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UPDATED DRAFT

Factories of the Future PPP

Strategic Multi-annual Roadmap

Prepared by:
Ad-hoc Industrial Advisory Group
Factories of the Future PPP

Note: This document is an updated DRAFT resulting from the work of the Ad-Hoc Industrial Advisory Group of the Factories of the Future Public Private Partnership. The final version of this document after consultation to the wide stakeholders community is expected in early December 2009. For any information or to provide comments, please contact: rbueno@fatronik.com.

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1. Introduction and Background

Introduction

The Factories of the Future Public Private Partnership (FoF PPP) 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 mandate to help define the research content of this initiative. The present document lays out industrial research priority areas for the implementation of the Factories of the Future Public-Private Partnership covering the period from 2010 to 2013.

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

The prepartion of this draft is also based on a wider stakeholders consultation, including 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), 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 oriented towards industrial application. Therefore, research priority areas include industrially relevant demonstration elements, especially for the benefit of SMEs. Increased demonstration activities are foreseen towards the end of the period in 2012-2013. Project results are expected to be implemented into production improvements within two years after the conclusion of the project.

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. On this basis, the main R&D needs have been derived, so that the achievement of the proposed goals will allow the European industry to face its main challenges in the coming years.

In today’s economic situation any research in technology in Europe would need to comply, as this initiative will do, with two requirements: the results of the research should start to pay back tax payers’ money after around four years and should make a significant contribution to the sustainability of society in Europe.

A sustainable business in Europe needs to approach sustainability not only in terms of energy and resource efficiency but also regarding the social issues related to its employees. There are many family type businesses in Europe that have functioned very successfully according to these concepts over decades. In addition, the European Factories of the Future need to be based on European ethics. Technology development will be placed into such context in order to achieve the goal of making a significant contribution to the European society. This requires a rethinking of internal strategies in enterprises.

The “Factories of the Future” PPP initiative arose as a European response to the current economic crisis. This crisis shows that sustainability as a strategic goal not only focuses on maintaining an adequate workforce but also on rewarding the investors. Environmentally friendly operation, including energy and resources efficiency, is a logical consequence. This has led to formulate “The Factory made in Europe” as a product of the future, in the framework of the this PPP, addressing simultaneously the competitiveness and sustainability challenges.

A factory is no longer a smart conbination of autonomous machines and processes that can easily be shifted to any other location in the world, but it is an entity which focuses on intelligent person-machine cooperation in which advanced technology is as important as a sound 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 impact will be to keep manufacturing-related jobs in Europe.

As an outcome of the strategic reflections, the European manufacturing industry needs a paradigm shift, from cost cutting approaches to knowledge-based value adding, in order to achieve a sustainable and competitive growth. Any future technology cannot be regarded in isolation.

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 include the following strategic sub-domains:

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

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 products, processes ans systems is the key concept: innovation leading to a new life-cycle based product-service, manufactured in a sustainable way, responding to the needs of customers and society.

By developing a public-private partnership (PPP), there is a commitment from both the public and private sides to invest in new technologies and innovation that will sustain businesses in the long term. For that reason, it is the aim of this roadmap to inspire industries to develop and demonstrate knowledge-based innovation leading to a European sustainable and competitive manufacturing.

2. Vision and strategic objectives

Europe is one of the main players in the global economy and manufacturing industries contribute to a large extent to this situation. In the globalised world of the third millenium the following Social, Technological, Environmental, Economical and Political (STEEP) factors are the main drivers for the current and future economy: Globalisation of the economy, Climate change, Scarcity of strategic raw materials, Overpopulation, Employment, Energy security of supply, Ageing population, Public health for all, Poverty and social exclusion, Loss of bio-diversity, Increasing waste volumes, Soil lost and Transport congestion.

In this context, many enterprises are struggling to survive in the currently turbulent markets, and some are leaders in markets and effectiveness. Others see their future in services and emerging technologies. Their base is technical innovation and strong customer-orientation. They are known worldwide as high performing manufacturers and deliverers of high-quality technical products. They all need to be orientated to the future vision and strategic development of factories in general as well as to the concrete plans for the specific changes to the particular factory system. This makes it necessary to implement the “Factories of the Future” initiative and secure and share experiences of the structural changes required to transition from the factory system of the past to more competitive and sustainable factories.

From the manufacturing R&D perspective, the above-mentionned global drivers lead to a new response: Competitive and Sustainable Manufacturing (CSM).

The new paradigm of CSM:

- interacts with the Social, Technological, Economical, Environmental and Political (STEEP) context
- generates wealth, sustains jobs, manages human and physical resources: i.e from materials to energy, from food to intermediate and consumer products.
- concerns High Added Value products/services, processes sustaining their life cycles, business models, stakeholders involved
- relies on stakeholders ranging from: Industry, to Research Institutes, Universities, European, National, Regional Public Authorities and intermediate Organizations, implementing the Research Innovation Market Value Chain
- sustains the Knowledge generation, diffusion and use

CSM requires the transformation of the European Manufacturing Industry into a High Added Value (HAV) and Knowledge-based Industry, aiming at global leadership, through HAV Knowledge-based products / services, processes and business models. All European manufacturing related industries need to be orientated to the future vision and strategic development.

