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Integrated Components for Complexity Control in affordable electrified cars

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Table of contents

1 Executive summary

This document provides an overview of the 3Ccar Vision 2016 Málaga workshop, which captures the main messages coming out of the discussions and sets out how the consortium is going to build upon the momentum gained. The document provides an overview on 3Ccar project's five domains' (Power electronics and Powertrain & Motors; Cabin & Body and Storage systems & Batteries; Challenges and Human Factors & Ergonomics; System integration and Simulation, Verification & Validation; Control and Communication) discussions and visions for the future research and development, both during the 3Ccar project and beyond.

During this high-level event, consortium members shared the current and future research strategy for 3Ccar; listened to, collated and synthesised the views of the industrial and scientific community about how to achieve proposed solutions towards the more and more evolving electrification of all subsystems in cars; and engaged with each other about how scientific evidence is assimilated alongside other forms of evidence and how they can work together to find new and innovative solutions.

2 Publishable summary

3Ccar project aims to address the vehicle control architecture and its subsystems in order to achieve the next level of efficiency. With this aim in mind, the 3Ccar consortium is working collectively on advanced system designs with high local smartness and far extended network bandwidth to enable smart system partitioning and reduce the system complexity of EVs with positive effects on costs as well as maintenance, monitoring and updated functionalities.

The aforesaid aims are ambitious and far-reaching. Therefore, to develop suchlike semiconductor-based solutions, the 3Ccar brings together the critical mass for a multidisciplinary consortium with 50 partners from 11 countries covering the complete value chain from the semiconductor supplier up to the vehicle manufacturer. Needless to say, it is vital for such a diverse and leader-based consortium to have a robust shared vision, if we are to achieve the planned accomplishments.

That is why on the 9th and 10th of December 2015 the 3Ccar consortium members convened a meeting of over 40 scientists across a range of disciplines, active in the field of automotive and electro-motive research and industry, in Málaga. During this high-level event, consortium members shared the current and future research strategy for 3Ccar; listened to, collated and synthesised the views of the industrial and scientific community about how to achieve proposed solutions towards the more and more evolving electrification of all subsystems in cars; and engaged with each other about how scientific evidence is assimilated alongside other forms of evidence and how they can work together to find new and innovative solutions.

This report is a summary of the 3Ccar Vision 2016 Málaga workshop, which captures the main messages coming out of the discussions and sets out how the consortium is going to build upon the momentum gained

3 Non publishable information

Place non publishable information here.

4 Introduction & Scope

4.1 Purpose and target group

This document provides an overview of the discussions and presentations that took place during the 3Ccar project's first year engineering workshop in Málaga.

The report is targeted for the consortium and its domain representatives as an overview of their deliberations, as well as for the wider audience of stakeholders, who are interested in the direction that the electro-vehicle and semi-autonomous driving research and development is taking.

4.2 Contributions of partners

Explain which partner were involved and their activities in their various sections

TABLE 1: CONTRIBUTIONS

Chapter	Partner	Contribution
All sections	MB	Main author, elaboration and completion
5.4.5	TTT	Communications domain's feedback following the workshop
5.4.5	BUT	Control domain's feedback
5.4.5	Tecnalia	Control and communications domain's feedback following the workshop
5.4.5	ST	Control and communications domain's feedback following the workshop

4.3 Relation to other activities in the project

This report comprises information gathered from all Technical Work Packages (WPs) and Supply Chains (SCs) in the project.

5 Málaga meeting overview

5.1 The reason for the workshop

3Ccar project aims to address the vehicle control architecture and its subsystems in order to achieve the next level of efficiency. With this aim in mind, the 3Ccar consortium is working collectively on advanced system designs with high local smartness and far extended network bandwidth to enable smart system partitioning and reduce the system complexity of EVs with positive effects on costs as well as maintenance, monitoring and updated functionalities.

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5.2 Outline of the two meeting days

- Alberto Peña (Tecnalia): Welcome address
- Reiner John (Infineon technologies AG): Why we meet: Vivion for the 3Ccar project
- Presentations by Angel Aghili (President of AVELE), Rafael Lucena (MINETUR), Gernot Spiegelberg (Siemens), Joaquin Rodriguez (CATEC), Miguel Suarez (Axter Aerospace)
- Presentations by 5 Domains of the 3Ccar consortium and moderated talks
- Panel Q&A sessions
- Break-out groups: Multi-criteria analysis and facilitated discussions
- Presentation of 3Ccar dissemination and exploitation efforts
- Feedback and round-up

5.3 Purpose statement of the 3Ccar Málaga Engineering Workshop

• The "3Ccar Vision 2016"- Engineering Workshop was a high level event to bring cross domain requirements and expertise together.

