REPORT ON CYBER-PHYSICAL SYSTEMS (CPS) ROADMAPPING WORKSHOP

WHAT DO YOU THINK THE EUROPEAN COMMISSION SHOULD CONSIDER?

ON THE 28TH OF JUNE 2017 AT THE 23RD ICE/ITMC CONFERENCE, MADEIRA ISLAND, PORTUGAL

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1. Workshop aim and agenda

The Cyber-Physical Systems (CPS) Roadmapping workshop held on the 28th of June at the ICE/ITMC Conference, Madeira Island, Portugal was organised by the Platforms4CPS partner Steinbeis 2i GmbH involving 15 participants from Large Enterprises, SMEs, Academics and Clusters/Associations. The interactive workshop followed a plenary introduction of the project and subsequent panel discussion and was designed to validate and discuss future CPS Technological and Non-Technological priority themes, recommended to be considered by the EC for the upcoming calls and next Framework Programme.

The initial themes proposed for discussion were derived from previous CPS Roadmapping projects, selected and adapted by the Platforms4CPS consortium. These findings were presented to the participants, discussed and further elaborated during interactive sessions allowing the participants to consider relations to their sector, make comments or raise additional recommendations. The overall aim was:

- to discuss visions and priorities of recently produced roadmaps in the area of Cyber-Physical Systems (CPS)
- to draw recommendations for future research and innovation activities

In more detail, the interactive workshop was focused on relevant technology fields and related research priorities to fuel the development of trustworthy CPS, as well as needs and barriers for a successful implementation in different application domains (manufacturing, transport, energy, health and smart cities). The workshop gathered CPS-experts to elaborate on specific CPS-themes and discuss platform concepts and success stories in relation to industrial demand and customer needs. The workshop counted on the knowledge and experience of experts in CPS and related technologies and applications.

The objective of the workshop was to stimulate:

- Discussion on research priorities in Cyber-Physical Systems: Which developments are needed?
- Discussions on platform concepts
- Alignment of the work of different initiatives
- Matching supply and demand: are current solutions fulfilling the needs of customers/users? What is the way forward to promote the right innovation ecosystems?
- Constituency building in the area of CPS

	AGENDA
09:00	Plenary Panel (presentation Platforms4CPS project)
09:30	Plenary Panel discussion
10.30	Coffee break
11:00	Workshop Introduction - Meike Reimann (Steinbeis2i GmbH)
11:20	Elaboration of Domain Specific Trends, Visions, Needs and Barriers
11:50	Research Needs & Technological Solutions and Strategies & Best Practices
12:20	Commonalities and Voting for Priorities
12:45	Final Discussion, Conclusion
13:00	Closing of Workshop

Fig. 1: Workshop Agenda, Cyber Physical-Systems (CPS) Roadmapping

2. Participants of the workshop

	Name	First Name	Company / Organisation	Website
1	Bageritz	Steve	Steinbeis 2i GmbH	www.steinbeis-europa.de
2	Bücker	Claudia	CeTIM UniBw Munich	www.cetim.org
3	Condry	Michael W.	IEEE Technology and Engineering Management Society	www.ieee.org
4	Correia	Ana Teresa	ATB Institut für angewandte Systemtechnik Bremen GmbH	www.atb-bremen.de
5	Garcia	Oscar	ICE Information Catalyst	www.informationcatalyst.com
6	Hornath	Imre	Boeing	www.boeing.com
7	Maki	Luke	Boeing	www.boeing.com
8	Martnes	Ingo	Hanse-Aerospace Wirtschaftsdienst GmbH	www.hanse-aerospace.net
9	Pinto Seppä	Isabel	VTT Technical Research Centre of Finland Ltd.	www.vttresearch.com
10	Reimann	Meike	Steinbeis 2i GmbH	www.steinbeis-europa.de
11	Sala	Roberto	UniBG International	www.unibg.it
12	Scholze	Sebastian	ATB Institut für angewandte Systemtechnik Bremen GmbH	www.atb-bremen.de

Fig. 2: Workshop Participants

3. Proceedings and outcome of the workshop

3.1 Welcome and Introduction

Meike Reimann, Senior Project Manager at Steinbeis 2i GmbH welcomed all participants to the Platforms4CPS Cyber-Physical Systems (CPS) Roadmapping workshop at the ICE/ITMC Conference in Madeira. She briefly presented the project objectives and domains and gave a definition of Cyber-Physical Systems (CPS). As a basis for the workshop discussion, she introduced the following topics:

