



Technical Foresight Report

Software Marketplaces for Cyber-Physical Systems

December 2015



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Executive Summary

While the scope of this foresight is narrower than cyber-physical systems (CPS), we frame it by listing trends, challenges, and opportunities for CPS in general below. As partners of EIT Digital are now preparing to launch a CPS software marketplace, after two years of joint activities, we then list the *status quo* of that narrower scope. This includes relating the EIT Digital take on CPS to other European initiatives and projects. A structured set of questions to innovators is presented, the answering of which will result in market readiness for a CPS marketplace. The focus is thus on software marketplaces for CPS, with tech trend scouting covering the entire CPS area. The purpose is to describe the ecosystem for the former and to show the *status quo* and beyond for the latter.

Trends

- There is an ongoing shift from products to services, manifesting itself as new entrants and as revamped business models in the context of CPS. Integrated customer-driven CPS technology developments have the potential for disruptive market impact in many domains.
- Related to business models, the complexity and required competencies in CPS form strong drivers for collaboration, creation of value networks, and open innovation. This is evidenced by open source efforts, cross-domain collaboration (e.g. in the context of ITEA and ARTEMIS), and through open standards such as OSLC (www.oasis-osl.org/) and FMI (www.fmi-standard.org/).
- The cloud is becoming decentralised with massive edge computing for computation, storage, and different network services [12]. This development provides opportunities for deployment of new services and their realization, as illustrated e.g. by cloud manufacturing [26].
- The augmented reality and virtual reality markets are seeing new devices and new content. Device shipments are expected to increase from 3m units in 2015 to 55m units in 2020, when revenue is estimated to hit \$120 billion (AR) and \$30 billion (VR) [7]. Applications will remain focused on high production cost products in the short-term, where minimal errors can be detrimental.
- Augmented industry solutions are helping investment in intensive industries to reduce production and maintenance errors and to empower employees. An assistive technology rather than an automation technology enables new employees to perform highly complex tasks. Overall an enhanced quality assurance, efficiency, and safety during sensitive operations can be achieved by reducing human errors and improving human/machine collaboration and learning.
- CPS are being employed not just in the process industry, but across many application areas. In smart cities, for example, intelligent pavements, indoor localization, and networked control systems today rely on CPS solutions. Within the healthcare sector, practice is increasingly steered towards a closed-loop approach for distributed medical device systems, where human interactions are limited or excluded to decrease the risk of human error. Innovative use of sensors is also making possible a rapid expansion of remote healthcare services. Automation solutions for new information- and value flows in care and prevention is gaining acceptance among clinicians.

- Still beyond state-of-the-art, mind interfaces let the human brain control external objects. Real-time interaction will be enabled by measuring electrical signals in the brain and translating these activities into command and control. Commercial brain control interfaces are already entering the market, such as Mind Solutions with their wearables enabling the brain to control a computer or a smartphone (e.g. the Emotiv EPOC or NeuroSky MindWave headsets, the Muse headband, or the NeuroSynch EEG interface from Mind Solutions). Moreover, academic research is making progress, e.g. [23].

Challenges

- Interoperability challenges pertain to products/services and to data/tools used for the engineering of a CPS over its life-cycle. The heterogeneity of CPS technologies and stakeholders, the multitude of organisational practices and scenarios for integration (targeting different stages and purposes), standardization, and business aspects make interoperability difficult.
- Interdisciplinarity and cross-technological skills present challenges in competence: hiring is currently difficult in CPS. In mathematics and computer science more generally, Germany alone has an estimated 173,000 unfilled jobs, expected to nearly quadruple by 2020 [11].
- The manufacturing industry and other asset-intensive industries face maintenance complexity, since industrial machinery and equipment are complex technologies requiring substantial resources for training, operation, and maintenance. Inadequate maintenance and production errors are expensive, and specifically trained personnel is often not immediately or locally available.
- Augmented industry solutions currently face a lack of standards, immaturity, expensive hardware (form factor, usability, style), and expensive software development.
- In general, a digital business transformation is ongoing, affecting all existing business models (sooner or later), CPS included. The market can no longer be seen as an arena in which commercial transactions take place according to a structure of perfect competition.
- Existing regulations in some European countries are inadequate for CPS and become innovation barriers. Fear of artificial intelligence and negative sentiment connected to visions like the Jobless Society already play a role in adoption of new technological developments.
- In CPS healthcare applications, designing a suitable and secure management system that can integrate a variety of dynamically reconfigurable, distributed, safe, secure, and reliable medical devices. This in turn requires methods for efficient and correct extraction of complex and possibly streaming data. The data must then also be handled in a secure manner to ensure patient privacy. ResearchKit and HealthKit are merely starting points of investigation, and are still experiments in trust.

Opportunities

- In anticipation of 5G, a change of business models for CPS from vertical to more horizontal is taking place. The industry is seeking to move higher in the value chain, with CPS and IoT business moving into general ICT.
- Increased connectivity in manufacturing will enable new CPS platform business models supporting industrial business networks. This is also the case in a large number of other application domains. Prime areas of opportunity include: [5].
 - Manufacturing
 - Transportation and mobility
 - Smart grid
 - Healthcare and medical devices
 - Smart cities
- The increasing complexity of software-intensive systems in CPS and IoT requires increasingly capable engineering environments and life-cycle support. Consequently, there are many opportunities for new tools and services providing engineering support, e.g. for design, analysis, data/model management, and data analytics.