The strategies envisaged aim at:

- increasing the efficiency of survival and transformation of enterprises to the requirements of customisation and sustainability,
- boosting the level of technologies of products and production towards global leadership,
- globalizing Europe as producer of factories and factory equipment (lead markets) with intelligent products and new business models,
- activating the potential of emerging technologies and developing solutions for emerging markets.

In the current turmoil, the pursuit of CSM is fundamental for relaunching the “real economy”, as the new frontier. The European Union is already addressing it. To pursue CSM, the Manufuture European Technology Platform has developed the necessary Strategic

Intelligence: i.e. 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 and Roadmaps and related implementation framework.

The recently launched European Economic Recovery Plan called for a "Factories of the Future Initiative", based on the Manufuture European Technology Platform and related European Technology Platforms and Sub-platforms in the field of manufacturing.The development and implemention of the "FoF PPP", requires:

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

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

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

In line with the goals set out in the European Economic Recovery Plan, this Factories of the Future PPP Strategic Multi-annual Roadmap (2010-2013) has been prepared to help EU manufacturers across sectors, in particular SMEs, to adapt to global competitive pressures by increasing 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.

3. Main industrial needs and related R&D challenges

Introduction

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

A key factor to strengthen European leadership in product engineering and manufacturing systems development will be the ability to achieve cost efficiency, high performance and enhanced robustness, within the increasing product variability and the continuously changing production volumes, both discrete and continuous.

Drivers	Factory Cost	Flexibility Convertibility	Optimized Shop Floor Mgmt	Maintainability	Environment & Safety
Production System	• Standard & lean • Low cost solutions • Modular and re-usable (“agile”) • Plug & Play modules • Industrial wireless applications • Life-cycle approach	• Flexible/Agile Systems • Re-programmable • Convertible solutions • Intelligent and rational use of automation vs. operators	• Integration of shop-floor automation at plant level • Intuitive HMI & field data collection and analysis • Virtual engineering • Digital Manufacturing (modeling & simulation)	• Local sensors for process monitoring • Remote diagnostics • Tele-service (WEB network)	• Design for safety and ergonomics • Energy saving applications • Innovative process (new joining technologies, MQL machining, ...) • Innovative materials • Dismantling

Sustainable Manufacturing Systems - Evolution Drivers

In the actual scenario of global market competition the main industrial needs and R&D challenges to achieve a higher competitiveness of the manufacturing systems may be described in terms of general evolution drivers, as follows:

a) cost efficiency as pre-requisite, with extensive adoption of standards in production machinery, equipment and controls and massive use of lean-cost solutions;
b) low Time To Market, from concept to market of new products thanks to ICT applications, which will more and more expand their reach in manufacturing industries;
c) low Time to Customer, reduced Lead Time from order to delivery to the Customer according to the specifications and the technical capability of the final use
d) increased focus on high-end components/goods through the implementation of enabling processing technologies and materials
e) quick and easy transformability/re-configurability through a modular approach in factories archetypes, in order to maximize model independency of machinery and continuous re-use of existing infrastructures
f) higher and stable product quality through increased process robustness and easy maintainability, thus impacting directly manufacturing key performance indicators (KPI);
g) higher productivity under better safety and ergonomics conditions, through an upstream integration of workplace optimization for human well-being;

h) optimised consumption of resources through the use of energy and material efficient processes and machinery, renewable power sources and extensive recovery of heat and dissipated energy.
i) better reusability of systems and applications towards global interoperable factories, able to provide services and develop products, anytime, anywhere, independently of the used technologies, culture or language in use in the different sites.
j) global knowledge merging for a "seamless knowledgeable factory of the future". Increased global knowledge will result in better production, less cost, less time to market and to customer, and enlarged opportunities for manufacturing business.

Manufacturing related R&D shall focus on incremental transformation of the main characteristics of the competitive scenario, towards "sustainable life-cycle cost": re-usable, flexible, modular, intelligent, complexity reduced, digital, virtual, affordable, easy-to-adapt, easy-to-use, easy-to-maintain and highly reliable "Factories of the Future".

3.1 Sustainable manufacturing

The competitiveness of European industry is promoted by generating step changes in a wide range of sectors and implementing decisive knowledge for new applications at the crossroads between different technologies and disciplines. A key objective for the manufacturing industry is not only to design green products, but also to produce goods using a sustainable approach. Sustainable production is defined as the creation of goods and services using processes and systems which do not pollute and which limit the consumption of scarse resources (feedstocks, energy; water, raw material,..) while respecting the constraints of economic sustainability and ofsafety and health of the workers. To close the loop on sustainable manufacturing, a clear support for “de-manufacturing” or advanced recycling/reuse of products/process materials is equally required.

For European industry, sustainability needs to be today a key strategy. Manufacturers have taken up the challenge of designing a sustainable production system that has less environmental and social impact. The Sustainability is now at the centre of industrial Research & Technology Development. Environmental challenges such as climate change and resources scarcity are the sources of both constraints and opportunities for technological developments. The challenge of the research is to satisfy both environmental and product needs, generating high added-value products, related processes and technologies to meet customer requirements as well as growth, public health, occupational safety, environmental protection, and societal values and expectations.

