Deliverable 5.1
Task Force Action Plan

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<td>CAPEX</td>
<td>CAPital EXpenditures</td>
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<td>CPD</td>
<td>Continuing Professional Development</td>
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<td>CPS</td>
<td>Cyber-Physical Systems</td>
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<td>CPSE</td>
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<td>Coordination and Support Action</td>
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<td>European Technology Platform on Smart Systems Integration</td>
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<td>European Technology Platform</td>
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<td>OPEX</td>
<td>OPerational EXpenditures</td>
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<td>OTJ</td>
<td>On the job</td>
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<td>RAMI</td>
<td>Reference Architecture Model for Industrie 4.0</td>
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<td>ROI</td>
<td>Return of Investment</td>
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<td>RRI</td>
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<td>SME</td>
<td>Small Medium Enterprise</td>
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<td>System of Systems</td>
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Executive Summary

This document includes the activities performed in Road2CPS till September 2016. Most of the task actions have been already completed. Based on the maturity level of these actions the insights provided by each of them are different. The document also includes the general procedures followed to capture information, the interaction methodologies and the results of the workshops held so far.

The main conclusion of the document are a set of recommendations including covering the areas addressed by the Task Forces. This outcome will be transferred to other project tasks in order to provide final recommendations. Nevertheless, through the work developed in the Task Forces the project has elaborated several conclusions that are presented below.

- Interoperability represents a huge challenge and although it is already among research priorities it is important to follow closely how things are progressing. Interoperability of platforms and devices can boost or decelerate the position of Europe as CPS and digital transformation provider.

- The digitalization of industry requires the provision of stronger and more reliable security frameworks. This applies at all level, from the devices to the application and service level.

- The need of testing facilities is also a barrier, there are several pilot programs but a bit closed so it is not easy to test CPS solutions in “real-environments”, it will be also very welcome to promote facilities like IoT-Lab and similar in the CPS domain and with possibilities to adapt them to different use cases.

- Because of the urgency of enriching and enlarging our knowledge of CPS and CPSE there is a need to undertake groundwork within the terms of the EHTA and the Bologna Declaration to create the necessary network for provision of training in the realms of CPS/CPSE.

- Given that CPS global RD&E is proceeding apace, it is recommended that the development of common, EU-wide curricula and support facilities for educating the European population for CPSE and CPS operation.

- The break of vertical silos will boost the development of technology and the creation of services. Building links across sectors will enable not only a better cooperation among industries but also the development and empowered of their individual data sets.

- Business opportunities in a new emerging market should be caught, the new opportunities offered by the availability of resources of technologies are opening the industry to other players like makers, and developers and the impact of community based solutions will be higher in the next years.

What this report makes clear is the set of technical and non-technical challenges that are already in place, what are the paths that can be followed to address some of them, and finally, how important it is to break traditional business and operational models and adapt to the new opportunities offered by disruptive technologies.
1 Introduction

This deliverable provides a description of the activities that have been developed by the different Task Forces of the project. Through the different sections of the report, the methodology, main inputs and Task Forces outcomes are described.

1.1 About this document
Task Forces develop activities seeking consensus building on the topics of future issues on implementing CPS, business trends and business models, barriers and pitfalls for implementing CPS within process and networks, and knowledge sharing. The current version covers the activities developed by Road2CPS until September 30th 2016.

1.2 Intended Audience
This document presents an overview of the status of CPS platforms and technologies and an introduction to the activities performed in terms of educational needs and awareness. The document provides relevant information for people involved in the different areas of the CPS environment, technology, education and awareness and cooperation among institutions.

1.3 Keyword list
CPS, Platforms and Technology, CPS education, CPS awareness, European Research Programs
2 Task Force methodology

The objective of Road2CPS Task Force is to provide not only conclusions and analysis of State of the art and available information in the CPS domain but also provide clear recommendations to the EC about the needs and requirements for boosting the development and deployment of these technologies.

The consortium has created four different Task Forces:

- CPS business models, regulations and service enablers
- CPS awareness and education
- CPS technology and platforms
- CPS connection – with ICT-1a, b, Artemis/ECSEL, Industrie 4.0

This document describes the methodology and action plan followed in all of them. This methodology aims at maximize the efficiency of experts feedback collection process. Finally the gathering of the multiple inputs will derive into the delivery of several key outcomes.

![Figure 1 Task Force methodology](image)

Figure 1 describes the process that will be followed by the Task Forces. The first process is based on the analysis of the information already generated by the project and also workshops and other projects working on similar domains. The result of this analysis is a first set of findings by Road2CPS, which are mapped into different questions that are distributed to the experts based on their knowledge and expertise to collect a first round of feedback. The information provided by the experts is used for the refinement of the recommendations that Task Forces create. The main
outcomes are inputs to CPS roadmapping activities, analysis per domain providing conclusions supported by experts’ opinions and recommendations to the EC. Before releasing them, they are shared with the experts for a last check and feedback collection.

2.1 Task Force Coordination
The TFs have to be developed in parallel but requires a coordination effort for promoting synergies and identify the main aspects that can affect several of them. This coordination involves TF leaders and represents the core for the selection of the questions to be delivered to the experts and also for distributing the feedback from expert side to the consortium.

2.2 Questionnaire creation
The Task Forces work on creating questionnaires targeting specific issues and also answering open questions that require experts’ feedback. The questionnaires address the aspects that are targeted by each task force from different perspectives. As presented in Deliverable 2.2 of the project, the main domains that are under the Road2CPS focus are:

- Transport
- Manufacturing
- Energy
- Health
- Cities

Moreover the experts have different expertise not only from the domain perspective but also from the focus area they are working in; research, technology development and business development. For each of the question that is presented by Task Forces, they are assigned for one or various domains and also to one or several areas.

The main scope of the questionnaires is to distribute the different questions to the most effective experts in the group, while allowing also maintaining their focus on their expertise area. The idea is minimize the number of questions sent to them and align them with their core activities.

2.3 Road2CPS Experts
Road2CPS has elaborated a list of the experts who has contributed to the project. Some of them have just participated in project workshops, some others have also contact with members of the
consortium and follow the project’s newsletter. What is really valuable is their commitment with project activities and the feedback and opinions generated in the interactions with Road2CPS.

The current population of the experts is presented in the following graph.

![Figure 2 Expert affiliation to organisation type](image)

Moreover, they have also presented their interests in the different Task Forces that have been defined in the project.

![Figure 3 Distribution of expert's interests across Task Forces](image)

The information below refers to the activities performed including online survey and Road2CPS event participation.

Finally, the next subsection digs into the classification of the experts based on an internal criteria that will help Road2CPS to obtained the maximum amount of valuable data from them focusing on their knowledge and working areas, and then mapping the information to the different project Task Forces.
2.4 Expert mapping

One of the challenges that Task Forces have to address is maximizing the feedback collection. In order to do this, the experts have been distributed by domain and by area. This helps to increase experts’ engagement with the questioners and also the quality of the feedback they provide.

As introduced in the previous section, the work in the Task Forces of Road2CPS depends on the feedback obtained from the experts in the different events and consultations made. Previously we have presented the distribution and their interests, in this section and supported by the figure above, we are providing the approaching methodology and the main outcomes obtained from those contacts.

The project is analysing several vertical domains, it is also expected that the expertise of some of the people contributing in our workshops could be more relevant in their domain rather than in a specific topic in a horizontal way. On the one hand it is valuable that the task force experts from specific sectors focus on domain-specific issues, because Industrie4.0 representatives will be interested more in finding solutions in manufacturing than in healthcare for instance, on the other hand horizontal issues will be also taken into consideration to guarantee cross-disciplinary approaches.

The questionnaires that are used for contacting experts follow this approach are not the same for all. Although some common questions are distributed to all of them, the questionnaires focus on the domain of expertise of participants, the number of questions is lower but they will target only those areas in which participants can provide effective and relevant information for the project.
3 Task Force Inputs

Road2CPS project has developed two events with the participation of experts that provided inputs to different tasks of the project. The interaction with these groups has been done based following a methodology that allows increasing the impact and the focus of the feedback collected. Moreover, in the Road2CPS constituency building workshop on future platforms held in Turin, a representative of the EC presented the top priorities of the Commission in terms of CPS technology, which also led to a very relevant input for the discussions that were held at the final part of the event.

This section provides information about how the different sources of information analysed are impacting the work of the Task Forces.

3.1 Road2CPS deliverables

The deliverables that have been already submitted in the project and that are under development provides useful information in the development of the committed activities for the Task Forces. At this point several WP1 and WP2 deliverables are available. The information contained in those documents and also in the Vulture website [4] where the analysis of running projects is included, provide an overview of the current status of the technologies and sectors analysed by Road2CPS.

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<td>State of the Art and current impact report</td>
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<td>This deliverable has produced a top-down assessment of the scientific and technological challenges over that period, with attention to sustainability. This aim was chosen to provide a long-term perspective, including some global aspects, to augment other reports that have taken a shorter, more market-focussed, perspective.</td>
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<td>Report on market requirements and socio-economical needs</td>
<td>This document elaborates the future vision of Cyber-Physical Systems (CPS), market requirements and socio-economic needs within the domains approached by Road2CPS: Energy, Transport, Health, Smart Production and Smart Cities.</td>
</tr>
<tr>
<td>D2.3 [39]</td>
<td>Intermediate technology and application roadmap</td>
<td>First findings concerning key technologies that support the CPS concept and the impact they will have over the different domains that are under study in the project. The deliverable represents an input but the work in progress is considered in the TFs too.</td>
</tr>
<tr>
<td>D1.2 [40]</td>
<td>Gap Analysis Report</td>
<td>The content of this deliverable includes</td>
</tr>
</tbody>
</table>
useful information that shows how projects have dealt with existing gaps and opportunities from the technical perspective.

