European Roadmap Smart Systems for Automated Driving

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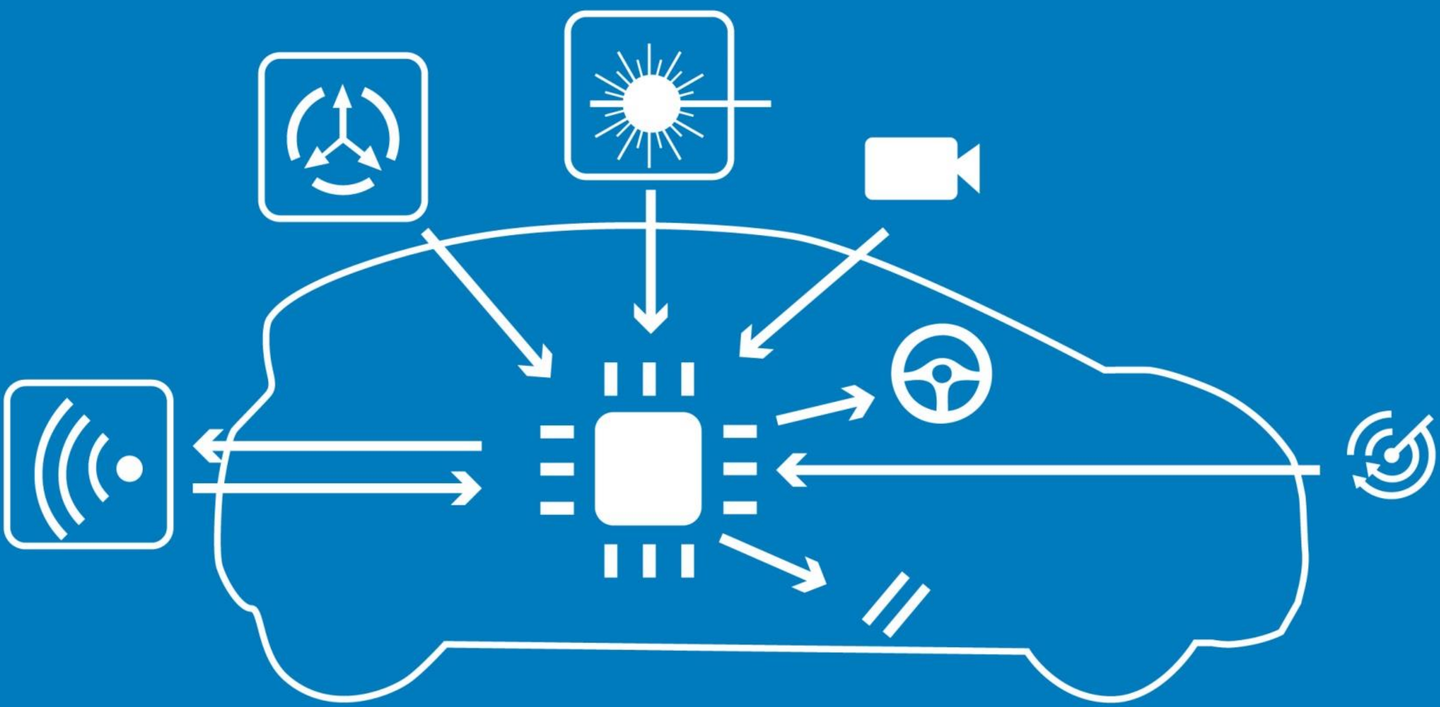
EPoSS
European Technology Platform
on Smart Systems Integration

European Roadmap
Smart Systems for Automated Driving



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European Roadmap Smart Systems for Automated Driving

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Abbreviations

ACC: Adaptive Cruise Control

AD: Automated Driving

ADAS: Advanced Driver Assistance System

ASECAP: European Association of Operators of Toll Road Infrastructures

AVGS: Automatic Vehicle Guidance System

C2C-CC: CAR 2 CAR Communication Consortium

C2X: Car-to-X

CEDR: Conference of European Directors of Roads

CITS: Cooperative Information and Technology Services

CLEPA: European Association of Automotive Suppliers

DAVI: The Dutch Automated Vehicle Initiative

DG: Directorate General

DIV: Driverless Intelligent Vehicles

DOT: Department of Transportation

ECS: Electronic Components and Systems

ECSEL: Electronic Components and Systems for European Leadership

EGVI: European Green Vehicles Initiative

EGVIA: European Green Vehicles Initiative Association

EPoSS: European Technology Platform on Smart Systems Integration

ERTRAC: European Road Transport Research Advisory Council

EUCAR: European Council for Automotive Research

FOT: Field Operational Test

INRIA: French Institute for Research in Computer Science and Automation

IoT: Internet of Things

ITS: Intelligent Transportation Systems

JTI ECSEL: Joint Technology Initiative Electronic Components & Systems for European Leadership

KET: Key Enabling Technology

LDW: Lane Departure Warning

LKA: Lane Keeping Assist

LTA: The Land Transport Authority of Singapore

MIT: Massachusetts Institute of Technology

MLIT: Japanese Ministry of Land, Infrastructures, Transport and Tourism

MOLIT: Korean Ministry of Land, Infrastructure and Transport

NHTSA: National Highway Traffic Safety Administration

OEM: Original Equipment Manufacturer

PPP: Public-Private Partnership

PROMETHEUS: PROgraMme for a European Traffic of Highest Efficiency and Unprecedented Safety

PVD: Probe Vehicle Data

RWW: Roadworks Warning

SAE: Society of Automobile Engineers

STTP: Strategic Transport Technology Plan

UNECE: United Nations Economic Commission for Europe

USP: Unique Selling Proposition

VDA: Verband der Automobilindustrie (German Association of the Automotive Industry)

WHO: World Health Organization

0 Preamble

This roadmap is based on surveys and consultations among major European automotive manufacturers and suppliers. Starting from an analysis of goals and challenges towards the introduction of automated driving (AD) and a description of the state-of-the-art technologies, technology roadmaps that provide information about content and timescales of actions in Research and Innovation (R&I) on technology and in framework conditions, are presented. These roadmaps are organized along milestones for implementation of highly automated driving.

The roadmap document has been prepared by a task force consisting of members of the European Technology Platform on Smart Systems Integration – EPoSS [1] (see Chapter 8). The findings about activity fields, timeframes and R&D topics are the result of an intense, focused and lean stakeholder dialogue. At several meetings and workshops, strategic discussions were held, involving a multitude of key industrial and academic stakeholders. Thus, the text contains names of projects, initiatives and mentions trademarks or manufacturer's names.

This document shall allow private and public stakeholders, particularly the European Commission and Member States authorities to determine what actions have to be taken when and for what reason. Besides, this document is meant as a contribution of the smart systems community to a broader strategy development process involving e.g. EUCAR, CLEPA, iMobility Forum and EPoSS, under the umbrella of ERTRAC, and the JTI ECSEL as well as the EGVI PPP.

1 Introduction

Smart components and their systems integration, traditional strengths of the European high technology industries, more and more develop into key enabling technologies (KET) for innovative products and applications [2]. This trend has been most obvious in the automotive sector for many years, where driver assistance systems enabled breakthroughs in road and passenger safety, energy efficiency and emission reduction [3]. Further along this path, higher degrees of road vehicle automation appear to be feasible soon [4, 5]. Automated driving (AD) will, on the long term, contribute to the reduction of road fatalities, increase productivity and social inclusion, and add value in terms of energy efficiency and the protection of the environment. As European car manufacturers and automotive suppliers have been successful in developing and implementing advanced driver assistance systems, the trend towards AD is based on an excellent knowledge foundation. It thus serves the objectives of increasing the competiveness of the European industry on global markets. Furthermore, AD, particularly high and full automation, represents a promising application of the Internet of Things (IoT) in the mobility sector [6].

Therefore, the aim of this roadmap is to share information about state-of-the-art efforts of the European industry, and to state what research actions have to be taken when in order to meet the milestones along the path towards implementing AD. Social and legal challenges that have an effect on complete system implementation and usage of AD in the future are carefully taken into account, and the worldwide developments in the field are reviewed.

The recommendations given by this roadmap are expected to influence the whole chain of economic value added. Therefore, this roadmap is kept open to contributions from all involved stakeholders.

1.1 Automation Levels

As a foundation for a deeper analysis the levels of automation and the criteria for their definition have to be considered (see Figure 1) since these may be a source of confusion when developments on AD are discussed. There are three such fundamental criteria to be considered when defining the level of vehicle automation. The first important criterion refers to the controlling functions, i.e., the ability of the system to take over none, either longitudinal or lateral control, or both at the same time. The second criterion is related to the human driver and whether he is allowed to dedicate his attention partially or completely to other activities except driving. The third criterion considers performances of the vehicle and its ability to independently "understand" the processes that appear during driving.

According to SAE International road vehicle automation can be classified into six different levels [7, 8]. Levels 0-2 take into account the human driver as the main actor responsible during driving. In case of faults, the human driver has less than one second to react and he or she isn't allowed to divert his/ her attention towards any other activities except driving. While the European suppliers of automotive smart components and systems invented and further improved driver assistance systems for lateral and longitudinal control of levels 0 and 1 in recent years, systems for partial automation of level 2 are currently under demonstration and in the early market place phase [4]. The most advanced solution, a combination of driver assistance systems like adaptive cruise control (ACC) and lane departure warning (LDW), is applied in high-end vehicles today [4]. For higher levels of automation, as Levels 3-5, complicated driving and decision making processes will be adopted by the vehicle in a stepwise manner. For level 3 or conditional automation, the vehicle is becoming aware of its surroundings. The reaction time for the human driver increases to several seconds, i.e. the vehicle will alarm the driver with a request to intervene, if necessary. For automation levels 4 and 5, the reaction of the human driver extends to the couple of minutes, as the vehicle is becoming able to react independently during the entire drive. Level 3 of automation thus allows the human driver to do other activities while driving, whereas, levels 4 and 5 consider a complete adoption of the driving process by the vehicle while the driver is even able to fall sleep.

