for the different DESERVE platforms (perception, application and IWI) is explained, based on fully autonomous manoeuvres. In WP41 –Warning functions- and WP42 –Control functions-, some of the warning and assisted functionalities were defined for each vehicle demonstrator. Some of them have only partial -longitudinal- control. For this reason, a set of simulated functions will be also considered in WP44, in order to test the whole architecture of DESERVE in different scenarios.

In this document a review of the automated functions for vehicle demonstrator and some simulated scenarios is presented. This report will allow to create the bases for future development of automated functions (the lateral and longitudinal behaviour of the vehicle), based on the integration of the application request, the driver behaviour and driving conditions for the DESERVE project. Different solutions of shared control have been analysed, based on the requirement described in D12.1.

INTRODUCTION

Definition of an Automated Manoeuvre

An Automated Manoeuvre is defined, for the purpose of the DESERVE project, to mean;

A manoeuvre that, once commanded, is performed autonomously by the vehicle without the need for human intervention in structured environment.

In order for an Automated Manoeuvre to be demonstrable, it must also be capable of dealing with the majority of the reasonably expected exception and error cases. Having said that, for demonstration purposes in a controlled environment, complete case coverage is not the main aim of DESERSE, since this project is focused in methodological process for embedded ADAS applications. This exception is permissible because human intervention remains possible in the demonstration environment and coverage of some of these cases may be disproportionately time consuming and expensive in relation to the probability of their occurrence. Automated Manoeuvres differ from control functions (WP42) due to the fact that autonomous driving considers structured scenarios featuring multiple stages and several potential ‘paths’ through a scenario.

There must, however, be a clearly defined and achievable route to complete exception case coverage with failsafe fall backs for production use – demonstrating a feature that could never reach production because of intrinsic exception handling limitations has only limited utility.

Note that an Automated Manoeuvre does not mean complete vehicular autonomy. There will remain override conditions and exceptions that will always need the intervention of the human user and the distinction between the desirable and achievable levels of autonomy that are possible is for study within the project. These control levels (between assistance and automation) are analysed in WP24 –Arbitration and Control-, and are not part of the scope of this document.

Objective and scope of the document

The purpose of deliverable D44.1 (output of work package 44, dealing with the development of Automated Functions in the framework of DESERVE project) is to analyse the candidate Manoeuvres, based on the requirements, vehicle control solutions and functionalities (developed in other work packages –particularly WP41 and WP42-) of the DESERVE platforms. Automated functions rely on the complete automation of Manoeuvres in medium and high complexity scenarios, with challenging requirements in terms of understanding and awareness of the evolution of the road scenario where the vehicles move. These functions will be tested in simulations and field demonstrators.

Structure of the deliverable

This document is structured as follows: section 1 describes a list of candidate Manoeuvres at the user level and the functionality that they provide. A mapping of these automated Manoeuvres, based on the requirements described in D12.1 and the different vehicle demonstrator is provided in section 2. Section 3 develops a selection of set of manoeuvres, considering the previous two sections. Section 4 refers to solution design for the implementation of these Manoeuvres, based on the demonstrator and simulators available in the project. Finally, conclusions are presented in last section.

1. CANDIDATE MANOEUVRES

The following section provides information about the set of Manoeuvres that could be developed and demonstrated within WP44 "Automated Functions", based on the 10 main DAS groups defined in D11.1. A subset of these will be selected for implementation based on criteria that will be defined in Chapter 3. For each manoeuvre, information is provided about:

- **Name:** The generic name for the manoeuvre class
- **Abbreviation:** Abbreviated form of name
- **Applicable Vehicle Classes:** What types of vehicles the manoeuvre is expected to be applicable to.
- **Expected Autonomy Level:** How much vehicle autonomy is expected during the execution of the manoeuvre (based on the levels described in [6]);
    - **Driver only:** the driver has the full control of the vehicle and does not receive any warning or assistance from the vehicle, e.g. vehicle without ADAS installed.
    - **Driver assisted:** the driver is in full control, but receives support via some form of HMI mechanism (light, sound, haptic etc.), e.g. during lane change Manoeuvres.
    - **Semi-automated:** the vehicle assumes partial control in specific scenarios and/or conditions, e.g. ACC or parking assist (specific configurations).
    - **Highly automated:** the vehicle performs the majority of the manoeuvre, but the driver remains in the control loop and can take over the driving task at any time with minimal lead time, e.g. Lane Departure Warning system.
    - **Fully automated:** the vehicle is completely autonomous under different situations, considering forecast and non-forecast scenarios. Human intervention remains possible but with significant lead time and with manoeuvre affecting consequences (c.f. emergency stop).
- **Related Manoeuvres:** Other Manoeuvres that contribute to this one, or that are sharing characteristics are mentioned.
- **Textual Description:** Prose description of the manoeuvre

- **Exception Conditions:** Conditions outside of the 'happy flow' that need to be accommodated.

Note that not all of these Manoeuvres are to be implemented within DESERVE, however this functionalities provide a good overview of the types of capabilities to be expected in the DESERVE demonstrators and simulations. This deliverable will focus on semi-automated, highly automated and fully automated functions as highlighted in the next tables.