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1. Introduction

The 2015 Business Plan describes the Innovation Radar as support in the marketplace and ecosystem task at hand “by investigating best practices for establishing marketplaces across a variety of communities.” The Innovation Radar as per usual focuses on ideas and concepts with high innovation potential, chiefly in the interval six months to three years into the future. As this report covers a relatively disruptive area of R&D, the task above is interpreted so that possible developments that influence the current and planned future business models of key European industry players are covered. The scope is software marketplaces for cyber-physical systems (CPS), with tech trend scouting covering the entire CPS area. The purpose is to describe the ecosystem for the former and to show the *status quo* and beyond for the latter. The Innovation Radar has since 2012 run a series of workshops with the intent of eliciting input from thematic experts, chiefly in the form of written text. Following this established work practice, text on software marketplaces for CPS was produced in the following methodological steps.

Pre-workshop

1. Invitation with concise background material on the area at hand sent out to thematic experts, Innovation Radar team members, and selected invited guests
2. Agenda writing and goals for output set by workshop leader and activity leader

Workshop

3. Introduction to workshop format and participants
4. Explanation of thematic delimitations
5. Individual silent trend/idea/concept generation
6. Text summary on paper, with quick explanations as necessary
7. Clustering
8. Formation of writing groups
9. Speedwriting sessions
10. Wind-down, open discussion and review of results, explanation of next steps

Post-workshop

11. Follow-up meeting of the activity, with participation of the radar team
12. Post-workshop editing
13. Decision upon form of publication (Foresight Technical Report in this case)
14. Internal dissemination, during grace period (January through March, 2016)
15. External dissemination, via the EIT Digital Publications Web page (April, 2016)

The output from the speedwriting sessions (step 9 above) are included as an appendix in this report, with only minor post-workshop editing. The more general results from the workshop and from the follow-up meeting the following day are to be found throughout this report.

2. A Helicopter View of CPS

A child of many names, CPS is suffering from the overlap with the connotations of terms like *embedded systems* and *Internet of Things (IoT)*, and with geographically anchored names like the German *Industrie 4.0*. What follows is the theoretical minimum: just what is required to proceed towards R&D work on software marketplaces for CPS.

2.1 Fusing the Virtual with the Real: Next-Generation Computing

The term CPS denotes enablers for a new generation of smart systems. Advanced CPS technologies—automation provided by industrial robots, mixed continuous and discrete control, and hierarchical distributed control systems—will change the future of industrial manufacturing [5]. Proven benefits of connecting the virtual with the physical include i) reduction of work in progress, ii) increase in productivity, and iii) increase in on-time-delivery [3]. While these benefits are in line with traditional industry efficiency, a digital business transformation is ongoing, affecting all businesses (sooner or later), CPS included. While not every physical aspect of the future factory, for instance, is affected by this transformation, the people working in and with the factory all are. Going digital means changing systems of administration, control, delegation, and much more. Well-being, clean energy, integrated transport, and resource efficiency are all important issues in modern societies, and CPS will fundamentally change how we handle all those aspects of our lives. It also promises and threatens to bring disruptive changes to economic value chains as well as societal processes: these systems are disruptive at an economic level since they connect previously unlinked technical and organisational processes, and at a societal level since they address societal processes that affect interaction between technical systems and humans. The power of disruption is also linked to the speed of change: CPS rapidly enable new areas of innovation, novel business platforms, and new business opportunities. Hence, it is a strategic investment opportunity on a global scale, and for many companies CPS are becoming critical to business success. Currently, Europe has a 30% share of the world market for embedded systems [8].

Five key areas for CPS with future potential and strategic importance to Europe are:

- industry
- transport
- infrastructures
- energy
- well-being

In a broad sense, Industrie 4.0 is production based on CPS, enabling smart products and flexible production units. In these smart factories of the future, new products and services will be provided and completely new markets created, establishing a different form of value-network – such as in the case of automated driving, where added value for customers becomes a service connected to automated functionalities and fleet management, rather than high-end vehicles [6]. Another example within the area of smart transportation is the aerospace industry. Airlines will, for example, be able to optimise travel routes, minimise waiting times, cut fuel consumption, and provide intermodal management of baggage. CPS will also enable in-flight care via telemedicine applications [14].

An example of a smart city CPS solution is intelligent pavement. The iPavement solution is a digital street, integrating Wi-Fi and Bluetooth wireless technology into the ground (see e.g. www.asepi.org/en). Another hot topic is indoor localization, that might transform the way people navigate indoors just like GPS affected people's outdoor navigation possibilities [20]. Buildings will also use a networked digital control system in order to optimise services. Energy, water, consumption, and lighting will be managed and controlled for economic and environmental sustainability. In order to operate autonomously, CPS also need to generate their own energy. Besides co-existing with nature, a building can also harness it. Thus, environmental energy harvesting through battery powered wireless embedded systems, or sensor networks, has emerged as an option to supplement battery supplies. The mainstream energy harvesting technology for CPS is photovoltaic cells [16]. Buildings will further impact healthcare via integrated tele care systems (see e.g. archive.futureagenda.org/pg/cx/view#415). Opportunities for CPS applications in health and wellbeing have so far been rather unexploited, but healthcare can possibly be the next big area for CPS, as shown by the following section.

2.2 Application Outlook: CPS in Healthcare

Most of the applications of CPS are in process industry, transport, infrastructures, and energy. One of the most expansive application areas is of a different kind, namely healthcare. Most of the CPS use in healthcare today focuses on the monitoring of patients, remote patient care, and computational intelligence systems for decision support. However, a wide variety of other applications have also been proposed, ranging from intelligent operating rooms and image guided surgery to prostheses controlled by brain signals via mind interfaces, where real-time interaction is enabled by measuring electrical signals in the brain, and translating the activities into command and control. Mind interfaces is currently seeing an annual growth rate of 113% [1]. Alongside this development, research topics like neuro-security continue to address ethical and security concerns of mind interfaces. Such concerns also arise in e.g. smart environments, games, and neuro-marketing.