- **CPS trends and challenges** (e.g. trends like open data and open innovation; e.g. challenges like intuitive system, human machine and neurocognitive systems)
- **New approaches and recommendations** (e.g. open modular platforms and Customers involvement in collaboratively co-designed products)
- **Application domains – barriers and needs** (e.g. barriers like security, safety and privacy and interoperability; e.g. needs like open solutions and standards)
- **Priority themes** (Technological and Non-Technological Priorities)

3.2 Interactive Session

Fig. 3: Workshop Session – Participants voting CPS Priorities

3.2.1 Methodology

Stimulated by the panel discussion (see chapter 4) in the morning and the introduction presentation, the participants were asked to rank the key CPS Technological and Non-Technological Priorities for future EC investments. Two posters presenting Platforms4CPS priority themes were used for identifying focal points as well as to add relevant future topics. Afterwards the participants were asked to evaluate the themes with the use of 4 dots on the respective topics he assessed to be of highest priority on each poster. Moreover, with the help of four different colors, the participants were differentiated into the categories ‘Large Companies’, ‘SMEs’, ‘Academics’ and ‘Cluster/Associations’. Due to the intensive panel discussion on themes such as safety and security, trust and ethics the participants were also asked to vote their subjective view on each future research topic. Next to this, the participants had the opportunity to give their personal opinion in addition to representing their ‘organizations view’. The Platform4CPS priority themes were as follows:

CPS-Technological Priorities:

- Integration, Interoperability, Standards
- Platforms, Reference Architectures
- (Cyber) Security, Privacy, Confidentiality
- Safety, Dependability, Resilience, Fault Tolerance
- Complexity, Adaptability, Flexibility, Emergence
- CPS Engineering (Requirements, Design, Testing)
- CPS Life-Cycle Management
- System-of-Systems, Distributed Control
- CPS Foundations, Science
- Modelling & Simulation
- (Big) Data, Real Time Analysis
- Situational Awareness, Diagnostics, Prognostics, Decision Making & Support
- AI, Cognitive Systems, Autonomous Systems
- Human Machine Interface (HMI)
- Humans as part of the systems

Non-Technological Priorities:

- Education, Training, Skills and Re-Skilling
- Eco-System, Community Building, Networks
- Collaboration (regional, national, global)
- Collaboration (across domains, value chains)
- Cross-Disciplinary in Research
- Societal Dialogue, Awareness Raising
- Trust
- Ethics
- Open Innovation
- Open Data, Architectures, Platforms
- Open Environments, Open Eco-Systems
- Demonstrators, Living Labs
- Regulation, Legal Issues, Single Digital Market
- Business Models

3.2.3 CPS Technological Priorities

After each participant had placed 4 votes as well as added the subjective view on different topics of the posters, the overall number of votes was counted (see results diagrams below).

Regarding the technological topics, and related future priorities '(Cyber) Security, Privacy, Confidentiality' as well as 'Safety, Dependability, Resilience, Fault' ranged highest in the workshop. These topics were also confirmed after the subjective voting as key priority or as an important field of action in the upcoming periods and matching well to the already existing Cybersecurity Strategy of the EC with focus on Open, Safe and Secure Cyberspace. Amongst the highly ranked themes also 'Integration, Interoperability, Standards', which are connected to digital platforms and reference architectures, are seen as main issues and are highly relevant topics to support the successful implementation of CPSs. For this reason these topics have already become a key priority theme for the EC in their Digitization Strategy. Next to this, 'AI, Cognitive Systems, Autonomous Systems' and 'Situational Awareness, Diagnostics, Prognostics, Decision Making & Support' received many votes and were discussed intensively during the workshop. Furthermore, themes such as 'Platforms, Reference Architectures', 'Complexity, Adaptability, Flexibility, Emergence','(Big) Data, Real Time Analysis', 'Modelling & Simulation', 'CPS Life-Cycle Management', 'CPS Foundations, Science', 'CPS Engineering (Requirements, Design, Testing)' are topics that have been classified as particularly relevant for the technological/research priority of the EC.

