Belmonte, F. J., Martín, S. Sancristobal, E., Ruipérez-Valiente, J. A., Castro M. (2020). Overview of embedded systems to build reliable and safe ADAS and AD systems. IEEE Intelligent Transportation Systems Magazine (In press).
https://doi.org/10.1109/MITS.2019.2953543

https://ieeexplore.ieee.org/document/8995493

Overview of embedded systems to build reliable and safe ADAS and AD systems

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***Abstract*— Automotive industry is a key sector in developed countries, taking advantage from Electronic and Semiconductor industries, for which this work is focused on, including an overview of embedded systems and related technologies for Advanced Driver Assistance Systems (ADAS) development, end user applications and their implementation (SoCs, Application Processors-APs, MCUs, software and boards), manufacturers solutions, architectures, trends and other aspects (like methodologies) to improve functional safety, reliability and performances. The current status to permit the transition from ADAS to Autonomous Driving (AD) systems and Self-Driving Cars (SDC) is also explored.**

***Index Terms*—ADAS, Advanced Driver Assistance Systems, AD, Autonomous Driving, Driverless Automotive, DSP, Digital Signal Processor, Functional Safety, GPU, Graphic Processor Unit, LRR, Long Range Radar, MCU, Micro Computer Unit, SDC, Self-Driving Cars SRR, Short Range Radar, SoC, System-On-a-Chip, AI, Sensor data fusion, DNN, Deep Neural Networks, VANETs**

I. Introduction

THE automotive industry, as one of the key sectors for developed countries, is continuously looking for new technologies [1][2][3], devices and subsystems, in collaboration with top electronic industry partners, which can reduce or, even, avoid the number of traffic fatalities and their severity [4], maintaining the reliability, comfort, consumption, environment impact and driving performances [5].

Throughout the last decades previous innovations have already contributed to this objective, like the multiple airbags, anti-lock braking systems (ABS) and electronic stability programs (ESP) [5].

Few years ago, new features like radar, LiDAR (light detection and ranging), camera-based systems, advanced computation and other digital and image-processing devices were introduced to make driving more comfortable, reliable and safer. Many of these ADAS applications [6], like adaptive cruise control, lane departure warning, traffic sign recognition and others, have been until now mainly complementary features, with a minimal influence on the vehicle and its direct driving behavior [5].

All these new technologies, are taking now a more active role in the control of the car and the driving itself, with applications like Lane Keep Assist (LKA), automatic emergency braking (AEB), Adaptive Cruise Control (ACC), Collision avoidance, parking assistance, lateral and longitudinal control, to achieve the intended goals, without creating an increased risk to the driver and occupants of the vehicles [2][5]. Some examples of such driver assistance systems applications can be seen in Figure 1 [7].

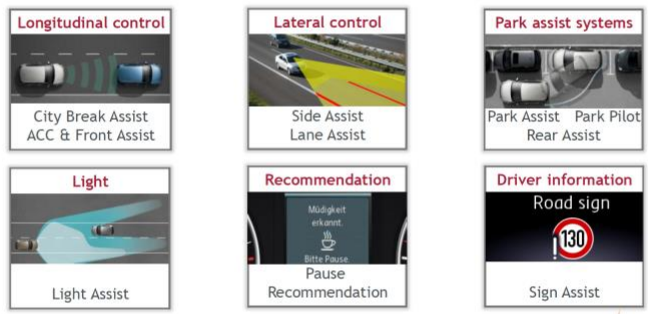

Fig. 1 Examples of ADAS/AD Systems applications [7]

Different international standards organizations (SAE, ISO, NHTSA, etc.) [7][8] are helping to define a set of autonomous driving levels, functional safety levels and other requirements and characteristics for ADAS and Autonomous Driving systems, also providing a common terminology [1] [3][9][10].

The present work will introduce some of those definitions, applications and technologies, exploring a bunch of current and future alternatives offered by different manufacturers with an important role in the electronic industry.

II. From ADAS to AD Systems: Concepts and Definitions

A. ADAS Definition and concepts

There is not a single definition of the acronym, one of the more representative ones can be [11]:

"An ADAS is a vehicle control system that uses environment sensors (e.g. radar, laser, vision) to improve driving comfort and traffic safety by assisting the driver in recognizing and reacting to potentially dangerous traffic situations. Since an ADAS can even autonomously intervene, an ADAS-equipped vehicle is popularly referred to as an 'intelligent vehicle'".

Advanced driver-assistance systems, or ADAS, are systems, which assist and help the driver in the driving process. If they are designed with functional safe and reliable human-machine interface, they should improve car safety, performance and road driving safety.

As general utilization, ADAS are systems developed to automate/adapt/enhance vehicle systems for safety and better driving [11], including smart parking solutions [12].