Eight elements of CPS in healthcare have been identified, with each element subjected to intense research into approaches, methods, and products [25]:

- application
- architecture
- sensing
- data management
- computation
- communication
- security
- control/actuation

We note that several of those will constitute common challenges across several domains, such as architecture and data management. Two projects still in development are *Cyberheart* and *Bio-CPS for the engineering of living cells* (see www.nsf.gov/news/news_summ.jsp?cntn_id=135105). *Cyberheart* will be a platform for performing minimally invasive radiation treatments for patients with cardiac arrhythmias through the CyberKnife system. The platform will also be used to virtually model a specific patient's heart dynamics and by doing that, optimize and test the settings for a cardiac medical device before it is implanted into the patient through surgery. *Bio-CPS* lies in-between the

two fields of robotics and synthetic biology. By using a robotic approach to engineer bacterial and mammal cells, inserting pre-programmed micron-scale mobile robots into cells, the cells can be forced to exhibit certain behaviours, e.g., a stem cell might be forced to differentiate itself into a myocyte or a neuron. The cells can thereafter be used to grow new organs or used for drug design and testing. The robots might also be able to supervise microscopic assembly within cells or to create a cell sensing system within the body. To make a robot trigger a desired chemical reaction at a specified time and location, magnetic fields and light will be used.

Changing demographics towards older populations has been a major concern for some years. One part of the solution is to limit the number of patients in hospitals by providing remote healthcare. This transition has been accompanied with new and innovative uses of sensors and a trend towards an increased patient autonomy. Alongside this development, treatments are also getting more personalised as new genetic/epigenetic markers and environmental factors are found. Another trend is towards a closed-loop approach for distributed medical device systems where human interactions are limited or excluded to decrease the risk of human error (i.e., increasing levels of automation). This is also closely related to the increased interest in continuous monitoring and care [18]. In addition, technical advancements have outdated mechanical and analogue medical devices and replaced these with digital or mechatronic systems, providing new functionality and increased connectivity. On the longer term time scale, social robotics is a domain receiving a lot of applications, for example in the form of home robotic assistants. The area, however, still is in need of further research.

Multiple challenges have been identified for CPS adoption in healthcare [15]. One challenge is to design a suitable and secure management system that can integrate a variety of medical devices. Since these devices might not be interoperable and might use different communication interfaces, the systems need to be dynamically reconfigurable, distributed, safe, secure, and reliable, in order to match various healthcare settings. Communication is not only necessary between devices, but also between devices and patients (or care administrators, or healthcare providers). This means that the systems must be reliable and provide proper feedback, like smart alarms. However, this type of feedback is associated with additional challenges, raising the need for a system which can extract complex data from patients in an efficient way. It is also important to ensure that the data collected through sensors are consistent, and that sensors do not conflict with each other. The data must then also be handled in a secure manner to ensure patient privacy.

2.3 Internet of Things

The number of connected devices and sensors is expected to be around 40bn in 2020 and mobile data traffic is expected to increase from 30 Eb in 2014 to 291 Eb in 2019 (CAGR: 57%) [4]. One enabler is 5G, expected to be deployed by 2020 (pre-standard 5G deployments are expected in 2018-2019). It promises lower energy consumption and higher network speeds (>10 Gbps) and lower latency (<1ms) with economic impact in terms of e.g. conversion time vs. load time. Another enabler is massive edge computing, a paradigm describing an extension of cloud computing towards the edge of the network. By implementing an additional layer, for computation, storage, and different network services between the end user or device and the cloud, augmented and virtual reality is supported in processing and transmission [12]. By maximising throughput and reducing latency, 5G will also enable further evolution of the future communication network, as well as transforming the network-centric perspective into a service-centric one, leading to the development of more disruptive business models built around integrated services and new devices in new vertical industries.

IoT can in simplified terms be described as consisting of devices (sensors, actuators), connectivity, and processing that are all interacting across networks. Whereas CPS traditionally has been more focused towards embedded systems in closed environments for vertical segments, the IoT area has emanated out of traditional internetworking to extend the networking area also towards machines and devices not controlled directly by humans, and that often had limited storage and processing capabilities. As with other areas in Internet R&D, there are strong directions towards opening up communication for all, and not limiting towards certain applications segments or markets, or confining it to certain application islands. This approach of providing generic or horizontal communication has proved very successful for the Internet. It has created a huge market in networking, and we have also seen this market merging with the wireless market into one horizontal market providing internetworking services irrespective of connection type. Currently there is drive from the cellular side to integrate sensor- and actuator-communication into 4G already, and even more so towards a more optimised connectivity for 5G. This holds also for mission-critical applications, by having real-time redundancy and by providing a distributed processing execution environment to decrease latency.

The advent of the horizontal market in IoT, where we expect a huge boom, would decrease the cost for IoT services and become very competitive for the more traditional vertical segments like automotive, transport, production, etc. One should expect a move from the vertical specifically defined IoT services towards more horizontal use of COTS (commercial and off-the-shelf) connectivity and services in order to take advantage of this development. At the same time, this will most likely impact the current business model of the vertical segments, in which applying CPS is normally a way of increasing productivity through technology rationalisation without changing the current business models. We have seen this happening in other areas where COTS solutions have become dominant over specifically tailored solutions.

Horizontalisation in the form of IoT would mean a change of business models with new competitors, where connectivity and execution services would be offered as COTS rather than being developed specifically, for a particular business segment. It has already started in certain areas, like connected cars, or utilities making use of LTE or 4G in their networks (rather than developing specific solutions that was the practise previously). All in all, this points to traditional CPS most likely being submerged into the more generic IoT.

