20 January 2010

Factories of the Future PPP

Strategic Multi-annual Roadmap

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Factories of the Future PPP

Table of contents

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1. Introduction and Background

Introduction

The Factories of the Future Public-Private Partnership (FoF PPP), launched under the European Economic Recovery Plan, addresses the development of the next generation of production technologies that will be applied from 2015 onwards. The overall budget contribution to the initiative amounts to €1,200 million between 2010 and 2013, to be equally shared between the European Commission and the private sector.

This Strategic Multi-annual Roadmap has been prepared by the industrial representatives in the Ad-Hoc Industrial Advisory Group for the Factories of the Future Public-Private Partnership (AIAG FoF PPP), which was created in March 2009 with the goal to help define the research content of this initiative. The present document lays out industrial research priority areas for the implementation of the FoF PPP covering the period from 2010 to 2013.

The European Technology Platform on "Future Manufacturing Technologies" ('MANUFUTURE') has strongly supported this process, together with its national Manufuture platforms, working groups and sub-platforms, namely Agriculture Engineering Technologies ('AET'), Clean Environmental Technologies ('CET'), European Concept, Foot Wear including Sports, Micro Nano Manufacturing ('MINAM'), Rapid Manufacturing ('RM') and European Tooling, following in this way a cross-sectoral and cross-disciplinary approach.

The preparation of this document is also based on a wider stakeholders consultation, including the input from the European Technology Platforms on Advanced Engineering Materials and Technologies ('EuMat'), European Steel Technology Platform ('ESTEP'), Future Textiles and Clothing ('FTC'), Photonics21 ('Photonics'), Sustainable Chemistry (SusChem), Food for Life (FOOD), European Robotics Technology Platform ('EUROP'), Networked European Software and services Initiative (NESSI), European Platform on smart systems Integration ('EPoSS'), European Nanoelectronics Initiative Advisory Council ('ENIAC') and Advanced Research and Technology for Embedded Intelligence and Systems ('ARTEMIS').

The focus of this PPP initiative is to support collaborative research projects on innovative enabling technologies of multi-sectoral benefit and oriented towards industrial factory application. Therefore, the research priority areas also include industrially-relevant demonstration elements especially for the benefit of SMEs, which are important stakeholders because they represent the large majority (above 90%) of manufacturing enterprises in Europe. Increased demonstration activities are foreseen towards the end of the four-year period.

Project results are expected to be implemented as improvements in production processes shortly after the conclusion of the funded projects, with commercial solutions leading to wealth creation through a competitive market position and added value generation.

Background

This Strategic Multi-annual Roadmap for research and technological development in the field of manufacturing has been developed taking into consideration the main social, technological, environmental, economic, political and market drivers for the manufacturing sector. Thus, the Roadmap identifies the research needed by European industry to meet its goals and face up to the challenges of the coming years.

Industrial research in Europe under this initiative is expected to comply with the following two main requirements: its achievements should make a significant contribution to the sustainability of economy and society in Europe and the results of the research should start to provide economic return within around two years after the conclusion of the projects.

A sustainable European manufacturing industry needs to consider sustainability not only in terms of energy and resource efficiency but also regarding the social issues related to employees. There are many companies in Europe, mainly family owned and SMEs, that have functioned very successfully according to these concepts over decades. A factory is more than a smart combination of autonomous machines and processes that can easily be shifted to any other location in the world. It is an entity which focuses on intelligent person-machine cooperation in which advanced technology is as important as a sound ethical basis for stabilising local and global manufacturing. All this will directly impact on the sustainability of the European manufacturing industry and its most important social benefit will be to keep manufacturing-related jobs in Europe.

Technology, even though it plays an important role, is only one term in the equation that leads to economic success and sustainable growth for Europe. Human skills, the organisational structure, the mid- and long-term strategic goals and the rules for financial decisions are at least as important. Knowledge-based innovation in processes, products, and systems is the key concept: innovation leading to new life-cycle based product-services, manufactured in a sustainable way, and responding to the demands of customers and society.

Technology development needs to be placed into such a global context and this can require a re-thinking of internal strategies in enterprises. The European manufacturing industry needs to change its approach from cost-cutting to knowledge-based value adding, in order to achieve sustainable and competitive growth. The “Factories of the Future” PPP initiative is part of the European response to the current economic crisis, placing sustainability alongside competitiveness, profitability and employment as strategic goals. This has led to formulate “The Factory made in Europe” as a product of the future, addressing simultaneously the economical, environmental and societal challenges, in line with the aims of this PPP.

As a result of many workshops and strategic discussions within the European stakeholders from manufacturing industries and the related research community, it has been determined that the successful development of high added value technology should consider the following strategic sub-domains:

- Sustainable manufacturing
- ICT-enabled intelligent manufacturing
- High performance manufacturing
- Exploiting new materials through manufacturing

In the following pages, the content of these sub-domains is further elaborated and specific priorities are identified, to be taken as input when preparing the call topics in the annual or biannual Work Programmes governing the FoF PPP Calls for proposals. All the research areas described in this document are expected to satisfy the following criteria: a clear enabling character, a specific focus on production technologies and, last but not least, an evident cross-sectoral application potential.

By developing this public-private partnership, there is a commitment from both the public and the private sides to invest in new technologies and innovation that will sustain businesses in the medium term. The main aim of this Multi-annual Roadmap is to inspire industries to develop and demonstrate knowledge-based innovations leading to sustainable and competitive manufacturing in Europe.

2. Vision and strategic objectives

Europe is one of the main players in the global economy and both process and discrete manufacturing industries contribute to a large extent to this situation. In the globalised world of the third millennium the following Social, Technological, Environmental, Economical and Political (STEEP) factors are among the main drivers for the current and future economy: globalisation of the economy, climate change, scarcity of strategic raw materials, overpopulation, employment, security of energy supply, ageing population, public health for all, poverty and social exclusion, loss of bio-diversity, increasing waste volumes, soil loss and transport congestion.

In this context, many enterprises are struggling to survive in the currently turbulent markets, whilst some are leaders in gaining new markets and effectiveness by putting their future in new products and services, and in emerging technologies, having their focus already on technical innovation and strong customer-orientation. The latter are known worldwide as high performing manufacturers and deliverers of high-quality technical products and/or services. All of these enterprises need to be orientated towards the strategic development of factories (including high added value manufacturing in general as well as the specific changes to the particular factory system). This makes it necessary to implement the “Factories of the Future” initiative and to share experiences on the structural changes required to facilitate the transition from the factory system of the past to more competitive and sustainable factories.