Safety features are designed to avoid collisions and accidents by offering technologies that alert the driver of potential problems, or to avoid collisions by implementing safeguards and taking over control of the vehicle, while, other adaptive features may automate lighting, provide adaptive cruise control, automate braking, incorporate GPS/ traffic warnings, connect to smartphones, alert driver to other cars or dangers, keep the driver in the correct lane, or show what is in blind spots. ADAS relies on inputs from multiple data sources and sensors, including automotive imaging, LiDAR, radar, image processing, computer vision, and in-car networking [11].

In Figure 2 has been included, as example, a flow chart to explain how different functions (and technologies) are required to process an acquired image and use it in the end ADAS (or AD system) application.

Additional interactions are possible from/to other sources/destinations separate from the primary vehicle platform, such as other vehicles, referred to as Vehicle-to-Vehicle (V2V) [29], Vehicle-to-Infrastructure (V2I), such as mobile, data networks) systems [14], Vehicle-to-Network (V2N), Vehicle-to-Pedestrian (V2P) or other complementary systems, working in a structured and well-defined cooperative operation [2][15][16][17][18][19].

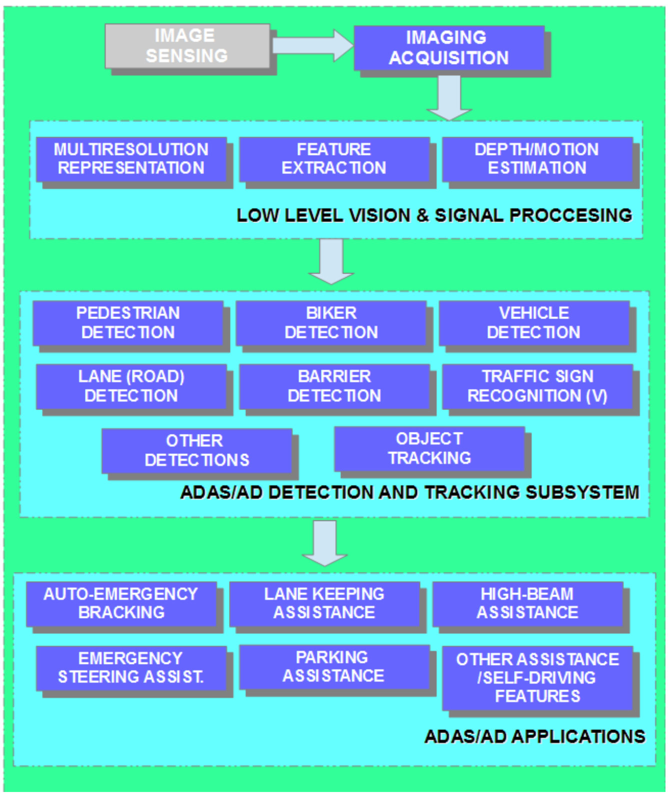

Fig. 2. Image Sensor ADAS Applications flow chart (adapted from [6])

In Figure 3 different ADAS technologies grouped by computation types [20][23] (Audio, Active/Passive Vision, Radar and Fusion DSPs) are shown [31].

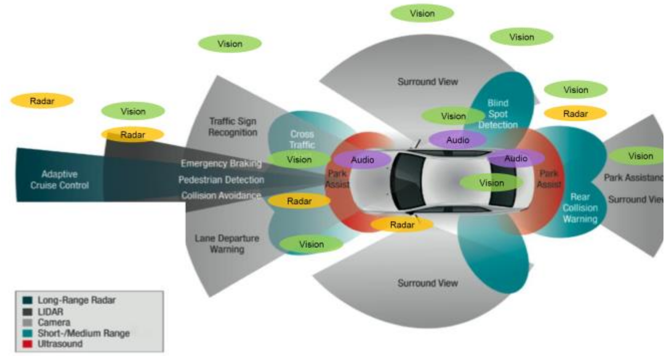

Fig. 3. ADAS Technologies grouped by DSP areas (Credit:[20] [23] [31])

B. *AD System Definition and concepts*

A representative definition for AD can be: "A*utomated or autonomous driving systems are complex combinations of various components that can be defined as systems where perception, decision making, and operation of the automobile are performed by electronics and machinery instead of a human driver, and as introduction of automation into road traffic. This includes handling of the vehicle, destination, as well as awareness of surroundings. While the automated system has control over the vehicle, it allows the human operator to leave all responsibilities to the system*" [7][25][26].

Automated driving implies that the driver has passed the driven control (i.e., all appropriate monitoring, agency, and action functions) to the vehicle automation system, maintaining, at the same time, an alert status and ready to take action at any moment, giving up still the ability to the automation system [7][25][26].

Automated driving (AD) systems can be found also as conditional, which implies that the automation system is capable of automated driving, but not for all conditions encountered during normal operation [7][25][26].

C. *Automation driving levels*

Table I summarizes AD levels from different references and standards [10], identifying until six levels of driving automation from "no-automation" to "full-automation".

