Manu*Future*© Platform

STRATEGIC RESEARCH AGENDA

assuring the future of manufacturing in Europe

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Abstract:
This is the document prepared by the Manufuture Platform which outlines the European strategic manufacturing industrial response to the foreseen global industrial revolution. Such response is based on research and innovation and requires moving collectively towards the European knowledge economy. This strategy is related to the Manufuture Initiative report "A Vision for 2020" published in November 2004.

Note:
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The Manu*future* Platform is a self-sustained organization funded by contributions from its members.

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Manu*Future* Platform

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Assuring the future of manufacturing in Europe

HIGH LEVEL GROUP AND SUPPORT GROUP

with the collaboration of
EPP Lab (ITIA-CNR)

Table of Contents

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To the Strategic Research Agenda reader

The document is made of 2 sections, **Strategic perspective and Manufacturing Agenda.**

The Glossary and the Manu*future* Examples complete the document and are available on the web site www.manufuture.org.

- **The Strategic perspective** section provides introductory elements concerning the economic importance of Manufacturing, taking in consideration the European Economy , the industrial sectors sustainability and European world leadership. This approach introduces to a collective response based on a strategic analysis relating to the Knowledge based Manufacturing Paradigm (Make and Delivery High Value Products and Services) and the Roadmap for Industrial Transformation.

  Considering a set of six drivers of changes (Competition, Rapid technology renewal, Eco-sustainability, Socio Economic Environment, Regulation, Values- Public acceptability) the collective response is outlined at multilevel action providing consideration and reflection in paragraph 2.3 about European, National/Regional and SME levels.

- **The Manufacturing Agenda** section focuses on the **transformation of Industry and of R&D**. This transformation is seen through **strategic pillars** (New added value product and services, Innovating Production, Infrastructure and education). Dedicated paragraphs describe in detail the topic with strategic goals description and Key research and intervention areas defining priorities features, RTD targets and Areas/Enabling Technologies within time horizon.

  In particular the pillar **Innovating Production** is threefold (new Business Models, Advanced Industrial Engineering, Emerging manufacturing sciences and technologies) with R&D context needs and expected RTD based responses.

  As far as the **transformation of R&D** is concerned pillar infrastructure and education covers this issues taking into consideration innovation in SME's (paragraph 5.1), Management changes and prospective RTD system (paragraph 5.2) and two level strategy for skill and Educational needs (paragraph 5.3).

  Chapter 6 and 7 mark the path towards the **implementation of the Agenda** introducing the importance of coordination of manufacturing activities at European level relating to the European Technology Platforms level including innovative SME's as strategic part of the industrial value chains.

  This path is supported by **Recommendations** for needed actions to set framework conditions to educational initiatives - like the Manu*future* International School for Industrial Research - and for establishing the EMIRA (European Manufacturing Innovation and Research Area) within the European Research Area in order to position Europe in the global RTD network.

  The Conclusions remark the needs for research for established and new manufacturing sectors, business models, advanced industrial engineering and emerging manufacturing science and technologies build on the strength and diversity of its businesses and regions.

PREFACE

Following the launch of the Manu*future* European Technology Platform in December 2004 in Enschede, Manu*future* took onboard the task of elaborating the Manu*future* vision document towards a Strategic Research Agenda (SRA).

As the Manu*future* vision took a holistic approach towards transforming the European manufacturing industry, by necessity, the SRA in its complete form will be a multifaceted and sizeable document. The present document represents the first iteration of such an SRA, presenting a new manufacturing paradigm, a high level roadmap for industrial transformation and its principal technology, business and framework drivers.

Subsequent versions of the SRA shall be providing more detailed roadmaps of the prioritised technology and research areas together with estimates of required investments and implementation plans for private and public initiatives/activities.

EXECUTIVE SUMMARY

The Manu*future* Technology Platform was launched at the second Manu*future* conference, held in Enschede, The Netherlands, in December 2004. On this occasion, the document Manu*future – a Vision for 2020* was published as the basis for development of a Strategic Research Agenda (SRA) underpinning a transformation of European manufacturing industry into a knowledge-based sector capable of competing successfully in the globalised marketplace.

The economic importance of sustaining a strong manufacturing base in Europe is indicated by the fact that it provides jobs for around 27 million people, and produces an added value exceeding €1 300 billion from 230 000 enterprises with 20 and more employees (2001). Some 70% of this total derives from six main areas – automotive engineering, electrical and optical equipment, foodstuffs, chemicals, basic and fabricated metal products, and mechanical engineering.

Although European manufacturing has huge potential for generating wealth, jobs and a better quality of life, it faces intense and growing competitive pressure on two fronts. In the high-tech sector, especially, other developed economies pose the greatest threat. On the other hand, manufacturing in more traditional sectors (mature sectors) is increasingly migrating to low-wage countries such as China and India. And these, too, are rapidly modernising their production methods and enhancing their technological capabilities.

A step further

A number of 'vertical' action plans and Technology Platforms have already been established, or are in the course of preparation, to tackle these issues in various technology- or sector-specific contexts. Manu*future* goes a step further by addressing underlying 'horizontal' approaches applicable across a broad spectrum of industries.

The initiative advocates a response based on an industrial transformation which will strengthen Europe's ability to compete in terms of high value, since purely cost-based competition is not compatible with the goal of maintaining the Community's social and sustainability standards. The initiative fosters also the transformation of R&D and Education infrastructure for high value manufacturing for a more and more "efficient" generation, distribution and use of knowledge in Europe and, specifically, in its regions.

Concentrations of such efforts will *attract* high value manufacturing industry as well as the other fundamental actors such as universities and research centres even from outside Europe.

In this SRA, the priorities for maximising added value are distilled in a strategic perspective linking the principal drivers of change with a series of 'pillars' of activity spanning activities across the short- to long-term timeframe.

The drivers are identified as:

- competition, especially from emerging economies;
- the shortening life cycle of enabling technologies;
- environmental and sustainability issues;
- socio-economic environment;
- regulatory climate; and,
- values and public acceptance

The competitive and sustainable reaction to these challenges is seen in terms of five pillars and their associated new enabling technologies for the industrial transformation of:

- new, added-value products and services
- new business models
- new advanced industrial engineering
- new emerging manufacturing science and technologies
- transformation of existing R&D and education infrastructure to support world-class manufacturing

Role for collective research

Collective research will evidently have a central part to play in realising the transformation. Attaining the objectives of the Lisbon and Barcelona Councils will only be possible by involving the largest possible number of stakeholders.

The existing and proposed Technology Platforms, whether applied at EU or national/regional level, therefore represent an extremely important conduit for sharing the Manu*future* concepts and results.

Another stakeholder group of outstanding importance is the innovative SMEs and other independent enterprises, which figure largely in the structure of all manufacturing sectors. Their participation in the integration activities of engineering platforms will engage them in partnerships across Europe, reinforcing the ability of the manufacturing infrastructure to achieve rapid, reliable progress from research results towards marketable products.

Traditionally, European products are associated with high quality, appealing design and cutting-edge technology The effectiveness of the Manu*future* research agenda in transforming industry will depend upon manufacturers' readiness to leverage these strengths, while adapting continuously to change in an open, fast-moving global industrial environment.

New products from new technologies

Developments in enabling technologies, such as innovative materials, nanotechnologies, ICT and mechatronics give almost limitless possibilities to develop new products or add functionality to existing product concepts. European industry must have access to these technologies and to the tools for incorporating them into product designs.

From products to product/services

The market increasingly demands products that are customised, yet available with short delivery times. It is essential that European companies be able to understand and satisfy the needs of customers, regardless of their geographical location. Consequently, the business focus must increasingly shift from designing and selling physical products, to supplying a system of products and services ('product/services' or 'extended products') that are jointly capable of fulfilling users' demands.

Product/services will offer greater satisfaction of customers' needs, reduce total life-cycle costs and environmental impacts, and avoid problems associated with the conventional buy-use-dispose products.

Innovating production

A fundamental concept of the Manu*future* vision is that of 'innovating production', which embraces new business models, new modes of industrial 'manufacturing engineering' and an ability to profit from ground-breaking manufacturing sciences and technologies.

Even the factories themselves are regarded as complex, long-lived products, operating with the latest technologies and adapting continuously to take account of customers' and market requirements. The 'virtual factory' of the future will manufacture in adaptable networks linking OEMs with value-chain partners (often SMEs) and suppliers of factory equipment/services selected according to needs at a given time. Its composition will not be limited by the presumption of physical co-location, nor by a need to maintain rigid long-term relationships.

In such a dynamic environment, entrepreneurial sprit will be a vital commodity. This has to be fostered by RTD and educational infrastructures that promote the exchange of ideas, the mobility of researchers, the shift towards multidisciplinary and the lifelong learning that will be essential to tomorrow's 'knowledge workers'.

Favourable climate

Reaching these objectives will depend on the implantation of supportive fiscal and legislative framework conditions at EU market scale. The realisation of such a favourable boundary relates to conditions developed at national and regional level.

A consensus of support for the Manu*future* vision will naturally enable the creation of a European Manufacturing Innovation and Research Area (EMIRA) as an integral part of the European Research Area. It will promote the interests of European manufacturing industry, take account of regional and national needs, promote participation to European Programmes (Framework Programmes, Eureka and other initiatives) and recognise Europe's wider role in the global RTDI network.

STRATEGIC PERSPECTIVE

In December 2004 in Enschede (NL), the Manu*future* Technology Platform was launched with the aim of enabling Europe to begin providing answers to the challenges facing its manufacturing industries.

At that time, Manu*future – a Vision for 2020*[1] was published, recommending the development of a strategic research agenda that would propose framework conditions for the transformation of the European manufacturing sector.

This science, technology and innovation plan that follows is designed to foster a call for European organisations to invest in a brave new effort to create a manufacturing industry capable of generating strong economic growth for the EU in the globalised marketplace.

It seeks to direct investment towards an ambitious but realistic set of targeted research, innovation and education activities, which would transform the competitive basis of producing and delivering the products and services our society expects.

A distinguished group of industrialists and academics from across Europe collaborated to produce this first evaluation of research priorities. This document represents a step towards a Europe-wide consultation process that would ensure the appropriateness of its proposals for all regions and all stakeholders within the Community.

This first version will be made available on the Manu*future* website (www.manufuture.org), which will serve as the forum to disseminate its content and gather comments.

The report that follows is not meant to be a specific work programme, but rather proposes a structure within which medium- to long-term strategic and innovative measures can be undertaken with synergistic effect in aiding the transition of European industry towards a new knowledge-based manufacturing system.

[1] http://europa.eu.int/comm/research/industrial_technologies/pdf/manufuture_vision_en.pdf

1. Economic importance and the Manufuture Process Implementation

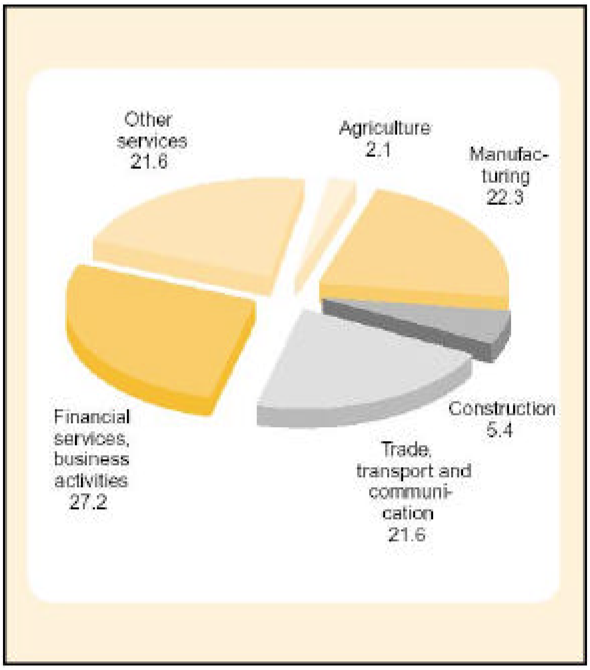
> "The mission of Manu*future* is to propose a strategy based on research and innovation, capable of speeding up the rate of industrial transformation in Europe, securing high-added-value employment and winning a major share of world manufacturing output in the future knowledge-driven economy."
>
> Manu*future* – Vision for Manufacturing for 2020

Key to economy and sustainability

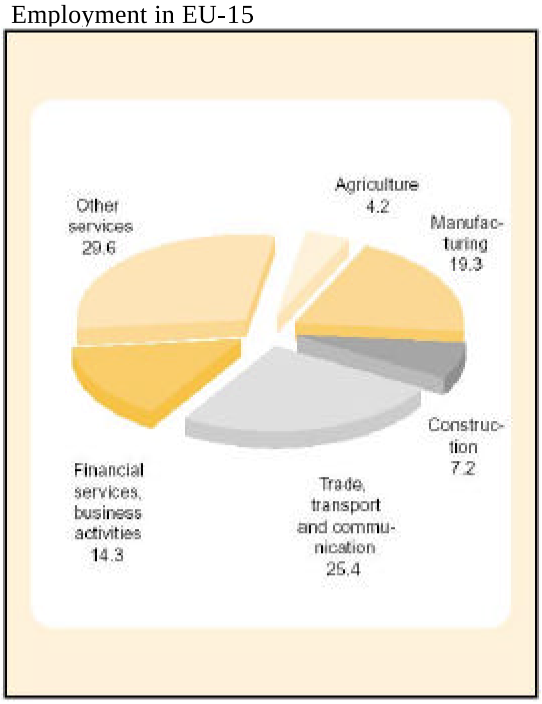
Around 230.000 European manufacturing enterprises with 20 and more employees provide 27 million people with jobs. In 2001, the last available reporting year, the value added by manufacturing amounted to more than €1 300 billion. Some 70% of this total was derived from six main areas – automotive engineering, electrical and optical equipment, foodstuffs, chemicals, basic and fabricated metal products, and mechanical engineering.

The European Manufacturing Statistics outlined the role of manufacturing in Europe and enabled to find common grounds with the stakeholders and with sector specific European technologies platforms.

Share of Manufacturing Industries at Gross Value Added in EU-15

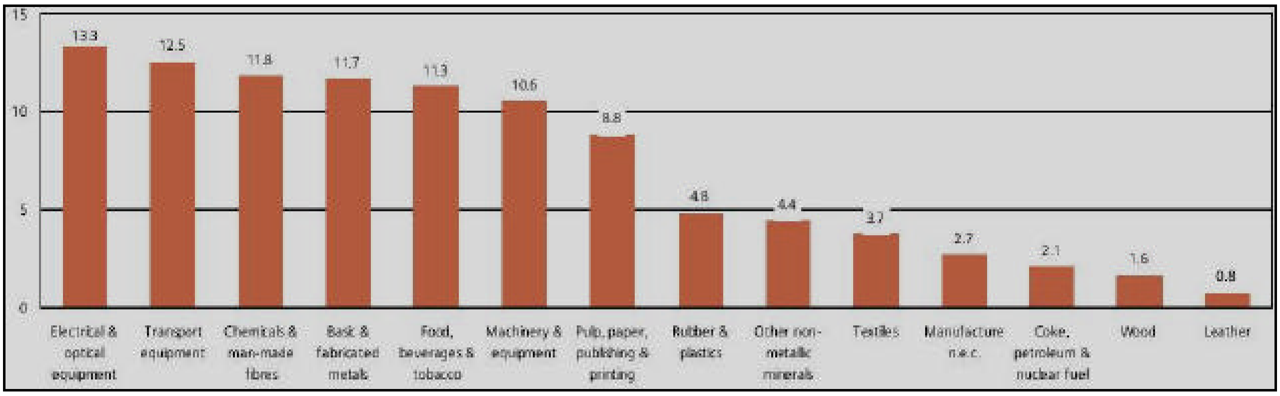


Share of Manufacturing Industries at Employment in EU-15



Source: EUROSTAT[2] "

[2] EUROSTAT , "Economic Portrait of the European Union, 2002"



Largest EU manufacturing activities
(share of manufacturing value added at factor cost)[3]

Apart from its economic and social importance, the location of manufacturing industry in Europe contributes to sustainable development through more efficient production and reduced transport costs, thus supporting the aim of decoupling growth from increased resource use.

Another import argument, as advanced in the *FuTMaN* report (Future of manufacturing in Europe 2015-2020 – the challenge for sustainable development [4], is that: ‘Not only does R&D drive new developments in manufacturing, but more importantly, manufacturing is the contextual driver for more R&D. The trend to move manufacturing physically abroad places strains upon the communication channel between manufacturing and R&D centres. At the same time within management discussions the conviction is growing that it leads to destruction of vital business interests. The view is shifting towards a mid-term perspective.

Leading the world

Moreover, European manufacturing is a dominant force in international trade. In 2002, the EU’s share of total global manufacturing trade was 18%, while the US had 12% and Japan 8%. In some key sectors such as automobiles, mechanical engineering, agricultural engineering and certain categories of telecommunications equipment, EU companies have achieved global leadership. These show above-average competitiveness and account for 42% of total manufacturing exports, although mechanical engineering and chemicals alone account for 31%.

Pursuit of the technological and organisational transformation described in the Manu*future* vision document will be crucial in sustaining and strengthening this vital activity.

The activities recommended in the following pages focus on the realisation of a set of four strategic objectives.

- Competitiveness of sustainable European manufacturing industries:
    - to survive in a turbulent economic environment by improving economic results (growth);
    - to benefit from migration of technologies;

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[3] Source “NACE Subsections, 2001”

[4] http://europa.eu.int/comm/research/industrial_technologies/pdf/pro-futman-doc1-final-report-16-4-03.pdf

- o to create more and high-added-value jobs;
- o to instil a culture of continuous innovation in products and services, concentrating on innovation efforts on cross-sectorally important technologies.

- Leadership in manufacturing technologies:
  - o to support innovative products and platforms;
  - o to lead manufacturing with global standards;
  - o to reach the forefront in networking;
  - o to ensure competitive efficiency and labour productivity.

- Eco-efficient products and manufacturing:
  - o to reduce adverse environmental impact;
  - o to cut the consumption of limited resources;
  - o use of renewable resources
  - o to maximise the benefits of each product throughout its life cycle.

- European leadership in cultural, ethical and social values and also in processes and products:
  - o to understand the interrelationship between social and ethical values and the prosperity of an enterprise;
  - o to ensure welfare and social standards of living, supportive of innovative and entrepreneurial business;
  - o to guarantee human and social standards of work.

Manu*future*, an industry-led initiative[5], aspires to promote investment in innovation that will ensure the future of European manufacturing in a knowledge-based economy. It represents a planning and implementation initiative that defines, prioritises and coordinates the necessary scientific technical and economic actions to achieve the objectives set out above.

R&D in this Agenda is considered a driving parameter to generate innovation and it should be profitable, becoming the High Tech competitive advantage, turning into profitability the relationship between R&D and manufacturing applications, what presently appears to be a weakness in Europe. R&D does not exclude other ways to generate innovation.

Its inherent value for investors, such as industries, research institutes, governmental and non-governmental organisations, lies in structural characteristics that permit an open and inclusive pan-European communication in medium- and long-term activities. Its goals are to encourage collaborative approaches towards high-level objectives; and, without directly relating to Governments' policies, to gather the resources necessary to unblock shared scientific and technology bottlenecks.

Through the inspiring governance of the platform, the achievement and delivery of the technology and innovation targets and deliverables is expected to provide the needed impetus for change towards an innovating European industrial system for manufacturing, capable not only of successfully competing but also of leading the world through research-derived knowledge and innovation.

[5] For further information refer to URL www.manufuture.org or contact Prof. H. Flegel at heinrich.flegel@daimlerchrysler.com

2. Response based on strategic analysis

The socio-economic and technological drivers identified in the Manu*future* vision document[6] pose various challenges for future European manufacturing. To address these challenges proactively and in a timely manner, industry, and policy-makers need to reconcile policies and approaches with the objectives of competitiveness and sustainable development.

A time span of 10 to 15 years can bring about dramatic changes. It is not only industrial labour that is cheaper in some regions outside Europe, but also engineering and management. Today, Europe still has the possibility and means to counteract this situation, but it must do so in a decisive, concentrated manner based on sound strategic analysis.