The following aspects should be considered and developed:

- ***New Eco-Factory model*** (short term impact): optimised utilisation of energy streams, the environmental impact reduction and the 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 to increase the overall efficiency by the conservation of resources and energy, the elimination of emissions and wastes by point source treatment and recycling.

Sustainability (balance in economic growth, social well-being and environmental friendliness) will be assured through enhanced environmental awareness in production systems design, sustainable manufacturing processes and supply chain.
The new Eco-Factory models and Green Product Manufacturing provide the means to design and produce sustainable products with drastically reduced resource consumption, enhanced advanced manufacturing processes based on renewable resources and safety and ergonomics for operators, users and customers.

The new Eco-Factory models and Green Product Manufacturing will be addressing at the same time:

- <u>Environmental friendliness</u>: specific solutions to minimize the environmental impact and resources consumption with minimum cost increase;
- <u>Economical growth</u>: technological and methodological solutions to achieve cost reduction by means of optimised resource management and consumption;
- <u>Social well-being</u>: safety/ergonomy of current and new manufacturing facilities as well as new ways of interaction between machine and human beings to redefine men’s role in the manufacturing environment.

(a) Environmental friendliness: The new Eco-factory, thorughtout technologies for resource efficiency and cleaner manufacturing, can cut up to 20% of energy consumption by monitoring production equipment resource usage, replacing and/or up-date out of date equipment, configuring systems according to differentiated processing needs, buying multi-functional devices and by simply ensuring equipment is turned off after use. The main objectives are the following:

- (a1) High efficiency and zero emissions production and manufacturing processes: based on 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 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: enabling low resource input, low emission and tailored for product and different activities like surface treatments/functionalisation, painting, coating and joining, development of compact processes, ensuring high process productivity while reducing environmental impact (proposed for 2011).
- (a3) Generation of renewable energies at factory level: development of new solutions for Green House Gases emission reduction by alternative material, energy sources and innovative technology application (proposed for 2012/13).
- (a4) Processing environment neutral materials: growing use of alternative materials in production environment (use of renewable materials, heavy metals control), coherent management of hazardous materials (measurement methods, treatment standards) and increased use of bio-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: Improve the sustainability of the product portfolios through new processes, technology or procurement changes, incorporating at the same time the needs and requirements of the users of the products.. The research area will be focused on the investigation of technological and methodological solutions with high potential in term of cost reduction supported by advanced decision making tools and correlated to optimisation of resources waste and equipment efficiency:

- (b1) Methodologies and tools on sustainable maintenance: aiming at the reduction of the production cost, through more efficient and energy conscious processes. Research should focus on smart and agile maintenance approaches that may increase the lifetime of the production equipment, increase its energy efficiency and reduce its maintenance cost. At maintenance process level, projects should address key relevant issues, such as maintenance flexibility, conflict handling in volatile production environments, predictive maintenance planning and scheduling, use of advanced embedded information devices, integration with MES and ERP systems. At equipment level, R&D should demonstrate tangible results, such as increased lifetime of critical components, increased resistance against failure, reduced energy consumption, minimized wear or corrosion, etc. (proposed for 2012/13).
- (b2) Methodologies and tools to support the re-use of final product, production equipment and infrastructure, by means of higher cross sector standardisation and modular approach. R&D should focus on proactive modularization and re-use strategies for the development of the future machinery and production systems 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 product design (proposed for 2012/13).

- (b3) Economical and technical methodologies for risk analysis: Probabilistic risk assessment in the design of manufacturing systems should be considered as a methodology to evaluate risks associated with a complex and/or innovative technological equipment design and fast integration capable of switching from producing one model to another to meet fluctuating and diverse demand. The results of the risk analysis for process design will identify and quantify risk for each equipments and their potential impact on economics and Time To Market. By constantly monitoring these risks and applying the mitigation plan, which include also the lesson learned from other applications of new equipment/technologies (process and knowledge archetypes), will result in a cost and schedule savings with an impact on the project in terms of reduction of breakdowns, quality problems and human errors (proposed for 2012/13).

(c) Social well-being: The main objective of this section is to develop new forms of interactions between machinery and human beings in such a way that future factories can be operated economically profitably and at the same time provide an interesting an challenging environment for people. The new Eco-factory will be characterized by a large variety of sophisticated technology and at the same time provide the advantage to use the ethical properties of the most sophisticated microsystems we know: the human being. The history of manufacturing proves that the cultural background of people in a factory are a determining factor for its success and a key element of distinction between well and not so well functioning installations. For the envisioned new factory the environment for humans will provide the best starting position for products with short cycle time and high variability, for handling possible ups and downs in economic cycles, for quick adaptation of manufacturing capability and the development of knowledge. These novel manufacturing environments have to be designed for cost effective production to assure a mix between advanced production systems and people's capabilities and capacities. Research area will be focused of redefining or reunderstanding workers capabilities:

