The “Smart Cyber-Physical Systems” Cluster of EU Projects

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Report from the Road2CPS Clustering and Communication Event

Held on 14th April 2016 in Vienna, Austria
(in the frame of the ARTEMIS-IA Spring Event and in conjunction with CPS-week)

May 2016

http://road2cps.eu

Disclaimer: The views expressed here are those of the workshop participants and do not necessarily represent the official view of the European Commission or Road2CPS project on the subject.

Executive Summary

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 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 CPSoS 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.

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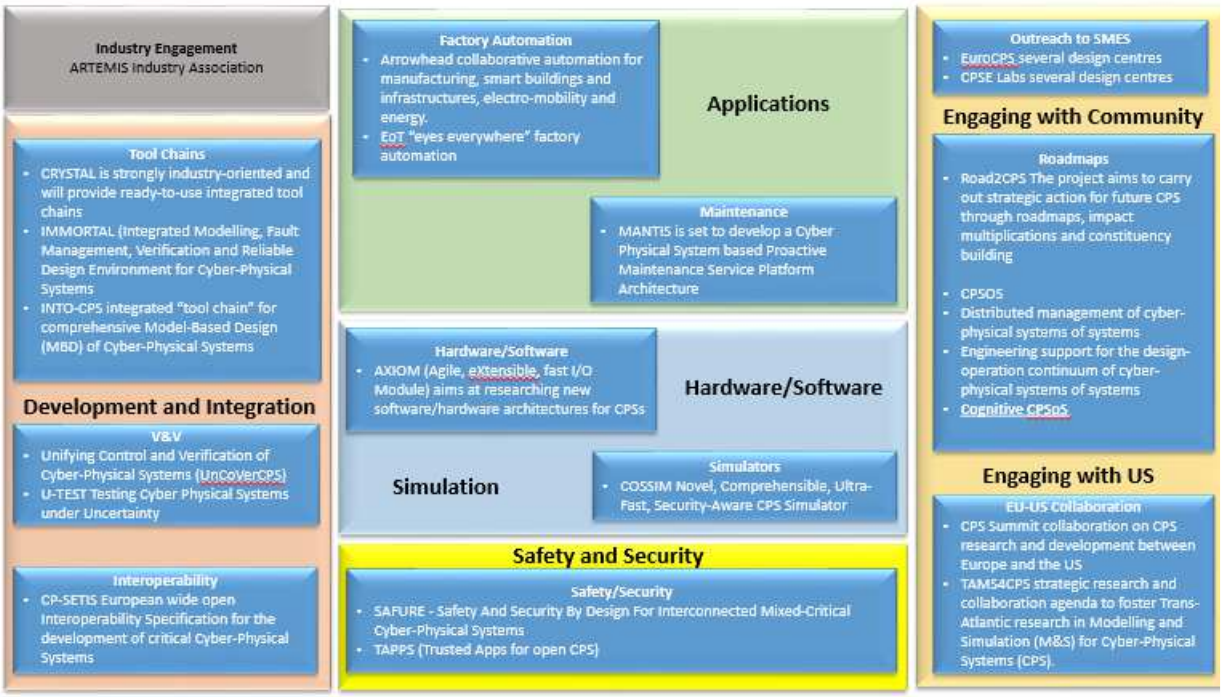

Figure 1 Overview of portfolio of running CPS projects (April 2016)

An overview with key points of the 16 H2020 and three ARTEMIS pilot projects presented is given in Figure 1. On the top left industry engagement is being led by the ARTEMIS-IA. This is driving ARTEMIS large-scale projects addressing key topics such as Factory Automation and Maintenance systems in the ARROWHEAD and the ECSEL MANTIS projects. Supporting this is the H2020 project EoT which is addressing a specific technology of visual processing which has application across a number of application domains.

Development environments are a key concern in industry and the CRYSTAL project is a major initiative to address the integration of tools for safety-critical applications. The interoperability specification (IOS) allows integration of tools from many vendors. Underlying this is an Innovation Action to develop and promote the IOS standards to the wider community. The H2020 projects IMMORTAL and INTO-CPS are also addressing aspects of tool integration. Verification and validation is also a key need in the safety-critical application domain and notably here new novel approaches are being investigated to deal with the new reality of not being able to predict all eventualities in autonomous applications such as cars (projects UnCoVerCPS and U-TEST). Hardware and software development is being directly addressed in a number of projects exploiting the use of multicore processors reflecting the trend towards increasing numbers of cores. Simulation is being addressed in one project, COSSIM, and notably this project is also considering safety as a key requirement. Underpinning the adoption of networked systems is the increased vulnerability to cyber-attack. Here foundational work on safety and security is being performed by SAFURE and TAPPS. In particular, dealing with the reality that Apps with little or no provenance are being increasingly downloaded onto hardware, e.g. in the automotive

domain, the TAPPS project is developing trusted execution areas to protect systems of higher criticality.

Notably the H2020 projects EUROCPS and CPSE Labs target at engaging with SMEs. As SMEs are the “powerhouse” of Europe these are important in raising awareness, transferring skills and providing access to the latest technologies. This directly supports Europe’s goal of Digitising European Industry. There are also two key roadmapping activities. Road2CPS has an important role to play in bringing together several roadmapping activities that have been performed previously and to create a constituency around CPS. At the Systems of Systems level the CPSoS project is putting forward recommendations that deal with the human and complexity aspects of large, highly distributed systems such as sociotechnical issues (e.g. trust for increased autonomy) and cognitive features to manage increased complexity. These are areas which are not represented in the current portfolio but which must be addressed in order for the technology to be adopted.

The CPS Summit and TAMS4CPS projects address both joint EU and US collaboration, one specifically on modelling and simulation and the other in a wider sense identifying areas within CPS where it may be possible to collaborate. It is clear that the problems being addressed are global problems which need to be tackled jointly to bring together critical mass. Here trustworthy CPS is an area which is being promoted. Looking beyond this there are many opportunities for standardisation. This has been demonstrated successfully by CRYSTAL and CP-SETIS for tool interoperability but is also required in other areas such as interoperability and standardisation for CPS and IoT more generally as highlighted in the agenda for Digitising European Industry. Finally, in order to enable successful uptake of technologies there is a need to remove barriers to commercialisation through harmonised regulation for privacy and liability.

In the main part of this report the strategic context of EU level support for Cyber-Physical Systems is presented along with summaries of the project presentations. The results of the discussion session and conclusions are also described. Project facts including partners, abstract, objectives and highlights are referred to in the Annex.

Introduction and Scope of Meeting

The aim of the Road2CPS Clustering and Communication Event, held in the frame of the ARTEMIS-IA Spring Event and back-to-back to the CPS week, was to bring together experts from the fields of Cyber-Physical Systems (CPS) and the Internet of Things (IoT) from projects that had been funded under H2020 and ARTEMIS/ECSEL. Each project presented their aims and key outcomes. This raised awareness of activities going on within the various projects and also provided an overview of the coverage of the research activities across the domain. This was particularly relevant and pertinent as the new ARTEMIS-IA Strategic Research Agenda had been announced on the day before highlighting a number of priority areas. A discussion session was then held with the aim to:

1) Identify synergies and put forward ideas for co-operation across projects and also across the H2020 work programme.
2) Identify if all the key research priorities were being covered, highlight key gaps and whether appropriate resources (i.e. funding) were being targeted at specific areas
3) Identify how the EC could better support collaboration/exploitation of synergies
4) Identify if Europe is doing enough to get over the valley of death to get research to the market place
5) Consider if all the right people are engaged, e.g. demand side, the commercialisation people, customers, etc.
6) Identify if the activities presented could be linked to digital platforms and digital innovation hubs
7) Identify any other significant barriers for industry, e.g. standards for interoperability, sociotechnical issues such as developing trust, needs for raising public awareness, needs for regulation for safety and privacy and legal support for Service Level Agreements and liability

The meeting highlighted a number of areas where there were opportunities for collaboration and also promoted fruitful discussions between projects both in the meeting and post meeting.

Welcome ARTEMIS

The delegates were briefly welcomed by Jan Lostroh from the ARTEMIS Industry Association (ARTEMIS-IA). The meeting was then formally handed over to the Road2CPS project who had organised the meeting with the support of the European Commission and ARTEMIS-IA.