• The intention is to discuss our proposed solutions towards the more and more evolving electrification of all subsystems in cars, including performance of electrical storages.

• We will discuss the steadily increasing complexity needed to fulfil functional integration, for further productivity and cost savings.

• We will analyse the path towards more safety such as fail operational requirements.

• There are customer needs which will be addressed by the next level of efficiency, giving range and predictable mileage. Where do we have to move when we integrate functionalities and furthermore applications?

• This creates more complexity which must be addressed by more holistic solutions, architectures and higher performance, realized by technologies.

5.4 Summaries of 5 Domains' presentations and discussions

5.4.1 Domain 1: Power electronics (Chargers, DC/DC Converters, Inverters) and Powertrain & Motors

Representatives from Domain 1, which is concerned with power electronics and powertrain and motor aspects within the 3Ccar project, started their discussion with a focus on the most pressing challenge for inverter products: power demand within vehicles is increasing – in fact it is at the very limits – and after these limits are crossed, numerous issues will arise. Possible solutions for this important challenge that were discussed were the following: ways to increase the voltage; near-wheel motors; recuperative breaking; power steering; electric suspension; sophisticated cooling systems

The aforesaid challenges and solutions were also discussed with their potential applications in other transport industries, not only the passenger cars: public transportation (busses, hybrid busses), agricultural and forestry vehicles, and small aircrafts.

To achieve a higher degree of the magnetic circuit and a more efficient thermal management, by gathering and utilizing the waste heat. Another overwhelming motion that was repeated throughout the discussion was that sensors have to be integrated practically everywhere; virtualization of the sensors may be one of the solutions, as well as life-time prediction sensors and increased software components, rather than hardware of the sensors.

The future vehicle was envisioned as a system encompassing the shift of control items towards a centralised cloud, with a number crunching unit within the car (the control strategy). In this context, cost-effective security and reliability features were noted as the key aspects to have a fail-safe operation.

5.4.2 Domain 2: Cabin & Body and Storage systems & Batteries

Second Domain's discussion kicked off with the information about the current state of the batteries: currently the best industry's commercially-available batteries offer 235watt-hour per kilogram, which is at about one fourth of the theoretical value. With this current state in mind, battery efficiency growth scenarios were discussed, encompassing expectations in energy density and expectation in costs were discussed.

The main challenges that were identified for the batteries' aspect of the 2nd Domain:

- Engineering challenges in battery pack design – the shapes of the cells, architecture of the packs, reduction of non-active material, thermal management
- Battery management systems' challenges: extending the lifetime, determining the state-of-charge and remaining useful life, and ensuring safety (safe operating area and voiding any risk of thermal runaway), with maximal cost-efficiency.
- Reliability of small cells vs. large cells

Creating a future battery – a battery made of smart cells, each of which will contain electronics that can perform all needed monitoring functions (starting from simple cell voltage and temperature measurements, up to more advanced functions like electrochemical impedance spectroscopy), and provide extended energy and useful lifetime.

One of the conclusions of the discussion was that the performance of the battery pack can be greatly improved and total costs of ownership can be reduced if cell and electronics are produced together.

Another important way of solving battery challenges in future vehicles that was discussed is improvement of the recuperation systems. If the energy that is within the mass of the car will be 100% recuperated (for example, the energy used for breaking/ slowing down, would be recuperated almost entirely) and the battery would only be used to accelerate the vehicle, then the batteries could be comparably very small.

In terms of the body and the cabin of the electrical vehicles, new design possibilities were envisioned. The fact that the electric car is a vehicle without the engine, there is no centralised mass which elevates the centre of gravity; secondly, as there is no central internal combustion engine, there is no need to thermal barriers and no centralised source of low and high frequency vibrations. These radical changes inspire the 3Ccar consortium to view the future vehicle not as a redesigned current car, but as an entirely new vehicle that is 'born electric'.

The new cabin and body structure must meet the future demands for lower energy consumption and the changed management of the available space.

The use of composite materials was discussed as a way to reduce the weight of the vehicles, as well as ways to make the new structures cost-effective and comfortable. In terms of the vehicle body, 3Ccar partners are looking for opportunities to harvest the energy of the body-motion. 2nd Domain representatives also described how the 3Ccar project is working on making the suspension intelligent, in order to address the challenges of the acoustics/noise and the comfort of driving (because with the lighter proposed structures of the future vehicles, the ride could become bumpy and noisy, if these challenges are not properly addressed within the vehicle's suspension).

