ICT Innovation for
The Factories of the Future

Report from the Workshop on
'ICT Innovation for the Factories of the Future'
held on 10\textsuperscript{th} July 2012 in Brussels, Belgium

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

This report presents the outcomes of a workshop held on July 10, 2012 to discuss ICT innovation in manufacturing in Factories of the Future (FoF). This workshop was part of two information days on research-based Public-Private-Partnerships (PPPs) addressing Factories of the Future (FoF), Energy Efficient Buildings and Green Cars held on July 9 and 10, 2012.

The workshop’s objectives were to:

- Update the constituency on the initial outcomes of road-mapping activities related to Horizon 2020 relevant to FoF;
- Broadly discuss the most important ICT-related research and innovation challenges in manufacturing;
- Identify enabling and innovative ICT relevant to the FoF initiative;
- Identify barriers to the integration and broad deployment of ICT in FoF;
- Assist the Commission in defining a strategic, technology-focused approach;
- Identify potential applications and their economic impact, especially in the manufacturing sector.

The manufacturing domain plays an important role in the European economy, accounting for 21% of the EU’s GDP and 20% of the EU’s employment [1]. The Factories of the Future initiative has been launched as part of the European Economic Recovery Plan, adopted in November 2008, to tackle the consequences of the global economic downturn. Although its initial focus was to restore growth and to boost competitiveness in a strategic sector, the Factories of the Future initiative faces tremendous structural and societal challenges in order for European producers to compete in global markets while maintaining their manufacturing activities in Europe. The anticipated technology shift towards more customised and higher-value products such as cars and aircraft and to more sustainable and green manufacturing will present many opportunities for economic growth and sustainable eco-friendly manufacturing.

The new advanced manufacturing systems will need substantial public and private investment. They will also place significant demands on European education systems to provide a well trained and competent workforce.

ICT will clearly play an important part in re-shaping European manufacturing industry as electronic devices become more powerful, enabling new smart products, a range of mobile devices, and high-performance computing and advanced simulation for all sizes of company. In particular, digital manufacturing tools and technologies will enable manufacturers to innovate and design new products, to plan, model, and validate components, their assembly and their production systems whilst avoiding physical prototyping and reducing time to production. SMEs are the backbone of the manufacturing industry in Europe. Micro, small
and medium enterprises provide around 45% of the added-value due to manufacturing whilst providing around 59% of the EU’s employment in manufacturing [1]. SMEs will have a significant role in the area of digital manufacturing, not only by providing specialist services, but also through the new markets created by the need for specialist software tools to make full use of the expert knowledge of engineers and to support collaborative working. However, up to now, digital modelling and simulation tools have been mainly used for high-value products and production. The majority of SMEs have neither invested in nor gained experience of even basic digital manufacturing tools, thus missing a huge opportunity to improve their competitive position.

European policy makers need to propose new models by which SMEs can gain access to digital manufacturing and advanced ICT devices in order to increase their competitive edge and foster innovation. Whilst ICT will drive innovation in manufacturing, the economic downturn in 2009 has shown that manufacturing is a major consumer of ICT components and services and will continue to be a major consumer of IT-related services in the foreseeable future.

In this context, the Cloud has significant potential to enable innovation in manufacturing, increasing productivity and improving competitiveness, whilst reducing environmental impact. At the same time, the EU needs to make sure that a greater number of innovative SMEs will benefit from novel cloud services and infrastructure. Although SMEs are faster to innovate than large enterprises, they generally lack the skills to exploit fully the opportunities that digital manufacturing tools offer. The costs of the maintenance and upgrade of IT infrastructure and related training and SW licences that would be required to take full advantage of the latest digital tools and services is simply beyond the means of the majority of SMEs. It is clearly an important priority to address the benefits that SMEs could realise from novel, Cloud-based usage models and to tackle the skills’ deficiency in order to enable effective exploitation of the Cloud. What is needed is a one-stop, pay-per-use service where computing, software licensing and domain expertise are bundled together.