Welcome and Introduction Meike Reimann (Road2CPS)

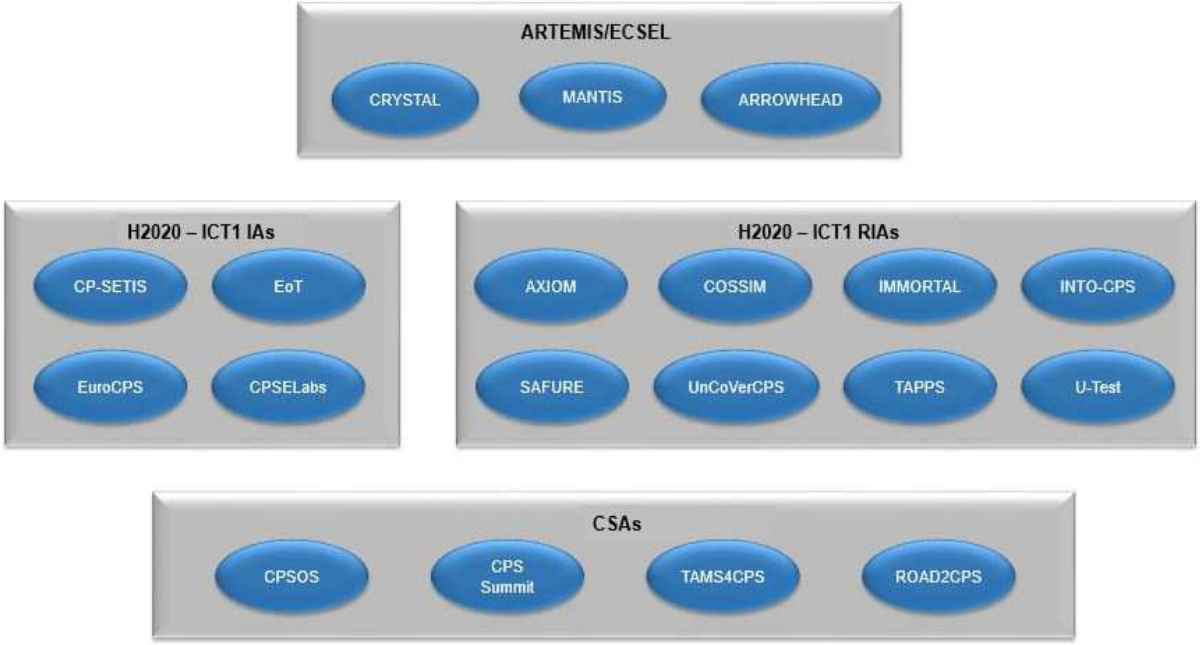

Figure 2 Overview of Projects Presented at Event

Meike Reimann gave a short welcome highlighting the aims of Road2CPS and thanking both ARTEMIS-IA and the European Commission for their support. One of the main aims of Road2CPS is to foster collaboration between all running CPS projects. In total 16 EC funded projects from the first call of Horizon2020 in 2014 were represented at the meeting with a further project, CPSoS from FP7, also participating as shown in Figure 2. The latter project was just about to complete providing strategic recommendations in the area of Cyber Physical Systems of Systems. Additionally, 2 ARTEMIS projects were represented at the meeting: CRYSTAL and ARROWHEAD and the ECSEL project MANTIS. These larger scale and industrially focused projects are directly addressing key near term needs within industry.

It was highlighted that the aim of the event was to bring people together and part of the role of Road2CPS is to encourage constituency building, identify synergies, foster discussions and identify how projects can collaborate. It was noted that invited participants were keen to come along to the event, highlighting a wish to engage. An overview of the agenda for the day was then given.

European Commission Strategy and Vision Keynote (Werner Steinhögl)

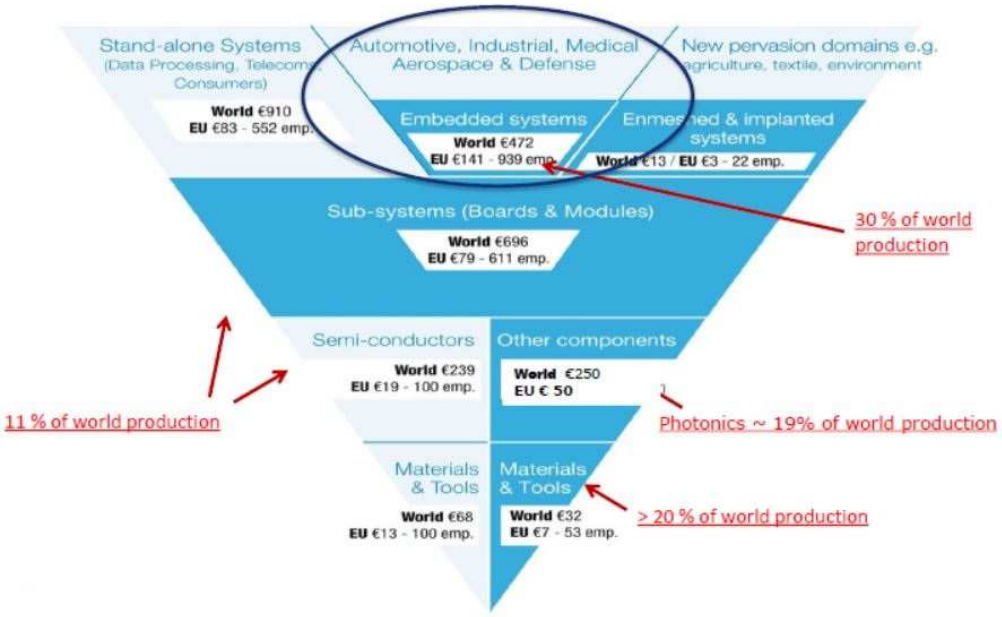

Figure 3 Europe's Strength in Embedded Systems

Werner Steinhölg highlighted the importance of the embedded systems market for Europe. Here Europe accounts for 30% of the world market with many key companies (See Figure 3). The embedded systems sector also is a major contributor to employment within Europe with 939M associated jobs. An overview of the current portfolio of CPS projects was given as well as the current H2020 ICT programme for 2016-2017. In the current portfolio there are 8 Research and Innovation projects with funding of 37MEuros, 4 Innovation Actions projects with a budget of 21MEuros and 3 Support Actions on Roadmapping and community building with a budget of 1MEuros. The strategy and outlook for under H2020 for 2018-20 was then presented. The strategy is to connect CPS value chains in all types of industry covering applications in aerospace, automotive, white goods, medical, industrial automation. It was noted that the importance of software is very high and is key to adding value to many products. Typically 40-50% of added value comes from embedded electronics in the automotive, aerospace and medical sectors. There is also a move towards providing services. The 8 Research and Innovation projects are addressing the science of CPS integration which includes co-simulation, modelling at all levels including circuits, communication networks, firmware, operating systems, systems architecture and software layers. The main vision is one of having model based design to build cutting edge CPS with the intention of saving development cost and time. Use cases being addressed include aerospace, automotive, telecoms, health, surveillance, smart buildings, logistics, smart grids, manufacturing, railway, agriculture and visual search. The underlying methods being developed, however, could also be reused in other areas.

Two Innovation Actions had been funded to support platform building. These are CP-SETIS which is addressing interoperability and EoT which is developing a low cost vision platform. Two networks of competence centres had also been funded under the Smart, Anything, Everywhere initiative, EUROCPS and CPSE Labs. Finally, 3 Support Actions have been funded to build communities, develop and validate roadmaps and explore EU-US collaboration.

Complementing this industry driven ARTEMIS/ECSEL projects have been funded in the areas of embedded intelligence/CPS systems to produce results at higher Technology Readiness Levels (TRLs).

In the existing Industrial Leadership 2016-2017 EC programmes there are a number of opportunities in:

- A new generation of components and systems
- Next generation computing
- Future Internet
- Content technologies and information management
- Advanced interfaces and robots
- Micro and nanotechnologies and photonics

A call for Large Scale Pilots in a number of areas has also been made:

- Smart living environment for ageing well
- Smart farming and food security
- Wearables for smart ecosystems
- Reference zones in EU cities
- Autonomous vehicles in a connected environment

Looking to the future the Commission is supporting the concept of Digital Transformation of all industry. The research and innovation programmes funded by the EC play a major role in this. Digital Transformation is built on three pillars:

(1) Better access for consumers and businesses to digital goods and services across Europe
(2) Creating the right conditions and a level playing field for digital networks and innovative services to flourish
(3) Maximising the growth potential of the digital economy.

Embedded systems are seen as an essential technology for Digitising European Industry as shown in Figure 4. The overall aim is to provide leadership in open digital platforms for industry. This should be driven by European actors so that any business can utilise them and make products, processes or provide services ready for the digital age. A key objective is to bring together demand and supply as the digital transformation of all industry in Europe requires a strong digital sector in Europe.

Figure 4 Digitising European Industry

In order to achieve this, the Commission wants to align national initiatives, create and support Digital Innovation Hubs and provide leadership through partnership. The aim is to create leadership in digital technology value chains and provide SMEs, midcaps and non tech. companies with access to the latest technology. There is also a need to skill the work force for digital change and adapt legislation to eliminate barriers for digitisation. The key challenge is to build upon strengths of vertical markets and develop a European presence in cross-sector platforms for IoT, Data Web and consumer.

To ensure European leadership in digital platforms for industry and provide technology gateways that business can use, the following activities are being promoted:

- The upscaling and further integration of R&D&I core platforms
- Reinforcement of the development of European Reference Architectures
- Support for experimentation environments such as reference implementation, test beds and large-scale demonstrators
- Fostering of constituency building across value chains and vertical silos

Innovation Hubs such as those funded under Smart, Anything, Everywhere are seen as a very successful mechanism to support bottom up integration and provide access to digital technologies and expertise at a local level.