Project participants are also researching car window's glazing options, use of solar panels, and organic photovoltaic parts, which would make the heating and cooling of the vehicle more energy-efficient. Pre-conditioning functions – both electrically and thermally – of the vehicle before the driver starts his/her journey, is also a part of the 3Ccar project's vision. The pre-conditioning functions are to be linked with the smart-phone app in the future. This 3Ccar's cluster is also working on heat tanks with stored energy for heating and isotropic behaviour models for the future vehicle.

5.4.3 Domain 3: Challenges and Human Factors & Ergonomics

Representatives from Domain 3, which is concerned with human factors, ergonomics, and future challenges within the 3Ccar project, addressed the more philosophical and behavioural aspects of the future vehicles.

The consortium believes that the human factor of scepticism – human habits – can be changed via education and advertisement, and the current trends in both Europe and Asia confirm this belief.

In the current situation, driving an EV still requires a lot of enthusiasm and commitment on the part of the driver/consumer, however the societal changes indicate a positive trend. Decision makers in the car industry were also addressed, as changing their perceptions and choices was identified as one of the most topical challenges.

Another important challenge, addressed by the 3Ccar partners throughout all their research activities is the price of the future vehicle. Currently, the vehicle users' attitudes are difficult to sway because electric cars are expensive to buy: compared to conventionally powered cars, the purchase price of an electric car can be anything from 15% to 50% higher. Production of EVs in larger numbers, governmental subsidies, raising awareness of the reduced running costs, free parking facilities in may towns, and higher resale values were discussed as ways to address the challenge of costs and change consumer attitudes.

The conclusion of this debate was the both the 3Ccar, and the automotive industry overall, has to make an "offer, which people will like to choose". To be widely accepted, the future technology-enhanced electric vehicles have to offer affordable, high technology, high functionality and be from a new kind of industry.

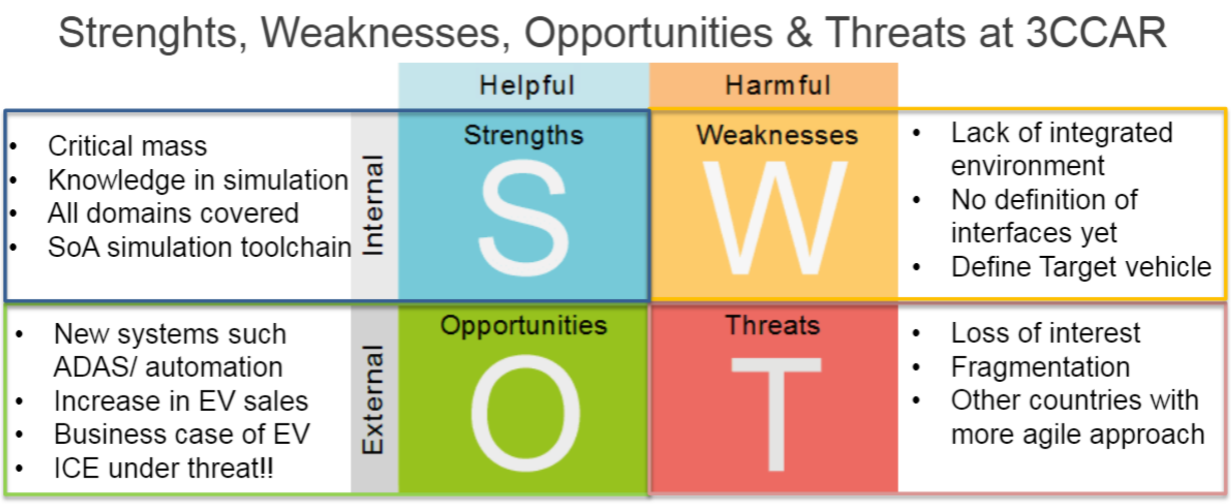
5.4.4 Domain 4: System integration and Simulation, Verification & Validation

The simulation aspects within the 3Ccar project are seen as a way to unify the domains, which allows a holistic and more unified approach. Simulation helps define a system, benchmark against competitors, foresee the costs, and avert risks.

Calculating the risks that come with the new components and incorporating the different driving cycles, driving styles, complex architecture: all these different aspects must be incorporated before the test in the most representative testing environment.