Apart from the contributions of the Manu*future* Support and High Level Groups, the solutions and research priorities proposed in this document are anchored in a number of recent strategic foresight studies, reports and workshops. Among the most significant are *MANVIS* (Manufacturing Visions - Integrating Diverse perspectives into Pan-European Foresight[7]) and *FuTMaN*[4]. The key conclusions of these two foresight studies are provided in Annexes. A bibliography of other important studies and workshops organised in the context of Manu*future* is given at the end of this document.

A common thread extracted from these studies points the way forward. The new 'knowledge-based manufacturing paradigm, the requisite 'roadmap for industrial transformation' and its principal technology-, business- and framework-enablers will be laid out in the following chapters.

For sure, new views must be adopted, so that threats in some cases may turn into new opportunities.

In this way, delocalization and entering in the new markets may facilitate the birth of new (often mini) European Multinational Companies generating knowledge and retaining know-how in Europe.

[6] Manu*future* – a vision for 2020, pp. 10-11

[7] http://www.manufacturing-visions.org/ManVis_Report_2_Final.pdf

2.1 Knowledge-based manufacturing

European manufacturing has huge potential for generating wealth, jobs and a better quality of life. It is generally knowledge-intensive, and embraces many different sectors: from the supply of capital equipment – machinery, systems and their related technologies and services – to the production of goods ranging from aircraft and spacecraft to intermediate-tech traditional products up to more labour-intensive industries. As the mainstay of the European economy and employment, however, manufacturing industry must continually adapt itself in order to survive in a globalised economy. Active and far-sighted technology development is indispensable, as is a rapid response to social and economic change.

New paradigm needed

The current industrial paradigm is no longer adequate to meet these needs. On the one hand, the EU faces continuing competition from other developed economies (i.e. Korea), particularly in the high-tech sector. On the other, manufacturing in more traditional sectors is increasingly taking place in low-wage countries such as China and India. The real threat of this process for Europe lies in the rapid take-up of automation in these countries.

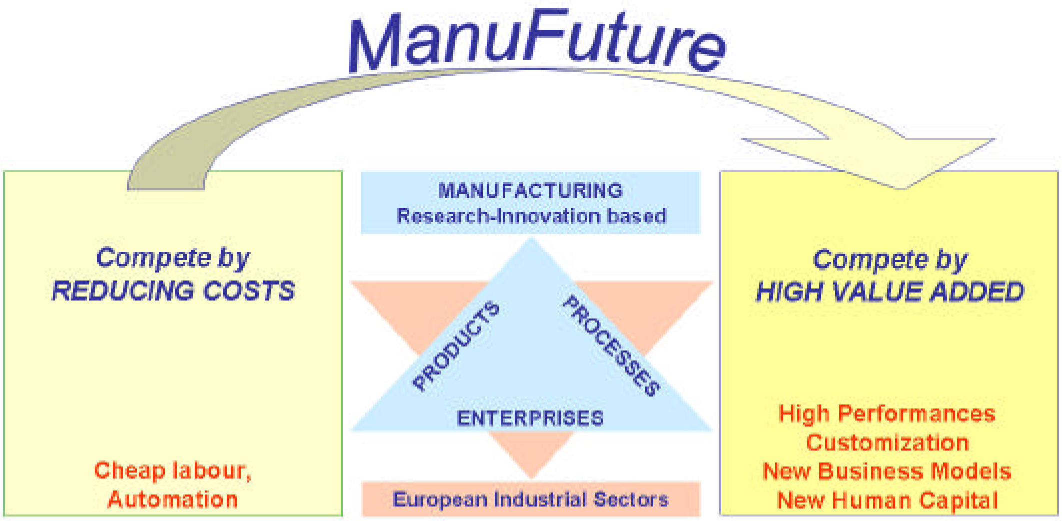

Figure 1. *- Competition shift - from reducing costs to high added value: Manufuture (Source ITIA-Series 2004)*

Europe must respond by strengthening its ability to compete in terms of added value, meant as hi-tech competitive advantage; this added value is the leverage to achieve dominance in markets, since purely cost-based competition is not compatible with the goal of maintaining the Community's social and sustainability values. This added value can be increased by introducing:

- innovative materials RTD-based;
- production systems;
- processes and products;
- developing new business models;
- and teaching/nurturing high-level skills and competences.

However, certain industries are physically tied to the European region. Therefore R&D in manufacturing must also support continuous productivity and efficiency gains in order to maintain the competitiveness of these industries.

2.2 A roadmap for industrial transformation

In the medium-term – i.e. up to the 2015 time horizon of the Manu*future* vision – foresight studies indicate both demand and opportunities for manufacturing. In summary, the main **drivers** of change are:

- competition, especially from emerging economies
- the shortening life cycle of enabling technologies
- environmental and sustainability issues
- socio-economic environment
- regulatory climate
- values and public acceptance

The competitive and sustainable reaction to such challenges is seen in terms of **five pillars** and their associated **enabling technologies**:

- new, added-value products and services
- new business models
- new advanced industrial engineering
- new emerging manufacturing science and technologies
- transformation of existing R&D and education infrastructure to support world-class manufacturing

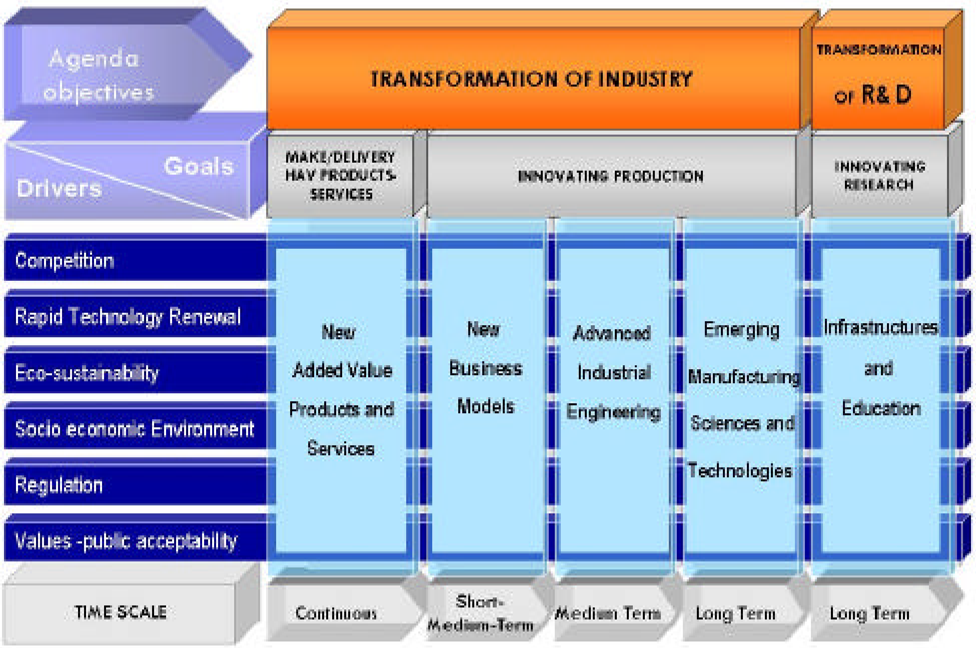

Figure 2. *Industrial transformation reference model guided by drivers, and based on five pillars to achieve an innovating environment for European enterprises .Time scale refers to when impact starts to be realised.*

Appropriate knowledge-based solutions can be derived using the industrial transformation reference model shown in Figure 2, and research areas and targets be prioritised on the basis of criteria such as the expected value addition. This document proposes a framework for the necessary transformation of European industry, and of the related RTD and educational infrastructures, under headings that correspond to each of the five pillars. As shown in Figure 3, the approaches used and the results obtained can be transferred to sectoral domains, according to their specific needs.

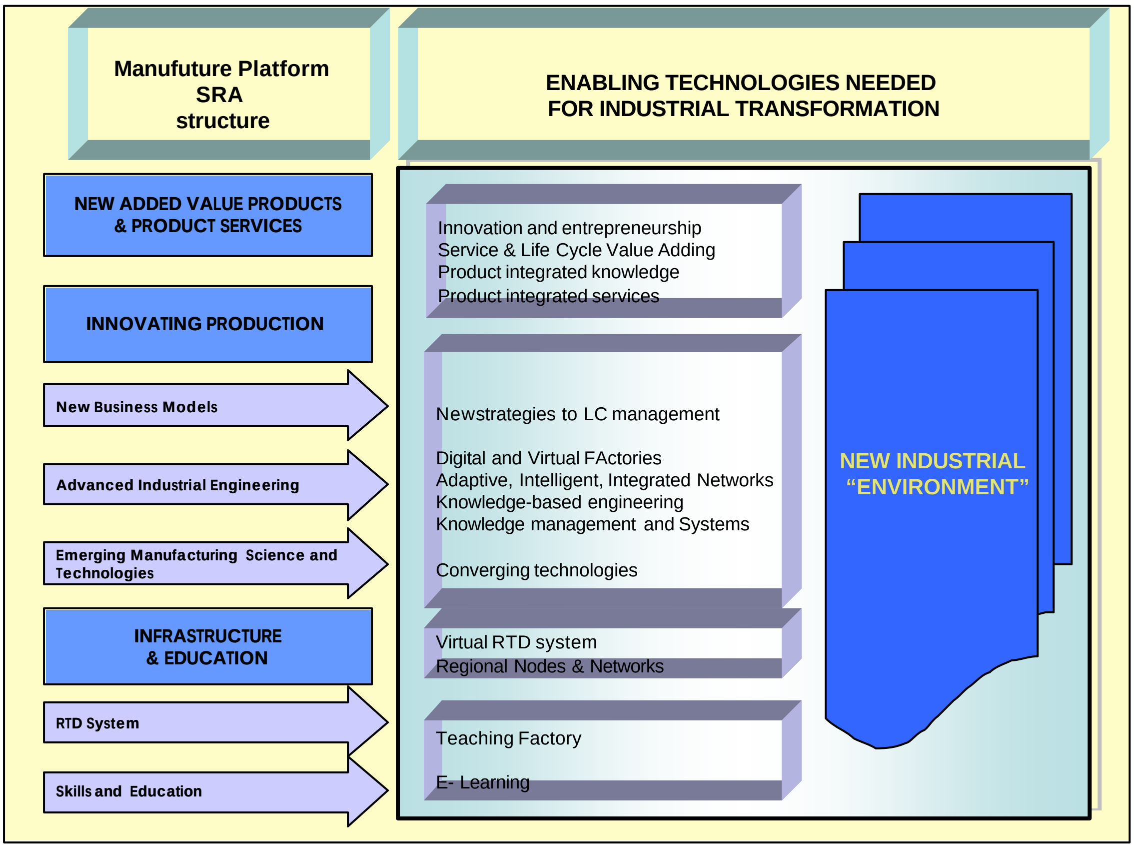

Figure 3: *Enabling manufacturing technologies for industrial transformation - global pillars (left) and Manufuture examples (right)*

Only with a concerted take-up of the elements of this 'new environment' throughout Europe EU industry will be capable of sustainable competition in worldwide markets.

2.3 Multi-level action

For Europe to move towards knowledge-based manufacturing and, hence, shift from cost-based to high-added-value competition, it is essential to combine the interests of the various sectors of industry, and to coordinate their RTD efforts.

Collective research will evidently have a central part to play in this process – reinforcing the European fabric by building networks of OEMs, technology services providers and SMEs; creating new kinds of supply chain, establishing R&D centres, etc.

Attaining the objectives of the Lisbon and Barcelona Councils will only be possible by involving the largest possible number of stakeholders. In this context, the benefit of cooperation between Manu*future* and the various existing and proposed Technology Platforms focusing on common goals and action plans – whether applied at EU or national/regional level, and whether sectoral or technological in scope – relates to the process of sharing the Manu*future* concepts and results, together with assessing a common "core" of business or areas of interest.

At European level

With the common purpose of overcoming problems posed by the complexity and diversity of the EU manufacturing scene, European Technology Platforms (ETP) can be considered as 'collective' stakeholders. They include:

- Sectoral European Technology Platforms such as in road transport, construction, aerospace, textile, food, etc...
- Trans-sectoral ETPs such as in industrial safety, micro-nano technologies, etc....
- Enabling technologies ETPs such as in embedded systems...

The objective of collective activities, resulting from the interaction between Manu*future* and the other technology platforms, is to define an all-inclusive strategic research agenda taking into account Europe's overall manufacturing needs from sectoral, trans-sectoral and enabling technologies viewpoints.

The mode of intervention will be to further promote the new industrial paradigm of high added value, using the industrial transformation reference model for coordination of manufacturing R&D actions at all interrelated levels.

At National/Regional level

National Technology Platforms related to the Manu*future* European Technology Platforms should be created in individual EU Member States, all adopting the main development goals identified in both *Manu*future – *a vision for 2020*[1] and the current document. Other initiatives can also stimulate the emergence at regional levels of equivalent concepts promoting competitiveness via synergy between sciences, education and industry. At the end, a coordinated effort at all levels is working with the aim of defining the manufacturing research priorities and committing to make it happen.

Aligning the development goals and priorities of all 25 Member States is therefore crucial in building a common interest in close co-operation between production companies and R&D organisations as a foundation for expansion into global markets.

National and local initiatives will be particularly important in the new Member States. After many years of socialist regulation, their move towards market economy – in R&D, as in other spheres – is a major mental, organisational, technical and financial challenge.

At SME level

Another stakeholder group of outstanding importance is the innovative SMEs and other independent enterprises, which figure largely in the structure of all manufacturing sectors.
SME's are main players in several sectors, capable to develop, produce and sell innovative products and services to more and more demanding consumers. In others, they are linked in diverse networks with OEMs in the value chains of:

- product engineering and design;
- production of parts, components and systems;
- supply and distribution of materials and products;
- supply of manufacturing equipment;
- services.

Their participation in integration activities in engineering platforms will engage them in a long term partnerships across Europe reinforcing the reliability of the manufacturing critical infrastructure for quick transfer of research results to marketable products.

MANUFACTURING AGENDA

The effectiveness of the Manu*future* research agenda for industrial transformation and for enhancing the capability of European regions to attract high value manufacturing industry even from outside Europe is highly dependent upon the readiness of European industry (the majority of which is composed of SMEs and other companies with less than 500 employees) to adapt continuously to change in an open, dynamic and global industrial economic environment.

Three criteria of excellence define the ability of organisations to enhance their management of performance within the results-oriented framework that would be created by widespread take-up of this SRA:

1. Delivery of ever-improving value to customers, contributing to greater marketplace success;

2. Improvement of overall effectiveness and capabilities such as networking, adapting and knowledge acquisition;

3. Continuous learning by organisations.

The starting point will be the definition of the new higher-added-value products and services that will be the outcomes of industrial transformation.

Next, innovative models of production will be required, in order to enable new factories effectively to deliver such products. This will demand:

- new business models;
- a new culture of advanced industrial engineering;
- emerging manufacturing sciences and technologies.

At the same time, the RTD and educational infrastructures must be brought into line with the new needs.

SMEs should play a central role in this process, because of their capability to adapt continuously to changing business conditions through the deployment of the latest available technology. The SMEs which will be able to be responsive enough will act as Transformable Enterprise Units and will be the “glue” to integrate networks of producers and users of knowledge for the high value manufacturing.

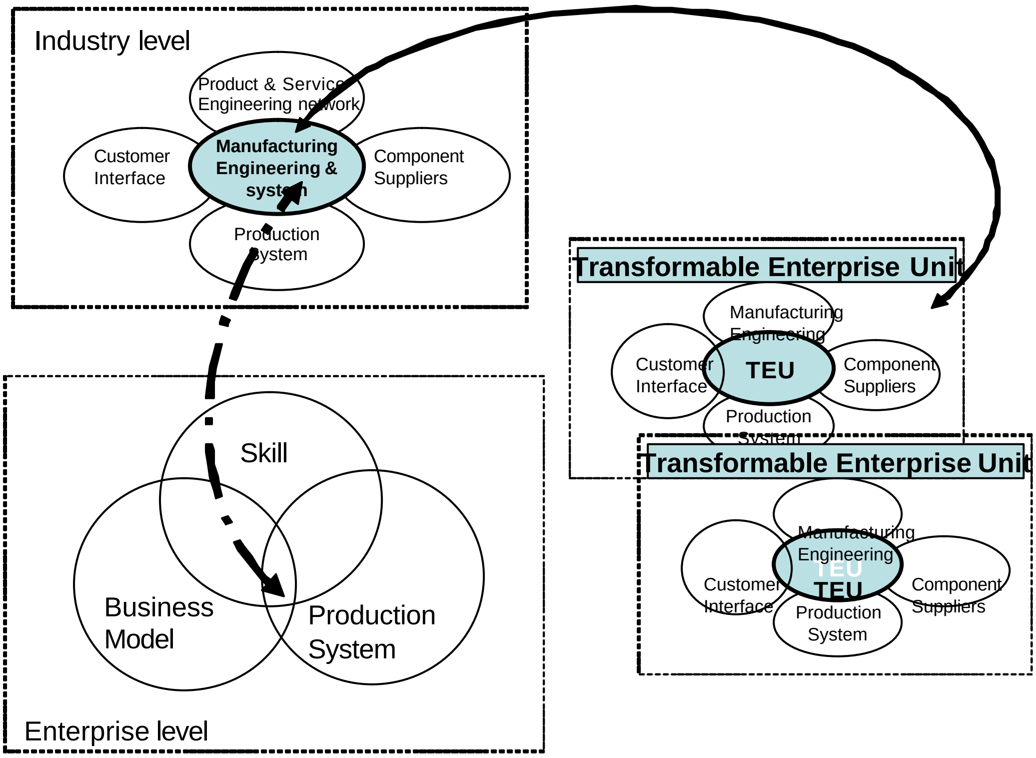

Figure 4. *Creating the right environment will enable all enterprises, especially SMEs, to develop in-built capability to transform rapidly by adapting continuously to changing business conditions through deployment of the latest available technology tailored to their specific needs. SMEs should be responsive enough to act as the 'glue' to integrate networks.*

3. New added-value products and product/services

The strategic goal N. 1

European industries achieve business leadership through continuous innovation of new products. The concept of a product encompasses components, consumer goods and capital goods – and extends to the provision of entire production facilities. High added value and superior quality result from exploitation of world-leading developments from European RTD in enabling technologies such as innovative materials, nanotechnologies, ICT and mechatronics. Focus increasingly shifts from 'product delivery' to sophisticated provision of product-based functions and services.

Traditionally, European products are associated with high quality, appealing design and cutting-edge technology; in many industrial sectors they continue to compete successfully in the marketplace. However, it is becoming increasingly difficult for Europe to contend in those areas where labour charges form a significant part of the overall manufacturing costs. In addition, the window for generating profits is becoming smaller and smaller as competitors are fast to get on-board. Often, they are able to undercut the price of the market pioneer – unless copying of the idea is too difficult (by design of the product/service, coupled with strong protection of intellectual property) to allow market entry.

Although the European manufacturers can make significant headway in improving the competitiveness of their manufacturing processes, competing on cost, quality and delivery alone will not provide a viable solution – therefore European products must evolve into high-added-value product/services.

While the importance of high-added-value products is indisputable, it must be emphasised that **continuous innovation in manufacturing processes as well as in products** will be central to tomorrow's dynamic businesses.

High- added-value products are created by a synergistic combination of various attributes and technologies, which together make them stand out in the competitive and crowded global marketplace. A promising product, in itself, is only one part of the equation – without the right business model and a competitive production system, it cannot succeed.

Radical product innovations are capable of spawning whole new industries. Although the birth of a 'killer-application' may not be an everyday event, Europe must keep investing in science, as many of the modern-day industries have emerged from a science base.

Fitness for purpose is the key attribute for any product. **Engineering** is a traditional European strength, and this tradition must continue in order to keep European products at the forefront.

Design is the process giving a physical shape to products that meet people's needs and desires. Apart from aesthetics, design can significantly contribute to utility value, and is often a decisive factor when choosing between different options. European industrial design contributes by adding value to products through functionality and aesthetics. Although design is already a strongpoint of many European products, the EU needs to leverage the strengths of its talent pool to greater effect.