<table>
<thead>
<tr>
<th>D1.3 [41]</th>
<th>Impact assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>This deliverable shows how the different achievements of ongoing projects will impact the CPS ecosystem, technology, market trends, use cases, that will shape the future of business models based on emerging technologies.</td>
</tr>
</tbody>
</table>

### 3.2 Project Workshops

Road2CPS has organised three workshops so far, the first one, the first roadmapping workshop in Paris, was devoted to the analysis of current status of CPS and the identification of the key priorities [5]. The second workshop, the first constituency building workshop in Turin, was oriented to the definition and understanding of the current platforms available for the development of the CPS industry in Europe[^3]. The summary of the activities performed in the different Task Forces includes a summary of the most important aspects of both workshops. The report summarizing all the activities performed and the slides shown by the different experts that contributed to them are available under Road2CPS website.

### 3.3 Inputs from other projects

There are other projects influencing the work which is being developed in Road2CPS. Moreover there are also other CSA like Road4Fame [6] whose work has fed the activities of Road2CPS Task Forces.

### 3.4 Inputs from material release by EC

As documented in Turin workshop report [7], Werner Steinhögl from the European Commission introduced the EC’s view on platforms highlighting the fact that platforms should not only be perceived in a technological way but also as a basis for business and economic growth. The key aspects presented during the event were:

- Real-time systems and safety-critical systems are the key nodes of the digital value chain. There is a significant competitive advantage to those who can master these challenges.
- In the context of this conference Werner acknowledges that the ARTEMIS community already works on key nodes of the value chain of the future: safety-critical and real-time systems. The control of these key nodes provides a competitive advantage and Europe needs to be prepared.
- A process of digital transformation is currently ongoing in many domains, particularly in manufacturing, which is becoming increasingly automated. More automation leads to increased efficiency with regards to resources such as electricity, and increased precision in regards to products.
- Digitalisation offers many opportunities to deliver different products in more effective ways, including process transformations (from logistics and product design to automation). This trend also impacts business models, by blurring boundaries (between products and services), and reshuffling value chains. We expect to see a strong emphasis on added value services, built on e.g., real-time information data analytics, etc. in the future, with a shift
towards XaaS (everything as a service). For example, aircraft manufacturers deliver performance rather than an engine.

But:

- Currently there is a lack of standards and interoperable solutions (these may be currently technically feasible but at a high cost and without relying on cost-saving standards)
- We see the advent of a new competition coming from non-EU digital platform owners (e.g. Google), while we note a fragmentation of effort in Europe

Key action lines pushed forward by EC include:

- Digitizing industry initiatives (15% of GDP €2,250 B): this includes creation of digital innovation hubs, developing smart regulations for industry, adapting and retraining workforces, investing in platform leadership; and building a strong digital sector: key programmes include 5G, ECSEL, IoT, Cyber security, photonics, robotics, big data (€900 B) (see yin/yang slide)

3.4.1 Platforms

There are many platforms available to aid developers and innovators as they develop new products and services, including approaches for reference architectures.

- A “platform” includes technologies and standards and also business models. Successful platforms provide a means to bring a community together, connecting elements of a marketplace. Examples include:
  - Amazon marketplace – connects people selling items with people who want to buy (people who search - advertisers)
  - Android/Apple – connects people with smartphones looking for functionality, with developers/sellers of apps delivering that functionality (people who buy phones - developers of apps)
  - Google – connects people searching for things with advertisers looking for targeted groups of people (people who search a product - companies selling a product)

- There is in general not one common platform for CPS, probably there is a need for several.
- Consensus building to agree upon platforms is important.
- Platforms are to be considered not only as stakeholder groups (Industrie 4.0, ETPs, etc.), or technological platforms (middleware, reference architectures, etc.) instead what is at stake are economical multi-sided market platforms creating value by enabling interactions between two or more groups (e.g. suppliers, customers, intermediaries)

Mapping the presentation by Mr Steinhögl into existing activities triggered by the Commission it is worth saying that there are several initiatives opened and some others ongoing. H2020 is not the only program targeting CPS, the work is complementing the activities addressed by the Electronic Components and Systems Joint undertaking (ECSEL, www.ecselju.eu), notably focussed on higher TRL large scale federating projects and integrated demonstrations and pilots. In that context topics under this area contribute also to the implementation of parts of the Strategic Research Agendas of Artemis IA (www.artemisia.eu) and EPoSS (www.smartsystemsintegration.org). With its emphasis on real time and safety critical capabilities, work on CPS system level is complementing the focus "Internet of Things" under Work Programme part 17, 'Cross cutting activities (Focus Area)'.

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3.4.2 Calls acting on CPS domain

3.4.2.1 Horizon 2020 Program
Currently the Commission has the following calls opened to boost and extend the development and adoption of CPS systems:

- **H2020 ICT 01 – Smart CPS.** The challenge addressed by the call is to design, programme and implement highly distributed and connected digital technologies that are embedded in a multitude of increasingly autonomous physical systems with various dynamics and satisfying multiple critical constraints including safety, security, power efficiency, high performance, size and cost. Such combination of several cyber-physical systems in "system of systems" gives rise to unpredictable behaviour and emergent properties. A significant improvement in design and programming of CPS is therefore needed including a "science of system integration" [8].

- **H2020-ICT-04 – Smart Everything Everywhere.** "Smart anything everywhere" stands for the next wave of products that integrate digital technology inside. A major challenge is to accelerate the design, development and uptake of advanced digital technologies by European industry, especially among them many SMEs and mid-caps in products that include innovative electronic components, software and systems. There are two areas of research specifically focused on CPS; the first one's goal is to help businesses from any sector uplift the quality and performance of their products and services with innovative embedded ICT components and systems and to support ecosystem building for promising platforms developed in earlier R&I projects. The second fosters the customisation of low energy computing powering CPS and the IoT: The goal is to help businesses who are developing products for situations where high computing capacity and low energy would be a competitive advantage and to support eco-system building for promising platforms developed in earlier low power computing projects [9].

3.4.2.2 ECSEL
The current call of ECSEL[10] covers CPS from many perspectives, the development of Smart domains are under the scope of ECSEL and the proposals expected shall cut across disciplines, supporting platform building, interoperability and the establishment of open standards. There is one specific topic covering CPS, but all the topics presented can be aligned with the areas covered by the project. The following list shows the research priorities of ECSEL:

- **Smart Mobility**
  - ECS for resource efficient vehicles
  - ECS for partial, conditional, highly and fully automated transportation
  - ECS for integrated and multimodal mobility networks

- **Smart Society**
  - Security enabling components and systems
  - Smart and Connected Things (including Internet of Things)
  - European assets protection

- **Smart Energy**
  - Sustainable power generation and energy conversion
• Reduction of energy consumption
  o Efficient community energy management

• Smart Health
  o Home Care and Well-being
  o Hospital and Heuristic Care
  o Food Processing and Quality

• Smart Production
  o Instant access to a (Digital and) Virtual dynamic factory.
  o Increased Information transparency between field devices and ERP.
  o Real-time sensing & networking in challenging environments.
  o Process Industry as an agile part of the energy system.
  o Management of critical Knowledge to support maintenance decision-making.
  o Automation service and function development process.
  o Open simulator platform.
  o Automation system for distributed manufacturing.
  o Balancing of system security and production flexibility.

• Semiconductor, manufacturing, technology, equipment and materials
  o Equipment and Materials for “More Moore / Advanced and Beyond CMOS”
  o Equipment and Materials for “More than Moore”
  o Process Technologies for Advanced and Emerging “More Moore” semiconductor processes
  o Process Technologies for Semiconductor Process Differentiation
  o Process Technologies for System in Package

• Design technologies
  o Technologies for Model-Based and Virtual Engineering
  o Managing complexity, safety and security
  o Managing diversity
  o Managing Reliability, Yield, and Robustness

• Cyber-Physical Systems
  o Architectures principles and models for dependable CPS
  o CPS for autonomy and cooperation
  o Computing platforms

• Smart systems integration
  o Building blocks of Smart Systems (sensors, actuators, controls and interfaces)
  o Safe, secure and efficient transfer of information and power
Integration methods enabling smart functionality, automation and reliable operation in harsh and complex environments.

3.4.2.3 EPoSS

EPoSS [11] is an industry-driven policy initiative, defining R&D and innovation needs as well as policy requirements related to Smart Systems Integration and integrated Micro- and Nanosystems. EPoSS provides a common European approach on Innovative Smart Systems Integration from research to production, defines priorities for common research and innovation in the future, formulates commonly agreed road maps for action, provides a Strategic Research Agenda [12], mobilises public and private resources, and supports its members in coordinating their joint research efforts and improving communication amongst the members as well as towards the European Commission.

EPoSS research interests are under the umbrella of Road2CPS topics of interests, the analysis of the information provided in the different reports will support the development of Task Forces activities.

3.4.2.4 ARTEMIS-IA

ARTEMIS Industry Association [13] continuously promotes the R&I interests of its members to the European Commission and the Public Authorities of the participating states. It continues the work of the European Technology Platform ARTEMIS and is therefore responsible for the ARTEMIS Strategic Research Agenda (SRA) on Embedded & Cyber-Physical Systems, which reflects the Research & Innovation (R&I) needs of the industry. The association strongly believes that the continued success of the Embedded & Cyber-Physical Systems sector in Europe depends on one coordinated, pan-European strategy.

ARTEMIS considers that Embedded Systems are everywhere, built into roads, cars, trains, aeroplanes, medical devices, homes, offices and factories (industrial automation), payment systems, mobile phones and even into virtual reality glasses. They are interconnected in networks of many devices – for example the car to the fixed road infrastructure, the smart card to the banking and payment systems and use of public services.

The presence of the internet provides the communication infrastructure which enables smart objects to be connected. Life in our society, along with security and safety, will increasingly depend on Embedded & Cyber-Physical Systems.

Many high-tech industrial systems are classified as Cyber-Physical Systems (CPS) because of the close interaction between computation, communication and control elements (the cyber part), and physical processes such as motion and vibration (the physical part).

Traditional design methods involve multiple, often isolated, design phases involving different disciplines (mechanics, electronics, control and software engineering). These methods usually imply over-provisioning of system resources, by large safety margins at each phase, to be able to fulfil high-level performance requirements under the worst-case conditions.