2.4 CPS Ecosystems

The opportunities and growth in all aspects of CPS are mirrored by challenges and opportunities for its engineering. Multiple disciplinary competences and tools will be required for the development of a non-trivial CPS. Because of the tight integration between physical elements, electronics, and software, the corresponding roles of the competences, decisions, models, data, and tools will have corresponding dependencies; a change made in for example the electronics design, will likely impact parts of the software, production, maintenance, etc. As mentioned earlier, this gives rise to quality assurance challenges. Tremendous efforts are spent in trying to improve the efficiency for the engineering of CPS, including efforts on modelling and simulation, data and tool integration, and continuous integration and deployment (all the way to 'DevOps'). Many of these efforts draw upon existing software concepts and attempts to transfer and extend them to a CPS setting. The corresponding opportunities are seen in a large number of start-ups and SMEs, providing for example new tools in the areas of quality assurance and information management (see e.g. CPSE Labs, www.cpse-labs.eu/). Data and tool integration provides a particularly cumbersome challenge because

of the heterogeneity of CPS. As a result of efforts within EIT Digital and ARTEMIS projects such as iFEST (www.artemis-ifest.eu/), MBAT (www.mbat-artemis.eu/home/), and Crystal (www.crystal-artemis.eu/), industrial organisations have understood that many of their challenges are common across application domains. As a consequence, open standards, open-source software initiatives, and other collaboration initiatives (e.g. the CP-SETIS FP7 project, cordis.europa.eu/projects/645149) are now strongly promoted, a fact closely related to the present discussion on software marketplaces. Many of those initiatives have adopted OSLC as an underlying lightweight standard for data integration.

2.4.1 Competing through Collaboration

Value creation from digitisation can come in the form of products ('digital inside'), processes (digital transformations), and (in the case of radical or disruptive changes) business models [19]. Thus, front-end offerings (e.g., smart products or new service opportunities) combined with back-end benefits (e.g., automation, integration, and standardisation) have the potential to lead to disruptive business models and a new form of competing dynamic. The political and regulatory landscape is changing as well, where initiatives like Smart Anything Everywhere (ec.europa.eu/digital-agenda/en/news/launch-european-smart-anything-everywhere-initiative) launched by the European Commission in February 2015 are increasingly based on collaborations between researchers, large industries, and SMEs. Thus, the ecosystem business thinking also affects the nature of policy language. A major challenge to a European ecosystem is the current and historical disparities in readiness (as indicated in Fig.1).

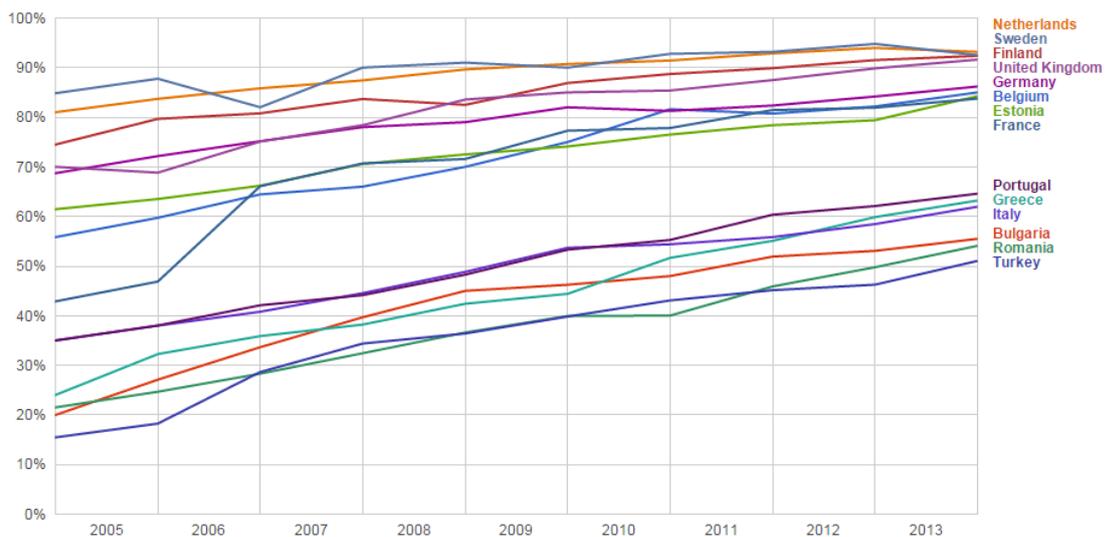


Fig.1: A weak indicator of readiness; Internet users (defined as individuals who have used the Internet from any location in the last 12 months) as percentage of population, and the rift between two clusters from a selection of European countries. Data from World Bank (downloadable from data.worldbank.org/indicator/IT.NET.USER.P2?cid=GPD_44), visualised using Google Public Data.

A productive social network defines its linkages according to both actual and potential transactions, and success in the software industry is often driven by ecosystems of developers. The market can no longer be seen as an arena in which commercial transactions take place according to a structure of perfect competition [24]. By placing yourself in the midst of an inter-organisational collaboration, or ecosystem, you are instead able to create value beyond your internal capabilities and boundaries, transforming the value chain into a value network. A potential software marketplace for CPS is related to competition in the sense of the power other agents may, or may not, have over it [22]. As aforementioned, however, the ecosystem thinking and the redefining competition paradigm stipulate a value network rather than a value chain logic, where the former is rather incompatible with the Porter model. Thus, in order to avoid the pitfall of claiming contradicting logics, the actual purpose of an ecosystem-based marketplace needs to be clearly defined, and then related to the correct narrative and model. In keeping with this, the following chapter contains a number of questions that need to be answered before launching a marketplace. Before this, however, the vision is detailed.

