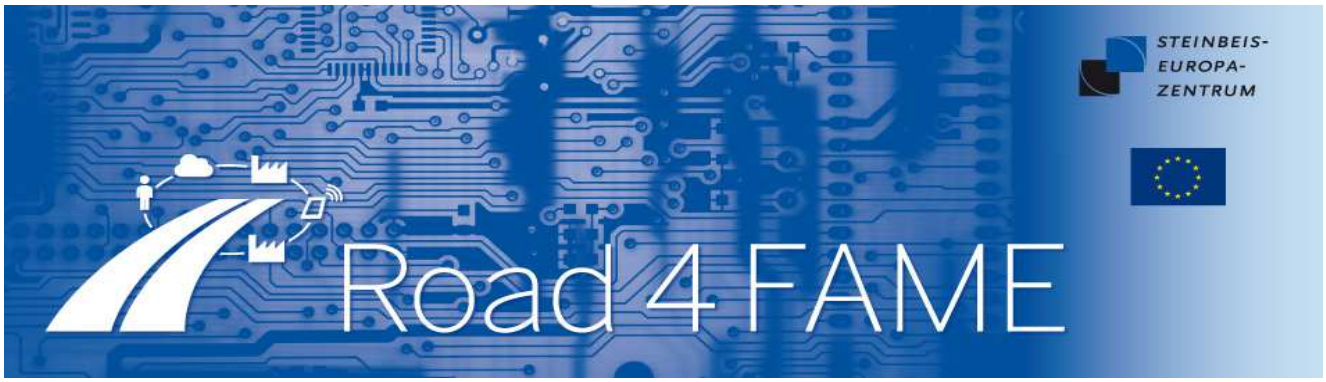

Road4FAME Consultation Event "Digital Revolution in Europe: Converging Visions for a Smarter World"

Haydn Thompson

Report from the Road4FAME Consultation

held on 22nd May 2015 in Brussels, Belgium

June 2015

http://road4fame.eu

Disclaimer: The views expressed here are those of the workshop participants and do not necessarily represent the official view of the Road4FAME on the subject.

Executive Summary

The Road4FAME consultation event attracted 90 participants bringing together a number of key roadmapping activities across Europe, the views of manufacturing organisations, and also the CPS and IoT communities. The Road4FAME, Pathfinder, Factories of the Future, I4MS and Allianz Industrie 4.0 BW viewpoints all indicated that there is a need to engage with manufacturing companies, particularly at the SME level, to promote the digitisation of industry. The Road4FAME, Pathfinder and FoF viewpoints give a glimpse of future manufacturing, but also the current technology and policy gaps that need addressing. The wider industrial context of CPS and IoT were presented by the ARTEMIS-IA, Smart Anything Everywhere, CPSoS and AIOTI projects. These indicated horizontal activities driving CPS and IoT that also have great synergy with the work being undertaken in the manufacturing sector. The two visions of the future for CPS and IoT looked further ahead and highlighted the convergence of the Internet of Things, Cyber-Physical Systems (CPS), Cloud Computing and Big Data within the industrial world to bring smartness and connectivity at all levels, not only within manufacturing, but also within future products.

A key outcome of the meeting was that the Road4FAME roadmap recommendations were confirmed by the presentations given by many of the speakers. There is great synergy between a number of roadmaps presented at the event and this consensus view is very good for Europe providing a sound basis for the future. The final section of this report highlights synergies and key messages identified in the meeting.

It was noted that manufacturing is changing with a move towards product services and also a move in where added value occurs within the value chain. There are also market drivers towards customised products, requiring new levels of connection between the customer and manufacturing, and flexibility within the manufacturing supply chain. The move to product services means that ownership is becoming increasingly decoupled from use of products leading to new ways for sharing products, providing value and generating revenue. The ability to associate information with products and provide customisation, combined with use of IT for cradle-to-grave tracking, measuring, analysing and billing, is creating new business models.

In order to contend in this new world there is a need for key actors in Europe to come together to compete with US platforms which currently dominate the market. There is a need to engage with SMEs, the innovation power house of Europe, to allow new ideas and technologies to flourish and become reality. Entrepreneurs need to be encouraged through education and supporting funding mechanisms. Regulation is required in a number of areas such as privacy, cyber security, for providing a legal framework for contracts between companies, and also in dealing with liability. Finally, humans are an integral part of the systems/factories. They are the solution and also barrier to implementing change. Here education and training is required at all levels to give workers and managers a new skill set to make them more adaptive and open to future technology.

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Introduction and Scope of Meeting

The aim of the Road4FAME Consultation Event was to bring together experts from the fields of cyber-physical systems (CPS), the Internet of Things (IoT) and Factories of the Future (FoF), to explore respective visions on a smarter world that is imagined to be highly performing, progressive, energy saving, socially and environmentally sustainable, but yet competitive. This is to support the European Vision of a Digital Economy based on a digital revolution that will uplift Europe's innovation capacity. The event attracted 90 participants with high-level speakers from the European Commission, as well as academia and industry.

Driving this are developments in Cyber-Physical Systems and the Internet of Things. Digital components are increasingly integrated and embedded into products and services of everyday usage. In the future, cyber-physical systems (CPS) will become natural in managing complex systems (e.g. smart grids, transport or water management systems) and will make everday objects intelligent (e.g. homes, offices, cars, trains, cities and clothes). If the latter are connected to the Internet, this leads to a network of physical objects – the Internet of Things (IoT). Both the CPS and IoT communities foresee great potential for creating a competitive edge for Europe, not only in existing markets, but also by creating new markets across industries and sectors.

Currently the world is undergoing a "digital industrial revolution". This fourth industrial revolution is based on, and fuelled by, development and uptake of ICT – specifically architectures and services. Already these are key innovation drivers for manufacturing companies. Creating suitable architectures and services as well as corresponding innovation strategies and new business models will modernise Europe's manufacturing capabilities and help it compete against fierce global competition. It is expected that in the future, traditional factories will increasingly be transformed into smart digital manufacturing environments. Currently, however, the full potential for ICT in manufacturing is far from being fully exploited. The exact needs of manufacturing companies and the supporting research to meet these needs call for alignment in order to succeed with the practical implementation of new IT architectures and services. The aim of the event was to showcase the visions and results from a number of complementary EU-financed projects and synthesize a common vision. The Road4FAME project which has already developed preliminary findings for ICT architectures and services in manufacturing organised the event to act as a catalyst in bringing together the communities.

The future world will be smarter and in order to generate smart products, services and industrial processes, multidisciplinary cooperation is required. There is a need to exploit synergies across value chains and application areas at all levels considering embedded software, hardware and microelectronics. The future vision is for a "smarter everywhere

society" and this is being supported by the European Commission's Smart Anything Everywhere initiative. A number of key actions are being undertaken to facilitate the smart specialization policy for future development of innovative, sustainable and competitive smart products and services. Speakers who are engaged in these actions also spoke at the meeting. There are a number of key questions for the future:

- Is the vision of highly performing, environmental friendly and socially sustainable, but yet competitive processes and products feasible?
- What is the potential of the Internet of Things?
- What are the research and innovation challenges for cyber-physical systems?
- Is the Factories of the Future Private Public Partnership (FoF-PPP) a good concept for boosting competitiveness and securing Europe's leadership?
- How best can we build European platforms building and establishment the innovation ecosystems to support the digitalization of Europe?

Digital Factories - Research and Innovation Perspectives (Max Lemke, Head of Unit of Complex Systems and Advanced Computing, DG for Communication Networks at the European Commission)

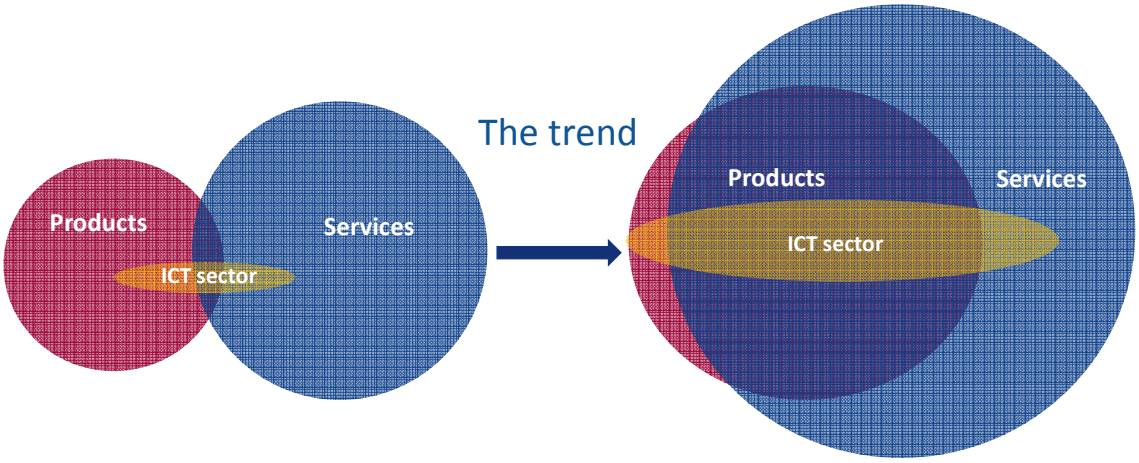

Fig. 1 Trend towards Services

The event was introduced by Max Lemke from the European Commission, who highlighted that a number of topics have become very important over the past 6 months within the Commission. Industrial competitiveness is higher on the agenda and there is a move to a Digital Single European Economy. Digital technology is inside all types of products leading to new innovations through the concept of "smart everywhere". At present no one can predict the products that are going to be successful. There is also a digital transformation of processes with increasing use of ICT in automation for digital process innovation and customer relationship management. This is resulting in radical disruptive changes in business models and a blurring of boundaries between products and services (see Fig. 1). There are also new disruptive manufacturing technologies coming along such as 3D printing. The ability of manufacturers to perform customisation is seen as a big opportunity to reshore work back to Europe. The concept of providing services is also leading to new ideas such as buying a service rather than a tangible good, e.g. purchasing a mobility service instead of a car. It was noted that ICT is everywhere in embedded systems on aircraft, cars, etc. and that new value chains are being developed across layers. Complex systems of systems are also being created and there is a need to develop a platform on which future applications can be built. The future is seen as an expansion to a systems of systems sharing economy.

There are already a number of high profile initiatives around Europe such as Industrie 4.0 in Germany, High Value Manufacturing in the UK and Smart Industry in Holland. Activities at the European level are, however, very fragmented. The Commission see Europe's future as being digital and four lines of actions to address this fragmentation are being proposed. 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.