Developments in **enabling technologies**, such as innovative materials (smart materials, intelligent and adaptative structures), nanotechnologies, ICT and mechatronics give almost limitless possibilities to develop new products or add functionality to existing product concepts. European industry must have access to these technologies and to the tools for incorporating them into product designs.

The market increasingly demands products that are **customised**, yet available with **short delivery times**. It is essential that European companies be able to understand and satisfy the needs of customers, regardless of their geographical location. In this context, the business focus will increasingly shift from designing and selling physical products only, to selling a system of products and services (described as 'product/services' or 'extended products') that are jointly capable of fulfilling specific users' demands (see third example at page 70). This concept is equally valid for the products and machines used for manufacturing.

Through **life-cycle orientation** and the provision of product/services, European companies will gain:

- more opportunities for innovation and market development;
- more and longer-term customer relationships;
- better feedback from consumers.

Product/services will offer greater satisfaction of customers' needs, reduce total life-cycle costs and avoid problems associated with the conventional purchase, use, maintenance and eventual replacement of goods. Product/services also have the potential to improve sustainability compared with the traditional buy-use-dispose products.

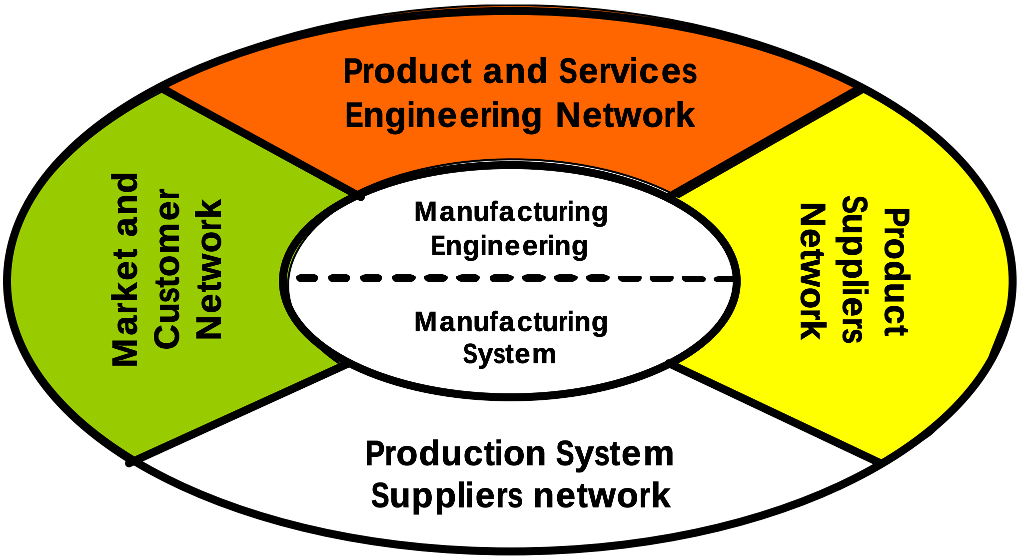

Figure 5. *Product innovation takes place in a complex network of actors, involving customers and their requirements, product engineering, the enterprise structures and physical manufacturing facilities assembled together in order to realise the product/service concept and to deliver it to the customer.*

Key research and intervention areas

To this end:

products may represented in terms of features , such

- Product architecture
- Structural materials
- Functional materials
- Components
- Product technologies
- Safe products

RTD targets, RTD areas/ETs priorities may be defined.

Product development needs to be tackled in conjunction with the development of the overall manufacturing process and vice-versa. To avoid redundancies a) manufacturing industry's generic RTD topics related to business models, innovating production and manufacturing engineering are presented in subsequent sections. b) Sector- or application-specific RTD topics or enabling technologies (e.g. nanotechnology) are subject to sectorial ETPs and/or research schemes.

4. Innovating production

The strategic goal N. 2

Innovating production brings efficient and competitive manufacturing of all products: it functions through networks of OEMs with value-chain partners and suppliers of factory equipment/services. The new culture is knowledge-based, operating with the most advanced manufacturing technologies, adopting new business models and intensively integrating emerging technologies.

Advanced engineering opens the way to new products. The factories themselves are regarded as complex, long-lived products that operate with high-value technologies – continuously adapting to take account of customers' and market demands, and of the competitive technical and economic environment.

Innovating production is both competitive and sustainable.

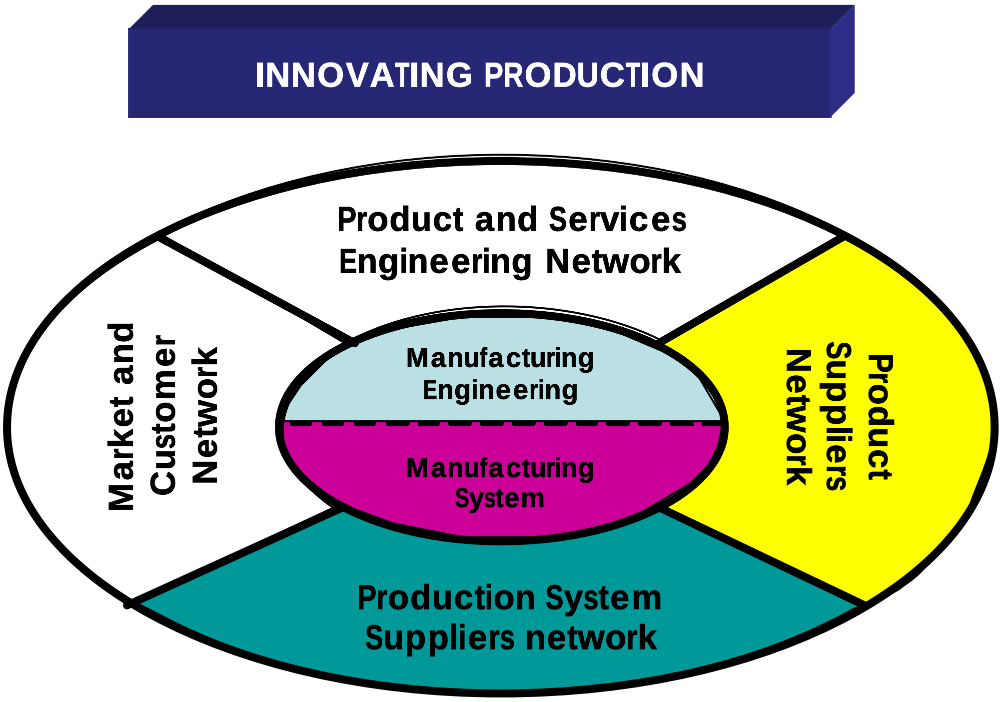

Figure 6. *Innovating production takes place in a network of actors, involving product suppliers networks, production system suppliers network and the manufacturing engineering and systems assembled together in order to manufacture the new value added products.*

A successfully innovating European manufacturing industry will be **adaptive, digital, networked** and **knowledge based**:

- **Adaptive manufacturing** focuses on agility and anticipation to permit flexible, small-scale or even single-batch-oriented production through integration of affordable intelligent technologies and process control for optimal efficiency;
- **Digital manufacturing** brings dramatic cost savings in the implementation of new production facilities through virtual representation of factories, buildings, resources, machine systems and equipment, as well as permitting closer integration of product and process development through modelling and simulation;

- **Networked manufacturing**[8] allows dynamic and value-adding co-operation in global production for fast-changing markets;
- **Knowledge-based manufacturing** strives for seamless integration of scientific, technical and organisational knowledge from all fields of production, such as process industries, advanced functional products, micro- and nano-scale engineering, and intelligent mechatronic systems for high performance design, engineering and production.

Two further trends which will have a significant impact on future manufacturing operations are **converging technologies** and **miniaturisation**:

- **Converging technologies** will exploit the convergence of nano-, bio-, info- and cognitive technologies to develop the next generation of high-added-value products and engineering concepts, with the prospect of stimulating the birth of new science-based industries;
- **Miniaturisation** and serial manufacture of multi-material micro-engineering components facilitate the conception of products that combine sensing, signal processing and actuation on a microscopic scale, with application fields as diverse as consumer electronics and medicine.

Real-time holistic adaptation of the manufacturing structure is one of the main challenges of the future. While the above concepts and trends certainly play an important part in **innovating production**, a more far-reaching approach needs also to consider/comprise also:

- new solutions in business;
- new advanced industrial engineering processes;
- existing technologies pushed beyond present frontiers.

8 A National Manufuture example is the virtual network 'Kompetenzzentrum Maschinenbau Chemnitz/Sachsen e.V' (see in www.manufuture.org the "Manufuture Best Practice - Sachsen-abstract.doc" in /Consultation Section/MANUFUTURE Examples)

4.1 New business models

The strategic target N.1

The continuing pressure of globalisation and changes in industry structure require European manufacturing businesses to transform. Businesses must rapidly form networks of complementary capabilities to respond to market opportunities. An enlarged Europe enhances the opportunities for businesses to remain competitive. New generations of manufacturing enterprises must be created.

A new, more networked and entrepreneurial, industrial mind-set underpins innovation and transformational change in European manufacturing. The identification, promotion and application of new business models, methods and information tools will both enable the growth of new businesses and allow existing industries to sustain global competitiveness fom a base within Europe.

Enhanced capabilities that bridge entrepreneurship and technology management must grow new industries that employ emerging science to meet emerging market demand.

"*The business model is at the core of the competitive response of the firm to the market. A business model outlines how a company generates revenues with reference to the structure of its value chain and its interaction with the industry value system*." (Michael Porter, Competitive Advantage, 1985).

Strategic business models are often framed in response to particular competitive circumstances, such as the length of a product's life cycle, or the length of the sector life cycle and its maturity. However, the underlying drivers are the same for all businesses. They are seeking to maximise their added value; profit from a differentiated capability; devolve risk; minimise exposure, headcount and capital expenditure; and thus optimise shareholder value.

Visible changes in business models over recent years have included:

- a transition from products to services;
- the reduction of vertical integration in large businesses;
- an increase in the importance of networks of smaller businesses working in open collaboration to form a value system.

The environmental perspective will modify business models by emphasising the whole product life cycle. Some national traditions will be challenged by business models arising solely from an Anglo-Saxon economic perspective. There are unique opportunities to build new brands and product-led businesses based on other European cultures, ethical traditions and aesthetics.

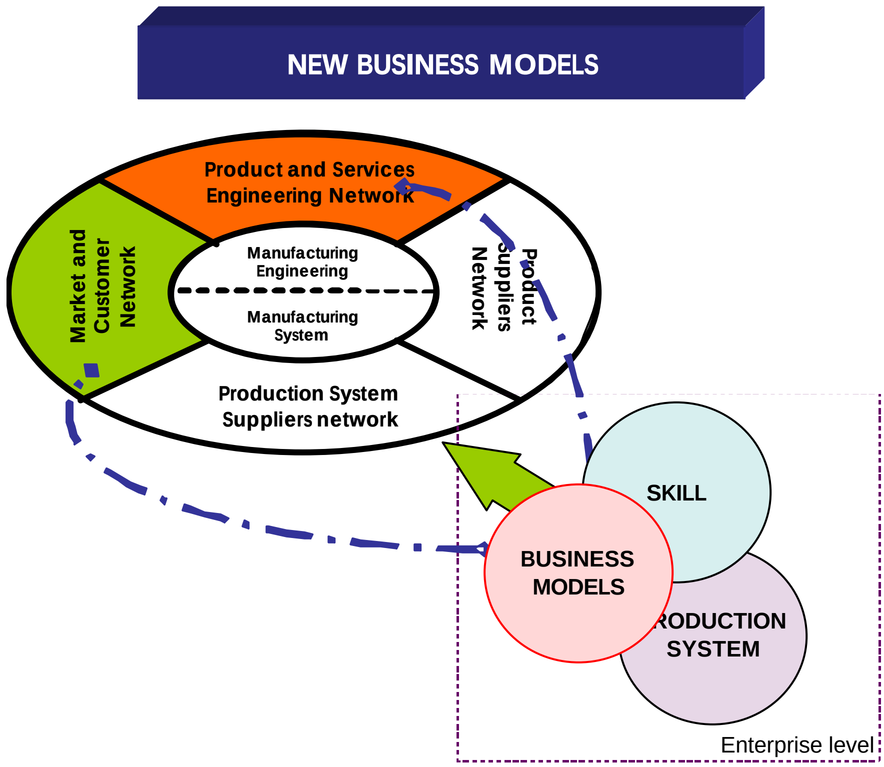

Figure 7. *The lower diagram: This enterprise or firm level diagram shows that the enterprise acts to integrate three key elements: the production system[9] that makes the physical product; the business model that matches the product to the market and determines how the enterprise generates revenue; and the skills and capabilities within the business necessary for success.*

The upper left diagram: This industry level diagram shows that industry actually operates via five networks: the network within the enterprise itself (at the centre of the diagram), the network of component suppliers, the network of production system suppliers, the customer network and the network of engineering capability suppliers (for instance external design houses).

With the continuing globalisation of manufacture and the political integration of an enlarged EU, there is a need for European manufacturing Industry to enhance its business models, to:

- identify and exploit new opportunities for maximising value in the product life cycle;
- embrace global change in industry and business structures and their value systems;
- establish partnerships for economically sustainable manufacturing in an enlarged Europe that works with the rest of the world;
- understand how to realise and supply manufacturing and other technology/knowledge-based services;
- embrace innovation and entrepreneurship as the routes to successful and secure business growth;
- recognise the product opportunities that emerging markets and new global science offer for the growth of manufacturing businesses.

New ways of working

Rapid formation of open networks in both traditional and emerging sectors will bring significant increases in capability, profitability and productivity for all European businesses. Creation of

[9] including people, machines, supply chain etc. etc.

environmentally benign product-based service companies will create a net increase in employment

With better understanding of the innovation and technology management processes, continuous innovation and entrepreneurship will become embedded in the enterprise culture. The transformation from traditional to knowledge-based operation could, for example, give small machine tool makers the capability to supply turnkey production services on customer sites. Furthermore, whole new manufacturing sectors will arise, based on new science or emerging markets

Time horizon

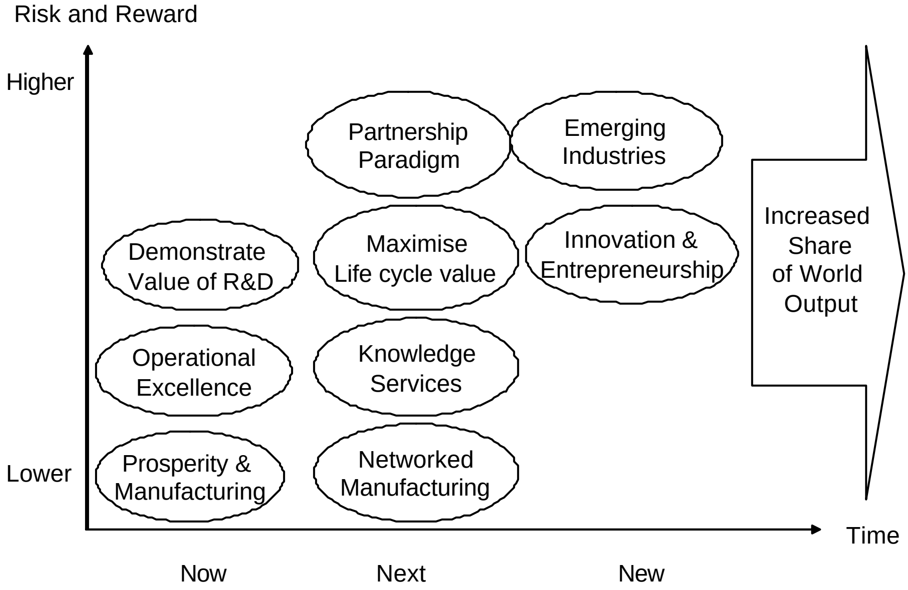

Figure 8. *Time scale vs risk and reward of the different approaches of in business models.*

These objectives require action over three time horizons.

In the **short term**: it will be necessary to expose SMEs and other businesses to the changes and opportunities, and to support of the exchange of best practice responses (among OEM's and SME's) by which businesses can sustain themselves through the changes. This includes replacing competition based on cost reduction with a focus on capability development, continuous organisational redesign and operational excellence as the means of maximising revenues (profit), productivity and learning.

These transformations can be boosted by giving SME's access to the results of R&D activities, allowing them to incorporate them rapidly in their innovation processes. Information and dissemination of research activities is, for that reason, a crucial aspect.

Medium-term: research must define new hard and soft 'business-process' technologies that can be applied to modify the framework conditions for innovation and new business growth.

Subsequently, the Community should look towards the **long term** by exploring approaches that will permit the growth of new manufacturing and product-based service industries from the science base.

Key research and intervention areas

To promote transformational change in European manufacturing industry and the firms within it by the education of industry to increase its capabilities, the identification and promotion of necessary change and by researching and applying tools and techniques that enable change.

Priority	Features and RTD targets	RTD Areas/ET's in medium term
High	**Networked business models** Globalisation, changes in business structures and new technologies have contributed to a progressive transition to a more networked way of working. Larger companies have been able understand and respond to these changes. Small and medium sized businesses with less capability and resource have been less able to likely to embrace these changes. **Target** Smaller businesses must understand which businesses strategies are appropriate responses to the drivers. Europe must have the capability to rapidly form and sustain value networks that respond to business opportunities. Tools and techniques are required that enable businesses to work in networks.	Successful business building in networks. Value network design. IP management. Productivity management. Knowledge tools. Pre-competitive demonstrators.
High	**Maximising life-cycle value** Environmental drivers and an increasing recognition that manufacturing businesses do not benefit sufficiently from the value that they add emphasise whole life cycle business models. This requires product architectures and technologies that enable thorough life approaches. **Target** Identify and exploit new opportunities for realising value in the product lifecycle. Environmentally benign products and services that are appropriate to a life cycle view.	Whole life-cycle business models Extended products.
Medium	**Design and manufacturing in an enlarged Europe** Europe is a larger market that the United States. The enlarged Europe gives unique opportunities to leverage difference in regional factor advantages. **Target** Exploiting our close proximity to a major market by maximising the value of that market that is secured by manufacturing and product based services. Responding to globalisation using current regional differences to give balanced economic growth.	Market leverage. Regional balance of finance. Regional balance of design and manufacture. Understanding regional change.
High	**Knowledge-based services** The product to service transition and the increasing outsourcing of manufacturing has driven manufacturing to become a knowledge based service. Design has seen similar trends. Manufacturing and machinery businesses must have the capability to sell production services (contract manufacturing capacity) and more appropriate production machines. **Target** Transformation of the contract manufacturing base to sustain industries that can be competitive from a base within Europe, transformation of the machinery supply industry. New information tools that enable manufacturing and design as services.	Contractual arrangements. Manufacturing as a service. Design for service. Information tools.
High	**Innovation and entrepreneurship** To regenerate it is necessary to create new businesses. Manufacturing businesses particularly contribute to economic growth and provide jobs. New business creation requires better understanding and improvement of the innovation process, new approaches to business growth including the provision of new financial instruments and increased skills in entrepreneurship. **Target** New manufacturing business growth by increasing Europe's capability in successful innovation.	Opportunity identification. Skill requirements. Management under uncertainty. Financial instruments. Process improvement.
Medium-high	**Manufacturing for emerging industries** Emerging markets and new science offer the product opportunities that will grow new manufacturing businesses and even new industries. This requires Identification and exploitation of new market opportunities and exploitation of new science. **Target** New businesses for new markets. Entrepreneurship in science based industries likely to have significant manufacturing value add. The creation of new industries and sectors.	Alternative and renewable Energy. Security. Life sciences and biotechnology. Disruptive process technology.

Table 1. *Key research and intervention areas for new business models*

Co-operative research will lead to better understanding and communication of evolving network business models. It will determine how business strategy choice leads to enterprise and value network design. The production of pre-competitive demonstrators will facilitate collaboration in networks to develop continuous learning and change of enterprise design.

Building secure and successful businesses in an open, highly networked and interdependent economy will require definition of the most appropriate mechanisms for technology and product development, and for market and investment risk analysis.