Table 1. Park Assistant Car

<table>
<tr><td>Name</td><td colspan="5">Park Assistant – Car</td><td colspan="2">Abbreviation</td><td>PA-C</td></tr>
<tr><td rowspan="2">Applicable Vehicle Classes</td><td>CAR</td><td>PSV</td><td>MCY</td><td>LGV</td><td>HGV</td><td>TRAM</td><td>TRAIN</td><td>Other</td></tr>
<tr><td>X</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Autonomy Level</td><td colspan="8">Driver Only | Driver assisted | Semi-automated | <u>Highly automated</u> | Fully automated</td></tr>
<tr><td>Related Manoeuvres</td><td colspan="8">PA-HGV</td></tr>
<tr><td>Textual Description</td><td colspan="8"><u>Rationale:</u> The driver wants to parallel park his/her car. Parallel parking is a reasonably advanced driver skill which many users are not comfortable with.
<u>Pre Condition:</u> The driver sees in the nearside a parking space that they would like to use. They stop the vehicle and command the PP-C functionality.
<u>Actions:</u> The assistance system selects a forward gear and moves forward past the parking space. It then selects reverse gear and reverses into the space making directional adjustments as required. Once in the space the assistance system may select forward gear to centralize itself in the space. The vehicle then stops and alerts the user that the manoeuvre is complete.
<u>Post Condition:</u> The vehicle is positioned in the parking space. The engine is 'running' and the gear is in neutral.</td></tr>
<tr><td>Exception Conditions</td><td colspan="8">Intrusion into the parking target zone or manoeuvre zone
Other vehicles too close to manoeuvring zone
Parking space too small
Vehicle Engine Failure
Driver Intervention
Loss of traction
Unexpected Motion (Lateral or Transverse)</td></tr>
</table>

Table 2. Park Assistant HGV

<table>
<tr><td>Name</td><td colspan="4">Park Assistant – HGV</td><td colspan="2">Abbreviation</td><td colspan="2">PA-HGV</td></tr>
<tr><td rowspan="2">Applicable Vehicle Classes</td><td>CAR</td><td>PSV</td><td>MCY</td><td>LGV</td><td>HGV</td><td>TRAM</td><td>TRAIN</td><td>Other</td></tr>
<tr><td></td><td></td><td></td><td></td><td>X</td><td></td><td></td><td></td></tr>
<tr><td>Autonomy Level</td><td colspan="8">Driver Only | Driver assisted | Semi-automated | <u>Highly automated</u> | Fully automated</td></tr>
<tr><td>Related Manoeuvres</td><td colspan="8">PA-C</td></tr>
<tr><td>Textual Description</td><td colspan="8"><u>Rationale:</u> The HGV driver wants to reverse their trailer into a specific space but, with limited visibility to the rear of a vehicle that is 15m or more long, an automated solution has definite safety advantages and can in some circumstances avoid the requirement for a Banksman (and thus two-driver operation). The location to be steered into has a Beacon Target at it’s centre which can be used as the destination selection. Typical use case would be a vehicle at a regular loading depot or dropping off point. An extension to this use case is the reverse steering to a Beacon Target of a double articulated HGV.

<u>Pre Condition:</u> The driver has identified the location they wish to reverse the articulated trailer into. The driver stops the vehicle at a location where no further forward monition is required and commands the AVRS-BT functionality.

<u>Actions:</u> The vehicle selects a reverse gear and steers the HGV towards the target beacon, transitioning between forward and reverse gears as required. Once in position the vehicle stops and alerts the driver that the manoeuvre is completed.

<u>Post Condition:</u> The vehicle is positioned with the back of the HGV trailer centred on the beacon. The engine is ‘running’ and the vehicle is in neutral.</td></tr>
<tr><td>Exception Conditions</td><td colspan="8">Intrusion into the beacon target zone or path to it
Other vehicles too close to manoeuvring zone
Target location incompatibility
Vehicle Engine Failure
Driver Intervention
Loss of traction
Unexpected Motion (Lateral or Transverse)</td></tr>
</table>

Table 3. Lane Change Assistance system

Name	Lane Change Assistance system				**Abbreviation**		LCA	
Applicable Vehicle Classes	CAR	PSV	MCY	LGV	HGV	TRAM	TRAIN	Other
	X	X	X	X	X			
Autonomy Level	Driver Only	Driver assisted	**Semi-automated**	Highly automated	Fully automated			
Related Manoeuvres	Lane keeping, lateral control, ACC							
Textual Description	**Rationale:** The driver wants to change lane on a multicarriage way road. The driver wants to overtake a slower vehicle ahead, or simply to move to another lane. Some situations do not permit drivers to perceive other vehicles coming from the rear (Blind Spot). **Pre Condition:** The system is activated when the turn indicator is on. These are most used in highways scenarios. However, in urban intersections (with several lines) the service can also be useful. **Actions:** Most of the LCA are used in a driver assistance mode. Lane Departure Warning (LDW) systems are used to keep the vehicle in the lane by providing feedback to the driver. The Blind Spot Warning (BSW) systems prevent dangerous situations during the lane change process, alerting the driver of unseen vehicles in the blind spot. LCA uses visual elements in the control panel and/or in the outer mirrors. Moreover, acoustic signals and haptic warning signals at the steering wheel may also be implemented. The Lane Keeping Assistance Systems (LKAS) controls both lateral and longitudinal actuators. **Post Condition:** the system is automated deactivated once the vehicle is positioned in the new lane and the blinking indicator is off. The driver can keep the same previous speed and the steering wheel in straight segments.							
Exception Conditions	Vehicle Engine Failure Driver Intervention Loss of traction High speed of other vehicles Sudden change in traffic conditions (jams) Abrupt driving of other vehicles							

Table 4. Pedestrian safety systems

Name	Pedestrian safety systems				**Abbreviation**		PSS	
Applicable Vehicle Classes	CAR	PSV	MCY	LGV	HGV	TRAM	TRAIN	Other
	X	X		X	X	X	X	
Autonomy Level	Driver Only	Driver assisted	**Semi-automated**	Highly automated	Fully automated			
Related Manoeuvres	Vulnerable road users detection, Forward looking system and Cruise Control System.							
Textual Description	**Rationale:** The driver wants to drive in urban environment with pedestrians nearby. A pedestrian enters into the trajectory of the vehicle, and the driver is distracted and does not have time to react to the situation. Pedestrians are the most vulnerable road users. Impacts are also potentially dangerous for the vehicle occupants (high decelerations and sudden accidents). **Pre Condition:** the vehicle is driving in an urban area. Pedestrians are in the vicinity of the vehicle. An interface displays to the driver the possible risk of the situation. Weather conditions should not disturb the pedestrian detection performance. **Actions:** Pedestrian detection functions should send the necessary object information. This can provide suitable measurements of the risks, based on the vehicle trajectory and pedestrian trajectory. Since the reaction time of the driver is slow (around 2 seconds), these systems usually have to activate the automated brake system. **Post Condition:** The driver resumes control of the vehicle once the risk decrease.							
Exception Conditions	Extreme weather conditions. Range of the perception sensors. Crowding of pedestrian. Driver interaction with HMI. Unexpected obstacles. Sensor failure. Engine failure.							