An enabler is Smart Regulation and this is required to encourage autonomous systems such as cars, robots and drones. There are major concerns considering safety and liability, and there may be a need to review regulations at a European level. Likewise there are key issues in ownership of data, data protection and consumer protection. Many new innovative services rely on exploitation of information extracted from data. If data is over protected by regulation it will not be possible to introduce new innovative services. The Commission has identified 4 key action lines. These are:

1. Access: Wide-spread adoption and best use of digital technologies
- In all industrial sectors
- Focus on key digital technologies

2. Leadership in digital platforms for industry
- Platforms on which value is created, e.g. embedded operating systems, Autonomous systems building blocks, Cloud platforms, data, security
- Openness, Interoperability, security

3. Filling the skills gap and preparing the workforce for change

4. Providing the best framework conditions
- Regulation: DSM, data protection, liability, safety
- Access to finance: EIB, EIF, etc.

Of particular interest to the consultation event were action lines 1 and 2. Action Line 1 is aiming to create a digital competence centre in every region to support digital transformation. The starting point for this are the two EU Innovation schemes, I4MS and Smart Anything Everywhere. The EU is using these to bootstrap activities addressing the “valley of death” between research and new innovation coming to market to help companies take up ICT technology. It was noted that already 300 SMEs are involved in I4MS.

Action line 2 is addressing leadership in platforms. This is being promoted via the ECSEL pilots and also in Platform Building within IoT. The aim is to produce reference implementations to encourage uptake in areas such as the home automation, automotive and energy sectors. In the automotive sector there is a lot of activity on autonomous cars and the AUTOSAR initiative

is leading work. It was highlighted that there are many different types of platforms, both open and proprietary, driven by different business models. In the community model no one makes money from the platform directly but the community collectively profits from having a platform. This is how AUTOSAR works for the automotive community. Within Europe all automotive companies use AUTOSAR and this is also now being used by automotive companies in the US and Japan.

It is anticipated that future platforms will sometimes be sector specific and sometimes they will be cross cutting. There are already major projects such as the ARTEMIS CRYSTAL Innovation Pilot project which is developing a platform for safety-critical systems and also FIWARE which could be the basis for a horizontal IoT platform. National initiatives are also of interest. Industrie 4.0 has defined a Reference Model Platform for factory automation and a question here is could this also be used in other domains. There is a need to establish and agree where European industry should, and want, to work together on platforms and reference models. Potential areas could be:

- A reference architecture for integrated industry
- Platform building for ecosystem innovation
- Manufacturing operating systems
- A reference architecture for connecting all humans services, things, machines, suppliers, value chain actors, etc.

A key question is how should Europe organise itself to support this? Increasingly, there is a convergence between embedded systems, Cyber-Physical Systems and IoT. The Commission is now supporting joint initiatives between IoT and customised low power computing as there are synergies between the two. There are also many developments coming from ITEA and the Commission are providing significant funding to the ECSEL joint undertaking.

The Coordination and Support Actions such as Road4FAME, Pathfinder and CPSoS are seen as being very important in helping to define the EU work programme. A draft of the 2016-2017 Work Programme will be available in July. This has specific support for Cyber-Physical Systems and low power computing which is a key enabler. Further budget will also be allocated to ECSEL.

In conclusion Max Lemke highlighted that the overall objective of the Road4FAME Consultation Event was to discuss and refine the Road4FAME roadmap for future architectures and services for manufacturing. The idea of the event was to bring different communities together. Notably looking to the future there is a need to adapt the workforce considering social aspects. In future workers are needed at the shop floor level who can program robots and use simulation software. This requires development of skills and here effort is required to enable this within member states at a regional level.

Roadmap Short Presentations

Road4FAME: A Roadmap for Future Architectures and Services for Manufacturing/Road2CPS (Dr Meike Reimann, Steinbeis-Europa-Zentrum)

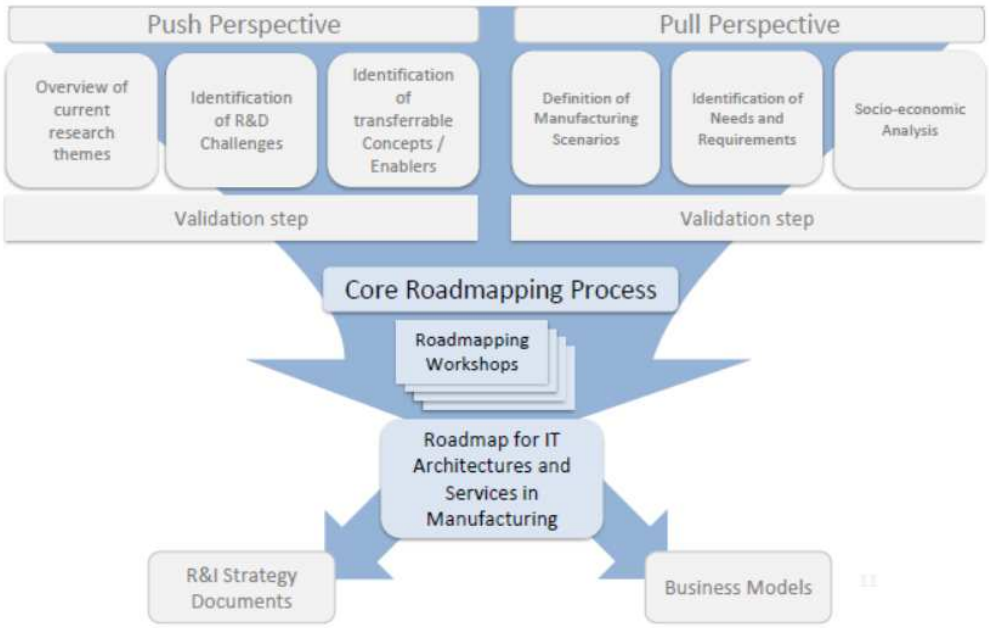

Fig. 2 Road4FAME Overview

Meike Reimann gave an overview of the Road4FAME project (see Fig. 2). Via wide consultation and organisation of expert workshops the project has produced a preliminary roadmap in manufacturing IT, focusing on future architectures and services in the manufacturing domain. The final roadmap will be available in autumn 2015. Input from key manufacturing partners and an expert group of 100 people has been solicited. Additionally, Road4FAME has produced a catalogue of business services and business opportunities that are enabled by future architectures and services. Based upon the consultation and analysis of trends, drivers, industrial needs and interviews with industry recommendations have been provided for future research priorities and innovation strategies tailored to the EC, policy makers, academia and manufacturing businesses. This has considered general megatrends and also manufacturing specific trends as seen in Factories of the Future, Cyber-Physical Systems and the Internet of Things. The “rise of the individual” is driving demand for customised products. Sustainability and green thinking is driving efficient manufacturing, CO2 reduction and recycling. Other drivers are knowledge as a key enabler, quality, the use of pervasive ICT and digitalisation, not only in manufacturing, but also in products themselves. Overall there is a need to be faster, cheaper and better.

Manufacturing needs to be more flexible and demand needs to be predicted and anticipated. The results of interviews with SMEs has highlighted that there is a need to reduce integration overheads for ICT and provide mobile devices that are intuitive. There is also a need for traceability from cradle to grave through the supply chain. Monitoring, optimisation and predictive maintenance are seen as a key means to enhance availability and productivity. It has been noted that currently ICT solution providers are pushing technology at industry rather than there being user pull for new technologies. Manufacturing ICT has grown up over many years in an ad-hoc fashion to address problems that are encountered. Within factories the current situation is a "wild garden" of many diverse and unconnected disjoint systems that are not interoperable. There is also a perception that ICT is expensive and hence out of reach for many smaller companies. Increased connectivity also raises concerns over security and privacy. A key concern is that SMEs may miss the wave of digitalisation.

A wish list of solutions has been created highlighting the needs for real-time data acquisition and analysis, the use of Big data analysis for quality control, flexible production equipment and interconnections, and an engineering platform for the design/operations continuum. There is also a need for cognitive systems for decision support. A key challenge is to provide supply chain visibility and decision assistance.

Recommendations have been made which were incorporated into the EC work programme via an orientation paper. These were for scalable Cyber-Physical System architectures for adaptive and smart manufacturing, real-time data acquisition and analysis, network-centric communication and collaboration between players, humans and systems across the entire value chain, an ICT platform for advanced supply chain decision support and modelling of virtual enterprises. Several cross-cutting and non-functional challenges were also identified:

- Interoperability / Standards
- Semantic mechanisms
- Socio-technical issues
- Training and education
- Cyber security

A fuller analysis of the Road4FAME recommendations compared with the other roadmaps presented at the event is discussed in a later section. Overall it was noted that the future is much more interconnection between organisations which requires IT systems interoperability. Living labs are seen as useful to demonstrate the effectiveness of ICT implementations and also to address socio-technical issues. There is also a need for commitment from large industry to support platforms.

Pathfinder – The Roadmap for Simulation and Forecasting Technologies (Prof. Paolo Pedrazzoli, SUPSI)

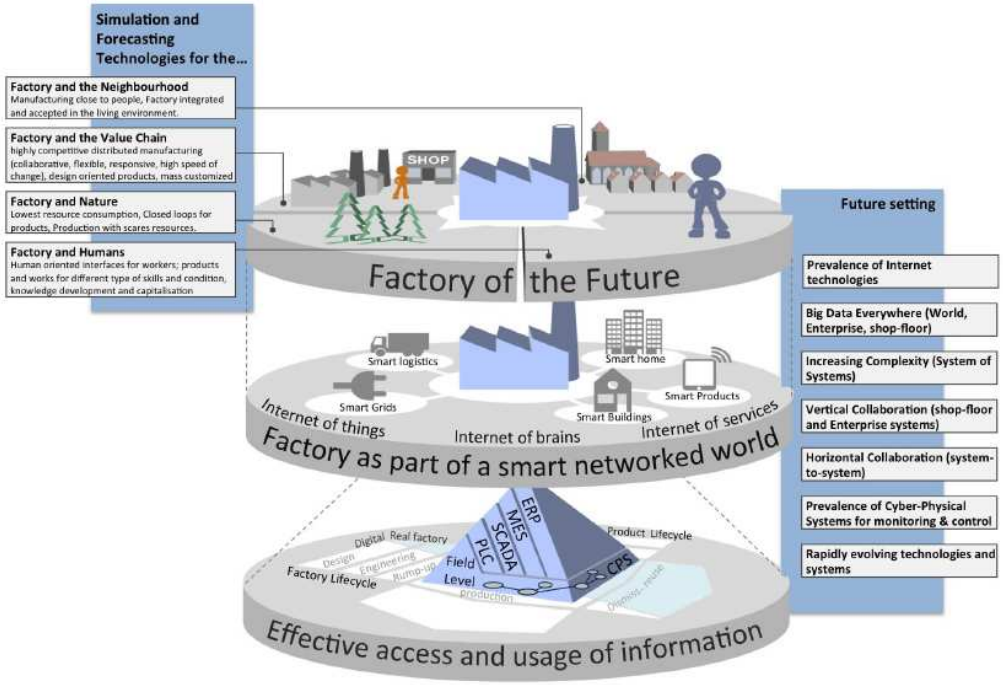

Fig. 3 PATHFINDER Vision

Paolo Pedrazzoli gave a presentation on the Pathfinder project. This highlighted that the wide spread use of ICT had resulted in major gains in productivity and that companies who had invested in this area are statistically the most productive. The PATHFINDER roadmap had adopted an approach looking at the trends in manufacturing and also the state of the market to identify gaps. Information from other roadmaps has also been considered such as the EFFRA roadmap and the Dutch Smart Industry Roadmap. The PATHFINDER vision for the future is based on three different layers (See Fig, 3). It was noted that the Factories of the Future roadmap highlighted the interaction between factories and humans, however, there is also a need for a lower level framework vision. A number of technologies are converging such as the Internet in manufacturing, CPS in manufacturing and also exploitation of Big Data. As a consequence there is a need to evolve from the traditional automation pyramid - shop floor, scada, and ERP levels, and look at the factory as part of the networked world. It was noted that Cyber-Physical Systems do not fit in with the traditional pyramid view of the world and cut across all the traditional levels. The PATHFINDER project has thus proposed a new manufacturing vision for the future as shown in Fig. 3 which integrates the layers together.