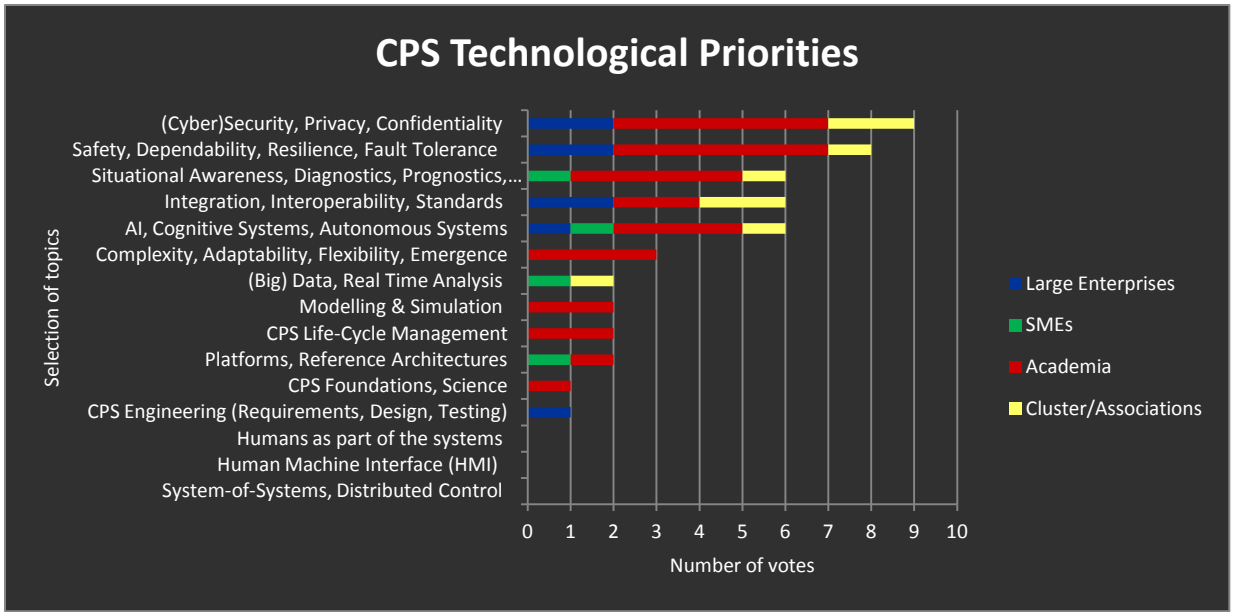

Fig. 4: Results voting of CPS Technological Priorities

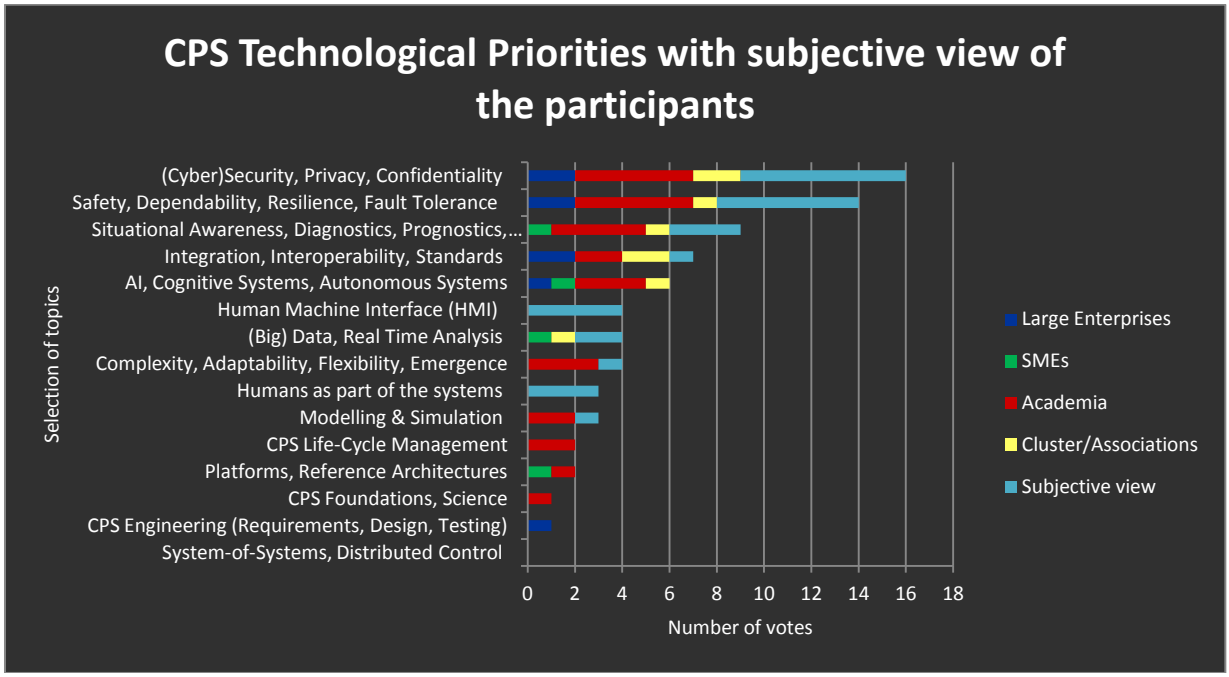

Fig. 5: Results voting of CPS Technological Priorities and subjective views

3.2.4 CPS Non-Technological Priorities

After each participant had placed 4 votes as well as added the subjective view on different topics of the posters, the overall number of votes was counted (see results diagrams below).