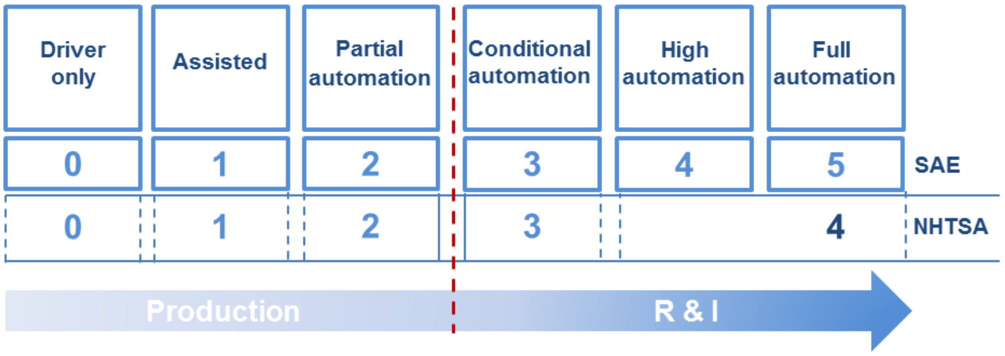


Figure 1: Levels of automated driving as defined by e.g. SAE. For comparison, definitions of automation levels of NHTSA are also given. The latter one comprises high and full automation levels towards level 4 (high automation).

There are however, other definitions for vehicle automation levels available and commonly used in practice. The National Highway Traffic Safety Administration (NHTSA) in the US uses five different subclasses instead of the described six. A vehicle having the driver only and no other assistance systems or automation classifies as level 0 and the fully automated classifies vehicle as level 4. In other words, with this arrangement no difference will be made between "high" and "full" automation as by SAE (see Fig. 1). Both, the conditional and high automation, assume that the human driver does not have to permanently monitor the system, but in necessary cases, he will be requested to take over the control with a certain time buffer.

In this document we will mostly concentrate on automation Level 3 and higher, where the vehicle's smart systems take control over the vehicle, even in critical situations.

1.2 Predictions on Automated Driving

Automated driving has attracted much attention recently mainly due to spectacular announcements by several players from the automotive and IT sectors. Also, a number of roadmaps or position papers were published announcing the importance of this topic. According to the VDA the greatest advantages of automated driving, compared to standard vehicles, are the increase in safety and the possibility of fluent, uninterrupted traffic [9]. The eNOVA Strategy Board on Electric Mobility and CLEPA emphasize the importance of R&D on key enabling technologies that would seriously contribute to an evolution of AD in Europe [10, 11]. Also, the electrification of vehicles is expected to leave space for synergies with an idea of automation of transport.

Already in 2012, European Tier 1 suppliers predicted that the implementation of highly automated driving will be possible from 2020 and fully AD to start from 2025 [12]. The usage of partial automation should already be available from 2016 for "stop and go" situations on freeways at the speed of 30km/h. Similar predictions were made in the ITS roadmap of CLEPA that forecasts the implementation of highly automated driving between 2020 and 2025 [4, 10]. The German VDA expects the implementation of the level 2 automation on a short term, and the level 3 on a mid-term [4]. Even though the research progress is enormous and would respond to the predicted terms, there are significant legal boundaries that need to be amended. Also, considerable safety issues of AD are a challenge that can only be bridged by further development of environment monitoring, perception, and driver assistance enabled by smart components and systems.

Intelligent Transportation Systems (ITS) are seen as an important enabler of AD in many of the roadmaps. CLEPA suggests development of technical solutions for cooperative systems and automated driving vehicle technologies [10]. The iMobility Forum published the first version of their roadmap on "Automation in Road Transport" in May 2013, where the emphasis was put on the analysis of all possible applications of novel technologies [13]. The authors provided contributions to the commercial aspect of future technologies with respect to various levels of automations.

Even though, as in the case of electrification of road transport [14], AD can be applied to all traffic participants like bikes, motorcycles, cars, trucks etc., the roadmap at hand concentrates only on the automation of passenger cars. This will simplify the analysis and enable constructive planning of tasks and timeframes, delivering the sphere of activities assignable to other systems. An extension to other vehicle classes and even a transfer of the concepts developed to other application domains, e.g. in manufacturing, or agriculture will be of great benefit.

2 Goals and Challenges

2.1 Motivations and Objectives

The motivations for implementing AD are versatile and consider among others environmental, demographic, social and economic aspects. The statistics say that 68% of the EU population including associated states live in urban areas, whereas six European cities count more than three million inhabitants [14]. According to the World Health Organization (WHO) the predictions are that almost one third of the overall world's population will live in cities by 2030. This justifies the need for technologies that will support urban mobility. AD offers an excellent solution due to its capability to optimize traffic flows, thus decreasing traffic jams and accidents. In this way, the reduction of fuel consumption and thus, the reduction of carbon dioxide and other noxious emissions, could be considerable [4]. Also a significant increase of road safety and comfort is to be expected due to avoidance of human driving errors. This can boost the flexibility of unconfident and elderly drivers and provide their inclusion in mobility. In a way we can speak about "personalized" transport where a certain level of automation can be individually adapted according to customer's needs. This implies that the time in which the driver doesn't fully pay attention onto the driving process, can be used either to rest or to work, for instance, increasing the comfort for employees who are frequently on the move. Therefore, one can expect that AD will induce an increase of productivity.

According to European Commission's White Paper on Transport [15], new forms of mobility have to be proposed for overcoming reliability, environmental safety and affordability issues towards sustainable solutions for the transport of people and goods. These solutions will finally contribute to solving global climate challenges correlating to worldwide requirements and standards. At the same time, for the road traffic and safety solution, the European Commission announced the ambitious goal to reduce the number of deaths on European roads by a half until 2020 [15]. Only in the year 2012, 27.700 people died and 313.000 people were seriously injured on European roads.

2.2 Challenges

The main objective of this roadmap is to predict the scope, identify actions and timeframes of the successive future developments of smart systems technologies, linking them to milestones defined for the progress of automated driving in Europe. Any vehicle that appears on the market has to fulfil standards that concern safety, security, functionality, efficiency and robustness. Additional features, comfort, design, quality and lightweight will finally define vehicle's market competitiveness and its price. Some of these go beyond the scope this roadmap on smart systems.

Also, for the smooth development of automated driving it is not sufficient to just push the technological progress but it is also necessary to identify all existing and imaginable risks. There are a number of challenges that have to be monitored and conquered in order to achieve given objectives.

2.2.1 Data Security

In order to ensure social acceptance of AD, any issues that concern data security and liability of produced systems and solutions, must be solved. The security of data has to be assured on a multitude of levels. Firstly, processing of a large amount of data followed by their storage and accessibility is essential if in future, steady communication between a car and its environment (other vehicles, road infrastructure, services and platforms) needs to be provided. Secondly, questions that concern data ownership, data evaluation and interpretation, or data misuse may slow down the implementation of AD significantly, if not solved properly in parallel to technology development. The “Preliminary Statement of Policy Concerning Automated Vehicles” which was published by NHTSA in the U.S. in 2013 [16], states that regulations need to be made to avoid issues of who can handle the data which were recorded by the vehicle’s own monitoring system. This implies that a number of abuse cases have to be analysed before creating regulations for the use of traffic data in a fair and ethical manner.

2.2.2 Legal Issues

Regulation detangling and abandoning existing regulations is another challenge for AD. One of the underlying regulatory hurdles in the EU and in many other regions is the Vienna Convention of 1968. According to Article 8 *"Every moving vehicle or combination of vehicles shall have a driver"* and Article 13 *"Every driver of a vehicle shall in all circumstances have his vehicle under control…"* there is practically no legal foundation that allows the implementation of highly automated driving in transport of humans and goods. Only assisted or partially automated driving would comply with this convention [4, 7]. This is implemented in road laws of almost all EU countries.

Rather rapid development of automation technologies caused an amendment on Article 8 of the Vienna Convention on Road Traffic in March 2014 [17]. In the new amendment the driver still has to be present and also be able to take over the steering wheel at any time, but it allows the car to drive itself, as long as the system *"can be overridden or switched off by the driver"*. Even though this represents a major step towards real application of automated vehicles there are still legal hurdles at work that need to be adjusted in order to apply vehicle automation on highways, for instance. One of such obstacles is the UNECE regulation No.79 on steering equipment [18]. It grants, for instance automated steering only at lower speeds. For highly automated driving and its applications in cities or highways, it is clear that such limitations need to be adapted according to already available technologies.

In other countries as in the U.S., for instance, the legal situation is much more relaxed which allows for more rapid development of AD compared to Europe. Therefore, legal issues have to be regulated for maintaining Europe’s competition in automation sector. Furthermore, regulations have huge impact on performance and quality requirements for smart systems.

2.2.3 Liability and Safety

Level 3 and beyond automated driving offers high comfort and flexibility for the human driver allowing, for example, he or she to phone or text while the vehicle is moving [7]. This introduces, however, concerns considering the liability of automated driving which implies the question of responsibility, particularly in accident cases. Thus, it of essential importance for insurance companies and all road users whether the responsibility lies primarily by the human who uses the car, the owner of the vehicle or the vehicle manufacturer or a vehicle supplier. For an acceptance of automated vehicles, the balance between these three potential responsibilities has to be established. Although, an alternative solution of such issue would be separating the victim in an accident from the matter of guilt, that is, indemnifying the victim independently from the question of who is guilty. The latter becomes secondary then, indicating that insurance system has to be thoroughly analyzed in order to respond to the problem of responsibility.