With respect to implementing future research policy, there is a clear requirement for innovative pilot actions that facilitate access digital manufacturing tools and high-performance computing platforms for SMEs. These actions should bring together the whole value chain from the SME to the domain specific expert to the Independent Software Vendor (ISV) to the Cloud provider in order to stimulate both the use of the Cloud by SMEs for simulation, modelling and forecasting and the provision of relevant services exploiting the Cloud’s capabilities to support innovation.
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Chp.1: Introduction

This report summarises the discussion at and conclusions of a half-day workshop held on the afternoon of July 10 at Commission premises in Brussels [2]. This workshop was part of two information days on research Public-Private-Partnerships (PPPs) addressing Factories of the Future (FoF), Energy Efficient Buildings and Green Cars held on July 9 and 10 [3]. The title of the workshop was “ICT Innovation for The Factories of the Future”. There were approximately 80-100 attendees including Commission staff. The workshop agenda is presented in Appendix A to this report.

The objectives of the workshop were to:

- Update the constituency on the initial outcomes of road-mapping activities related to Horizon 2020 relevant to FoF;
- Broadly discuss the most important ICT-related research and innovation challenges in manufacturing;
- Identify enabling and innovative ICT relevant to the FoF initiative;
- Identify barriers to the integration and broad deployment of ICT in FoF;
- Assist the Commission in defining a strategic, technology-focused approach;
- Identify potential applications and their economic impact, especially in the manufacturing sector.

The background to the workshop was the ICT theme of “Leadership in enabling and industrial technologies” in HORIZON 2020 which promotes:

- Robotic solutions
- Photonics and laser-based manufacturing
- Control, System-of-Systems and complex system engineering
- Advanced computing

A clear aim was to support the preparation of HORIZON 2020 through the development of the 2014 Work Programme and continued consultation with experts.

Further information relevant to this workshop is available at:

- cordis.europa.eu/fp7/ict/computing
- www.ec.europa.eu/research/horizon2020
Chp.2: Why is this important- Background, Trends, MegaTrends

Overview

In this section we will present the potential for the deployment of ICT in FoF and discuss the major trends and opportunities for innovation. Much of the information presented in this section comes from the ActionPlanT project (www.actionplant-project.eu) and from the European Factories of the Future Research Association (EFFRA, www.effra.eu) both of which gave presentations at the workshop. In particular, both are developing roadmaps (www.actionplant-project.eu/public/documents/roadmap.pdf and www.effra.eu/research-a-innovation/technology-roadmap.html) directly relevant to the discussion in this document.

The Factories of the Future PPP is a collaboration between the European Commission and European manufacturing industry to support the development of enabling technologies and to foster innovation and growth in the EU manufacturing sector. Highly relevant participation from industry has been achieved in past FoF Calls for Proposals, where, on average, industry represented more than 55% of the partners, and SMEs corresponded to about 29% of those partners [1]. A multi-annual Roadmap has been a key issue for defining the priorities of the long-term R&D programme, in the context of FP7 and also towards Horizon 2020.

These roadmaps depict the way forward for investing in key, enabling technologies for manufacturing. These technologies will enable innovative ideas to be turned into new products and services that create economic growth, high-skilled added-value jobs, and help address European and global societal challenges. A critical mass of stakeholders with a clear industrial commitment and leadership is required for the successful implementation of the Factories of the Future roadmap. This implementation goes beyond the capacity of individual Member States.

EFRA is launching a wide, stakeholder consultation for continuous development and validation [4] of its roadmap. A clear aim is to support the preparation of HORIZON 2020 Programme. By understanding the challenges and opportunities facing European manufacturers, it will be possible to determine those technological developments which industry most needs and so set the right research priorities.

ICT has been recognised as an enabling technology for innovation in product design and novel, agile production paradigms. However, past experience has shown that the manufacturing sector has been slow to adopt radically new ICT and the anticipated ICT revolution faces significant challenges in manufacturing when compared to other sectors. These challenges, outlined below, are set through a combination of market pull and technology push, which together will guide the definition of an industrially relevant research agenda.
Ec Workshop on ICT Innovation in Factories of the Future

Market pull

Firstly, we consider market pull based on trends in consumer demand and what European industry needs to do to address that demand. It should be noted that competition from the BRIC nations is growing and that the EU has been relatively slow to recover from the economic crisis. Furthermore, global competition is lowering barriers based on cost against quality, that is to say the difference in cost between high-quality and mass-market products is decreasing. There is a growing demand for low-volume, smarter, niche products from the younger generation and from the ageing population, which needs new products for assisted living.