Table 5. Forward/Backward looking system

<table>
<tr><td>Name</td><td colspan="4">Forward/Rearward looking system (long range)</td><td colspan="2">Abbreviation</td><td colspan="2">FRLS-LR</td></tr>
<tr><td rowspan="2">Applicable Vehicle Classes</td><td>CAR</td><td>PSV</td><td>MCY</td><td>LGV</td><td>HGV</td><td>TRAM</td><td>TRAIN</td><td>Other</td></tr>
<tr><td>X</td><td></td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td></td></tr>
<tr><td>Autonomy Level</td><td colspan="8">Driver Only | Driver assisted | <u>Semi-automated</u> | Highly automated | Fully automated</td></tr>
<tr><td>Related Manoeuvres</td><td colspan="8">Object detection, Night vision system, Collision Warning System, Collision Avoidance System, Ahead emergency braking Park Assistant.</td></tr>
<tr><td>Textual Description</td><td colspan="8"><u>Rationale:</u> The driver wants to avoid a collision. A perception system is monitoring forward (and Backward, e.g.: Park Assistant) unexpected situations. If an obstacle is ahead, and it is a high rick of collision, then the emergency braking system is activated.

<u>Pre Condition:</u> The situational awareness of the driver is augmented by forward and backward perception systems, such as radars, lasers, cameras, infrared sensors and fusing some of them.

<u>Actions:</u> Most of the applications are for driver assistance. In some ADAS applications, the action of the steering wheel has recently been considered. However, most of the current systems use brake actions, engine control and active suspensions.

<u>Post Condition:</u> The driver can take the control of the vehicle. The system can be deactivated whenever, if the vehicle user wishes.</td></tr>
<tr><td>Exception Conditions</td><td colspan="8">Driver Intervention
Driver interaction with HMI.
Unexpected obstacles.
Sensor failure.
Hard environmental conditions (rain and snow).
Unexpected obstacle in blind Spot (e.g.: lateral crashes).</td></tr>
</table>

Table 6. Adaptive Light Control

Name	Adaptive Light Control				**Abbreviation**		ALC	
Applicable Vehicle Classes	CAR	PSV	MCY	LGV	HGV	TRAM	TRAIN	Other
	X	X	X	X	X			
Autonomy Level	Driver Only	**Driver assisted**	Semi-automated	Highly automated	Fully automated			
Related Manoeuvres	Map supported, Night vision system, Collision Warning System.							
Textual Description	**Rationale:** The vehicle is driving in taking a curve by night, and some undesirable obstacles may not be illuminated –pedestrians, bicycles or animals-. ALC can orientate the lights in the direction of the curves or the path, or can highlight specific hazards. **Pre Condition:** The light control is activated when the steering wheel of the vehicle is turning, adapting their action range to the orientation of the curves. Further, if sensors detect potential hazards then the lighting may be adjusted highlighting the risk. **Actions:** The main advantage is that the lights can be adapted to the scenario (straight and curve roads). The front lights of the vehicle turn when steering and the map supported information if the driver considered appropriate. **Post Condition:** Once the vehicle finishes the curve, the light return to the straight position.							
Exception Conditions	Unexpected motion (lateral or transverse) Steering failure. Electric-Power-Assisted steering EPS failure. Light fault. Sudden driver input (e.g. turn of the steering wheel.)							

Table 7. Night Vision Systems

<table>
<tr><td>Name</td><td colspan="4">Night Vision Systems</td><td colspan="2">Abbreviation</td><td colspan="2">NVS</td></tr>
<tr><td rowspan="2">Applicable Vehicle Classes</td><td>CAR</td><td>PSV</td><td>MCY</td><td>LGV</td><td>HGV</td><td>TRAM</td><td>TRAIN</td><td>Other</td></tr>
<tr><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td></td></tr>
<tr><td>Autonomy Level</td><td colspan="8">Driver Only | <u>Driver assisted</u> | Semi-automated | Highly automated | Fully automated</td></tr>
<tr><td>Related Manoeuvres</td><td colspan="8">Forward looking system</td></tr>
<tr><td>Textual Description</td><td colspan="8"><u>Rationale:</u> There are a set of sensors which extend the effective capacity of human vision where it would be otherwise be impaired by environmental conditions including dark, fog and driving rain or snow. These sensors may be primarily provided on the vehicle for other purposes and the NVS is a secondary capability. Delivering the output of these sensors to the human driver serves to increase their situational awareness under compromised conditions.

<u>Pre Condition:</u> The situational awareness of the driver is compromised by visual impairment such as darkness, snowy or rainy situations. For this reason, an adverse environemental conditions is needed. A set of sensors that can provide additional scene awareness is available. An interface provides information to the driver.

<u>Actions:</u> The driver enables the NVS and the output from various augmentation sensors is fused and delivered to the driver to help his/her understanding the scene in the road ahead. The means of delivery may vary according to driver preference and the delivery mechanisms available in a particular vehicle.