Table I. Comparison of several levels of automation [10][31][60][88]

Aut. Level	BASt expert group	NHTSA	SAE J3016	Role of the Driver	ADAS/AD Examples
0	Driver only	Level 0 - No Automation	Non-Automated	Full control	Information and Warning systems
1	Assisted	Level 1 - Function-specific Automation	Assisted	Permanent Monitoring. Resume Control at any time.	CC, ACC, LKA, ESC
2	Partial automation	Level 2 - Combined Function Automation	Partial Automation	Permanent Monitoring. Resume Control at any time.	ACC, LANE Keeping, TJA
3	High automation	Level 3 - Limited Self-Driving	Conditional Automation	Monitoring Not Required. Resume control Required after a certain lead time.	Lateral and Longitudinal Control
4	Full Automation	Level 4 - Full Self-Driving Automation	High Automation	Resume Control may be asked, but not Required	Lateral and Longitudinal Control
5	N/D		Full Automation	Driverless Vehicle (SDC)	Lateral and Longitudinal Control

III. Functional Safety and Autonomous Driving Levels

With respect to Safety, one of the main objectives introduced has been the so-called “vision zero”, which refers to the goal of eliminating traffic fatalities and injuries by 2050 [29].

Safety is also addressed in the transport roadmap, although it receives considerably less attention compared to other issues, such as competitiveness, sustainability, resource-efficiency, or, innovation. It is mentioned as the ninth of ten goals of the transport roadmap, aiming by EU to reduce at half road casual-ties by 2020 [29] [31]. Other legal aspects and regulations are covered in references [1][3][9][14].

A. Automotive Functional Safety

As far as the complexity of ADAS and AD is arising the automotive industry and standards organizations have increased the efforts to provide safety-compliant systems. For instance, if current automobiles want to use by-wire systems such as throttle-by-wire (i.e. when the driver pushes on the accelerator and a sensor in the pedal sends a signal to an electronic control unit, with a control unit analyzing several factors such as engine speed, vehicle speed, and pedal position and relaying a command to the throttle body) it is a challenge of the automotive industry to address it at system level [19], test and validate it [29][31].

A main goal of ISO 26262 [31] and similar international and national standards is to provide unified safety standards for all automotive E/E systems. Implementing ISO 26262 and derived normative and rules, allow leveraging a common standard to measure how safe (and probably, also reliable) a system will be in service (Figure 4). It also provides the ability to reference specific parts of the system as a common vocabulary is provided by the standard. This falls in line with other safety-critical application areas; for which a common standard provides a way to measure how safe (and secure [32]) your system is [36].

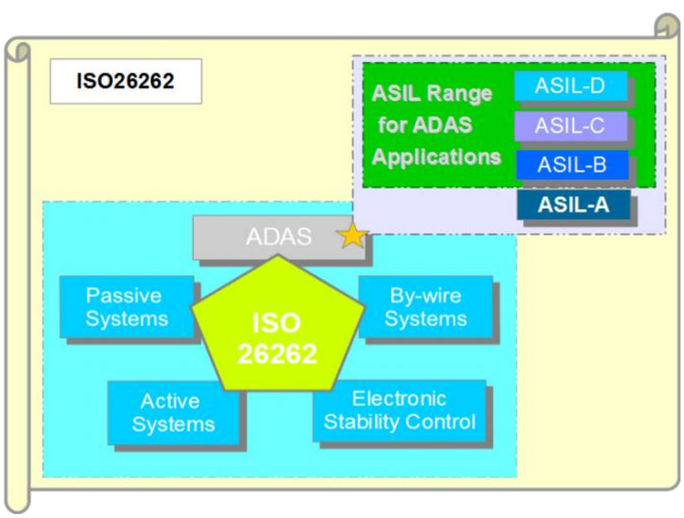

Fig. 4. ISO26262 Automotive Functional Safety areas with ASIL range

B. Safety Requirements and ASIL

ISO 26262 uses a system of steps to manage functional safety and regulate product development on a system, hardware, and software level. It provides regulations and recommendations throughout the product development process, from conceptual development through decommissioning. It details how to assign an acceptable risk level to a system or component and document the overall testing process, through the definition of a safety lifecycle and risk classes (Automotive Safety Integrity Levels, ASILs) [31].

Apart from other performance and functional requirements, ADAS (and AD Systems) applications and technologies need to meet specific functional safety requirements. In 2011, with this purpose, a new standard for passenger vehicles up to 3.5 tons was introduced, also to minimize the risk of a malfunctioning system to create a dangerous and non-controlled situation. This standard, ISO26262, tries to address the reduction of systematic faults by implementing a rigorous design process as well as detection of random hardware faults during the application execution. It covers the analysis and development of a system or multiple systems. It also outlines guidelines for individual hardware components used in the system, including potential software running on those hardware components, by specifying requirements for the entire safety lifecycle of the product [5] [36].