2.4.2 The Marketplace Vision

The nature of CPS provides vast opportunities for innovation. The merging of previously disparate competencies provides new opportunities for collaboration and business. The systems at hand are evolving, and so are the technologies, platforms, and services that constitute CPS engineering environments. This leads to the realisation that multiple and overlapping efforts are spent on creating CPS-related assets, in areas such as co-simulation, data integration, and middleware platforms. Collaboration, synergies, and business opportunities should thus be within reach, but would require that active involvement can be achieved.

Marketplace as a term can refer to different things, referring to its mode of operation, from purely commercial to non-commercial, or with mixed modes of operation [2]. At one end of the spectrum there are open source forums which promote collaboration, but may only indirectly involve business. At the other end of the spectrum, a marketplace may primarily be related to business (compare with an App store) according to a specific business model. A typical category of marketplaces are those driven by championing companies: a large company driving a marketplace is in the literature often referred to as a *keystone company*. Other typical categories include those that are open source and/or non-profit. Marketplaces are relevant for various stages of the lifecycle of CPS products and services, e.g. referring to CPS development, platforms, and components. Marketplaces also typically refer to a specific technology or platform. Examples of marketplaces include ones centred on Eclipse (marketplace.eclipse.org/), Android (play.google.com/store), and Modelica (openmodelica.org).

3. Asking the Right Questions: CPS Marketplaces

At an EIT Digital Innovation Radar workshop, a large number of questions were formulated to pinpoint where R&D efforts have to go in order for the realisation of a CPS marketplace. Some questions are basic, even naïve, while others are deep and far reaching. The questions have been sorted below under the following headers:

1. Purpose
2. Technology
3. Participation
4. Organisation
5. Business models
6. Marketing and communication
7. Legal aspects
8. Social aspects

All of the questions are meant to be answered, as a means to realising the right marketplace, at the right time, and in an efficient manner. The team for realising the marketplace, founded on the basis of the EIT Digital 2014 and 2015 activities, have started addressing each question. Some answers are found already in this foresight, and some were addressed in relevant projects or industry efforts among the partners throughout the collaboration. A concentrated follow-up effort will take place in 2016.

3.1 Purpose

- What is the marketplace for? For whom?
- What are the specific customer needs?
- What should be exchanged on the marketplace?
- Who benefits from successful integration? How?
- What are the drivers for an exponential increase in speed of integration, as envisioned?
- What is the potential impact of the marketplace, in terms of economic or other indirect gains (such as productivity), for the various involved stakeholders?

3.2 Technology

- How does one plan to handle rapidly increasing emergent complexity?
- Which elements can be combined successfully?
- What are the pre-requisites, in terms of technology platforms and standards?
- When is it better to start with an existing forum (for OSLC, LYO would be an example, see www.eclipse.org/lyo) or marketplace and evolve it to specific needs rather than starting something from scratch?

3.3 Participation

- What skills/competencies/perspectives are needed when building the marketplace?
- What constitutes a minimum critical mass for establishing open innovation for CPS engineering environments?
- Everyone says they want integration, but who makes the effort in practice?
- Why should anyone participate in communities? What is the motivation and benefits?
- How does one contribute to a marketplace? Can the open source community be attracted to the marketplace? How does one kick-start developers and hackers?
- Openness to whom, and to which degree; who will be able to access data?
- Who are the contributors? Would any of the 85 EIT Digital partners be interested?
- What rewards are given to contributors? What is the commercial interest to contribute to a marketplace?
- Would tool vendors be helpful? If so, how could they be convinced to join open interfaces?
- Which cases are beneficial to open innovation? Would it require companies from different domains with less of competition, or can the 'collaborate to compete' be formed to focus on non-competitive assets?
- Who is the 'typical' customer (Volkswagen, Siemens, ABB, Magna Steyr, Brembo, Bosch, Continental,...) entering the marketplace?

3.4 Organisation

- How does one maintain and organise a marketplace for CPS engineering environments? Is a focus towards industrial (factory) environments required?
- What is the organisational setup? Keystone company lead? Community lead?
- As the main stakeholders (from Ericsson, Siemens, FindOut, KTH, Åbo Akademi...) do most likely not constitute a big enough consortium to run a marketplace, what other companies would be interested in joining?
- Can OLSC Oasis take some responsibility for the marketplace?

3.5 Business models

- What are the appropriate business models for a marketplace for CPS engineering environments?
- How can we find ways to build business models capable of funding the open communities?
- How is it possible to become competitive through added value services?
- How much scaling effects can be achieved?
- What would the benefits of collaboration be? Collaborate to compete? How?
- Where to draw the line of the marketplace? Interorganisational? European? Global?

3.6 Marketing and communication

- When is "the right time" to set up a marketplace for CPS engineering environments?
- How does one solve the marketing factors in a marketplace?
- How does one reach visibility?
- How does one attract interest?
- How does one keep interest?
- What are the selling points?
- Are there too many marketplaces?

3.7 Legal aspects

- What is the role of governments and government agencies? What is their impact?
- How does one deal with IP and liability issues during open innovation; what are pros and cons of existing open source software licenses, and are they sufficient in the context of CPS?
- How does one deal with regulation and requirements?
 - privacy
 - data security
 - industrial espionage
 - cartels
 - homeland security
- Who should be able to regulate the community? Unions? At which level? Law?
- Should there be voluntary codes of ethics?
- If data creates added value and IP, who should get the credit for it?
- Who owns the products? Who owns the interface to the end users?
- Who owns the data? How is this handled?