With increased demand for performance, stringent constraints on resources, together with the need for better predictability of both the design trajectory and the properties of the final product, make such overly conservative designs no longer sustainable.

Therefore there is an urgent need for integrative design trajectories that bring together relevant disciplines involved in CPS. This kind of design should allow for trade-offs between cost and quality, coping with the tight coordination between the cyber parts and the physical parts.
4 Task Forces outcomes

4.1 Results
Road2CPS' Task Forces are dealing with aspects that support the development of the CPS roadmapping activity which is the main objective of the project. The main contribution that they are providing focus on supporting the roadmap by confirming periods and objectives based on the findings done in each of the Task Forces. As it has been explained the four TFs created deals with relevant aspects for the European CPS industry, such as technological aspects, education and training, support from the different EC programs and finally the raising on innovative business models.

All these topics create as result not only a document supporting the development of the activities, but also a visual result that allows understanding each of the topics in a single sight. The key idea behind creating this kind of material is to facilitate external experts to easily understand the problems and situation identified at this point, and collect feedback that can be further transferred to the roadmapping activities.

The section summarizes the main findings for each of the project Task Forces based on the analysis of the information collected and drawing also conclusions related to those findings.

4.2 Task Force CPS Technology and platforms

4.2.1 Methodology followed in this task force
According to the general methodology defined in the section 2 of this document, this Task Force is aligned to it in the way the information collection process has been developed. Since this TF is dealing with platform and technology, the initial inputs come from the analysis of the deliverables created in WP1 and WP2, moreover the first workshop held in Paris provided was focused on the identification of research priorities according to the different profiles of the workshop attendees. Finally, the information resultant from the EC calls is also a very relevant input, although the participation of a representative of the Commission in project workshops support the information collected.
The flow presented above shows the iteration cycle between Road2CPS and the experts that participated in the Workshop. Initially the speakers were selected by the project and we approached them requesting their participation and the topic that was expected to be covered by each. After that point, Road2CPS proposed a list of questions that must be addressed in the presentations of each of the platforms. A discussion followed the presentations and the main conclusions of the workshop were drafted and populated two matrices with the most important topics – a matrix with focus on technological/research topics and a second matrix with focus on non-technological/implementation topics. Finally all the information, including the presentation from Commission representative was reported in [7]

As result of combination of the different sources of information, the following subsections will summarise the main outcomes of the Task Forces.

4.2.2 Facts that support research priorities selection
According to the results of the Paris Workshop, the top priorities identified from the CPS platforms and technologies point of view are the following:

- Integration, interoperability and standards
- Safety, reliability, resilience and fault tolerance
- Architectural tools

These are the top priorities identified in the project workshop. The three groups of actuations cover main current barriers for the massive deployment of CPS technologies. This task force aims at providing a bit of light on these aspects, summarizing why these topics represent a problem, which stakeholders are currently providing solutions to them, and finally, how each topic fits in the market.

The first and most relevant priority is the integration, interoperability and standards issue. The next figure illustrates the large number of available platforms that are currently available.
But this problem is not only restricted to Platforms, also the provision of some technical enablers such as Big Data tools face the same problem of the wide variety of similar solutions available and interoperability as shown below.
The number of solutions is really high and covers individually many domains. The problem resides in the lack of interoperability and potential collaboration among those solutions. In this sense, the development of open and horizontal platforms which is currently one of the priorities of EC in the different calls, represents a key driver for the expansion of CPS technology and what is more important to the development of synergies among strategical sectors.

The domains addressed by CPS are usually critical environments which require special protective measures to guarantee that data collection, analysis and storage processes are robust against attacks. However, due to their relevance there are a lot of attacks which implies that CPS must be resilient to cyber-attacks.

Finally, the provision of tools that facilitates the integration of new elements into current CPS will facilitate the deployment of CPS technology. These tools will provide a methodology for assessing the new components but also for the evaluation of the impact that the new changes will have over the existing ones. The combination of real deployment and simulation facilitates a seamless integration and growth of current CPS technology deployments and also accelerate the adoption of CPS to those who have not done it yet.

4.2.3 Market status

CPS ecosystems change very quickly and technology providers must adapt to these circumstances. In this sense, this sub-section offers an overview of the specific areas that are currently hitting the market presenting how they have evolved, what is the current status and what is expected in the near future.

A good reference to understand what is the current status of IoT Market is the Gartner’s Hype Cycle for Emerging Technologies [14]. In the last two years’ reports, CPS elements are in the innovation trigger slope such as IoT Platforms and Security, IoT itself is at the peak of inflated expectations with a period of 5 to 10 years to impact strongly the market.

![Gartner Hype Cycle for Emerging Technologies, 2016](image-url)
But as it has been stated previously, the IoT environment changes rapidly and after checking how Gartner has ranked it during the last years this can be confirmed.

Figure 9 Gartner’s Hype Cycle for emerging technologies - 2015

Figure 10 Evolution of IoT in Gartner’s Hype Cycle
Gartner’s and other firms report is presenting clearly that IoT is entering in a crucial phase, and as a key enabler of CPS, it is really important to understand its maturity level and the impact on the different cases that are under research in the project. After analysing the information and seeing the current deployment status is time to create business models on top of technology and monetize the developments done for assuring the sustainability of such promising technologies.

Companies have understood this new paradigm and have invested in evolving their equipment and technologies to move towards the next level. This is not only an European initiative but as it can be seen in the figure below, there is a global push for the adoption of emerging technologies for transforming the whole value chain in the different industries [15].

![Internet of Things: A vision with huge economic potential](image)

Figure 11 IoT Market evolution (src: The Economist)

This forecast is also reflected in the expected market size, both in terms of devices deployed but also in terms of revenue as presented in the Figure 12.

![Global IoT/IIoE revenue forecasts](image)

Figure 12 Global IoT Market revenue (source IoT analytics)
The mapping of the prediction into the different domains addressed is presented in Figure 13[16]. As it can be seen, there are two segments analysed by most of the firms that have made their forecast, on the one hand, impact in consumer goods, mainly devices that follow IoT rules in terms of power consumption, simplicity, application... and on the other hand the impact in businesses, the expected revenue that each sector is expected to achieve. Both things are related but not in a direct way.

![Segment-specific IoT forecasts (% of total market)](image)

**Figure 13 Segment analysis of IoT expected impact**

### 4.2.4 Main challenges and opportunities

The task force deals with CPS platforms and technologies and as it has been presented in the previous subsections, the current CPS landscape offers big opportunities but there are also some barriers that need to be overcome.

The current heterogeneous environment which is a clear barrier also provides several opportunities as solution to this problem. On the one hand the rising of horizontal open platforms whose main asset is the integration and interoperability aspects will facilitate the operation of multiple systems in the CPS ecosystem. On the other hand, the development of components that bridge the differences among platforms are also required and could impact notably the market.

Europe is currently positioned as the most important industrial CPS provider, for keeping this position against emerging stakeholders and markets, there are some steps that must be done:

1. Increase reliability of CPS systems – this opens the door to the certification of secure systems, the creation of validation methodologies and the impact of these activities into the different standardisation bodies

2. Implementations of full CPS systems in different domains – currently there are very good solutions for individual parts of systems like smart grids, but there is a lack of a full deployment that allows the validation of the whole CPS subsystem. The provision of such facilities in this and other environments will strength the position of Europe and its technology providers.
In summary the market is ready and waiting for innovative solutions based on CPS technology, but this will not be exploited in its full potential until existing concerns are addressed. The next subsection summarizes the key aspects that have to be addressed.

4.2.5 Task Force Recommendations

The work done in the taskforce has led us to create some clear recommendation that require actions from different actors. The table below reflects the key ones.

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Actions ongoing</th>
<th>Actuation required</th>
<th>Main bodies involved</th>
<th>Priority level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Promote Platform interoperability</td>
<td>Commission has already launched several calls for addressing these aspects from the IoT point of view, but with the objective to be expanded to the whole CPS value chain. ICT-30</td>
<td>Keep pushing these activities, involve large industry and providers</td>
<td>European Commission, Large Industry</td>
<td>Medium (Clear need, but corrective actions ongoing)</td>
</tr>
<tr>
<td>Promote Device interoperability</td>
<td>Devices are very use case oriented at CPS level, there are some projects trying to adapt them to a more horizontal trans-use case.</td>
<td>Semantic device models standardisation so as to allow the seamless interaction regardless technology before reaching platforms</td>
<td>Standardisation bodies; Research institutions; European Commission</td>
<td>High (This is stopping the disruptiveness of new business models and applications derived from out of the box thinking)</td>
</tr>
<tr>
<td>Development Security algorithms</td>
<td>Security has been identified by all consultancy firms as one of the hottest topic in CPS, the current status is not strong enough</td>
<td>Despite devices capabilities, security levels should be improved and moreover validators of the security measures should build trust on them.</td>
<td>EC and European standardisation bodies</td>
<td>High</td>
</tr>
<tr>
<td>Privacy - Big Data applications</td>
<td>Big Data technologies are becoming more and more exploited nowadays. There are EC programs and institutions promoting and boosting its adoption, however there is a clear lack of common regulatory framework. At European level only Directive 95/46 EC and in each country the situation could be different</td>
<td>Development of clear and common regulatory framework for the whole EU</td>
<td>European Commission</td>
<td>High</td>
</tr>
</tbody>
</table>
Many domains where CPS is applied are critical; this implies that solutions must be validated on beforehand in critical large scale facilities. This is not always feasible especially for newcomers in the market. Commission has launched IoT large Scale pilots and SCC programs for creating such lighthouse projects that can guide implementation and validate technology.

Open Infrastructure and testing environment, validation frameworks

European Commission and interested industries. This applies to many bodies with interested in counting on disruptive solutions as part of their offer.