Overall, the EU needs to manufacture better products, which have been developed and produced in better ways. In doing this, attention needs to be paid to economic, social and environmental sustainability. Relevant issues here include the continuing employment of a skilled workforce and the development of manufacturing techniques which minimise waste and which are highly efficient in the use of energy.

To respond to this market pull and global competition, EU manufacturing needs to be more agile using ICT to enable faster, more flexible production and design at a lower cost with easier and cheaper maintenance of capital equipment. Furthermore, it should be realised that innovation is driven by users as well as by suppliers and this needs to be reflected in the mapping of the technological developments industry needs and in the setting of research priorities.

Technology push

Secondly we consider technology push based on the development of innovative enabling technologies. The Cloud, with its inherent elasticity, low entry barriers particularly for SMEs, and support for the Internet of Things, mobility and the analysis of “big” data, will create opportunities for European industry and its competitors alike. Those who take the earliest and greatest advantage of what the Cloud enables will be those who gain the maximum benefits. New technological developments will be needed to enable this exploitation. However, although SMEs are faster to innovate than large enterprises, they generally lack the skills to exploit fully the opportunities the Cloud brings. It is clearly an important priority to address this skills’ deficiency in order to enable effective exploitation of the Cloud.

The Cloud is not the only technological innovation which enables more responsive and productive interaction between OEMs and their subcontractors. The proliferation of mobile and embedded devices will enable both new and more efficient businesses. There will be a paradigm shift from the “Intranet of Things” to the “Internet of Things”. Low-cost computing, connectivity, and data analysis and storage will be combined to enable more intelligent manufacturing. Together, these all suggest areas where new technology should be developed and enable industrially relevant research priorities to be set.
Areas for new technology

The areas where new ICT technology is needed include:

- “Big” data processing to enable more efficient and responsive manufacturing;
- Modelling, simulation and forecasting to develop better products and to enable them to be manufactured in a better way;
- Mechatronics where several disciplines including ICT and Control Engineering are combined to design and manufacture products and to address increased speed and precision in manufacturing;
- Continuous monitoring of the condition and performance of manufacturing systems at both the component and machine levels and the introduction of autonomous diagnosis capabilities and context-awareness.

These areas will be complemented by and interact with developments in other areas which include:

- Cognitive systems and robotics where intelligent components in machines will enable the deployment of safe, energy-efficient, accurate, flexible and reconfigurable production systems;
- Smart Spaces including novel ways and interfaces through which humans can interact with machines and large complex datasets (e.g. augmented and virtual reality). These developments will enable real-time assistance and training to workers allowing them to work on a larger variety of production facilities and providing assistance in the context of an ageing work force.
- Photonics-based materials-processing technologies and laser-based manufacturing;
- Shaping technologies such as forming and machining;
- High-productivity and “self-assembly” technologies, the further development of conventional processes (joining, forming, machining) and new micro and nano-manufacturing processes;
- Methods for handling of parts, metrology and inspection.
**Final remarks**

The EU needs a greater number of innovative SMEs to create growth and jobs. Strategic investments in key technologies (e.g. advanced manufacturing, micro-electronics) underpin innovation across existing and emerging sectors. In particular, the EU needs to attract more public and private investment to support research and innovation. Indeed, EFFRA has set out an ambitious target for public funding per year for the FoF PPP of which continuous support for ICT research is anticipated (~40% towards ICT research).