Methodologies, measures and/or information tools must be developed to determine the fitness-for-purpose of business models, with respect to the requirements and life cycles of often complex product/service systems. An essential ability will be to exploit the whole life cycles of products, while minimising the environmental impact of their delivery

Necessary operational improvements for the rapid implementation of collaborations in volatile networks include the management of IPR, decision processes, productivity, risk management, information & process integration and value retention across business interfaces. Product and process technologies must be designed to allow the embedding of IP, thus safeguarding the interests of the originators. Equally important will be understanding the contractual and technical requirements for selling production and other knowledge-based services.

Establishing how businesses in the enlarged Europe can work together to deliver mutual benefit entails awareness of the regional balance of finance, design and manufacturing. The goal will be to increase business and economic growth, efficiency and local added value, while retaining the manufacturing advantage factor of an enlarged Europe

Methods are required to identify new business opportunities from early-stage science, determine the requirements for improvements to the innovation process and foster entrepreneurship in science-based industries likely to produce significant manufacturing value addition.

Key skill needs will be in networked lean new product and process introduction, project and supply chain management, and procurement. Vocational education and training systems will be required to equip people for working in networks. Those capable of managing and financing innovation under high uncertainty and as a partnership activity will be highly valued. At the same time, instilling the need for ethical practices will be essential to uphold Europe’s societal standards.

4.2 Advanced industrial engineering

The strategic target N. 2

Development, supply and management of adaptive, digital and knowledge-based factories are major strategic priorities for European manufacturing enterprises in all sectors. Global leadership in the delivery of factories including all the elements – buildings, machines, systems, tools, training and other services for optimally efficient production – is an imperative objective.

'Manufacturing/enterprise engineering' simultaneously addresses all interrelated aspects of product life cycles, from design to disposal/recycling. Engineers who design products, processes and enterprises work with knowledge-based IT tools, operating in networks with standardised platforms.

Adding value by leveraging traditional European strengths, e.g. in engineering and design, while enhancing functionality by the incorporation of new technologies, differentiate products from those of the competition.

Industrial enterprises must re-examine their organisational structures and basic activities to accommodate the changes foreseen in manufacturing processes in a fully functional new industrial engineering environment.

For European industry to play a leading role at global level based on the RTD-to-market value chain, the factory itself has to be approached as a new and complex type of product with a long life cycle, but able to adapt continuously to the needs and requirements of markets and economic efficiency.

New complex products and process, together with production systems, will be developed through efficient reuse of technical/scientific, business, and process knowledge to make accurate decisions. Shared knowledge of material and process properties and their interactions will support optimised process design and total understanding of complex transformations and interactions at the micro- and macro-levels.

Creating new markets/industries, or gaining share in existing markets, will come through radical science-based product innovations (comparable in impact to the. walkman, cell phone, jet engine, semiconductor, laser, etc.)

Enterprises will seamlessly interconnect between their internal functions, and with external partners and stakeholders. This will permit operation of open, complex distributed engineering and supply chains and extended enterprises that function as integrated entities. Networking will improve the efficiency of information exchange in terms of inventory levels and production/delivery schedules. The research focus will be upon:

- adaptive network, systems, machines, intelligent controls and functional elements and partial autonomy;
- interoperability and ongoing standardisation efforts that benefit Europe's 'open' approach;
- integrated and product life-cycle-oriented ICT infrastructures, providing the means for secure and reliable communication in terms of both space and time;methods and tools for knowledge management and collaborative environments related to either products, processes and markets.

4.2.1 Knowledge-based factories as products

The strategic target N. 3

Factories are treated as socio-technical systems; they are capital intensive, complex and long life products, operating through complex relationships between the material value chain and information chains, involving technical and human elements. In contrast with other complex products, factories have an overall system architecture enabling the continuous adaptation to the needs of customised products, economic environment and objectives. Just as for other complex products, knowledge is the key to maximise the economic success and the dynamics of this socio-technical system.

Knowledge, which currently exists only implicitly within the skills of workers, technicians and engineers, is explicitly implemented in the systems of management, engineering and control of processes.

All processes inside and outside the factory are interlinked. The overall efficiency of the manufacturing network depends on the efficiency of each system element. European standards for knowledge based manufacturing are able to compensate turbulent environment influences by system based methodologies and intelligent technical solutions.

The main research objective is the development of concept for factories which are capable of adapting themselves continuously to the requirements and tasks of changing market requirements or changing product- and production technologies. This continuous adaptation at all levels of the factory requires explicit and implicit knowledge and hierarchical system architectures taking into account the complexity and synergetic work in the networks.

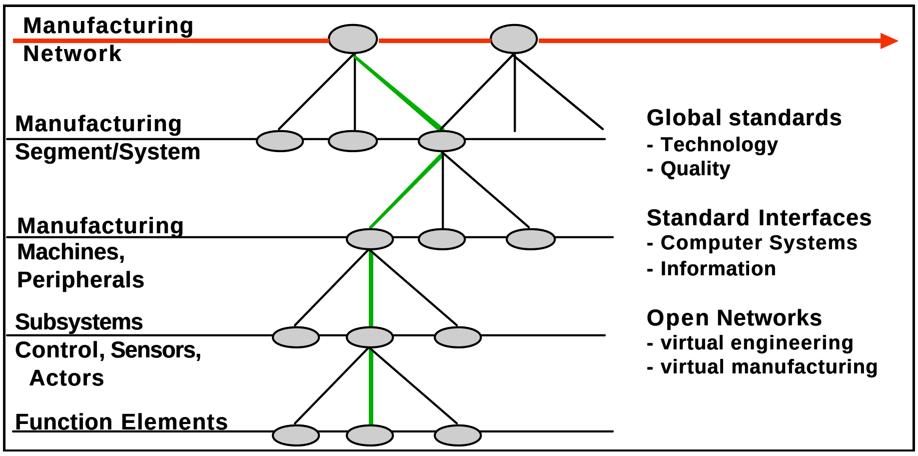

***Figure 9**. Factories are socio-technical systems with scales in the hierarchy from networks to processes and functional elements (humans and machines).*

The development of future knowledge based factories[10] requires research for adaptive structures and solutions which take into account the aspects of continuous change by:

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[10] An European Manufuture example is the EUROShoE mini-factory (see in www.manufuture.org the "Manufuture Best Practice - Vigevano.doc" in Consultation Section/MANUFUTURE Examples)

- management models and systems following the objectives of self-organization and self-optimisation;
- reconfigurable technical systems and integration of the processes to systems,
- technical intelligence with actuator and sensor integration by process control systems with process models and semi-autonomy and cooperation functionality elements efficient interaction in the human machine interface;
- efficient networking in the systems based on standards and open system architectures.

The backbone of knowledge based manufacturing is the information (digital) system. Therefore it is important to develop a kind of a “Windows Platform” for manufacturing in networks and scalable from networks to function elements.

Development directions

The mainstream of future development defining manufacturing as adaptive, digital networked, knowledge-based will be characterised by:

Life-cycle orientation Factories and their components will be linked in manufacturing networks extending from engineering to end-of-life, as the basis for enhanced customer relations and value addition by product-oriented services. This implies a clear understanding of the requirements and usage of products (customisation), their manufacture and associated services. Europeans have the human skills to activate value in the life cycle by online support and communication with the user population. Acquiring such abilities will enable EU industries to stabilise and strengthen their positions in world markets.

Product-integrated knowledge and intelligence Knowledge is the resource of the future. Its efficient use in the engineering and manufacturing aspects of factories, as well as in the implementation of control and management systems, offers the way towards intelligent knowledge-based manufacturing, and allows to keep track of the product relevant information during the whole product life cycle, from manufacturing, in service utilisation, maintenance/upgrading, dismantling, recycling, etc.. Knowledge will be used to improve the performance of machines in parameter fields were the processes are becoming unreliable or very high speed control is required. This will be accomplished by the use of process modelling, online simulation, planning, reasoning, software embedded in mechatronic systems integrating sensors and actuators, intelligent processing of smart materials, and cognitive or learning systems adapting process information to human cognition, giving the potential to sell knowledge as a product or parts of a product. Digital manufacturing will be a key element in product and process knowledge acquisition, helping to translate from implicit to explicit knowledge.

Product-integrated services The majority of technical products, and of manufacturing systems themselves, need the support of services during their life cycles. Services can be made globally available by linking manufacturing systems to the networks of manufacturers and incorporating intelligent diagnostics into machines and processes. In this way, Europe can add value by supporting users around the world in solving technical, organisational and financial problems.

European Standards for manufacturing Prominent among other essential supporting elements is the framing of high-level European manufacturing standards. Standards do not serve simply for the technical definition of specifics. They represent the philosophy of manufacturing: the management of innovation, implementation of best practices, protection of the human workforce and responsibility for the environment. In addition, the adoption of European standards will enforce the integration and interoperation of digital engineering tools, which are nowadays still very dependant of a small number of individual system suppliers.

Standardisation of the main manufacturing components, procedures and processes at high levels of efficiency and quality would allow exchange and co-operation between industrial players in a global economy.

Intelligent Machines and systems Internal automation and modularisation of the design is needed. To reconfigure systems standards are required for the internal control and information system (real time digital control). Such intelligent machines are integrated in manufacturing supply chains and networks.

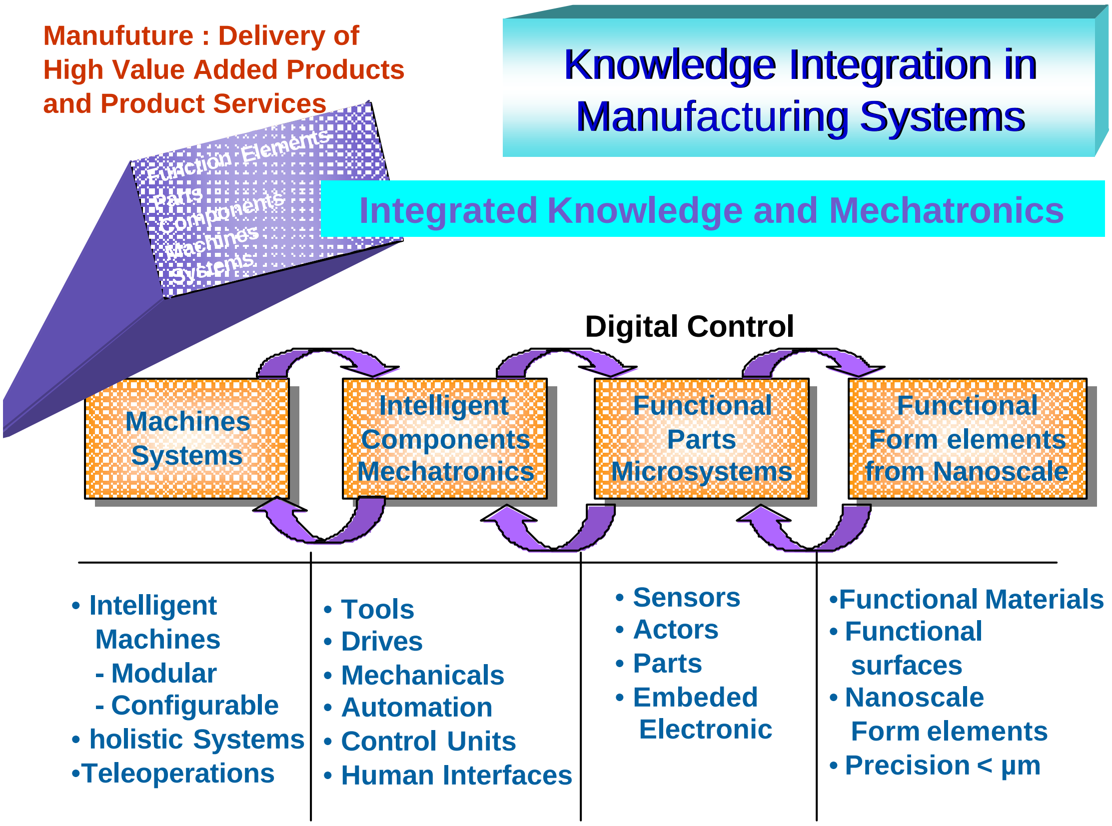

Figure 10. *One key element facilitating delivery of high- value-added products and product/services is the integration of knowledge in manufacturing systems at all levels, cascading from intelligent machine systems down to knowledge-based engineering of functional elements at nano-scale.*

Time horizons

In the **medium term** (up to seven years) RTD must focus primarily on the implementation of new adaptive and digital manufacturing systems. Essential needs are:

- setting up the basics for technical, social and cultural standards in manufacturing;
- expanding the potential of adaptive manufacturing and realisation of intelligent factories;
- development of real-time digital factories;
- implementation of knowledge-integrated solutions in factories and supply chains;
- raising quality standards and efficiency.

Long-term RTD should be directed towards the artefacts of innovating production and their deployment in a knowledge-based European manufacturing environment, in which ICT and related technologies are fully integrated and the social and cultural systems are drivers of continuous adaptation and innovation.

Key research and intervention areas

Priority	Features and RTD targets	RTD Areas/ET's in medium term
High	**Digital manufacturing** uses a wide range of planning tools, software and ICT to integrate new technologies into the design and operation of manufacturing processes and their corresponding production systems. Modelling and presentation tools make it possible to create a scalable virtual representation of an entire factory that includes all buildings, resources, machines, systems and equipment. With the ability to simulate dynamic behaviour over the whole life cycle, planners and designers can gain dramatic time and cost savings in the construction of new facilities. By the same means, they are able to optimise reliability and minimise environmental impacts. **Target** Main area of research is the development of integrated tools for industrial engineering and adaptation of manufacturing taking into account the configurability or partial autonomy of systems. High priority has the development of a standard data model of factories and the management of factories data taking into account open networks of engineering and real time management of manufacturing data (factories data management)	Scalable Process- Models Process Simulation Digital Machines, Digital System Digital Information Management Smart Factories ?
High	**Adaptive manufacturing** responds automatically to changes in the operating environment. It integrates innovative processes, the capability to change the structure of the socio-technical system permanently and integrate knowledge and embedded intelligence in the technical systems to control the processes on high performance level through intelligent combinations (such as intelligent mechatronics), and handles the transfer of manufacturing know-how into totally new manufacturing-related methods and systems. It embraces manufacturing systems and equipment incorporating automation and robotics, cognitive information processing, signal processing and production control by high-speed information and communication systems. **Target** to overcome existing process limitations, and transfers manufacturing know-how using completely new themes or manufacturing-related themes and to implement knowledge automated planninig, reasoning, and learning in manufacturing machines, systems and equipment	Embedded Electronics Multi-sensor & Actuators Intelligent Process Control Systems Adaptive Robotic
High	**Networking Manufacturing** replaces the conventional linear sequencing of processes with complex manufacturing networks that often operate across multiple companies and countries. This mode of production makes it possible to insert processes and manufacturing systems into dynamic, value-adding co-operatives, and also to remove them when no longer needed. In the lower levels of the factories the collaboration of system elements in the material and information chains are part of networking manufacturing. **Target** To become possible to integrate manufacturing processes into dynamic, cooperative manufacturing and value-added networks and also to remove them from those networks if needed.	Configurable Machines&Systems M&SC Integration of Processes Networked Logistic Systems Flexible Carriers Smart Logistics
High	**Knowledge-based manufacturing** draws on in-depth understanding of the behaviour of machines, processes and systems. It will demand more research into simulation as the means of integrating these inter-related aspects. Today, simulations are used for the engineering of logistics, machines and kinematics – and partly for processes. **Target** Future engineers will need multi-scale simulation, with high-performance computing and the ability to adapt to real or forecast system behaviour. New basic models of processes and simulation techniques must be developed, possibly incorporating provision for automated planning, cognition and learning features, as well as integrating diverse simulation aspects such as mechanics, control and process physics into unified models.	Process Simulation Learning Control Systems, embedded planning and autonomous control History analysis Methodology based on changeability
High	**New Taylor** Taylor defined the basic paradigm for manufacturing management more than 80 years ago. nearly all industrial manufacturer use tayloristic methods based on this paradigm to plan the operations in all areas of manufacturing. The tayloristic organisation characterises the organisation model of nearly all manufacturing processes and systems. The taylorism divides work for humans based on elementary processes. Work of humans is planed in detail by usage of basic methodologies like MTM or REFA. Process plans are highly detailed standard times. Global operating companies in the automotive and other sectors use this methodology to calculate, to compare and to standardise processes world wide. This methodology is contradictory to the paradigm of a socio technical system following knowledge based manufacturing, manufacturing in networks or principles of self-organisation and self-optimisation. Even the integration of knowledge into machines and systems is not to combine with detailed process planning. **Target** Holistic and changeable manufacturing requires the implementation of innovative methodologies for zero defect manufacturing (in critical areas) and scientific methodologies to activate manufacturing human potential	Global process standards T&M Management standards T&M

Table 2. Key research and intervention areas for Knowledge-based factories as products

Digital manufacturing uses a wide range of planning tools, software and ICT to integrate new technologies into the design and operation of manufacturing processes and their corresponding production systems. Modelling and presentation tools make it possible to create a scalable virtual representation of an entire factory that includes all buildings, resources, machines, systems and equipment. With the ability to simulate dynamic behaviour over the whole life cycle, planners and designers can gain dramatic time and cost savings in the construction of new facilities. By the same means, they are able to optimise reliability and minimise environmental impacts.

Adaptive manufacturing responds automatically to changes in the operating environment. It integrates innovative processes as well as the capability to continuously change the structure of the socio-technical system and integrate knowledge in the technical systems to control the processes at high performance levels through intelligent combinations (such as intelligent mechatronics), and handles the transfer of manufacturing know-how into totally new manufacturing-related methods and systems. It embraces manufacturing systems and equipment incorporating automation and robotics, cognitive information processing, signal processing and production control by high-speed information and communication systems.

Networked and integrated manufacturing replaces the conventional linear sequencing of processes with complex manufacturing networks that often operate across multiple companies and countries. This mode of production makes it possible to insert processes and manufacturing systems into dynamic, value-adding co-operatives, and also to remove them when no longer needed. At the lower levels of the factory structure networked manufacturing requires the collaboration of system elements in the material and information chains.

Knowledge-based manufacturing draws on in-depth understanding of the behaviour of machines, processes and systems. It will demand more research into simulation as the means of integrating these inter-related aspects. Today, simulations are used for the engineering of logistics, machines and kinematics – and partly for processes. Future engineers will need multi-scale simulation, with high-performance computing and the ability to adapt to real or forecast system behaviour. New basic models of processes and simulation techniques must be developed, extended by automated planning and programming and possibly incorporating provision for cognition and learning features, as well as integrating diverse simulation aspects such as mechanics, control and process physics into unified models. Learning and reasoning will enable the system to cope with effects that exceeds simulation capacities. Planning will make efficient use of simulation and process models

Learning is a central feature in knowledge-based manufacturing - learning by education, from experiments, from analysis of best practices, from methodologies or with simulation machines (Learning machines, learning systems).

Leadership in this field will depend on the development of a European real-time platform resembling a '**Windows for Manufacturing'**, with well defined IT standards and the flexibility to allow sectors to apply their own specific solutions. Intense research on robotics and flexible manufacturing will be needed to deliver 'plug-and-produce' systems with integral automated services. This, in turn, will influence the way that people work. A new methodology for the organisation of human labour, taking into account the European culture and work standards, will also be required.

New Taylorism

Taylor defined the basic paradigm for manufacturing management more than 80 years ago. The Tayloristic organisation characterises the organisation model of nearly all manufacturing processes and systems and industrial manufacturers still use these methods to plan the operations in all areas of manufacturing. Taylorism specifies the tasks of workers based on elementary processes. The tasks are planned in detail by usage of basic methodologies like MTM (Methods-Time-Measurement) or REFA (Association for Work Design/Work Structure, Industrial Organization and Corporate Development). Process plans are based on highly detailed standard times. Global operating companies in the automotive and other sectors use this methodology to calculate, to compare and to standardise processes world wide.