In terms of CPS Non-technological priority themes, particularly 'Collaboration (across domains, value chains)' and 'Regulation, Legal Issues, Single Digital' and followed by topics such as 'Education, Training, Skills and Re-Skilling', 'Societal Dialogue, Awareness Raising', and 'Business Models' were classified from the workshop participants as highly relevant EC future technological/research

priorities. In relation to CPS Non-Technological Priorities subjective view the participants vote particularly for themes such as 'Ethics', 'Education, Training, Skills and Re-Skilling', and 'Trust', which is certainly due to the main focus of the previous conference panel discussion. The participants feared especially the risk that large companies exploit big data and thus also for hacker many possibilities arise.

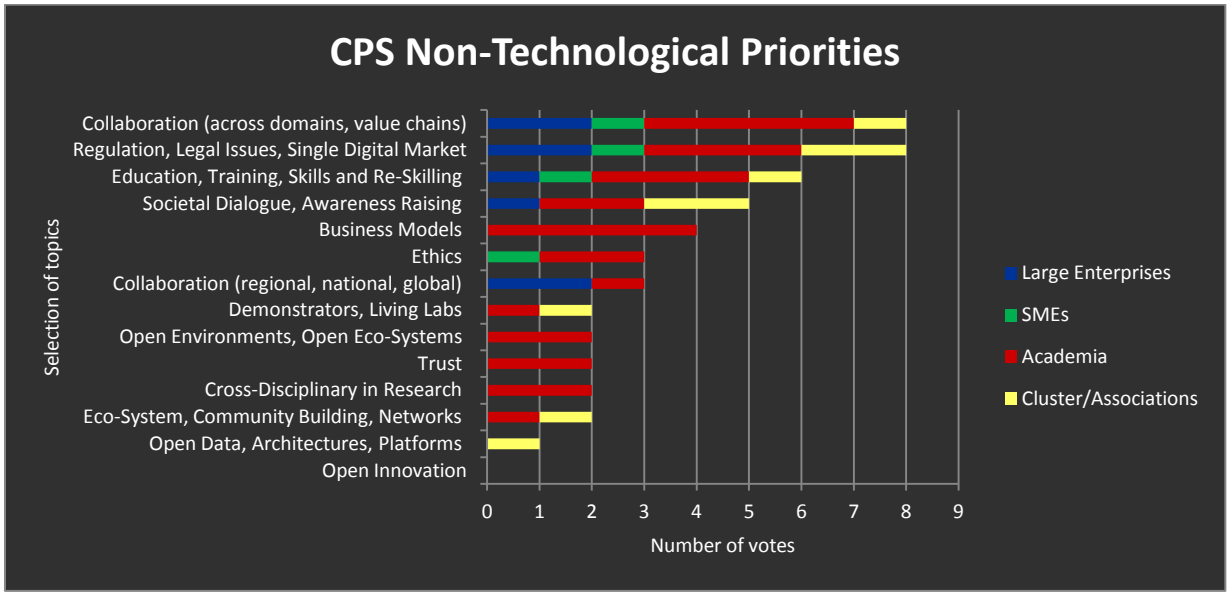

Fig. 6: Results voting of CPS Non-Technological Priorities and subjective views

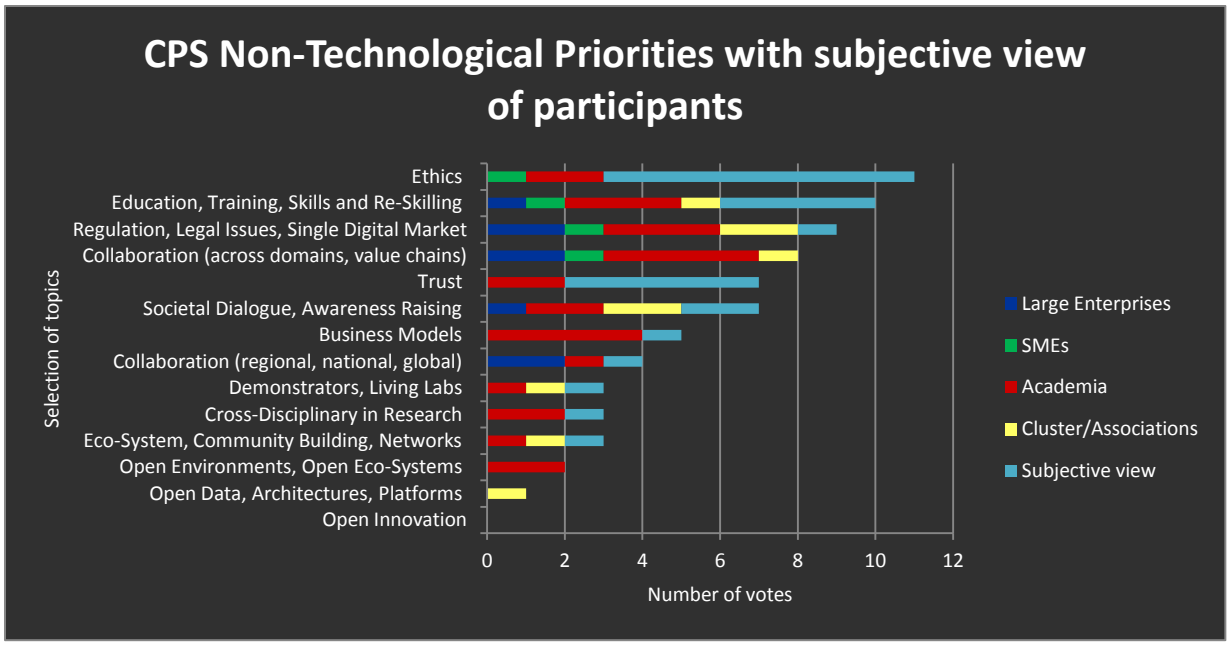

Fig. 7: Results voting of CPS Non-Technological Priorities and subjective views

3.2.4 Group discussion

After the voting process had been concluded the results were discussed with the group.
The audience was asked which topics were missing in the above a list and the following were mentioned:

- **Human Impact**: especially regarding autonomous systems. As these systems could be dangerous or even kill humans, there is a need for a panic button to stop the machine…
- **Legal Frameworks**: Supervision (who makes the decision?)/ liability
- **Economic Impact**: CPS holds great promises regarding efficiency, flexibility, etc
- **Technological themes**:
  - Networks as an key enabler, seamless connectivity is key
  - Principles of compositionality
  - Non AI based reasoning mechanisms
  - CP Computing
  - Realisation of self x (awareness)