Resolving mentioned issues will positively contribute to an overall acceptance of AD in future even more, if one recognizes that AD has to be smoothly incorporated in mixed traffic consisting of automated and non-automated vehicles on the short term. If one also imagines a mid- to long-term scenario of multi-modal urban transport, where a huge number of different means of transportation, logistic and public services and road users has to be taken into account, the question of liability of AD and thus responsibility for the safety of all road users, is more than legitimate. For this, AD will face three major challenges. Firstly, it is not trivial to build the communication between automated vehicles and those vehicles that possess no modern technologies. Secondly, considering vulnerable road users into every-day traffic can be challenging, since there are sudden situations in angles that cannot be easily captured and processed by vehicle’s equipment. The third major challenge for AD in multi-modal transport is its regional dependence. If we take bikers in the Netherlands as an example, it is clear that automated driving has to even parry to regional requirements. The solution to this problem could be than easily translated beyond European markets, towards possibly more complicated traffic demands, as in other regions of the world. This will put additional requirements to the performances of sensors, for instance.

2.2.4 Rebound Effects

Energy efficiency is one of the most important motivations for AD. Even though the energy efficiency is expected to lead to significant reductions of the overall fuel consumption, it may conceal a rebound effect [19]. This means that an actual increase of efficiency wouldn't lead to the expected lowering of fuel consumption, but an increase due to modified driving habits as farther, faster and more often driving.

2.2.5 Economic Aspects

Costs are for the customer equally as important as for the vehicle manufacturer. Beside already mentioned technical standards that an automated vehicle has to include, the product still has to be affordable in the end. Offering good quality at reasonable price is the key solution for staying on international market's lead positions and one of the major objectives of the European OEMs. Unique selling propositions (USP) represent alternative ways in reaching economic competitiveness, for instance, with products that promise unique functions and quality, that no other manufacturer can outclass. According to the EU funded Smart EV-VC project, higher degrees of automation would contribute to the USP of the electric vehicle made in Europe [20].

Being the next step in mobility, AD will build on current maturity future progress of demonstrated technical assistance systems such as radars, laser scanners, sensors and cameras [4]. Given the present, intense testing activities of EU OEMs and Tier 1, in research centres abroad, it has to be ensured that Europe's knowledge and intellectual property in this domain can be fully exploited for the good of the economy. The protection of intellectual property is, therefore, one of the highest priorities in this domain, also matching the policy of the European Commission towards development of the market that is being favourable for innovation and investment [21].

2.2.6 Validation Aspects

AD vehicles will be very complex systems. Thus, their validation will be extraordinarily complex, too. If we consider that automated vehicles contain a large number of sensors, should communicate to the infrastructure, deal with the behavior of other traffic participants (some of them with AD functionality, others without) and evaluate the received data with algorithms, vehicle architectures are combined in uncountable number of variations. Under all these conditions considering also additional environmental effects as temperature or humidity differences, AD has to be safe (and secure).

2.2.7 Ethics

Ethical questions are one of the most important issues, being often brought in the context of AD. According to Goodall [22], even though AD vehicles will be safer because most of the crashes are due to human errors, it cannot be excluded that such vehicles will be involved in accidents. This creates high demands on future technologies since for vehicles on the road there are hundreds of varieties for predicting an accident. Thus, it will be expected from the vehicle itself to select a path with the lowest damage or likelihood of collision. Here come the ethics into the front row: who decides who will be killed in an accident? Whether thereby a child is killed, an old lady with a shopping caddy or a human driver suicides in order to minimize a number of victims, are just some of scenarios that represent enormous challenges influencing the acceptance of AD. Therefore, further research will be needed in order to minimize that problem [22].

As remarked earlier, ethics have a significant role when examining data security and even more significantly, data privacy. As expected, automated vehicles will be connected with an entire traffic infrastructure, receiving and sending an enormous amount of data. What kind of data and for which institutions will those be collected, owned, and shared, what is their purpose, how long can the data be stored and finally, how the regulatory framework complies with all these issues, are just some of ethical concerns needed to be taken seriously into account and included in early technological development steps. This problematic doesn't only apply to the human driver who sits in the vehicle but also to pedestrians filmed with cameras which are being installed in vehicles and are a part of an infrastructure.

3 State of the Art

The analysis of this roadmap starts with a study of the state of the art in functionalities of automated driving.

3.1 Research and Innovation Projects

The European Commission and public authorities of the EU Members States have already funded a number of research and innovation projects that built a firm fundament towards further developing of automated driving in Europe:

1) One of the earliest research actions supporting the creation of concepts and solutions towards an increase of safety degree on European roads was the PROMETHEUS-Project in the EUREKA program [23]. The project was PPP-funded with total costs of nearly 750 Million Euro over the period of eight years, between 1987 and 1995. Among participants of the programme were companies, universities and research institutions from 11 European countries. This research project contributed enormously to the development of radar technology. The financial backbone of EUREKA are national funding agencies.

2) The Integrated Project (IP) PReVENT was funded in the period between February 2004 and January 2008 by the European Commission [24]. The project brought together more than fifty partners from automotive industry and research towards developing, testing and awareness spreading of Advanced Driver Assistance Systems (ADAS). By combining sensor information with communication and positioning services, a remarkable improvement of overall driving safety was achieved.

3) HAVEit was an EU project funded from 2008 until 2011 with a budget of 28 Million Euro [25]. The project was led by Continental Automotive for a network of 17 European partners coming from an automotive industry and universities. The aim of HAVEit was to increase driving safety and boost the European automotive industry in an international market. Within the project several automation modes were developed and implemented as lane keeping assistance or an emergency braking assistance, for instance [4].

4) The SARTRE Project was financed by the EU from 2009 until 2012 [26]. The aim of the partnership that included seven European companies was to encourage the usage of roadtrains (platoons) for personal transport. Practical applications of platooning were tested for high speeds on a public motorway near Barcelona, Spain. Worth noticing is that SARTRE had a number of forerunners, such as the two CHAUFFEUR projects and PEIT, both developing intelligent vehicle systems and both working as a consortium of companies and educational institutions [27]. The COMPANION project will be funded by the EC until 2016 as a SARTRE successor project, with the goal to identify means for practical use of platooning in daily transport, primarily for heavy-duty vehicles [28].

5) The project interactIVe was funded by the EC in the period between 2010 and 2013 [29]. 29 companies from 10 countries were working together towards the increase of an accident-free traffic in Europe and developed advanced assistance systems for safer and more efficient driving.

6) The European project AdaptIVe develops features for automated driving and is built as a consortium of 29 partners [30]. The project started in 2014 and it aims to deliver improvements that would lead to safer and more efficient AD, within the project duration of 42 months.

7) An example for the successful integration of driverless intelligent vehicles (level 5) in urban environments is the project of CityMobil2 [31]. As a successor of CityMobil, the project is implementing intelligent transportation systems (ITS) for automated transport in protected environments. The applied vehicles are based on the "CyberCars" concept defined and promoted by INRIA in France. One of the first practical tests within the CityMobil2 has been realized in Oristano in Sardinia, Italy. Two electric vehicles having no conductor are bringing passengers over the loop line that connects the beach and the hotels in Oristano. This separate road area allows no entrance to other vehicles and works under a top down safety concept like in railways, excluding the risks that might influence a fluent movement of automated vehicles. This is however not the only example for testing automated driving in Italy. Another project is planned for the EXPO exhibition in Milan in 2015 and the third one for the region of Calabria. Within the frames of CityMobile2 tests on automated driving will be carried out in nine other environments all over the Europe: in CERN and Lausanne (Switzerland), León and San Sebastián (Spain), Vantaa (Finland), Brussels (Belgium), Trikala (Greece), La Rochelle and Sophia-Antipolis (France).

This is just a minor part of projects that are being funded by the EC. All such projects are shown in Figure 2 for the last ten years. They are sorted in four different categories: a) Networking and Challenges, b) Connectivity and Communication, c) Driver Assistance Systems and d) Robot car, though it was often difficult to classify the projects strictly into one of the categories. A more detailed description of illustrated projects, including duration and specific areas of R&D is given in Appendix I of this document.