<u>Post Condition:</u> The driver is better informed about the state of the road in front of/around them.</td></tr>
<tr><td>Exception Conditions</td><td colspan="8">Driver Intervention.
Sensor range exceeded (e.g. flare).
Inconsistent sensor output.
HMI device unavailable or compromised.
HMI device rendering unavailable/not performing (e.g. it is not possible to project an over image when it is very bright inside the vehicle).</td></tr>
</table>

Table 8. Cruise Control Systems

Name	Cruise Control System				**Abbreviation**		CCS	
Applicable Vehicle Classes	CAR	PSV	MCY	LGV	HGV	TRAM	TRAIN	Other
	X			X	X			
Autonomy Level	Driver Only	Driver assisted	**Semi-automated**	Highly automated	Fully automated			
Related Manoeuvres								
Textual Description	**Rationale:** The car itself is much more capable of establishing a constant speed than the driver, as it can use a variety of sensors to more accurately track the demands of the terrain, and adjust the output of the engine accordingly. There are, however, external factors (e.g. the varying speed of the vehicle in front) that also need to be accommodated to be as efficient as possible. **Pre Condition:** The vehicle is travelling at >20km/h with a headway to the next vehicle of at least 3m [6]. The driver engages the CCS. **Actions:** The CCS uses either the current vehicle speed or a previously set vehicle speed as its target, and adjusts the speed of the vehicle to match this goal using both the engine and the brake. It then maintains this speed until an override is demanded by the driver. If information about the headway to the vehicle in front is available then this is used to modulate the speed of the vehicle to maintain this headway. If information about the local speed limit currently in force is available then this is also used to modulate the speed of the vehicle. **Post Condition:** The vehicle speed is controlled by the CCS taking into account local (possibly dynamic) speed limits and the headway to the vehicle in front.								
Exception Conditions	Driver Intervention. Sensor range exceeded (e.g. flare). Inconsistent sensor output. HMI device unavailable or compromised. Vehicle not responding to control input. Intrusion into headway zone. Vehicle Engine Failure. Driver Intervention. Loss of traction. Unexpected Motion (Lateral or Transverse).							

Table 9. Traffic Sign and Traffic Light Recognition

<table>
<tr><td>Name</td><td colspan="3">Traffic Sign and Traffic Light Recognition</td><td colspan="2">Abbreviation</td><td colspan="2">TS&TLR</td></tr>
<tr><td rowspan="2">Applicable Vehicle Classes</td><td>CAR</td><td>PSV</td><td>MCY</td><td>LGV</td><td>HGV</td><td>TRAM</td><td>TRAIN</td><td>Other</td></tr>
<tr><td>X</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Autonomy Level</td><td>Driver Only</td><td><u>Driver assisted</u></td><td>Semi-automated</td><td>Highly automated</td><td>Fully automated</td></tr>
<tr><td>Related Manoeuvres</td><td colspan="8">Forward looking system,</td></tr>
<tr><td>Textual Description</td><td colspan="8"><u>Rationale:</u> perception systems are more able to recognize traffic signs and lights than the driver. Different algorithms and fusion techniques are available to this end. However, external factors have to be considered to increase the performance of these systems, such as traffic sign location and they can be occluded by other objects, and may suffer from different problems such as fading of colours, disorientation, and variations in shape and size, especially in images captured at night, or in the rain or sunny conditions.

<u>Pre Condition:</u> The vehicle is travelling in urban or interurban areas with many light intersections. The TS&TLR systems can recognize the traffic signs with daylight conditions in real scenarios. The speed limit is changing in different segments of the road (urban or highway scenarios).

<u>Actions:</u> An interface displays to the driver the legal speed, local traffic instructions and other urban restrictions (STOPs, priorities, give-way, etc). Speed information can be sent to Cruise control systems, to allow the longitudinal speed to be controlled automatically.

<u>Post Condition:</u> The driver is informed about the traffic signs and the traffic light status. After the sign is passed, information is removed from the display.</td></tr>
<tr><td>Exception Conditions</td><td colspan="8">Driver Intervention.
Driver interaction with HMI.
Occluded signs and lights behind other objects.
Disorientation of the traffic signs.
Sensor Failure.
Adverse metereologic environmental conditions (rain and snow).</td></tr>
</table>

Table 10. Over the Horizon Driver Advice

<table>
<tr><td>Name</td><td colspan="4">Over the Horizon Driver Advices</td><td colspan="2">Abbreviation</td><td colspan="2">OHDA</td></tr>
<tr><td rowspan="2">Applicable Vehicle Classes</td><td>CAR</td><td>PSV</td><td>MCY</td><td>LGV</td><td>HGV</td><td>TRAM</td><td>TRAIN</td><td>Other</td></tr>
<tr><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td></td><td></td><td></td></tr>
<tr><td>Autonomy Level</td><td colspan="2">Driver Only</td><td colspan="2"><u>Driver assisted</u></td><td>Semi-automated</td><td>Highly automated</td><td colspan="2">Fully automated</td></tr>
<tr><td>Related Manoeuvres</td><td colspan="8">Map-Supported ADAS, Curve Speed Warning (CSW) and Dynamic Pass Predictor (DPP)</td></tr>
<tr><td>Textual Description</td><td colspan="8"><u>Rationale:</u> There are a large number of services that require data that cannot be sensed directly from the vehicle, and these data need to be marshalled into a map. These applications generally fall into the category of Map Supported Systems, and OHDA are presented as exploitation service used in this kind of applications.

<u>Pre Condition:</u> A geographically representative map, populated with the appropriate static data, is available for the region being traversed.

<u>Actions:</u> As new data are sensed by the vehicle (e.g. delivered by another vehicle in a collaborative fashion, collected by broadcast from TMC or similar services or perhaps sensed by local components). These informations are assimilated onto the map to be available for applications. For the exploitation service (OHDA), these data are processed into suitable information alerts to be delivered to the driver. These alerts shall exploit both static and dynamic (road condition, road works) data.