- (c1) Adaptive and responsive human machine interface: Solutions have to show in a convincing way how a factory can be run economically profitably and at the same time provide a sustaining work places for the humans working there. Advanced adaptive and responsive technical devices have laid the foundation for the possibility of creating such environments. Aspects to be covered should outline the technological approach, technical requirements for the factory installation and at the same time provide evidence that this operation makes use of the cultural and ethical qualities of the people working there, inspire how employment mechanisms have to be designed so that economic conditions are observed while avoiding outsourcing people in times of economic down turns (proposed for 2012/13).
- (c2) New human skills to interact with factory environment: developing scenarios for a manufacturing environment that interlinks the personell skills of humans with machines in such a way that human ingenuity, intuition and structures learning is enhanced and changing working conditions met due to the quality of human behaviour and not due to – admittedly for special tasks – smart machines. It should be proven that human interaction, human complex knowledge and the ethical attributes of human behaviour build a strong long term asset as a absis for a longterm stable industrial enterprise (proposed for 2012/13).
- (c3) The new production site: for Europe to compete against low wage countries, on the one hand every employee has to contribute to the full potential of his abilities and develop these further. On the other hand management of European enterprises has to safeguard

parts of the return on investment for the further development of the local enterprise. Research and study of best practice is necessary to understand and prove that this mixture can lead to very successful factories and thus make a strong sustaining contribution to European society. Technology as a basis for this is well developed, now interdisciplinary research has to show the way on how an understanding of the ethical and cultural is a necessary ingredient for success, looking for stable society that provides for a sustenance through production, work that stabilizes individual human beings with dignity (proposed for 2011).

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 business processes in an increasingly globalized industry, requiring continuous change of 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 fatories in different industrial sectors.

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

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

(a) Smart Factories: Agile manufacturing and customisation

Future production sites with 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. Related industry driven R&D activities include:

(a1) Advanced[1] process automation, control and optimisation technologies and tools. Novel large-scale control-intensive applications for high yield performance and energy efficiency to validate and benchmark the effectiveness and usability of the integrated automation and control systems (proposed for 2011).

(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, thus providing cooperative machines and constrol systems for scalable factory solutions (proposed for 2011).

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

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

[1] Advanced means adaptive, fault tolerant, optimising, reconfigurable, self-, etc.

(a5) Laser applications: (i) Novel lasers and adaptative and dynamically controlled laser materials processing systems, and (ii) further development of mass customisation applications (proposed for 2011).

(a6) New metrology tools and methods for large-scale and real-time handling of manufacturing information. Assessment of manufacturing, automation, handling and metrology equipment using standardised methodologies and metrics (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 knowledge from data thereby supporting decision making and creating value from global networked operations ('virtual factories'). R&D activities include:

(b1) Increasing management efficiency of global networked manufacturing: Enabling technologies under the emergent Internet of Things (IoT), 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 the 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 or disposal (proposed for 2012/13).

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

(b4) Managing volatile manufacturing assets: Manufacturing knowledge is essential to the survival of Europe's industrial competence. A migration to virtual manufacturing environments requires robust methods to manage intangible assets such as knowledge (e.g. bill-of-material, recipes, routings, inventories) and IPR (distributed across production sites, stakeholders and machinery) (proposed for 2012/13).

(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 (eg. innovative methods for knowledge capturing; innovative access to new and existing knowledge on products/services, effectively supporting re-use of knowledge and collaborative work on product/design/manufacturing/usage) across stakeholders (digital competence & knowledge profiling methodology can be used for the management of design capabilities) and the lifecycle, for example from use to design (proposed for 2012/13).

(c2) <u>Enhanced, interoperable models:</u> Better and 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 hidden impacts of gradients in stress, temperature, etc. (proposed for 2012/13).

(c3) <u>Design environments:</u> Self-organising, collaborative design environments able to adapt to the needs of different sectors and industries besides facilities for modelling, decision-making (eg. 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) <u>Lifecycle management:</u> 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 environmental as well as economic and social issues, classical lifecycle assessment (LCA) methods and tools may prove inadequate for a holistic lifecycle assessment which is based on a consistent set of information on products, components and energy. The results of LCA analyses need to be analysed, aggregated and made available to product designers to effectively feed them back to future products. Decision makers should be able to weight 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 deeply modifying the conditions for any decisions on industrial investments in production equipment, and particularly for SMEs. Therefore, the return on investment must be justified in such a manner that the risk of loss is presented as being under control during the whole duration of the investment project.
This seems to lead, more than before, to an increased need of technical solutions, which would require to be less based on complex systems entirely composed of heavy machines and spreaded out automation. On the contrary, these solutions should be based on light and adaptive systems, with an increased role of the human workers, with more human/machine safe interactions.

The planning of progressive production investments should be possible, as well as the easy reconfiguration from small to large production series, or small to large production capacity using flexible technologies such as modular production units. Furthermore, new solutions should allow the integratation of the necessary ICT support providing simplification and real user friendliness.
Moreover, the cost of transportation and the capacity of the international logistic flows able to cope with the variation of the orders, could stimulate that more production is handled "locally" (in Europe for the European manufacturing). This is expected to increase the investments for high performance manufacturing in Europe.