ARTEMIS-IA and ECSEL Presentations

ARTEMIS-IA – Introduction as ETP and Industry Driven Association Jan Lohstroh (Secretary General of ARTEMIS-IA)

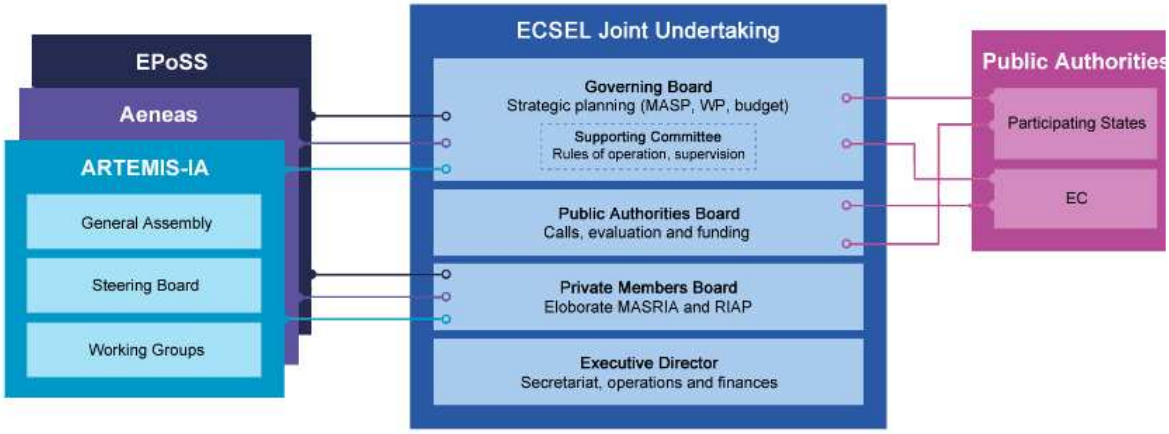

Figure 5 ARTEMIS-IA

The ARTEMIS Industry Association covers Embedded & Cyber-Physical Systems with more than 170 members and associates from all over Europe. An overview of the organisational structure was given in terms of general assembly, steering board and working groups. The role of the ARTEMIS-IA in being a member of the ECSEL Joint Undertaking was also highlighted (See Figure 5).

The mission of the ARTEMIS-IA is to nurture the ambition to strengthen Europe's position in Embedded Intelligence. The ARTEMIS-IA promotes the R&I interests of its members to the European Commission and to the Public Authorities of the participating states. To explain the areas and importance of embedded systems and Cyber-Physical Systems for industry and society as a whole a video was shown that has been created as part of the launch of the Strategic Research Agenda. It was noted that the multidisciplinary nature of the membership provides an excellent network for the exchange of technology ideas and cross-domain fertilisation, as well as for promoting large innovation initiatives. The focus areas for the ARTEMIS-IA are embedded systems, CPS and IoT.

It was highlighted that there is a need to explain to politicians and the public the importance of CPS as this is not well understood in general. It is a rapidly changing world and it is now possible to connect systems together either directly or via the cloud in the Internet of Things. Increasingly many systems use a combination of both direct and cloud connections. In order to help industry deal with this change there is a need for digital platforms for areas such as automotive and health. In particular, in order for Europe to take a leading position in Embedded Systems and CPS there is a need for a systems approach across the full value chain. ARTEMIS has supported this by initiating 56 projects in the areas of reliability, safety-critical systems, scalability, cost effectiveness, etc. There are also three major innovation pilots: CRYSTAL, ARROWHEAD and EMC^2.

It was highlighted that being a member of ARTEMIS gives influence on the priorities for the Strategic Research Agenda and the definition of technical fields within ECSEL. It also provides a link to the European Commission to promote industrial requirements. The organisation runs a Spring and Summer Event, and also a Technology Conference.

ARTEMIS CRYSTAL (AIPP) Christian El Salloum (AVL List)

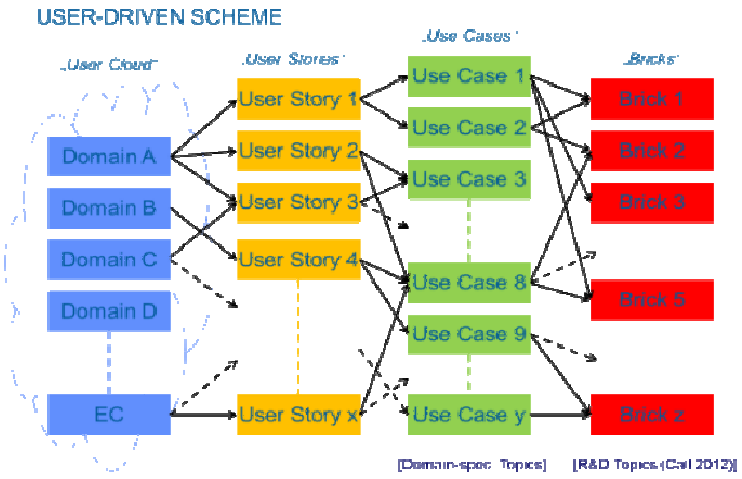

Figure 6 CRYSTAL Project Use Cases

The ARTEMIS JU CRYSTAL project is establishing an Interoperability Specification (IOS) and a Reference Technology Platform (RTP) as a European standard for safety-critical systems. It has a budget of 82 million Euro and 71 partners from 10 different European countries including OEMs, suppliers, tool vendors and academia. The project is strongly industry-oriented. The aim is to provide ready-to-use, integrated tool chains having a mature technology-readiness-level (up to TRL 7) validated by use cases (See Figure 6).

The application areas being addressed are for the aerospace, automotive, healthcare, railway, and general safety-critical applications. Typically there is a need for a large number of tools (100's to 1000's) to develop such systems to cover the total development cycle from requirements, through design and test. These tend to be used by individual departments who work in silos. The lack of tight interaction or connection between tools results in the need to manually convert outputs from one tool into the inputs for another tool. This is very inefficient and also leads to errors. Tool integration is thus needed but point-to-point inegration does not scale. If this approach is used it gets increasingly difficult to integrate tools and the whole tool environment becomes brittle with a need to assess the impact of tool changes across all the possible interactions.

There are two approaches that can be adopted to try and solve this. The first is one of using monocultures, however, if a single vendor provides a toolset that does everything there are problems with vendor lock-in. It is also never true that a vendor can provide a toolset that

does “everything” so there is always a need to integrate with other tools. It was noted that many projects go overbudget in setting up tool environments and that making changes to tool environments is expensive. The solution is to build an open integration platform for connecting tools and to expose data for use by other tools. In this way tool interaction is standardised, but not a tools‘ capabilties. The aim is to allow loosely coupled tools to share and interlink their data based on standardised and open Web technologies that enables common interoperability among various life cycle domains. This separates the data from the tool functions. This has been applied to a set of real-world industrial use cases from the automotive, aerospace, rail and health sectors.

It was noted that in order to create a successful platform there was a need for a sound technology foundation, critical mass, open standards and stability to create a supporting ecosystem. This requires working with the standardisation community to create open standards. It is also necessary to provide the tools plus use cases and create a developer community. The CRYSTAL tools are available commercially and they have been tested in multiple applications. Heinrich Daembkes added that it is important not to try and roll out new tools everywhere in a company as it is easy to fail. It is better to use the tools in a limited environment, develop good references and then publicise this inside the company for more gradual uptake.

MANTIS (RIA) Erkki Jantunen (VTT)

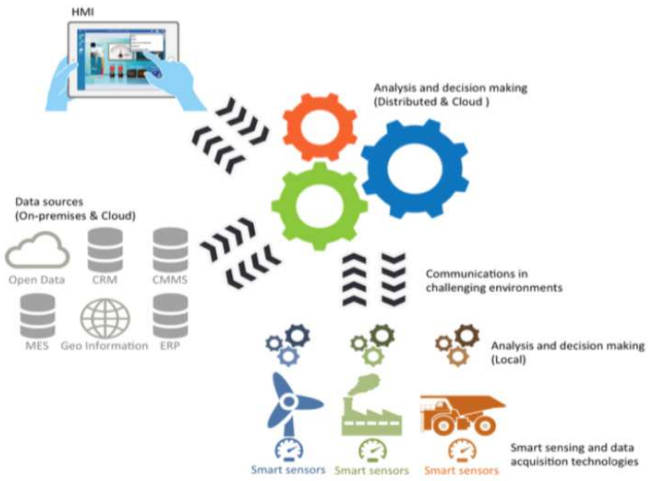

Figure 7 MANTIS Overview

The main objective of the MANTIS project is to develop a Cyber-Physical System based proactive maintenance service platform architecture enabling collaborative maintenance ecosystems. This is called the MANTIS Maintenance Framework (See Figure 7). It was noted that maintenance is now an important function to increase the efficiency of processes and also to earn money in new service businesses. This has an impact on competiveness, reducing unscheduled maintenance, minimising parts use whilst also improving the availability of assets. The project has partners from 12 countries and the goals are to increase availability and reduce maintenance time. The technical objectives are to define an overall service platform architecture for proactive maintenance utilising highly distributed

sensing, including pre-processing, data acquisition and adaptive information processing. Supporting this is a distributed collaborative maintenance decision making system that provides user-friendly, ergonomic and intuitive, context-aware, human-machine interaction. The project is exploiting embedded solutions and new intelligent sensing approaches. A key requirement is that these need to be easy to use and install so wireless communication connections to the cloud and big data approaches are being developed. MANTIS aims to demonstrate the benefits of the framework in a range of use cases.