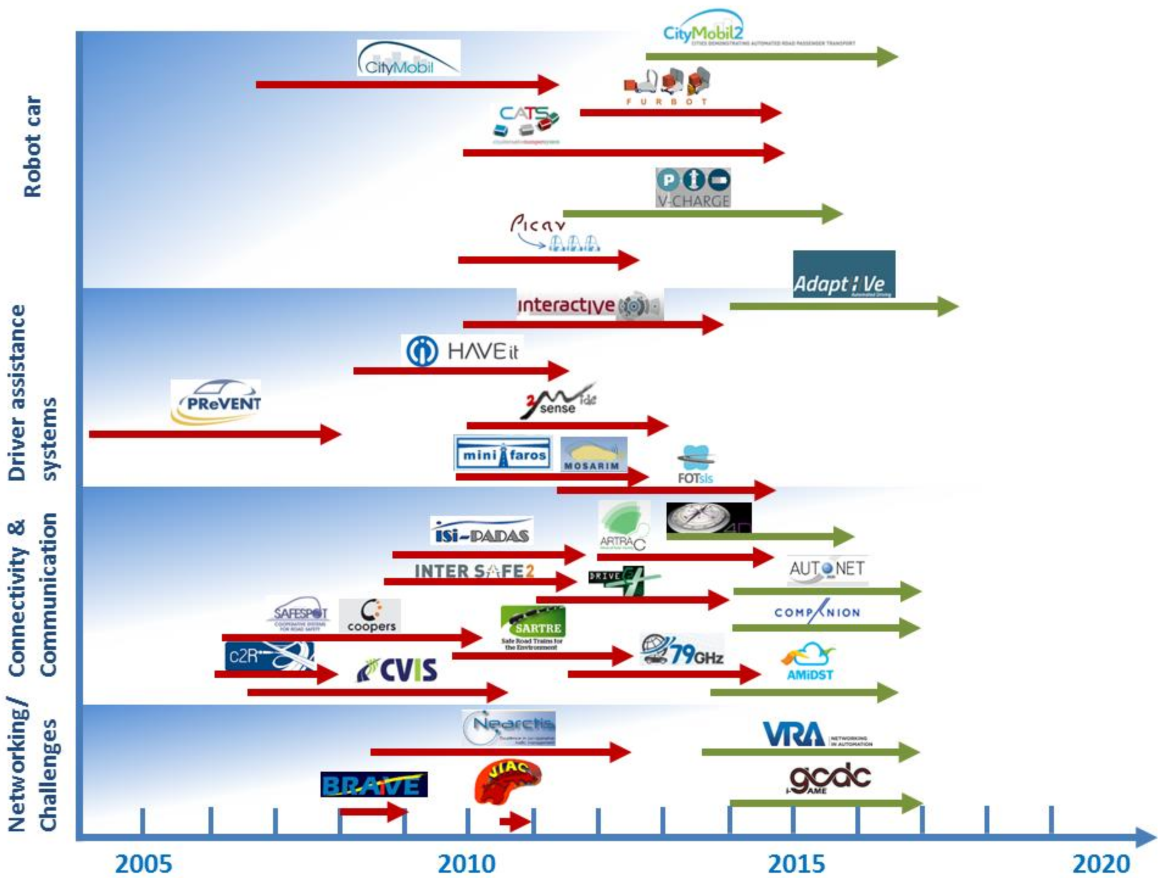


Figure 2: An overview of the EC funded projects that support the development of automated driving. The analysis has been done for the period of the last ten years. With red arrows, completed projects are shown and with the green ones, the projects that are still running.

3.2 Market Development

Thanks to these comprehensive project activities driver assistance systems have greatly advanced in recent years. The advanced driver assistance systems (ADAS) like adaptive cruise control (ACC) and lane departure warning (LDW) are commonplace today. In the ACC, the desired speed and the distance to be maintained to the vehicle ahead are set by the driver. LDW warns the driver in case the car moves to close to the edge of the lane. Lane keeping assist systems (LKA) are actively steering the vehicle to keep it in the lane.

Many of the smart systems and components enabling AD are shown in Figure 3 according to their degree of market maturity and level of automation. Conditional automated driving (level 3), combining ACC and LKA with environment perception (shown as “X”), such that the driver interaction is obsolete, has not been launched to the market yet. However, there are already some vehicle manufacturers offering these features as level 2 automation with the required driver interaction, though.

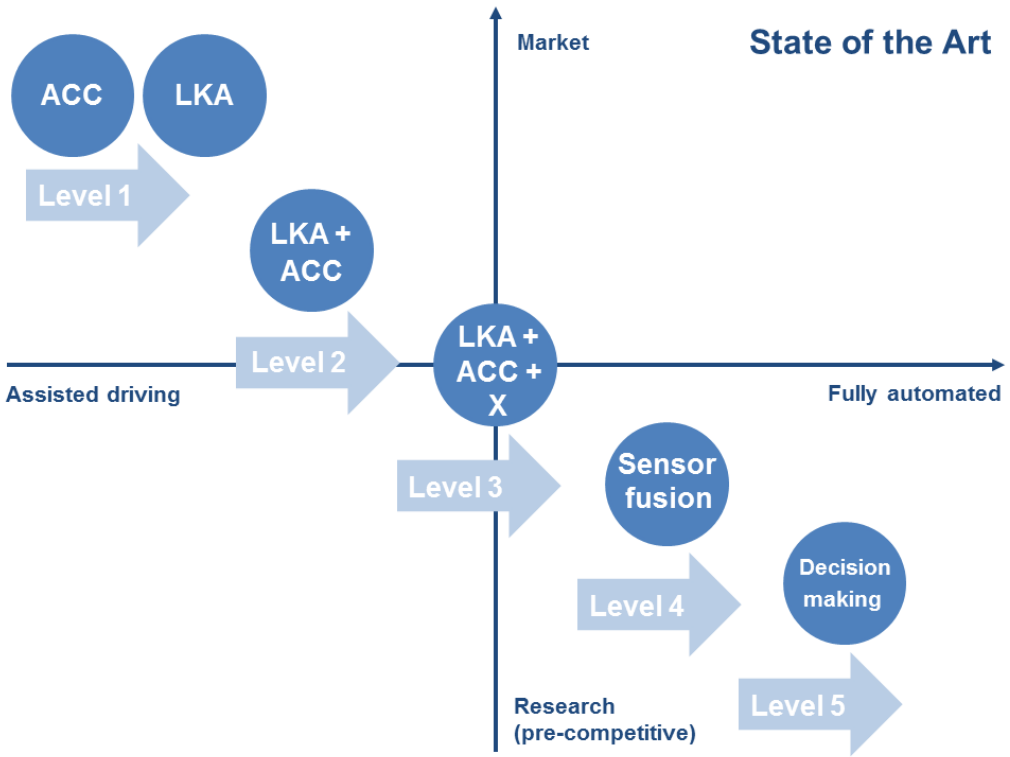


Figure 3: State of the art of smart systems enabling AD.

3.3 Demonstration

Most recent trends clearly show how important it is to create and demonstrate a vision that will work as a pull for innovation in automated driving, going beyond present research and development. One example is the presentation of a self-driving car by Google [32]. Even though the solutions presented may still be far from mature, this kind of communications may significantly contribute to raise awareness of the potential benefits of automated driving among all road users and future customers. In this same sense as Google, European vehicle manufacturers have organized demonstration events which show impressive features and thus enable the broader audience to get familiar with new technological developments [4]. Daimler e.g. recently mastered the route from Mannheim to Pforzheim with a Mercedes-Benz prototype car equipped with production-based technologies for autonomous driving. Bertha Benz had set out on the first long-distance automobile journey 125 years ago along the same route [33].

In addition to this, the development of automated driving technology for heavy trucks obviously has the potential to completely revolutionize the freight sector [34]. The so-called Future Truck from Daimler runs without the driver and is being completely supported by numerous assistance systems.

At the premises of their research center near Paris, Renault recently demonstrated its autonomous valet parking technology with an electric vehicle. It uses mainstream automotive sensor components to run in auto-pilot mode without passengers from a drop-off area to a parking lot or wireless charging station and vice versa [35]. Just in early 2014 Renault revealed its self-driving car prototype, the NEXT TWO, performing a leisure drive along a controlled road. The French maker plans to launch a self-driving electric vehicle until 2020, aiming at applications at lower speeds that account for tedious city driving and autonomous valet parking [36].

4 International and Member States Developments and Initiatives

4.1 Actions beyond EU

Public authorities around the world recently presented action plans to facilitate the development and introduction of automated vehicles. At the same time many announcements and demonstrations from automotive companies and research groups showed that the industry is globally moving closer to a scenario where the driving task will be gradually transferred from the human to the vehicle's smart systems. Beyond Europe, recent developments in the U.S. and in Japan are of particular importance. Also South Korea, China, Singapore and Australia are present with their national programmes and initiatives in the vehicle automation landscape.

4.1.1 USA

The Department of Transportation (DOT) in the U.S. has announced a national program on vehicle automation [37], with an ambitious goal to *"position industry and public agencies for the wide-scale deployment of partially automated vehicle systems that improve safety, mobility and reduce environmental impacts by the end of the decade".* Thus, the 5-year-automation-program-framework should cover research and development in all levels of automation as defined by NHTSA, namely: a) Level 1, Development and testing of Human-in-the-loop (HITL) Connected Driving Assistance, b) Level 2/3, Conditional Automation Safety Assurance, and c) Level 4, Limited Driverless Vehicle Operations. Besides, from the DOT perspective, the potentials of automation can only be achieved if vehicles are seamlessly connected to infrastructure.

The regulatory framework for testing and operation of autonomous vehicles on public roads has already been established in California, USA, in September 2014. "Senate Bill No.1298" states that the Department of Motor Vehicles should adopt novel regulations on autonomous vehicles by January 1st, 2015 at the latest [38]. This follows from the fact that solutions for different stages of automation, according to the SAE definition, are already available on the market. At the same time, solutions for Level 3 are now on trial, whereas solutions for Level 4 are already being developed. These regulations will thus enable manufacturers' testing of autonomous vehicles in public. Similar legislations are being passed in Nevada, Florida, the District of Columbia and Michigan [39]. Further states will follow [40].

4.1.2 Japan

The Japanese Ministry of Land, Infrastructures, Transport and Tourism (MLIT) stresses the importance of communication between vehicles and infrastructure for the introduction of automated vehicles and introduced the "ITS spot" technology which enables such communication with high bandwidth. 1600 "ITS spot" locations have now been installed with appropriate transmitters in Japan and more than 100,000 vehicles communicate with them. They already provide information and warnings on traffic and will, in future, be combined with lane keeping assist and adaptive cruise control. In 2013 Japanese "Autopilot System Council" announced, in an interim report, roadmaps that will lead to practical employment of highly automated driving on Japanese highways until 2020 [41]. In May 2014 an Automated Driving System Research Program has been announced, as part of the Cross-Ministerial Strategic Innovation Promotion Program (SIP) [42]. The program recognizes development and verification of AD systems, development of technologies that will contribute to the reduction of traffic fatalities and congestion, international cooperation and deployment for next generation urban transport.

Therewith, considerable reduction of traffic accident fatalities is expected in future. Symbolically, Olympic and Paralympic Summer Games in Tokyo 2020 are chosen as the central milestone for demonstrating autonomous driving in Japan.