The main research areas relevant to high-performance manufacturing include:
- those aimed at the conception of new machines production systems and plants at macro and micro level:

- Flexible adaptive machines and production systems, process equipments and plants for rapid (re)configuration and low energy consumption
- High precision micro-manufacturing machines and systems

- and those aimed at the development of new methodologies and tools for the design and management of machines and systems:

- Planning tools and in situ simulation for open reconfigurable and adaptive manufacturing systems, process equipments and plants
- Zero-defect production and manufacturing

(a) Flexible adaptive machines, systems and plants for rapid (re)configurations and optimal energy consumption

The current industrial market is characterized by a turbulent and uncertain demand of highly customized products, whose complexity is in constant increase. Compared to the past, the quality requested by customers is higher, accepted delivery times are lower, as well as products lifecycle. Two additional aspects must be considered: the current negative financial situation pushes manufactureres 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 equipments and production systems to products and process evolution, with special consideration to traditional industries. The research areas will be:

- (a1) New high performance manufacturing technologies in terms of efficiency (volumes, speed, Capability of Processes) and accuracy, providing smooth and even super finishing conditions. New system architectures with self-adaptive machine structures based on mechatronic modules, multi-layer controls and highly redundant sensing and actuator structures will be the object of the development. Furthemore, machines will require less shop floor space, by means of reduction of peripherals, optimization of cycles and process planning (proposed for 2011).

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

- (a3) New hybrid production systems for manufacturing and assembly, based on improved robotics technology for human and robots cooperative production tasks. These systems will be developed considering the specific needs of small and medium enterprises (proposed for 2012/13).

- (a4) Adaptive machines for optimal energy consumption. The main objective will be the flexible adaptation of electric-fluidic energy resources for high performance drives. Concepts such as generating energy on demand and feed-forward strategies will 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. Miniaturization of products and production appliances and integrated compact systems design are 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.

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

- (b2) 3D Micro-parts Production. 3D microcomponents using a wide range of materials (metallic alloys, composites, polymers, ceramic) and on large volumes. New process chains integrating different processes tecnologies (e.g. Machining, EDM). Analysis of the microstructural behaviour of materials and its interaction with the production process. Quality issues for micro components, measurement machines and equipment, fixturing and handling systems (proposed for 2012/13).

- (b3) Micro Manufacturing Systems. A new generation of modular macro/meso/micro machine tools and robots with self adaptive and reconfigurable capabilities to implement a portable and easy configurable factory for manufacturing and assembly of high tech miniaturized devices. Development of an appropriate control system for supervision and reconfiguration and quality standards for Micro systems. New tayloired business models for the Micro Manufacturing Systems targeted to SMEs (proposed for 2012/13).

(c) Planning tools and in situ simulation for open reconfigurable and adaptive manufacturing systems

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

- (c1) Methodologies and tools for reconfigurable manufacturign systems design for healthy, green and safe custmer products, that define the set of resources and the control system architecture whose characteristics and performance optimally match the demand and the process plan over time. Production system solutions will also face internal uncertainty, such as unforeseen events, by continuously tuning process parameters and production flows (proposed for 2001).

- (c2) Knowledge based tools for process planning. A platform integrated in the information and execution system of factories will be realized for non linear process planning. By considering "local" productions and outsourcing, these tools will allow to optimise and monitor manufacturing, wherever in the world the processes are running at (proposed for 2012/13).

- (c3) Integrated shopfloor simulation, that will work in an integrated way on different levels (machine, cell, line and factory). The connection with the machine/system control will allow to start simulation from the real current status. Receiving results of simulation, multilevel decision support sytems that will support workers tasks will be developed (proposed for 2012/13).

- (c4) Advance and interactive graphical user interface that allows workers to deal with the increased complexity of simulation and decision systems embedded in machines and lines (proposed for 2012/13).

(d) Zero defect manufacturing
Customisation and reduction of lot sizes down to "build to order" causes the cost of set up, changing processes and adaptation to explode. Innovative solutions are needed in support of customization and build to order strategies in automotive supply, electric and electronic components industries inducing the reduction of losses through quality control and the increase of efficiency in manufacturing. New quality monitoring methodologies are needed grounding 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 constituting intelligent and self-optimising manufacturing and production systems.

- (d1) Quality monitoring and proactive process improvement for geometric shape data New quality monitoring tools for multiple geometric specification on product's shape able to quickly detect unusual or out-of-control shapes. New approaches for process optimization aiming at selecting the best settings for controllable factors to best target the specifications. Multiresolution measuring systems and distributed intelligent measuring systems will be developed (proposed for 2011).

- (d2) Intelligent Measuring Systems for Zero-Defect Manufacturing. Development of fast and reconfigurable measuring systems for accurate and time efficient measuring through the multiresolution measurement devices integrating low/medium resolution and high resolution systems. Distributed Intelligent Measuring Systems reconfigurable both in space and time acting in coordination with other measuring devices to form complex and articulated measurement systems (proposed for 2001).

- (d3) Advanced decision-making tools for zero defect manufacturing, to pursue cost-effective process chains since the early phases of product development. New tools to enhance the empirical and derivative approach of design procedures by means of defect-tolerant product configurations, analysis and optimization of tolerance specifications, selection and evaluation of manufacturing processes and validation of equipment (proposed for 2012/13).