The challenges for the future are to provide digital continuity and scalability to deal with changes in dimension. There are also challenges for tool use and real world synchronisation. It was stressed that human interfaces are very important in the new digital world.

CPSoS – Roadmap (Prof. Haydn Thompson, THHINK Wireless Technologies Ltd.)

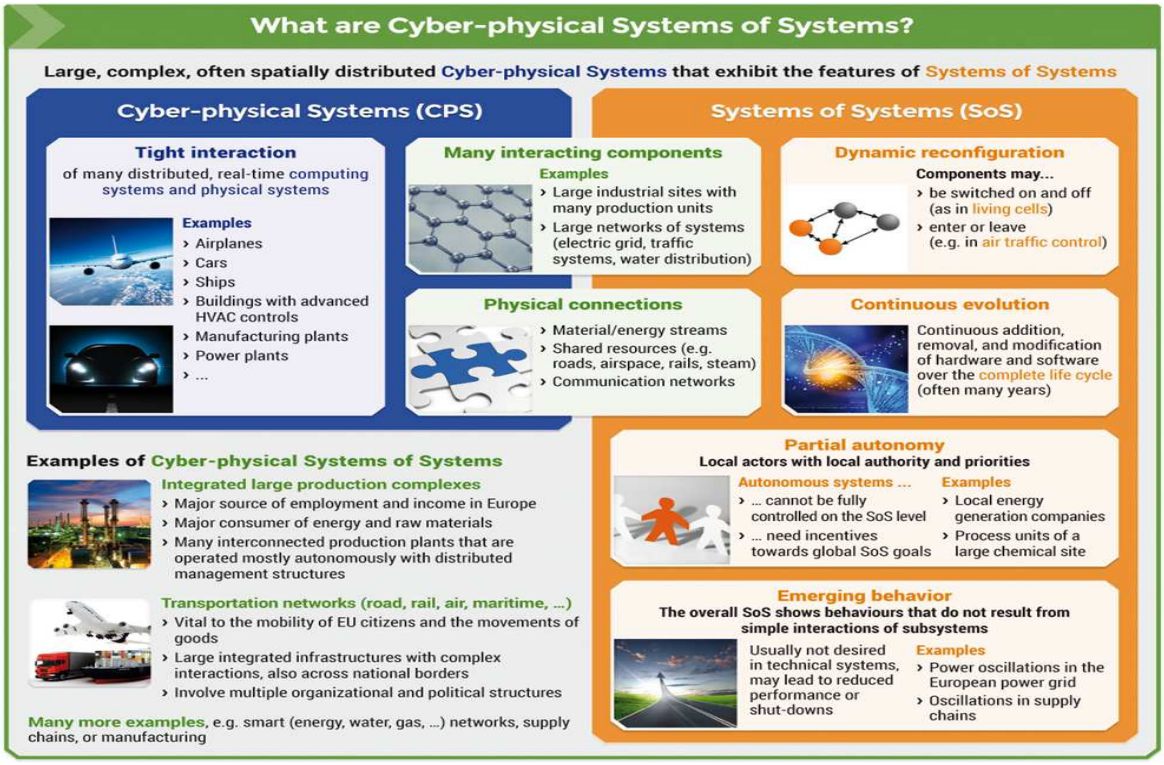

Fig. 4 Cyber-Physical Systems of Systems

The aim of the CPSoS project is to develop a roadmap for Cyber-Physical Systems of Systems as shown in Fig. 4. 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.

CPSoS brings together several different domains: systems and control, computer science, software and systems engineering, physics and also tool developers (simulation, verification, software engineering). A bottom up and top down approach has been used. 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 ben considered. This includes incorporation of new concepts from IoT, Big data, Industrie 4.0. From this important gaps in research have been identifed. A

number of examples were given from rail, traffic and automotive, air traffic control and marine, highlighting the drivers for increasing capacity, increased safety and the need for monitoring for fault detection and management. In all areas there is a move to increased optimisation for increased capacity, cost reduction and time efficiency, increased monitoring with sensors everywhere leading to Big data, increased communication between vehicles/assets and intelligent infrastructure, and increased automation/autonomy. Safety, security and trust are key concerns. Three key research areas have been identified.

Distributed, reliable and efficient management of cyber-physical systems of systems which considers decision structures and system architectures, self-organization, structure formation, emergent behaviour, real-time monitoring, exception handling, fault detection and mitigation of faults, adaptation and integration of new components, humans in the loop, collaborative decision making and trust in large distributed systems.

Cognitive cyber-physical systems of systems which includes situational awareness in large distributed systems with decentralized management, real-time handling of large amounts of data for performance monitoring and fault detection, good operation pattern learning, auto-reconfiguration, adaptation, analysis of user behaviour and detection of needs and anomalies.

Engineering support for the design-operation continuum of cyber-physical systems of systems. Here new design and validation and verification approaches are required for systems that are "never finished" as they are continuously evolving removing the separation between the engineering/design/operational stages. These systems have a high degree of heterogeneity, utilise partial autonomy, are highly flexible, are subject to frequent, dynamic reconfiguration and failures, abnormal states, and unexpected/emerging behaviours as the norm. Design support tools are required to enable efficient engineering.

Finally, it was noted that CPSoS are socio-technical systems in which machines and humans interact closely and so the human-in-the-loop is extremely important. A consultation document has been produced www.cpsos.eu/public-consultation/ and input for this is being sought.

Short Project Presentations

The IoT/CPS Big Data Challenge (Stamatis Karnouskos, SAP)

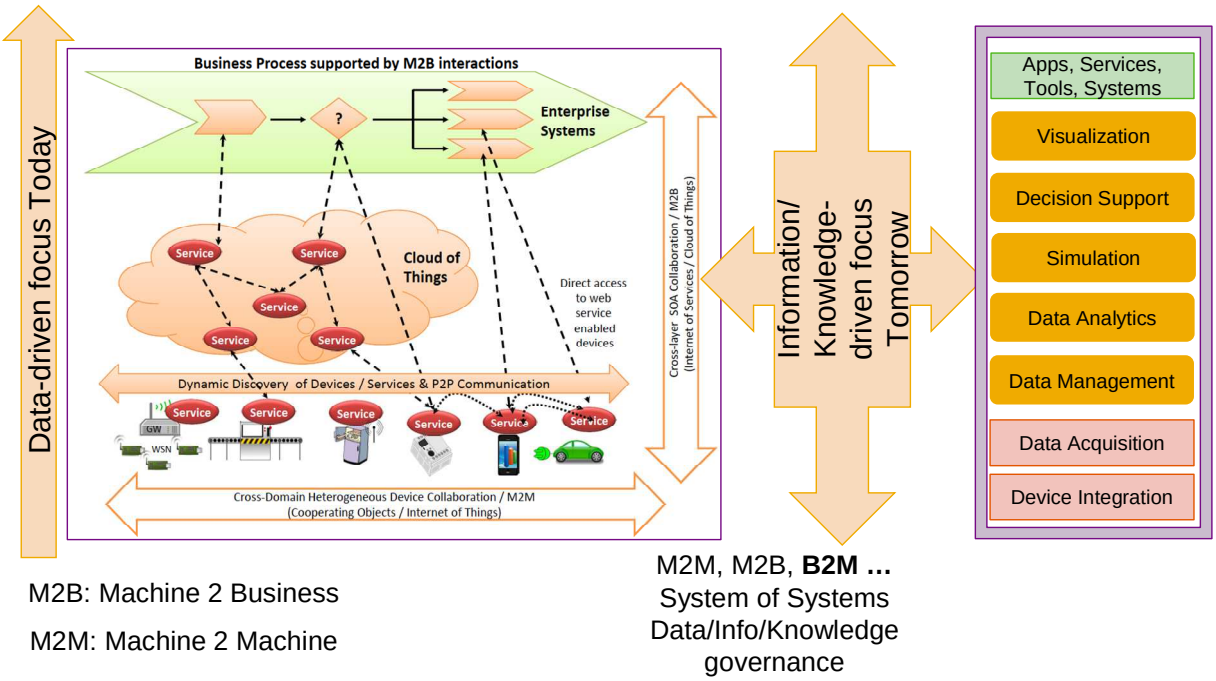

Fig. 5 From CPS/IoT towards Information/Knowledge-driven interaction & collaboration

It was highlighted that data acquisition is becoming easier and far more fine grained with the introduction of low cost sensors, interoperable interactions among cyber-physical systems and digitalization of processes & interactions. It is now possible to provide data in real time and perform machine to business integration as shown in Fig.5. The key goal is to be able to monitor the real world and understand what is going on and from this gain new insights and take better decisions. There is already a lot of work being performed on analysing large amounts of data e.g. in smart cities, factories, etc. however, how these are analyzed and managed in large-scale systems of systems applications is still work in progress. The current goal is to automate this process (data acquisition, analysis, decision-making, enforcement etc.) and optimise it for the infrastructure that is being used. At present most of the effort is being concentrated on developing devices, integrating them with systems and storing information but in the future the challenges of how to fully capitalize from a service based eco-system needs to be considered. It is now possible to collect a lot more interesting data from systems, however, there is a need for supporting decision-making and risk analysis processes, including the

appropriate visualisation tools and techniques to understand this (also by non-experts) and integrate it effectively in other applications and services.