4.3 Task Force Awareness and Education

Given that CPS technologies not only hold the promise of future, long-term prosperity for the EU but also provide the most potent means for addressing the goals of a sustainable world, it is imperative that our societies are prepared for, and are able to work with, a future Europe in which CPS are pervasive in all the main sectors; industry, health, transport, etc. There are two basic requirements; firstly to ensure that all citizens of the EU and the EEA (approximately 500 million) are aware of the roles of CPS and can live informed and responsible lives within the parameters of the multitude of CPS with which they will have to engage. Secondly, the community of people who will work within the CPS domain as designers, co-workers, managers, maintainers, and in other internal roles (perhaps 30 million people) must be educated and enabled to execute their roles efficiently, effectively, and promptly. The sections that follow are aimed at both of these large constituencies in our European home.

4.3.1 Methodology followed in this Task Force

The methodology followed by the Awareness and Education Task Force is aligned with approach followed by the other Task Forces. During the Paris workshop, the specific working group on Awareness and Education identified the main impacts, barriers, research needs and some recommendations that will be the bases of this section.

Awareness and Education is an issue tackled from a different perspective within CPS, since it is not directly related with technology but with the PERSON.

From the Paris workshop, this task force has worked internally among the Road2CPS partners, with the support of bibliography and information from EC calls.

It has also taken into account some inputs coming from other workshops such as the RRI Workshop: Responsible Research and Innovation in ICT-related research and from cognate Deliverables from EU-funded projects such as CPSElabs [17], CPSoS [18], CyPhERS [19], HYCON2 [20], and T-AREA-SoS[21].

4.3.2 Impact of Awareness and Education in CPS

CPS and Awareness and Education should go together. On the one hand, CPS is a new concept that involves different disciplines, and on the other hand, education about CPS will improve the knowledge in this field and at the same time raise awareness among the different professionals about the need of working together.
A new paradigm in education in terms of CPS should include the main stakeholders, who are engineers, decision makers, and persons responsible for regulatory frameworks. Education institutions need to integrate the new discipline of CPS in their training programme to fulfil the demands of a CPS-orientated economy.

Life-long learning, hands-on and best practice transfer to working engineers and job-related learning of the labour force should be supported together with extended awareness building measures for the citizens of the EU and EEA to live fulfilling lives.

Finding technological solutions necessarily must integrate the human factor more and more. Furthermore, in order to overcome outdated educational programmes innovation platforms and virtual environments should be made the centre of attention. Common methods are only using online platforms without integrating aspects of the ‘real’ world. Especially with regard to Cyber-Physical Systems a strong interaction between virtual and physical elements and systems should be taken into account. These innovative methods could result in easier learning processes.

During the Paris workshop, within the topic description, 3 main key groups were identified to generate awareness within the Life-Long learning paradigm (LLL):

- engineers
- decision-makers
- legislators

But to reach a wider audience and achieve a real awareness, the general public should also be addressed.

The impact of Education, Awareness and training affects areas related to competitiveness, costs and people, in the sense that:

- It represents a critical success of factor for regions, and therefore countries. If there is no skilled people, the regions are not competitive, and therefore the industry migrates to other regions
- If there is a good education and training based in LLL, more cost-effective and trustworthy systems will be achieved
- Being aware about CPS will imply human-centric systems, since humans will be the priority.

Research is currently partitioned into isolated sub-disciplines such as sensors, communications and networking, control theory, mathematics, software engineering and computer science. This problem is mainly related with the existing gap between research and education.

Different gaps and barriers have been identified:

- No status or priority in European Education related to CPS (it is not taken into account)
- Limited resources for education on CPS
- Traditional educational methods dominating (no testing in real environments)
- Big gap between Academia and Industry. Improvement in collaboration is needed

4.3.3 Activities performed and main outcomes

"Beyond the scope of the Cyber Physical Systems, the Cyber Physical Society concerns not only the cyber space and the physical space but also humans, knowledge, society and culture. It is a future interconnection environment that connects nature, cyber space and society under certain rules."
Research on Cyber Physical Society will lead to the extension of information science and technology”[22].

According to Máire Geoghegan-Quinn, European Commissioner for Research, Innovation and Science (2012) “we can only find the right answers to the challenges we face by involving as many stakeholders as possible in the research and innovation process. Research and innovation must respond to the needs and ambitions of society, reflect its values, and be responsible.”

In recent years, the field of Responsible Research and Innovation (RRI) was therefore, strongly supported by the European Commission. It is regarded as a key element to facilitate the consolidation of the European Research Area (ERA) and, more specifically, to better tackle the Grand Societal Challenges identified by the European Commission and reflected in the Horizon 2020 Programme. Implementing a novel RRI strategy, Europe is expected to strengthen its position as innovation actor and thus contribute to enhancing both competitiveness and quality of life. Furthermore, application of RRI, for instance open access, will contribute to a more vibrant, innovation-based economy, favouring thereby the achievement of the Innovation Union goals. In the area of ICT in particular the RRI approach is meant to shed light on the societal impact and extent to which digital transformation affects the human condition.

Against this background DG CONNECT and RRI-ICT Forum organized the first RRI-ICT Event [23] (July 8-9, 2015 in Brussels) – which Road2CPS attended - in order to spark the discussion on how to enact a responsible approach to H2020 ICT-related research and innovation. The event was set to give an introduction to, foster synergies and identify challenges around the RRI-SSH domain in connection with ICT projects through informative and interactive sessions. A general definition of the term was introduced by EC representatives; in the area of ICT, RRI has five different aims:

- Public engagement (engaging society in research and innovation)
- Open access (facilitating open access to scientific results)
- Gender dimension (ensuring gender equality in both research process and content)
- Ethical issues (taking into account ethical issues)
- Education (promoting formal and informal science education)

All these points are important when assessing the impact on society in the newly emerging hyper connected era. In fact, the ‘human condition’ shall not be neglected, but taken into account by multidisciplinary co-creation and collaboration between social sciences, humanities and innovators in order the ensure better outcomes for citizens. Most notably, co-creative and collaborative methodologies are product- and market- oriented, thus likely to ensure better acceptance, consumer adoption and sales results for novel products and technologies. However, this also involves taking into account unexpected consequences and reflections and anticipation about what a given project, results or product is likely to do. “Who will benefit?”, “Who might suffer?” and “Who needs to learn what?” are central questions to be addressed.

In an interactive session 144 participants from DG Connect, DG RTD, EC executive agencies and Project coordinators from ICT-related Horizon2020 projects were asked to respond to the question: “What will make us confident and proud regarding our commitment for responsibility in ICT-related Research and Innovation?” In an interactive session, participants judged the following ideas to be most pressing when reflecting on RRI in an ICT-related context:
Pillar A summarizes the goals foreseen by incorporating RRI in ICT related research:

- Value for society, sustainability (business, finance, society, environment), avoiding discrimination, ensuring users/citizens trust

Pillar B adheres to issues arising from Research and Innovation in ICT:

- Quiet consciousness, decision-making vs. decision support (minding the borderline)

Pillar C comprises measures important to deliver on responsibility:

- Interdisciplinary dialogue, user-centricity, data protection and responsibility by design

Pillar D puts forward the significance of a “user-centric approach”:

- User-centric design for and by co-creation, diversity and inclusion of users in e.g. design

The final pillar E points to the importance of monitoring, measuring and evidencing the impact of applying RRI approaches in ICT-related research.

In sum, participants agreed on the fact that, in the new digital age it is important to innovate responsibly and acting responsibly means to involve all those active in the system.
Based on the documents mentioned above and the Paris workshop, it is evident that there are two important characteristics of research and education within the Cyber-Physical Systems/Cyber-Physical Systems Engineering (CPS/CPSE) arena. The first of these is that CPS will exist in real-life societies; they will not be laboratory-scale systems. Consequently, much of the learning and knowledge capture will have to occur in field situations. Clearly, then, a collaborative support network (see Figure 1 below) will be required to link the academic and industrial knowledge base and experience which can then become encapsulated into formal, non-proprietary knowledge for future generations of students, necessarily involving the professional engineering and cognate societies.
The second characteristic is that many of these CPS/CPSE instantiations will involve safety-critical systems and systems whose effective operation is critical to the social and economic well-being of the societies within these systems operate. Consequently, experimentation with these systems will be difficult to justify and organise. This in turn means that observation of the behaviour of CPS will be the only knowledge-creating channel left, and the development and application of observation metrics, simulation technologies, modelling and visualisation techniques will be required; CPS/CPSE training will need to include the development and application of these techniques as well as the design and operation of the CPS.

The educational needs can be condensed into five implementation areas as indicated below and categorized in Table 1 below:

- General conceptualisation of CPS (clarity, definitions and explanations)
- Engineering the structure and planned behaviour of the CPS for their instantiation into society
- Predicting and managing emergence in operational CPS
- Methods & toolkits for carrying out CPSE
- Privacy, protection, safety and security (virtual and physical) in CPS
Table 3 Knowledge areas categorised by implementation area. Note that knowledge areas may occur in more than one implementation area.

<table>
<thead>
<tr>
<th>Implementation Area</th>
<th>Knowledge Areas</th>
</tr>
</thead>
</table>
| **General conceptualisation of CPS (clarity, definitions & explanations)** | • The identification of generally agreed framework for CPS theories  
• Elaboration of fundamental principles for CPS  
• Establish the paradigms (conceptualisation) for CPS in sectors and hence for CPSE  
• Establishing common terms and definitions for characterising CPS and CPSE |
| **Engineering the structure & planned behaviour of the CPS** | • Development of methodologies for the model-based CPS approach and the development of skills for architecting and for interpreting of architectures  
• Understanding the consequences of interactions in the network of contracts between the component systems of a CPS  
• Design methodology to incorporate context, evolution and likely emergent behaviour into a CPS prototype  
• Characterising governance structures and processes for different classes of CPS [10] |
| **Predicting and managing emergence** | • Understanding the consequences of interactions in the network of contracts between the component systems of a CPS (both business contracts and between-device contracts)  
• Development of a scientific understanding of how and why emergence occurs (causes of emergence)  
• Design methodology to incorporate context, evolution and likely emergent behaviour into a SoS prototype |
| **Methods & toolkits for CPSE** | • Development of methodologies for the model-based CPS approach and the development of skills for architecting and for interpreting of architectures  
• Development compilation of toolkits and strategies to deal with positive and negative emergent behaviour (e.g. prediction of emergence, prevention through design and operation, amelioration of negative emergent behaviour, and exploitation of desirable emergent behaviour)  
• Design methodology to incorporate context, evolution and likely emergent behaviour into a CPS prototype  
• Characterising governance structures and processes for different types of CPS |
| **Protection privacy, safety and security in CPS** | • Characterising governance structures and processes for different types of CPS  
• Design methodology to incorporate context, evolution and likely emergent behaviour into a CPS prototype  
• Design methodology to ensure the safety and security of end-users and the environment for CPS where AI-based systems and other non-ethical decision systems are involved |

The table below lists the key areas for new CPSE skill sets to deliver required.
Table 4 Cross tabulation of skill set requirements and implementation areas, for which delivery mechanisms will be required.