<u>Post Condition:</u> The driver shall be better informed about the road conditions ahead.</td></tr>
<tr><td>Exception Conditions</td><td colspan="8">Illegal (out of range) data presentation to mapping service
Illegal (out of range or unexpected) data received from mapping service to exploitation service.
HMI device unavailable or compromised
Data not available from sensors – map is sub-populated, and so user is not fully informed.
Incorrect or out of date map.
Lack of location information.</td></tr>
</table>

Table 11. Vehicle Interior Observation

<table>
<tr><td>Name</td><td colspan="4">Vehicle Interior Observation</td><td colspan="2">Abbreviation</td><td colspan="2">VIO</td></tr>
<tr><td rowspan="2">Applicable Vehicle Classes</td><td>CAR</td><td>PSV</td><td>MCY</td><td>LGV</td><td>HGV</td><td>TRAM</td><td>TRAIN</td><td>Other</td></tr>
<tr><td>X</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Autonomy Level</td><td colspan="2">Driver Only</td><td>Driver assisted</td><td colspan="2">Semi-automated</td><td>Highly automated</td><td colspan="2">Fully automated</td></tr>
<tr><td>Related Manoeuvres</td><td colspan="8">Lane Change Assistant System</td></tr>
<tr><td>Textual Description</td><td colspan="8"><u>Rationale:</u> The driver has been active for a long time period, he/she is tired and/or the route is monotonous. Driver drowsiness and distraction is one of the major causes of road accidents.

<u>Pre Condition:</u> The driver is tired, and his/her sense begins to fail (vital symptoms). A driver drowsiness warning system alerts the driver that has to stop the vehicle, and take a rest. Sometimes, he/she ignores this caution.

<u>Actions:</u> A vision (camera) system monitors the driver’s eyelids to detect signs of sleepiness or drowsiness. Biomedical signals can provide information about the driver’s physiological state and not the driving process. Indirect Driver impairment diagnostic based on the observations of driver actions and vehicle behaviours can provide information about degradation of the driving performance related with drowsiness or sleepiness occurrence. If the driver ignores this warning message, the vehicle takes the control, and it safely brings the vehicle to a stop on the nearside of the road, in total security.

<u>Post Condition:</u> The driver has to take a rest, maybe to sleep a little, and then if his/her (and if vital symptoms are OK), he/she can take the control of the vehicle again.</td></tr>
<tr><td>Exception Conditions</td><td colspan="8">HMI device unavailable or compromised.
Driver Intervention.
Sensor failure.
Engine failure.
The Steering wheel failure.
Hard traffic jams conditions.</td></tr>
</table>

2. MAPPING OF CANDIDATE MANOEUVRES TO MANEUVER INDEPENDENT BUILDING BLOCKS

In this section each of the candidate Manoeuvres proposed above is mapped onto the set of primitive functionalities that are to be defined by DESERVE as part of the output from WP 12 (deliverable D12.1 –Development Platform Requirements-).

This process ensures that an exploitation case for each of the functionalities being developed within DESERVE is present in the demonstrator (the back check) and also to ensure that the set of functionalities being constructed is sufficient to meet the real world needs of individual Automated Manoeuvres.

It is also possible that this process will lead to the identification of building blocks which are not currently covered by functionalities being developed within DESERVE. In that case these blocks will be re-visited during future phases of this Work Package.

Table 12. Mapping of the candidate Manoeuvres

			Lane Change assistant system	Pedestrian safety systems	Forward / Rearward system (long range)	Adaptive Light Control	Park assistant	Night vision system	Cruise Control System	Traffic sign and traffic light recognition	Map supported Systems	Vehicle interior observation / Driver Monitoring
Perception Platform	1	3D Reconstruction (3D-R)			o	o						
	2	ADASIS Horizon (ADA)		o		o						
	3	Assignment of objects to lanes (AOL)	o		o							
	4	Detection of the free space (DFS)			o							
	5	Driver monitoring automotive (DMA)		o								o
	6	Driver monitoring motorcycle (DMM)										o
	10	Frontal object perception (FOP)		o	o				o			

	11	Lane course (LC)				o						
	12	Lane recognition (LR)	o	o								
	13	Moving object classification (MOC)			o				o			
	15	Parking lot detector (PLT)					o					
	16	Recognition of unavoidable crash situations (RUCS)			o							
	17	Relative positioning to the road of the ego vehicle (RPR)	o									
	18	Road data fusion (RDF)	o									
	20	Scene Labelling (SL)				o						
	21	Self Calibration (SC)				o						
	22	Side/rear object perception (SROP)	o		o		o					
	23	Traffic sign detector (TSD)								o		
	24	Vehicle filter/state (VFS)	o									
	26	Vehicle trajectory calculation (VTC)	o	o	o				o			
	27	Vulnerable road users (VRU)		o								
Application Platform	1	ACC control (ACC-C)							o			
	6	Driver intention detection (DID)	o	o								o
	9	IWI manager (IWI)	o	o	o	o			o	o		o
	10	Reference Manoeuvre (RM)					o					
	12	Target Selection (TS)		o	o				o			
	13	Threat Assessment (TA)	o	o	o				o			o
	14	Trajectory control (TC)					o					
	15	Trajectory planning (TP)					o					
	16	Vehicle model (VM)					o					
	17	Vehicle Motion Control (VMC)	o	o					o			o
IWI Platform	1	Acoustic	o	o	o		o		o	O		o
	2	Displays	o	o	o	o	o		o	O		o
	3	Telltales	o	o	o		o		o	O		
	4	Warning Steering Wheel	o									o
	5	Warning Accelerator Pedal			o							o
	6	Warning Safety Belt			o							o
	7	External lights			o	o						
	8	Steering Angle Controller					o					
	9	Steering Torque Controller	o									
	10	Brake deceleration controller		o			o		o			o
	11	Engine acceleration controller		o			o		o			

3. SELECTION OF CANDIDATE MANEOUVERS FOR ONWARD DEVELOPMENT

In this section the subset of Automated Manoeuvres which are to be taken forward into prototype development (simulation, lab demo, vehicle demonstrators) are identified, then, by cross reference to Section 2 above, it is possible to identify exactly which building blocks are required from WP 12, WP 24 and WP42 to support these manoeuvres in the field trial environment.