When a new application is identified, the designer must define specific safety goals with specific ASIL assignment to each of the goals, justifying them with feasibility and technical related arguments. The highest ASIL for this application usually defines the requirements to which the development and operation up to end of life of each component has to adhere. Figure 4 shows the current range of ASILs, seen from customer requirements, to which ADAS shall comply [5] [36].

Currently, ASIL-B is the lowest level in the market, but some applications require up to ASIL-D for certain functionality. With an increased ASIL come more stringent requirements, also is to be supported by the necessary figures of merit and reliability.

Both safety and reliability are crucial for the intended applications, however generalizing an ASIL on the component or even item (system) level may introduce unnecessary complexities in a specific implementation and can have impact on the cost and schedule of the development. It is sometimes advisable to look into the application requirements (functional, quality and dependability ones) in more detail. This is usually done by analyzing the system concept and deriving the safety concept and requirements from it. It may be possible to split the application into several different steps with varying ASILs and thus make it easier and more efficient to implement [5].

Anyway, a specific high-level analysis should look into more detail. A good example to achieve this level of detail for a mono front camera application can be found in [5].

IV. Manufacturers from Electronic Industry working for ADAS and AD Systems

A. Functional safety-oriented product families and design trends

A compilation of available ADAS (and AD systems) oriented product families (embedded HW and SW) has been summarized in Table II.

For each of these products and manufacturers we have included information about their coverage of Functional Safety (ASIL and automation levels, as per Table I and Figure 4) and possible ADAS to AD integration capabilities. Additional details, data-sheets, SoC and new processes technology [87], packages, field applications and characteristics can be also found in the compilation and references.

TABLE II.
ADAS & AD PRODUCT FAMILIES FROM SOME REPRESENTATIVE ELECTRONIC SECTOR MANUFACTURERS. [5][23][30][32][34][35][39][40][49][50] [51][52][53][54][55][56][57][58][62][63][64][66][67][68][69][70][71][73][74][75][76][77][78][79][80][81][82][89]

Manufacturer	Product Family (ADAS/AD)	Chipset / SoC	Technology	Functional Safety
Leddar Tech [leddartech.com/leddar core-ics/]	LeddarCore LiDAR SoC LeddarVu LiDAR platform LeddarOne Sensor Module Leddar M16 Sensor Module	LCA2, LCA3	Automotive 3D Solid State Flash LiDAR Automotive 3D HD Hybrid LiDAR	Yes [ASIL-B]
Bosch [www.bosch-semiconductors.com]	MEMS (SMA130, SMA131, SMG130, SMI130) Ultrasonic Transducer ICs (CA270, CA271) Radar Power Supply IC (CS520) Integrated airbag IC (CG904) System Base IC (CY324)	SMA13x, SMG13x, SMI13x CA27x CS52x CG90x CY324	Packages: QFN 5x5 (MLF28) TQFP64_ePad TQFP128_ePad	Yes
Toshiba [toshiba.semicon-storage.com]	Image recognition processors: TMPV75 and TMPV76 series Video decoders: TC9010x Screen Video Processors: TC9019x Functional Safety IP Library and MCUs (CoHOG Algorithms)	TMPV760, TMPV752, TMPV750 TC90105FG, TC90107FG TC90193ASBG, TC90195XBG, TC90197XBG TMPR45410TFG	32-bit RISC MeP and ARM® Cortex®-A9 MPCore ARM Cortex-R4	Yes [IEC61508 SIL3] [ASIL-D]
Renesas [www.renesas.com]	R-Car SoCs RH850 MCUs	R-Car 3 family R-Car 2 family R-Car 1 family	G3 (16 nm) G2 (28 nm) G1 (40 nm)	Yes
NXP (FreeScale) [www.nxp.com]	MR2001–77 GHz Radar Transceiver TJA108x FlexRay transceiver Qorivva MPC577xK	Qorivva MCUs and derived ones	FTF Technology (16nm FinFET process technology)	Yes [ASIL-B]
Texas Instrument [www.ti.com]	F/R Cameras (LRR) Surround View System (ECU) Ultra Short Range Radar Ultrasonic Park Assist Specific ADAS SoCs	Jacinto™ TDAx ADAS SoCs (Scalable HW & SW arch.) TDA3x SoC Processors	2 ARM Cortex-A15 cores 4 ARM Cortex-M4 cores 2 C66x DSPs 4 EVEs	Yes
Cadence IP [www.cadence.com]	Tensilica Vision DSPs Design IP and verification IP	Tensilica Vision ConnX DSP,	16 nm FinFET	Yes
Nvidia [www.nvidia.com]	DRIVE PX Xavier and Drive PX2 Dual mobile SoCs and dual discrete GPUs	DRIVE PX Xavier Tegra (Parker) SoC of the Drive PX 2 NVIDIA DRIVE™ PX AI car computers	TSMC's 16 nm FinFET+ process technology High Performance ARM	Yes
Intel [www.intel.com]	Intel GO Dev. Platform • Intel Atom processor • Intel Xeon processor - FPGAs (Intel Arria) - Infineon AURIX* MCUs - Elektrobit EB robinos - NCV81340 PMIC - NCV81341 Power ICs • AUTomotive Open System ARchitecture (AUTOSAR) SW	Intel Atom CPU Intel Xeon CPU	Power-efficient microarchitecture on Intel® 14 nm	Yes [ASIL-C] [ASIL-D] (AD level 4) (AD level 5)
Altera (Intel-FPGA) [www.altera.com]	FPGA as an SoC Processor and DSP	STRATIX ARRIA MAX CYCLONE	20 nm FPGA Intel 14nm Tri-Gate technology	Yes