From the manufacturing R&D perspective, the above-mentioned global drivers lead to a new vision for the future, the so-called Competitive and Sustainable Manufacturing (CSM), which:

- embraces the Social, Technological, Economical, Environmental and Political (STEEP) context;
- generates wealth, which in turn sustains high quality jobs, and manages human and physical resources (including skills development);
- concerns High Added Value products, processes and product based-services sustaining their life cycles, business models and the stakeholders involved through the supply chain;
- relies on stakeholders ranging from the customer-base to industry to research institutes, universities, European, national, regional public authorities and intermediate organizations, implementing the research innovation market value chain; and
- sustains knowledge generation, diffusion and use.

CSM promotes the transformation of the European manufacturing industry into a high added value and knowledge-based industry, which is competitive in a globalised world.

The strategies envisaged are targeted at:

- transformation of enterprises due to the needs of customisation and sustainability, thus increasing the chances of success and global leadership.
- boosting the level of technologies for products and processes towards global leadership,
- making Europe a global leader as both the producer and operator of factories and factory equipment (lead markets) with intelligent products, processes and new business models, and
- activating the potential of novel enabling technologies and developing solutions for emerging markets.

The Manufuture European Technology Platform has developed the necessary Strategic Intelligence: the Vision 2020, the Manufuture Porto Manifesto with its action lines (stimulate private R&D investment, foster collaboration within a research network, prepare appropriate standards and regulations, overcome fragmentation in EU R&D and leverage EU's science and research potential), the Strategic Research Agenda (SRA) and Roadmaps and related implementation framework.

Within the research activities of the European Economic Recovery Plan, the new "Factories of the Future Initiative" is building on the work of the Manufuture European Technology Platform and related European Technology Platforms and Sub-platforms in the field of manufacturing. The development and implementation of the "FoF PPP" is linked to:

- a Strategic Intelligence: Vision, SRAs, Roadmaps, as provided by Manufuture and related Platforms;
- a Reference Model for action, taking into account STEEP conditions, deriving potential "Factory System" concepts at given time horizons and defining the Enabling Production Technologies necessary to implement them;
- human, infrastructural and financial resources;
- continuous revision of the above, following a 'rolling approach', taking into account the evolution in STEEP conditions and changes in European policy.

In line with the goals set out in the European Economic Recovery Plan, with this Factories of the Future PPP Strategic Multi-annual Roadmap (2010-2013) it is hoped to provide the research tools to help EU manufacturers, in particular SMEs, across sectors, to adapt to global competitive pressures. This will be achieved by improving the technological base of EU manufacturing through the development and integration of the knowledge-based enabling technologies of the future, such as engineering technologies for adaptable machines and industrial processes, ICT, and advanced materials, covering the production value-chain from raw materials to semi-finished and to final products and their related services.

To account for the complexity and make optimum use of the work done by the Manufuture Platform and other European Technology Platforms, this Roadmap has been structured into the four already mentioned sub-domains:

- Sustainable manufacturing
- ICT-enabled intelligent manufacturing
- High performance manufacturing
- Exploiting new materials through manufacturing

3. Main industrial needs and related R&D challenges

In order to face the challenge of global competition, the European manufacturing industry will increasingly be forced to concentrate on specific issues providing a large competitive advantage through long-term innovation at the factory level.

A key factor to strengthen European leadership in product and process engineering and in the development of manufacturing systems, both discrete and continuous, will be the ability to achieve cost efficiency (including factors such as material supply, transportation, and cost of manpower), high performance and enhanced robustness, in a context of increasing product variability and continuously changing production volumes

In the present scenario of global market competition, the R&D challenges to achieve a higher competitiveness of the manufacturing systems should be considered in terms of general evolution drivers, such as:

a) cost efficiency, with extensive adoption of standards in production machinery, equipment and controls and massive use of the lean approach;
b) optimised consumption of resources through the use of energy and material efficient processes and machinery, renewable power sources, and smart energy management with extensive recovery of heat and dissipated energy;
c) short Time to Market (from the concept to new products on the market), enabled by ICT applications, which will increasingly be relevant in manufacturing industries;
d) increased focus on high added value components/goods through the use of enabling processing technologies and enhanced materials;
e) adaptability/re-configurability through a modular approach in production systems, in order to maximise autonomy and interaction capability of machinery and continuous re-use of existing infrastructures;
f) higher and more stable product quality through increased process robustness and accuracy, while ensuring an easy process maintainability;
g) higher productivity under enhanced safety and ergonomics conditions, through an upstream integration in factory design of workplace optimisation for human well-being;
h) increased reusability of production systems towards global interoperable factories, which are able to provide services and develop products anytime and anywhere, independently of the technologies, culture or language in use in the different production sites;
i) new products, requiring new manufacturing technologies adapted to new features.

Manufacturing research should focus on the transformation of the present factories, towards re-usable, flexible, modular, intelligent, digital, virtual, affordable, easy-to-adapt, easy-to-operate, easy-to-maintain and highly reliable "Factories of the Future".

3.1 Sustainable manufacturing

For European industry, sustainability needs to be today a strategic objective. The competitiveness of European industry can be enhanced by implementing key knowledge for new applications in different technologies and disciplines. However, the manufacturing industry needs to be able to design and produce goods using a sustainable approach. "Sustainable" in production terms means energy efficient with a minimal environmental impact, compliant to the regulatory constraints and fulfilling the safety and health requirements, while ensuring profitability for economic growth. Support for "de-manufacturing" or advanced recycling of products and production process waste is equally required.

European manufacturers have taken up the challenge of designing sustainable production systems that have a minimal unfriendly effect for environment and society. Sustainability is now at the centre of industrial R&D. Environmental challenges such as climate change and resource scarcity are the source of both constraints and opportunities for technological development. Research has to satisfy both environmental and customer needs, generating high added-value products, related processes and technologies to meet functionality requirements as well as growth conditions, public health, occupational safety and environmental protection concerns.

The following approaches should be developed:

- ***New Eco-Factory model*** (short term impact): optimised utilisation of energy streams, reduction of environmental impact and improvement of resource efficiency will be the basis of the new advanced green manufacturing.
- ***Green Products Manufacturing*** (medium term impact): application of an integrated preventive environmental strategy to processes and products in order to increase the overall efficiency by the conservation of resources and energy, towards the elimination of emissions and wastes by point source treatment and recycling.