As the proposed topics from the voting posters included some very generic / cross cutting issues, the audience was asked, which topics would be the most prominent ones to be funded under a 'CPS focused programme'. The following topics were chosen:

- CPS Foundations & Science
- Artificial Intelligence
- Situational Awareness
- Decision Making & Support
- Diagnostics, Prognostics
- Cognitive Systems
- Autonomous Systems

4. ICE Plenary Panel

Fig. 8: ICE Plenary Panel discussion with Meike Reimann

The Plenary Panel took place on the topic 'New Challenges and New Approaches related to Engineering, Technology & Innovation Management beyond 2020'. As a technical sponsor Platforms4CPS was invited to participate as a panelist. Next to Meike Reimann (Steinbeis 2i GmbH), Chris Decubber (EFFRA), Richard Stevenson (IDC), Alberto Sanna (San Raffaele Scientific Institute), Luis Flores (Introsys), Karina Marcus (COST – European Cooperation in Science and Technology), Arian Zwegers (European Commission), and Vivian Kiousi (Intrasoft International, Transport and Social Network Lab) join the Plenary Panel. In this context Steinbeis 2i presented the audience following Platforms4CPS Tends, Challenges and Approaches:

Emerging Trends & New Challenges

- **IT addicts**, dependence of society on IT systems, vulnerability
- **Business models** decoupled from ownership, servitisation, data driven economy, crowd funding, blockchain
- **Openness**, open data, open innovation
- **Political crisis**, international conflicts, migration, destabilisation, change
- T-shape **education**, life-long learning, **digital divide**
- **Intuitive systems**, human machine collaboration, humanoid robots
- Wearable systems, implantable, **decision support**
- **Neurocognitive systems**, brain inspired computing
- **Secure, legal & ethical** by design CPS