This methodology is contradictory to the paradigm of a socio-technical system characterised by knowledge based manufacturing, manufacturing in networks or principles of self-organisation and self-optimisation. The concept of integration of knowledge into machines and systems is not compatible with detailed process planning. As a consequence manufacturers need to adopt a new type of Taylorism, which takes into account dynamic change and adaptation, the specific human skill and the requirements of cooperation in networks. This new European standard of manufacturing takes into account the social culture of Europe.

The factors accounting for the success of European manufacturing industries to date are mainly related to the great diversity and skills of personnel at all levels. Harnessing these abilities in the factories of the future will be vital to the economies of the Member States. It will be essential to adapt the structures as quickly as possible, aided by research into all aspects of manufacturing. Rapid evaluation of change under practical conditions, monitoring the success in meeting the demands of markets, and exchanging knowledge are the keys to growth and leadership.

RTD will be required to deliver:

- better understanding of new interdisciplinary fields;
- enhanced environmental impact assessment;
- interoperability and ongoing standardisation efforts that benefit Europe’s ‘open’ approach;
- integrated and product life-cycle oriented ICT infrastructures providing the means for secure and reliable communication in terms of both space and time;
- methods and tools for IPR management and collaborative environments,
- empowerment of the workforce to operate in a rapidly evolving technical and organisational environment;
- implementation of an open European standard platform of the digital manufacturing;
- formulating the European standard of human work in the factories.

4.2.2 *Manufacturing engineering and services*

The strategic target N. 4

Manufacturing engineering is the strategic methodology used to develop enabling technologies for planning, design, optimisation, adaptation, reconfiguration and recycling. Manufacturing engineering takes a holistic approach that includes the engineering of the enterprise structure, the development of the organisation, the design- and process-engineering and the tools and systems for high engineering efficiency. The agility of manufacturing engineering enhances the strategic development of enterprises. Manufacturing Engineering is hence the "glue" for constructing Factories, Networks, all technical elements, equipment and IT systems for manufacturing, including services.

Traditional factories have seen dramatic improvements in efficiency and changes in working methods brought about by the introduction of automation and control systems based on **digital** technology. With most influencing factors in a constant, and even turbulent state of flux, the next step is to progress towards what can be described as the **'virtual factory'** of the future. This will require a European platform for digital manufacturing engineering, having the capability to create, maintain and use a dynamic system of networks, in which all the actors contribute and add value in the manufacturing chain, without the constraints of physical co-location or rigid partnerships.

The concept of **manufacturing engineering** – the way that processes and production are organised in novel production patterns within factory units able to respond flexibly to global demand – is the core of manufacturing development. It will be embedded in networks of product engineering, materials and component suppliers; in the network of manufacturing suppliers; and – in the future world of customised products – in the network of customers. This inevitably implies significant changes in manufacturing processes along the whole product value chain within the networked enterprise (Figure 11).

It will require both engineering competence and the tools to support engineers working in distributed and open networks. Here, their role will be to implement new technologies and to design manufacturing systems by employing an intimate blend of virtual and real-world techniques. The development of engineering infrastructures in open networks is thus the way to achieve leadership, high value addition and competitiveness. The better and faster the engineering processes, the greater is the potential for success.

As a consequence, there is a need for European Industry to progress towards simultaneous development of product/services and processes within the enterprise/network organisations.

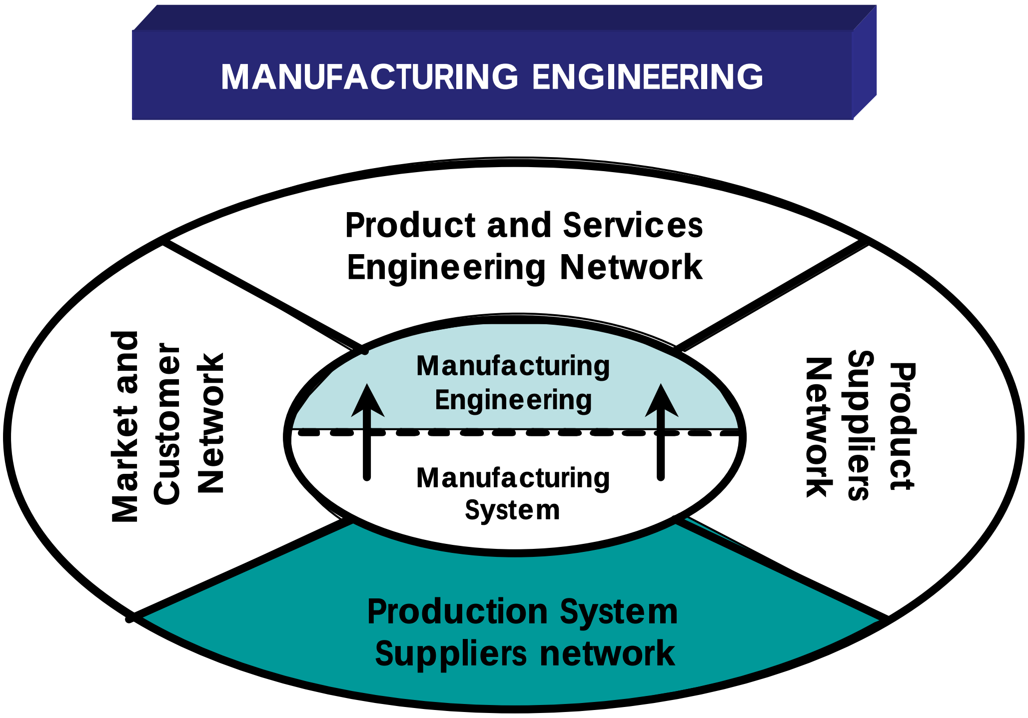

Figure 11. *Manufacturing engineering addresses all inter-related aspects: high-level and highly diversified competences, applications, and engineering tools that interface manufacturing systems from manufacturing networks down to the individual components*

Manufacturing Engineering has a holistic approach that includes the engineering of the enterprise structure, the development of the organisation, the design- and process-engineering and the tools and systems for high engineering efficiency. At all manufacturing levels, the factory/manufacturing can be defined in its "current" and/or "future" states, under the so called *digital* and respectively *virtual* representations. This relates on the employed digital methods and tools or simulation applications/systems, used to represent the static or the dynamic states.

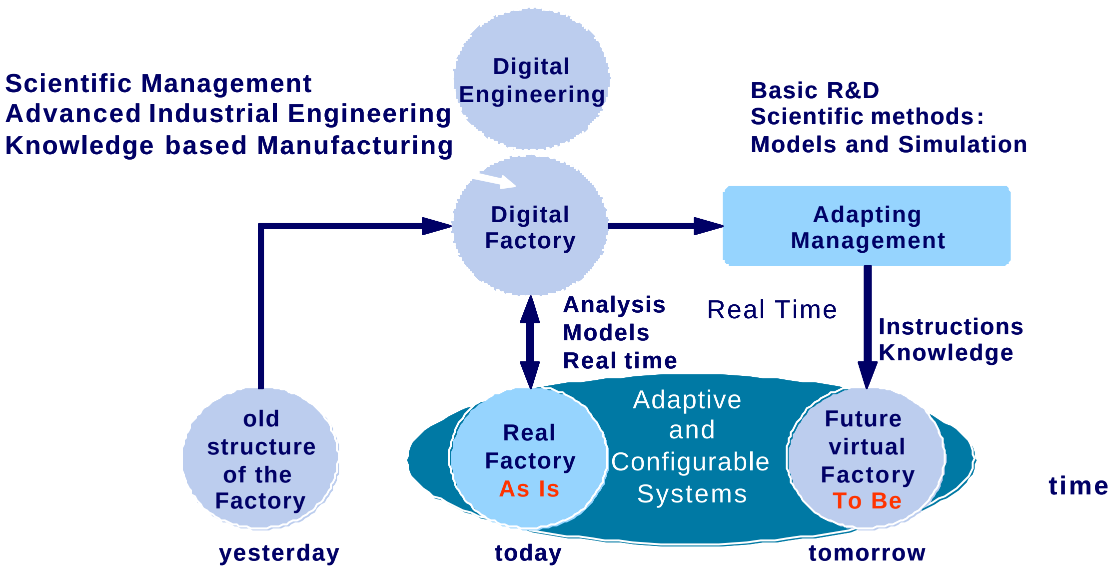

Figure 12. *The changing approach to the planning of factory structures: from the traditional/existing (yesterday), to the real digital factory (today), and finally to the desired virtual factory of the future (tomorrow)*

The challenge of advanced Industrial Engineering

The research field of advanced Industrial Engineering[11] arises from the need to enhance the Industrial Engineering concept with new models, methods and deployed tools for two main reasons. First, the Industrial Engineering has to reflect the new way of operation, the so called "digital business". The "digital business" represents an enhanced mode of developing businesses, suitable for any industrial sector, which uses/employs the newest state-of-the-art information and communication technologies in any part/segment of the supply chain. Second reason resides in the requirement to approach (plan, realise and manage) the factory as a new kind of "transformable and adaptable" product, as already presented in the previous chapter.

Digital manufacturing engineering as a key component of manufacturing engineering uses a wide range of engineering and planning tools, software applications, and information and communication technologies (ICT) for efficient and effective integration of new technologies into manufacturing processes. Main area of research is the development of integrated tools for industrial engineering and adaptation of manufacturing taking into account the configurability of systems. Digital manufacturing employs the: distributed data management, tools for process engineering, tools for presentation and graphic interfaces, participative, collaborative and networked engineering, interfaces to the reality. Digital manufacturing gives to the factory engineer the representation of the factory as it is today, that means the static image of the so called *digital factory/manufacturing*.

Starting with the digital picture of the factory/manufacturing and by deploying the *virtual manufacturing technologies* consisting of simulation tools and specific applications/systems, the engineers deal with the factory and manufacturing processes in their dynamicity, by having the reflection of the "is" state in the future, the so named in the approach the *virtual factory/manufacturing*.

At present, the developmental activities associated with the digital factory/manufacturing focuses on the planning of factories, production plants, new logistic systems, and of the manufacturing processes.

Development and Innovation of industrial products and processes is still experience-oriented. Experiments and experience are the basics for reliability. In the knowledge-based industry, the 'costs of experience' – loss of productivity and time – can be reduced by modelling of all manufacturing processes in combination with (partial) automated planning and programming.

Virtual factories will integrate flexible supply chains for:

- engineering and designing products to match market needs;
- logistics, from customer orders to final delivery;
- consumable materials and waste treatment;
- factory machines; and,
- equipment and tools

The constituent parts making up the virtual factory will be created from basic components, supporting transformability/changeability. Fast response at all scales, from individual processes to complete networks, will take place within a digital infrastructure, relying on a high level of knowledge, and making extensive use of RTD for:

- incorporation of functional and structural materials into machines, tools and other equipment;

[11] *Advanced Industrial Engineering aIE*" aims at combining the basic knowledge in production and process planning – i.e. Industrial Engineering – with the methods, models and procedures used to enhance the transformability, and thus to advance industrial engineering by adding: a) *collaborative* and team-based planning, b) *integrated* planning approaches, including interfaces to product design and distribution, c) *digital* tools and methods, d) the potentials of technology management and e) the analysis of continuous process chains.

- implementation of ICT and cognition-based solutions for control and management of all processes;
- application of micro- and nanotechnologies
- enhancement of human/machine interfaces, and
- integration of methodologies from different disciplines for human work and management.

Product design is the activity concerning the product-system: the integrated body of products, services and communication strategies that either an actor or networks of actors (companies, institutions, non-profit organisations, etc.) conceive and develop so as to obtain a set of specific strategic results.

This will be based on such requirements as:
- response to life-cycle processes and contextual conditions;
- compliance with competitiveness and sustainability goals, while pursuing the added-value approach;

and will require:
- the acquisition of enabling technologies covering architecture and components, structural and functional materials, and processing;
- an increasing incorporation of new technologies as they emerge from research.

Process design will address processes throughout the whole product life cycle – production, distribution, use and maintenance, recycling. – as well as the life cycles of individual processes, whose phases are design, implementation, use and maintenance, and reconfiguration. It will be based on such requirements as:
- interrelation with other product life-cycle processes and the product itself;
- compliance with competitiveness and sustainability goals, while pursuing the added-value approach;

and will require an increasing incorporation of new technologies as they emerge from research.

Manufacturing systems engineering will address the development of machines and equipment, and the technical factory supply systems (energy, air, water, information) with integrated tools for design, analysis and simulation under real conditions.

The engineering platform can be modelled after product life cycle management systems. But there is a strong requirement to formulate the standards for the data management for all objects and elements of the factories. A specific objective is the management of (real time) any changes in the factories caused by wear, maintenance, set-up, end of life of machines and equipment). The digital engineering platform includes models of humans and workers (digital bodies)

Time horizon

Adaptation to the global economy requires the consideration of two time horizons: medium term and long term.

In view of the competitive situation Europe faces, the focus in the **medium timeframe** should be on methodologies for better, faster and cheaper engineering. This will enable innovation to be pushed speedily towards competitiveness and technical leadership. In this time-scale, industry will adopt integrated solutions running from product design to manufacturing. A high degree of customisation will be needed, based on new modelling and engineering methodologies, together with configuration tools and 'custom-oriented' engineering systems. These will enable manufacturers to reduce the time between product offer and delivery.

The **longer-term** prospect for manufacturing engineering relates particularly to the use of knowledge-based tools for new generations of products. It will become a strategic imperative to integrate new technologies in products like:

- structural and functional materials,
- integrated functions,
- innovative mechatronics,
- intelligent and cognitive control,
- nano-scale components
- highly specialised engineering tools into products.

Key research and intervention area

Priority	Features and RTD targets	RTD Areas/ET's in medium term
High	**Enterprise engineering** The processes, applications, and tools with which the enterprise conducts management and administrative functions, including budgeting, estimating, payroll, human resource management, purchasing, marketing, sales, order fulfilment, product support, reporting, and similar functions. Manufacturing efficiency depends on the efficiency of the networks. Networks are changing permanently driven by the dynamic of products-technology requirements and market and customer demands. The configuration of networks is a task of engineering: Places, logistic systems, management systems **Target** Research and development of methods and tools for engineering and management of high performance networking. Develop a holistic meta-language to achieve multilevel interoperability when using different data and models	Network-Engineering Virtual enterprise Network Management Standards Interoperability
High	**Product development and Engineering** the process of translating a requirement, idea, concept, or defined need into a saleable product that conforms to its defined requirements and is ready for manufacture. **Target** Efficient engineering of complex products and services with integrated tools based on integration of material and system engineering in an open European engineering model. Main target is the research and development of methods and tools for engineering and management of high performance networking that enable to integrate from research to market while reducing its "throughput" time.	Structuring adapting Materials Rapid & digital prototyping Integration of Green Materials Micro sensors and actuators
High	**Product design definition** a domain embracing all processes used to translate a product from concept to a design ready for manufacturing execution, including a computer-sensible definition (e.g., CAD file) able to be shared across different applications and used in downstream processes. **Target** Implementation of knowledge based tools and methodologies for modular and system technologies to design high added value products and to manage complexity. Main target is the integration of design systems for mechatronic elements and system architecture of products and to design micro or nano structured products. In the light of the previous target is also important to consider presence of Dynamic Networks of Users and Life Cycle Perspective.	Methodologies for Product design Integrated Mechatronic design of machine/controls
High	**Manufacturing process Engineering** the conception, design, development, and implementation of a production process. MPE is related to planning of processes equipment, fixtures and tools taking into account flexibility and performance of processes and workplaces for the workers. **Target** Knowledge based methodologies and software systems for engineering processes and industrial engineering in an digital environment	Advanced Human Interface Increasing quality of transformation Processes Capability of Processes
High	**Engineering Tools and System** the processes, applications, and tools with which the enterprise designs, develops, validates, controls, and supports products and processes. Engineering tools and systems refers to the increasing demand of engineers for manufacturing and tools for their engineering work in networks. **Target** European platform for digital engineering in order to develop reliable tools which may be easily integrate and efficiently validated in "real" users context to fast respond to variable requirements.	Multidomain engineering systems Configuration and Evaluation tools "Problem oriented" design tools Improvement of traditional modelling Specific simulation tools Data standards

Table 3. *Key research and intervention area for manufacturing engineering and services*

Reconfigurable manufacturing Rapid and adaptive design, production and delivery of highly customised goods will establish closer coordination between demand and supply sides. Continuous change will demand improvement in modelling and simulation of new complex phenomena (complexity, uncertainty management, multi-domain support…).Enterprises will create networks and virtual factories, achieving reduced time-to market, reduced order quantities, mass - and extreme- customisation, just-in-time production and reduced need to transport components and products. New paradigms such as ambient intelligence will facilitate the integration and adaptation of people and manufacturing devices. Research must determine optimal enterprise configurations and management of production and networks to improve flexibility of the whole manufacturing chains

Digital and virtual production Tools and methodologies for high volume response will establish higher dynamic rates of change in manufacturing. The main area of research is the development of integrated tools for industrial engineering and adaptation of manufacturing, taking into account the configurability of systems.

Lean, efficient enterprises Businesses will develop efficient processes to create, manage and control the entire production chain and life cycle of products. RTD will address the development of intelligent controls, expert systems, improved and supply chain management; while exploitation of emerging technologies will radically reduce the cost and time of designing, manufacturing, delivering, and supporting products. RTD goals are:

- development of design-for-manufacturing tools and techniques to facilitate the introduction of innovative concepts and new devices, thus shortening the distance between research lab and commercial fabrication;
- development of new basic models of processes and simulation techniques, integrating cognition, learning and validation of product design.
- improvement in work conditions towards virtual and organised methodologies by using a codified information exchange;
- efficient specialisation in work procedures and specifications based on scientific results;
- optimised transfer and codification of SMEs internal know-how.

Technology-innovative manufacturing: Future manufacturing enterprises will leverage revolutionary technologies that radically change the way they design, build and support products. The role of research will be to:

- integrate new technologies with currently applied standards and methodologies (non-disruptive approach);
- adapt the new technologies according to users' needs based on modelling at nano/micro/macro levels;
- develop engineering methodologies for the ubiquitous computer environment in product/process design, control and simulation.

Key elements of this field of innovation are:

- holistic manufacturing systems technology;
- modular and configurable technologies;
- intelligent, flexible automation;
- real-time management systems;
- real-time digital factories;
- knowledge integration in control systems and embedded components; and
- methodologies for management.

The trend will be towards the generation of robust design and planning systems giving higher quality solutions in relation to the quantity of input information. Reaching this target demands:

- standardised models of product data and manufacturing resources;

- data management systems following the product and manufacturing life cycle;
- cognition-based tools and methodologies to minimise errors by dealing with uncertainties in automatically evaluating and elaborating solutions for complex systems;

In order to obtain knowledge-based systems, great attention must be devoted to the development of ‘self-learning’ systems, able to:

- use experience and histories of development processes in processing real-time data to extrapolate information or predict behaviour;
- generate new knowledge by proposing several solution options.

Knowledge-based systems will facilitate the rapid transfer of data across product-process domains and life-cycle phases.

European manufacturing service industries have the potential to realise an open engineering platform, for which many different applications can be envisaged. The platform in itself represents a future market, in addition to those for the products and factories it will produce.

A characteristic of next-generation manufacturing systems will be their ‘evolvability’. Here, the term is intended to indicate change that goes far beyond simple re-configurability. As yet, this remains an unattained goal. Its realisation will depend on engineering, as the technology of the future, which can strengthen and speed the innovation process, support the progression from traditional to life-cycle-orientated paradigms, and contribute to the science-based modelling of processes to realise science-based artefacts.

4.3 Emerging manufacturing sciences and technologies

The strategic target N. 5

RTD is opening new avenues to European leadership in manufacturing systems and technologies through the application of advanced solutions beyond the current state of the art. European manufacturers set world standards for factory equipment in all industrial sectors. Manufacturing technologies move consistently towards new levels of efficiency, and overcome existing technical limits by developing processes and intelligent machines. Technologies are able to handle and create more complex and unconventional materials, including those from biology. A holistic approach takes into consideration the converging nature of these sciences and exploits the potentials of process technologies, application of advanced materials, and implementation of intelligent mechatronic systems, cognition-based IT and downscaling of dimensions to the micro- and nano-scale.