<table>
<thead>
<tr>
<th>New CPSE skills required</th>
<th>Components of the skill set</th>
<th>General conceptualisation of CPS (clarity, definition &amp; explanations)</th>
<th>Engineering the structure and planned behaviour of the CPS</th>
<th>Predicting and managing emergence</th>
<th>Methods &amp; toolkits for CPSE</th>
<th>Protection, privacy, safety and security in CPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyber-Physical Systems Integration:</td>
<td>Defining and building the internal and external interfaces</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPS attribute and boundary definition/identification</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Requirements for interoperability in CPS</td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IT &amp; T Integration for heterogeneous, complex systems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Socio-technical aspects of CPS:</td>
<td>Design and operational control</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Methods for assuring ethical, cultural and legal behaviour in CPS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Cross-Domain CPS theories and principles</td>
<td>Knowledge of taxonomies/ontologies relevant to CPS</td>
<td>x</td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understanding of CPS/CPSE paradigms</td>
<td></td>
<td>x</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New CPSE skills required</td>
<td>Components of the skill set</td>
<td>General conceptualisation of CPS (clarity, definition &amp; explanations)</td>
<td>Engineering the structure and planned behaviour of the CPS</td>
<td>Predicting and managing emergence</td>
<td>Methods &amp; toolkits for CPSE</td>
<td>Protection, privacy, safety and security in CPS</td>
</tr>
<tr>
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<td>-------------------------------------------------------------------</td>
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<td>----------------------------------</td>
</tr>
<tr>
<td>Model-based CPSE approaches</td>
<td>CPS models and simulations: multi-level, heterogeneous etc</td>
<td>X</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Model-based CPSE approaches</td>
<td>Theory and understanding</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Model-based CPSE approaches</td>
<td>CPS prototyping methods and approaches</td>
<td>X</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Model-based CPSE approaches</td>
<td>CPS measurement, metrics and performance evaluation</td>
<td>X</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>CPS Architecting - generic and domain specific</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPS Governance structures &amp; processes - generic and domain specific</td>
<td></td>
<td>X</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Understanding emergence in CPS</td>
<td>Theories for emergence in CPS</td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Understanding emergence in CPS</td>
<td>Methods to deal with positive and negative &amp; emergent behaviour</td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
</tbody>
</table>
## New CPSE skills required

<table>
<thead>
<tr>
<th>Components of the skill set</th>
<th>General conceptualisation of CPS (clarity, definition &amp; explanations)</th>
<th>Engineering the structure and planned behaviour of the CPS</th>
<th>Predicting and managing emergence</th>
<th>Methods &amp; toolkits for CPSE</th>
<th>Protection, privacy, safety and security in CPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Understanding CPS risk management</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Methods for CPS risk management</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Process for CPS delivery</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>CPS business models and contract networks</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Defining and parameterising CPS trade-off spaces</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Current and emerging CPS/CPSE standards</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
The core skill sets identified above will be relevant to all sectors where CPS are found and hence where CPSE is required to design configure, operate, maintain and decommission CPS; however, particular sectors will have differences in details.

4.3.3.1 Delivery mechanisms to spread the knowledge across the EU and EEA

The aim of this section is to outline the range of channels through which the skill sets can be delivered to the target audiences,

There is a vast range of mechanisms as is evidenced by the range of education and training systems across the EU28. However, in this report we use generic terms that will be understood across the EU28:

- **Higher Education Institutions (HEIs):** Often categorised as Universities; they provide programmes with academic qualifications at undergraduate and postgraduate level.
  - Undergraduate = up to first degree level (full/part-time)
  - Postgraduate = from first degree to doctoral level (full/part-time)
- **Apprenticeships:** An apprentice is usually over 16 and not in full time education and undertakes a real job in a range of sectors with time off for training for recognised qualifications: usually takes between one and four years to complete.
- **Continuing Professional Development (CPD):** This is the means by which people maintain the knowledge and skills that are related to their professional lives. CPD is a structured approach to learning to help ensure competence to practice, taking in knowledge, skills and practical experience. CPD can involve any relevant learning activity, whether formal and structured or informal and self-directed, and can be delivered/ certified by academia, professional institutions, industry, or consultancies.
- **Short courses:** These are courses for which payment is typically required and offered by industry, consultancies, professional societies, academia etc. They can last from days to weeks and may offer some form of certification on completion of the course.
- **On the job training (OTJ):** This is where employees receive training whilst remaining in the workplace. The main methods include:
  - Demonstration / instruction - showing the trainee how to do the job; Coaching - a more intensive method of training that involves a close working relationship between an experienced employee and the trainee;
  - Job rotation - where the trainee is given several jobs in succession, to gain experience of a wide range of activities;
  - Membership of a project team which provides exposure to other parts of the business and other disciplines and approaches.
- **Distance Learning (DL):** DL is a mode of delivering education and training to students who are not physically present in a traditional setting such as a classroom and who have discretion over the scheduling of lessons. Hybrid or blended DL courses require an occasional physical on-site presence and can be taken on a full or part-time basis.

It should be noted that in recognition of the principle of Subsidiarity which operates in the EU28, this report is not prescriptive or pre-emptive in its recommendations. Subsidiarity is defined as:

“Since the 1992 Maastricht Treaty, subsidiarity has been a guiding EU principle. It was introduced to try to dispel the image of Union officials as meddling bureaucrats hell-bent on interfering in all aspects of people’s lives. Basically it means decisions should be taken at EU level only if the same result cannot be achieved as effectively through national measures. If, for example, a local council comes up with an effective way of reducing traffic congestion, Brussels should, in principle, not get involved”[24].
4.3.4 Levels at which education and training can be delivered

Four levels of training and qualifications are generally agreed in the literature to deliver the requisite skills into the workplace. It is recognised that different terms or levels may be used across the EU28; however it is anticipated that the definitions provided below for each of the four levels as they apply to CPS and CPSE skills, will be applicable to most skill situations likely to be encountered. It is important to note that an individual or group may have, for example, Level 2 knowledge of CPS/CPSE but Level 4 knowledge in another knowledge area:

- **Level 1 “Awareness”:** At this level, an individual knows that a CPS/CPSE topic exists and has some awareness of its content and applicability (i.e. he/she knows that the required knowledge exists, and for what it is used and how to make use of the CPS, but there is no understanding or deep knowledge). An example is the average person’s understanding of the systems and processes in the EU Commission.

- **Level 2 “Entry level”:** The individual will have received basic introductory training which provides sufficient CPS/CPSE context and understanding to apply basic tools, methods and/or processes within a clearly defined CPS/CPSE context securely and safely under ‘normal circumstances’. This individual will require supervision. An example here would be a paramedic working within an accident and emergency hospital CPS.

- **Level 3 “Experienced”:** This individual will have been working in a CPS/CPSE context for several years and will have encountered a range of different CPS in different operational states. He/she will have a good knowledge of the theory and practice of CPS/CPSE but lacks detailed knowledge in a range of specialist areas. People of this level of skill are expected to constitute the large proportion of people working within a CPS context. An example here would be an Air Traffic Controller.

- **Level 4 “Expert knowledge”:** As for Level 3, but in addition the individual will have sufficient formal, technical knowledge and application expertise to be able to meet almost any demand or problem arising within a CPS – at least within their specific area of expertise. They are not always right, but are known to have deeper/wider/more accessible CPS/CPSE knowledge than most other people. An example would be a Chief Systems Engineer in a global aerospace company or a high level academic with an accepted international reputation in a particular SoS/SoSE area.

Some examples of current activities in this area are:

- CPSELabs an example of awareness generation in the field of CPS that addresses European SMEs.

- Tools training (Crescendo and VDM) course at University of Newcastle. Newcastle aims these courses at small groups of experienced users, who ideally already have training in modelling concepts. It is designed to equip those who have not used the tools with the key concepts. This is a hands on course for experienced engineers and aims to give practical modelling experience. The maximum length the course has been spread over is 5 days, and it is categorised as dissemination of knowledge. We also use feedback from the sessions to add value to the toolset

4.3.5 Task Force Recommendations

At this stage of the project and emergent from the discussion above, a number of recommendations can be made.

1. need to undertake groundwork within the terms of the EHTA and the Bologna Declaration to create the necessary network for provision of training in the realms of CPS/CPSE. Because the infrastructure and superstructure necessary to support cyber-physical systems (CPS) in an eco-system is necessarily supplied by SoS, and because of
the speed at which the CPS field is developing, this could be seen as a near-future recommendation.

2. Given that CPS global RD&E is proceeding apace, it is recommended that the development of common, EU-wide curricula and support facilities for educating the European population for CPSE and CPS operation. This should include academia, the professional societies and institutions of the EU28, and EU industry, since it is likely that some form of network will be required to deliver this.

3. Given the likely global reach that will be necessary for many safety-critical CPS and societally-significant CPS in order to deliver their benefits, and the consequential, closely-associated requirement for distributed CPS/CPSE knowledge and skills, it is recommended that support for the distribution of these skills beyond the borders of the EU28, especially in the developing regions of the world, should be created. It is likely to be necessary to go beyond formal centres such as Universities and colleges, to include trained, mobile educators and facilitators able to access the more remote regions that may be involved in CPS. While distance learning can usually reach these areas, the novelty of CPS knowledge and its practice indicate a need for localised, specific support.