Sustainability, balancing environmental friendliness, economic growth and social well-being, will be assured through enhanced environmental awareness in production systems design, sustainable manufacturing processes and an eco-friendly supply chain.
The new approaches of Eco-Factory models and Green Products Manufacturing should provide the means to:

- design and produce sustainable products with drastically reduced resource utilisation and
- develop advanced manufacturing processes based on renewable resources, if possible, and on safety and ergonomics for operators and users.

These approaches will address at the same time:

- <u>Environmental friendliness</u>: specific solutions to minimise the environmental impact and resources consumption with optimised costs;
- <u>Economic growth</u>: technological solutions to achieve cost reduction by means of optimised resource management and efficient production processes;
- <u>Social well-being</u>: safety and ergonomics of current and new manufacturing facilities as well as new ways of interaction between machine and human beings which redefine the human role in the manufacturing environment.

The main research areas related to sustainable manufacturing are listed in the following sections, taking into account which of the three elements above is the closest to the centre of gravity of the research:

(a) Environmental friendliness

The new Eco-factory model, using technologies for resource efficiency and cleaner manufacturing, can make large cuts in energy consumption by monitoring the process conditions and the resources used in production, replacing and up-dating equipment, configuring systems according to differentiated processing needs, employing multi-functional devices and even by simply ensuring equipment is turned off after use. The main objectives are the following:

- (a1) High efficiency and near to zero emissions in manufacturing processes. Optimised self-adaptive and fault tolerant strategies, which lead to higher productivity and reduced energy consumption and process emissions (dust, air, water, noise, waste, etc.). Control-intensive applications with high effectiveness and usability of the integrated automation and control systems. Energy-efficient production equipment able to improve energy recovery, harvesting and scavenging capabilities, as well as self-cleaning production systems (proposed for 2011).
- (a2) Alternatives to energy-intensive processes based on advanced production and manufacturing systems. Production solutions enabling low resource input, low emission, products tailored for different applications, surface treatments and functionalisation, painting, coating and joining, development of compact processes, ensuring high process productivity while reducing environmental impact (proposed for 2011).
- (a3) Improved use of renewable resources at factory level. Development of new solutions for Green House Gases emission reduction, in particular by using alternative materials and/or energy sources and innovative technology application (proposed for 2012/13).
- (a4) Production using environment-neutral materials. Growing use of alternative materials in the production environment (e.g. use of renewable materials, bio-processes, heavy metals control, fossil resources control), adequate management of hazardous materials (measurement methods, treatment standards) and increased use of bio-renewable materials. Development of new technologies for processing, recycling and recovery of materials and energy from waste, producing secondary materials with a high degree of purity and re-workability at lowest energy consumption (proposed for 2012/13).

(b) Economic growth

Improvement of product sustainability through new processes and technologies, incorporating at the same time the customer requirements. The focus will be on solutions with high potential in terms of cost reduction supported by advanced decision making tools and correlated to optimisation of resource and equipment efficiency:

- (b1) Methodologies and tools for sustainable maintenance of production equipment. Smart and agile maintenance approaches that may increase the lifetime and energy efficiency of the production equipment and reduce its maintenance cost. At maintenance process level, research should address maintenance flexibility, conflict handling in volatile production environments, predictive maintenance planning and scheduling, use of advanced embedded information devices, integration with the appropriate software (i.e. MES and ERP) and remote control systems. At equipment level, R&D should aim at increased lifetime of critical components and reliability, higher resistance against failure, reduced energy consumption, minimised wear or corrosion, etc. (proposed for 2012/13).
- (b2) Innovative re-use of equipment and integrated factory lay-out design with higher cross-sector standardisation and modular approach. Proactive modularisation and re-use strategies for the development of the future machinery and production systems and their

integration in old, new or renewed factory buildings. A new approach should leverage all potential synergies between concurrent process and building design, as well as best practices for de-manufacturing, dismantling, recycling and value chain extension, integrated with information related to the recovery of the product with environmental policies at the product design stage. A further approach should focus on flexible, low-cost assembly solutions to aim at a high penetration of the machine component supplier market by developing low weight and mobile solutions (e.g. flexible grippers), as well as visual systems for object recognition and environment detection/interpretation (proposed for 2012/13).

(b3) Decision support methodologies for the design of manufacturing systems based on integrated product-process approaches and economic/technical risk analysis. Risk assessment in the design of manufacturing systems based on the knowledge-based engineering concept linked with re-usable CAD/CAE based solutions, methodologies to evaluate risks associated with a complex and/or innovative technological equipment design (e.g. Technology advisor, Cost advisor and LCA advisor), fast integration of machines and control systems capable of switching from producing one model to another to meet fluctuating and diverse demand (proposed for 2011/12).

(c) Social well-being

The main objective of this section is to develop new forms of interaction between process, machinery and human beings in such a way that future factories can be operated profitably and at the same time provide a stimulating environment for the employees, and make the most from their skills and knowledge through life-long learning and trainings. The history of product manufacturing proves that the cultural backgrounds of people in a factory are also a determining factor for its success. In the new Eco-factory the environment for humans will provide the best conditions for coping with products with a short cycle time and a high variability, for handling possible ups and downs in economic cycles, for quick adaptation of manufacturing capability and for the development of knowledge.

- (c1) Adaptive and responsive human machine interface. Innovative solutions have to be developed on how a factory can be run profitably and, at the same time, to provide satisfactory work places for the employees. Advanced adaptive and responsive technical devices enable the creation of such environments (proposed for 2012/13).

- (c2) New human-robot interactive cooperation in advanced factory environments. Development of tools for a manufacturing environment that interlinks the personal skills of humans with machines in such a way that human intuition and learning are enhanced and changing working conditions are optimally met. Effective collaboration between robots and humans requires the use of an efficient interface whereby a human can communicate and interact with a robot almost as efficiently as he would with another human. Human-robot collaboration is facilitated by a number of capabilities built into the robot and the robot interfaces, including voice recognition, natural language and gesture understanding, as well as behaviours supporting dynamic autonomy. By aiming to shorten ramp-up times and increase machine availability, the development of intrinsic machine safety concepts for increasing human-robot and human–machine interaction is required for reliable protection for machine operators and maintenance personnel (proposed for 2012/13).

- (c3) The new human-centred production site. Methodologies for enhancing flexible smart automation while maintaining a level of employment with highly satisfied and highly skilled workers. Research is necessary to guarantee an efficient transition from current to future situations in relation to the definition of future worker skills (multidisciplinary involvement of single workers in operations, maintenance, logistics and quality control), enhanced ergonomics (optimisation and personalisation of working conditions and methods based on worker's age, experience and physical state) and integration of the European Factories of the Future in its social and urban environment (urban transport, parking, shopping and entertainment centres, support to families, etc.) (proposed for 2012/2013).