On the other hand, automotive engineers must determine with this "state of the art" information how it can be implemented and whether processing the data from all of ADAS (or AD) subsystems should happen in a distributed (i.e. data processing is close to the sensor) or centralized (i.e. automotive head unit connected to each subsystem) manner[34].

The so-called failsafe multi-processors ADAS SoCs require an adequate software framework for runtime applications of monitoring and control [7][13]. In other cases are used Computer Aided Engineering (CAE) techniques to meet requirements imposed by ADAS [14][24], dedicated "Functional Safety" IP Libraries, MCUs and algorithms (see Toshiba row in Table II) or the development and implementation of new systems to improve perception, motion prediction and motion planning and control, through dedicated chips for AI (deep learning), integration of multiple sensors (sensor data fusion) and optimization of Deep Neural Networks (DNN) [20][22].

The benchmarking of these control systems for ADAS will help to select the most convenient for each purpose [28].

New opportunities for Semiconductor companies, as well as, current design trends for automotive electronics and sensors are described in references [41][45][46], including Autonomous Driving levels 4 and 5, as "Democratized AI" emerging technologies [47].

B. *Heterogeneous ADAS SoC Architectures and disruptive technologies*

In the final application (i.e. ADAS or AD) will be required a well-defined integration and implementation with other key automotive subsystems because of existing (or foreseen) heterogeneous ADAS SoC architectures, as the examples included in Figures 5 and 6.

A demonstration with a high-computing platform (MPP) intended to satisfy ADAS solutions for next generation vehicles is introduced in the reference [37].

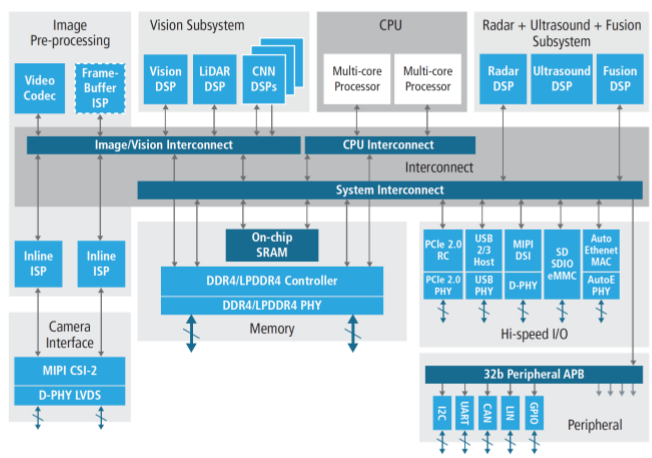

Fig. 5 Example of a generic ADAS SoC architecture [34]

One of the questions for coming processor/chip technologies and products oriented to ADAS and AD applications, apart from increased reliability, extensive ASIL/AD level

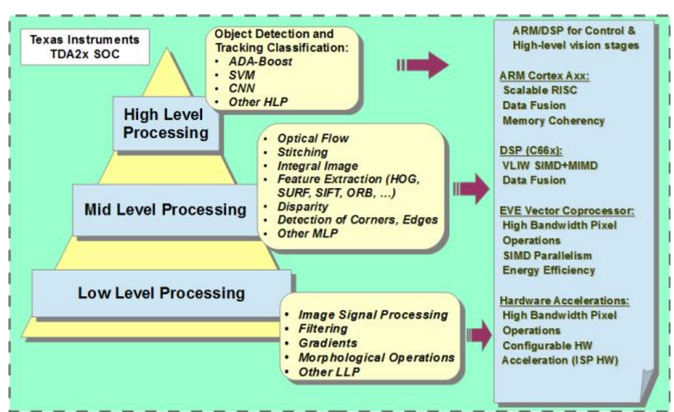

Fig. 6 Texas Instruments TDA2x SoC heterogeneous architecture (adapted from [55]

categorization (for intended target system) and higher computation per watt prepared for AI applications, is if they will follow the well-known Moore's Law, which is still considered by Intel as valid for next generations (i.e. in comparison with the new trends about No Moore's Law ones)[39][65].

From the same manufacturer, the "Intel Go Development platform" for AD systems is developed in two versions with Intel Atom or with Xeon processors [40], as it is shown in Figure 7.