It should be note that consistent with the discussion above, the ICT theme of “Leadership in enabling and industrial technologies” in HORIZON2020 promotes:

- Robotic solutions
- Photonics – Laser-based manufacturing
- Control, System-of-Systems and Complex System engineering
- Advanced computing
Chp3. What –ICT-Innovation in FoF

The new ICT landscape and its impact on manufacturing

Previously diverse areas of computing, such as the embedded systems, sensor networks and control areas, the managerial services area, including logistics, data-centric computing and storage, and the engineering and scientific areas, involving simulation, modelling and forecasting, are rapidly converging to form a computing continuum, offering a range of services to industry, science, government and large and small enterprises alike.

In manufacturing, the focus will shift from static applications, for example in design or in factory automation, to more dynamic, lean and agile services based on real-time data from the “Internet of Things”. This paradigm shift will be supported by the proliferation of mobile devices and the easy availability of Cloud-based resources and services. It will impact not only on manufacturing, but also on science and society.

There will be significant economic opportunities for those who can take advantage of this ICT-enabled revolution. It will create new opportunities for innovative SMEs, which are more agile than larger organisations, and it will enable the manufacture of high-quality, low-volume, niche products addressing a range of existing and emerging markets.

The challenges ahead

Several challenges need to be tackled to take full advantage of these economic opportunities. These challenges include:

- Achieving adequate investment from both public and private sources to create the underpinning technologies needed to enable the ICT-driven FoF;
- Realising European leadership in enabling and industrial technologies;
- Fully exploiting the paradigm shift in computing;
- Creating an environment where innovative SMEs have access to simulation, modelling, forecasting and design services from one-stop shops;
- The realisation of a digital environment with “soft machines” producing digital products in digital factories powered by the Cloud as a precursor to manufacture in the real world;
- The realisation of highly automated physical manufacture supported by advanced mechatronics;
- The development of lean and agile applications underpinning adaptive and intelligent manufacturing systems;
- Realising economic, social and environmental sustainability

We will now consider each of these challenges.
Adequate investment
There needs to be significant investment in research and innovation from both public and private sources in order to exploit these developments in ICT. For example, the emergence of Cloud computing, which shifts computing costs from high levels of capital expenditure to an operational, pay-per-use tariff, reduces the barriers to the use of advanced simulation, modelling and forecasting by SMEs. However, an SME may not be able to afford the in-house domain expertise necessary to perform a particular simulation or indeed be aware that such simulations could benefit its business. What is needed is a one-stop, pay-per-use service where computing, software licensing and domain expertise are bundled together. The creation of such services will require investment and development from the different organisations involved in the value chain, such as the service provider, the Cloud provider and the software vendor. The development of such services and their underpinning technology should be a clear research priority. This need for investment is common to many of the necessary technologies underpinning the FoF.

European leadership in Enabling and Industrial Technologies under Horizon2020
The Commission has launched strategic priorities under its forthcoming framework programme for research, development and innovation, called Horizon 2020. Under priority 2, the EU should strive for leadership in enabling and industrial technologies (LEIT) amongst which ICT has a central role [5]. The importance of advanced computing, enabled via the convergence of technologies, has been identified within the action ICT in LEIT. To complement R&D actions, strategic investments in key technologies (e.g. advanced manufacturing, micro-electronics) will underpin innovation across existing and emerging sectors. Within the action ICT in LEIT, there needs to be a strategic, technology-focused approach addressing potential applications and their specific challenges from across several sectors. This will follow a different path from that taken in addressing societal challenges, which are demand-led and focus on different technologies, or the bottom-up approach adopted by the European Research Council.

The approach to ICT under LEIT will need to encompass

- A new generation of components and systems: engineering of advanced and smart embedded components and systems;
- Next generation computing: advanced computing systems and technologies;
- Future Internet: infrastructures, technologies and services;
- Content technologies and information management: ICT for digital content and creativity;
- Advanced interfaces and robots: robotics and smart spaces;
- Microelectronics, nanoelectronics and photonics.
Exploiting the paradigm shift in computing

New ICT-based systems will support data analytics and forecasting on-the-fly, leveraging cheaper storage and low-cost processing to provide better visualisation of and intelligence on the manufacturing process.

Enhanced connectivity enabled by the rapid developments in mobile devices will allow the embedding of sensors and controllers in a wide range of devices. There will be a shift from the “Intranet of Things” to the “Internet of Things” enabling real-world objects to communicate amongst themselves and with the digital systems of the “soft machines” described below.