- (c4) Development and adaptation of organisational structures and leadership for sustainability. Historical management structures and industrial business models need to be radically expanded in order to take into account sustainability requirements. New key performance indicators that include sustainability parameters need to be developed, as well as new management strategies and ways to deal with cultural differences will be needed in order to support sustainable competitiveness. To make such knowledge more tangible for the day to day operation of an enterprise, new forms of interdisciplinary research are needed, to understand the correlation of such areas as financial decision mechanisms and ethical business strategy with continuous business success (proposed for 2012).

3.2 ICT-enabled intelligent manufacturing

The contribution of Information and Communication Technologies (ICT) to manufacturing aims to improve the efficiency, adaptability and sustainability of production systems and their integration within agile business models and processes in an increasingly globalised industry, requiring continuous change of processes, products and production volumes. Also the further integration of any newly developed ICT into the production lines and the industrial environments requires complementary research and innovation efforts. These integration aspects will play a key role for generating and using smart production systems for factories in different industrial sectors.

ICT is a key enabler for improving manufacturing systems at three levels:

- agile manufacturing and customisation involving process automation control, planning, simulation and optimisation technologies, robotics, and tools for sustainable manufacturing (<u>smart factories</u>);
- value creation from global networked operations involving global supply chain management, product-service linkage and management of distributed manufacturing assets (<u>virtual factories</u>);
- a better understanding and design of production and manufacturing systems for better product life cycle management involving simulation, modelling and knowledge management from the product conception level down to manufacturing, maintenance and disassembly/recycling (<u>digital factories</u>).

The main research areas related to ICT-enabled intelligent manufacturing should include:

(a) Smart Factories: Agile manufacturing and customisation

Future production sites for a large variety of sophisticated products will offer flexible, short cycle time and variability controlled manufacturing capability. These manufacturing approaches ensure energy-efficient, reliable and cost effective production as well as production set-up/ramp-up with reduced cost and time through lean and simpler ICT. Important developments in automation are foreseen from the increasing convergence of machine control and personal computer technology. Related industry-driven R&D activities should include:

<u>(a1) Adaptive and fault tolerant process automation, control and optimisation technologies and tools</u>. Novel large-scale control-intensive applications for high yield performance and energy efficiency, in order to validate and benchmark the effectiveness and usability of the integrated automation and control systems, e.g. by means of fully integrated interfaces from Manufacturing Execution Systems (MES) to shop floor level or knowledge management of process data with shop floor relevance (proposed for 2011).

<u>(a2) Intelligent production machines and “plug-and-produce” connection of automation equipment, robots and other intelligent machines, peripheral devices, smart sensors and industrial IT systems</u>, thus providing cooperative machines and control systems for scalable factory solutions, including concepts for migration and transition of existing systems to modern architectures (e.g. service oriented architectures – SOA) (proposed for 2011).

(a3) Large-scale testing and validation of robotics-based and other automated manufacturing and post-production automation processes in real-world environments (proposed for 2011).

(a4) Novel methods of interaction with, and automatic tasking of, intelligent cooperative automation and robotic control systems that support flexible, small batch and craft manufacturing and new programming paradigms for production (proposed for 2011).

(a5) Laser applications. Novel lasers including ultra-short pulse lasers emitting in the IR, VIS and UV and adaptive and dynamically-controlled laser-based materials processing systems and further development of their mass customisation in manufacturing applications (proposed for 2011).

(a6) New metrology tools and methods for large-scale and real-time handling and processing of manufacturing information. Assessment of manufacturing, automation, handling and metrology equipment using standardised methodologies and metrics, including the development of self-learning and adaptive procedures for process and quality control (proposed for 2012/13).

(b) Virtual Factories: Value creation, global networked manufacturing and logistics

ICT, if integrated end-to-end, can provide clear insight and exact and useful knowledge from the relevant data, thereby facilitating or supporting decision making and creating value from global networked operations ('virtual factories'). Related industry driven R&D activities should include:

(b1) Increasing management efficiency of global networked manufacturing. Enabling technologies under the emergent Internet of Things (IoT), meaning a network of devices such as RFID, wireless sensor networks, and machine-to-machine communication, significantly contributing to increased logistics efficiency, real-time monitoring of material flows and resource use. Integrating the IoT with an Internet of Services (IoS) in order to enable new real time network visibility for global manufacturing and logistics network (proposed for 2011).

(b2) ICT for sustaining the value of products. ICT tools supporting the production of smart industrial goods, allowing advanced maintenance technologies and services (e.g. predictive and remote equipment maintenance simultaneously and across different sites), addressing challenges such as product quality and reliability, reducing waste and energy demand, enhancing safety and supporting fully automated lifecycle management, including product upgrades, re-manufacturing, recycling and disposal (proposed for 2012/13).

(b3) Product/service systems: Supporting the manufacturing industry in its transition towards providing customer value via product-linked services and solutions based on integrated product/service systems and the co-creation of value (proposed for 2012/13).

(b4) Managing volatile manufacturing assets: Market related manufacturing knowledge is essential to the global success of Europe's industry. Effective networked manufacturing requires the inclusion of virtual factory and multi-level supply chain elements related to economic factors, such as real-time asset management methods (e.g. for materials & high-tech commodity costs, routings, inventories), skills and IPR and value sharing which are distributed across production sites, stakeholders and machinery (proposed for 2011).

(c) Digital factories: Manufacturing design and product life cycle management
Addressing the front-end stages of manufacturing, in particular early concept modelling, simulation and evaluation, as well as the transformation of the knowledge-time curve, thus ensuring greater acquisition of knowledge earlier so that better informed manufacturing decisions can be taken. The handling of uncertainty is also a crucial area. The R&D focus is on:

(c1) Knowledge and analysis. Comprehensive engineering platforms that enable cross-disciplinary information sharing and the capture and transfer of industrial design knowledge (e.g. innovative methods for knowledge capturing, innovative access to new and existing knowledge on product-services, effectively supporting re-use of knowledge and collaborative work on product/design/manufacturing/usage) across stakeholders and throughout the lifecycle, for example drawing knowledge from customer use to improve design (proposed for 2012/13).