4. Closer to home, it has been shown that industry has a key role to play in specifying requirements, developing material, and providing students and finance for the range of training types and delivery mechanisms identified in this report. Industry-led input here should come from both engineering and other commercial organisations that require CPS skill sets, including the range of tool vendors of modelling software and other simulation toolsets with which CPS and other engineers will need to familiarise themselves. This report indicates that the new CPS training and education required must be a combination of theory and practice, likely delivered by a range of different types of providers across academia, industry, consultancies and professional institutions.

5. Again, in recognition of the global reach of SoS, it is recommended that networks of expertise be developed with other developed regions outside the EU28 be pursued.

6. To assist in the exploitation of the benefits of CPS operation, it is recommended that the development of standards in this field be strongly encouraged.

Based on these recommendations this Task Force delivers the following conclusions.

Table 5 Awareness and Education task force conclusions

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Actions ongoing</th>
<th>Actuation required</th>
<th>Main bodies involved</th>
<th>Priority level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Promote training in the realms of CPS/CPSE</td>
<td>Infrastructure supplied by SoS, Existing knowledge at scientific level</td>
<td>undertake groundwork within the terms of the EHTA and the Bologna Declaration to create the necessary network for provision of training</td>
<td>European Commission, Member States</td>
<td>High, education is the bases for generating knowledge</td>
</tr>
<tr>
<td>development of common, EU-wide curricula and support facilities</td>
<td>CPS global RD&amp;E is proceeding apace, Some initial networks are starting to appear</td>
<td>Common understanding among actors to educate the European population for CPSE and CPS</td>
<td>academia, the professional societies and institutions of the EU28, and EU industry</td>
<td>Medium (clear need but common agreement among actors is required)</td>
</tr>
<tr>
<td>Promotion of CPS skills beyond the EU borders</td>
<td>operation</td>
<td>support for the distribution of these skills beyond the borders of the EU28. Encourage mobility in universities, institutes...</td>
<td>European Commission, EU-28</td>
<td>High</td>
</tr>
<tr>
<td>---</td>
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<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Promote combined training of theory and practice</td>
<td>Some Universities are already combining both concepts. Specially in the technical and engineer careers</td>
<td>Encourage actors to promote a combined education of theory and practice in different matters</td>
<td>academia, industry, consultancies and professional institutions</td>
<td>High</td>
</tr>
<tr>
<td>Promote the creation of networks of experts</td>
<td>Some specific networks on CPS have already been created</td>
<td>Promote the jointly work and network creations between EU28 and regions outside EU28</td>
<td>European Commission</td>
<td>Medium</td>
</tr>
<tr>
<td>Development of standards</td>
<td>There is a need in different fields and domains to create standards</td>
<td>Common frameworks that allow the generation of standards through regulations</td>
<td>European Commission</td>
<td>High</td>
</tr>
</tbody>
</table>

RRI in ICT is important to consider in that it fosters societal dialogue and societal acceptance for results from research and innovation processes in ICT. Negative effects on society, unintended consequences can be foreseen and any potential concerns eliminated. The human condition is important to consider in future ICT projects, especially those leading to hyper connectivity and an ever increasing digital society. Road2CPS recommends to intensively foster and enhance the dialogue with society and bring the domains of RRI and ICT together even closer within the H2020 programme. Activities like this event are a good starting point towards consensus building within the programmes and further steps should be taken to address and involve society even more directly.

4.4 Task Force CPS connection – with ICT-1a, b, Artemis/ECSEL, Industrie 4.0

The task force ‘CPS connection – with ICT-1 projects, Artemis/ECSEL, Industrie 4.0’, which is led by SEZ, aims at building deep connections to CPS related projects and relevant stakeholders at European, National, and regional level. The task force was installed to exchange ideas, information, and knowledge specifically between various H2020-ICT1 and FP7 projects in terms of CPS and related topics as well as fostering exchange between Road2CPS and ARTEMIS/ECSEL as well as the Industrie 4.0 initiatives in Germany and Baden-Württemberg.
4.4.1 Connection to ICT-1 through Road2CPS Workshops

Representatives of FP7-, H2020-, ARTEMIS/Excel- and Industrie 4.0 CPS related projects were involved in the Road2CPS activities and workshops on a regular basis, such as the first Road2CPS roadmapping workshop held in Paris (June 2015), the first constituency building workshop on future platforms held in Turin (October 2015), and the Road2CPS ICT-1 clustering event in Vienna (April 2016) co-organised with ARTEMIS-IA.

a) Roadmap Alignment Workshop (Paris; June 2015):

In the framework of the first Roadmap Alignment Workshop the project coordinators/representatives of CPS related roadmaps were invited. Next to this experts from academia and industry of the areas systems engineering, CPS, and IoT and from the domains manufacturing, energy, transport, and smart city attended the one-day workshop.

During the morning session, the different CPS related roadmaps were presented:

- **ARTEMIS-IA SRA** (Ad ten Berg, ARTEMIS-IA)
- **ATOS Vision** (Nuria de Lama, ATOS Spain)
- **CPSoS Roadmap** (Haydn Thompson, Thhink Wireless Technologies Ltd.)
- **CyPhERS** (Saddek Bensalem, Verimag/UJF)
- **Road2SoS/Road2CPS** (Roadmap, Meike Reimann, Steinbeis-Europa-Zentrum)
- **T-Area-SoS/TAMS4CPS** Roadmap, Murray Sinclair, Loughborough University
- **COMPASS** (Roadmap, Claire Ingram, Newcastle University)
- **Road4FAME Roadmap** (Carsten Rückriegel, Steinbeis-Europa-Zentrum)
- **sCorPiuS Roadmap** (Giacomo Tavola, Politecnico di Milano)
- **ProcessIT Roadmap** (Pär-Erik Martinsson, Lulea University)
- **Industry 4.0** (Daniel Stock, Fraunhofer-IPA)

In addition an overview of the CPS related domains was given:

- **Manufacturing Domain** (Daniel Stock, Fraunhofer-IPA)
- **Energy and Transport Domain** (David Servat, CEA)
- **Smart City Domain** (Dolores Ordóñez, AnySolution)

Following the project and domain presentations and discussions in the morning, the afternoon focussed on interactive sessions to jointly elaborate a matrix of research and implementation priorities, followed by a deep dive into priority topics and on the elaboration of barriers and funding strategies. These interactive sessions provided an excellent frame and atmosphere for fruitful discussions, to exchange views, to discuss different perspectives and reach consensus to support the European Commission with regard to priorities of their funding programme in the field of Cyber-Physical Systems. Themes like interoperability, standards, safety, and modelling & simulation were seen as top priorities (technological/research). Furthermore, demonstrators, platforms, and CPS education were seen as essential (non-technical) themes for successful implementation. The experts recommended to focus EC incentives on (open) platform building, supporting demonstrators, CPS research, and further open approaches – such as open calls and open source solutions. As show-stoppers, next to high implementation costs, lacking interoperability/standardisation and safety and security issues, regulatory and business (model) aspects were highlighted. (For more detailed results see [35])
b) Constituency Building Workshop on future Platforms (Turin; October 2015):

The Road2CPS Workshop on Future Platforms was held on the 8th October 2015 in Turin, Italy. The main motivation of the workshop was to understand the current situation of European players in the field (ongoing platform activities) and analyse to which extent existing efforts are addressing needs and demands from different industrial sectors in an effective way. Road2CPS gathered 35 experts from industry, academia and policy making bodies with knowledge and experience in Open Platforms and Architectures, both horizontal (cross-sectorial) and vertical (domain-oriented) for this purpose.

Experts from different projects and platforms were joining the workshop sessions, such as representatives from Crystal [25], Arrowhead [26], Virtual Fort Knox [27], FITMAN [28], FIWARE [29], Industrial Ring 4.0, HANA Platform [30] – representing the supply side. The demand side was focused on the sectors of manufacturing, health, transport, and smart cities. The representatives were involved by contributing insights to the elaboration of consideration of platform relevant statements by discussing needs, demands, solutions and offerings each of the four domain sectors.

They contributed to a lively discussion on platform concepts where some characteristics and challenges for future platforms were identified. Discussions were also useful to create awareness about the different European initiatives and stimulate the alignment and coordination between them.

The workshop was structured around the following pillars:

- understanding the offer (i.e. platforms resulting from projects funded by the European Commission (EC) or other bodies)
- understanding the demands and needs coming from different domains: manufacturing; automotive; energy; smart cities, etc.
- panel discussion and interactive sector-driven session (in groups), sharing outcomes; checking potential gaps from platforms vs. needs

More specifically, seven presentations from the supply side (a view on existing/developing platforms) were provided:

- **Crystal** (Christian El Salloum, AVL LIST GmbH)
• **Arrowhead** (Pär-Erik Martinsson, Lulea University)
• **Virtual Fort Knox** (Ursula Rauschecker, Fraunhofer-IPA)
• **FITMAN** (Sergio Gusmeroli, TXT)
• **FIWARE** (Nuria de Lama, Atos)
• **Industrial Ring 4.0**: A platform for the Catalan Smart Industry (Sergi Fuiguerola, i2CAT)
• **HANA Platform** (Raik Hartung, SAP)

The different presentations from the platforms providers revealed strong similarities in terms of technological conception and also economic success factors. The presentations indicated that there is a strong need for openness, interoperability/standardisation and flexibility, early user/customer involvement, as well as definition of the right business concept behind it. European Union (EU) funding can considerably help to realize a successful platform strategy in the EU by bringing the right stakeholders (sometimes also competitors) together; this should lead to agreements on standardised approaches and the setting up of successful ecosystems.