ARROWHEAD (AIPP) Jerker Delsing (Ltu)

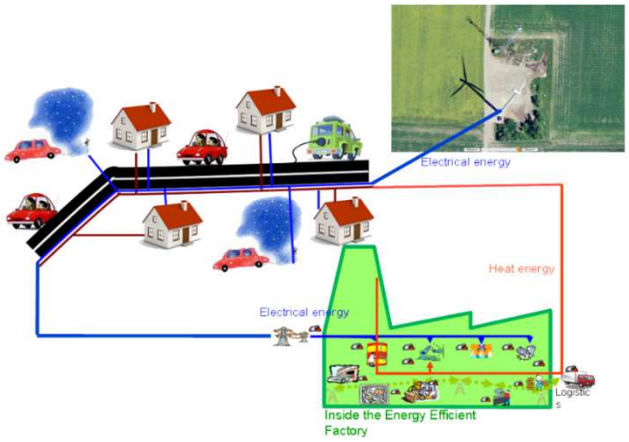

Figure 8 ARROWHEAD Collaborative Automation

ARROWHEAD is addressing efficiency and flexibility at the global scale by means of a service-based approach to collaborative automation for manufacturing, smart buildings and infrastructures, electro-mobility and energy (see Figure 8). The project brings together 78 partners and 68MEuros of funding to address the technical and application challenges associated with cooperative automation. The project is focused on ISA-95 systems in the cloud with the aim of supporting service based systems. In order to promote industrial uptake of ARROWHEAD results the outputs have been made open source. A pragmatic approach has also been adopted for interoperability using a framework that works with local clouds which is more acceptable to industry. It was noted that automation is physically local so it is only necessary to provide appropriate connections to a local cloud. This avoids the security issues that one would experience with connections to the overall cloud. An Open Source Arrowhead framework Wiki has been launched. This has been evaluated in 21 demos in 5 application domains. The results have shown that engineering time can be reduced by a factor of 4-5 (although this does not include the learning time for adopting the framework).

CPSoS (FP7-CSA) Christian Sonntag (TU Dortmund)

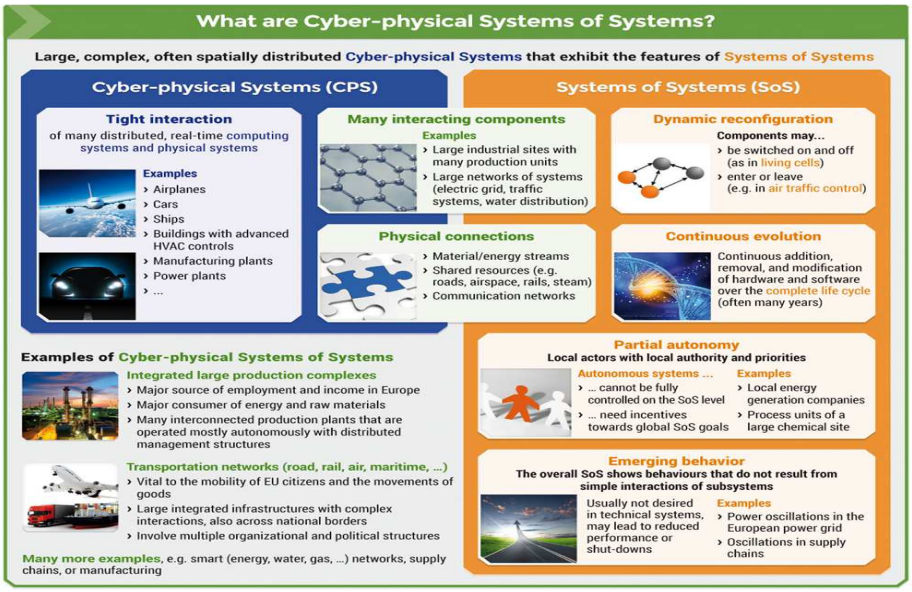

Figure 9 Cyber-Physical Systems of Systems

CPSoS brings together several different domains: systems and control, computer science, software and systems engineering, physics and also tool developers (simulation, verification, software engineering). The aim of the CPSoS project is to develop a roadmap for Cyber-Physical Systems of Systems as shown in Figure 9. CPSoS are large, often spatially distributed physical systems with complex dynamics. They are socio-technical systems with user/operator interaction but rely on distributed control, supervision and management. Partial autonomy of the subsystems is common to manage complexity of operation, and as the systems are in place for many decades, they dynamically evolve and reconfigure on different time-scales. There is also a possibility of emerging behaviors. It should be noted that due to the physical size of systems failures are the norm.

Interviews have been carried out with around 100 key industrialists and 3 working groups have been set up in systems of systems in transport and logistics, physically connected systems of systems, and tools and methodologies. The needs in the application domains have been analysed and the state-of-the-art in methods and tools has been considered. Three key research areas have been identified.

- Distributed, reliable and efficient management of cyber-physical systems of systems
- Cognitive cyber-physical systems of systems
- Engineering support for the design-operation continuum of cyber-physical systems of systems.

It was highlighted that CPSoS are socio-technical systems in which machines and humans interact closely and so the human-in-the-loop is extremely important. CPSoS has produced a Strategic Research Agenda which identifies 11 medium term and 4 sector specific priorities.

CPS Innovation Actions H2020 –ICT-1 IAs

CP-SETIS (IA) Jürgen Niehaus (safeTRANS)

CP-SETIS is developing a common, European-wide, open, Interoperability Specification for the development of critical Cyber-Physical Systems. The project is closely related to CRYSTAL and is targeted at interoperability between development tools. As highlighted in CRYSTAL there can be 100's or 1000's of tools used in the development of a complex system and these need to be integrated into engineering environments. As an example, an Airbus aircraft is built all around the world by different companies using many different tools. The work in CP-SETIS is built upon a number of other initiatives including CESAR, MBAT, CRYSTAL and HOLIDES. A key aim is to achieve cross-sectorial reusability of Embedded Systems devices and architecture platforms (for example, for interoperable software components for automotive, railways, aerospace and manufacturing). The project also aims to build consensus across key stakeholders (i.e. end-user organisations, tool providers and research organisations) and projects on a common IOS Standardisation Strategy. The IOS is a set of specifications which provides bridges between standards. The aim is to create a formal and sustainable standardisation of the IOS. To achieve this an IOS Coordination Forum (ICF) has been set up.

Eyes-of-Things (IA) Noelia Vallez Enano UCLM (Universidad de Castilla-La Mancha)

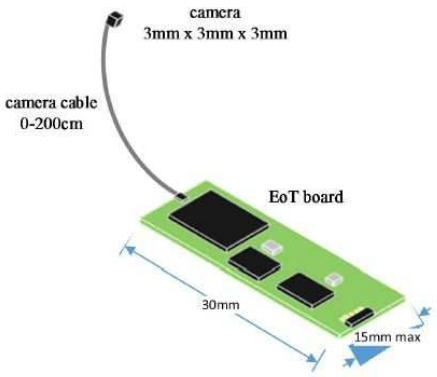

Figure 10 EoT Camera Platform

To be "smart everywhere" it is necessary to have "eyes everywhere", e.g. for wearable applications, augmented reality, surveillance, ambient-assisted living, etc. It was highlighted that vision is our richest sensor and allows mining of big data from reality, however, at the same time it is also the most demanding sensor in terms of power consumption and required processing power. Vision processing is complex for both humans and for machines. It is increasingly being used in many applications, e.g. drones and Advanced Driver Assist Systems (ADAS). There are also many innovative applications being developed for smart phones, however, the camera in a smart phone is not appropriate in many cases as it

consumes a lot of power. In general, it was highlighted that systems are not being designed with computer vision in mind. The aim of EoT is thus to build a flexible, small, low power, low cost ($15) core vision platform (hardware and software) that can be embedded into all types of artefacts. The final prototype will be memory stick sized using a NanEye camera and a TI processor (See Figure 10). This contains an embedded broker and a library optimised for the device. An easy to use EoT programming language is also being developed and the code can be wrapped in Python. The project is producing 4 demonstrators for peephole surveillance, a hands-free automatic museum guide, a doll that recognises a child's emotions and a wearable lifelogging camera. The aim is to provide 1 week of use from a mobile phone battery.

EuroCPS (IA) Philippe Bonnot (Thales group)

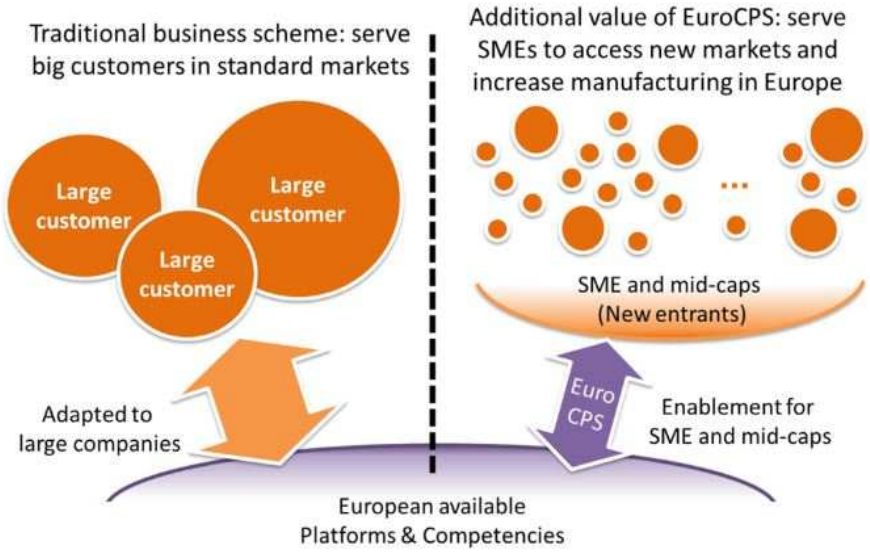

Figure 11 Euro CPS Approach

EuroCPS gathers several design centres together in order to boost and initiate synergies between innovative companies, major CPS-platforms and CPS-competency providers. The aim is to enable companies making new CPS products to get access to leading edge technology platforms from large companies and support from competency partners as shown in Figure 11. 8 technology platforms are provided across 9 countries. These include platforms for avionics, platforms based on the STM32 micro-controller, the Inemo and Quark and also a platform for power control in factory automation. Each centre can coach up to 3 design experiments. These can be industrial experiments, software prototype demonstrators or integrated system demonstrators. The centres provide a platform plus cascade funding and competence funding to coach fast track experiments. EuroCPS supports projects considering their excellence, their impact on the ecosystem and their prospects for industrial implementation. The initiative has made 2 open calls to date, has received 72 proposals and 24 have been funded. A new call opens in April 2016. Notably it is possible for a proposal to combine the use of several platforms.