(c2) Enhanced, interoperable models for products and processes: More intelligent models providing details of design intent, as well as with better predictive capabilities to help reduce the need for physical prototyping or the erection of pilot plants. Modelling encompassing material and component properties and variations of these, and helping to identify impacts of corrosion, stress, temperature, etc. (proposed for 2012/13).

(c3) Design environments: Self-organising, collaborative design environments able to adapt to the needs of different sectors and industries, including facilities for product modelling, decision-making (e.g. needs/requirements identification by means of offer/demand market analysis and perceived qualities), and client-oriented simulation (virtual reality, reverse engineering). Location- and context-aware design environments with filters that direct selected information to users according to their roles and needs (proposed for 2012/13).

(c4) Lifecycle management: In addition to the technical data management perspective, product lifecycle management for all design information and analysis results requires synthesis methods and tools to adequately design products. As sustainability assessment includes economic and social as well as environmental issues, classical lifecycle assessment (LCA) methods and tools may prove inadequate for a holistic LCA approach based on a consistent set of information on products, components and energy. The results of the LCA need to be digested and made available to product designers to effectively shape future products. Decision makers should be able to weigh environmental and economic impacts against each other along the complete product lifecycle (proposed for 2012/13).

3.3 High performance manufacturing

The economic crisis is having a strong effect on new industrial investments in production and process equipment, in particular for SMEs, since the return on investment must be thoroughly justified. Therefore, there is a need for manufacturing systems that are flexible enough and, at the same time, are robust, reliable and cost effective. This cannot be achieved through advanced technology alone. Optimisation of such complex manufacturing systems increasingly relies on human workers, advanced machinery, ICT and use of resources.

The aim would be to allow improvements through successive investments in production equipment, as well as an easy reconfiguration from small to large production series, or small to large production capacity using flexible technologies such as modular production units. Furthermore, the new solutions should bring the integration of the necessary ICT support providing simplification and real user friendliness.

The main research areas relevant to high-performance manufacturing fall into four domains:

(a) Flexible adaptive production equipment, systems and plants for rapid (re)configurations and optimal energy use

The current industrial market is characterised by a turbulent and uncertain demand for highly customised products, of a complexity which is in constant increase. Compared to the past, customers require higher quality, faster delivery times, and shorter times between successive generations of products. Two additional aspects must be considered: the current financial situation pushes manufacturers to reduce investments in production resources over time and sustainability issues impose that machines are able to efficiently and ecologically support the production of new future products without being substituted. All this requires high flexibility and permanent adaptation of machines, process equipment and production systems to products and process evolution, with special consideration to traditional industries. The research activities should include:

<u>(a1) New high performance manufacturing technologies in terms of efficiency (volumes, speed, process capability), robustness and accuracy</u>. New system architectures with self-adaptive machine structures based on mechatronic modules, multi-layer controls and highly redundant measurement, sensing and actuator structures. New equipment, machines and production systems requiring less shop-floor space, by means of reduction of peripherals, optimisation of cycles and process planning (proposed for 2011).

<u>(a2) Plug and produce components based on intelligent materials or combinations of passive and active materials (engineered materials) to increase the adaptability of production systems</u>. Sensing and actuator structures, adaptive control and energy harvesting will be key developments. This includes self-adaptive and self-optimising modules (proposed for 2011).

<u>(a3) New hybrid production systems for manufacturing and assembly/disassembly, based on improved robotics and/or automation technology for cooperative production tasks between humans and robots.</u> These systems will be developed considering the specific needs of SMEs (proposed for 2012/13).

<u>(a4) Adaptive machines and production systems for optimal energy consumption.</u> Flexible adaptation of energy resources for high performance machine drives. Concepts such as obtaining energy on demand and feed-forward strategies should be exploited, with special attention to high energy footprint industries (proposed for 2012/13).

(b) High precision micro-manufacturing machines and systems

Future manufacturing technologies will move towards the manufacturing of topologically 3D optimized parts with complex internal structures such as conductive or cooling channels and material gradient structures. Miniaturisation of products and production appliances and integrated compact systems design will be key issues for future manufacturing. High quality and high performance manufacturing, parts consolidation and simplification, multiple materials and the reduction of manufacturing and assembly costs must be addressed.

<u>(b1) Rapid micro-manufacturing technologies.</u> Micro-electromechanical systems (MEMS) for computer controlled deposition and curing of radiation-curable materials and for embedded (micro) sensors. Improvement of Rapid Manufacturing Technology (e.g. beam-based, scanning optics) to address high performance, process productivity and flexibility to frequently changing operating or product-mix conditions (proposed for 2012/13).

<u>(b2) 3D micro-parts production.</u> 3D micro-components using a wide range of materials (metallic alloys, composites, polymers, ceramic) and on large volumes. New process chains integrating different process technologies (e.g. machining by EDM). Analysis of the microstructural behaviour of materials and its interaction with the production process. Quality issues for micro-components, measurement machines and equipment, fixtures and handling systems (proposed for 2012/13).

<u>(b3) Micro-factory and micro-manufacturing systems.</u> Easily configurable assembly lines taking up a small space to assemble and test small parts (MEMS, devices, sensors, actuators, etc). New generation of modular macro/meso/micro machine tools and robots with self adaptive and reconfigurable capabilities to implement a portable and easily configurable factory for manufacturing and assembly of high tech miniaturised devices. Development of appropriate control systems for supervision and reconfiguration and quality standards for micro-systems (proposed for 2012/13).

(c) Tools for production planning and in-situ simulation for open reconfigurable and adaptive manufacturing systems

New high performance processes, machines and production systems will require new methods and tools for machine design and operation monitoring. Considering the need of production systems to evolve in line with products and processes, new ways to manage initial and ongoing system configuration are needed. During operation, knowledge based tools supporting production planning should be developed, and simulation methodologies should be introduced in Manufacturing Execution Systems (MES) and on board in the machine, integrated with process control. Using the input by sensorial supervision and monitoring and with the actual load, it will be possible to predict the process behaviour and, if necessary, to compensate deviations of precision and accuracy or to control manufacturing processes by learning for the future. These systems must be smooth (smart and fault tolerant) in their interaction with human workers.

<u>(c1) Methodologies and tools for reconfigurable manufacturing systems design for healthy, green and safe products. M</u>ethodologies that define the set of resources and the control system architecture having characteristics and performance that optimally match the demand and the process plan over time. Developed production system solutions should also address internal uncertainty, such as unforeseen events, by continuously tuning process parameters and production flows (proposed for 2011).