Manufacturing is the integrator of basic technologies coming from natural sciences, material sciences and information sciences. Fundamental process knowledge is required for the realisation of new functionalities; in turn the application of the new functionalities in the manufacturing is required to make innovations happen. The objectives are the development of artefacts well beyond the current state of the art and the setting of new levels of performance standards (leadership).

The history of industrial technological development can be traced in permanent innovations and solutions that have had advantages over former generations by being better, faster, cheaper, more convenient, and more flexible.

Even in conventional sectors like machining, the creativity of engineers has produced innovations making it possible to step beyond the prevailing state of the art in processes such as:

- high precision and ultra high precision manufacturing;
- high speed cutting, dry cutting;
- thixo-forming and -casting;
- manufacturing of composite materials;
- rapid manufacturing;
- laser-assisted manufacturing processes.

Some of these innovations replaced traditional technologies; some introduced new product functionalities or reduced the consumption of energy and materials. Others brought new management methodologies, such as the ‘lean manufacturing’ concept originated in Japan.

Continuing to exploit emerging sciences and pursue specific objectives of R&D in emerging technologies will lead to:

- desirable new product characteristics;
- improved or new product functionalities of manufacturing technologies;
- intensive integration;
- new industries able to cope with global markets,
- radically enhanced efficiency in labour intensive manufacturing.

Many thousands public and private researchers in Europe – operating in the Manu*future* domain, within research institutes, universities and industries – can be engaged intensively in the continuous development of enabling technologies, blazing a new European trail towards implementation of the science-market knowledge-production value chain. They make up the most strategic asset of Europe: the knowledge base of an industry that can launch and sustain high-added-value manufacturing engineering.

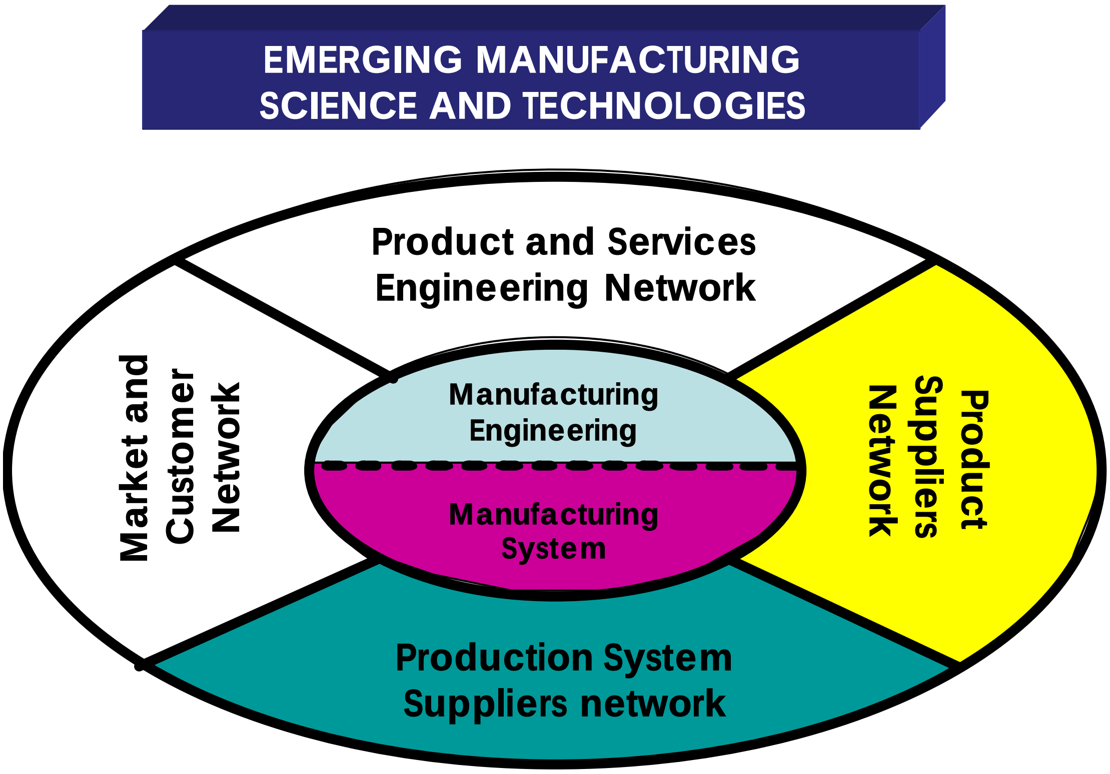

Figure 13. *Emerging manufacturing science and technologies are crucial in the core of the new manufacturing engineering systems. However, they will involve new relationships with the product suppliers and production system networks.*

Future advances will derive from fundamental knowledge of processes, and the successful incorporation of that knowledge into intelligent solutions. These will enable manufacturing systems to transcend current technical limitations in order to reach higher levels of performance and efficiency in terms of:

- new product properties (dimension, flexibility (deformation, bending);
- production scalability/volumes;
- production speed, cost and quality;
- energy and materials consumption;
- operating precision (zero defect rates); and,
- waste and pollution management.

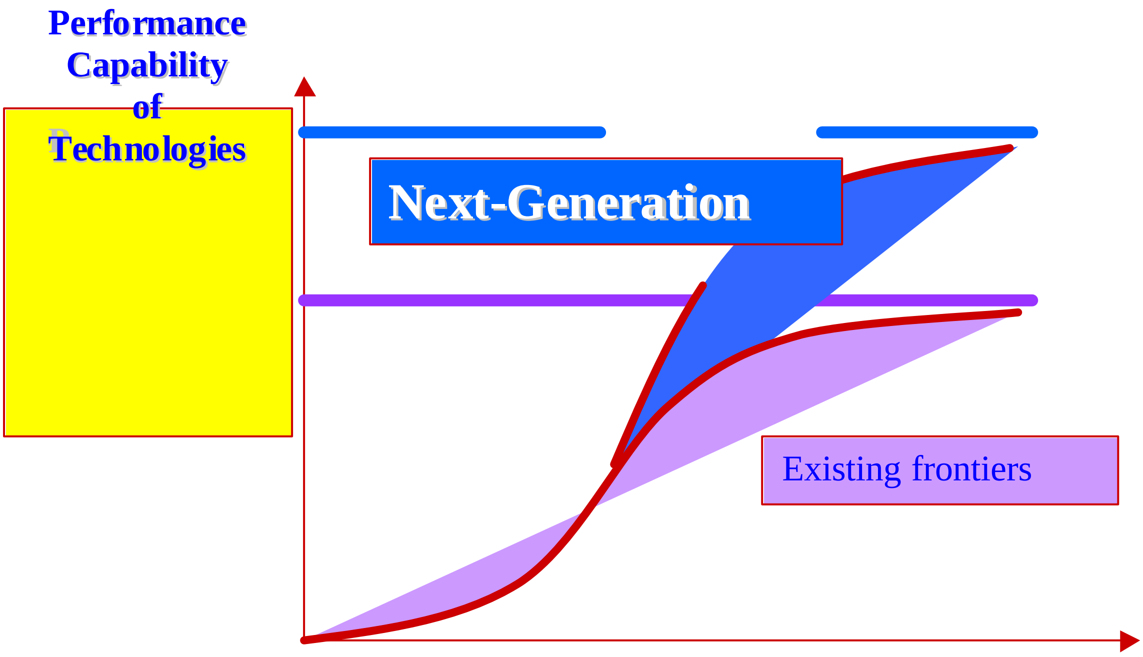

Figure 14. *Improvement of performance in scientific and technical engineering and processes through removal of existing scientific and technical barriers*

The main objective is the acceleration of technological innovation in manufacturing by the development of high-end machines and systems. This includes the whole field of investment in assets for factories and preparation for industrial manufacturing of products based on new micro-, nano- and bio-technologies.

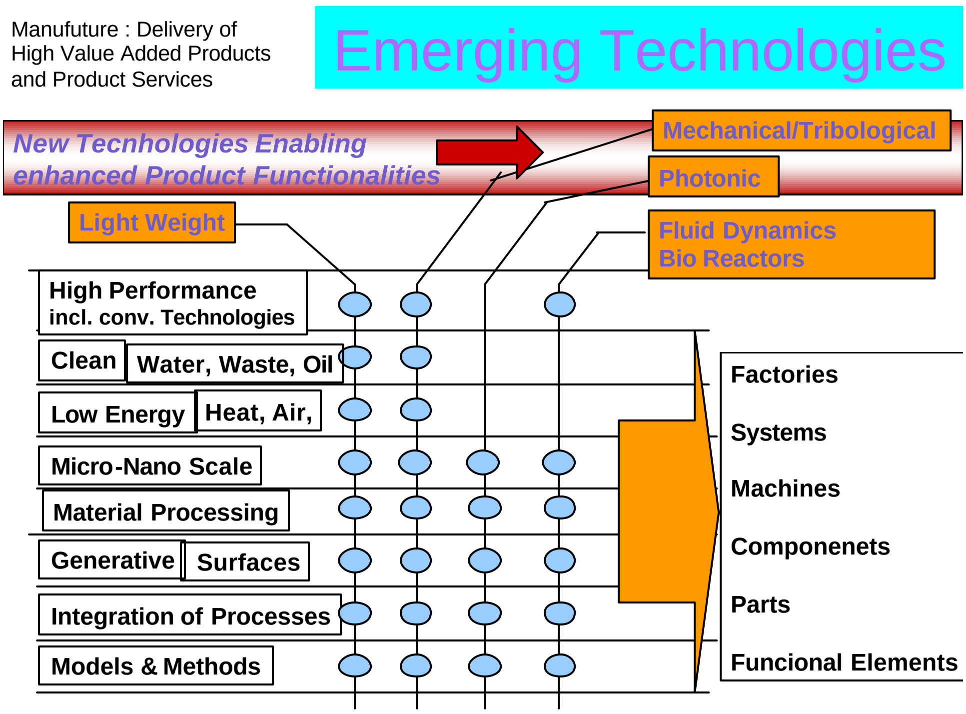

Figure 15. *Objectives and technologies for overcoming existing frontiers in realising product functionalities*

Conventional manufacturing technologies have to be pushed to their technical limits in all respects.

Pursuing specific objectives by R&D can give rise to desirable new product characteristics, such as the reduction of weight – often leading to reduced energy consumption – through the use of new materials, new design and new bonding technologies.

Many more product functionalities can be improved by manufacturing technologies. Wear reduction, for instance, may be achieved through mechanical or tribological solutions.

Other functions depend on optimisation of the reproducibility of production, e.g. for the manufacturing of high precision photonic elements or in the development of fluid reactors used in automation or medical/food production.

Overcoming current manufacturing limitations by introducing new manufacturing sciences and technologies will help to drive innovation towards new industrial capabilities and the sustainable business of the future. To achieve these objectives, innovation processes centred on single competences will increasingly give way to a multidisciplinary convergence of: physics, mathematics, social sciences, biology, chemistry, medical sciences, etc.

In the medium term, added value is likely to come primarily from some of the most revolutionary technologies: machine intelligence (or artificial cognition), microelectronics, nanotechnology and biotechnology. However, the potential also exists to break new ground in the majority of traditional manufacturing technologies

The contribution of extended technologies to environmental objectives is likely to be extremely high. A sustainable reduction of energy consumption by manufacturing processes and products over their whole life cycles would have a high impact on society. On the other hand, even modest advances will demand higher skill levels among workers and technicians in the factories.

An intensive engagement in emerging technologies through the cross sectional form of Manu*future* will be beneficial to the manufacturing industry as well as for more focused technology platforms. The ability to generate new knowledge and new capabilities increase with an early engagement in new technologies. On the other hand, potential and not foreseen "killer-applications" could possibly be identified in the manufacturing sector.

Time horizon

Investigation of the potential of underlying technologies such basic processes, mechatronics, cognition systems and materials is the **first step** on the road to industrial applications.

In the **medium term,** effort will concentrate in the development of prototypes and artefacts to deliver new functionalities such as enhanced tribological or dynamic behaviour of lightweight components, leading to new machine and system capabilities.

In the medium and longer timeframe new technologies such as nanotechnologies, cognition systems and integrated mechatronic systems will push the innovation and the technical development. The result will be the development of highly innovative components such as drives, sensors and actuators.

In the **long term** a broad engineering initiative and a supporting dissemination process in the various sectors of manufacturing can advance the industrial position towards leadership in applications based on basic process models and cognition control in a European platform for manufacturing.

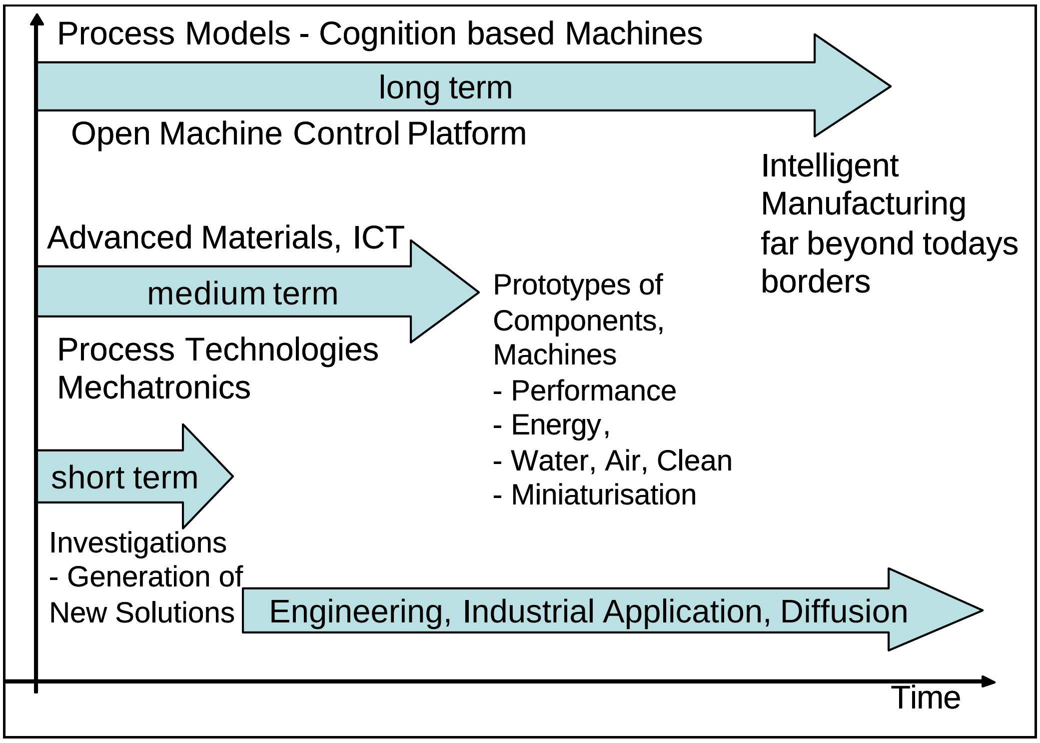

Figure 16. *Prioritisation of research targets*

Key research and intervention areas

Priority	Features and RTD targets	RTD Areas/ET's in medium term
High	**High performance, Speed Volume Precision** High performance includes the development of basics of processes taking into account new solutions for machines and systems. **Target** It is necessary to integrate high dynamic components and solutions in machines and to optimise the utilisation of peripherals like tools, moulds and dies and the usage of new materials or fluids and to optimise the technical systems.	process models parameters drives and actuators high precision measurement
High	**Micro- and Nano scale Manufacturing** Precision and miniaturisation of products and components to realise new functionaluities based on micro- and nanotechnologies **Target** Need new solutions for serial manufacturing of micro and nano scale components and functional elements and realise table top micro factories with capable processes and industrial systems	capable Micro Processes Micro Machines Process Automation
High	**Clean Environmental Pollution** addresses existing limitations of the consumption and contamination of processes and environment. **Target** It is the objective to fulfil all future regulations and reduce the contamination of air, water and humans by production technologies.	Dry and Low consumption of air, water, oil Components and equipment
Medium-High	**Generative integrative and adaptive Technologies** address the generation of usable forms, parts for rapid product development and manufacturing in series: lower time, higher reproducible quality and precision, lower cost. **Target** Development of processes and industrial systems for the generation of parts with integrated functionalities like functional near net shaping) with high reliability and integrated in rapid tooling and design.	Metal, Polymer composites ceramics soft-Tools and fixtures
High	**Energy & Materials** refers to the consumption of these resources by manufacturing processes. It is evident that both are increasing cost factors. **Target** to save time, and to reduce the consumption and loss of material and energy with innovative solutions. Fast activation of technological potentials in manufacturing technologies are prerequisites to achieve advantages in the competition of manufacturing industries and users in a broad.	wear, tribology process efficiency application of advanced materials
Medium	**Methodologies for Monitoring & Management** are part of holistic manufacturing systems. There are many losses in utilisation caused by missing methodologies for example in the field of quality management, inspection, diagnosis, learning from experiences, technology evaluation and many more. The knowledge of processes is fundamental for fastening speed or control of machines and systems., taking into account the strategies towards the role of European manufacturers as leaders in the world market for all equipments of factories in all industrial sectors **Target** it is of highest importance to lead the technology standards with the knowledge of solutions behind the state of the art by development and integration of scientific based material and process models	basic work elements self-optimisation self-organisation

Table 4. *Key research and intervention areas for emerging manufacturing sciences and technologies*

Main objectives and fields are indicated in this table. There are some, which are oriented to activate potentials of performance like speed or volume per time. Others follow actual developments under usage of fundamentals like nano-scale technologies. A third group is driven by environmental and sustainability requirements like clean or energy saving. The next group reflects to the industrial need of reducing the time for development and market like generative technologies or the integration of processes in the process chains. The last group follows the role of humans in factories and the efficiency of the manufacturing culture in Europe.

High performance

To overcome existing technical limits in manufacturing it is necessary to find the theoretical potential of all manufacturing processes and to activate it by the design of new machine generations and artefacts.

Micro scale technologies

Conventional technologies have their limits in µm dimensions. For high performance micro manufacturing, technologies for machine internal measurements in nm dimensions are required. For this, the dimensions of sensors and actuators must be downscaled. Optical technologies for measurement have to be integrated in manufacturing systems. They will contribute to the industrial operation in the nano-scale dimensions.

Clean technologies and reduction of environmental pollution address the existing process limitations. The objective is to fulfil all future regulations and reduce the contamination of air, water and humans by production technologies.

Generative technologies address the generation of usable forms, parts for rapid product development and manufacturing in series: shorter cycle time, repeatable quality and precision, lower cost. It even takes into account new solutions for the integration of sensor and actuators and functions in one step operations.

Energy & materials refers to the consumption of these resources by manufacturing processes. It is evident that both are increasing cost factors.

Methodologies for monitoring & management are part of holistic manufacturing systems. Operational losses are caused by lack of appropriate methodologies for example in the field of quality management, inspection, diagnosis, learning from experiences, technology evaluation and many more. Just taking into account the necessity of adding value by product oriented services, new methodologies are required for efficient operation and management. One important field is the basic methodology of life cycle control of technical products.

5. Infrastructure and education

The strategic goal N. 3

A Europe-wide co-operative RTD infrastructure with systems and education that favour collaborative research efforts for manufacturing excellence promotes technology transfer and market take-up of R&D results, provides competitive technical assistance, and improves lifelong learning and re-training of a workforce including growing numbers of ageing and displaced workers.

New business models, products and manufacturing processes will transform traditional industry through the intervention of enabling technologies via both top-down and bottom-up approaches. Science-based enabling technologies will form the backbone of a science-based innovation process.

Progress of knowledge-based manufacturing from breakthrough research to market innovation will be realised by considering this breakthrough research, together with enabling technology research, product/process development and industrial innovation, as a set of integrated activities.

The top-down R&D approach of radical Innovation is a science-driven process, leading to new high-added-value products/processes 'looking' for potential use.

The bottom-up route to incremental innovation, going from market towards RTD-based development results in upgraded products and processes responding to shorter term contextual challenges and opportunities with improved science-driven products.

Both approaches are capable of delivering new products for existing markets, and new products for new markets.