The one based on Xeon processor, includes an integrated 16-port 10 gigabit Ethernet (10 GbE) switch which provides high-bandwidth Ethernet connectivity between two CPU boards and allows a large amount of sensor data to be received and mirrored across both CPUs, as well as to an external data logger.

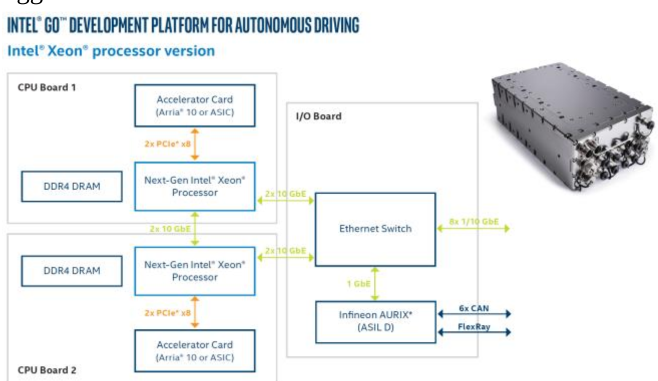

Fig. 7 Intel Go Development platform (Intel Xeon version) [40]

Infineon AURIX MCUs provides the required elements for the development of functional safety concepts and automotive connectivity via CAN and FlexRay© interfaces.

A separate camera interface box, featuring 12 GMSL camera ports to capture serial video streams and convert them from GMSL to Ethernet, are also available.

Apart from Electronic industry, other "Key Players" that can take benefits from Self-Driving Cars with AD technologies are included in the table III [10].

As vehicles become smarter, more autonomous, and better connected, hardware and software security becomes increasingly critical. Intel and other manufacturers deliver multilayered and proven security solutions for autonomous driving, from strong protection in and around the Electronic Control Units (ECU) to robust authentication for over-the-air (OTA) software updates and V2V/V2I communications. Other critical aspects to be considered in the security of ADAS and AD systems are covered in next sections.

TABLE III.
INDUSTRIES WITH BENEFIT FROM SELF-DRIVING CARS (SDC) (ADAPTED FROM [10][19][20])

TECHNOLOGY	PURPOSE	KEY PLAYERS
LIDAR	Obstacle detection and Collision Avoidance	Velodyne, Quanergy, Leddar Tech, ASCar Inc.
IMAGING SENSORS	Viewing objects Reading traffic signs and road marks Reading speed limits and warnings	Toshiba, Omnivision, ON Semiconductor, SONY
COMPUTER POWER	Si with greater computer power Low Power Consumption	Intel Corporation, Analog Devices, Qualcomm.
BIG DATA & SECURITY	Data Security Systems Traffic Monitoring Systems Communications Systems (V2x)	Google, IBM, Hadoop, IBM AREMA, Aspera, GM, BMW, Daimler, Honda, Audi, Volvo, Tesla Motors
ARTIFICIAL INTELLIGENCE (Deep Learning) & ROBOTICS	GPS, GNSS, Localization Maps, Cognitive Learning and Response, Augmented Reality (3D)	DeepScale, Google, Trimble, Tom-Tom, CSR, Intel (Nervana), Movidius, DEEPHi, MYTHIC, Novumind, Grop, Graphcore, Cambricon, Thinci, Wave Computing, Cerebras, Samsung, G, Facebook, Nvidia

With the arrival of new and disruptive technologies, to be used with ADAS/AD systems, as global Cellular Vehicle-to-Everything (C-V2X) products, standardization and certification are essential to ensure a successful deployment. With such purpose, the Global Certification Forum (GCF) and 5G Automotive Association (5GAA) are collaborating to merge their resources and expertise to accelerate the introduction and to harmonize C-V2X at a global level [41].

Another representative example, presented as core component for next intelligent transportation systems, are the Vehicular Ad-Hoc Networks (VANETs), which will be used for safety and non-safety applications, through real time data collection, optimization of Traffic Aware Protocols (TAR) in different traffic density scenarios and the use of new electronic assemblies to have reliable and efficient communications (V2V, V2I, V2X) [41][42].

Artificial intelligence (AI) can be considered as a key knowledge-driven enabling technology, to be applied in autonomous vehicle development, testing and validation, through devices (e.g. dedicated AI processors with better computation-per-watt than traditional GPUs) used in embedded systems (with more sensors and specific SW frameworks), optimized IT infrastructure (big data with more efficient servers and communications) and other discrete technologies (DNNs, deep intelligence, etc.), which will work together to permit image and voice recognition, data processing, motion detection and driving control with safer and shorter response times for different road and traffic conditions [21][22][48]. Some key companies can be found in Table III.

C. ASICs/FPGAs in ADAS/AD Applications

The ASIC (Application Specific Integrated Circuit) and FPGAs (Field Programmable Gate Arrays) can be considered as one of the more flexible devices to implement and support new ADAS and AD applications, probably with specific AI features, considering compliance with functional, safety and dependability (availability, reliability and maintainability) requirements, at short-term development schedules.