A problem at present is that data silos exist (in systems, companies, domains). Data in one domain is optimised for capturing & processing in that domain and hence it largely cannot be used in other domains (or is prohibited of doing so by technical, business, regulatory measures). This means that it is not currently possible to take advantage of this data across silos e.g. in a cross-domain setting such as a smart city. It is very important to understand the full value chain and the potential for vertical as well as horizontal interactions in large cyber-physical ecosystems. Here there is an opportunity to use data to enhance decision making processes and optimize infrastructures and processes. Work in this area is still at an early stage and there are a number of issues that need to be considered such as security, privacy, trust and data life-cycle management. A key question is "how to benefit from the data and also where to focus activities in the coming years?" Much of the current research work focuses on complex analytics for historical data, but there is a need to think differently and use data (including real-time data) to get new insights into the processes and systems. A key problem that needs addressing is how to make the tools and techniques available also to non-experts. There is a need to understand and capitalise on Big Data to understand the complex behaviour of systems of systems and also emergent behaviour. Rapid advances in technology make possible today things that were very difficult or practically impossible to realize 5 years ago. More work is needed, however, on how to derive knowledge from data. It was noted that the focus today is mostly data and their visualization, considering a bottom up approach but in the future there is a need to also consider horizontal integration, and, as shown in Fig. 1, how we can derive new knowledge from both horizontal and vertical foci in the interactions among cyber-physical systems, services, and complex infrastructures and their stakeholders.

Product-Service Innovation in Manufacturing: a Digital Revolution? (Sergio Gusmeroli, TXT e-solutions SpA)

Fig. 6 The SMILE Challenge

Sergio Gusmeroli highlighted that manufacturing was very important for Europe's economy, however, in recent years it has been in decline. There is a need to concentrate on the high added value activities and here the major change was a move towards product service innovation in manufacturing and service innovation in general across industry. It was noted that there is a dichotomy between value added and employment and looking at the trend in recent years the value added has been stable or increasing in industry. The SMILE Challenge Europe, as shown in Fig. 6, is an initiative focused on promoting high value added activities. From this it can be seen that value creation in manufacturing is shifting towards pre-production (R&D and design) and post production (marketing and pre-or-after sales services) activities. It is now quite common for companies to gain substantial parts of their revenues from services. This trend towards providing services is also happening in US. Here only 17.2% of effort is now concentrated on physical assembly manufacturing. There is thus a change in the industry towards an increase in service jobs. To support this change there is a need for a Manufacturing Service Ecosystem (MSE). Currently, a concern is that every service innovation project is performed in isolation and so the experiences gained are not being exploited.

It was noted that manufacturing companies cannot address the servitisation challenge alone. TXT e-solutions had looked at 4 use cases, in textiles, TVs, Indesit washing machines and BARMIA. An experiment had been performed by adding technology to an old washing machine to provide more services for a consumer. Following this the company had introduced a new line

of products with updateable software that allowed the company to provide new washing cycles that could be tailored to customer needs (e.g. for a garage worker who needs to wash oily clothes every day). By exploiting technology a range of services can be created for different stages of the life cycle of a product. Under the Factories of the Future Product Services, Objective 5, new projects have been funded creating a community in this area.

Smaller Devices, Bigger Challenges (Dr Wouter Haerick, Ghent University)

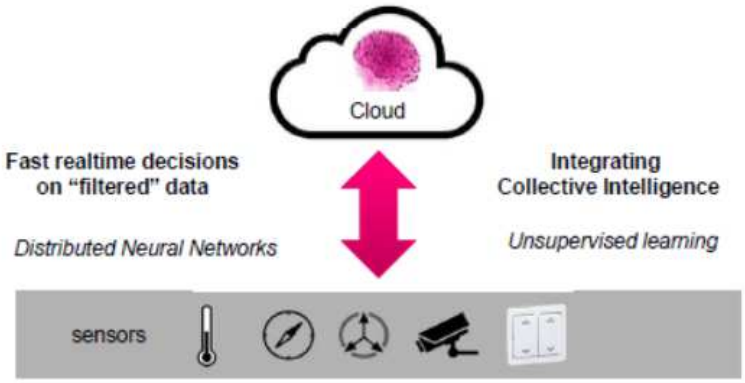

Fig. 7 Vision of Cloud Connected Sensors

Wouter Haerick highlighted a number of examples of how embedded intelligence and connectivity to increasing compute power can add value to products. An example was given of a toy that exploits IBM Watson computers that is adaptive to the child who plays with it. This could be used to help children to learn. It was noted that the future will be small sensors and actuators interconnected to big infrastructures generating Big data with external computing power providing functionality as shown in Fig. 7. Configurability and plug-and-play devices will be important as connectivity will be a key driver for the future. Reliable connectivity is also required. It was noted that the predictions are that by 2025 is should be possible for Big data analytics to have the intelligence of the brain. To enable access to this though it is necessary to make things configurable at orders of magnitude lower cost. It was highlighted how technology has improved in this respect over the years. In the 1980's peripherals had to be configured manually and plugging in wireless devices and getting them to work was difficult. The current situation is much improved but in future it is necessary to work out how to install and configure sensors and make them discoverable for services at higher levels. Currently, manufacturers lose productivity when installing new equipment and also during maintenance when updating drivers.

Looking to the future there is also a requirement to be able to connect things reliably in a dense wireless environment particularly for critical processes. iMinds is working on this within harsh environments. An example of high bandwidth wireless video was given for controlling manufacturing robots. The use of wireless technologies avoids cable defects but introduces

other wireless reliability issues that need to be solved. Here gigabits/s transfer of video is required to allow for real-time control. Presently this is not possible, however, research is being performed in a project called the “cube”. The aim of this is to try and run 100 wireless devices collocated in 1 cubic metre without wireless collisions. In the longer term the idea is to provide Cloud intelligence from interconnection of small devices for fast real-time decisions. For this there is a need to work with filtered data using distributed neural networks with unsupervised learning to identify patterns.

ICT for Manufacturing and in Particular the Role of IoT/CPS (Prof. Marco Taisch, Politecnico di Milano)

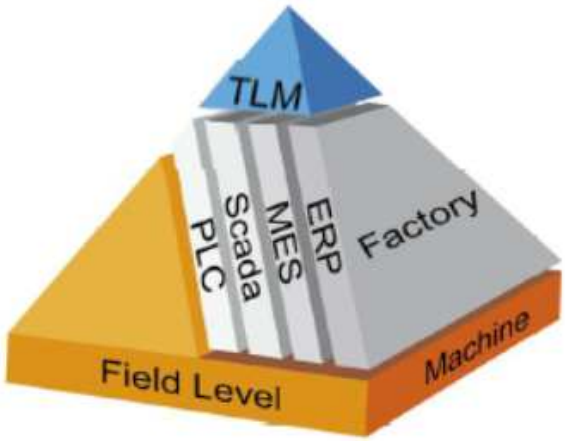

Fig. 8 sCorPiuS Evolution of the Automation Pyramid

Marco Taisch highlighted that SMEs and midcaps are the backbone of European manufacturing, however, it is difficult for SMEs to access innovative ICT solutions. This is mostly due to lack of awareness and knowledge but also because SMEs are not able to pull innovation from the market. A challenge is that there is a very strong offer of cheap IT services from outside of Europe from Google/Amazon/Facebook/Apple (GAFA) which are all US led. There are also barriers which need addressing. It was noted that 26% of cyber-attacks are on manufacturing companies so security is a key concern.

It was highlighted that there was a move from Manufacturing Execution Systems to a Manufacturing Operating System that provides a “manufacturing service bus” for connecting systems together. The newly funded SCorPiuS project was introduced which is looking at developing a roadmap for Cyber-Physical Systems in manufacturing. This is linked to the evolution of the automation pyramid but the work wants to go beyond this to Total Life Cycle Management (TLM). It was noted that the Cyber-Physical Systems research community is an integral part of manufacturing as well as being customers for its products. Fundamentally the skills lifecycle also needs to be addressed to better educate factory workers for the future.

Innovation Support for CPS, IoT, Industrie 4.0

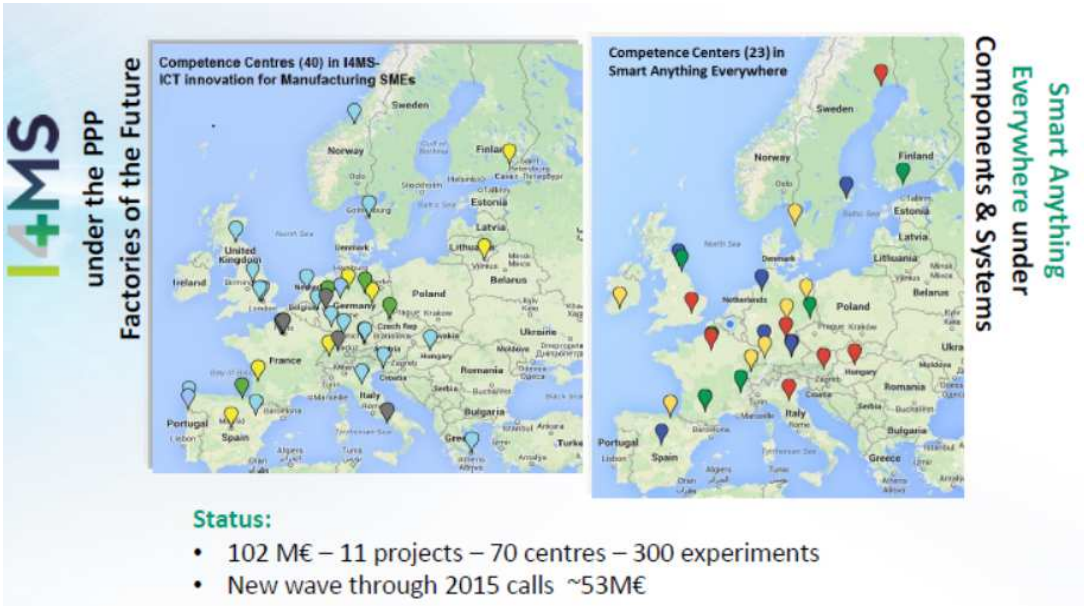

Fig. 9 EC Funded Europe-wide Competence Centres under I4MS and Smart Anything Everywhere Initiatives

As highlighted by Max Lemke one action line of the EC is to engage with industry (and SME's in particular) at a regional level. To support this transfer of knowledge competence centres are being funded around Europe. Fig. 9 shows the competence centres currently being funded under I4MS which is specifically targeting manufacturing and also Smart Anything Everywhere which has funded two sister initiatives under ICT1, 4 projects overall in SAE: CPSELabs (6 design competence centres) and EuroCPS (9 design competence centres). Representatives of I4MS and CPSELabs gave presentations at the event. A new initiative AIOTI – the Alliance for the Internet of Things Innovation, also gave a presentation. This initiative is more open and does not provide funding but allows interested parties to join together and share knowledge and technology in the IoT area. Finally, a presentation was given by Industrie 4.0 Baden Württemberg which is a regional initiative in Germany building upon the German National Industrie 4.0 programme.