- (d4) Developemnt of a new generation of knowledge-based self-learning systems through multi-layer controls and model based real-time compensation routines, embedding machining process knowledge. Optimization of process capability (Cp) by means of In-Process or Pre-Process measurements taking full advantages of sensored machines 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 are working with new materials to take advantage of increased functionality, lower weight, lower environmental burden, energy efficency as well as providing for a sustainable manufacturing base by moving to high added value prodcuts 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 materials combinations such as sandwich structures and composites and smart materials involving integration of sensing and actuation technology within a material (e.g. smart textiles). In other cases, there is a need to work with and more effectively integrate bio-inspired materials with conventional and new materials to meet the needs of new bio-industries and environmental targets.

Most industrial sectors of importance to European manufacturing have a requirement for manufacturing with new materials using new and improved processes which will form a basis for future Factories of the Future. The transport sectors are driven by a need to reduce weight to improve energy efficiency as well as to provide a degree of cutomisation (particularly automotive) and key changes are required in greater use of low weight materials such as composites and in efficient use of high value added metals such as high strength steels and nickel based alloys. Moreover, the drive towards renewable energy sources is stimulating new industries able to respond to the increased demand for wind, wave and tidal, solar, fuel cells and hydrogen options.

New materials such as composites (and composites on a large scale) as well as photovoltaics now need to be manufactured to volumes and costs not previously anticipated, whilst ensuring manufacturing emissions are minimised.

The fashion market, in the textile, garment and footwear sectors, is a major traditional manufacturing base of Europe, where new approaches are needed to retain a global advantage for consumer and specialist products. This requires, for example, mass customisation and increased functionality as well as high flexibility and cost efficiencies. In paralell, this is a fertile ground for the development of new materials, namely technical textiles for high added value added applications, such as consumer products, construction, transportation, energy and medical, requiring 3D shaping, drapability, anisotropy in new automated factories. Design plays an important feature of the manufacturing process for tailor made solutions production, as well as considerations for a complete change in traditional industries. Integration of electronics and customisation of smart products also demand for new manufacturing conditions.

Electronics and photonics are core to many other sectors providing the ‘smartness’ into many new materials on the one hand and the intelligence to support manufacturing operations on the other, by means of improved sensing and control systems. Within Factories of the Future, there is a strong connection between ICT and manufacturing (see Section 3.2), much of which is realised by the intelligence just referred to as well as in providing new flexible manufacturing options by increased use of laser technologies and roll-to-roll manufacturing.

The bio-inspired industries range from industrial biotech (e.g. plant, marine) to new health related products, including food processing, that utilise bio-materials such as biopharmaceuticals, stem cells and integrated biological materials with modern and new implantable and/or biocompatible materials (e.g. polymers, metal alloys). At one level there is a need to manufacture such new multifunctional materials into products that span a biological-physical interface. At another level there is a need to introduce good manufacturing practice for such products (automation, quality control, traceability) with volume learning from existing industrial practice. Due to the high cost of the testing and analysis phases prior to market delivery, simulation of the product behaviour made of bio-materials with the respective manufacturing process is crucial.

Spanning many of the above sectors and more, Europe is at the forefront of micro-nano-research, stimulating a new family of materials that provide the functionality to meet specific industry needs. Such materials require new manufacturing processes to convert them into products that function at the micro-nano scale particularly for volume manufacture within a safe environment. Manufacturing to combine materials with integrated macro-micro-nano-features are required to cover such processes as design, assembly, joining and reliability (e.g. new coatings on traditional substrates).

Manufacturing as a horizontal activity can contribute to these industrial applications with common requirements able to ensure a value contribution to a large manufacutirng base. The prioritised range of manufacturing processes able to respond to industrial drivers are:

(a) Net shape manufacturing for advanced structural and functional materials Net-shape manufacturing technologies have gained industrial significance for 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 of materials and processing costs (proposed for 2012/13).

(b) New material functionalities through manufacturing processes
The interaction of new manufacturing processes and new materials can have a considerable influence on the quality and function of new products, providing significant added value. There are several key aspects, all of which require development of new manufacturing platforms able to transfer laboratory processes to high and/or customised volume production:

- Using manufacturing processes to integrate materials of different scale and functionality to provide completely new products with new functionalities
- Incorporating smartness into new structures by 'manufacturing-in' sensing and actuation technologies in new materials.
- Enhanced processing of new materials with novel laser sources including new wavelengths based on improved understanding of light / matter interactions.
- Roll-to-roll manufacturing of large area and high throughput flexible plastics electronics 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).

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

(d) Sustainable material processing technologies and associated product design.
New materials bring new challenges in sustainable manufacturing that require new approaches for low resource input 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, improved behavior and functionality. This will then provide significant reduction of currently unused or undesirable processing emissions and new methods to process micro-nano-materials (minimising potential environmental and human health impacts). 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) Manufacturing process modelling and simulation. Research should focus on applicable modelling and simulation technologies in the fields of processes with mechanical, energetic, fluidic and chemical phenomena for modelling and simulation of parts manufacturing (proposed for 2012/13).

(d2) Manufacturing of engineered composite materials. The research should be focused on the development of new and innovative technologies aiming at increasing the reliability and reproducibility of the so called smart composites (proposed for 2011).