An optimal compute architecture will depend on different use-cases (processing speed, HW interfaces, processing per watt, backward compatibility, flexibility, form factor, required technical capabilities, etc), which are very important for ASICs, FPGAs and GPUs used in Autonomous Driving [48].

In particular, Intel FPGAs division (former Altera) and product families (Table II) are helping with rapid advancements in driver assistance technology and addressing some key challenges [50] [52].

V. STUDIES, TRENDS AND IMPACT OF ADAS & AUTONOMOUS DRIVING

A. ADAS/AD Safety related International Studies

Different studies and reports have been completed by organisms in Europe [25][27][38][59], North-America

[4][8][9][26][31][83][85], Asia [4] and Australia [4] to help manufacturers in both, automotive and electronic sectors, in the development and introduction in the market of respective AD products [61][72].

A good initiative was the creation of a Code of Practice (CoP) by the European Commission, which comprised a suitable ADAS description concept including ADAS specific requirements for system development, summarizing best practices and methods for risk assessment and controllability evaluation [90].

More recently, in the frame of United Nations (UN) World Forum for Harmonization of Vehicle Regulations (WP.29) some objectives have been set to initiate and pursue actions aimed at the development or worldwide harmonization of technical regulations for vehicles, dedicated also to the preparation of regulatory proposals on active safety, braking and running matters. It was completed with a report [38], which included different tasks, review of State of the Art, best practices with respect to regulation of complex automated systems in other industries/sectors and specific implementation examples (e.g. Mercedes Benz LCA, Tesla Autopilot, Volvo IntelliSafe Autopilot).

B. Analysis of critical aspects in ADAS/AD systems

The analysis of critical aspects in design and implementation is key to ensure the ADAS and AD systems can be operated and used in safe, secure and reliable way, so, there are several challenges to design, implement, deploy, and operate them. These systems are expected to gather accurate input, be fast in processing data, accurately predict context, and react in real time, while maintaining a certain degree of robustness, security, reliability and processing speed (including low error rates). A significant amount of effort and research in the industry is required to solve all these challenges and to develop the technology that will make ADAS and AD systems a reality [32] with sufficient level of maturity and confidence.

The review of safety testing processes in other industries (railway, nuclear, process, machine and aviation) found that the main standards were, in principle, similar to the ones to be considered in automotive industry, with:

- Hazard identification and risk assessment
- Setting of safety requirements (goals)
- Verification of safety requirements

From safety assurance perspective of electrical/electronic/programmable electronic systems, the review showed that an assessment of the development life cycle (including considered processes and standards and verification of safety requirements) were considered necessary as part of the regulatory requirements [38]. Additional conditions and requirements to ensure system functionality is safe (maintaining other performances and reliability requirements) and secure in all real world-driving scenarios must be also reviewed [32].

ADAS and AD systems provide assistance to the driver and improve driving experience, helping or replacing the human depending on the implemented AD level. Its primary function is to ensure safety of the vehicle, the driver, other vehicles and the pedestrians or bikers. To function in a real driving environment ADAS and AD systems must be able to recognize objects, signs, road surface, and moving objects on the road and to make decisions whether to warn or act on behalf of a driver [32].

In addition to functional requirements, ADAS and AD systems must be secured from adversaries with malicious intent whose goal is to compromise the system and cause catastrophic accidents with loss of life and damage to property [32].

Security aspects, as complementary to safety ones, should be considered as a fundamental non-functional requirement (together with reliability, robustness, performance, and low error rates), so a vulnerability analysis should be performed in a conceptual ADAS architecture through representative use cases. Based on such analysis results, both, security requirements and recommendations on countermeasures against malicious (or unintended) attacks will be defined, as well as for other adaptative security and QoS design challenges [33].

On the other hand, while current anti-jamming techniques can be considered adequate today, with the extended use of automotive radar sensors, in a "Potential Urban Electronic Battlefield", more resilient mitigation is needed, including time/frequency domain signal processing, complex radar waveforms analysis and new adapted jamming avoidance techniques [41].

Several good examples of ADAS threats, requirements and required security solutions have been considered (also applicable to AD systems) in the white paper [31] with different use cases. One of these use cases is for the Adaptive Cruise Control (ACC) Usage Case, which refers to another specific function by the ADAS system that enables the vehicle to autonomously manage its moving speed, based on the following four sources of information:

- Current vehicle condition
- Driving condition and relative speed of leading vehicle
- Road conditions
- Driver's preference

The use of sensor data fusion (laser scanner, computer camera, context and inertial systems, stereo-vision, lidars, etc.), its scalability and related methodologies (models and algorithms) to provide robust and reliable safety applications for vehicles detection and collision avoidance, in different and complex road and inter-urban scenarios, has been explored in recent works [19][20][43][44][62].