Selection Considerations

The selection process has taken into consideration a number of factors, including;

- How practical is a demonstration of the functionality within the constraints of the partners, budgets and geographic reach of the DESERVE project?
- How compelling and 'demonstration friendly' is the proposed functionality?
- To what degree does the proposed demonstrator highlight the potential benefits of DESERVE?
- Is hardware (and supporting software) available to implement the demonstrator within the DESERVE project?
- Is the demonstrator commercially interesting with short term exploitation potential?
- Does the demonstrator have safety implications? Can these issues be addressed and risks mitigated?
- Are there other potential mechanisms by which the same functionality can be delivered?

It is recognised that the demonstration mechanism for each of the selected functionalities may be different, and this possibility will be expanded upon over the course of the coming months; It will be possible to demonstrate some of the functionalities in 'live' vehicles with real world stimuli, but this may not be practical for some demonstrators for practical logistical, safety or cost reasons.

The considered demonstration environments, in order of increasing realism, are;

- **In-silico**– Complete non-physical implementation in a soft environment. In this scenario the demonstrator is completely software based and does not requires have any physical presence. It is possible that visualisation aids (e.g. 3D rendering) may be used to improve the presentation of the output data.

- **Hybrid (Lab)** – In this type of test the demonstrator supports hardware in the loop. This hardware might be in the sensor or the actuator side, or might cover both aspects. The use of this approach allows stimuli to be delivered to demonstrators that might be difficult or dangerous to originate in the real test conditions. This type of demonstrator is 'hosted' in a lab situation which allows richer instrumentation and infrastructure to be deployed at the expense of realism.

- **Hybrid (Field)** – In this type of test the demonstrator is again using hardware in the loop, similarly to the Hybrid (Lab) case, but this time it is field based. This reduces the amount of instrumentation and infrastructure that can be deployed, but allows demonstration in a more realistic environment.

- **Field Demonstration** – This type of demonstrator is the most realistic and complete of the options, and is a 'controlled' implementation of the functionality (e.g. without fully implemented safety, exception or HMI components which are not essential to the correct operation of the system).

With modern development processes it is reasonable to expect any system to start off as an In-silico implementation before migrating through these steps. With this in mind, the demonstration environment is a reasonable analogue for the level of maturity of the demonstrator and the amount of effort required to realise it.

Selected Functions

Taking into account the considerations in the section above, the following Automated Functions, and associated demonstration environments, have been selected (highlighted in green in the section below);

Table 13. Selected functions

Name	Location	Type
Over Horizon Driver Assistance	Hybrid - Field	Driver Assistance
Traffic Sign and Traffic Light Recognition	In Silico	Driver Assistance
Cruise Control System	Field Demonstration	Semi Automated
Night Vision System	Hybrid – Field	Driver Assistance
Automatic Light Control	Hybrid – Lab	Driver Assistance
Pedestrian Safety Systems	Hybrid – Lab	Semi Automated
Lane Change Assistance System	Field Demonstration	Semi Automated
Parking Assist – HGV	Hybrid – Lab	Semi Automated
Parking Assist – Car	Field	Semi Automated

This selection gives a spread of implementation stages from In-Silico through to field test, according to the specific demonstration case under consideration.

Note that the principle of the DESERVE platform, to enable new functionalities to re-use capabilities cheaply and cost-effectively, should make it possible to extend these selected demonstrations with new capabilities as the programme is developed, and this opportunity will be embraced.

4. SOLUTION DESIGN

Based on the requirements for automated functions presented in previous sections, a design solution is presented. Three platforms (CRF –two vehicles- and Volvo demonstrators) and two simulations (from IKA and INRIA) will be considered to test the embedded platform of DESERVE. Different control levels are considered in autonomous driving (see D24.2). In WP41 and WP42 are explained warning and control functions to be implemented in the design solution. This section is focused in the most risky situations will be considered in the project based on automated functions. Each of the following subsection describes the relation with the tables presented in section 1.

Interurban ACC (IKA):

Traditional Adaptive Cruise Control (ACC) adjusts the speed and the headway to the vehicle ahead. In particular, the system maintains the specific speed set by the user when the ACC does not detect any vehicle ahead of the equipped vehicle. On the other hand, when a vehicle is detected, the system modulates the headway to the vehicle ahead based on the settings specified by the user (and, as a consequence, the speed changes accordingly). In addition to the basic features offered by a regular ACC, the IU-ACC presents some more automated functionalities:

- Consider speed limits and reduce set speed where appropriate (***Table 8. Cruise Control Systems***);
- Consider road topography -mainly curvature- and reduce temporary speed -not set speed- where appropriate (***Table 10. Over the Horizon Driver Advice***);
- React on commands from other trajectory control -i.e. lateral control- (***Table 3. Lane Change Assistance system***).

Up to now the IU-ACC is not designed to work in intersection areas, while situations like construction sides, parking vehicles, pedestrians moving close to the road in longitudinal direction and slow right-moving vehicles are considered by the lateral control function of the Inter-Urban.