All of these will draw on the convergence of computer systems, networking, storage and sensors to form a computing continuum. It will be those who exploit this continuum most effectively who will gain the maximum economic benefits.

Simulation, modelling, forecasting and design services for SMEs

Simulation has until now been predominantly used in the design of high-tech, high-value products such as aircraft and automobiles. The convergence of computing now offers the opportunity to use simulation to design and manufacture a wider range of products with improved quality, with greater ease of manufacture and at a lower cost and faster time to market. In particular, the availability of services via the Cloud will change manufacturing value chains and will enable SMEs to engage more effectively in the design and manufacture of a new range of niche products addressing new and wider markets.

Digital factories with “soft machines” producing digital products

The vision of the factory of the future is one where engineering becomes a digital environment with “soft machines” producing digital products in digital factories powered by the Cloud as a prelude to manufacture in the real world. Administration will move to this digital environment, monitoring a set of changeable individual workflows corresponding to different products. This environment will require well trained engineers equipped with appropriate tools and supported by effective ICT-based services. Such a scenario will depend heavily on the establishment of trust between the actors. Important issues to be addressed will be security, costs, bridging the gap between the digital and real worlds and the establishment of a light-touch bureaucracy.

Mechatronics in highly automated physical manufacturing

To complement the digital environment above, the physical manufacture of goods will be highly automated. It will deploy cognitive systems and robotics where control technologies will exploit increasing computational power and intelligence to address the need for increased speed and precision in manufacturing. Intelligent components in machines will enable the deployment of safe, energy-efficient, accurate, flexible and reconfigurable production systems.
Lean and agile applications

Lean and agile applications will underpin these adaptive and intelligent manufacturing systems which go beyond traditional shop-floor planning and execution. ICT is considered an enabler for collaborative manufacturing, ubiquitous connectivity and data access, mobility of workers and resources, and manufacturing intelligence during design and production cycles. ICT can play a fundamental role in meeting these challenges by enhancing end-to-end manufacturing processes starting from the shop-floor, via an integrated supply chain through to increased customer engagement. ICT has become increasingly intertwined with Factories of the Future by delivering efficiency gains through automation and the integration of diverse processes along the entire value chain.

These applications will be central to the FoF to enable the fast and flexible development required by the market, making full and immediate use of real-time data and the capabilities of mobile devices and sensors. The digital world will connect to the real world by integrating ICT resources into the physical fabric of the factory, enabling close monitoring and awareness of the physical processes involved in production. The FoF will involve high levels of machine-to-machine interaction supported by Cloud-based applications. Interaction with human operators will be via sophisticated user interfaces drawing heavily on advanced computing and artificial intelligence.

These lean and agile applications will support new products addressing many of the challenges society now faces such as ageing, individualism, urbanisation and the sustainable use of energy, resources and materials.

Economic, social and environmental sustainability

The challenge facing the EU is to lead in the manufacture of future products whilst retaining economic, social and environmental sustainability.

Economic sustainability means:

- Realising reconfigurable, adaptive and evolving factories capable of small-scale production in an economically viable way;
- High-performance production, combining flexibility, productivity and precision with zero defects while remaining energy-efficient;
- Effectively addressing the economic impact of efficient use of resources efficiency in manufacturing, including the end-of-life of products.

Social sustainability means:

- Providing meaningful employment;
- Creating safe and attractive workplaces;
- Addressing care and responsibility for employees and citizens along global supply chains.
Environmental sustainability means:

- Reducing the consumption of energy, while increasing the usage of renewable energy;
- Reducing the consumption of water and other natural resources;
- Near to zero emissions in manufacturing processes;
- Minimisation of waste in manufacturing processes.

The new methods of manufacture will need to make the most efficient use of resources. FoF will need to make highly efficient use of energy and produce the minimum amount of pollution and waste materials. By operating efficiently and competitively, the FoF will provide sustainable employment to a skilled workforce. This workforce will need to be well and appropriately trained, placing new, clear and continuously evolving demands on European education systems.