4.1.3 South Korea

The Korean Ministry of Land, Infrastructure and Transport (MOLIT) has created an agenda towards the development of safety technologies in transport sector, with the goal to drastically decrease the number of accidents on Korean roads until 2016. Also private Korean companies are promoting the relevance of automated driving. For instance, Hyundai-Kia Motors is organizing a biennial "Future Autonomous Technology Contest" [43]. Vehicles have to successfully accomplish a 3,4 km long race along mixed paved and unpaved roads, demonstrating the ability of automated vehicles in road obstacle avoidance, managing narrow road passes and vehicle avoidance, passenger recognition, escaping in case of accidentally moving obstacles and similar. Apparently, research facilities in Korea are currently differentiating between two types of self-driving vehicles: the autonomous vehicle that collects information from in-vehicle sensors, and the second type which uses the "Automatic Vehicle Guidance System" (AVGS), that is, the vehicle receives information in a combined manner, from in-vehicle sensors and a roadside infrastructure. The Electronics and Telecommunication Research Institute (ETRI) has started research on autonomous vehicles by further developing its IT Convergence technology towards AVGS [44].

4.1.4 China

Analysing traffic conditions in China that are coupled to the continuous growth of car owners leads to the conclusion that in future, automated (and safe) systems will become a decisive criterion for the development of the autonomous vehicle market in China. Not only have different OEMs recognized this opportunity, but the Chinese Government also sees automated driving as pure reality already in 2020. Near Beijing, in the city of Tianjin, for instance, first tests with the driverless GM EN-V 2.0 vehicle took place [45, 46].

4.1.5 Singapore

In order to explore the opportunities and challenges of automated driving, the Land Transport Authority of Singapore (LTA) has signed a five-year Memorandum of Understanding with the Agency for Science, Technology and Research (A*STAR) for starting a joint partnership “The Singapore Autonomous Vehicle Initiative” (SAVI). SAVI will provide a technology platform for managing R&D on autonomous vehicles, autonomous mobility system and automated road system, as well as diverse trials for automated driving for public and industrial stakeholders. The LTA will undertake a regulatory role for implementing automated driving in Singapore’s transport network, while A*STAR will use its expertise for the development of technologies and roadmaps. Together with JTC Corporation, the LTA will start with the driverless vehicles testing on public roads in the north of Singapore as of 2015. Besides SAVI, there are already several ongoing trials for automated driving on Singapore’s roads, for instance involving MIT and the National University of Singapore (NUS). Within this project a fleet of autonomous golf buggies is currently tested for car-sharing concepts [47].

4.1.6 Australia

Gigantic self-driving trucks known as “Autonomous Haulage System” are already in use for mining purposes in the Pilbara region in West Australia [48, 49]. The machines are programmed to drive and navigate themselves with the help of sensors, GPS and radar guidance technology and are supervised by the controller stationed in Perth, 1800 km away from Pilbara. Besides, each of the trucks contains the total of 200 sensors and is being operated by Cisco networking technology. The fleet currently containing about 50 self-driving trucks should grow up to 150 until the end of 2015. Also other iron ore producers at Pilbara will set on self-driving trucks, primarily due to the sinking of costs and safety increase of an entire mining process [50]. Not only the mining industry is profiting out of vehicle automation. Preparing roads for automated cars and the advent of cooperative ITS (C-ITS) equipped vehicles, the Association of Australian and New Zealand road transport and traffic authorities “Austroads” [51] has endorsed the so-called C-ITS Strategic Plan. This plan is seen as an emerging platform assuring a two-way communication between motor vehicles and roadside infrastructure. Besides, within the CITI Project initiated by the Australian Government, New South Wales Government and the National ICT Australia Research Centre of Excellence (NICTA), one of the first large scale tests with heavy duty vehicles will be carried out [52]. Using C-ITS, up to 60 vehicles will create a 42 km connected vehicle smart corridor in the south of Sydney.

4.2 EU Member States Initiatives

Europe has also been active in implementing and further developing innovative concepts for automated driving. There are approaches that represent magnificent progress in this field, nevertheless mostly at level of EU Member States.

4.2.1 France

Recently, the French government presented a plan containing 34 different innovation fields that will contribute to the development of a new industrial France [53]. One of the goals is to build autonomous vehicles equipped with sensors and radars in order to achieve safer transport, in future. The role of ICT manufacturers and suppliers is to continue the development of sensors, software, control systems and services that will lead to affordable and thus, more competitive autonomous vehicles and components until the year 2020. The motivation lies in the fact that autonomous driving will contribute to a more flexible and adaptable traffic flow and allow elderly and disabled persons to take an active role in daily traffic.

4.2.2 Germany

The recently formed "Round Table Automated Driving", guided by the German Federal Ministry of Transport and Digital Infrastructure, resumes the issues concerning legal frameworks, infrastructure and technological requirements of automated driving. The round table consists of experts from the fields of politics and insurance, vehicle manufacturers and suppliers as well as research institutions, with the main target of establishing a legal framework that would support automated driving on roads [54]. In the recent past the German Federal Ministry of Economic Affairs and Energy and the Federal Ministry of Education and Research funded a series of research and development projects with a focus on ADAS and cooperative systems.

4.2.3 United Kingdom

End of July 2014 British government announced two new measures that would initiate "the green light to driverless cars" on UK roads [55]. The intention of the UK Government is to help Britain becom a global leader in the emerging “Intelligent Mobility” market. Firstly, UK cities can take part in a competition for hosting a driverless car trial and win a portion of 10 Million Pounds (around 12.5 Million Euro). Each of the projects is expected to last between 18 and 36 months and start from January 2015. Business and research institutions were explicitly called to nominate for joint proposals. Secondly, the review is launched in order to analyse current road regulations and discuss possible implementation of driverless car in an everyday traffic. According to the UK Government, both of the steps are necessary in order to keep the UK at the forefront of autonomous car technology.

Beginning of December 2014, British Chancellor of the Exchequer George Osborne announced in his Autumn Statement that the competition for driverless cars, innovation and transport infrastructure will receive a boost of additional 9 Million Pounds [56]. The Chancellor also announced that four UK cities: Milton Keynes, Coventry, Bristol and Greenwich, have won the Driverless Car Competition.

4.2.4 Sweden

The launch of the joint initiative "Drive Me - Self driving cars for sustainable mobility", endorsed by the Swedish Government and motivated by the vision of zero traffic fatalities, will enable research within different areas associated with self-driving cars on public roads [57]. Beside Volvo Car Group, the Swedish Transport Administration, the Swedish Transport Agency, Lindholmen Science Park and the City of Gothenburg are involved in this pilot project. Over approximately 50 kilometres of selected roads, in and around the area of Gothenburg, 100 self-driving Volvo-cars will be daily used by real customer. An added value of the project lies in the fact that automated driving will be tested on typical commuter areas strained by congestion. Another aim of the project is not only to demonstrate the social benefits of autonomous driving but to also explore all accompanying factors such as infrastructure requirements, traffic situations and surrounding interactions, as being of importance for AD.

4.2.5 The Netherlands

The Netherlands is quite active in the field of automated vehicles. The Dutch Automated Vehicle Initiative (DAVI) [58] is a public-private partnership initiated by the Dutch scientific and transport institutions. The role of DAVI is to investigate and demonstrate automated driving on public roads. Beside trial engagements, the Netherlands is quite active towards development of cooperative Information and Technology Services (ITS) necessary to support AD. Within such frame “The Amsterdam Group”, a strategic alliance, is aiming at a large-scale deployment of cooperative ITS in Europe [59]. The core of the group is Europe’s umbrella organizations which are dealing with harmonization and standardization issues, thus facilitating the implementation of novel ITS: C2C-CC, Polis, ASECAP and CEDR. One of prominent efforts of the Amsterdam Group is a joint initiative between Dutch, German and Austrian governments that will enable a pan-European deployment of the roadside cooperative ITS infrastructure [60]. Two cooperative ITS services: a) Roadworks Warning and b) Probe Vehicle Data, should be offered by 2015 on a corridor between Rotterdam and Vienna with an ultimate goal of improving traffic flow and motorway safety.

The Netherlands will also introduce a legislation in the early 2015 that will enable AD on public roads. Currently, the government is drafting the document that will outline all legislative changes required for implementing highly automated vehicles into the traffic [61].

4.2.6 Spain

The Spanish Ministry of Science and Innovation funded diverse projects which focused on the development, implementation and validation of methodologies for supporting a system control and navigation of automated vehicles [62]. Just recently Spanish researches from the University of Alicante succeeded in developing an automated driving system that is capable to learn from an environment on its own [63]. Interactive sensors are used for mapping the area and the vehicle camera supports the navigation system. Even though the tests are currently being performed on a golf cart, apparently in this way, every conventional vehicle could be transformed into an automated system operating in protected environments. At the current stage such vehicles can be used in warehouses due to their ability to identify obstacles and move objects, choosing an optimal path for reaching a certain point.

5 Roadmaps

5.1 Milestones

When talking about future technical progress in automated driving, evolutionary and revolutionary development paths can be distinguished (see Figure 4): by stepwise improvements from advanced driver assistance systems can evolve into the AD system. Fundamental transformational developments characterize the revolutionary scenario that is based on technology transfer coming from the field of robotics.

According to the evolutionary scenario, development and introduction of AD will pass through steady increase of levels of autonomy of the vehicle system in more and more complex environments allowing for higher and higher velocities. On the other hand side, the protection of vulnerable road users and synergies of automated driving with modes other than passenger cars are to be considered when describing the revolutionary development path of automated driving. The revolutionary scenario should not be underestimated, maybe leading to fully autonomous driving applications sooner than originally conceived. When excluding upfront all the external factors seen as possible threats for the safety and security of passengers, the conditions that allow for self-driving are instantly created. Particularly for higher levels of automation, as for Levels 3 and 4 as the focus of this roadmap, the following milestones can be set:

Milestone 1 (2020):
Conditional automated driving (level 3) arising along an evolutionary path will be available at low speed and less complex driving environments, e.g. in parking lots or in traffic jam situations on motorways. Until 2020 the traffic jam chauffeur with lane deviation should be completely applicable at lower velocities, followed by the availability of the highway chauffeur in 2022.