3.8 Social aspects

- From an individual perspective, what are the impacts of rolling out a CPS marketplace?
- What is the impact on society, and on technical as well as non-technical stakeholders?
- How does one handle rapidly increasing emergent complexity?
- What is the impact on forms of interaction?
- What is the impact on the workforce and their tasks? Will there be redundancies? How does one deal with worries related to such redundancy?
- What will be the roles and required competences of stakeholders, given an increasing automation also for CPS engineering environments?
- How will society handle unwanted sharing and dependencies?
- Are there any upsides from a social and/or individual perspectives?
- Manipulation of data? Augmenting data? Commercialisation of data?
- In what dystopian shadowland can interoperability strand us, and how do we avoid it?
- What can be done that is truly useful for people? Who will benefit?

4. Towards a Market-Ready Software Marketplace

Due to the current lack of marketplaces for CPS in Europe, a first mover advantage may be possible given that it is possible to deal with barriers related to the investment costs, access to suppliers and distribution channels, economies of scale, and reaching critical mass of customers, cf. [22]. The impact potential of a CPS marketplace is also affected by non-economic factors, e.g., laws, regulations, and interoperability between different standards, some of which being considered major challenges when implementing CPS today. In addition, design, development, exploitation and evolution are factors: “While progress is being made every day, advancements to CPS continue to be challenged by a variety of technical (i.e., scientific and engineering), institutional, and societal issues. These range from technical system-level issues such as interoperability, infrastructure, and reliability, and better business models and value propositions for next generation systems.” [5]:2. In order to build a strong community, the EC is envisioning an integration of European academia and industry [8]:4:

“A challenge for Europe is that it needs to respond to Information Technology multi-nationals who dominate the area of technology and business platforms. Europe is not prominent in driving such platforms today and the aim of the meeting was to identify how Europe could stimulate a new wave of innovation and capitalise on new CPS markets. The intention is to bootstrap ecosystems around platforms driven by EU actors exploiting synergies across sectors and applications. The Industry visions for CPS indicate that there are many opportunities for the future. ‘Smart Everywhere’ is already happening and there are some success stories – but there are still technology and knowledge gaps. There is also a need to provide platforms with open elements and business ecosystems that support innovation within Europe. ... Challenges are in providing ‘real world in real time platforms’ that are sustainable, and in building Cyber-Physical Systems based upon this that consider interoperability, sociotechnical issues, big data, standardisation, certification and liability.”

Three policy areas are in focus within the European Digital Single Market initiative [9]:

1. Better online access to digital goods and services
2. An environment where digital networks and services can prosper
3. Digital as a driver for growth

The EC further stipulates that “It’s time to make the EU’s single market fit for the digital age – tearing down regulatory walls and moving from 28 national markets to a single one. This could contribute €415 billion per year to our economy and create 3.8 million jobs” [ibid.]. “By creating a connected Digital Single Market, we can generate up to €250 billion of additional growth in Europe in the course of the mandate of this Commission, thereby creating hundreds of thousands of new jobs, notably for younger job-seekers, and a vibrant knowledge-based society.” [10]:6. From the industry side, the NESSI member organisation states that “Software-based services constitute a key enabler for leveraging, packaging and delivering the core capabilities of a CPS infrastructure, realizing the potential that lies in creating value to business applications.” [21]:2 and they list the following challenges [ibid.]:6.

- Quality assurance of CPS in the presence of dynamic adaptation and discovery
- Middleware and platforms for dynamic evolution and composition of CPS
- Powerful abstractions for understanding and modelling CPS

Paving the way for a marketplace also requires overcoming barriers to CPS development environment [13]. As elaborated on in Section 2.4, both standardization and support tools—strongly driven through the Integrated Information Engineering EIT Digital activity and its carriers—have matured to a point that a marketplace initiative may be feasible. A community of end-users now have increased awareness and manifest interest in promoting open innovation.

Maturation of technological foundations such as support tools and standards (at the right level), drastically facilitate the creation of data analytics and added value services; **Fig.2**, from the iFEST ARTEMIS project *industrial Framework for Embedded Systems Tools* [17], illustrates a setting where tool integration adaptors can be developed for various data sources in a cost-efficient way. Data is then made available, enabling a wide variety of opportunities for added-value services such as visualisation and traceability.

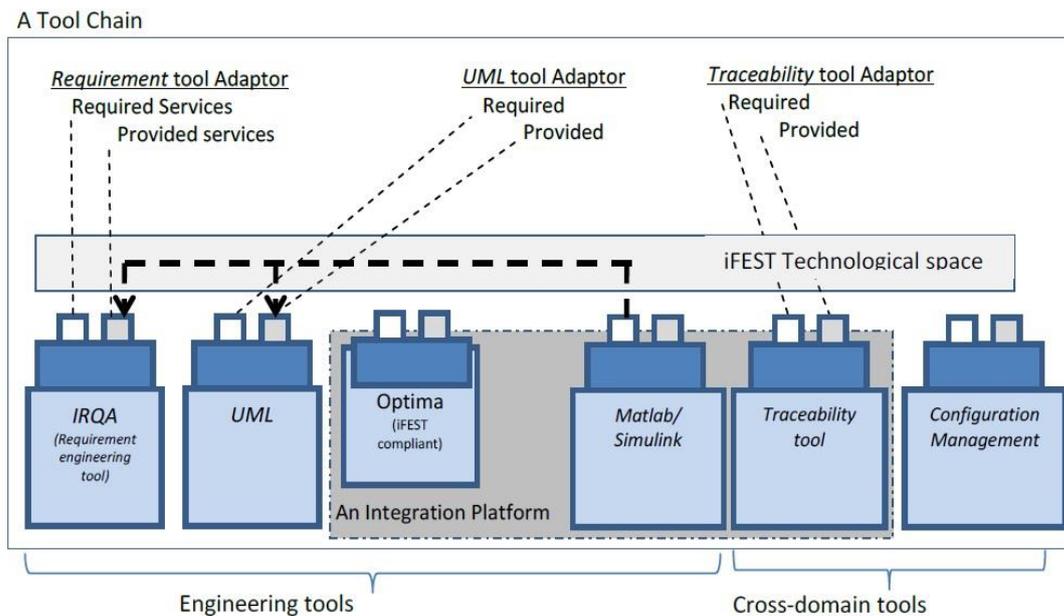


Fig.2: An example tool chain in iFEST (Figure 9 in [17]).