(d3) Manufacturing processes for new flexible materials and textiles. It focuses both on investigation and exploitation of new materials and textiles, and on innovative processes - such as surface modification techniques/high tech treatments - to improve final performance and properties, safety, comfort, fashion and appeal of for example, footwear and other consumer products (proposed for 2012/13).

(d4) Up-scaled systems for high performance manufacturing of textile-based structures for high value added and XXXL size applications. Technologies driving tailor-made solutions in the field of textile-based structures, high value added near net shaped 3D products, produced with varying volumes are the current need of the technical textile manufacturing industry (proposed for 2012/13).

(d5) Light-matter interactions and new wavelenghts for enhanced processing of new materials. The rapid development of new laser systems and optical components make it necessary to head into R&D work of new processing parameter possibilities (proposed for 2012/13).

(d6) Materials for energy generation and supply. Advanced energy systems of all kinds (fossil fuel or renewable are becoming progressively more dependent on the performance of the materials used for their construction and for functional purposes. Therefore it is important to ensure the sustainability and cost-effectiveness of the manufacturing processes and of the components in service (proposed for 2012/13).

(d7) Manufacturing chain for bulk nanophased components. The research should be focused on the updating/development of high throughput processes (extrusion, forming, casting, quick sintering processes) able to produce net-shape or semi-finished products with nanotechnologies and nanomaterials (proposed for 2011).

(d8) Complete Manufacturing chains for Nanophased Coatings. Future technologies for setting up highly engineered nanocoatings requires, beyond available source nanophased/engineered powders, highly organized and intelligent manufacturing chains having at the core quick time/temperature processes allowing the tuning of nanostructures (proposed for 2011).

4. Timeline and budget

The Factories of the Future PPP covers the period from 2010 to 2013, with a total budget of €1.2 billion, half of which coming from 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 to provide industrial input for the preparation of the FP7 Work programmes 2010. DG Research and DG INFSO are going to launch a dedicated Coordinated Call of €95 million, which can be expected to raise around €65 million of private R&D investment. This results in a total R&D investment of around €160 million into Factories of the Future PPP in the year 2010.

Table: Indicative topics in the FoF PPP Coordinated Call in Workprogramme 2010

Identifier	**Title**
FoF.NMP.2010-1	Plug and Produce components for adaptative 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 below has been made according to the preliminary definition of research priority area and number of priority R&D topics expected within each area. One tentative budgetary scenario is outlined in the tables below:

Table: 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: 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 whole Factories of the Future PPP as proposed has a first direct economic impact in all issues related to innovation and research. This public-private partnership for research will stimulate the innovation activities in more European manufacturing related companies, specially SMEs, as the Factories of the Future PPP is specifically focused on this type of companies. Moreover, the research and development results will not stay in just one sector: manufacturing spreads thrugh most of the industrial sectors and therefore the new production methods, processes and technologies will reach industries across the whole Europe and beyond.

An important impact is linked to the cooperation, as requested in the Factories of the Future PPP objectives, between the academia and the industry. This research programme will further promote the joint research activities of the researchers, both from industry and from academia, towards a common goal.
Focusing in the manufacturing companies in Europe, largely represented by SMEs , there is a close link with regional clusters for diverse manufacturing sectors with an important amount of jobs. The manufacturing industries' landscape in Europe has a close relation with regional clusters of interconnected companies that provide to their specific regions a very significant amount of jobs and wealth. These regions can be identified in several areas as e.g. north of Italy, south west Poland, south west Germany, north of Spain. With the current decline of finance and real state based economy, those industrial clusters are back again the pillars of the European regions' economy.

Regarding the international aspects of the economy, such a PPP will have two main positive impacts. On one side, the export share of the European manufacturing equipment builders' will be reinforced as a result of the achievement of the Factories of the Future PPP's technological objectives. European capital equipment is renowned by its quality; improving it together with an increased environmental performance will lead to competitive advantages. Moreover, in relation to third countries, the use of this equipment will also lead to ecological and economical advantages due to a reduced environmental impact.

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 the need of material resources, reduction of emissions and 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 manufacturing sector, both providers and users of manufacturing equipment need to achieve more ambitious environmental goals so to keep their competitive advantage in face to other regions.

Savings in energy consumption and related operating costs, more productive European factories by means of the use of more energy efficient manufacturing systems. Decrease of CO_2 footprint of European Production Equipment life-cycle and decrease in factory processes CO_2 footprint worldwide when incorporating "European Factory" concepts

Savings from improved manufacturing systems utilisation by means of continuous sustainability tracking along the whole manufacturing chain, increased lifetime of industrial systems and structural parts and increased resistance against failure by optimized materials

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 on implementing sustainable manufacturing, and as an additional spillover effect, the rest of the manufacturing industry in Europe will follow the trend set up by the first industries getting results through the Factories of the Future PPP in sustainable manufacturing.

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

As far as information and communication technologies (ICTs) are concerned, they contribute significantly to economic growth. Europe however is still lagging behind the US and this PPP, through its contribution to *intelligent manufacturing,* may help European industry to catch up on productivity.