Smart Anything Everywhere Initiative / CPSELabs (Prof. John Fitzgerald, Newcastle University)

John Fitzgerald gave an overview of the new CPSE labs action which began in February 2015. This 36 month Innovation Action is one of two that has been funded under the smart anything everywhere initiative. CPSE is concentrating on early stage design trustworthiness. The aim is to develop a network of design centres and transition technology into the market place. Open calls are being made for experiments with the aim to spread best practice and learning between academia and industry at the regional level. A goal is to establish a marketplace for CPS engineering assets via the 6 design centres. Each centre has different competences based on different methods, tools and devices. This includes model based engineering and software, Internet of Things, robotics and engineering for dependability. It is possible to apply existing platforms to new applications or transfer tools and experience from one domain to another. There will be 3 rounds of open calls and Call 1 is currently open. An overview was then given of the CPS Lab at Newcastle which is investigating collaborative modelling, analysis of CPS and urban sustainability. Here urban data is being put into the Cloud and then algorithms are being run on it to extract useful information.

I4MS – ICT Innovation for Manufacturing SMEs (Silvia de la Maza, I4MS-Gate, Innovalia Association)

Silvia de la Maza highlighted that European SMEs have a big problem taking up ICT technologies. The aim of I4MS is to help SMEs by supporting technology suppliers. In particular, many small companies need a first client and need to be able to demonstrate how good quality their product is to potential customers. Additionally, there is also a need to promote future success from previous good experiences. Competence centres have been set up with capacities that can be provided to SMEs. Experiments are solicited via open calls which allow small consortiums of companies to get together. The projects are funded on a fast track and can be running within 3 months with typical projects lasting 1 year. The administration overhead for these is designed to be light so that the consortium can focus on their experiment to get a product. Facilities are available such as High Performance Computing time, laser assessment, etc. I4MS gate started in July 2013 and will continue throughout H2020. In the beginning 60 experiments were funded and 85 application experiments are currently being performed. This includes projects on HPC simulation, advanced lasers, robotics and intelligent features for manufacturing in the machine tool sector with 20MEuros in funding. There are 4 new research innovation projects covering topics including IoT and autonomous robotics. The success rate for proposals is 25%. Future planned activities include development of a cloudflow open call brokerage area/portal and engagement with social media. Notably most participants to I4MS are newcomers to EU projects.

AIOTI – Alliance for Internet of Things Innovation (Anna-Maria Fimin, European Commission)

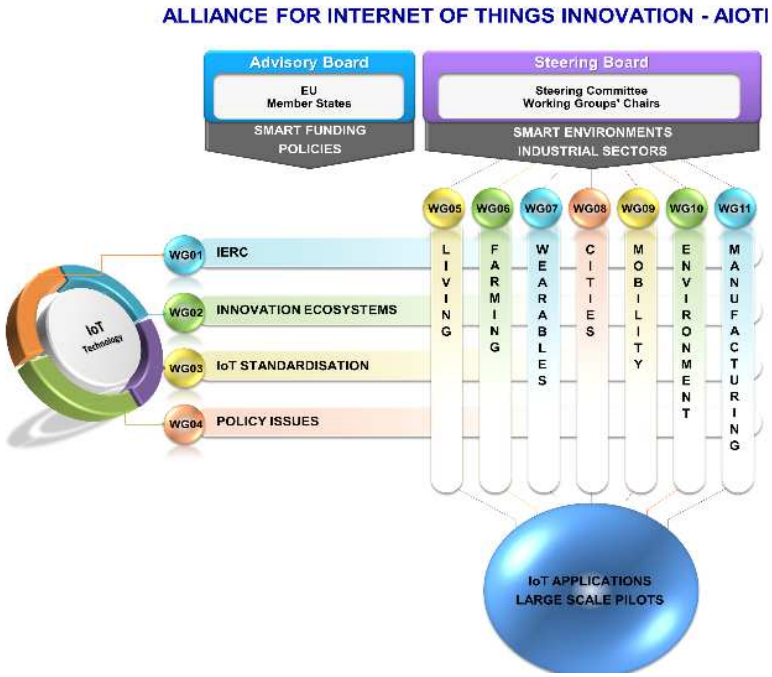

Fig. 10 Overview of Alliance for the Internet of Things Innovation

AIOTI, the Alliance for Internet of Things Innovation (See Fig. 10) is a European Commission initiative to give Europe a lead in the field of IoT. Currently the Internet of Things is emerging through vertical silos with work on wearables, smart cities, etc. However, to make the Internet of Things "happen" there is a need for cooperation as no single entity can provide all the elements of an IoT solution. A number of mission areas have been identified addressing market barriers, the IoT ecosystem, IoT update and Large scale Pilots. It is necessary to bring the actors together across the whole value chain. The calls for the 2016-2017 work programme will develop large scale pilots to bring the Internet of Things to a different scale in terms of experimentation and deployment. AIOTI is focused on a cross cutting context with a special link with EU institutions, building upon the IERC and results from previous research. It is easy to join the AIOTI however, it is necessary to provide resources to the community.

Allianz Industrie 4.0 BW (Prof Norbert Höptner)

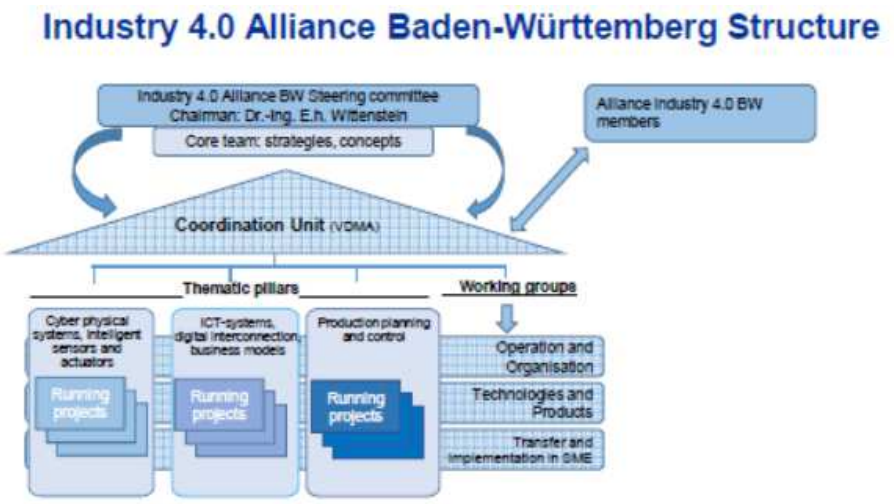

Fig. 11 Industrie 4.0 Baden Württemberg

Prof Norbert Höptner described the Industrie 4.0 in Baden Württemberg initiative as shown in Fig. 11. This was formed as it was realised that 8 out of the 14 members of the Industrie 4.0 National Platform came from the Baden Württemberg region. The aim of initiative is to support SMEs but also larger companies. It was noted that there are a lot of owner managed companies in the region that are not technically SMEs due to their size but are still operated in an SME style. A key question for the region is how to bring actors together. SME's are frightened of losing their unique company knowledge which is a core asset and differentiator, and they are also at risk of being bought by a larger company. Socio-economic activities are thus key. The aim of the initiative is to provide intensive networking between sectors and also between technologies. Technology transfer to SMEs will be based on best practice examples, via research projects and via creation of a competence atlas. It was noted that it is difficult in Germany to persuade a University Professor to work with a small company (there is a preference to work with larger well-known companies). Industrie 4.0 BW is being led by VDMA and three thematic pillars have been defined: CPS, ICT Oriented Systems, and Production Planning and Control. The core objective is to transfer technology to SMEs. Workshops and communication activities will be performed as well as social economic activities with a focus on engaging with employees. Work will also investigate computer assisted learning environments for realistic simulation of production processes and the development of ergonomic user interfaces.

Visions

A number of visions for the future were presented with industrial views from EFFRA and ARTEMIS, and also more general views of the future from key actors in the CPS and IoT communities. This led into a panel discussion which is described in a later section.

Factories of the Future (Chris Decubber, EFFRA)

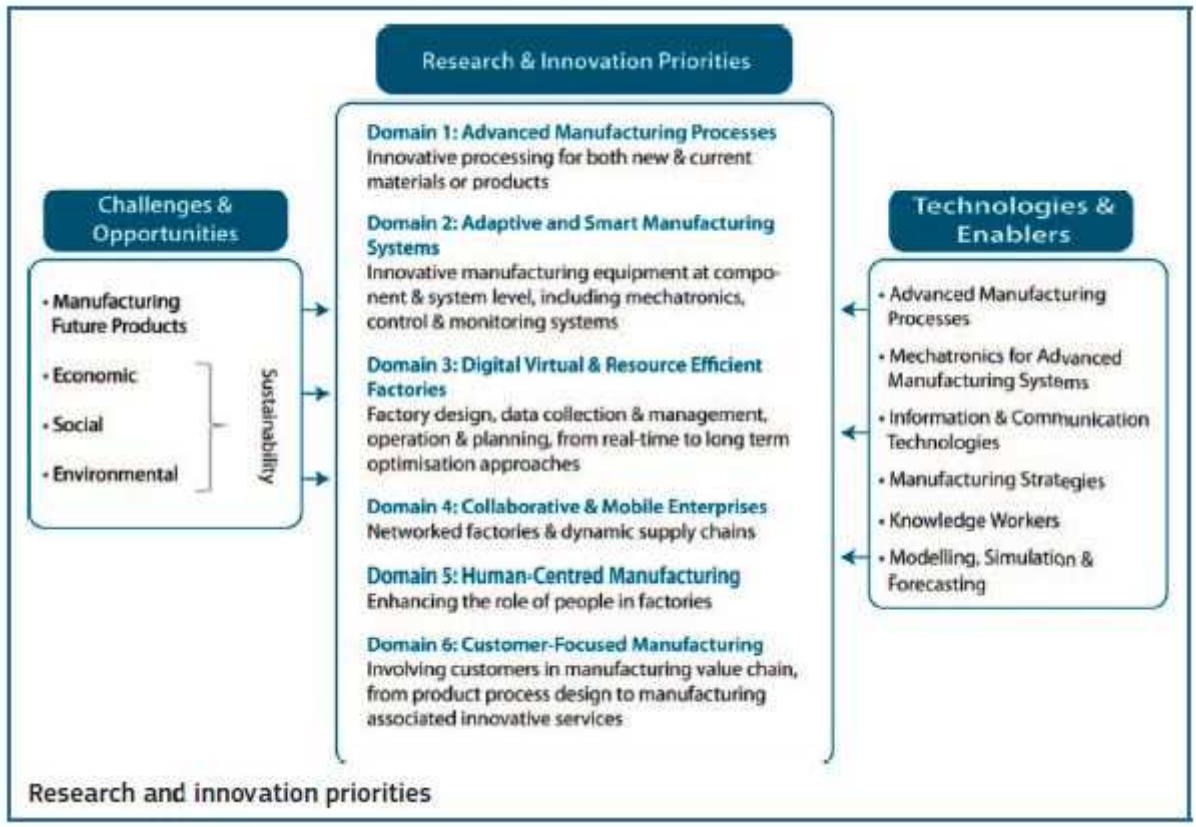

Fig. 12 EFFRA Roadmap Priorities

Chris Decubber gave an overview of EFFRA. It was highlighted that 180 projects had been launched already and a further 25 projects are planned. The initiative has been very successful and a number of projects were highlighted, e.g. ManMade, KAP, Plant Cockpit, etc. One project RLW Navigator was particularly cited as it had improved the quality of laser welding through the integration video processing. EFFRA have also produced a Factories of the Future roadmap (see Fig. 12). This highlights challenges, opportunities, technologies and enablers. Many

opportunities have been identified in materials handling through the supply chain. Other interesting areas are “digital twins” of the real world using a model and smart data. Here it was noted that this was not necessarily achieved by exploiting “Big data”. Open approaches (e.g. Open APIs) for integration are also important to migrate technologies to SMEs. It was highlighted that although presenting a vision is fine, the key thing is converting this into something that is meaningful for SMEs.