New Approaches

- **Customers involvement** in collaboratively / co-designed products will increase massively
- Open, modular **platforms** could boost involvement of SMEs
- Ad hoc collaboration in virtual factories will lead to new **business models**, radically new services based on data will emerge
- Innovative entrepreneurs as well as suitable (legal) frameworks are urgently needed

The plenary panel began to discuss and to explain each subjective panelist's point of view regarding the above mentioned three key issues. Overall, some of the panelist's as well as the audience began to discuss non-technical issues, for instance, who owns and who benefits from big data and how the next generation will cope with the digital change. Generally, the audience was reserved and suspicious when it came to questions e.g. Ethics, Trust, and Security. The participants made statements like:

- The digital revolution is a Tsunami overwhelming us, much to fast to hold stake
- Privacy and security of data becomes more important, due intrusions to systems by criminals and governments (which makes it more difficult)
- We are more vulnerable and easily observable/controllable
- Holistic approach needed, test in smaller safe harbors

However, some participants were set positive to the digital change and expressed their opinion as follows:

- Mankind was able to cope with all those revolutions and adapt, we should not be too much afraid/hesitant
- We need a vision to work towards, politics need to create a positive vision, a plan

5. Concluding Remarks

The workshop brought together experts, from a varied cross-section of domains (mainly academics), with an interest on Cyber Physical-Systems, to discuss visions and priorities in this context, to draw recommendations for future research and innovation activities as well as to elaborate strategies for their implementation.

Regarding the technological topics, and related future priorities 'safety and security' ranged highest in the workshop, which corresponds very well to previous workshops (with the ARTEMIS/ITEA community at the DIF and also within the Road2CPS workshops). There is a broad consensus that these topics will be crucial for the success of CPS, and that concerns related to safety, security, privacy and trust might act as show-stoppers if not solved. Another very important topic is related to 'integration, interoperability and standards', including digital platforms and reference architectures, which have already become a key priority theme for the European Commission and their Digitization Strategy, and have also been discussed in the frame of the ICE/IEEE conference (FoF-11 projects sessions). Integration of legacy systems and the harmonization of standards are seen as crucial to speed up the developments and make them accessible and useful for a broad range of users. While big data and modelling and simulation was seen as an important enabler, 'autonomous CPS' including the human within the system, based on artificial intelligence, equipped with decision making and means of actuation were seen as key priorities for future CPS related programmes. Cognitive systems, including capabilities like diagnosis, prognosis, prediction and self x awareness, situational awareness were seen as core CPS topics to be further emphasized in future.

Main barriers were seen to be missing interoperability, the fragmentation of initiatives, missing IT/CPS skills and high implementation costs. Moreover, mastering the complexity and emergence of systems will be crucial for the success of future CPSs. Business related barriers include missing business models, legal frameworks, and questions related to liability. Moreover, social acceptance needs to be ensured and ethical concerns alleviated.

In terms of the CPS Technological Priorities the workshop participants had put a strong emphasis on '(Cyber)Security, Privacy, Confidentiality' as well as on 'Safety, Dependability, Resilience, Fault Tolerance', which was expressed in discussion comments such as 'Couch hacking is today easier than throwing a Molotov-Cocktail'. These priorities were again confirmed more pronounced by the subjective workshop voting. Regarding the voting we have seen that a decisive influence on the workshop certainly had also come from the plenary panel held before the interactive session, which revealed a strong focus on ethics and security. In contrast to the CPS Technological voting, the CPS Non-Technological voting pointed out that there is - in relation to some CPS themes, a gap between the company/institutional and the subjective view of the workshop participants. A good example of this was the category 'Ethics', which were voted on place six, afterwards ranked - in relation to the subjective view, on the first place of the survey. Here again the concerns were expressed that the

following generations might show deficits in social behavior, due to the increased pervasiveness of digitization.

Moreover, the participants in particular suggest to enhance the support of ‘Education, Training, Skills and Re-Skilling’ and ‘Regulation, Legal Issues, Single Digital Market’. However, as an overall conclusion of the workshop session there is an evidence to act, due to upcoming ethical and security challenges in terms of the global advancement of CPS Technologies. Therefore, the workshop participants recommended the EC to emphasize more deeply the above mentioned priorities to reduce societal fears for an optimized development and acceptance of CPS Technologies in the European Union.

The Platforms4CPS consortium thanks all participants for their valuable contributions as well as fruitful and open discussions!