Smart Factories: Advanced automation and control are key technologies to help all manufacturing sectors become more competitive, energy efficient and innovative. The size of the world market in monitoring and control is EUR 180 billion of which Europe has about a 30% share. There are more than one million robots operational in industry worldwide . The automotive industry accounted for only 36% of the 2007 supply, whilst their use in the electrical/electronics industry and food & beverages sector (the latter mainly in Europe) showed significant increases. Industrial robots have also moved away from traditional tasks like welding to handling and assembly operations. The focus of activities should not so much be on heavy industry sectors but particularly in the light industry, those market domains which until now have been "robot-resistant", e.g. co-worker robots in the food industry or "apprentice" robots in SME industries. Future production sites with a large variety of sophisticated products will have to offer flexible, short cycle time and variability controlled manufacturing capability. These manufacturing approaches ensure energy efficient, reliable as well as cost effective production. This will impact on: (a) Higher level of intelligence on the shop floor through context-aware, fault-tolerant, adaptable, reconfigurable interoperable, wireless and robust ICT. (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 as well as the end user industry. (c) Development of an early European market for advanced technologies such as electronic and photonic devices, automation equipment, and robot systems.

Virtual Factories: ICTs, whilst still playing a major role in productivity improvement, they increasingly play an important role as a business value proposition differentiator. ICTs if integrated end-to-end can provide clear insight and exact knowledge from data thereby supporting decision making and creating value from global networked operations. This will impact on: (a) Improved efficiency of (embedded) product intelligence enabling advanced product-centric services (e.g. product authentication, IPR security, ICT-facilitated diagnosis and repair, 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 so that better informed manufacturing decisions can be taken. The handling of uncertainty is also a crucial area. This will impact on: 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"

The world economy and society are transforming. A new international division of labour is emerging, with the rise of players such as Brazil, Russia, India and China (the so-called BRIC economies) and the increasing globalization of production. With the growing relevance of manufacturing SMEs within the European economy in terms of GDP and number of jobs, the increase of competitiveness and production flexibility became critical aspects for the survival on this changing and uncertain 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 on productivity.

The reliability of machines 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 ratios. In that sense, mechatronic strategies based on adaptronic systems, intelligent materials or vibration damping systems can compensate deviations on initial accuracy requirements detected by the continuous monitoring and control system.

Generally speaking, the achievement of more reliable and efficient manufacturing systems (machine tools, fixturing, cutting tools and peripheral equipment), integrating also process modelling and part's quality prediction, could entail benefits about:

- Reduction of the number of rejected components (scraps) and the amount of material used;
- Reduction of the cost and weight of manufactured assemblies;
- Increase the throughput, tool life and machining speeds maintaining repeatability and accuracy;
- Reduction of the waste, power consumption and number of finishing operations;
- Minimise or even eliminate the use of coolants (dry cutting), reducing environmental pollution around factories;
- Extend maintenance intervals;

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

The demands of the 21st century society for solutions of the "grand challenges" 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 depleting resources are still unanswered. These topics are driving forces which increase markets for goods employing innovative materials with improved and incredible properties.

Factories of the Future PPP is expected to make a significant contribution to these big open issues, facilitating the development of cost effective, safe, affordable and friendly technology and production equipment for processing these new materials:

- Composite processing: automated processing (tape lying, fibre placement) of windmill blades, a process that nowadays is being made manually. This automatic placement could leave to benefits of 70% on time for producing a blade as well as a reduction of 80% on finishing operations.
- Functional surfaces obtained by microtexturing: It has been known that the functional performance of tools, workpieces, solar cells, aeroengine blades, medical implants, prosthesis and components for many industrial sectors can vary depending on what surface features are present or dominate, 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)
- Scale up of production processes of nanomaterials and coatings for multifuctional applications in nanomedicine, energy, transport and electronic devices.
- Manufacturing process improvements to increase efficiency safety and performance of light materials, like Magnesium and Al-Mg alloys, to reduce weight and emissions in transport..

6. Stakeholders involvement

The Factories of the Future PPP vision and action plan cannot be seen in a single perspective, nor realised through narrow, highly specialised approaches. An integrated knowledge community must be created, embracing a broad variety of manufacturing interests, and including as many actors as possible, such as:

- The European Manufacturing Industry: large companies, SMEs (including knowledge intensive SMEs) and midsize companies, as well as the Trade Associations. This includes both supplier companies for production technologies and customer companies.
- The European Research and Education Infrastructure: Universities and polytechnic schools, basic research centres, applied research organizations, Technology Centres and Technology Brokers.
- MANUFUTURE European, National and Regional Technology Platforms, and related Sub-Platforms.
- Other European Technology Platforms (ETPs): Sectorial European Technology Platforms, Enabling technologies ETPs, ICT Manufacturing relevant ETPs and other Trans-sectorial ETPs
- EFFRA – The European Factories of the Future Research Association.

Besides, research areas identified in this FoF Strategic Multi-annual Roadmap can well deserve a global action. In that context, it is worth exploring if joint activities involving partners from outside Europe would lead to win-win situations. Therefore, international collaborations (bilateral and/or multi-sided) have to be envisaged, when appropriate, trying to maximize the benefit for European industry and society. In this sense, the Intelligent Manufacturing Systems initiative (IMS) and, in particular, the IMS2020 coordination action, need to be taken into account.