<u>(c2) Knowledge based tools for process planning.</u> Platforms integrated in the information and execution system of factories should be developed for non-linear process planning. By considering local production and outsourcing, these tools will allow the optimisation and

monitoring of manufacturing processes, wherever in the world these are performed (proposed for 2012/13).

(c3) Integrated shop-floor simulation, Modelling tools working in an integrated way on different shop-floor levels (process, machine, cell, line and factory). The interaction with the machine and the system control should allow simulation to start from the real current status. Simulation results will allow multi-level decision support systems to support workers' tasks (proposed for 2012/13).

(c4) Advanced interactive graphical user interface. Tools allowing workers to deal with the increased complexity of simulation and decision systems embedded in machines and production lines (proposed for 2012/13).

(d) Zero defect manufacturing

Customisation and reduction of lot sizes even down to "make to order" dramatically increase production cost because of the additional costs linked to set up, changing processes and adaptation of the production equipment. For example, innovative solutions are needed in support of customization and "make to order" strategies in automotive and electric and electronic components industries, improving methodologies through quality control and the increase of efficiency in manufacturing. New quality monitoring methods are needed based on supervision and control of the process parameters and on pre-processing prognosis and proactive controls. This includes sensors for process diagnostics and process monitoring and visualisation, integrated with cognitive systems for intelligent and self-optimising manufacturing and production systems.

(d1) Quality monitoring and proactive process improvement for geometric shape data and material quality. New quality monitoring tools for multiple specifications on product shape and material quality able to quickly handle unusual or out-of-control situations. New approaches for process optimisation aiming at selecting the best settings for the controllable factors to best target the product specifications. Multi-resolution measuring systems and distributed intelligent systems will be developed (proposed for 2011).

(d2) Intelligent Measuring Systems for Zero-Defect Manufacturing. Development of fast and reconfigurable low/medium and high resolution measuring systems for accurate and time efficient measurements. Distributed Intelligent Measuring Systems reconfigurable both in space and time (proposed for 2001).

(d3) Advanced decision-making tools for zero defect manufacturing. New tools to achieve cost-effective process chains from the early phases of product development by enhancing the empirical and derivative approach of design procedures by means of quality by design, defect-tolerant product configurations, selection and evaluation of manufacturing processes and equipment (proposed for 2012/13).

(d4) Development of a new generation of knowledge-based self-learning systems. Multi-layer controls and model based real-time compensation routines, embedding machining process knowledge, for novel self-learning systems. Optimization of process capability by means of In-Process or Pre-Process measurements taking full advantage of machines equipped with sensors for quality monitoring. Selection of controllable factors assuring adequate performance through signal analysis and machine-self-learning (proposed for 2012/13).

3.4 Exploiting new materials through manufacturing

Traditional and new industries in Europe are working with new materials to take advantage of increased functionality, lower weight, lower environmental burden and energy efficiency. This is needed to achieve a sustainable manufacturing base when moving to high added value products and customised production. New materials pose new challenges for cost efficient manufacturing to shape, handle and assemble complex structures that can involve macro-micro-nano scale, multiple material combinations such as sandwich structures and composites and smart materials involving integration of sensing and actuation technologies within a material (e.g. smart textiles). In other cases, there is a need to work with bio-inspired materials to integrate them more effectively with conventional and new materials, to meet the needs of new bio-industries and environmental targets. Recycled materials are also relevant in this domain, due to their large potential both for cost and environmental reasons.

Most industrial sectors of importance to European manufacturing have a requirement for new and improved processes to deal with the need to exploit new materials through manufacturing. In the transport sector key changes are required to achieve a greater use of light weight materials, such as composites, and the efficient use of high value added metals, such as high strength steels and nickel based alloys. New composites are also used by industry in the drive towards renewable energy sources, where components need to be manufactured at volumes and costs not previously anticipated, whilst ensuring that waste is minimised. In the textile and footwear sectors new approaches such as 3D shaping and drapability in new automated factories are needed for mass customisation and increased product functionality. Integration of electronics, e.g. using improved sensing and control systems, and customisation of smart products, such as in intelligent packaging, also demand new manufacturing methodologies, e.g. an increased use of laser technologies and roll-to-roll manufacturing. For the bio-inspired industries, there is a need to incorporate new multifunctional materials into products that span a biological-physical interface and to introduce good manufacturing practices (automation, quality control and traceability) for such products. The use of materials that provide a micro/nano-scale functionality, particularly in volume manufacturing within a safe environment, requires the development of new micro/nano-manufacturing processes that encompass design, assembly, joining and reliability issues (e.g. for new nano-coatings on traditional substrates).

The main areas where research is needed to ensure that novel manufacturing processes can efficiently exploit the potential of new materials for all these industrial applications should include:

(a) Net-shape manufacturing for advanced structural and functional materials
Net-shape manufacturing technologies have gained industrial significance to produce structural parts made of a wide range of materials, namely metals, ceramics and polymers. Transferring traditional low-cost net shape manufacturing processes to novel material classes, such as advanced metallic materials (e.g. intermetallics), functional ceramics (e.g. bioceramics) or structurally reinforced composites (e.g. metal-ceramic or polymer nanocomposite materials) will lead to completely new possibilities in the design of components and to significant savings in materials and processing costs.

<u>(a1) Complete manufacturing chains for nanophased components</u>. Development of high throughput processes (e.g. extrusion, forming, casting, coating and quick sintering) able to produce net-shape or semi-finished products as well as coatings, using nanotechnologies and nanomaterials. Novel supply chains to provide the nanophase to a micro- or macro-component need to be included. (proposed for 2011).

(a2) Manufacturing of engineered metallics and composite materials. Development of new and innovative technologies aiming at increasing the reliability and reproducibility of smart composites and metallics, and for further integration of functions (proposed for 2011).

(a3) Up-scaled systems for high performance manufacturing of fibre-based structures for high value added and very large size applications. Tailor-made solutions in the field of fibre-based structures and high value-added net- or near-net- shaped 3D products, produced at varying volumes (proposed for 2013).

(b) New material functionalities through manufacturing processes

The interaction between new manufacturing processes and new materials can have a considerable influence on the quality and functionalities of new products, providing significant added value. The development of new manufacturing platforms able to transfer laboratory processes to high and/or customised volume production is required.

(b1) Roll-to-roll manufacturing of large area and high throughput flexible plastics electronics. Manufacturing of products such as OLED for lighting, displays and technical textiles, organic PV, organic sensor arrays using new organic functional polymers and hybrid materials (proposed for 2011).