**Final remarks**

The anticipated revolution in manufacturing will present many opportunities for economic growth. It will also present the research community with many challenges. These challenges will be set through a combination of market pull and technology push, which together will identify an industrially relevant research agenda. The development of the necessary technologies and their implementation in the manufacture of new goods will require considerable research activity. The new advanced manufacturing systems will require substantial public and private investment. They will also place significant demands on European education systems to provide a well trained and competent workforce.
Chp4. Evidence – Impact

There is a growing recognition in the EU of the importance of manufacturing to create real wealth and employment. For the EU to manufacture competitively with respect to other nations, often those with low-cost economies, it needs to address issues including quality, productivity and design. The objective is for European industry to be able to make the best products in the best way with the shortest development times, using the least energy, making the best use of resources and minimising pollution and waste.

- Maintaining employment in Europe in times of economic difficulties

The manufacturing domain plays an important role in the European economy, accounting for 21% of the EU's GDP and 20% of the EU's jobs [1]. A higher investment in manufacturing is therefore central to maintaining European leadership in many manufacturing sectors and for increasing the competitiveness of our companies. Analysis following the financial crisis has shown that countries with a larger industrial base were less affected by the economic down-turn in 2009 and took less time to recover. In the meantime, tackling the peripheral problems of the financial crisis as well as resource shortage and mitigating the effects of climate change remain pressing challenges for the manufacturing sector, in particular.

- ICT driving innovation and growth in the manufacturing sector

The contribution of ICT to the manufacturing sector has become paramount over recent years. ICT is increasingly intertwined with critical manufacturing design and production processes and progressively more involved in developing efficient business processes. The WEF report [6] highlights the key role of ICT infrastructures and technologies in enabling ‘manufacturing to flourish and contribute to job growth’. ICT will clearly have an important role in the evolution of manufacturing as electronic devices become more powerful enabling new smart products, a range of mobile devices and gadgets, high-performance (as opposed to high-throughput) computing and advanced simulation, modelling and forecasting for all sizes of company.

A major impact is expected from ICT solutions if manufacturing industry can leverage progress in ICT which may radically re-shape traditional innovation cycles, re-structure production processes and existing value chains, and provide novel opportunities for innovation and growth. Manufacturers are also a main consumer of ICT. In 2009, manufacturers spent more on IT than any other industrial sector [Gartner 7]. In the future, it is evident that ICT will drive innovation in manufacturing and manufacturing will itself become a major consumer of ICT components and IT-related services.
• Closing the gap of ICT investment and ICT tool access for SMEs

SMEs are the backbone of the manufacturing industry in Europe. Micro, small and medium enterprises provide around 45% of the added-value due to manufacturing while they provide around 59% of employment in manufacturing. (Source: Eurostat, EFFRA).

The impact of making advanced and novel ICT available to SMEs will be maximised provided they have access to affordable and high-yield modern production technologies, and they exploit them rapidly to deliver innovative products at a competitive prices.

As large OEMs like Airbus and Boeing have looked to reduce costs and increase flexibility, a change in the value chain is occurring with the emergence of specialist SMEs who collaborate with larger organisations by contributing to their design, development and manufacturing processes. An example of this is in the automobile industry where headlight assemblies are often designed by specialist optical companies. The discussion at the workshop also highlighted the importance of regional clusters of expertise where the close proximity of SMEs to the large manufacturing companies, which they serve, is an important factor. Regional clustering will become even more important as manufacturing evolves. For example, the development of higher-productivity machines with lower defect rates needs to involve machine manufacturers, IT experts and domain engineers working together in close proximity. The EU should position itself to take advantage of this clustering effect building on its existing manufacturing strongholds.

Whilst SMEs are more agile than larger companies and can help reduce the time to market of new products, their very specialism means that they often lack the resources to exploit new technological developments. Simulation using the Cloud is a good example of this, where, rather than having in-house, domain-specific expertise and appropriate compute resources, an SME would prefer to deal with a one-stop shop providing the appropriate simulation service. Through the development of such innovative services, it should be possible to provide a tighter, more effective and more valuable integration of SMEs in the overall manufacturing value chain.