There are also cloud-based platforms for matchmaking and analytics within CPS under development, such as Predix (predix.io), promoted by GE Digital. Cloud Foundry (cloudfoundry.org) is a collaboration between several CPS-heavy companies, relying on open source, and with a potential for cloud-based services enabling CPS marketplaces. In addition, two testbeds have recently been made public by the Industrial Internet Consortium (iiconsortium.org), one for industrial manufacturing and one for microgrids.

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Appendix: Speedwriting Output

1A – PEOPLE, SOCIETY, INDUSTRY

Systems of systems of systems

Whenever value is created through disruptive innovation, we ultimately have to decide and rule on how the mechanism affects people, and there is a plethora of political, commercial, and human perspectives to consider. In what ways is it, for example, possible to tie the evolution of CPS to the great challenges of our time, such as the environment, the spread of democracy, and the distribution of wealth? The consequences of technological development need more attention.

In addition, what are the impacts of rolling out CPS, from an individual perspective? As a consequence of automated systems we will, for example, continue to witness massive changes in our working environments. Besides a networked society the future may also entail a jobless society. Worries about redundancy must be handled, as must the burning question of how wealth, power and time will be distributed if and when people no longer work. What are the upsides for the workforce, is it the reduction in number of dangerous or tedious jobs? An analysis of who will benefit is badly needed. How will society handle unwanted sharing and dependencies? Will the winners in the future be the ones that manage to integrate or crowdsource many different disciplines, including manufacturing?

Another critical aspect is complexity. Future systems will have plenty of components (subsystems). The number of connections between these components will be massive and may change dynamically. How do we avoid building complexity into such systems of systems that they become counter-productive, or even useless? Another dimension of automation is increased speed in the number of iterations on how to develop your systems as a means of coping with complexity and of increasing overall quality. How will people be able to navigate through complex velocity systems? Perhaps automation is, in fact, just as much an answer to, as part of, such complexity.

There is an emerging interest in communities, and in collaboration within ecosystems. Indeed, trust-based collaborative environments, with a low level of regulation, is an interesting model for tackling complexity. From a critical stance, however, it would also be possible to argue that sociality is grossly overestimated. Even good communities, when having grown large enough, need to be regulated. Unions may wish to have a say at this point, as will regulators and policy makers. A codex or similar means to addressing ethical issues might surface in the process.

Engineering, and who will be included in the process of building these highly automated systems, is a related matter. This helps shape our future. Essentially, this is a question of power. In particular, in terms of open source collaboration within the framework of a CPS marketplace it becomes important to know how different actors are motivated to participate. Different stakeholders have different interests. The main incentives from an organisational and an individual perspective need to be identified. The importance of early adopters and forerunners is uncertain, there might be a “bleeding edge”. People’s loci of motivation during open community work usually differ from competitive work.

Through personalised CPS – my very own integration – data will also be accessible across value chains. This leads to the vision of “the transparent human”. Counter-movements is a societal trend, so there might be a development of analogous parallel societies. Probably this will be the choice and privilege of the few, since most people will increasingly be digitally connected.

1B – AUGMENTATION (BUSINESS MODELS)

Rise of the machines

Artificial Intelligence will augment human capacity in several areas. We will, for example, see smart household robots and intelligence in manufacturing where AI/VR will conquer industry maintenance. Future of CPS involve dynamic negotiation/ resolving of conflicts between its components, domain knowledge databases, including the rules for re-adjusting its behaviour / dynamic reconfiguration mechanisms, effective runtime monitoring and machine learning capabilities. We need to focus on issues such as security, stability and robustness, and move towards greater adaptability, scalability and resilience. Simple tools, requiring complexity beneath, is a must, as well as an architecture enabling speed, adaptability and agility. Thus, probably aspects such as standardization and open source should be driven/ensured. For being useful, content must be compatible and/or a community must be enabled to make it compatible/customize it to specific needs. SW engineering can combine features, but we still have to know what can be combined, and what works.

There are many perspectives and interpretations of “augmentation”, but the definition / application of cyber-physical can also be linked to a human-machine interaction. Automation often implies that we need to teach machines to think so that they can replace people. However, since machines cannot think – only search for solutions – we still need to guide them using existing (and learned) expertise. A semantic framework is required to expose cognitive behaviour.

If operated by EIT Digital, business might not only be in direct revenues, but also in driving adoption and standardization. If operated by industrial/research partners of EIT Digital, their research results, software products could be positioned or their physical goods could be promoted for encouraging software solutions for these from the community.

There could be revenue sharing per download, per use, or a backend-as-a-service is provide with functional building blocks that developers can integrate into their solutions. In this case, a pay-per-use model seems feasible, either billing developers or end-users.

It is further possible, maybe even necessary, to separate automation from smart automation. When comparing robots and nanotechnology based humans, for example, how do we determine which is better and more secure?

Our environment needs to become more intelligent, but what can be done that is truly useful for people? Some simple examples could be a connected car with a mirror braking state to the cloud. The business model could then be built around “friction” services (already being experimented) where info is sold to governmental traffic administration as a support for salting roads, for example. Instead of a static state, business models with connectivity is evolving, and one example is the evolution of APPs. In terms of Telecom networks we previously had dedicated networks, but now the networks are more generic (larger scale economy).