In summary, to have safe, reliable, secure and efficient autonomous vehicle operations, is required an incremental and successful integration of several critical technologies (AI, deep learning, DNN, safety integrity oriented devices and methodologies, adaptative security and anti-jamming techniques, cameras and sensors data fusion, suitable network and IT infrastructures, VANETs, etc.) [21][22][33].

C. Implications and Trends of Driving Automation

Because the increasing and deployment of driving automation (through ADAS and AD) systems is expected an alteration of the historical roles of drivers, vehicle manufacturers, regulators, and law enforcement agencies in maintaining automotive safety with certain implications [61]. Technology Innovations and zero defects initiatives are also essential in ADAS & AD systems [23][29] [55].

Maintaining reliability, security and safety throughout this transition is an important concern. In order to support the development and deployment of driving automation technologies it is very important to consider and communicate the way in which these roles may change. The task of driving can be divided into three types of activities necessary to operate a vehicle:

- **Operational** behaviors such as longitudinal and lateral control as well as object and event detection and classification
- **Tactical** behaviors such as speed selection, lane selection, object and event response selection, and maneuver planning
- **Strategic** behaviors including destination planning and route planning

The operational behaviors of longitudinal and lateral control refer to the actions that drivers traditionally perform using closed-loop control of vehicle speed (using the accelerator and/or brake pedals) and position within the driving lane (using the steering wheel). Object and event detection, classification, and response refer to the perception of any circumstance relevant to the immediate driving task, and the appropriate reaction to such circumstance [61]. The examination of changes in the driver's role can become the basis for categorizing driving automation systems.

A complete justification of the key considerations and implications of future AD Systems or Self-Driving Cars development and description of required safe transitions from manual to automated driving, as well other implications to achieve reliability and safety goals, can be found in references [10][31][36][38][59][61][84][86].

Some of these implications have been already considered in the representation of current technologies applied in commercial cars, like the Tesla Model S [83] or the Google car [10]. However, IIHS (Insurance Institute for Highway Safety) has performed several tests to determine which car company, among their available models (Mercedes-Benz, Volvo, Tesla or BMW), has the safest implementation of Level 2 driver assistance (i.e. ACC plus active lane-keeping), but they were not able to conclude on it, noting "none of these vehicles are capable of driving safely on their own" [91].

Another survey research [92], focused on autonomous vehicles developed since DARPA challenges (i.e. equipped with system categorized with autonomy level 3 or higher), is describing typical SDC architecture and listing autonomous research cars.

The exploration of key technologies, including Artificial Intelligence (IA) with deep learning, and expectations, from traditional car manufacturers (as Ford or BMW, in collaboration with Intel and subsidiary Mobileye), to put in the market vehicles with level 3 (ADAS) and with capacity to get levels 4 or 5 (Figure 4), by 2021, is another challenge [22].

An estimation of the global market for cars, including Traditional, Semi-Autonomous and Self-Driving Cars is included in Figure 8 [10].

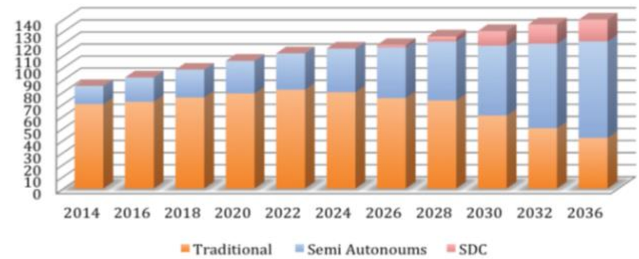

Fig. 8 Global Market for Traditional, Semi-Autonomous and SDC, in millions of units [10]

VI. Conclusions

The transition from ADAS to AD systems has already started, different manufacturers are offering their products and solutions or developing new ones, the standards organizations are defining rules, authorities (America, Europe, Asia, and Australia) have prepared studies and reports to anticipate potential issues and to improve the current and coming AD systems.

In the present work have been introduced some of the standards, design trends, features and examples required to build safe, reliable and secure traditional, semi-autonomous and self-driving or fully Autonomous Driving cars, with different levels of automation and human driver participation, exploring available ADAS and AD systems technologies, applications and product families from key actors in the Electronics and Semiconductor industries, already being used or to be integrated in next generation vehicles.

Current and future market needs will be satisfied through these technologies or new ones derived from them, keeping in mind are essential the respect to environment and energetic efficiency, the compliance with performance, reliability and functional safety requirements, as well as, other critical aspects, like maintaining security and integrity of the exchanged data between autonomous driving systems and services or information available in roads and cities, in a cooperative manner.

Acknowledgments

The authors acknowledge the support provided by the following projects IoT4SMEs (2016-1-IT01-KA202-005561), IoE-EQ (2017-1-IT01-KA202-006251), eMadrid project (P2018/TCS-4307) and the Grant 2019-IEQ13 of the UNED Industrial School.

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