SMEs will have an important role in the cloud revolution, not only by providing specialist services, but also through the new markets created by the need for specialist software tools to make full use of the expert knowledge of engineers and to support collaborative working.
Chp.5: How -- A technology-based strategic approach

How can the EU take most advantage of these changes in the manufacturing paradigm? Which strategies will best enable this advantage to be realised? Clearly any strategy needs to be technology-based, because it is technology which is both enabling and driving the changes in manufacturing.

In view of Horizon 2020, the EC (Directorate A, unit A3) intends to develop a strategic technology-oriented approach built on the areas of complex systems, smart spaces, and advanced computing systems whilst using its funding instruments and resources most effectively[8]. The EC will specifically support Europe’s manufacturing sector in exploiting ICT to deliver innovative, high-quality products at competitive prices. The challenge facing the EU is to lead in the manufacture of future products whilst retaining economic, social and environmental sustainability.

The development of new, advanced manufacturing processes will involve multidisciplinary collaboration in areas including mechatronics, ICT, and simulation, modelling and forecasting. To support this collaboration an appropriate, secure, trusted IT infrastructure is needed at the regional scale, which can realise continental benefits by pooling of resources. Industry will need to make better use of trained engineers through improved productivity and reassignment from sales-led activities. There is a clear need to educate knowledge workers to address the demands of these new methods of manufacture. The teaching of such skills will need to become an integral part of the education system.

Based on the above discussion, the EU should build on its strengths by:

- Focusing on the most attractive design and production technologies and market sectors where ICT can make the difference;

- Focusing on radically novel ICT such as the Cloud, but importantly putting emphasis on its application to new production methods and products, so maintaining the manufacturing base in Europe and enabling the manufacturing of novel ICT-based products in sectors such as photonics.

- Research policy makers seeking a coherent, strategic programming approach across different research programmes and initiatives so as to exploit fully synergies across the different programmes and funding instruments. The goal should be to push R&D in enabling and industrial technologies in areas such as robotics, photonics, control and complex system engineering as well as advanced computing (under LEIT) complemented by measures to facilitate technology adoption and broad take-up in diversified industrial domains. LEIT in Horizon 2020 should ensure a synergistic approach to research programs combining efficiently the relevant PPPs (FoF, SPIRE, Photonis21 [9], EUROP2020 [10]) and JTIs (e.g. ARTEMIS [11]).
• Reinforcing the influence of manufacturing industry as an important user of ICT. Given that the manufacturing sector is one of the largest consumers of ICT, future initiatives should aim to pool resources within the manufacturing domain to drive standardisation and interoperability of ICT technologies and tools. Reference architectures and standards for cooperative (digital) Engineering with Cloud technologies are vital for an accelerated adoption and rapid promulgation of novel usage models for digital tools and technologies.

• Addressing support models to lower entrance barriers for manufacturing companies, especially SMEs by turning CAPEX into OPEX through the use of the Cloud for simulation, modelling and forecasting. This should involve support for the establishment of one-stop-shops making available Cloud-based services to SMEs across a range of domains;

• Investing in the IT infrastructure and promoting the regional clusters and competence centres needed to respond to global dynamics, through a reinforced integration of SMEs, to facilitate the adoption of innovative ICT component, devices and tools, and to pilot new models and tools for data mining, design, simulation and forecasting, for example by creating a virtual digital engineering centre. A tool repository of engineering applications would contribute to new paradigms in education, training, data visualisation, analysis and knowledge elicitation. This would involve the creation of an appropriate, secure, trusted IT infrastructure for engineering services capable of bringing together experts at the regional scale, but also enabling the realisation of EU-wide benefits through pooling of resources. It is essential to connect regional, national and European programmes to maximise the benefit for individual players and for Europe. Ideally, a network of competence centres should be developed using a combination of structural, regional and national research funds;

• Developing manufacturing skills drawing on partnerships with industry and the proposed EIT KIC on value-added manufacturing.
Chp.6: Conclusions

We stand on the verge of a revolution in manufacturing due to developments in ICT and other key technologies. This revolution will enable the manufacture of high-quality, low-volume, niche products addressing a range of existing and emerging markets, for example the ageing population, which will need new products for assisted living. There will be significant economic opportunities for those who can take advantage of this ICT-enabled revolution.