It is important to find the global optimum for different domains, not the local one; therefore the multi-domain approach was confirmed as the most important aspect of the 3Ccar work.

The Strength/ Weakness/ Opportunity/ Thread Analysis was discussed for the 3Ccar project, with the following result:



The future envisioned for the 4th domain's simulation was described as:

- Complex vehicle & system multi-domain models
- Real time operating atmosphere/environment
- 3D info from roads & city surroundings
- Virtual sensors, actuators and control algorithms
- Modelling of aging, wear and faults of elements
- Complex Artificial Intelligence for vehicles / traffic / pedestrians
- Challenging computing time
- Big Data for multidomainpost processing & re-design
- Cloud collaborative computing...
- Hardware, Human, Infrastructure,..XIn the Loop

4th domain's representatives agreed that with the current trend of transport moving from individual vehicles towards cyber-physical systems, holistic approach with detailed simulations (of nearly entire world) is needed.

In terms of the system integration and human-centred design architecture, the 3Ccar consortium debated on the overall notion that the 21st century is one of personal freedom, democracy and human empowerment; partners thus considered how new interaction tools for use on mobile platforms, virtual worlds and the internet of things are needed to distribute and democratise the automotive design process.

An interesting future perspective was envisioned for perception enhancement and user experience: the automotive industry could team up with the gaming industry, to gain valuable know-how. In the 21st century video and other games have demonstrated the addictive potential of well-designed sensory stimuli and cognitive tasks. Therefore, design strategies based on driving flow criteria and video game criteria can sharpen the driving experience and enhance brand satisfaction.

In terms of system integration, the consortium representatives noted that the first aspect of system integration is, paradoxically, disintegration. In other terms, to manage the system, its different components have to be looked at and their faultless functioning ensured, before the entire system is put together. Another important aspect of the system integration was the fact that different components of the system must be designed in a way as to not rely on one supplier. In avoiding such monopolisation of the system's parts, partners will cater to the future involvement of Small and Medium companies (SMEs) in the industry, as diversification will mean that they will be able to collect parts from different suppliers and stay competitive in the market. Essentially, this would keep the SME's independent from suppliers who manage the inverters.

5.4.5 Domain 5: Control and Communication

The high speed communication's supply chain within the 3Ccar follows an evolutional approach for both assisted and piloted functionalities of the future vehicle. In the automotive domain the current position on the way towards high automation of operation up to autonomous driving (SAE levels 4 & 5) is somewhere at the end of SAE level 3 starting into SAE level 4. ADAS systems start to provide functionality in highly safety relevant applications, such as braking assistants etc. But the "driver is still seated" and has to take the full responsibility. Most of the systems currently are operating "fail silently". In order to take the next steps an innovation towards "fail operational" behaviour has to be taken.

The communications supply chain noted that for their domain, the 3C#s of the 3Ccar stand in for: (a) Reduce number of on-board networks (b) Reduce number of wires/harness, (c) Increase reliability of networks, (d) Deterministic networks (scale linearly) vs. event driven approach (scales exponentially), (e) Make aerospace approach cost feasible for automotive (see highly automated/autonomous driving), (f) Provide platform approach making application independent from communication technology, (g) Provide Integration facilities and (h) Provide safe/secure wireless connections V2V, V2I.

The following challenges were identified for communications, and partners defined appropriate mitigations as summarized below.

Challenge	The way to overcome the identified challenge
High complexity of communication	Deterministic comm. backbone
Interference of applications (shared memory/timing)	BRR automotive Ethernet data communication
Integration problem	Platform based integration/partitioning
Wireless connection insecurity	New concepts and technologies
Safety challenges	Safety architecture / switched NW
Security challenges/hostile intrusions	Novel security concept

The Strength, Weaknesses, Opportunities and Threats analysis has been conducted for Communications, with the following results:

Strengths

1. High embedded know-how in EU
2. Highly advanced skills in high automation
3. Platform developments quite advanced
4. Good chances in EU's urban environments

Weaknesses

1. "Go for standards rather than for quasi standards" - destroys time advantage
2. Aiming at perfection prior to first release – not be first to market
3. Regulations / infrastructure development slow
4. No unified tax advantage against conventional car
5. Hesitance of "going for it"

Opportunities

1. New approach– new architectures
2. Less components- less cost of maintenance
3. Low center of gravity – cool road performance
4. Solves many of the environmental problems
5. China market – 5 years plan

Threats

1. US e-Vehicles (google, Tesla, Apple, …)
2. High prices in batteries eat up cost advantage
3. Low mileage dis-attracts customers
4. Low density in charging stations limit range
5. Different charging connectors cause problems
6. Not clear if eVehicle will make the race against hydrogen/fuel cell (Toyota!)