(b2) Manufacturing processes for new flexible components. Innovative processes for new components, in particular in textiles, such as surface modification techniques and high-technology treatments incorporating different scales, to improve final performance and add in smartness (sensing and actuation) for enhanced safety and personalisation, for example in footwear or food packaging (proposed for 2013).

(c) Manufacturing strategies for renovation and repair

Extending life of existing and new structures as well as designing in re-use or ease of renovation requires smart approaches for the incorporation of advanced materials. Integrated design and manufacturing for re-use (renovation and repair) as well as increased ability to track material/product use to recover added value from new materials and components should be simultaneously addressed to optimise life cycle manufacturing and supply chains (proposed for 2012/13).

(d) Product design using sustainable material processing technologies

New materials bring new challenges in sustainable manufacturing that require new approaches for low resource consuming processes and process intensification, integrated with hybrid processes, as well as knowledge-based processes exploiting advanced modelling and simulation techniques. These new materials include, among others, “carbon neutral” materials as well as materials for improved product quality, weight saving and improved behaviour and functionality. This will then significantly reduce undesirable processing emissions and provide new methods to process micro-nano-materials (minimising the potential impact on the environment and human health). There is also a need for the development of manufacturing technologies for sustainable production and recycling of process residuals that are suitable for new materials.

(d1) Modelling and simulation of manufacturing processes. Modelling and simulation methods of component manufacturing processes involving mechanical, energetic, fluidic and chemical phenomena (proposed for 2012/13).

(d2) Manufacturing processes using advanced materials for energy generation and supply. Development of manufacturing processes for advanced energy systems optimising the performance of the materials used for their construction and for functional purposes. The sustainability and cost-effectiveness of the manufacturing processes and of the components in service should be ensured (proposed for 2012/13).

(d3) Manufacturing of highly miniaturised components. Manufacturing methods based on new materials processing to move from batch to continuous formulation and to manufacture highly miniaturised components (proposed for 2012).

(d4) New technologies for casting, material removing and forming processes. New process technologies to support casting, material removing and forming processes when applied to new materials, considering life-cycle impacts as well as the performance requirements for these processes (e.g. roughness, accuracy, robustness) (proposed for 2012/13).

4. Timeline and budget

The Factories of the Future PPP covers the period from 2010 to 2013, with a total estimated budget contribution of €1.2 billion, to be equally shared between the European Commission and the private sector. The dialogue in the framework of the Ad-hoc Industrial Advisory Group with European Commission officials from DG Research and DG INFSO already allowed the provision of industrial input for the preparation of the FP7 Work Programme 2010. DG Research and DG INFSO launched in this way a dedicated cross-thematic Coordinated Call of €95 million in July 2009, which is expected to raise around €65 million of private R&D investment. This would result in a total R&D investment of around €160 million into Factories of the Future PPP in the year 2010.

Table 1: Topics in the FoF PPP Coordinated Call in Work Programme 2010

Identifier	Title
FoF.NMP.2010-1	Plug and Produce components for adaptive control
FoF.NMP.2010-2	Supply chain approaches for small series industrial production
FoF.NMP.2010-3	Intelligent, scalable, manufacturing platforms and equipment for components with micro- and nano-scale functional features
FoF.ICT.2010.10-1	Smart Factories: ICT for agile and environmentally friendly manufacturing (including a Coordination Action)

The tentative budget distribution shown below has been made according to the preliminary definition of research priority areas in each of the four sub-domains and the number of priority R&D topics expected. The tentative budget distribution per sub-domain and per year is outlined in the tables below:

Table 2: Indicative budget distribution per sub-domains

Sub-domains:	**%**
Sustainable manufacturing	30
ICT enabled intelligent manufacturing	30
High performance manufacturing	25
Exploiting new materials through manufacturing	15
TOTAL	100

Table 3: Indicative budgetary scenario for the Factories of the Future PPP (in €million)

2010	2011	2012	2013	TOTAL
160	290	350	400	1200

5. Expected impact of the Factories of the Future PPP

The Factories of the Future PPP has been launched in order to have a direct economic impact on innovation and research in manufacturing. This public-private partnership will promote research focused on the needs of European manufacturing companies, especially SMEs. The main goal is wealth creation through a competitive market position and adding value. The research and development results will be applicable across many industrial sectors and the new production methods, processes and technologies are expected to reach industries across all of Europe and beyond.

An additional expected benefit is linked to the cooperation, in line with the Factories of the Future PPP objectives, between the academia/research institutes and the European industry. There will also be benefits at regional level since manufacturing industries in Europe, which are largely dominated by SMEs, are characterised by the existence of regional clusters of interconnected companies that provide to their specific regions very significant employment and wealth.

Regarding the international aspects of the globalised economy, two main positive impacts are expected. The export share of the European manufacturing and process equipment industry will be reinforced as a result of the achievement of the Factories of the Future PPP objectives because technological improvements combined with better environmental performance will lead to competitive advantage. Moreover, the supply of this equipment to third countries will also lead to a reduced environmental impact worldwide.

Impact of achieving the objectives in the sub-domain on "Sustainable manufacturing"

The first sub-domain, *Sustainable Manufacturing*, addresses objectives related to the reduction of material resources and emissions and the increase of safety in manufacturing. Achieving these goals will lead to direct economic impacts such as:

- Impact on competitiveness of the European manufacturing industry: with a growing concern of informed consumers and increasingly demanding legislations worldwide, the European manufacturing sector, as both providers and users of manufacturing equipment and processes, needs to reach more ambitious environmental goals in order to keep its competitive advantage over other regions;
- Savings in energy consumption and related operating costs in more efficient European factories by means of the use of more energy-efficient manufacturing systems. Decrease of the CO_2 footprint and of the NOx and hazardous materials emissions of European production equipment life-cycle and factory processes worldwide when incorporating "European Factory" concepts;
- Reduction of costs related to emissions (air, water, noise, etc) by means of applying self-cleaning systems and emission-free production.

With the support of the public authorities to implement sustainable manufacturing, and as an additional side-effect, the rest of the manufacturing industry in Europe will follow the trend set by the first industries applying the results from the Factories of the Future PPP in the Sustainable Manufacturing sub-domain.

Impact of achieving the objectives in the sub-domain on "ICT-enabled intelligent manufacturing"

The application of Information and Communication Technologies (ICT) to Manufacturing contributes significantly worldwide to economic growth. Europe, however, seems to be still lagging behind major players in this area such as the USA or Japan, and this PPP, through its contribution to intelligent manufacturing, will help European industry to catch up on competitiveness.