The system acts on the throttle, the brake and the steering wheel to adjust the speed, the headway and to change the trajectory of the vehicle. Besides, it employs digital maps to obtain information about the speed limits and the curvature of the road ahead. Data to be matched with the digital map come from the perception platform and the lateral control function (the *Steering Torque Controller*, the *Brake deceleration* and the *Engine acceleration* controller, mapped in section 2 and described in [5]).

As reported in the Deliverable D42.1 [8], the IU-ACC will be developed and tested in a virtual environment using the traffic flow simulation programme PELOPS as core element. The PELOPS architecture includes three models: the driver model, the vehicle model and the environmental model, which are working in a closed loop.

ACC with auto-brake (Volvo):

A full speed ACC with Auto-Emergency Brake Systems (AEBS) will be implemented in heavy commercial truck, provided by Volvo. The Adaptive Cruise Control (ACC) keeps a safe distance, considering the Time to Collision and the speed of the vehicle (or truck) in front. The automated actions will be used to control the accelerator and the brakes (***Table 8. Cruise Control Systems***).

The Advanced Emergency Brake System has the advantage that in case of imminent impacts, the emergency braking is activated automatically. The ACC is controlling the vehicle speed based on ranging to forward vehicle, the motion of the ego vehicle and driver commands. More details for the low level control implementation are available in D42 [8].

AEB + driver monitoring (CRF):

The Automatic Emergency Braking (AEB) with driver monitoring is an automated function that has been designed for a typical inter-urban environment. The driver monitoring module is composed by two elements, the driver drowsiness detection and the driver distraction detection (

***Table 11. Vehicle Interior* Observation**). Both systems provide a warning to the driver and allow increasing the automation level (the automation level is increased because it might be necessary to intervene with the AEB in case the driver does not promptly react to an oncoming dangerous situation). More details of the longitudinal controller are available in D42 [8].

AEB+ pedestrian detection (CRF):

The Automatic Emergency Braking (AEB) with pedestrian detection is an automated function that has been designed for a typical urban environment (***Table 4. Pedestrian safety systems***). The Frontal Object Perception module employs laser information to track the obstacle (the pedestrian, in this particular case). In case a pedestrian is detected and the driver is not promptly reacting (pressing the brake), the brake pedal is automatically activated by the IWI Manager in order to avoid to impact with the pedestrian. Based on the perception information, a risk management strategy is applied to determine when the driver should take the control of the vehicle and which situations are more dangerous.

Fully automated driving (INRIA):

A control architecture for autonomous driving has been previously tested in Cybercars at INRIA [9]. The modularity and adaptively have been always considered in design process. For this reason, this function can be adapted for commercial vehicle in urban environments, through PROSivic. This simulator offers a multi-sensorial environment, and takes into account several parameters of a real car such as the inertia, steering wheel response, lateral acceleration with yaw angles, damping suspension, simple weather conditions, friction parameters and more. Figure 1 shows the modules used in the control architecture. There are six main stages in our approach: acquisition, perception, communication, decision, control and actuation. Description of each module is presented in [9].

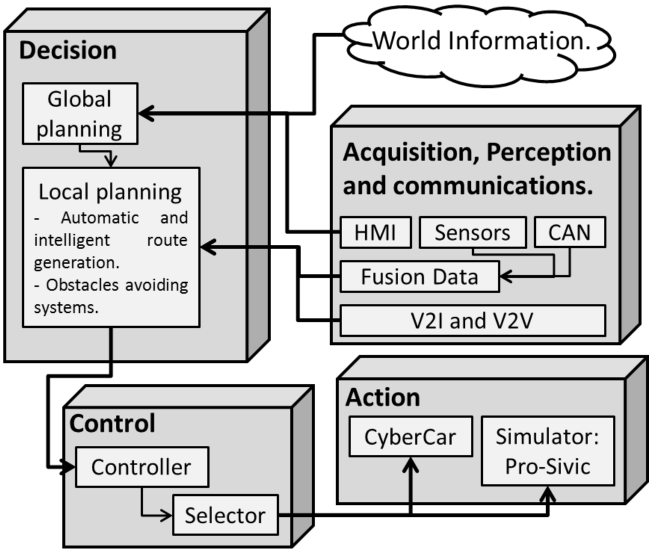

Figure 1. Architecture for automated Manoeuvres.

Moreover, synchronized time, acceleration (in wheel torque), steering, odometer information, lidar information and camera viewports are some of the components supporting the connection between the control architecture in RTMaps and the simulation. The Local Planner and a Dynamic Trajectory Generator can achieve a real time trajectory generation, taking into account structural and sudden changes in straight and bend segments (e.g. roundabouts and intersections)

A smooth trajectory and a continuous curvature are also achieved, with respect of the reference path. Different manoeuvres will be simulated and partial tested in some the DESERVE demonstrator:

- ***Longitudinal controllers***: In [10], a comparative study of four longitudinal control techniques is presented. The fuzzy controller can be intuitively re-tuned and its behaviour can be considered acceptable. These controllers can be easy tuned in simulation (PROSivic) and commercial vehicle.
- ***Lateral controllers***: Lateral control concerns the action on the steering wheel. Based on the contributions presented in [16], a lateral control strategy for unexpected emergency situation will be implemented. Dynamic trajectory generation will be also considered.

- ***Collision avoidance***: Rear-end collision warning and avoidance system will be simulated, especially considering sudden pedestrian insertion in urban areas [12][17].
- ***Autonomous overtaking***: The overtaking in one of the most dangerous situations [18]. This manoeuvre will be considered with a vehicle in front, using information from the laser and cameras.
- ***Ramp merging***: Merging from a minor to a major road in congested traffic situations is other interesting scenario that needs V2V communication and environment around information. An automated merging system is developed with two principal goals: to permit the merging vehicle to sufficiently fluidly enter the major road to avoid congestion on the minor road, and to modify the speed of the vehicles already on the main road to minimize the effect on that already congested main road [15].