Within the 3Ccar project, the following break through opportunities were introduced: Centralized back-bone architecture implementation; Platform approach as quasi standard accepted in industry; Aerospace ideas in safety architectures successfully adopted for automotive use; Independence of application from integration and communication; Strict partitioning of applications in multi core architectures.

Partners working on the Communications also presented their vision for the year 2030 in automotive advancements:

a) eVehicles will have conquered 30% of the market (new registrations)

b) Architectures will be using centralized back-bone technology

c) Partitioning of applications will become a standard

d) Wireless technologies will provide safety/security services and applications will be widely spread

e) Regulations and taxes will support eVehicle purchase rather than punishing for "pollution" in combination with conventional cars (no difference between conventional cars and eVehicles)

In terms of Control, 3Ccar partners are facing the following challenges:

- To provide high-performance control platform at affordable price
  - High-speed signal processing (e.g. computer video for ADAS)
  - Implementation of advanced control algorithms (e.g. MPC for powertrain)
- To allow new functionality
  - Diagnostics of sensors, actuators, self-diagnostics of the control system
  - Fail-safe and fail-operational control

- Reduction of complexity while processing data from network of sensors located on relatively large area and controlling actuators on large area

The usual idea is to integrate the function of several independent controllers to one controller. However, this is a rather simplified view – network of sensors and actuators will remain the same and complexity of coordination of several control units would be simply transferred to complexity of signal/communication network between centralized controller and distributed sensors/actuators. It is necessary to concentrate not only on control units' integration, but also on the overall system design and its simplification (e.g. using techniques of virtual sensors where possible instead of use of redundant sensors).

It is expected that SW development in 3Ccar will be based on model-based approach with significant amount of automatically generated code. This approach has been already proved to be highly efficient in previous projects (e.g. MotorBrain), allowing rapid prototyping and testing of the designed algorithms as well as very flexible cooperation where individual modules are developed by different partners.

The control platform architectures discussed during this meeting are mostly based on combination of microcontroller with FPGA. Such architecture is very useful for practical applications (e.g. in powertrain control – time critical part of FOC and PWM generation handled by FPGA, while high-level control and diagnostics handled by microcontroller) and becomes the state-of-the-art solution in many industrial applications. However, it will also be necessary to take into account the interests of the semiconductor partners involved in the project and deliver solution based on available components used by automotive industry. This mean that two solutions for control platform will be developed – one more visionary for concept evaluation and another one closer to practical application.

Therefore, the key considerations for the Control domain following the meeting in Málaga are the following:

- Two target applications, each needing its platform:
    - CCU, state of the art Domain Controller;
    - Next-Gen domain controller (SoC)
- Aim to use MBD + automatic tools
- Importance of understanding requirements from other supply chains, but only to a point. Reasons:
    - Generic character of the obtained solution is desired
    - Inputs from other supply chains are not easy: WIP and uncertainty
- First and crucial step: state-of-the-art (very extensive work). Benchmarks and tool-chain follow.
- Conceive in a way to minimize dependency with development of powertrain others
    - Other supply chains develop, and afterward we eventually integrate functions into CCU

- Develop, prototype and demonstrate functionality using HiL setups
- Emphasize research on elaborate algorithms
- Evaluate appropriateness of automated tool-chains

6 Conclusion

6.1 Outcome of the 3Ccar Málaga Vision Workshop

Going forward, the 3Ccar consortium wants to build on the momentum of the workshop in bringing together the different domains into a community with one shared vision. Rather than separate the research themes according to discipline and expertise, the overwhelming suggestion within the 3Ccar consortium was that a multidisciplinary systems-based approach needs to be taken to developing a strategic overview and plan for going forward. The main conclusions following the workshop were the following:

- The 3Ccar consortium **needs to utilize its cross domain knowledge** and inspiration from different research areas and domains;
- Consortium partners wish to stipulate a **continuous discussion** which enables the utmost **understanding of the hurdles** from top of the application down to its separate components, such as semiconductors and batteries and even technologies;
- For sure, the extended discussions during this workshop were a successful experiment to understand and **translate 3Ccar's vision into its mission and objectives**. The detailed and **inspirational presentations** from the numerous leaders of the 5 domains were an excellent start for discussions, contributing towards an envisioned successful implementation of our 3Ccar project.

7 List of tables

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