CPSE Labs (IA) Holger Pfeifer (fortiss)

Figure 12 Location of CPSE Labs

The Cyber-Physical Systems Engineering Labs (CPSE Labs) is an initiative designed to provide technical support and funding for European technology businesses. A network of design centres provides support for the design and development of trustworthy CPS as shown in Figure 12. In particular, the aim is to stimulate uptake in SMEs. A range of platforms is provided across a number of domains. Experiments are expected to be focused and fast-track. Proposers need to demonstrate how the proposed experiments will improve TRL typically to level 5 or 6. The design centres also provide training and technical support on the platforms and can provide some collaborative development effort. 14 experiments have been funded so far in a variety of application domains and focus areas. These include airfield maintenance, maritime shore-based voyage planning and in the areas of smart cities improving water efficiency and safety in living areas. A new call will be launched in April 2016.

Key-Note – Research Challenges in CPS Radu Grosu (Vienna University of Technology)

Radu Grosu gave a keynote presentation on research challenges in CPS. This gave a history of how the area of embedded systems had evolved from the 1980s with airbag control systems, to networked embedded systems in the 1990s, to even higher levels of "networked" networked embedded systems creating CPS in 2010. It was highlighted that a typical car has 40 processors, 60 sensors and 40 actuators and 1 million lines of code but the current trend is towards having systems at a new scale which requires consideration of time and space in very distributed systems. This leads to problems in understanding where something is happening within a system and in managing uncertainty in systems. The timeline of adoption of the concept of CPS was also outlined. In 2008 NSF and US-Scientists sent a CPS Manifesto to the President of the US. In 2012 Acatech and German scientists sent a CPS Manifesto to Germany's Federal Ministry of Education and Research. In 2012 the EC launched the H2020 program in CPS. It was noted that there is now a need for a big push in Austria for a CPS initiative as well.

Considering the situation today there is increased autonomy in many areas. There are also a number of trends towards CPS ecosystems such as IoT, The Cloud, The Fog, M2M, Smarter Planet, Industry 4.0, Industrial Internet and The Swarm. A number of key challenges were highlighted which include discrete/continuous mathematics, huge architectural complexity requiring a CPS-OS platform, space-time (through space-time aware programs), uncertainty (partial knowledge) and precision (which has an impact on uncertainty). To highlight the implications of precision a car parking simulation example was given with varying levels of precision utilising a neural network displaying stochastic behaviour. It was highlighted that there is a need for need for education in multidisciplinary skills for Systems Engineering.

CPS Research and Innovation Actions H2020 - ICT-1 RIAs

AXIOM (RIA) Roberto Giorgi (University of Siena)

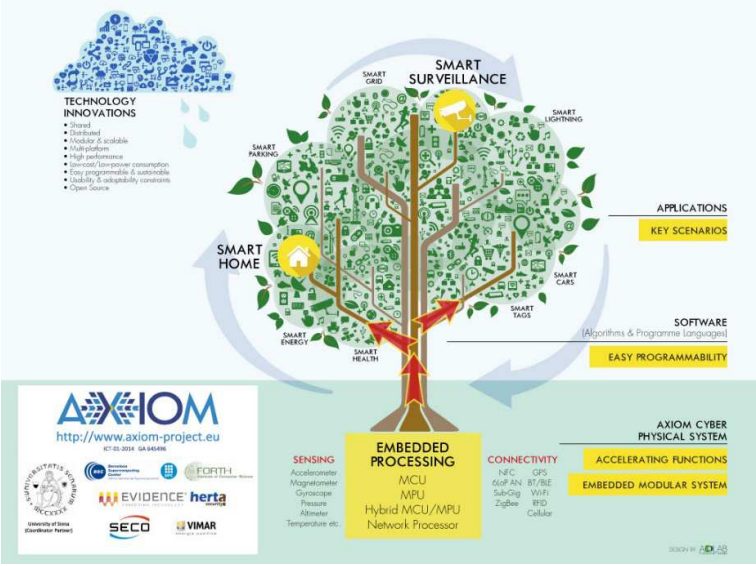

Figure 13 Overview of AXIOM

The AXIOM project (Agile, eXtensible, fast I/O Module) aims at researching new software/hardware architectures for CPS considering that objects and people will become nodes of the same digital network (See Figure 13) with rapid and close interaction between system-system, human-system and system-human. Within AXIOM smart home applications and smart surveillance are being explored. A hardware module combining a Quad-core ARM and FPGA for easy programmability has been produced and it is planned also to create a 6-core ARM version. OmpS is being used for programming with a shared memory model. Open source software is used to manage the board and it is possible to plug in Arduino shields allowing different I/O. The company EVIDENCE is providing real-time scheduling support.

COSSIM (RIA) Apostolos Dollas (TSI - Telecommunication Systems Institute)

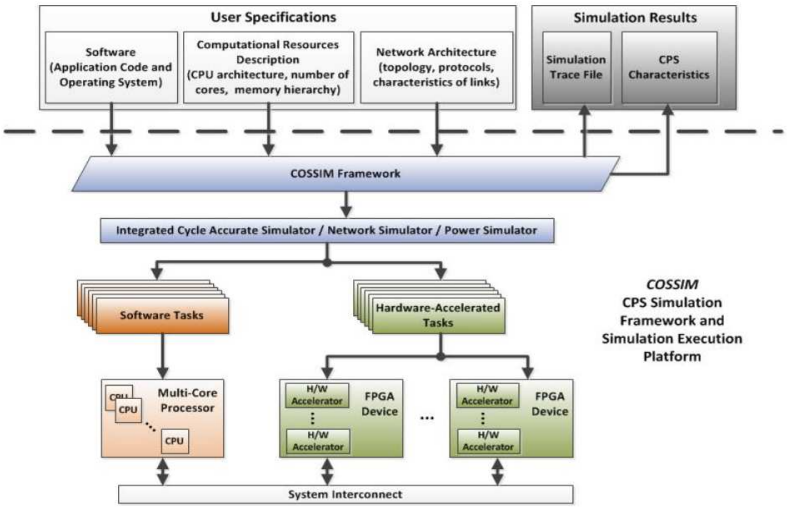

Figure 14 COSSIM CPS Simulator

The COSSIM (Novel, Comprehensible, Ultra-Fast, Security-Aware CPS Simulator) project is developing a novel simulator framework as shown in Figure 14. This will seamlessly simulate, in an integrated way, both the networking and the processing parts of the CPS with the aim of performing simulations orders of magnitude faster. The environment also provides information on power consumption and will also address security measurement via models. The environment provides support for multicore ARM CPUs and multiple networking protocols. A key important part of the system is a clock to synchronise different simulators. Parts of the simulation can be accelerated on a FPGA. Two case studies are being pursued, one in intelligent buildings and the other addressing a visual search problem.

IMMORTAL (RIA) Heinz Riener (DLR)

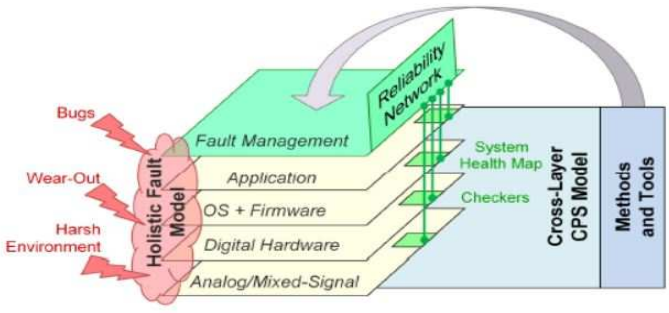

Figure 15 Cross-Layer Fault Management

IMMORTAL (Integrated Modelling, Fault Management, Verification and Reliable Design Environment for Cyber-Physical Systems) is developing an integrated, cross-layer modelling

based tool framework for fault management, verification and reliable design of dependable Cyber-Physical Systems (CPS) as shown in Figure 15. The aim is to enable development of dependable CPS with improved reliability and extended effective lifetime, ageing and process variations. The project is developing a cross-layer CPS model spanning the device (analogue and digital), circuit, network architecture, firmware and software layers. This takes account of probability of failures, soft errors and ageing phenomenon as defined by the Bathtub curve. Automated debugging is used for localising and correcting cross-layer faults. A holistic fault model for fundamentally different error sources in CPS (design bugs, wear-out and environmental effects) is being proposed. A fault management infrastructure will be built for ultrafast fault detection, isolation and recovery in many-core based CPS networked architectures. The tool framework will be evaluated on a satellite on-board computer.