Regarding the demand side (a view on the sectorial requirements and needs), five presentations were provided:

• **CPSoS** (Christian Sonntag, Eutexoo)
• **Manufacturing/Automotive** (Óscar Lazaro, Innovalia)
• **Energy** (Alexander von Jagwitz, Baumgroup)
• **Smart Cities** (Lanfranco Marasso, Engineering)
• **Manufacturing (FoF)** Sergio Gusmeroli, Politecnico di Milano

Presentations focused on domain specific demands and needs but also identified a large number of common cross-domain topics. Even though some differences exist in terms of sectors (for example, while some domains are more open to changes others are reluctant to adopt new technologies), many of the necessary building blocks raised by the sectorial representatives were repeated.

The panel discussion as well as the interactive session focused mainly on the most pressing needs (technological solutions as well as requirements for a successful implementation) and actions to be taken. A short analysis comparing domain specific but also cross-domain demand and offering to identify the current gaps was conducted. It became clear that there are already promising solutions in place, of which some are being tested by customers already; nevertheless, further developments and maturity are urgently needed to fulfill industrial requirements in a production environment.

A need for a more coherent (unified) regulation has been pointed out by various domains, but care has to be taken not to hinder the development of new markets. Privacy is a key issue from domains collecting personal data (energy, transport, smart city). The market should drive standardisation especially to promote interoperability and avoid vendor lock-in. There is a need to engage with industry - specifically SMEs - as well as to build innovation ecosystems around the stakeholders. Initiatives like I4MS are appreciated as starting point and should be continued or even enhanced. An ecosystem of users needs to be developed in order to sustain new platforms, which basically means that we should not only work on the supply side (developing new platforms and frameworks) but should work to create the demand.

There was a general agreement on main requirements and challenges, including:

- openness
- interoperability/standardisation
- (suitable degree of) regulation, privacy, safety & security
- business thinking
- involvement of customers
- creation of ecosystems around platforms
- tools and mechanisms for pan-european testing and experimentation, among others.
Participants pointed out that there is a need to further elaborate on such discussions, exchanging views and aligning supply and demand side of platforms. In a next step, the direct platform users / customers should be involved more deeply, as it is crucial to reply to real needs and create a relevant value proposition (avoiding pure technology-push approaches). EU funding for this topic is a need to accelerate the process and has proved to be effective in the last years in terms of maturing platforms as well as strengthening the related ecosystems. Such investment is seen to be crucial to bring main actors across the industrial sectors and various disciples together, to jointly face the challenge. In order to bring EU-platforms to a successful implementation we need to ensure that there is collaboration in research and development, openness in finding new business opportunities, de-fragmentation of initiatives and efforts, constructive dialogue on conveying themes (regulation, privacy, legal frameworks, etc.), building and sustaining the ecosystem, and involving SMEs and getting the commitment of large industry.

From all presentations and activities during the day it became clear that there is a need for key actors in Europe to come together as the only way to face the strong competition coming from US platforms that currently dominate the market. EU-funding as well as industry commitment can massively help to generate the right standards and interfaces. Moreover, EU-projects are a good way to bring the relevant stakeholders together, enter into dialogue and create the innovation ecosystem for a sustainable value proposition. (For more details please check [38])
c) Road2CPS Clustering and Communication Event: The “Smart Cyber-Physical Systems” Cluster of EU Projects (Vienna; April 2016):

An outstanding example of the close collaboration and connection of the Road2CPS project with the ARTEMIS/ECSEL community is the organisation of a joint event: The Road2CPS ICT-1 clustering event was held in the frame of the ARTEMIS-IA Spring Event and in conjunction with CPS-week.

The Road2CPS Clustering and Communication Event brought together over 120 experts from the fields of Cyber-Physical Systems (CPS) and the Internet of Things (IoT) and presented 16 projects that had been funded under the first ICT-1 call of Horizon2020 complemented by three ARTEMIS and ECSEL projects. The meeting was very successful in raising awareness of the activities being performed and highlighted that the areas being addressed within the project portfolio provide good coverage of the research, development and innovation needs across the domain. The timing of the meeting was also very pertinent with the launch of the new ARTEMIS-IA Strategic Research Agenda and also the Digitising European Industry initiative with many synergies being apparent.

Notably there was a mix of higher TRL activities being addressed by the ARTEMIS-IA and ECSEL large scale projects addressing key industrial topics such as integration of tools for safety-critical systems development, interoperability, factory automation and maintenance systems. Underpinning and extending this H2020 projects are performing novel work in the areas of verification and validation to deal with the new reality of not being able to predict all eventualities in autonomous applications such as cars, and to deal with key issues such as guaranteeing safety and security in a world which is becoming increasingly vulnerable to cyber-attack. A number of projects are addressing multicore processors to maximise application performance and to provide trusted computation when mixed-criticality applications are implemented.

To get past the valley of death and successfully introduce technologies it is notable that the CRYSTAL and CP-SETIS projects that address interoperability and standardisation provide a model for similar proposed actions within the agenda for Digitising European Industry. Likewise the Innovation Hubs projects, CPSE Labs and EuroCPS, that target engagement with SMEs to raise awareness, transfer skills and provide access to the latest technologies, also directly support Europe's goal of Digitising European Industry.

Looking to the future the roadmapping activities being performed in projects such as Road2CPS and CPSSoS have an important role to play in bringing together the constituency around CPS and in providing recommendations for future research needs. The markets for CPS are global and the CPS Summit and TAMS4CPS projects are identifying areas within CPS where it may be possible to collaborate with the US to tackle common problems and work jointly to bring together critical mass. Here it is also important to address barriers that exist to technology roll out through harmonisation of standards, regulation for privacy and approaches to liability at a world-wide level.
4.4.2 Connection to CPS Projects (ICT-1, ARTEMIS/ECSEL, Industry 4.0) through other events and activities

a) Connection to ARTEMIS/ECSEL

The first link from Road2CPS to ARTEMIS was installed by participating at ARTEMIS/ITEA co-summit 2015 held in Berlin, by sharing a booth including a Road2CPS poster with further ICT1 projects. Furthermore, themes of the Road2CPS project were discussed during the ARTEMIS Summercamp in Helsinki 2015 in order to build consensus in terms of CPS-relevant themes. Road2CPS contributed with a presentation and within the panel discussion.

Thereafter, Road2CPS organised a workshop for ARTEMIS on 7th of October 2015 in Turin, which targeted on the elaboration and update of the new ARTEMIS Strategic Research Agenda. This one-day workshop resulted in updating mini roadmaps for the following main topics: a) Architectures, b) system design, c) autonomous control, and d) computing. These gained insights influence the overall Road2CPS roadmap as well.
Moreover ARTEMIS published an article on Road2CPS in the ARTEMIS Magazine December 19\textsuperscript{th} 2015 https://artemis-ia.eu/publications.html:

The connection between Road2CPS and ARTEMIS has become very close and fruitful.

b) Connection to ICT-1

In preparation for the Road2CPS organised event in Vienna, the Road2CPS consortium entered into close contact with all ICT-1 project coordinators, to create a portfolio booklet for the event [37]. Moreover, Road2CPS was invited to give a presentation at the HiPEAC EU consultation meeting in June 2016 in Brussels, including a ‘Smart Anything Everywhere’ event as a second day focussing on ‘Collaboration Workshop on Advanced Computing and Cyber-Physical Systems’. Road2CPS information was also published in the event related brochure.

c) Connection to Industrie 4.0

Cyber-physical systems are seen as the technological enablers of Industrie 4.0 – they connect the virtual (cyber) world with the real (physical) world. Cyber-physical systems in production consist of intelligent (smart) machines, warehouse systems and means of production which can independently exchange information, trigger actions and manage their own performance. The most important actors in the Industrie 4.0 context on a national are Bitcom, VDMA and ZVEI, which form the Industrie 4.0 platform. The Industrie 4.0 platform consists of a number of working groups regarding important topics like business models, standardization and IT architectures, where the platform members, also encompassing the most important industrial partners, discuss research topics and requirements for standardization, which is handled by the VDI for example.

The Road2CPS Industrie 4.0 Taskforce is in constant communication with these partners and also provides input for the relevant working groups and standardization bodies. Furthermore research findings from research projects and research programs provided by the German government can be used as additional input. The feedback and upcoming topics from these sources will be brought back to the discussions taking place during the Road2CPS workshops.

![Figure 20 - Road2CPS I4.0 Connection](image)

The workshop conclusions lead to new findings and outcomes from the workshops were distilled to final outcomes from the workshops which serve as inputs for the Road2CPS roadmapping reports on the one hand but also as instruments to find and define new research topics which can be used as new discussion material in the aforementioned working groups and standardization bodies. Since the Industrie 4.0 platform is closely connected with many large companies, but also a lot of SMEs, which
are one of the main pillars of Germany’s industry, the topics which constantly emerge and are regarded as most important are standardization (e.g. the Industrie 4.0 reference architecture RAMI), business models, legal frameworks and security.

Besides the Industrie 4.0 initiative at national level, Road2CPS is in addition linked to the Baden-Württemberg Industrie 4.0 Alliance, which is a similar, but regional network initiative fostering knowledge exchange processes and assisting firms in the sectors of production, information and communication technology in their digital transformation processes.

### 4.4.3 Next steps

Road2CPS will be holding further workshops and a final event, bringing together the community for further discussions and building linkages across the various fields and domains.

### 4.4.4 Task Force Recommendations

The work done in the taskforce has led us to create some clear recommendation that require actions from different actors. The table below reflects the key ones

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Actions ongoing</th>
<th>Actuation required</th>
<th>Main bodies involved</th>
<th>Priority level</th>
</tr>
</thead>
<tbody>
<tr>
<td>To connect the community across the EU-funded ICT projects, with the ARTEMIS/ECSEL community (working on higher TRLs) and with national/regional initiatives like Industrie 4.0</td>
<td>Commission has already launched several calls for addressing these aspects (especially ICT-1 CSA focussing on community/constituency building)</td>
<td>Longer lasting and more sustainable activities are needed, to keep the contacts established for a longer period (CSAs only last e.g. 2 years)</td>
<td>European Commission, CSAs, possible Networks of Excellence, Competence centres</td>
<td>High</td>
</tr>
<tr>
<td>Promote links across sectors, between industry and academia, across value chains, etc.</td>
<td>Commission has already launched several calls for addressing these aspects (especially CSA focussing on community/constituency building)</td>
<td>Longer lasting and more sustainable activities are needed, to keep the contacts established for a longer period (CSAs only last e.g. 2 years)</td>
<td>European Commission, CSAs, possible Networks of Excellence, Competence centres</td>
<td>High</td>
</tr>
</tbody>
</table>

### 4.5 Task Force Business Models

The development of the activities related with the roadmapping of technologies and use cases selected in the project in addition to the gaps and impact created by the ongoing projects in the CPS fields have allowed us to identify several critical aspects that are driving the definition of sustainable business models in this new era.