Internet of Things (José Gato Luis, ATOS Spain SA)

Fig. 13 Sensors as URLS

ATOS presented their IoT Vision and ambitions. It was noted that they are currently participating in 10 research projects working on hardware and protocols. Cloud computing is a major driver and work is investigating graphical interfaces with the concept of sensors being everywhere and everything being connected. It is predicted that 20 billion devices will be connected to the Internet by next year. There is a need for platforms and different worlds need to come together; the device people, cloud services, hardware and sensors. The ARI IoT platform was presented which has Open APIs to allow companies to create their own business applications. This combines Cloud services for integration purposes and smart gateways to provide connectivity and intelligence. The key objectives are to be easy to learn, easy to use and easy to integrate. In the future users may want to connect a laptop to a T-shirt, etc. The solution needs to be simple, common, lightweight and standard. The approach being adopted by ATOS is to use simple Internet URLS as shown in Fig. 13. The advantage of this is that a simple URL can be used to retrieve a small piece of data. This can be done via an IoT hub. The major challenge is in resource management and deployment of systems with millions of devices. To support this there is a need for rules for collaboration, e.g. to provide privacy.

Cyber-Physical Systems, Research and Innovation Challenges (*Prof. Manfred Broy, Technical University of Munich)*

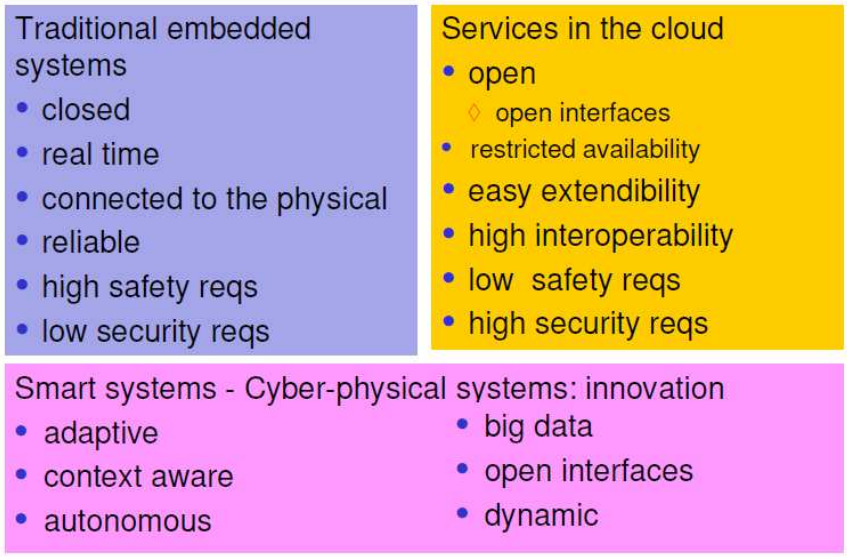

Fig. 14 Differences between Embedded Systems, Cloud Services and Smart Systems

Manfred Broy highlighted that the concept of Cyber-Physical Systems with connectivity, physicality and autonomy started off 6 or 7 years ago. CPS brings together embedded systems, telecommunications, IT infrastructure, software, the Internet, the World Wide Web and the Cloud to create a cyber-physical system. However, a scientific basis is needed in engineering to put everything together. The areas of embedded systems and Internet are coming together and there is an evolution of embedded systems to Cyber-Physical Systems as shown in Fig. 14. Looking to the future there are activities on the Future Internet and there is a lot of activity in Cloud Services. With IPv6 a lot of Internet addresses are available. 128 bit addressing offers 10^{30} addresses which is more than 10^{20} IP addresses per head of mankind. Thus there is scope for enormous connectivity. There are differences between the worlds:

- Traditionally the world of embedded systems offers closed, real-time, reliable systems with operational safety and security.
- Services in the Cloud are driven by open interfaces, restricted availability, easy extendibility, high interoperability, low safety requirements and high security requirements.
- Smart systems are adaptive, context aware, autonomous, exploit big data, have open interfaces and are dynamic.

It must always be remembered that there is a human in the loop so human factors, physicality and real-world awareness are important. Real-world awareness requires support from lots of

sensors and actuators. There is a need for mobility platforms and fusion between the digital and real world. A key problem is that there are not enough platforms being developed in Europe. Companies like Amazon are very strong in this area. One thing that is not required is proprietary platforms. Service oriented architectures may be the future here. There are some fundamental needs. There is a need to change programming languages, a need to understand requirements engineering and a need to support the evolution of systems. For this new paradigms of engineering are needed for CPS. There is also a need for engineers to move from software to systems engineering using model based development. Systems need to be open, and to be cost effective, there is a need for adoption of product lines and families of systems.

It was noted that the real revolution going at the moment is in financial services. It was also highlighted that a fundamental difference between Europe and the US is that in America the companies are closer to their customers. Because of their large user community Apple can do an experiment in one day and improve products. This methodology for development cannot be replicated in the automotive sector. New developments here typically take 7 years. Fundamentally there is a need to encourage entrepreneurial thinking and to train future engineers in “integrated cyber mechanical systems”.

ARTEMIS Industry Association (Laila Gide, THALES)

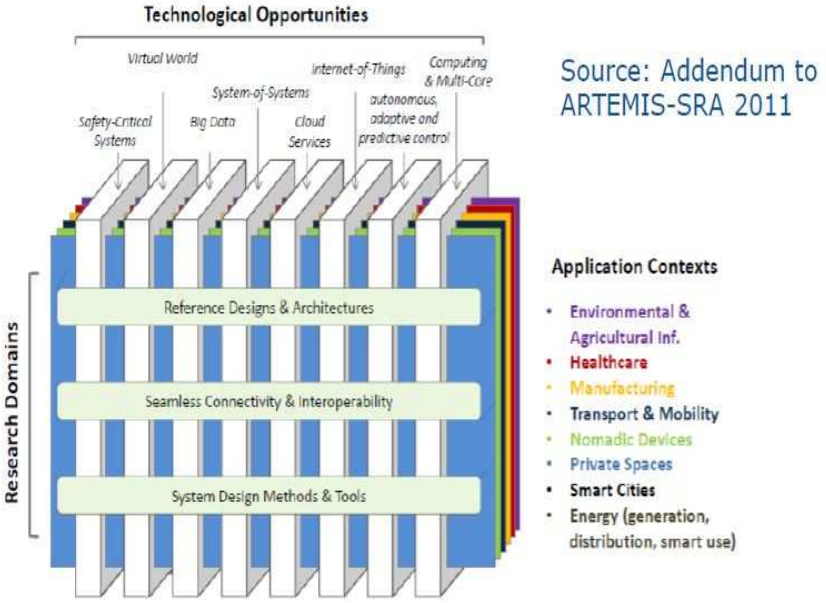

Fig. 15 ARTEMIS Strategic Research Agenda

The mission of ARTEMIS-IA is to promote and strengthen the competitiveness of industry in Europe. ARTEMIS is now a member of the new ECSEL joint undertaking. Looking across the industries supported by ARTMEMI-IA it has been noted that CPS is everywhere. Looking long term, aircraft will be piloted remotely, cars are becoming increasingly automated, etc., and there is a need to support these technological developments. A problem is that there are so many areas that need addressing and so there is a need to focus on key areas which are the most important. The objective of the Strategic Research Agenda (See Fig. 15) put forward by ARTEMIS-IA is to select key areas. 4 key drivers have been identified. These are:

- Mastering complexity
- Meeting the environmental challenge
- Competitiveness of Europe
- Cost efficiency

The aim is to build on Europe's leading position and also create new opportunities in Europe. The automotive, aeronautics, space and health sectors are key manufacturing sectors in Europe but the aim is to open new markets with high potential growth such as smart mobility, smart production, etc. The idea is to build a self-sustaining innovation environment and create an ecosystem around embedded systems. A Vision 2030 document was published which aligned research agendas. ARTEMIS has supported 56 projects in the areas of reliability, safety-critical systems, scalability, cost effectiveness, etc. There are three major innovation pilots: CRYSTAL, Arrowhead and EMC^2. A challenge for industry is that mechanics are melting with ICT and there is a move to digitalisation, connectivity, highly automated cars, aircraft, and production equipment. There is a need for Big data analysis and handling for remote diagnostics and for providing services. Humans are an integral part of this change and education and training are important. There is a move towards cooperation business models and also a move from "analogue biz" to "digital biz" models. Looking to the future hyperscalable business models like those found in the Internet world are interesting. A key overall aim is to boost value added by European Industry from 15% to 20%. In conclusion it was noted that the profile of future jobs will be different and so the workforce needs to change to meet this need.

Panel on Converging Visions for a Smarter World

A panel session was convened chaired by Prof. Haydn Thompson of THHINK with panellists Prof. Manfred Broy from the Technical University of Munich, Stamatis Karnousko from SAP, José Gato Luis from ATOS Spain, Laila Gide from THALES (and ARTEMIS), and Werner Steinhögl, DG Connect European Commission. The aim of this was to discuss converging visions for a smarter world.

Fig. 16 Hyperconnected Society Vision (Courtesy Silicon Labs.)

The panel was introduced by Haydn Thompson in a short presentation. It was highlighted that ICT is a having a profound effect on industry. It is important as a core technology in products, and as an infrastructural technology affecting the way offerings can be made available, and how (and where) networks of organisations can be configured. The ability to coordinate activity through collaborative, interactive, inter-organisational connections has never been greater. Current developments show some prospects for the near future. Cloud computing and widespread wireless networks will make it possible for organisations (manufacturers or service providers) to connect with each other and also potentially in future with "informated" products. Longer term, informated products will be able to connect with one another leading to new possibilities for data gathering and selling services.

The future is thus much higher levels of connectivity combined with increasingly smart elements leading to visions of smart cities, smart manufacturing (*Factories of the Future/FoF*), smart transportation, smart grid, indeed "smart everywhere". This has led to the concept of hyperconnectivity (See Fig. 16) with increasing digital interconnection of people – and things – anytime and anywhere. According to figures from Cisco by 2020 there will be 50 billion networked devices. This level of connectivity will have profound social, political and economic consequences for the future.