Milestone 2 (2025 at the latest):
The next step would be the availability of higher AD (level 4) on motorways. Such a highway autopilot would provide more freedom for the driver, e.g. concentrating on some other activities while driving from A to B. At the same time vehicles will have highly developed monitoring systems of the surroundings that would allow them to act instantly, in particular to avoid collisions with animals as well as to handle dangerous situations at railway crossings for medium and high velocities of vehicles.

Milestone 3 (2030 at the latest):
Highly AD (level 4) will be deployed in cities probably arising from another new revolutionary technology path (driverless intelligent vehicles). The challenge lies in the traffic complexity that ranges from communication and negotiation among vehicles, over monitoring of traffic signs, pedestrians, cyclists up to the vehicle control in curvy lanes and roundabouts. One peculiarity here is the regional dependence where not all the cities share the same requirements of AD.

The functionality described in shown milestones 1 and 2 can be understood as being switchable depending on actual situations and needs. This means practically that a car that e.g. is not able to drive automatically in a city should be able to switch to a highway chauffeur on a protected lane. An automated vehicle should thus adapt to needs and wishes of a driver.

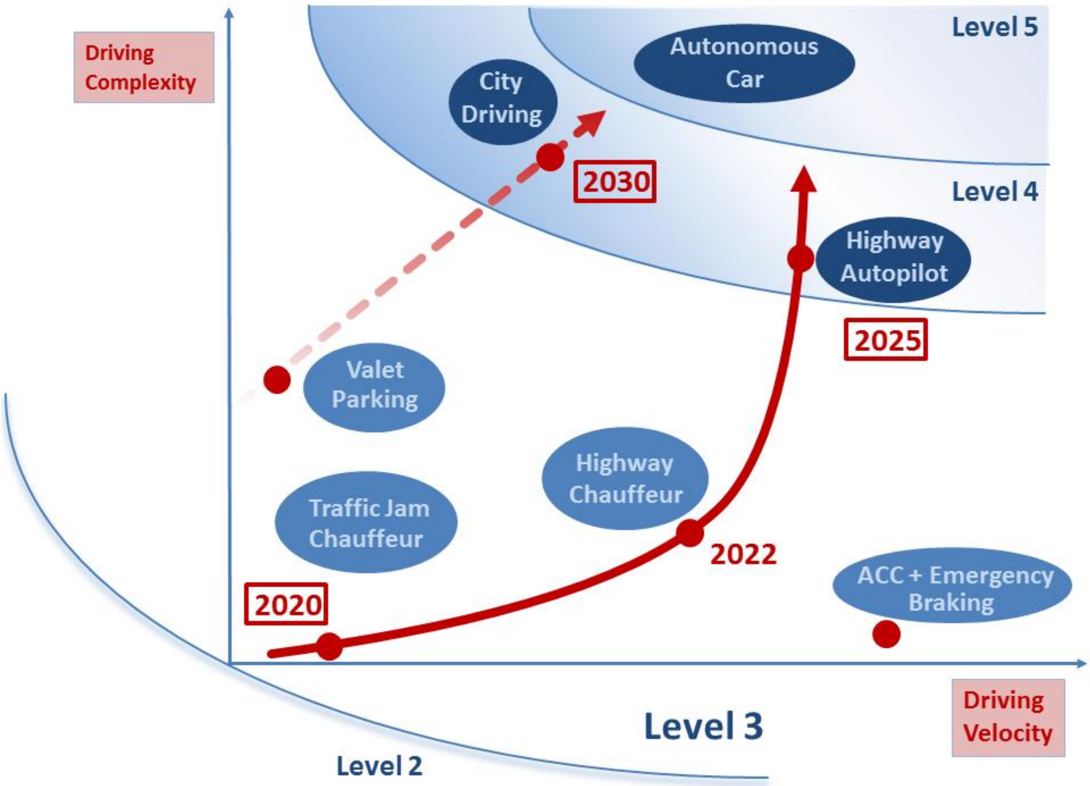


Figure 4: Development paths and milestones for Levels 3 and 4 of road vehicle automation until 2030 depending on velocity and complexity of the driving situation. The solid path represents the evolutionary scenario and the dashed line the revolutionary one. Both paths may eventually lead to the autonomous car which is indicated here as Level 5 of automation. The three milestones are indicated as years surrounded by frames. The full availability of the traffic jam chauffeur is to be expected for 2020 at the latest, while the availability of the highway chauffeur should follow right afterwards, around 2022. The highway autopilot as Level 4 is indicated as the second milestone which is to be reached in 2025. Undisturbed and safe driving in cities is considered to be the most complex task of the Level 4 automation for which full availability will be expected for 2030 in protected environments.

5.2 Activity Fields

The roadmap covers actions for a multitude of technical and non-technical aspects that need to be taken in order to achieve the milestones. Their classification is made according the following categories:

Technology Inside Car:
The roadmap is covering key enabling technologies for sensing, system integration and communication architecture, handling of human factors and functional safety. For these technologies further developments are required in the field of electronic components and systems (ECS). For instance, a network of processors and sensors within the vehicle has to handle many actions in parallel and at the reaction time less than a millisecond. Another major challenge is to produce technologies that have reasonable cost for the manufacturer and the customer, but provide all the features (high resolution and contrast for the cameras, for instance) guided by safety rules. The new technologies have to also be transferrable to all vehicle types and weather conditions, be stable in large temperature ranges, be failsafe, have a long lifetime and correlate to high quality standards and requirements. For instance, sensors have to be miniaturized and optimized in order to be able to adapt to future market demands.

At the same time, it is possible the achieve synergies and learn from experiences of other domains as aeronautics or robotics, for instance.

Infrastructure:
The roadmap is identifying necessary installations for communication at the roadside and to the data backbone. Even though creating of a dedicated vehicle communication infrastructure is not deemed necessary for AD, it can accelerate it, and it is also a prerequisite for application in urban areas.

Big Data: New technology has to be able to filter, process and evaluate the data that are vital for the transport and the passenger. An unavoidable factor is the data safety and data privacy that has to protect all the road users from possible manipulations and in case of system failures.

System Integration and Validation (Sensors, Operating System):
The roadmap is considering fundamental concepts of sensors data fusion and system operation, also at hardware level.

System Design:
The roadmap includes methods and tools for testing, simulation, certification, reliability of AD.

Standardization:
Communication standards for car to car and car to infrastructure communication are a prerequisite for AD at higher levels on the long therm. These have to be agreed on and harmonized at a European level.

Legal Frameworks:
The lack of appropriate legal framework conditions is one of the greatest roadblocks for the deployment of AD. These have to be created on time in parallel to the development of key technologies and to the establishment of infrastructure. As already mentioned the Vienna Convention of 1968 (as described in Paragraph 2.2.1) hinders further implementation of AD on roads by assuming that the driver is constantly steering and controlling its vehicle in all situations. As earlier mentioned (Paragraph 2.2.1) there are already first amendments on Article 8 of the Vienna Convention.

Awareness Measures:
Creating awareness is crucial for achieving the acceptance of automated driving in future in Europe and beyond. Especially progress concerning safety increase, energy efficiency, productivity, social inclusion and applications should be communicated for future users and traffic participants.

5.3 Roadmap Structure

For each of the activity fields a separate roadmap is presented, however existing interlinks between those fields are carefully considered in order to achieve a coherent progress. The roadmaps indicate the content and the timescale of actions in R&D, demonstration and industrialization that are required to achieve the three milestones of the introduction of automation Levels 3 and 4. These actions are ordered according to the activity tracks and along the milestones.