Smart Factories: Advanced automation and control are key technologies to help all manufacturing sectors become more competitive, energy-efficient and innovative. Industrial robots have moved away from traditional tasks like welding to handling and assembly operations. The focus of activities should shift from heavy to light industry, which until now has been "robot-resistant", e.g. co-worker robots in the food industry or “apprentice” robots in small and medium-sized enterprises. Future production sites with a large variety of sophisticated products will have to offer flexible, short cycle-time manufacturing capability. This will result in: (a) a higher level of intelligence on the shop floor through context-aware, fault-tolerant, adaptable, re-configurable interoperable, wireless and robust ICT tools and systems; (b) opening-up of new market areas for next-generation automation equipment and advanced industrial robots providing a boost to both the European industrial automation and robot suppliers and the end-user industry worldwide; (c) development of an early European market for advanced technologies as applied to electronic and photonic devices, automation equipment, and robot systems.

Virtual Factories: ICT also plays an increasingly important role as a business value proposition differentiator in global networked operations. Research activities in this domain will result in: (a) improved efficiency of (embedded) product intelligence enabling advanced product-centric services (e.g. product authentication, IPR security, ICT-facilitated diagnosis and repair/resetting, remote performance/energy monitoring and logistics); (b) new business models and capabilities for improved management of global networked operations.

Digital Factories: R&D efforts addressing the front-end stages of manufacturing, in particular early concept modelling, simulation and evaluation, as well as the transformation of the knowledge-time curve, will ensure greater acquisition of knowledge earlier and better handling of uncertainty so that better-informed manufacturing decisions can be taken. This will result in maintaining Europe's leadership in providing knowledge-driven platforms, tools, methodologies and lifecycle orientation to product development and manufacturing (e.g. planning, optimisation and monitoring of processes, plant configurations and assets in real time, as well as web-based engineering).

Impact of achieving the objectives in the sub-domain on “High performance manufacturing”

With the growing importance of manufacturing SMEs within the European economy in terms of GDP and number of jobs, increase in competitiveness and production flexibility have become critical aspects for the survival of European manufacturing in the changing and uncertain global scenario.

For most manufacturing factories, activities such as material handling, scheduling, part or process setup or changeover times still occupy too large a fraction of the total time that parts are “in process”. In some cases, up to 90% of product manufacturing time represents non-value-added delays. Reducing this wasted throughput time is and will continue to be a major driver for improvement in productivity.

The reliability of machines, equipment and production systems is paramount for efficient low-cost production. The key goal is to have maximum availability of machinery, producing high-quality zero-defects parts and in-specification materials at highest production rates. As an example, mechatronic strategies based on adaptronic systems, intelligent materials or vibration damping systems can compensate deviations from initial accuracy requirements detected by the continuous monitoring and control systems.

The achievement of more reliable and efficient manufacturing systems (e.g. machine tools, fixtures, cutting tools, process and peripheral equipment), integrating process modelling and part quality prediction, is expected to give rise to benefits such as:

- Reduction of the number of rejected components or products and the amount of raw material used;
- Reduction of the cost and weight of manufactured assemblies or the cost of manufactured product;
- Increased throughput, tool and equipment life and productivity maintaining repeatability and accuracy;
- Reduction of the waste, power consumption and number of finishing operations;
- Minimisation or even elimination of the use of services such as coolants (dry cutting);
- Extension of maintenance intervals.

Impact of achieving the objectives in the sub-domain on "Exploiting new materials through manufacturing"

The demands of society for an ever-increasing use of renewable energy sources, higher standards of living, constantly changing markets and highly customised goods, as well as the risks posed by increasing energy costs and depleted resources are still unanswered. These topics are driving forces which increase markets for goods involving innovative materials with improved properties.

The Factories of the Future PPP is expected to facilitate the development of cost-effective, safe, affordable and friendly technology and production equipment for processing these new materials, such as:

- Composite material manufacturing processes (tape laying, fibre placement) and the recycling of these materials after end of life;
- High strength and light weight metal components including hollow, foam and sandwich structures;
- Functional surfaces obtained by micro-texturing: it has long been known that the functional performance of tools, workpieces, solar cells, aeroengine blades, medical implants, prostheses and components for many industrial sectors can vary depending on the surface features, e.g. controlled porosity on a tribological surface can contribute to friction reduction at sliding contact interfaces;
- Development of new manufacturing technologies to handle, process and validate new materials for the upscale production of renewable energy sources, such as fuel cells, photovoltaic solar cells, thermal concentration solar systems or wind energy systems;
- Developing and characterising high throughput processes for length scale integration (micro / nano) and manufacture of components and devices with complex 3D features in a single material;
- Micro- and nanomanufacturing systems: design, modelling and simulation tools. Intelligent, scalable and adaptable micro- and nanomanufacturing systems (processes, equipment and tools integration);
- Scaling-up of production processes of nanomaterials and coatings for multifunctional applications in nanomedicine, energy, transport and electronic devices; and
- Manufacturing process improvements to increase efficiency, safety and performance of light materials, such as magnesium and Al-Mg alloys, for instance to reduce weight and emissions in transport.

6. Stakeholders involvement

This "Factories of the Future" PPP strategic multi-annual roadmap should not be seen as representing the perspective of only one group of stakeholders, nor as having being realised through narrow, highly specialised approaches. The knowledge of the wider community of stakeholders, embracing all the relevant manufacturing sectors (users, customers, researchers, environmentalists, etc.) is expected to be integrated together for this initiative, including:

- The European Manufacturing Industry: large companies, SMEs (including knowledge-intensive SMEs), as well as the Trade Associations. This includes both supplier companies for production technologies and customer companies.
- The European Research and Education sectors: universities and polytechnic schools, basic research centres, applied research organisations, technology centres and technology brokers.
- MANUFUTURE and its European, National and Regional Technology Platforms, and related Sub-Platforms.
- Other European Technology Platforms (ETPs).
- EFFRA – The European Factories of the Future Research Association.

Moreover, the research areas identified in this FoF PPP Strategic Multi-annual Roadmap can deserve action on a global scale. In that context, it is worth exploring if joint activities involving partners from outside Europe would lead to win-win situations. Where appropriate, international bi- /or multi-lateral collaborations might be envisaged to maximise the benefit for European industry and society. In this sense, the Intelligent Manufacturing Systems initiative (IMS) and, in particular, the IMS2020 coordination action, should be taken into account.