The R&D infrastructure engaged in the conception or creation of new knowledge, products, processes, methods, and systems, and in managing the RTD projects represents a strategic asset for a competitive and sustainable HVA European Manufacturing Industry success on global market.

The actual European RTD system is composed by:

- universities,
- research centres,
- applied research organisations,
- knowledge-intensive SMEs,
- manufacturing enterprises.

According to the Eurostat Yearbook 2004, 981.209 EU-15 researchers (RSE) are professionals employed by this system. That figure includes managers and administrators engaged in the planning and management of the scientific and technical aspects of a researcher's work as well as postgraduate students engaged in R&D. Considering the amount of enterprises and workers operating in manufacturing sectors (§1), the percentage researchers/manufacturing workers is around 3,6.

To the end of the industrial transformation, turning this system, that already exhibits a high potential, into an effective infrastructure, requires a new course (§4.3) implementing a research market knowledge production and supply chain, the foreseen ***Knowledge industry fabric*.**

To integrate Knowledge industry and High Value Added (HVA) manufacturing, the actors concerned need align policies, strategies, SRAs and roadmaps, by EMIRA Platforms that will induce (see the chapter 6 Recommendations), help such strategic alignment of the actors.

FACTORY, as a very successful *umbrella* of EUREKA for production projects and a bottom-up initiative with national level of aggregation, is opening room to strategic solutions to industrial demand for competitiveness following the Manu*future* approach.

The re-launch of the EUREKA *cluster project* Factory DNA, sectors oriented, can help developing competitive and sustainable strategic sectoral solutions as required by HVA manufacturing industry.

The combined efforts of networks by both “industries” will enable to respond with High value solutions to medium-short term challenges.

By combining the High Added Value potential manufacturing Industry Fabric and ***Knowledge industry fabric*** fostered by the Manu*future* approach, Europe may produce the Knowledge energy required to re-launch and sustain its world industrial leadership.

For European industries to remain competitive in the increasingly complex global economic environment, it is crucial that they modernise their manufacturing base and strengthen the links between academia and industry, and between research and innovation.

Building a world-class R&D infrastructure is a prerequisite to the development and adoption of the new business models, organisational concepts and working methods envisaged in Manu*future.* This will only be possible against the background of a favourable economic and regulatory climate that encourages research investment and entrepreneurialism. It will also necessitate a restructuring of education and training to reflect the lifelong learning needs of tomorrow's 'knowledge workers'.

To ensure the availability of a suitably qualified workforce, another essential will be to Increasing public awareness of the value of science, the rewarding career opportunities that will arise in knowledge-based manufacturing and the importance of sustainable production/consumption patterns.

To cope with the demographic change and with the aging population in many western European countries, new forms of work organisation are to be developed to enable the full integration of the elderly workforce, including the integration of low qualified men and women.

5.1 Innovating SMEs

The strategic target N. 6

SMEs develop into transformable enterprises capable of continuous, rapid and smooth adaptation of their operations, management and strategies in the continuously changing industrial environment.

Transformable SMEs with variable product portfolios operate profitably in a networked industrial landscape, where they manufacture and market added-value products and product/services. They fulfil:

a) leading roles in consumer product and service sectors, that can benefit from the sharing of costly or specialised technologies/plants – e.g. manufacture of high value added shoes; or

b) complementary roles in a given value chain – as product designers, manufacturers of 'intelligent' components or materials, providers of outsourced operations such as component assemblers, and providers of product-related services, or of dismantling/recycling services.

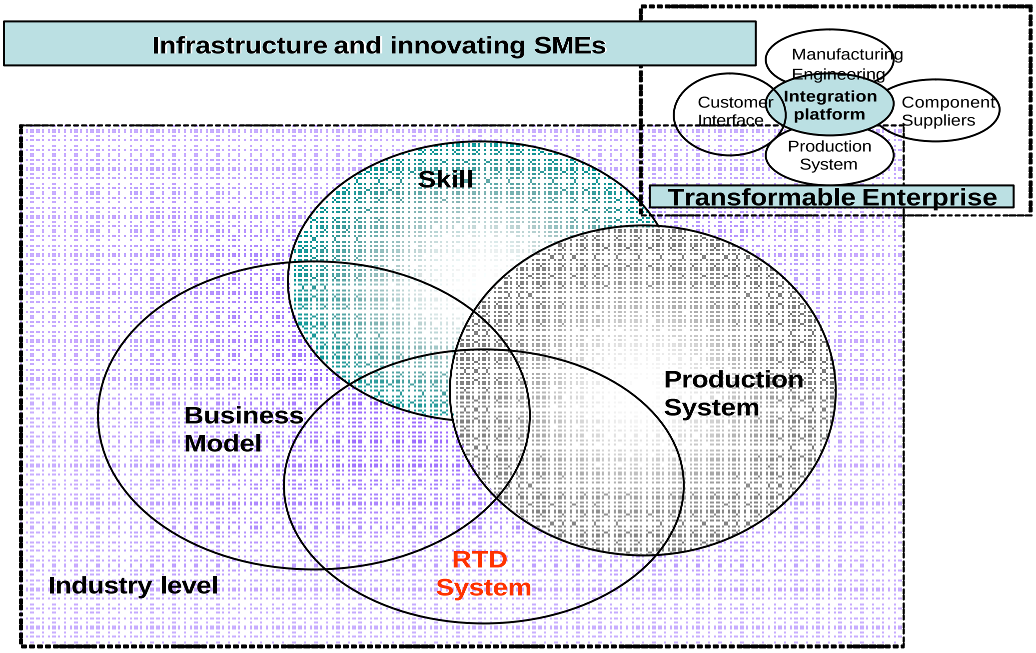

Figure 17. *Industry-wide integration of SMEs into networks with research providers is necessary to ensure continuous flow of new knowledge to support their long term success in an open business environment.*

European SMEs make up the majority of industrial manufacturing landscape for which the Manu*future* SRA represents a means of achieving market success and ensuring a viable future in a knowledge-based economy. Securing that future depends upon developing a scalable approach based on a single platform that follows the principles of cooperation in a networked value system for high performance SMEs that are self-organising, self-monitoring, and self - configuring.

Transformable SMEs will build their technical and organisational processes around the strategy of innovating production, employing optimised inputs of materials, energy and information. They will continuously develop operational, organisational and financial solutions that answer day-to-day challenges, while also taking account of a planning perspective aimed at improving their competitive position in the medium to long term.

‘Value-based’ internal and external developments will be identified at an early stage by means of risk analysis of future developments and their impact on investment decisions. Systems and methods enabling SMEs to react swiftly to dynamic situations should be capable of defining action alternatives in the fields of strategy, structure, human and technical resources; as well as determining points of leverage whereby strategic management can increase transformability.

Integrated management control systems should be in place to guide decision-making through systematic classification of relevant options and indicators when conflicts of interest arise as a result of process changes.

For systems and human resources to act co-operatively throughout the value-adding chain, and to enable an SME to negotiate independently with partners at its own and other hierarchical levels, new theories and methods must be proposed. These would ensure a dynamic process through which the enterprise could acquire the desired degree of freedom in both tactical and strategic decision, empowering it to pursue and self-regulate its goals.

Structural concepts with standardised interfaces for rapid configuration by ‘plug and play’ will be central to the common platform – as will digital tools (modelling, simulation, and virtual reality), enabling SMEs to maintain a forward-looking stance and optimise the configuration of their operational processes, performance units and networks.

Test-beds for innovating production

The research output of innovating SMEs is a key value-adding component of the SRA. This will be used to test, validate and demonstrate solutions suitable for other small enterprises moving towards innovating production in tomorrow’s virtual factories, thus permitting rapid deployment of new technical knowledge by the SME community.

Topics such as start-up of production operations, optimising production networking ability, validating knowledge-managed technologies and testing human resource potential would be the object of development in the new Innovating SME platform.

This would further clarify the relationships being researched under the new advanced industrial engineering environment of innovating production. It would test whether the deployment of innovating production could cope with the growing complexity of network operations in a robust and application-oriented environment.

Proving whether networked transformable SMEs can function as full working participants in a new knowledge-based world would thus show that the virtual factory concept represents a real opportunity for would-be investors.

5.2 RTD system and RTD management changes

The strategic target N. 7

European Manufacturing to enter the Knowledge economy needs to move strategically towards High Added Value. To achieve this HVA at system level, the fragmented European RTD needs to become a strategic and fully operational knowledge production system, hence transformed into a strategic European infrastructure for competitiveness - the foreseen ***Knowledge industry fabric*.**

European research organizations and universities are the backbone of European k generation process for Knowledge Manufacturing and need to start dynamic research and innovation networks to fast play as an efficient, effective and competitive actor on the ETs global market.

This K-industry mission aims at overcoming the present 'paradox' between the generation of scientific knowledge, (which is abundantly present in the EU) and the insufficient ability to convert this knowledge into innovation and in particular into production (REPORT on Science and technology- Guidelines for future European Union policy to support research (2004/2150(INI) FINAL A6-0046/2005. Committee on Industry, Research and Energy - Rapporteur: Pia Elda Locatelli).

The Manu*future* vision document listed a number of priorities for changes in the form and management of RTD infrastructures. These should:

- foster an entrepreneurial culture to deliver and develop the marketing and exploitation of research results and schemes to help the creation of knowledge-based SMEs;
- create research infrastructures, mainly through networking, with due regard to manufacturing research needs and the already existing infrastructures;
- establish favourable framework conditions to create an attractive fiscal environment at EU level; and,
- promote involvement of SMEs with RTD centres by co-financing multidisciplinary research programmes and knowledge transfer mechanisms.

This transformation requires new and dynamic research and innovation networks that must be nurtured to stimulate knowledge generation and ensure efficient transfer of its benefits to the manufacturing sector.[12] This involves clear recognition of the mutual value in an intimate collaboration between the academic and industrial communities and knowledge transfer intermediaries. Major RTD actors in this dynamic knowledge value-adding network are:

- **universities**, where basic scientific and technical education and training takes place;
- **research centres**, in which graduate and postgraduate students can to gain confidence and build mature experience in dealing with new sciences and technologies;
- **applied research organisations**, providing professional know-how transfer by means of projects or knowledge transfer, in solving real problems of manufacturing and with researchers moving from institutes into enterprises;
- **knowledge-intensive SMEs** (e.g. spin-offs), which can transform the knowledge produced by applied research into products and services for manufacturing industry;

[12] A National Manufuture example is the Sintesi case: A Manufuture public-private research company to develop K-based HVA machinery and systems (see in www.manufuture.org the "Manufuture Best Practice - Sintesi.doc" in Consultation Section/MANUFUTURE Examples)

- **manufacturing enterprises**, equipped to incorporate the knowledge acquired along the value chain into products and processes with the qualities needed to support enhanced competitiveness

Key research and intervention areas

To achieve the objective of introducing and continuously enhancing efficiency in knowledge based production processes (reduce cost, increase quality, shorten life-cycle…), the following actions are needed:

- **Speed** up knowledge-based advances in an increasingly competitive knowledge-driven global economy – requiring large investment in scientific/ technological/industrial fields, addressing the fact that:
    - Long-term high risk basic research needs public investment
    - Medium term applied research needs private/public investment
- **Change the** basis of competition, promote and stimulate intimate collaboration and knowledge generation to the mutual benefit of the academic and industrial communities;
- **Carry on** from R&D projects to collaborative research in Platforms implementing new governance, IPR schemes and participation mechanisms
- **Develop** stability and unity of purpose through strong governance of public/private collective research among RTD actors: research institutions and universities' role and level of intervention (local, regional, European,)
- **Define** a European plan to develop and integrate the existing research infrastructures by designing a variable 'geometry', with recognition of the fact that not every country needs to take part in every manufacturing policy, but that some can co-operate more closely in R&D-based manufacturing following a three-step approach:
    - prioritise the leading products/services,
    - identify the potential actors,
    - define the axis of integration.
- **Introduce** the Manu*future* governance of innovation (bridging the gap between science and innovation) for the efficient transfer of RTD benefits and ensuring manufacturing sectors by new value-adding approach to innovation.
- **Encourage** innovation, coordinate research efforts and promote involvement of SMEs with RTD centres. These measures will motivate individuals and companies, engender competitiveness in the RTD community, and foster the sharing of knowledge. They will also promote the involvement of industrial partners, in particular start-ups and SMEs in research and innovation activities, together with technology transfer centres, and increase public awareness and enthusiasm for manufacturing science and technology

  Manufacturing industries can derive added value from the knowledge created within knowledge-intensive SMEs and from applied research organisations. This will enable them to focus on their own core activities, while leaving tasks that require specialised skills to the SMEs that have direct links with universities and R&D centres in so-called 'knowledge factories'. As a result of their extensive networking, SMEs will thus become important reference points for manufacturing enterprises seeking frontier knowledge and innovative services. They will also form fertile breeding grounds in which personal growth and creative talent are strongly stimulated.

5.3 Skills and educational strategy

The strategic target N. 8

In order to create the strategic European infrastructure for competitiveness - the foreseen *Knowledge industry fabric*, it is essential to prepare people trained and educated to serve the scope of new manufacturing, i.e. the core condition to generate industrial HVA.

People are the strategic asset that the European research system should prepare to continuously apply and transform knowledge into a competitive tool producing HVA for European Manufacturing.

This objective meets the political European goal which declares "the Knowledge triangle of research, education and innovation to function within favourable framework conditions, which reward the knowledge that input to work. In Europe, we need to become much better at producing knowledge trough research, at diffusing knowledge through education and at using and applying knowledge through innovation. (REPORT on Science and technology- Guidelines for future European Union policy to support research (2004/2150(INI) FINAL A6-0046/2005. Committee on Industry, Research and Energy - Rapporteur: Pia Elda Locatelli)

The challenge for European manufacturing is to increase skills and capabilities of the EU workforce by developing the competences needed by new generations of 'knowledge workers' combining technological expertise with entrepreneurial spirit, ensuring continual training of a workforce that must be capable of working in volatile business networks and facilitating the mobility of researchers and engineers

A basic need is to align the differing national educational systems with the demands of future manufacturing, taking into consideration that the responsibility for those systems lies within different departments in each of the Member States.

Knowledge-based production requires the support of new kinds of education and training schemes integrating research with technology and manufacturing. The priorities are to:

- **reorganise educational programmes** around new engineering disciplines with a high potential impact on EU manufacturing competitiveness'
- **establish Europe-wide educational systems** by introducing an EU credit system allowing students of manufacturing engineering and other disciplines to complete parts of their education in other regions and countries; and
- **address the workforce as a societal Issue,** focussing on attracting and keeping adequately trained people to make European manufacturing more competitive and sustainable.

Meeting tomorrow's needs

In the new knowledge-based industries, managers and employees will be required to learn continuously and to re-skill themselves to meet changing customer demands. New ICT skills, together with a broader scientific and technical background, will be required for accessing new knowledge from a wide range of information sources relevant to the work in hand on a daily basis.

Worldwide shifts in the division of labour, broader and faster diffusion of new knowledge and the shortening of product life cycles have established new industry-science relationships. These depend heavily on industrial dynamics and on the way the science world realises its role in each country.

Integrating education and industry

During the 1990s, universities were faced with significant pressure to produce innovative results that could be exploited more effectively by industry. This was mostly due to the fact that the European innovation gap was deemed to result from insufficient and inefficient scientific and technological transfer.

In this context, universities and technical schools around Europe have been trying hard to adapt themselves to the new manufacturing reality of the 21st century. The modern university is distinctly different from that of 30 or even 15 years ago.

Development of educational curricula has nevertheless failed to keep pace with either the growing complexity of industry or the economy, and even less with the rapid development of new technologies. Studies are often too lengthy and too general. Furthermore, it can be argued that manufacturing is a subject that cannot be handled efficiently inside a university classroom alone.

A highly promising approach would be to integrate the factory environment with the classroom, to create the ‘teaching factory’, in which academic study is combined with practical work experience and exposure to the needs of industry.

New forms of basic and life-long training, moving beyond the traditional disciplinary boundaries, with world-class targeted interdisciplinary teaching at university and postgraduate level, should also be envisaged (e.g. academic start ups and ‘venture capital universities’).

Human-oriented machine interfaces can support workers’ and users’ skill development in learning to handle the complex technical systems of intelligent manufacturing. This includes work with remote operations and virtual workplaces.

Key research and intervention areas

New education and training goals in the global economy are:

1. **Define and comprehend** the needs of the manufacturing industry for training and education in the years to come:
    a. enable industry and educational institutions jointly to define the requirements to set
    b. out the content, approach and delivery mechanism for future curricula:
    c. facilitate the integration of research and innovation with education and training activities;
    d. develop the training of industrial researchers, through dedicated initiatives by research institutes;
    e. coordinate higher education with European manufacturing research, to contribute to industrial competitiveness and technological innovation; and to promote the concept of self-employment and entrepreneurship.
2. **Create** a European framework for pilot implementation of the ‘teaching factory’:
    a. establish a continuous process to train within companies, incorporate the management and entrepreneurial skills into lifelong learning schemes, support training activities without any age limit;
    b. develop competence in high-end manufacturing technologies;
    c. introduce new teaching principles and industry-based case studies that will promote concrete expertise in manufacturing;
    d. complement training through existing and new instruments within the Seventh Framework Program, in addition to regional and national training schemes.
3. **Develop** the Manu*future* educational system, with engineering curricula embedding entrepreneurship and innovative spirit, to harmonise the manufacturing qualifications of EU Member States:
    a. develop lifelong learning programmes to maintain the skills of learning organisations;

b. familiarise young manufacturing engineers with ‘start-up’ concepts by complementing typical engineering qualifications with entrepreneurial subjects in graduate and postgraduate education;

c. set up university-level European exchange programmes between technical and business schools, focused on European research organisation competences;

d. enhance mobility between university and industry, and mobility of workers in industries, for learning purposes.

4. **Retrieve** the respect and appeal of manufacturing, in order to attract young people as the workforce to give society the capacity to achieve sustainability in manufacturing:
   a. adopt more flexible and intelligent businesses systems for the management of production and human resources;
   b. introduce new mechanisms to tackle skill shortages, and provide incentives for skilled staff retention at their retirement age limit;
   c. provide training and education in sustainable manufacturing practices;
   d. develop new and consistent methodologies/protocols for implementing sustainability concepts. Establish measurable indicators to evaluate and follow the fulfilment of corporate sustainability goals;
   e. spread best practices among manufacturing industry, publicise manufacturing success stories in Europe;
   f. convince young people, even at secondary school level, that manufacturing, engineering and related disciplines offer exciting, challenging and attractive career options, building a more positive image for employment in manufacturing.

6 Implementation of the SRA through collective action

The strategic goal N. 4

European industries and research providers achieve high levels of productivity in delivering, transferring and exploiting research outputs through co-ordinated and collaborative partnership schemes. Through the identification and integration of common requirements they plan, develop and execute joint programme of activities promoting the aims of the Manu*future* SRA.

The review and integration of critical areas of research and development from all manufacturing-dependent sectors would provide the fundamental means for synergistic co-operative schemes ensuring ease of commercialisation. Such actions would provide a solid foundation for the whole spectrum of manufacturing innovation technologies. They would also address the diffusion of new knowledge to SMEs and the education of the next generation of manufacturing leaders, technologists and workers.

Appropriate actions at the right level

Manu*future* will promote successful Europe-wide implementation of solutions at various levels (Figure 18), facilitating the structuring of effort and funding, and encouraging pan-European convergence between regional centres of industrial competitiveness.

Coordination of policies, high level R&D and standardisation at the European level will provide an ‘umbrella’ for actions at the level of individual nations – including information dissemination, support of SMEs, education and adaptation of national regulations. These, in turn, will create an environment for local actions such as technology transfer, aid to SMEs and cluster formation at the regional level.