This comes at a time when the EU needs a greater number of innovative SMEs, which are more agile than larger organisations, to stimulate growth and employment. It also comes at a time when manufacturing in the EU faces strong competition from our traditional competitors and increasingly from the BRIC nations. To address this competition, the EU needs to produce better products which have been developed and manufactured in better ways. That is to say, European industry needs to be more agile, using ICT to enable faster, more flexible production at a lower cost with easier and cheaper maintenance of capital equipment.

Simulation, modelling and forecasting have until now been predominantly used in the design of high-tech, high-value products such as aircraft and automobiles. The convergence of computing in terms of processing, data storage and network bandwidth, now offers the opportunity to use simulation, modelling and forecasting to design and manufacture a wider range of products with improved quality, with greater ease of manufacture and at a lower cost and faster time to market. It will be those who exploit this computing continuum most effectively who will gain the maximum economic benefits. In particular, the availability of services via the Cloud will change value chains in manufacturing and will enable SMEs to engage more effectively in the design and manufacture of a new range of niche products addressing new and wider markets.

The emergence of Cloud computing, which shifts computing costs from high levels of capital expenditure to an operational, pay-per-use tariff, reduces the barriers to the use of advanced simulation, modelling and forecasting by SMEs. However, an SME may not be able to afford the in-house domain expertise necessary to perform that simulation, nor even be aware of the potential benefits to its business of such simulations. What is needed is a one-stop, pay-per-use service where computing, software licensing and domain expertise are bundled together. There is a clear need for innovative pilot actions bringing together the whole value chain from the SME to the domain specific expert to the ISV to the Cloud provider to stimulate both the use of simulation by SMEs and the provision of relevant services exploiting the capabilities of the Cloud.

Equally, there needs to be a fresh approach by industry towards creating new manufacturing services, operational excellence and the sustainable and efficient use of resources. This approach will make full use of innovative ICT technologies and tools and will draw heavily on
the convergence of computing and the availability of the Cloud and Cloud-based services. The full spectrum of RD&I instruments under HORIZON2020 should be used to support the integration of innovative ICT into manufacturing, particularly involving SMEs. The use of such instruments will need careful monitoring in order to maximise their relevance to the needs of European industry and its markets. This monitoring should complement the roadmapping activities of initiatives such as EFFRA and ActionPlanT in order to give informed advice to funding agencies, researchers and industry alike.

**References**

8. Support of research, development and innovation in Directorate A 'Components and Systems'; [http://www.eu-jordannet.eu/documents/connect_who_we_are_and_what_we_do.pdf](http://www.eu-jordannet.eu/documents/connect_who_we_are_and_what_we_do.pdf)


Appendix A:

Agenda for ICT-driven Innovation under FoF beyond 2013

14:00h Towards Horizon 2020
- Rainer Zimmermann, Head of Unit DG Connect/A3
- Erastos Filos, Coordinator FoF-ICT

14:30h European Roadmapping Activities:
- ICT Vision for the Factories of the Future
  Anirban Majumdar, SAP Research (D)
- ICT-related Challenges in the context of the EFFRA roadmap
  Zeljko Pazin, Executive Director EFFRA (B)
- Cloud Engineering for the Factories of the Future
  Engelbert Westkämper, Fraunhofer IPA (D)

15:30h Related ETPs, JTIs, PPPs: Short Messages
- EURON – EUROP21
  Geoff Pegman, . R U Robots Limited
- ARTEMIS
  Alun Forster, ARTEMIS JU
- Photonics21 N.N. ???
- ENIAC N.N. ???

16:00h Discussion: ICT-related research and innovation challenges in manufacturing 2014-2020
- Chair: Rainer Zimmermann, HoU DG Connect/A3

16:45h Conclusions & next steps
- Rapporteur: Francis Wray

17:00h Closing