INTO-CPS (RIA) Peter Gorm Larsen (Aarhus University)

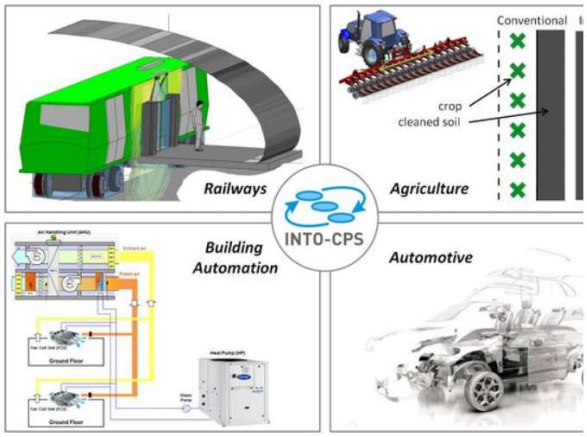

Figure 16 INTO-CPS Applications

The aim of the INTO-CPS project is to create an integrated tool chain for comprehensive Model-Based Design (MBD) of Cyber-Physical Systems (CPS). The tool chain will support the multidisciplinary, collaborative modelling of CPS from requirements, through design, down to realisation in hardware and software. This will enable traceability at all stages of development. The tool chain will support multiple modelling paradigms and will cover multiple development activities, including requirements modelling of hardware and software (SysML), analysis, simulation, validation, verification, and traceability. It will also cover heterogeneous systems models and code/hardware. Co-simulation is used to gradually integrate various components. The toolset is being demonstrated in an industrial setting in applications from the automotive, agricultural, railway and building automation domains as shown in Figure 16.

SAFURE (RIA) Carolina Reyes (TTTech)

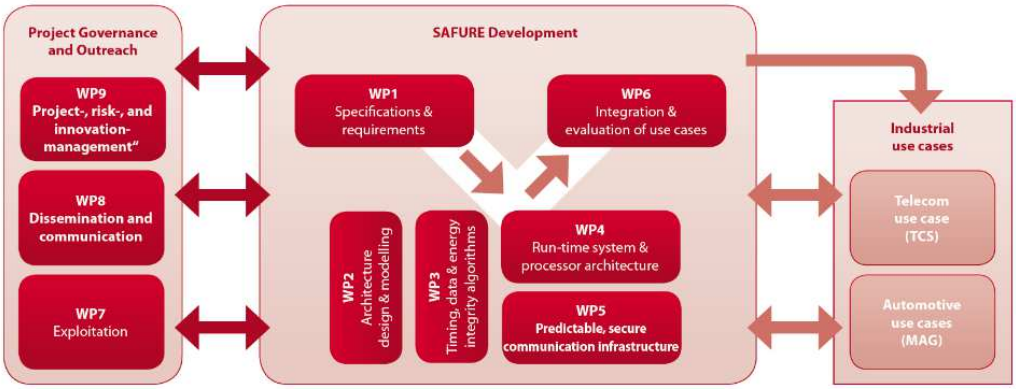

Figure 17 SAFURE Framework

The SAFURE (Safety And Security By Design For Interconnected Mixed-Critical Cyber-Physical Systems) project is targeting the design of Cyber-Physical Systems by implementing a methodology that ensures safety and security "by construction". The goals of the SAFURE project (See Figure 17) are to implement a holistic approach to safety and security of embedded dependable systems, preventing and detecting potential attacks. It will produce a framework with the capability to detect, prevent and protect from security threats to safety with the ability to monitor system integrity from the application level down to the hardware level. This includes consideration of time, energy, temperature and data integrity. The aim is to produce SAFURE-compliant, mixed-criticality, embedded products. The project is using multicore processors, cryptographic algorithms and TTEthernet to demonstrate concepts in two automotive applications, and Bluetooth LE for a medical device body area network. A key difference is that mixed-criticality is normally addressed independently, in SAFURE it is addressed in a combined fashion.

TAPPS (RIA) Nora Koch (fortiss)

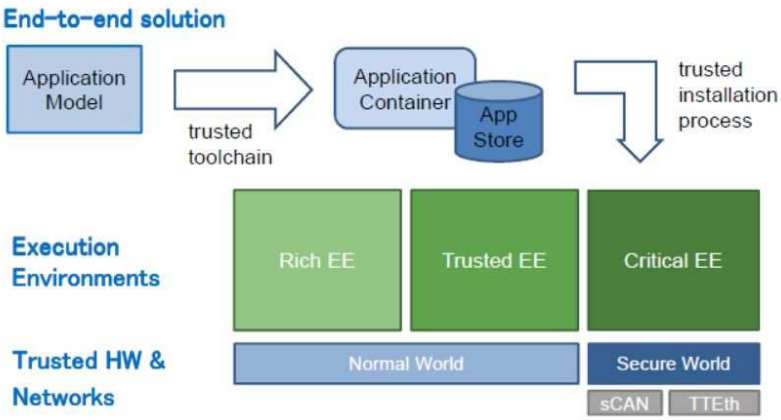

Figure 18 TAPPS Architecture

The main goal of the TAPPS (Trusted Apps for open CPS) project is to extend and customise CPS devices with new 3rd party services and features in an Apps platform in an efficient,

secure and trusted way as shown in Figure 18. This addresses the growing trend towards adding functionalities on demand, e.g. Apps in the automotive domain. The aim is to address the safety, privacy and security risks of doing this. This is being done using special hardware on a multicore ARM processor which is partitioned into regions to allow normal and secure processing for critical applications. TAPPS provides a dedicated execution environment for distributed, safety-critical CPS applications offering multiple layers of security and a holistic, open end-to-end tool chain for developing and deploying CPS Apps. The project is producing dedicated, real-time Trusted and Critical Execution Environments (TEE & CEE) for highly-trusted CPS Apps. They provide the spatial and temporal isolation of the Apps through virtualization. The platform is being validated on electric motorbikes for Apps that check trip capability based on battery status and traffic conditions. More critically it can also provide braking adjustment based on weather and sports package settings. A second use case is being explored for a health care case study providing a smart trolley for safe drug management. This utilises automatic drawers that only open according to patient identification. The trolley also has the ability to access health records.

UnCoVerCPS (RIA) Matthias Althoff (Technische Universität München)

Figure 19 UnCoVerCPS Automotive Applications

The Unifying Control and Verification of Cyber-Physical Systems (UnCoVerCPS) project is developing new methods for de-verticalisation of development processes. The aim is to provide a generic and holistic approach towards reliable Cyber-Physical Systems development with formal guarantees. A key objective is to create a means to synthesise and verify controller's on-the-fly during system execution. This is important for the reliability of autonomous vehicles (See Figure 19). It is not possible for an engineer to think about all the eventualities that could possibly happen in real life. There is thus a need to verify new controllers as new situations occur. Generally, behaviour depends on past experience and formal methods are used to guarantee correctness. This relies on deterministic behaviour, however it is impossible to predict what other cars are going to do even with trajectory planning. Completely new methods are thus needed, which need to be integrated into tools for modelling, control design, verification, and code generation. Applications being considered include automated vehicles and human-robot collaborative manufacturing, wind turbines and smart grids.

U-Test (RIA) Hong-Linh Truong (Technical University of Vienna)

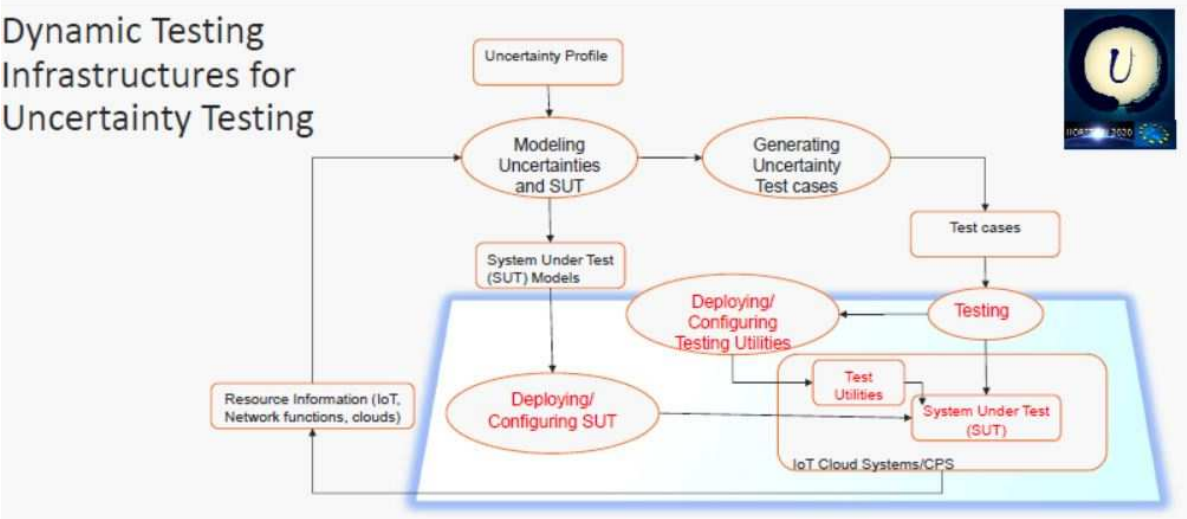

Figure 20 U-Test Framework

The U-Test (Testing Cyber Physical Systems under Uncertainty) project aims at ensuring that CPS are tested adequately under uncertainty using systematic and automated techniques, such as model and search-based testing, to guarantee their correct operation in a real environment. U-Test will improve dependability of CPS by defining extensible MBT frameworks supporting holistic testing of the systems under uncertainty in a cost-effective manner by providing a comprehensive and extensible taxonomy of uncertainties, classifying uncertainties, their properties, and their relationships. An Uncertainty Modelling Framework (UMF) will be created to support modelling uncertainties at various levels (relying on exiting modelling/testing standards). An Uncertainty Testing Framework (UTF) will also be created to identify unknown uncertainties and generate cost-effective test cases to test CPSs under known and unknown uncertainties as shown in Figure 20. Two test cases will be developed for Handling Systems and Geo Sports.