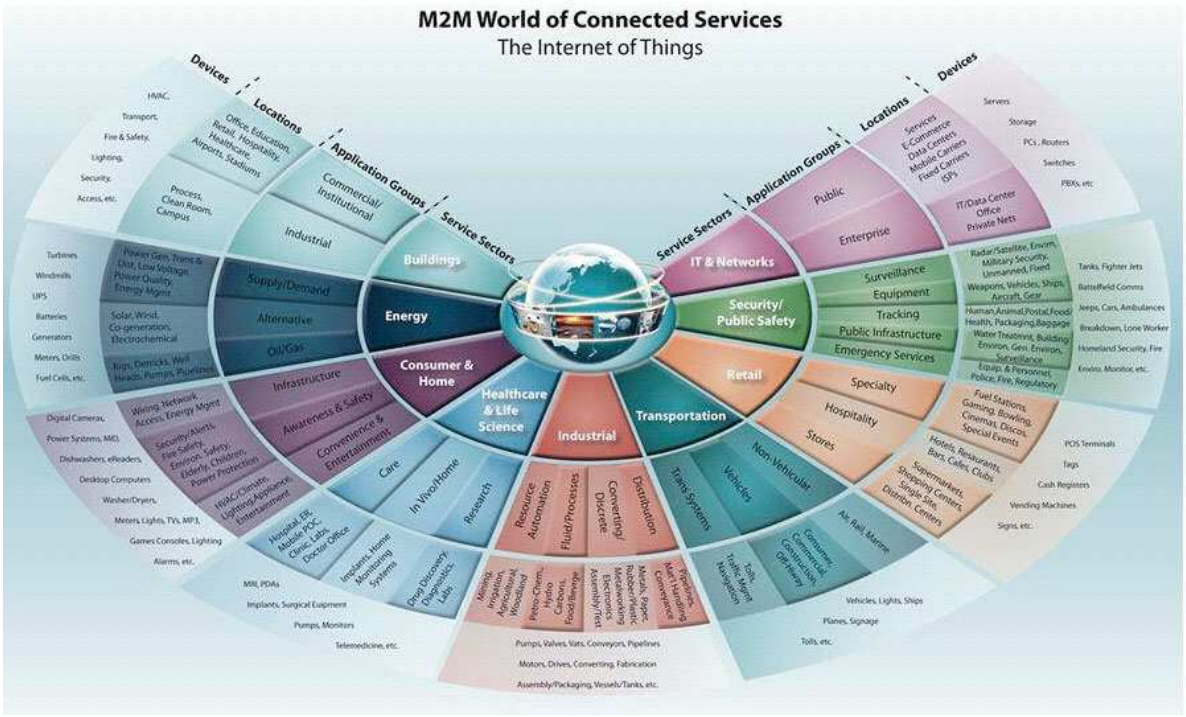

Fig. 17 M2M Connected World (Courtesy Beecham Research Ltd.)

The *Internet of Things (IoT)* is an essential element of the *hyper-connected society* vision. Here the Internet of Things, Cyber-Physical Systems (CPS), Cloud Computing and Big Data conjoin with the industrial world, for instance, in autonomous cars/in-car Internet. There is thus a need for different communities to come together to create new applications and services. This cuts across the value chain shown in Fig. 17 with at the lowest levels device manufacturers producing components, with application engineers and service providers producing applications and service software to support deployment. Of note is that implementation in different locations may result in different requirements. Privacy for instance is different when considering a person on the street, a hospital where medical information is sensitive and in manufacturing where data may be commercial and confidential. A blanket approach to privacy regulation may not be appropriate across different sectors.

The panel session discussed how the different visions coming from different communities, e.g. the IoT "best effort", the CPS safety critical and embedded systems communities, who have different needs and approaches to development, can be brought together to address the following questions:

- *What are the key differences and similarities in the different visions being presented by communities and where could the fields come together and cross-fertilize best?*
- *What do you see are the main opportunities for exploiting ICT technology in the future?*
- *What are the main new challenges EU industry is facing?*
- *What are the key barriers and enablers to adoption, e.g. regulation, standardisation, privacy, cyber security, education, legal framework, and are there areas which could be addressed?*
- *Who is best placed to address these barriers and how best can development be supported at a National/European/International level?*
- *A large proportion of the value chain is now being generated by non-European, non-manufacturing companies, e.g. Google etc... Will the development of European platforms create new opportunities for EU industrial growth?*
- *The manufacturing industry tends to be very conservative. Is there a need for education and raising awareness, and if so, what is the best mechanism to do this?*
- *A legal framework is being developed oriented towards the IT sector and internet solutions. Are there specific requirements for manufacturing IT support?*

In the discussion the panel noted that there was a convergence of visions as was evidenced in the presentations during the day. A challenge is that the mind sets of CPS and IoT are different. The IoT community are used to working with very fast development cycles with products being developed and put onto market within 5-7 months. In the CPS domain developments take a long time. In the automotive industry, for instance, it is not uncommon for a new idea to take 7 years to come through to market. It was noted that the IoT community also have a much more entrepreneurial mindset. This is something which is largely absent in the CPS domain.

The funding situation is also a concern. There is a fear of failure in Europe and young engineers need to be educated that failure is not a bad thing. In the US the approach to funding ideas is one of funding many ideas with the acceptance that only a few need to be successful in order to get a high return. There is also a much greater linkage between companies in places such as Silicon Valley and it is relatively easy for companies to come together and develop new ideas due to personal connections. The ease of gaining funding in the US was also highlighted as a key

advantage. It is much more difficult for small companies to get funding within Europe. The SBIR and venture capital funding mechanisms in the US can keep companies funded for many years while they develop products. It is not thought that the funding situation will change in Europe, however, the European Commission are specifically funding initiatives to try and encourage entrepreneurship.

Although there are many new exciting developments in ICT the acceptance of new technology by industry which is very conservative is a concern. European industry takes many years to accept a new concept. In the US there is a more progressive attitude and it takes 2-3 years to introduce a new technology. In China there is very much an approach of taking up new ideas and technology immediately. Here support for education and raising awareness of technologies is needed. The I4MS, CPSELabs, EuroCPS and AIOTI initiatives are seen as a positive move to support this.

There is a need for regulation but only where it is needed. Too much regulation can be a major barrier to developing new markets, however, if used correctly there can be successes. A blanket approach to privacy for instance may not be appropriate. The market should drive standardisation but here again care needs to be taken to prevent proprietary solutions being promoted. A key area where standardisation is needed is in the area of interoperability. Examples of successful standardisation are GSM which is used world-wide and AUTOSAR which has become standard across Europe in the automotive sector (and also in Japan and the US).

Many of the new ideas within industry come from servitisation and increased collaboration between companies. Here there is a need for a flexible approach to setting up Service Level Agreements between companies. An appropriate legal framework is required to support this. Liability is also a concern when introducing new systems such as autonomous systems (this is particularly an issue for the automotive industry at the moment) and a solution to this needs to be found.

Action is needed at the regional, national and European levels to raise awareness of ICT technologies, to SMEs in particular, but also to encourage uptake of new technologies so that Europe is not left behind. Here it was noted that there is considerable competition from the US GAFA platforms. Although competing platforms had been developed in Europe the history was that these were bought up by much larger US companies. The major players in Europe need to get together and develop platforms. An ecosystem of users also needs to be developed in order to sustain new platforms.

Concluding Remarks

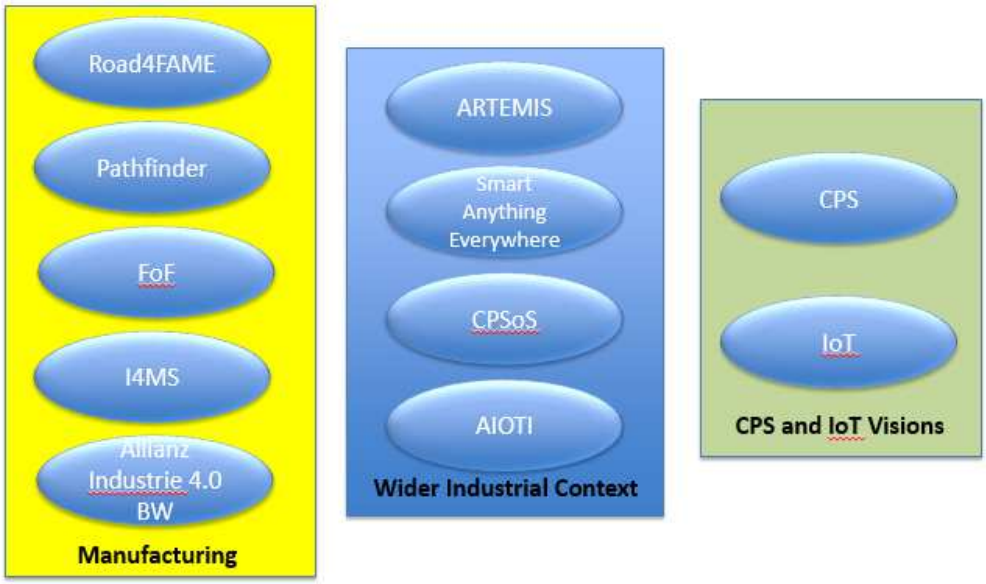

Fig. 18 Overview of Presentations at Road4FAME Consultation Event

The Road4FAME consultation event brought together a number of key roadmapping activities across Europe, the views of manufacturing organisations and also the CPS and IoT communities (See Fig. 18). The Road4FAME, Pathfinder, Factories of the Future, I4MS and Allianz Industrie 4.0 BW viewpoints all indicated that there is a need to engage with manufacturing companies, particularly at the SME level, to promote the digitisation of industry. These viewpoints give a glimpse of the future but also the current technology and policy gaps that need addressing. The wider industrial context of CPS and IoT was presented by the ARTEMIS-IA, Smart Anything Everywhere, CPSoS and AIOTI projects. These indicated horizontal activities driving CPS and IoT that also have great synergy with the work being undertaken in the manufacturing sector. The two visions of the future for CPS and IoT looked further ahead and in both cases the convergence of the two areas was highlighted. There will be a convergence of Internet of Things, Cyber-Physical Systems (CPS), Cloud Computing and Big Data within the industrial world to bring smartness and connectivity at all levels, not only within manufacturing, but also within future products.

A number of key messages were put forward by speakers and these resonate strongly with the Road4FAME roadmap and recommendations. In the table below these are summarised.