These functionalities will be tested by following these steps:

1. ***Algorithm's simulation***: All these algorithms will be simulated in their respective tools (e.g.: in RTMaps and ProSivic) [see D13.2].
2. ***Dynamic model***: After a first validation, a complete dynamic model is considered, previous to be tested in each platform [see D23.1].
3. ***Hardware implementation***: each hardware (sensor, interface or actuator) will be tested separately before to be installed in the platform (Simulation in the loop -SIL-).
4. ***Final implementation***: the component and devices will installed progressively (testing different hardware configuration and testing hardware in the loop -HIL-), and finally the first automated functions will be tested in private tracks.

5. CONCLUSIONS

This document presents the first release of automated function solution for the DESERVE platform. Some of the Manoeuvres proposed in this document will be implemented, in a first stage, in simulations (In-silico), and some will go all of the way through to Field Demonstrations. The contributions are based on the main DAS groups defined in D11.1 - Application Database-, and explained with more details in the D12.1-Development Platform Requirements-. Based on these requirements and the functionalities for warning and control systems of WP41 and WP42, a design solution for automated functions is proposed in this document. The most risky situations will be considered in simulations and real implementation of some of the DESERVE vehicle demonstrator.

A list of Candidate Manoeuvres at the user level, considering the *applicable vehicle classes*, the *expected autonomy level* and a *brief descriptions* were presented in section 1. Different tables show the functionalities of each manoeuvre. A mapping of these candidate manoeuvres were presented in section 2. A selection of the candidates for the development in the frame of DESERVE project was also achieved. Finally, a solution design for the implementation of these Manoeuvres, which ones that will be in tested in field demonstrators and in lab demonstrators, is presented in last section of this document.

All the functionalities defined in this document are linked with the developments in other WP of the project. For example, the risk management in the arbitration and control, to determine when the driver should take the control of the vehicle, and **which situations are more dangerous**, can used in the simulation in PROSivic to validate the proposed functions. The next steps in this Work packages will be focused in the testing and integration of these functions in the demonstrator and simulators.

REFERENCES

[1] R. Hudda, C. Kelly, G. Long, J. Luo, A. Pandit, D. Phillips, L. Sheet, I. Sidhu, “Self Driving Cars” College of Engineering University of California, Berkeley, 2013.

[2] A. Broggi, P. Cerri, M. Felisa, M. Laghi, L. Mazze and P. Porta “The VisLab Intercontinental Autonomous Challenge: an extensive test for a platoon of intelligent vehicles” Int. J. Vehicle Autonomous Systems, Vol. 10, No. 3, 2012.

[3] Google's Trillion-Dollar Driverless Car -- Part 2: The Ripple Effects, Forbes, January 24, 2013.

[4] http://www.gentemotori.it/anche-bosch-testa-l-auto-che-si-guida-da-sola/

[5] D12.1 -Development Platform Requirements-, SP1, DESERVE project, 2013.

[6] D24.1 - Vehicle control solutions-, SP2, DESERVE project, 2013.

[7] D13.1 -Development Platform Specification-, SP1, DESERVE project, 2013.

[8] D42.1 - Control functions solution design -, SP4, DESERVE project, 2013.

[9] D. Gonzalez and J. Pérez, “Control architecture for cybernetic transportation systems in urban environments,” in IEEE Intelligent Vehicles Symposium, 2013.

[10] Milanes, V., Villagra, J., Perez, J. y Gonzalez, C. Low-speed longitudinal controllers for mass-produced cars: A comparative study. IEEE Industrial Electronic, vol. 59(1), pages 620-628, 2012.

[11] 2009 European Consumers’ Desirability and Willingness to Pay for Advanced Safety and Driver Assistance Systems, March 2010.

[12] Llorca, D.F.; Milanés, V.; Alonso, I.P.; Gavilán, M.; Daza, I.G.; Pérez, J.; Sotelo, M.A. Autonomous Pedestrian Collision Avoidance Using a Fuzzy Steering Controller. IEEE Transactions on Intelligent Transportation Systems 2011, 12, 390–401.

[13] Paromtchik, I.; Laugier, C. Motion generation and control for parking an autonomous vehicle. IEEE International Conference on Robotics and Automation (ICRA), 1996, Vol. 4, pp. 3117–3122 vol.4.

[14] Vicente Milanés, David F. Llorca, Jorge Villagrá, Joshue Pérez, Ignacio Parra, Carlos González, Miguel A. Sotelo, Vision-based active safety system for automatic stopping, Expert Systems with Applications, Volume 39, Issue 12, 15 September 2012, Pages 11234-11242,

[15] Vicente Milanés, Jorge Godoy, Jorge Villagra, Joshué Pérez, Automated On-Ramp Merging System for Congested Traffic Situations, IEEE TRANSACTIONS ON INTELLIGENT TRANSPORTATION SYSTEMS, VOL. 12, NO. 2, JUNE 2011.

[16] Pérez, J., Milanés, V. y Onieva, E. Cascade architecture for lateral control in autonomous vehicle. Intelligent Transportation Systems, IEEE Transactions on, vol. 12, NO. 1(6), pages 73-82, 2011.

[17] Vicente Milanés, David F. Llorca, Jorge Villagrá, Joshué Pérez, Carlos Fernández, Ignacio Parra, Carlos González, Miguel A. Sotelo, Intelligent automatic overtaking system using vision for vehicle detection, Expert Systems with Applications, Volume 39, Issue 3, 15 February 2012, Pages 3362-3373

[18] Pérez, J., Milanes, V., Onieva, E., Godoy, J. y Alonso, J. Longitudinal fuzzy control for autonomous overtaking. En Proc. IEEE International Conference on Mechatronics ICM 2011 , pages 1-5. 2011.