CPS Coordination and Support Actions
H2020 - ICT-1 CSAs

CPS Summit (CSA) Harald Ruess (fortiss)

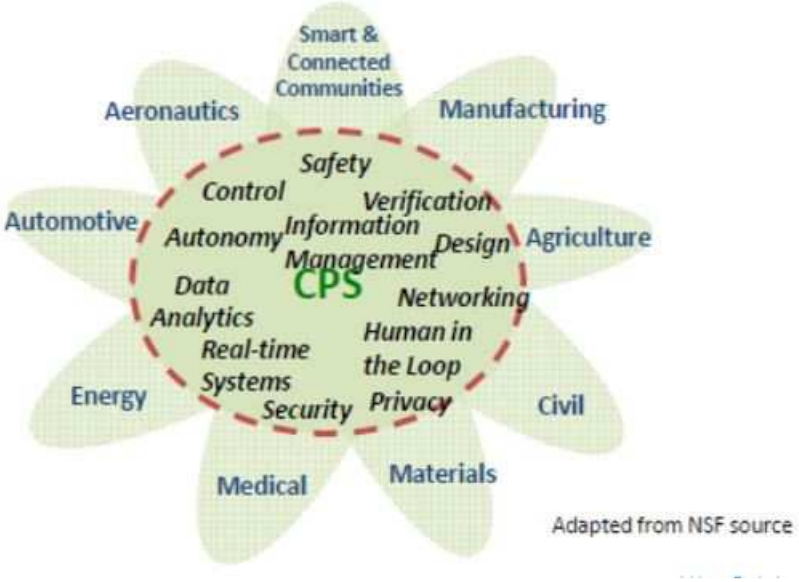

Figure 21 CPS Needs and Applications

The Transatlantic CPS Summit is an 18-month support action with the goal of facilitating and creating an enduring and sustainable collaboration campaign on CPS research and development between Europe and the US. The support action achieves its overall aim by means of a series of CPS Summit Workshops. It will identify common challenges and evaluate possible R&D co-operations between Europe and the US and promote implementation of opportunities for cooperation (see Figure 21). A roadmap for R&D cooperation on CPS engineering is being produced together with recommendations for action. The final results will be presented to interested stakeholders (e.g. public bodies, industry, academic researchers) on both sides of the Atlantic. Here it is thought that trustworthy CPS may be an area for collaboration and there are also synergies with the NIST framework for CPS.

TAMS4CPS (CSA) Michael Henshaw (Loughborough University)

TAMS4CPS has a mission to develop a strategic research and collaboration agenda to foster Trans-Atlantic research in Modelling and Simulation (M&S) for Cyber-Physical Systems (CPS). The aim is to lay the foundations and agree scope for concrete EU-US collaboration in modelling and simulation for CPS.

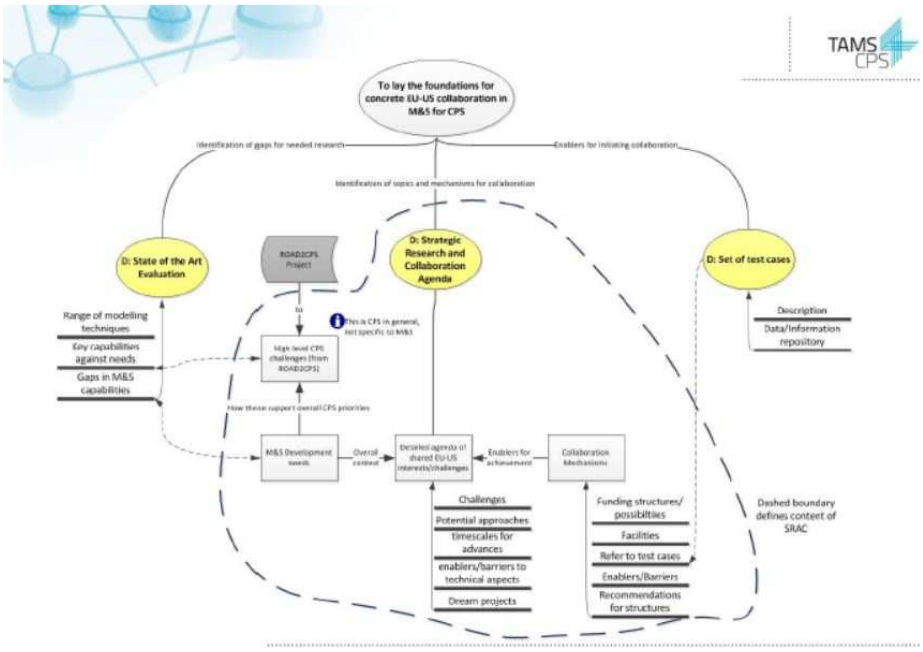

Figure 22 TAMS4CPS Approach

Priority research and development needs for modelling and simulation for CPS are being identified and a strategic research agenda is being developed using an approach as shown in Figure 22. The aim is to get this endorsed by European and US industry and academia. Once this is achieved the research agenda will be disseminated widely.

Road2CPS (CSA) Meike Reimann (Steinbeis-Europa-Zentrum)

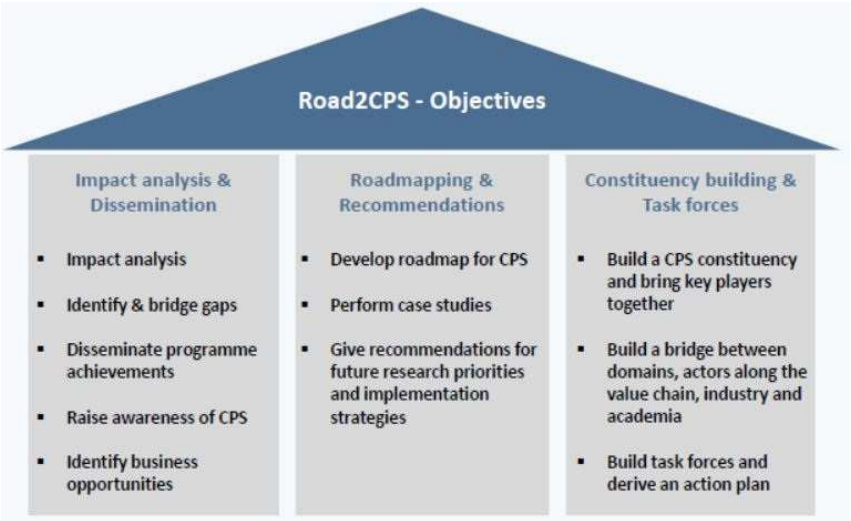

Figure 23 Road2CPS Pillars

Road2CPS is a 24-month coordination and support action in the area of Smart Cyber-Physical Systems. The project has 3 pillars as shown in Figure 23 that perform strategic actions for future CPS through roadmaps, impact multiplications and constituency building by:

- Identifying the gaps in current research and bridging the efforts
- Analysing future research priorities and business opportunities
- Bringing the relevant stakeholders together to facilitate mutually beneficial collaborations between them.

The project will build a constituency united by the commonly faced challenges and will also create a joint action plan for the future development of CPS.

Short Rapport & Synergy Session Rapporteur/Panelists (Haydn Thompson)

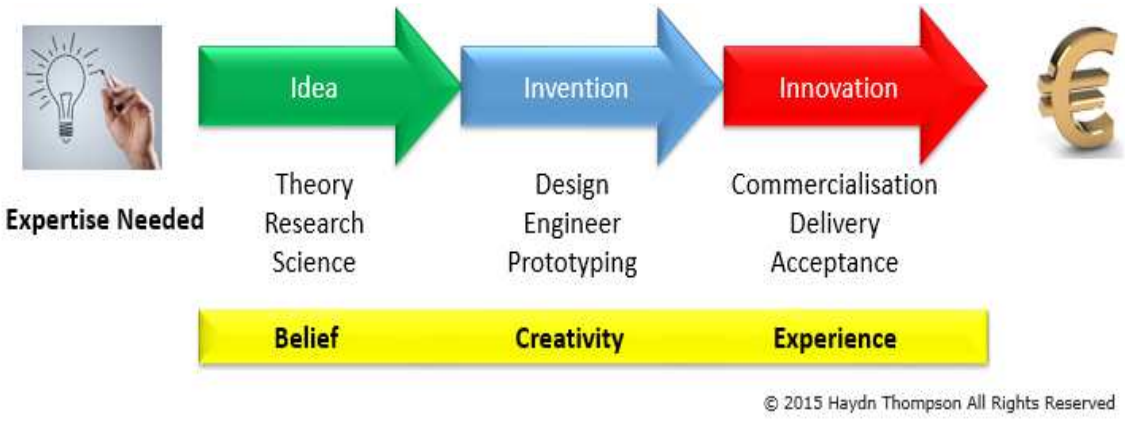

Figure 25 Research and Innovation Pipeline

Haydn Thompson gave a short summary of the projects that had been presented, highlighting key features and outcomes of the projects, and their relevance to industry. There was then a synergy session with the presenters of the projects and wider audience to discuss potential synergies between projects and needs. This was prompted by a number of key questions.