Augmentation of present industrial operation, by the use of ICT, is a form of tech rationalization. Augmenting the business models, on the other hand, can be seen as more revolutionizing. There is a clear connection between technology and business models, where completely new types of spaces, services and markets are emerging, reshuffling whom will contribute. True information integration require BMs that support open communities in practice. This is an advantage for those that are used to work horizontally, but commercial interests of various stakeholders can, on the other hand, become a hindrance. In terms of e.g. electricity and general communications, The Royal Seaport in Stockholm was an example of horizontal vs. vertical where there was a real clash of business models, since some stakeholders were eager to keep their existing BMs (e.g. full control of electricity of ABB or Siemens) in order to minimize the risk. There are other examples, however, where big players still wants to collaborate through communities and business ecosystems. In order to increase the market, telecom companies have, for example, started to collaborate around standards and software.

The real disruptive element in new business models, however, is redistribution of revenue streams, where end customers no longer pay for the service they are using. Revenue comes instead from e.g. advertising or selling data. Clicking on ads while browsing has become indirect services. Telecom customers initially paid for voice, but now for other services.

In terms of a CPS marketplace, how is it possible to become competitive through added value services, and what would the benefits be for such collaboration? How to deal with e.g. IP issues during open innovation? The question of network externalities also has to be investigated, i.e. how much scaling effects we can achieve? How can we find ways to build business models that is able to fund the open communities? Would ads be a solution?

2A – DRIVERS & ENABLERS

Show me the money

We need to find the right incentives for change. Visibility to users and developers is required, standardization and interoperability are big drivers. R&D are used to solving challenges in-house, but now people are getting more into collaborating, communities and standardization, so time is right to establish foundation for integrated engineering. The example of “Industry 4.0” seems quite relevant for CPS AND for the IEE activity. Mature technology also changes ways of working, and creates opportunities for new types of business models; e.g. software based networks now a reality. Even if the engineering environment is different it is also possible to learn from other marketplaces, e.g. app stores. There are further possibilities of licensing, or rent models.

How is it possible to convince participants to join and to contribute? To work with distributed teams? Incumbents are often not willing to open up. Sometimes IP considerations further block traditional organisations in adopting open innovation, for example in contributing open source. This implies weakened communities. A marketplace for CPS might be further limited by regional boundaries (EU and US), but this type of regulation hinder productivity and development. Competition between US and Europe is a driver that we cannot control. The international competition also regards many other relevant players coming from e.g. Korea and China. Also Japan shall be considered with attention, as part of CPS systems are born there. Another hindrance is companies’ unwillingness to share data. A convincing incentive to open up through finding commercial possibilities is needed; a win-win for working communities as well as from a commercial perspective.

Hence, there need to be balance between openness and commercial interest, and both big and small players have to benefit. In niche markets there are often dominant players and conflicts of interests. Furthermore, large companies are often locked-in by smaller vendor solutions → industry dialogues required to drive change through collaboration between bigger players. Tailor-made integration could be enabled by open-source, whereas today they are forced to use inefficient toolsets from existing providers. The ability to cooperate and integrate will be equally important for small/mid-size businesses but in this case rather between companies than departments. Marketplace enable competition, but experience and expertise can be traded as well, so open source can also ensure enough “content”. Depending on how sensitive the data is, and how willing players are to share, there can be a public vs. private cloud for data and services.

Customers might not always have the power to influence, but they might also require standardized interfaces. In that sense, customer needs can also drive demand. Marketplace, then, is not only a market, but also an environment for running services. Thus vendors in the marketplace need to be able to sell through it: they should not feel threatened but rather see opportunities from opening APIs. It basically boils down to revenue: for hardware; for data (raw); for analysis; for traffic (networks); and for productivity.

2B – RESPONSIBILITY

Autonomous disaster?

Current tools are not always doing the job, and vulnerabilities exist in software code or other systems. Would open communities provide a solution? Or would vulnerabilities increase by allowing others to put their hands on, or exploit your code? Why should e.g. Ericsson start engaging with Open Source Communities within their business/product development? Due to their respective domains there is no direct competition between the two main stakeholders in the (CPS) marketplace, Siemens and Ericsson. For several companies the fear of losing markets/business is also greater than allowing newcomers to enter into the (proprietary) systems. Due to the trend of 'servitization,' companies are increasingly challenged and need to find/create new markets. Standardisation, open source and value based development is a possible strategy; there are advantages of moving intelligent software solutions out of unreadable, mostly not reusable, code to standard reusable knowledge representation. Economic balance and fair return could be the key to allow collaboration. The prosumer concept is not actually fully deployed so far in CPS systems but could also have some relevance for discussions about (CPS) marketplaces & developer communities.

If you don't own the architecture you might have less interest in it, so how to balance openness and revenue for all? Having the second may regulate the first, but it is, no less, a question of intellectual property as well. If data creates added value who should get the credit for it? Who owns the products? Who owns the interface to the end users? Who owns the data? How is this handled? Some vulnerabilities include attacks in infrastructure and stolen data. The impact on society also deserves attention. When companies have to change their operations mode, not only employees need a mind-set change, but the majority of citizens will be affected in various ways.

Making a system work, and maintain it, needs modularity, but it is difficult to say how to implement it. Issues such as accountability, responsibility and risk need to be carefully considered. Which partner would e.g. be responsible for running the community, marketplace and/or interplay of products? The next big thing is to make previous big thing usable, but what are all the connected devices going to talk about, and who will have the power to decide? Who will be held accountable if something goes wrong? Network failures have huge impact; billion of sensors constantly transmitting can e.g. lead to jammed networks, autonomous cars can cause collisions, we might see blackouts, reactor meltdowns. In what shadowland can interoperability strand us, and how do we avoid it? In other words, how do we deal with potential autonomous disasters?

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