The impact of vertical vs horizontal solutions in CPS ecosystem has been already discussed, nevertheless regardless of the approach followed there are common opportunities that facilitate and justify the adoption of these technologies. In the following subsections we will get into them aligning opportunities, business models and requirements.
4.5.1 Methodology followed in this task force

This task force aims at supporting the technical findings of the studies developed in the project linking them with real business opportunities already in place, or emerging trends based on the opportunities presented by CPS. In this sense the methodology followed is presented in the following picture.

![Image of methodology diagram]

This Task Force takes as input the work developed in the different technical WPs and also the results obtained in the Workshops and in other Task Forces. The first WP through the provision of the gaps and impacts that the different projects have allow the identification of the key emerging technologies, the areas where special attention is paid and the trends from the technical point of view. This input is complemented by WP2 which goes a bit further in the technical analysis and combines it with the main domains addressed by the project providing a roadmap that facilitates the identification of the adoption dates for some of the concepts currently under development. The case studies provide real world examples of how CPS is transforming different sectors, since those are real cases a first idea on how CPS deployment can be sustainable is provided. Finally project Workshops and other Task Forces help complementing these inputs.

4.5.2 CPS and its impact on CAPEX and OPEX

The deployment of CPS in any environment requires an initial investment that represents an impact on the CAPEX of the entity that relies on it. Nevertheless the ROI for these systems will come in two main forms:

- **OPEX reduction** – the digitalization of the processes and methodologies followed will facilitate a better operation of the whole business.
- **Open new revenue streams** – the information generated by the CPS (as a whole or part of them) can be opened to third parties interested in it to improve their performance.
The following subsections present examples of how these two approaches can be presented in real scenarios.

### 4.5.3 Data Driven economy

According to data landscape website [32] the data market is growing in popularity and participation. The activities are going beyond provision of open data portals and more elaborated and competitive solutions are being released.

CPS relies on the digitalization of processes, thus the whole data market value chain is covered. The business opportunities derived from this scenario are:

- Data holders. The data sets created by the different systems can be anonymised to extend its value to other sectors, thus creating a new revenue stream to add to the optimisation of their own business processes.
• Data analytics. The analysis of the data provided by external sources that can be related to the activities of multiple sectors requires specific knowledge that will be monetised.

• Infrastructure. Finally extending from local application of CPS technologies towards a global phenomenon requires the provision of efficient and secure infrastructures, thus this will be another important leg of data driven economy.

The expected value for each sector is presented in the previous figure where all the domains considered by Road2CPS are represented.

4.5.4 Predictive maintenance

Maintenance services demands a lot of attention and resources for maximize machinery availability while minimizing the amount of materials. The availability at certain points of some applications is a critical success factor for companies. It is easy to understand the impact of not having critical infrastructures in a nuclear energy plant properly working. In this case the application of predictive maintenance will save not only time, but also improves efficiency and facilitate the planning of resource for keeping overall performance unaltered.

Predictive maintenance is about more than stopping small issues becoming big ones – it’s about gaining actionable intelligence for continually improved operational efficiency. [33]

The four main aspects enabled by predictive maintenance are:

• Automatic early detection of equipment malfunction
• Active repository of critical data
• Advanced diagnosis tools, essential for planning
• Rapid information transfer, enabling experts to deliver timely and focused assistance to local operators.

Predictive maintenance works based on the application of Big Data technologies to the data sets that are locally generated by the owner of the infrastructures but also combined with other sources that reduce OPEX while maximizing the working time of all critical machinery.

4.5.5 Remote asset monitoring

The tracking of machinery in industries, hospitals, cities or any environment is a key aspect for the management of the operations, the control of stocks and the efficient use of storage facilities. Traditionally this work was done only by people manually counting and reporting the kind of activities that are going to be executed and the planned used time. This becomes more important when tracking stock availability, the control was based on daily monitoring but not on real time, thus the typical situation was running out of existences or being over the needs. By the introduction of CPS technologies all these procedures will be completely transformed.
• Real-Time asset monitoring allows controlling any time the position and status of controlled equipment. Due to this digitalization the schedule and the adaptation to real needs and circumstances is possible. In addition to this, all the users that have required a slot of certain good can be alerted in case it is not available and having the overall picture of the whole set of assets.

• Stock Management – The digitalization of stocks and its direct connection to ERPs enable real time tracking of the status of goods. This way is possible to react always in time to the specific needs for assuring a proper provision of service.

A clear example of how this kind of systems works is HLL [34]. This company applies CPS for controlling everything in hospital environments.

4.5.6 Demand response operations

Next generation of utility services is going to be based on demand-response paradigm. The new infrastructures is not going to be deployed as it was done before, the minimization of CAPEX demands a full control of the infrastructures and also cooperation with their users. The combination of both aspects assures the provision of service minimizing overall costs. New equipment will require a closer monitoring and the combination of user information and their behavior must be used for operating the utilities infrastructures.

New opportunities are appearing for optimizing operational procedures, and they are also presented as benefits for users. The incentive mechanisms that can be presented to them will help infrastructure managers to better shape the overall performance while benefiting those users who can accommodate their needs to the requirements of the infrastructure.

This new scenario is possible thanks to the “smart anything everywhere” concept, from home appliances to power plants are part of the hyper connected society.

4.5.7 Task force recommendation

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Actions ongoing</th>
<th>Actuation required</th>
<th>Main bodies involved</th>
<th>Priority level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extend the value of digital information beyond companies boundaries</td>
<td>There are several calls targeting exploitation of data. The focus of that calls ICT-15 2016-2017 is to demonstrate and improvement of 25% in performance</td>
<td>Safety, security and privacy frameworks developed and adopted</td>
<td>European Commission, CSAs, possible Networks of Excellence, Competence centres</td>
<td>High</td>
</tr>
<tr>
<td>Implementation of demand/response paradigm for utility providers</td>
<td>Companies are adapting to the opportunities and requirements of this new scenario</td>
<td>Education of consumers and companies</td>
<td>Industries, SMEs and citizens</td>
<td>High</td>
</tr>
</tbody>
</table>
5 Conclusions

This document summarizes the main activities developed in the context of Road2CPS Task Forces. Although there are some open activities we have already collected several meaningful conclusions derived from the research done in them. The main objective of Task Forces is to provide a list of actionable recommendations whose impact is identified.

For achieving the objectives of the different Task Forces Road2CPS has implemented a methodology that assures the integration of the multiple sources of information. This process facilitates the validation of conclusions, not only as Road2CPS thoughts but as a combination of the project’s findings and the assessment and inputs from experts in several iterations. One of the most important activities developed are the workshops, they allowed us to gather experts discussing and providing inputs to the work developed by us, thus creating richer development cycle. These events have been a perfect place for sharing and interacting with relevant players in the CPS domain representing large industries, SMEs, academia and public administrations, moreover, the heterogeneity of profiles also covered the different domains that are under study in the project and even going beyond them.

The main recommendations from the Task Forces are summarised in the following list.

- Promotion of Platform interoperability, there are multiple platform for different domains, but also for the same domain available, some of them developed by private companies but others are the result of research projects funded by the European Commission. One key aspect to develop the cross-domain collaboration in the CPS is to promote the interoperability among platforms that will facilitate data and experience sharing.
- Promotion of device interoperability, the situation with device protocols, standards is much worse than with platforms, there are too many different technologies that can be applied for communicating devices in CPS. There is a need of the adoption of measures that promote collaboration and cooperation that help device manufacturers and system designer to avoid hardware lock in.
- Development of new security features, the scandals with privacy and security are a huge barrier for the digitalisation of any systems. This problem is more severe in CPS because it requires changing traditional working habits and systems. It is mandatory to provide security features independent and robust that will pave the way of CPS adoption in critical systems.
- The need of testing facilities is also a barrier, there are several pilot programs but a bit closed so it is not easy to test CPS solutions in “real-environments”, it will be also very welcome to promote facilities like IoT-Lab and similar in the CPS domain and with possibilities to adapt them to different use cases.
- To connect the community across the EU-funded ICT projects, with the ARTEMIS/ECSEL community and with national/regional initiatives like Industrie 4.0 as well as across domains.
- Because of the urgency of enriching and enlarging our knowledge of CPS and CPSE there is a need to undertake groundwork within the terms of the EHTA and the Bologna Declaration to create the necessary network for provision of training in the realms of CPS/CPSE.
- Given that CPS global RD&E is proceeding apace, it is recommended that the development of common, EU-wide curricula and support facilities for educating the European population for CPSE and CPS operation.
- Given the likely global reach that will be necessary for many safety-critical CPS and societally-significant CPS in order to deliver their benefits, and the consequential, closely-associated requirement for distributed CPS/CPSE knowledge and skills, it is recommended that support...
for the distribution of these skills beyond the borders of the EU28, especially in the developing regions of the world, should be created.

- It is recommended that networks of expertise should be developed with other developed regions outside the EU28 be pursued.

- To promote links across sectors, this will enable not only a better cooperation among industries but also the development and empowered of their individual data sets. Thus new business opportunities will appear and a stronger industrial community would be created.

- To extend the value of digital information beyond companies boundaries

- Education in every aspect concerning the opportunities derived from the adoption of CPS. From industry to SME and also citizens need to be aware not only of the savings that the deployment of CPS implies in mid-term, but also how the modernization of every single step in all value changes makes more sustainable the whole digital and physical ecosystem.
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