Speaker	Key Messages
Max Lemke	• Currently there is a Digital Transformation in industry driven by smart everywhere • There is a shift towards Product Services • Digital competence centres designed to bootstrap research and innovation to get over valley of death • There is a need for European Platform building • Reference models are needed for industry • We need to adapt the workforce for the future
Road4FAME	• A "wild garden" of ICT technology exists in industry • It is difficult for SMEs to adopt ICT • There is a need for traceability through the supply chain • ICT is seen as expensive by industry (especially SMEs) • Security and privacy are key concerns when considering Internet/Cloud connectivity • There is a need for real-time data acquisition and analysis for situational awareness • There is a need for flexible production equipment and support for design/operations continuum • Cognitive systems are required to help operators manage complexity • Supply chain visibility and decision assistance is needed • Interoperability and standards are required for integration • Sociotechnical issues are extremely important • Training and education is required to raise awareness for SMEs
PATHFINDER	• The interaction between factories and humans is extremely important • Exploitation of Internet and Big Data will have a big impact on factories • The factory is part of the networked world • The human interface is very important
CPSoS	• CPS offer increased optimisation for efficiency • There is need for increased capacity using existing infrastructure • There is a drive for cost reduction and time efficiency • Increased monitoring data acquisition is required for situational awareness • Automation and autonomy for managing complexity and efficiency • Safety, security and trust are key considerations • There is a need for real-time monitoring, flexibility, humans-in-the-loop decision making • Cognitive systems are required that provide situational awareness and automatic reconfiguration when required • Engineering support is required for the design/operations continuum • There is a need for dynamic reconfiguration • Design support tools are need for validation and verification • CPS are socio-technical systems
SAP	• There is a need to analyse large amounts of data to get better situational awareness • We need to avoid data silos and allow sharing of data across domains • Security and trust are key enablers • Data mining and pattern recognition are required

	• Tools need to be understandable by non-experts
PSYMBIOSIS	• The added value is now in pre-production, R&D and after sales services • Adding intelligence to products allows new services to be provided
iMinds	• Increased intelligence is being provided to products - this may be provided remotely in future via the Cloud giving sophisticated functionality • Need for interoperability and easy to configure systems • Need for reliable wireless connections in dense sensor environments
sCorPiuS	• It is difficult to get SMEs to use ICT solutions • There is a lack of awareness and knowledge of ICT • There is strong competition from US GAFA platforms • Security is key concern • Total life cycle management is the future and will change automation pyramid • Education is needed for factory workers
Competence centres (I4MS, CPSELabs, AIOTI and Ind4.0)	• Aim of competence centre sis to engage with SMEs • Short projects to provide expertise, access to equipment and perform experiments • Education highlighted as important
EFFRA	• ICT is everywhere in roadmap and CPS is a key feature • Need open APIs for integration • There is a need to migrate technologies to SMEs
ATOS	• The future is increased connectivity and link to Cloud services • The technology needs to be easy to use and easy to integrate • Privacy is important
Manfred Broy	• CPS and IoT merging • The human-in-the-loop is important • Real world awareness using lots of sensors is important • There is a need new paradigms for CPS, as well as programming languages, and developments in requirements engineering • Fundamentally there is a need to encourage entrepreneurial thinking and to train future engineers in “integrated cyber mechanical systems”.
ARTEMIS	• There is a need to master complexity and meet the environmental challenge • An aim is to open new markets with high potential growth such as smart mobility, and smart production • Big data analysis/handling is important for remote diagnostics and for providing services • Humans are an integral part of the system and education and training are important. • There is a move towards cooperation business models and from “analogue biz” to “digital biz” models. • The profile of future jobs will be different and so the workforce needs to change to meet this need.

Table 1 Projects/Speakers and Key Messages

Confirmation of Road4FAME Key Recommendations

The overall recommendations that are made in the Road4FAME roadmap were confirmed by the meeting. Below is a brief summary of the recommendations and confirming statements.

Integration

Integration approaches for existing ICT systems and information (tackling the "wild garden") - A number of speakers highlighted the difficulties of interconnecting systems and the difficulties of transferring new technologies into industry (particularly SMEs). Interoperability is seen as key to addressing this problem. It was shown that the future will be much more "connected" moving factories, away from traditional MES systems and the automation pyramid, to new more pervasive CPS architectures connected to the Internet linking both the shop floor and factories together.

Integration of new smart components (e.g. new improved low cost, miniaturised sensors) for data collection, analysis and visualisation – This was highlighted in a number presentations and indeed is also highlighted in the CPSoS roadmap. Although integration has got easier over the years there is a still a need for low cost configurable plug-and-play devices. A simple approach to addressing devices and managing them is required. Looking long term the ability to connect sensors and actuators to the Cloud will allow very sophisticated management and control systems.

Development/promotion of standardisation and reference ICT architectures as well as interoperability and harmonization of different interfaces - The need for reference architectures in manufacturing was highlighted by Max Lemke of the EC, however, here industry needs to agree on where they want to work together. Interoperability is a key requirement for integrating systems and the need for standardisation was highlighted in a number of presentations.

Data and Information

Big Data capture (live streaming for situational awareness), storage (event driven databases) and analysis (data mining – ideally in real time) – Situational awareness was noted as a key requirement by a number of speakers and is also a key recommendation made in the CPSoS roadmap. Data mining and pattern analysis is seen as a way of helping factory operators and manager's deal with and master complexity as expounded by ARTEMIS. It was noted by SAP that analysis tools must be useable by non-experts.

Distributed processing algorithms for data and systems in real time supported by resilient "industrial strength" cloud computing for the plant floor – Several speakers spoke about connecting factory floor equipment, sensors and actuators to the Cloud. A key barrier at the

moment are concerns over security and privacy and this issue was highlighted by a number of speakers. It is thought that the solution to this requires a combination of both education and regulation.

Visualisation techniques and specifically context-aware responsive visualisation of data – Human interfaces were highlighted as very important and the need to support the "human in the loop" was noted by a number of speakers, PATHFINDER, CPSoS, EFFRA, etc. Providing information in a comprehensible way for non-experts is a goal as many tools that are developed are too complex to understand.

Decision support systems to reduce operator load – The world is getting more complex and systems are becoming increasingly automated. A number of speakers mentioned the need for cognitive systems to reduce operator load. The need for cognitive systems is one of the 3 key recommendations from CPSoS.

Unified engineering exchange of data considering provenance, accuracy, contextual awareness and semantic content of unstructured data – The need for trust and trustworthiness was mentioned by a number of speakers. Approaches to accessing and formatting data were highlighted by ATOS in their URL approach to accessing. The difficulties of connecting heterogeneous systems were highlighted by a number of speakers as a barrier to adoption.

Machine Learning and Adaptive Systems to Enable Flexible and Adaptive Manufacturing

Environments and infrastructures for machine learning, self-adapting and reconfigurable manufacturing – The need for flexible, reconfigurable and adaptive systems was mentioned as a need within CPS (and also the tools to support development of such systems). This is a key recommendation area of CPSoS and is also highlighted by EFFRA.

Intra-and inter- machine communication standards – The need for interoperability and also fast and easy plug-and-play for systems was highlighted as crucial for the future. This was highlighted as an issue for the short term in many presentations but also iMinds and ATOS highlighted that reliable, easy and simple to use interfaces will become more important in the future as complexity increases.

Human-centric adaptive interfaces to enhance usability – The need to provide the right sort of understandable interface (in particular not overly complex) was highlighted. The majority of speakers noted that the human-in-the-loop and sociotechnical issues are key. EFFRA specifically highlighted a number of projects being undertaken in this area. This really emphasized the fact that humans an integral part of the system.

Multidisciplinary Modelling

Modelling of factories, information modelling and work domain modelling of socio technological systems – It was noted that there is a need to move to model based engineering by Manfred Broy. The CPSoS roadmap also has modelling as one of its key themes. The EFFRA roadmap also highlights this issue. The ARTEMIS pilot projects addressing development of safety-critical systems are also adopting a model based approach. Information modelling and the use of Big data was highlighted as important by PATHFINDER and SAP. The sociotechnical issues were highlighted as being very important by nearly all the speakers.

Security and Privacy

Robust Machine-to-Machine (M2M) security protocols that guarantee operational safety and reliability –The need for reliable communications was highlighted by iMinds. Here it is noted that future wireless networks will become very dense transferring considerable information, e.g. video. The use of wireless as a transmission medium is seen as a means to reduce installation cost but also make the systems more reliable by removing wiring. Safety was mentioned but more specifically in the sense that large ARTEMIS pilot projects, e.g. CRYSTAL, are addressing this issue.

Affordable security for privacy, especially within manufacturing supply networks – A number of speakers raised the issues of security and privacy. This is seen as a key blocker at the moment to adopting more interconnectivity and particularly the Cloud. Here it is noted that already approaches exist, e.g. encryption, but there is a lack of awareness and so education is required. It was also noted that privacy means different things in different contexts. Privacy of data for an individual may be different to medical privacy or privacy for data in a factory. Care must be taken not to introduce blanket regulation that is not appropriate for a given domain.

Demonstrators & Education

To convince the conservative manufacturing sector of the cost/benefits of new ICT architectures and services – It was noted by many speakers that manufacturers, especially SMEs, are very conservative. The formation of the Competence Centres is seen as a very good approach to engage with SMEs and transfer technology and knowledge. Looking towards development of platforms there is a need for large scale pilots to demonstrate in a convincing context that new technologies provide business benefits.

Education initiatives and training materials to increase awareness – Education was highlighted by many speakers as a key need in order to educate/re-educate the work force to promote new skills. The change in where added value is delivered, as highlighted by TXT e-solutions, and the move towards product services, as highlighted by Max Lemke of the EC, requires a different profile of worker in the future. The need for new skills and education is a common theme across many roadmaps being put forward by EFFRA, ARTEMIS, CPSoS, PATHFINDER, etc.

Other Areas Highlighted

A number of other needs were also highlighted by the meeting. Market drivers towards customised products requires new levels of connection between the customer and manufacturing and flexibility within the manufacturing supply chain. Green thinking (& regulation) drives the circular economy which requires an ecosystem that supports recycling and re-manufacture. The move to product services means that ownership becomes decoupled from use of products leading to new ways for sharing products, providing value and generating revenue. The ability to associate information with products allows tracking from cradle-to-grave to gather data on sustainability or to provide personalised products. Here IT has an important role in tracking, measuring/analysing and billing.

There are needs for regulation (but only where necessary) and here the key areas where it may apply are in privacy, cyber security and in providing a legal framework for contracts between companies and also in dealing with liability.

It was noted that there is strong competition from US platforms and a need to bring together key actors at a European level. There was also a need to engage more with SMEs as they are the innovation power house of Europe. Education is required to encourage entrepreneurial thinking and to remove the fear of failure that exists in Europe. Supporting this, access to funding mechanisms is required that allows new ideas and technologies to flourish and become reality.

Finally, the overriding message was that it is always important to remember socio-technical issues as humans are an integral part of the systems/factories. They are the solution and also barrier to implementing change. Here education and training is required at all levels to give workers and managers a new skill set to make them more adaptive and open to future technology.

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