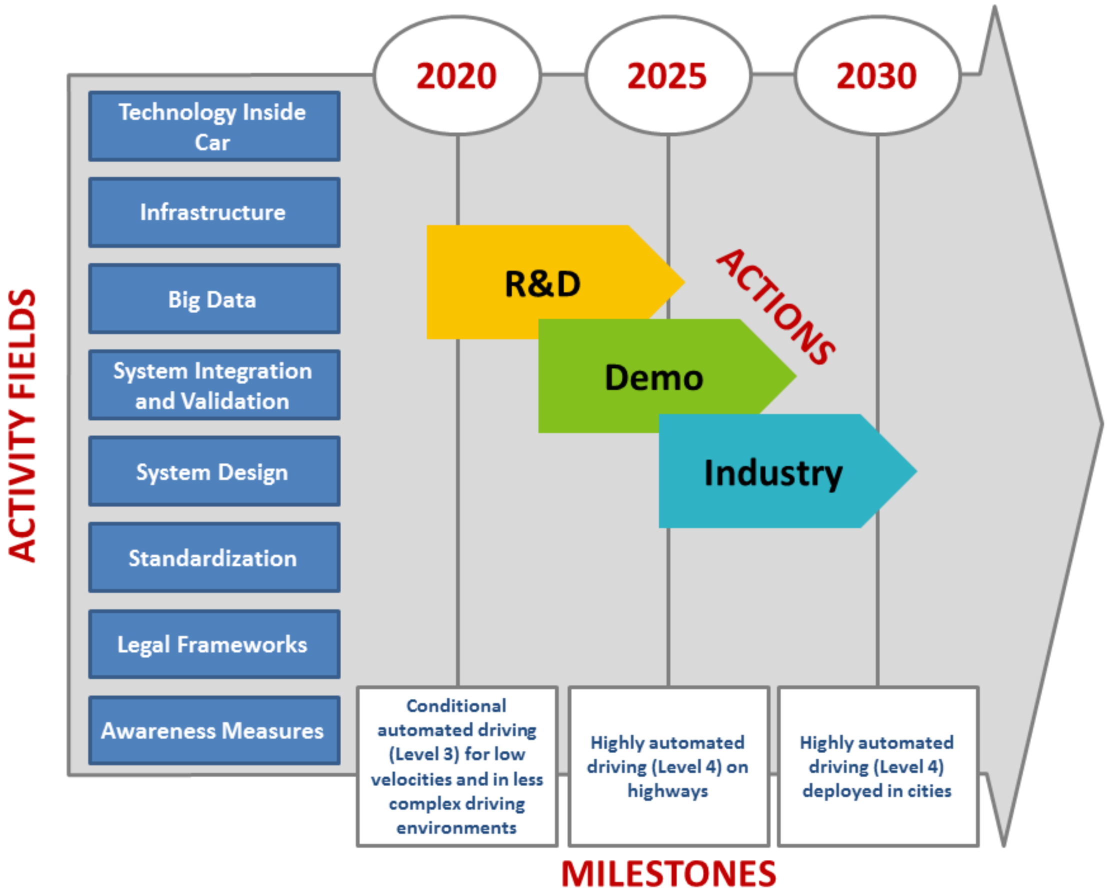
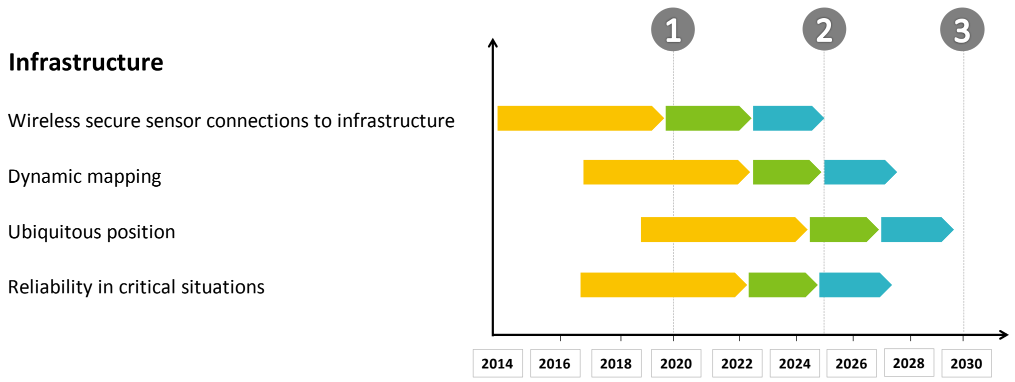


Figure 5: Structure of the roadmap integrating milestones and activity fields and indicating actions (R&D, Demonstration (or Testing) and the Industrialization) for Levels 3 and 4 of AD.

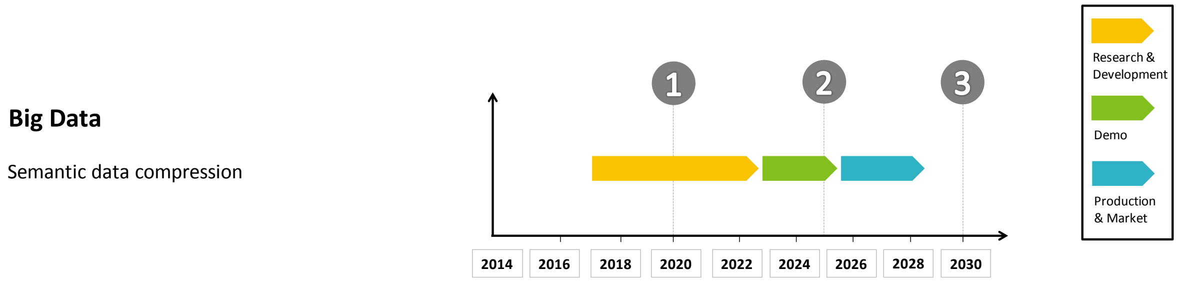
5.4 Technology Roadmaps

5.4.1 Technology Inside Car

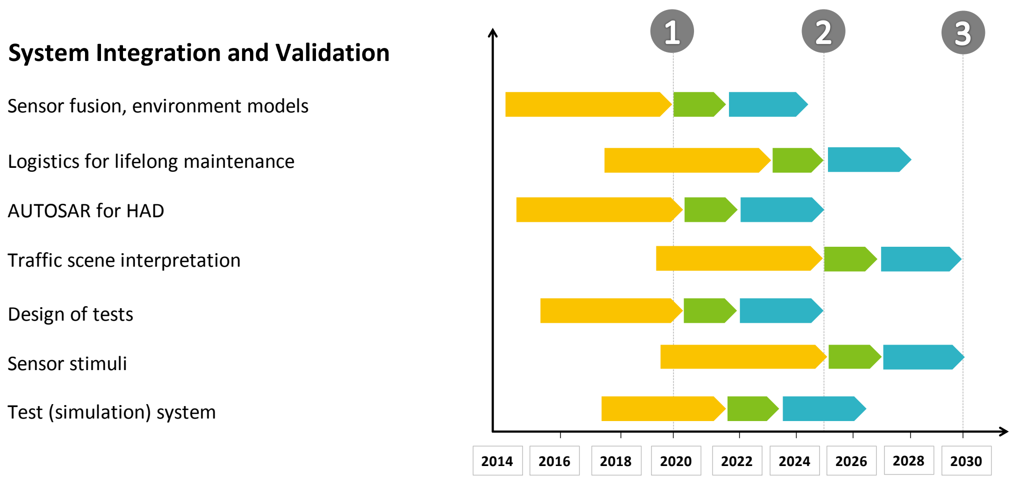
5.4.2 Infrastructure



5.4.3 Big Data



5.4.4 System Integration and Validation



5.4.5 System Design

System Design

Improve adequacy and efficiency of reliability / robustness test strategies (physics of failure, combined loads)

Comprehensive understanding of failure mechanisms

Implementation of virtual techniques (testing, FMEA, prototyping)

Validation technology

Data base for use cases

5.4.6 Standardization

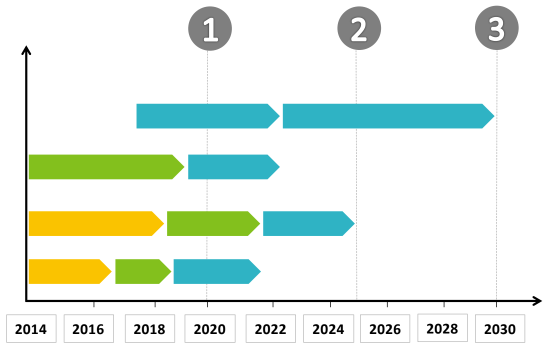
Standardization

Vehicle certification (market access, UNECE)

Traffic signs (signalisation)

Car2X signals

Vehicle functions (steering and lighting systems)



5.4.7 Legal Frameworks

Legal Frameworks

Adjustment of regulations (UNECE)

Road traffic regulations (Vienna Convention)

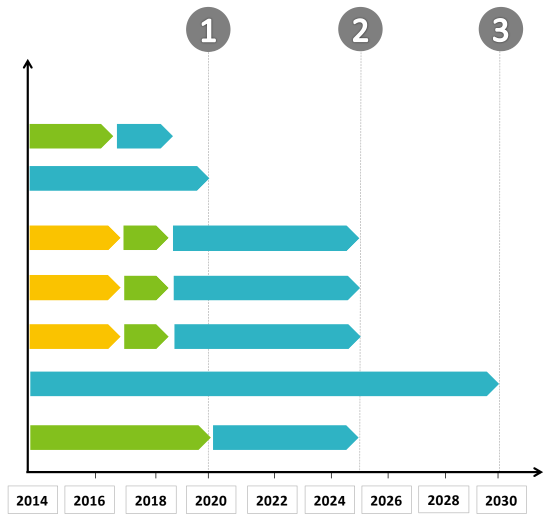
Data privacy of the driver

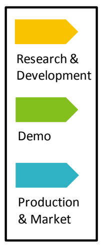
Data security

Data ownership

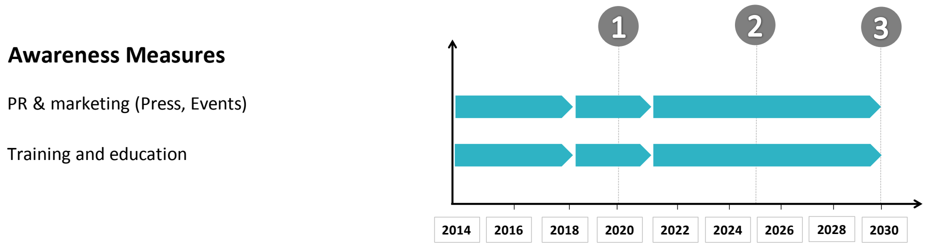
Ethical decisions

Product safety





5.4.8 Awareness Measures



6 Recommendations

Based on the roadmaps presented in Chapter 5 of this document, recommendations can be made on what actions in R&I and beyond need to be taken by when in order to achieve the milestones for the introduction of higher levels of automated driving in Europe. For the short to medium term, those recommendations can be summarized as follows

- Further **technological progress in smart systems for automated driving** is needed and should be supported through the funding of focused industrial and academic R&D projects in Horizon 2020. This particularly applies to technologies enabling higher degrees of automated driving (SAE Level > 2) like sensors and sensor fusion for environmental and driver monitoring, components meeting legal requirements, subsystems providing redundancy, functional safety, and reliability, and the concepts for smart integration into vehicle architectures as well as reliable and secure data communication. Eventually this progress shall lead to more affordable automated vehicles, thus accelerating the market uptake and strengthening Europe's leadership position in the automotive industry. Particularly for more revolutionary scenarios of highly automated driving in cities and fully autonomous driving, better connectivity of vehicles and their integration into the Internet of Things will require large scale actions.