- Have we got every research priority covered?
    - Is there sufficient funding for these areas?
    - Are there any key gaps, e.g. cognitive systems, sociotechnical issues?

- Are we doing enough to get over the valley of death to get research to the market place?
    - How could the EC better support the collaboration/exploitation of synergies?
    - Have we got all the right people engaged, demand side, the commercialisation people, customers (See Figure 25)?

- Are there any ideas for co-operation across projects and programme?
    - How do the activities of your project link to digital platforms and digital innovation hubs?

- What are the barriers for industry?
    - Sociotechnical, e.g. developing trust, raising awareness with public?
    - Need for regulation, safety, privacy, legal (SLAs, liability)?
    - Standards for interoperability?

The discussion identified that there is always a need for more money. A question is whether the targeting of the existing funds is appropriate. It was felt that there had been a major shift in funding with more being targeted at higher TRL activities, e.g. large amounts of money was being put into large scale pilots and as a consequence there was less funding available for research projects at a lower TRL. It was, however, noted that other funding schemes exist to support more fundamental research such as Future Emerging Technologies (FET) which has considerable funding. It was also highlighted that the Strategic Research Agenda put forward by the ARTMEIS-IA has many topics and building blocks. The amount of funding required to address all the areas in the Agenda would be considerable and not possible to support. Therefore some targeting of resources is needed so there will always be areas which could be considered to be gaps. Although the activities funded are producing very good results and keeping Europe ahead there is also a need to support research work looking longer term. Notably the current H2020 programme is targeted much more at Research and Innovation and so is much closer to market.

In response to the question of whether enough was being done to get over the valley of death it was highlighted that a key aim of the ARTEMIS projects was to directly address the valley of death. Here there has been considerable success through the large projects that have been funded. It was acknowledged, however, that considerable funding is required in order to commercialise the outcomes of R&D projects and get uptake within industry. The outcomes from some projects were at a much higher TRL addressing industry needs which made them far more attractive for uptake with a consequence of drawing in more of the innovation pipeline.

The role of the innovation hubs is seen as being important to transfer results to SMEs and also to provide access to platforms and knowhow. There was some discussion on platforms. Large scale initiatives are needed as evidenced by the ARTEMIS projects. Although access to platforms is being provided via the Innovation Hubs much more work is needed to promote European platforms and build an ecosystem around new evolving platforms. This is something that will need further funding.

A number of barriers exist and the new Digitising European Industry initiative is trying to remove these by supporting standards for interoperability and by addressing regulatory and legal issues. It was noted that there is a need for education, not only to address sociotechnical issues and develop trust, but also there is a fundamental need for education to keep upskilling the workforce as the technology rapidly evolves.

Concluding Remarks

The event successfully brought together 120 experts with presentations from the H2020, ARTEMIS and ECSEL communities covering 19 projects. Notably the meeting highlighted good coverage of research, development and innovation needs across the domain and demonstrated good synergy with both the ARTEMIS-IA Strategic Research Agenda and also the Digitising European Industry initiative. In general the ARTEMIS-IA and ECSEL large scale projects were at a higher TRL addressing integration of tools for safety-critical systems development, interoperability, factory automation, maintenance systems and also standardisation. However, more foundational work was also being performed addressing new approaches for verification and validation, safety and security. Several projects addressed hardware development, in particular, the exploitation of multicore processors for performance enhancement and in mixed-criticality applications.

Although many projects were driven by larger industry, the Innovation Hubs targeted at engaging with SMEs are seen as vital for raising awareness, transferring skills and providing access to the latest technologies. This is seen as key to Europe's goal of Digitising European Industry. It is also necessary to bring together the community and consider the future research priorities, particularly to maximise the impact of the finite research budget available. The roadmapping projects have an important role to play providing recommendations for future research needs but also in bringing together the constituency and providing a single voice. It is clear that major initiatives are also underway around the world in CPS and that the market is global. Actions that support transatlantic collaboration such as CPS Summit and TAMS4CPS are thus crucial to identify where it is possible to collaborate and bring together critical mass. Here it is also important to also address barriers that exist to roll out of technology through standards and harmonised regulation for privacy and liability at a world-wide level.

Agenda

8:30	***Registration***	
9:00	Welcome and introduction	Meike Reimann - Road2CPS (Steinbeis-Europa-Zentrum)
9:15	EC - key-note – strategy and vision	Werner Steinhögl (DG Connect)
9:45	ARTEMIS-IA – Introduction as ETP and Industry driven association	Jan Lohstroh (Secretary General of ARTEMIS-IA)
10:15	ARTEMIS CRYSTAL (AIPP)	Christian El Salloum (AVL List)
10:25	***Networking coffee / Poster Session***	
11:00	ARTEMIS/ECSEL projects MANTIS (RIA) ARROWHEAD (AIPP)	 Erkki Jantunen (VTT) Jerker Delsing (Ltu)
11:20	CPSoS	Christian Sonntag
11:30	CPS Innovation Actions H2020 - ICT-1 IAs	ICT-1-project representatives
12:30	***Lunch***	
13:30	Key-note – research challenges in CPS	Radu Grosu (Vienna University of Technology)
14:00	CPS Research and Innovation Actions H2020 - ICT-1 RIAs	ICT-1-project representatives
15:30	***Networking coffee / Poster Session***	
16:00	CPS Coordination and Support Actions H2020 - ICT-1 CSAs	ICT-1-project representatives
16:20	Short Rapport & Synergy Session	Rapporteur / Audience
17:00	***End of the day***	

Projects	Project Representative	Institution
ARTEMIS Projects		
CRYSTAL (AIPP)	Christian El Salloum	AVL List
Arrowhead (AIPP)	Jerker Delsing	Lulea University of Technology
MANTIS (RIA)	Erkki Jantu	VTT
FP7 Coordination and Support Action (CSA)		
CPSoS	Christian Sonntag	TU Dortmund
H2020 Innovation Actions (ICT-1 IA)		
CP-SETIS (IA)	Jürgen Niehaus	safeTRANS
EoT (IA)	Noelia Vallez Enano	UCLM (Universidad de Castilla-La Mancha)
EuroCPS (IA)	Philippe Bonnot	Thales group
CPSE Labs (IA)	Holger Pfeifer	fortiss
H2020 Research and Innovation Actions (ICT-1 RIAs)		
AXIOM (RIA)	Roberto Giorgi	University of Siena
COSSIM (RIA)	Apostolos Dollas	TSI (Telecommunication Systems Institute)
IMMORTAL (RIA)	Heinz Riener	DLR
INTO-CPS (RIA)	Peter Gorm Larsen	Aarhus University
SAFURE (RIA)	Carolina Reyes	TTTech
TAPPS (RIA)	Nora Koch	fortiss
UnCoVerCPS (RIA)	Matthias Althoff	Technische Universität München
U-Test (RIA)	Hong-Linh Truong	Technical University of Vienna
H2020 Coordination and Support Actions (ICT-1 CSAs)		
CPS Summit (CSA)	Harald Ruess	fortiss
TAMS4CPS (CSA)	Michael Henshaw	Loughborough University
Road2CPS (CSA)	Meike Reimann	Steinbeis-Europa-Zentrum

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Reimann	Meike	Steinbeis Innovation GmbH	Germany
Reyes	Carolina	TTTech Computertechnik AG	Austria
Riener	Heinz	DLR	Germany

Rogo	Francesco	Finmeccanica S.p.A	Italy
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Ruck	Ben	Netherlands Enterprise Agency	Netherlands
Ruess	Harald	fortiss GmbH	Germany
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Stamatescu	Grigore	University "Politehnica" of Bucharest	Romania
Steinhögl	Werner	European Commission	Belgium
Stocker	Alexander	Das virtuelle Fahrzeug Forsch.gesellschaft mbH	Austria
Syschikov	Alexey	Saint Petersburg State University of Aerospace	Russian Federation
Taumberger	Markus	VTT Technical Research Centre of Finland Ltd.	Finland
Thompson	Haydn	THHINK Wireless Technologies Ltd.	United Kingdom
Törngren	Martin	KTH	Sweden
Troubitsyna	Elena	Åbo Akademi University	Finland
Truong	Hong-Linh	Vienna University of Technology	Austria
Unamuno	Gorka	IK4-IDEKO	Spain
Uribeetxeberria	Roberto	Mondragon Goi Eskola Politeknikoa	Spain
Vaclavek	Pavel	Brno University of Technology	Czech Republic
Vallez	Noelia	University of Castilla-La Mancha	Spain
Vallez Enano	Noelia	UCLM	Spain
Verbeke	Mathias	Sirris	Belgium
Verhagen	Stefan	Zoof-it	Netherlands
Vierbauch	Doris	FFG Austrian Research Promotion Agency	Austria
Vinter	Jonny	SP Sveriges Tekniska Forskningsinstitut	Sweden
Voyiatzis	Artemios	SBA Research	Austria
Watzenig	Daniel	Das virtuelle Fahrzeug Forsch.gesellschaft mbH	Austria
Wiesmüller	Michael	Bmvit	Austria
Zafalon	Roberto	STMicroelectronics s.r.l	Italy
Zamfirescu	Constantin	Lucian Blaga University of Sibiu	Romania

Annex 1 Project Information

For the 19 projects presented in the event facts on funding and partners, abstract, main objectives and highlights are detailed in the Annex.

(Please see additional document)