- A vital obstacle that needs to be overcome is the lack of an appropriate **legal framework for both testing and use** of higher degrees of automated driving in Europe. Firstly, this concerns the fast adoption of the modified Vienna Convention into national practice which would enable European countries to keep up with competing regions. Secondly, legal issues and regulations, as e.g. liability in case of accidents, and data security and privacy in the cloud, are of the highest priority for insurance companies. Harmonization of laws and smart solutions like an insurance fund are therefore of great importance for an acceptance of automated driving in general, and particularly for autonomous vehicles. Thirdly, ethical issues of decision making by machines have to be considered.

- Additional significant effort is required to create **new concepts and test-systems for validation** of complex AD system in simulated environments. All relevant safety critical situations have to be tested as quickly as possible. Also the effect of varying sensors and actuators, varying road conditions, varying traffic partners or implementing novel AD concepts must be covered.

- Also **Field Operational Tests** are of the high importance particularly for showcasing safety, security and reliability of highly automated driving at SAE levels 3 and 4. This primarily would support revolutionary approaches towards the development of urban and fully automated driving, but it would also strengthen the development and implementation of automated driving in an evolutionary approach e.g. on highways. The dissemination of best practices for the implementation of automated driving is highly recommendable for demonstrating its societal, economic and ecological benefits. Such actions would have a strong impact on promoting the unique selling proposition of automated vehicles made in Europe.

- Moreover, there is a significant need for **creating synergies between involved sectors** (i.e. vehicle manufacturers, energy, communication services and providers, transport, IT and smart systems sectors, as well as users) that are coming together in the novel value chains for automated vehicles. Standardization and harmonization issues that are unavoidable concerning technologies in- and outside the vehicle should be included in projects, for the purpose of facilitating market introduction and distribution of research results. Harmonization of standards is needed in order to avoid fragmented solutions and loss of public funding as well as industrial investments.

- For a targeted European action it is fundamental that the **Commission takes a leadership** role the approach towards an introduction of automated to fully automated vehicles. The respective DGs of the European Commission and the involved stakeholders should collaborate in developing a **joint implementation strategy** e.g. in the framework of the Strategic Transport Technology Plan (STTP).

- As already practiced with great success in other domains, the industry, utilities, infrastructure providers, academia and public authorities should join their efforts in specific Public-Private Partnership and joint programs horizontally covering all aspects of automated driving including research and innovation. These should be supported by targeted **coordination and support actions**, e.g. on technology transfer from robotics and semiconductor technologies, or on the assessment of global value chains in automated driving from a European perspective. It is also essential to create parallels and coherences between the programs at European Union and Member States level, in order to extend the perspective beyond research and development, towards innovation and implementation of automated driving in Europe.

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Appendix I: EU Projects List

Category	Acronym	Name	Duration	Purpose / Keywords
Robot car	CityMobil	Towards Advanced Road Transport for the Urban Environment	02/2004-01/2008	Safety applications and technologies: safe speed and safe following, lateral support, intersection safety, active 3D sensor technology for pre-crash and blind spot surveillance
	PICAV	Personal Intelligent City Accessible Vehicle	08/2009-07/2012	Passenger transport, urban traffic, car sharing, networking, assisted driving, vulnerable road users
	CATS	City Alternative Transport System	01/2010-12/2014	Robotic driverless electric vehicle, passenger transport, transport management, urban transport
	V-Charge	Automated Valet Parking and Charging for e-Mobility	06/2011-09/2015	Autonomous valet parking, EVs coordinated recharging, smart car system, autonomous driving, multi-camera system, multi-sensor systems
	FURBOT	Freight Urban RoBOTic vehicle	11/2011-10/2014	Fully electrical vehicle for freight transport in urban areas, robotics
	CityMobil2	Cities demonstrating automated road passenger transport	09/2012-08/2016	Automated road transport system, automated vehicle, driverless, urban transport, safety, infrastructure, legislation
Driver assistance systems	PReVENT	Preventive and Active Safety Application	02/2004-01/2008	Development and demonstration of preventive safety applications and technologies (advanced sensor, communication and positioning technologies); subproject Response 3
	HAVEit	Highly Automated Vehicles for Intelligent Transport	02/2008-07/2011	Automated assistance in congestion, temporary auto-pilot
	MiniFaros	Low-cost Miniature Laserscanner for Environment Perception	01/2010-12/2012	Develop and demonstrate innovative low-cost laserscanner
	MOSARIM	MOre Safety for All by Radar Interference Mitigation	01/2010-12/2012	Interference mitigation, automotive short-range radars
	2WideSense	WIDE spectral band & WIDE dynamics multi-functional imaging SENSor ENabling safer car transportation	01/2010-12/2012	Development and testing of next generation imaging sensors, new camera systems
	interactIVe	Accident avoidance by active intervention for intelligent vehicles	02/2010-06/2013	Development of safety systems supporting the driver (joint steering and braking actuators)
	AdaptIVe	Automated Driving Applications and Technologies for Intelligent Vehicles	01/2014-06/2017	Automated driving, cars, trucks, motorways, transport in cities, close-distance manoeuvres; subproject Response 4 (beyond ADAS)

Category	Acronym	Name	Duration	Purpose / Keywords
Connectivity & Communication	**COM2REACT**	Cooperative Communication System to Realise Enhanced Safety and Efficiency in European Road Transport	01/2006-12/2007	Road and in-car communication systems, cooperative system, involvement of two-way communication systems: V2V and V2I, contribution for standardization and harmonization throughout Europe
	SAFESPOT	Cooperative Systems for Road Safety	02/2006-01/2010	Implementation and demonstration of V2V-based technology, Local Dynamic Maps, multi-sensor data fusion
	COOPERS	Co-operative Networks for Intelligent Road Safety	02/2006-01/2010	Development of intelligent transport systems (ITS), I2V technology, co-operative traffic management
	CVIS	Cooperative Vehicle-Infrastructure Systems	07/2006-06/2010	Development of a technology platform that provides wide-ranging functionality for data collection, journey support, traffic and transport operations and driver information.
	Intersafe2	Cooperative Intersection Safety	06/2008-05/2011	Development of a Cooperative Intersection Safety System (CISS) – detection of static and dynamic components of the traffic environment.
	ISI-PADAS	Integrated Human Modelling and Simulation to Support Human Error Risk Analysis of Partially Autonomous Driver Assistance Systems	09/2008-08/2011	Joint Driver-Vehicle-Environment Simulation Platform, prediction of driver errors in realistic traffic scenarios, driver modelling, Human Error Risk Analysis
	SARTRE	Safe Road Trains for the Environment	09/2009-10/2012	Development of strategies and technologies allowing vehicle platoons to operate on public highways – introduction of the vehicle platoons concept
	DRIVE2X	DRIVing implementation and Evaluation of C2X communication technology in Europe	01/2011-12/2013	Creation of harmonized Europe-wide testing environment for cooperative systems, promotion of cooperative driving
	FOTsis	European Field Operational Test on Safe, Intelligent and Sustainable Road Operation	04/2011-09/2014	Intelligent transport systems, electronic stability control, cooperative I2V & V2I technologies, emergency management, safety incident management, intelligent congestion control, dynamic route planning, infrastructure safety assessment
	ARTRAC	Advanced Radar Tracking and Classification for Enhanced Road Safety	11/2011-10/2014	Generic detection system, detect low-friction road sections, automatic braking, VRU safety technologies, radar hardware, software and performance-related algorithms

Category	Acronym	Name	Duration	Purpose / Keywords
Connectivity & Communication	**79GHz**	International automotive 79 GHz frequency harmonization initiative and worldwide operating vehicular radar frequency standardization platform	07/2011-06/2014	Global harmonization, 79GHz band, automotive short-range radars
	Compass4D	Cooperative Mobility Pilot on Safety and Sustainability Services for Deployment	01/2013-12/2015	Forward collision warning (FCW), red light violation warning (RLVW), energy efficient intersection service (EEIS), cooperative system, standardization cooperation
	AMiDST	Analysis of Massive Data STreams	01/2014-12/2016	Big data, stream processing, software development, automotive
	COMPANION	Cooperative dynamic formation of platoons for safe and energy-optimized goods transportation	10/2013-09/2006	Application of platooning on heavy-duty vehicles; concepts development for platoon applications in daily transport operations (off- a on-board systems for coordinated platooning, multimodal user interfaces)
	AutoNet2030	Co-operative Systems in Support of Networked Automated Driving by 2030	11/2013-10/2016	Development and testing of a co-operative automated driving technology with a time-horizon between 2020 and 2030.
Networking/ Challenges	**BRAiVE**	BRAin-drIVE	2008	A prototype vehicle development by VisLab, designed for the testing of concepts, sensors and specific HMIs. The prototype was also used for the design of new ADAS.
	Nearctis	Network of Excellence for Advanced Road Cooperative Traffic Management in the Information Society	07/2008-06/2012	Academic network for traffic management and optimization with focus on cooperative systems able to cope with safety, energy consumption, environmental impacts and congestion.
	VIAC	VisLab Intercontinental Autonomous Challenge	07/2010-10/2010	Challenge conceived by VisLab as an extreme test for automated vehicles.
	VRA	Support action for Vehicle and Road Automation network	07/2013-12/2016	Should create a collaboration network of experts and stakeholders working on deployment of automated vehicles and its related infrastructure.
	GCDC	Grand Cooperative Driving Challenge	10/2013-10/2016 (annually)	Is arranged by the i-GAME project that is aiming at speeding up real-life implementation and interoperability of wireless communication based automated driving.