Correlation of regional manufacturing activities will derive from the industrial transformation reference model. (Fig. 3 in 2.2)

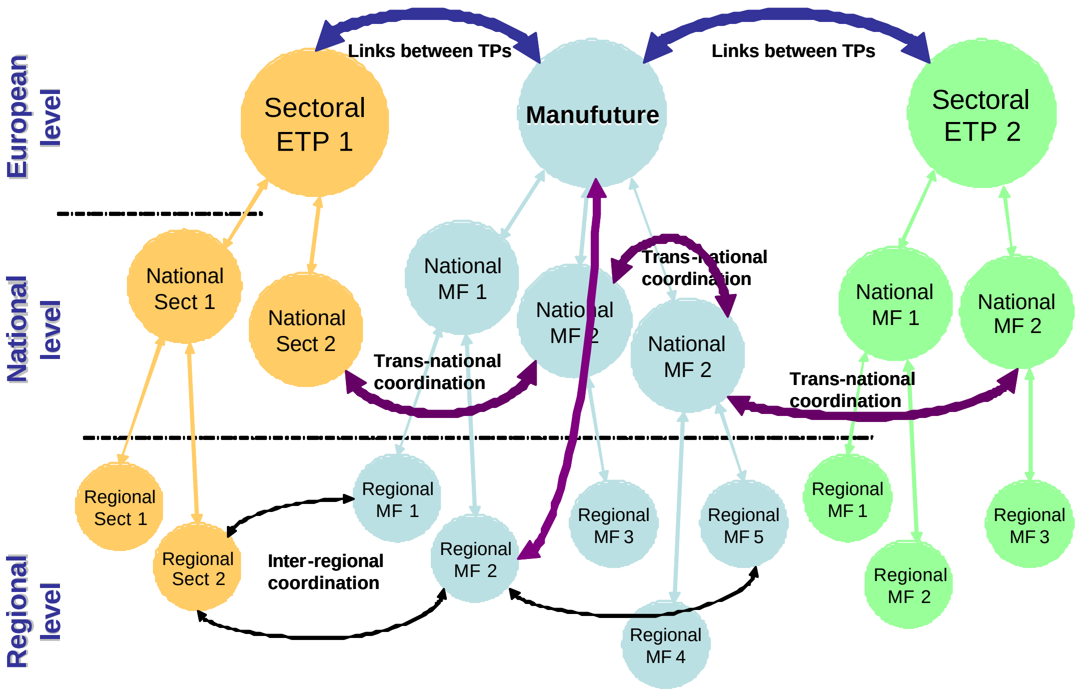

Figure 18. *Manufuture coordination at three levels*

6.1 At European level

With the common purpose of overcoming problems posed by the complexity and diversity of the EU manufacturing scene, European Technology Platforms can be considered as 'collective' stakeholders. They include:

- Sectoral European Technology Platforms (ETP): Errac, Ertrac, Warterborne, Construction, Aeronautics, etc...
- Trans-sectoral ETPs: industrial safety, EuMat…
- Enabling technologies ETPs: Eniac, Artemis, E-Mobility...

To achieve the necessary broader convergence, as many different industrial sectors are concerned, Manu*future* operates to assess the common core of business or areas of interest, in collaboration with other platforms and other European and international initiatives such as EUREKA, IMS and interactions with world RTDI networks, to make usage of the paradigm most efficient and effective. This will enable to develop benefits for individual TP interests and those of the European economy as a whole.

In this SRA, the issues are discussed in general terms. Their sectoral application will be reviewed in conjunction with the various dedicated Platforms (Figure 6.2), with which case-specific interactions will be developed.

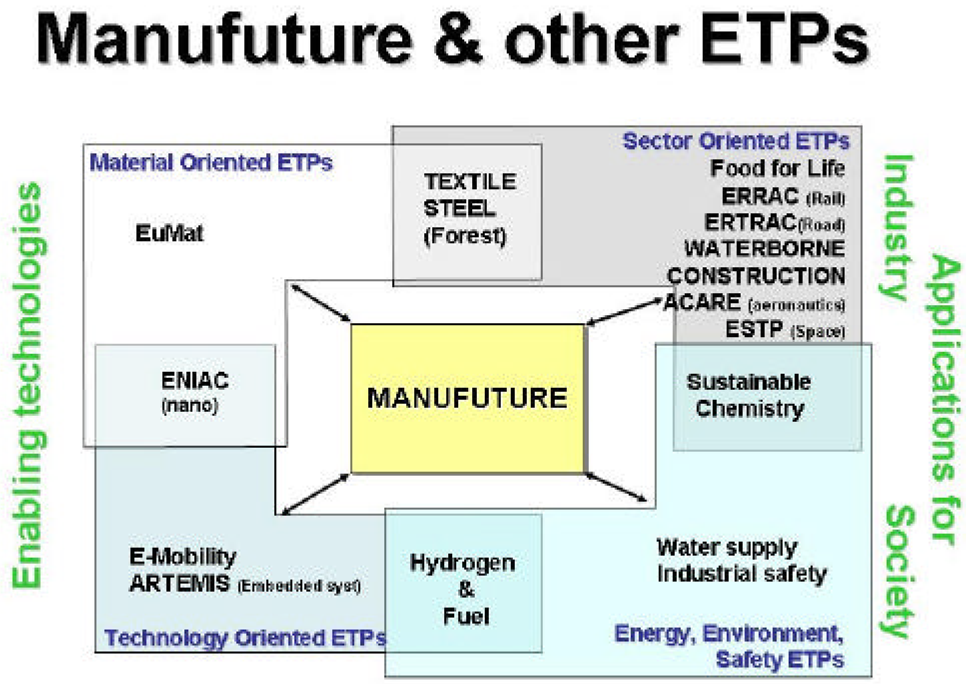

Figure 19. *Manufuture and the other TPs*

Intervention through interaction

The objective of collective activities (Figure 6.2), is to define a complete Manu*future* SRA taking into account Europe's overall manufacturing needs from sectoral, trans-sectoral and enabling technologies viewpoints (RTDI agenda).

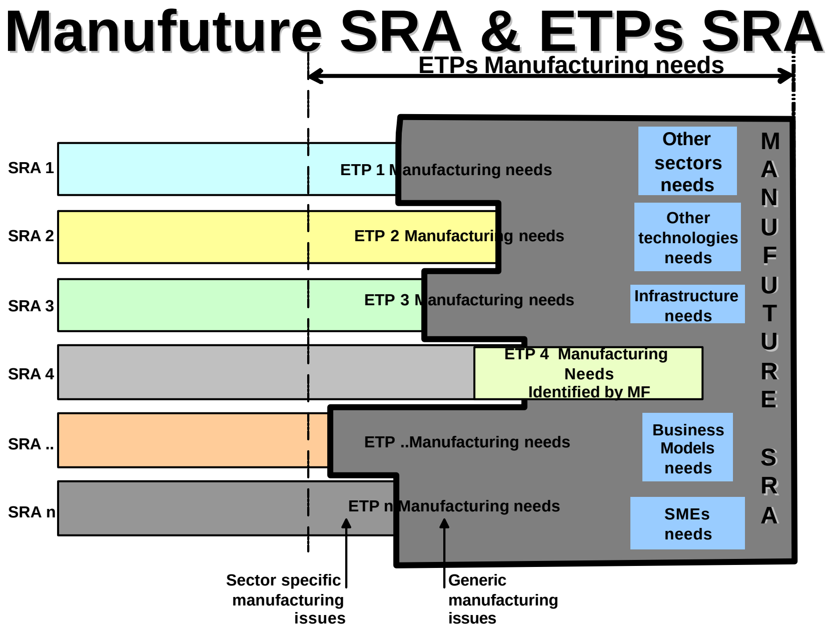

Figure 20. *Interactions between Manufuture SRA and other ETP SRA*

For the Sectoral ETPs, Manu*future* can provide a generic reference model expressing their manufacturing R&D orientations. Such an approach will greatly facilitate the cross-referencing of common issues. Manu*future* will act as a facilitator of discussions and exchanges on process commonalities between different sectors.

Where sectors focus exclusively on their own particular products, Manu*future* will play the role of stimulator, initiating the definition of process needs and implementation of suitable actions to retain the manufacturing in Europe.

For the trans-sectoral ETPs, Manu*future*'s contribution is in the coordination of interfaces with Manu*future* itself and the sectoral TPs.

For the Enabling Technologies ETPs, Manu*future* will, through the common reference model, pool the needs for manufacturing and act as a supplier of the available and emerging technologies. Like Sectoral TPs, Enabling Technology TPs concentrate on technological research in their specific fields, and give low priority to industrialisation or the manufacturing of products based on their new technologies.

The mode of intervention will be to promote the paradigm of high added value and the Manu*future* reference model, through coordination of manufacturing R&D actions at two interrelated levels:

- the industry-wide level, addressed directly by Manu*future* initiatives,
- the sectoral level, addressed by interactions with the ETPs and with sectors not covered by ETPs.

6.2 At national/regional level

National Technology Platforms related to the Manu*future* ETP must be created in individual EU Member States. All Manu*future* National Technological Platforms should adopt the main development goals identified in both *Manufuture – a vision for 2020*[13] and the current document. Other initiatives can also encourage the emergence at regional levels of equivalent concepts promoting competitiveness by stimulation of the synergy between sciences, education and industry.

National Manu*future* initiatives, while adopting different models of organisation, should share the common Manu*future* vision and aim to promote widening acceptance of, and participation in, Manu*future* by European industry, by:

- alerting public opinion and politicians to the challenges that European manufacturing faces, as well as to industry's critical role in delivering economic output, skilled employment and sustainable growth;
- aligning the interests of the R&D community and technology providers in strong and effective cooperation networks that develop and source knowledge and technology;
- identifying and strengthening the highly competitive local/regional networks of large multinational OEM companies, SME suppliers, technological partners, consultants and R&D contractors.

The most important contributions of these national and local initiatives should be in:

- Build a clear link to and incorporate a wide SME participation, as especially smaller SMEs can harder participate on European levels of platforms than international large companies;
- horizontal integration, coordination and synchronisation of R&D efforts in EU Member States;
- vertical application of competitive technologies, products, methods and processes in enterprises (both OEMs and SMEs) – including multidisciplinary networks coordinating R&D activities in new industrial sectors such as medical technologies, telematics, nanotechnologies and mechatronics.

Enlargement adds opportunities

Over the next decade, the integration of new EU Member States will have a significant influence on European manufacturing of products for global markets. In a strategy of integration and cohesion, they could become world-class suppliers to OEMs.

This can be seen as an EU strategy of transition, to maintain strong national/regional sectors in the interim period, opening a competition between EU members in all areas, even in R&D as a key factor to promote excellence and fostering the European manufacturing progresses connected to the high-added-value industrial paradigm.

Aligning the development goals and priorities of the original 15 with those of the 10 is therefore crucial in building a common interest in close cooperation between production companies and R&D organisations as a foundation for expansion into global markets.

National and local initiatives will be particularly important in the new MS. After many years of socialist regulation, their move towards market economy – in R&D, as in other spheres – is a major mental, organisational, technical and financial challenge.

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[13] http://europa.eu.int/comm/research/industrial_technologies/pdf/manufuture_vision_en.pdf

6.3 At SME level

Another stakeholder group of outstanding importance is the innovative SMEs and other independent enterprises, which figure largely in the structure of all manufacturing sectors.

SME's are main players in several sectors, capable to develop, produce and sell innovative products and services to more and more demanding consumers. In others, they are linked in diverse networks with OEMs in the value chains of:

- product engineering and design;
- production of parts, components and systems;
- supply and distribution of materials and products;
- supply of manufacturing equipment;
- services.

SME's are undoubtedly the critical component of the European manufacturing fabric, able to partner to each other and with global OEMs, technology centers and R&D organizations.

They build up innovative product and service development cells and agile supply chains capable to ensure an effective flow of innovative components and technology-based services, and form variable-geometry co-operative networks able to bid for businesses on a larger scale.

Experience has already shown that SMEs certainly represent one of the strongest assets for Europe in maintaining sustainable competitive advantage against the emergent Asian competitors.

Their participation in the integration activities of engineering platforms will engage them in long-term partnerships across Europe, reinforcing the ability of the manufacturing infrastructure to achieve rapid, reliable transfer of research results into marketable products.

A number of practical measures can be envisaged for realising Europe's competitiveness goals, while also meeting national/regional needs, e.g.:

- launching specific local network initiatives to establish new R&D infrastructures for technologically innovative and knowledge-driven economies, which would build local market strength and permit entry into global markets;
- developing regional and sectoral maps of technological and manufacturing competencies, R&D centres and universities ;
- creating European networks of suppliers, supply chains of standard components and adaptable technological systems, including low-cost technologies in the new MS;
- forming virtual institutes and linking them with sectoral manufacturing networks to generate high added value;
- establishing innovative multidisciplinary technology and business centres
- transferring new business models and communicating success stories to SMEs of the new EU countries;
- actively participating in pan-European R&D initiatives within ETPs, EU programmes, especially the Seventh Framework Programme, and EUREKA;
- introducing universities and technology centres to the European system for educating highly qualified engineering staff who are prepared to work in large or small enterprises – entailing the adoption of 'exportable' standards, coverage of innovative technologies and encouragement of student mobility;

7. Recommendations for action

1. Manu*future* should be a label for successful research and competitiveness at **EU level,** the Manu*future* initiative advocates the promotion of change towards manufacturing paradigms with high industrial application and value-generation potential, with particular respect to:

- life-cycle orientation of the manufacturing industries;
- implementing knowledge in products, processes, enterprises; and,
- development of product/process-oriented services.

2. The setting of favourable **framework conditions** depends upon:

- a blend of basic, sector-specific and regionally focused application-oriented research in:
    - o new business models;
    - o advanced industrial engineering;
    - o emerging manufacturing science and technologies[14];
- development of a cost effective and robust shared research infrastructure capable to deliver results according to the current and future needs of Europe's manufacturing industry.

3. Because RTD processes are long and complex, involving several layers of society, an integrated set of actions is required at **Member State level**. In addition to pan-European efforts, national and regional authorities must participate, either independently or in a complementary manner, by

- fostering the creation of clusters (sector, technological or other) at national and/or regional level, creating local research and transfer nodes/centres of excellence, and integrating SMEs into networks. These can then join and support the creation of clusters at EU level;
- developing competence in high-end manufacturing technologies;
- and establishing local centres of excellence in manufacturing, incorporating a Manu*future* network of educational and research communities, to permit the involvement of university researchers, knowledge transfer to industry and the formation of spin-off companies.

4. At **Educational level,** the Manu*future* recommendations are to

- build strong links between industry and academia, by establishing joint postgraduate degrees, postgraduate industrial training and industrial real-life-driven courses, as well as manufacturing departments and/or universities driven by industry;
- develop schemes to help to create knowledge-SMEs that should foster a new industrial model in terms of the links with reasearch centres and this group on enterprises. These SMEs will act as tool for linking academic/research centres with large manufacturing industries;
- integrate all manufacturing qualifications of EU Member States into European engineering curricula;
- introduce new teaching principles and industry-based case studies that will promote concrete expertise in manufacturing;
- re-organise educational programmes around new engineering disciplines with a high potential impact on EU manufacturing competitiveness. Such disciplines need to address all levels of the extended products, systems and embedded services of the manufacturing sector;

[14] List cribbed from page 18, will need to be revised to fit the way the document evolves.

- activate an appropriate Manu*future* International School, leading to Masters and PhD qualification in industrial research, based on research institutes and leading manufacturing companies.

5. Finally, Manu*future* Platform defines a consensus vision of the research and innovation needs for high-added-value manufacturing. This vision should be used by stakeholders to integrate and coordinate research in a 'European Research and Innovation Area for Manufacturing – EMIRA (Fig. 21) within the European Research Area (ERA).
This coordination should take account of regional and national needs, and recognise Europe's wider role in the global RTDI network.

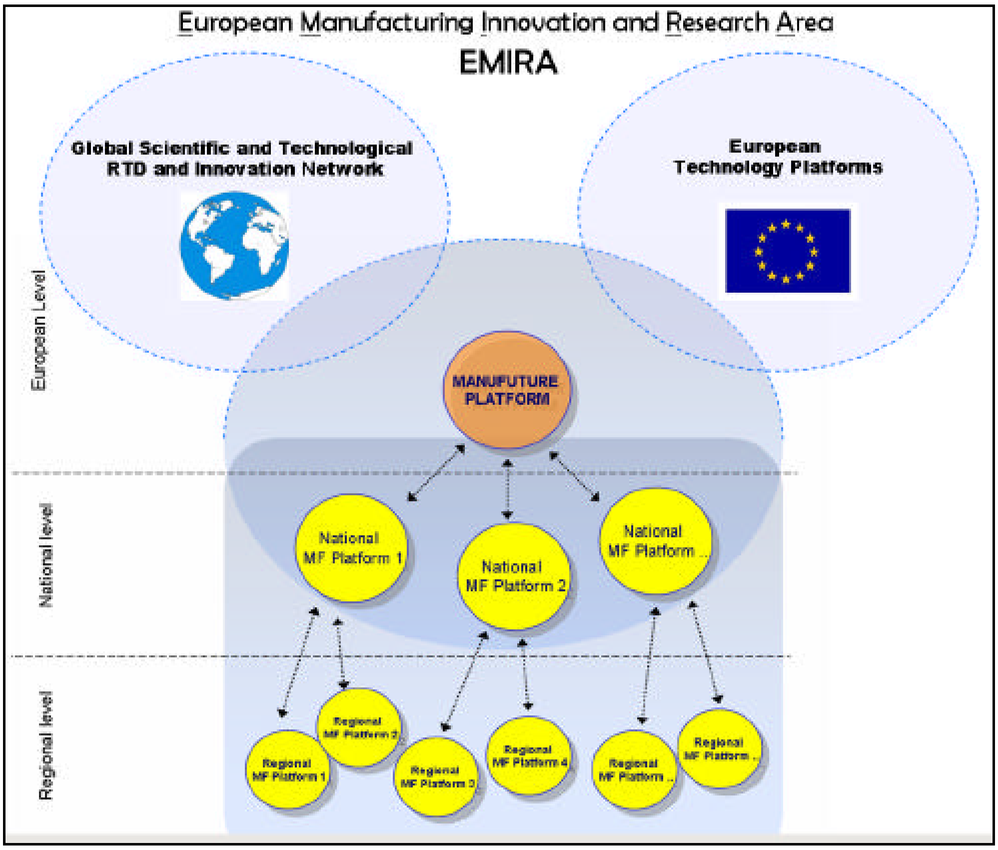

Figure 21. *The Manufuture Platform's role in establishing: the European Manufacturing Innovation and Research Area, EMIRA*

Conclusions

Manufacturing is, and will continue to be, a significant component of economic activity in Europe. In a turbulent and highly competitive global environment, it must continuously evolve and embrace transformational change in order to maintain and increase its economic impact.

European manufacturing must drive to increase its ability to add high value, meant as hi-tech competitive advantage, by generating and exploiting new knowledge in manufacturing within a globalization context; this value is the leverage to achieve dominance in markets, beyond costs.

This requires step changes in manufacturing engineering capabilities and the engineering tools that are applied; skills in innovation and entrepreneurship must be enhanced.

Research should be focussed on new business models, new products and services and new processes. Open standards are key enablers.

New manufacturing sectors must be grown; Europe must be ready to manufacture products for emerging markets and to leverage its cultural traditions in new generations of products. New manufacturing industries exploiting the results of new science must be created.

Globalization impact will make traditional industries a fertile ground for new processes, new technologies and new business models thus becoming a target for the Manu*future* strategy.

Europe must focus its efforts to transform itself by co-ordinating research in manufacturing and innovation – and by exploiting, through collaboration efforts, through pre-competitive collaboration, the strength and diversity of its businesses and regions.

Manu*future* examples

The Manu*future* Platform is collecting European and National cases referring to patterns followed by stakeholders in order to achieve the Manu*future* goals.

Some examples are reported below.

1. An European example: EUROShoE project, Shoe Industry to fit Customer Demand in Vigevano

   (see in www.manufuture.org the “Manufuture Best Practice - Vigevano.doc” in Consultation Section/MANUFUTURE Examples)

2. A National example: Network of Manufacturing in Sachsen (Abstract)

   (see in www.manufuture.org the “Manufuture Best Practice - Sachsen-abstract.doc” in /Consultation Section/MANUFUTURE Examples)

3. A National example: Sintesi: a Public-Private Research Company to develop K-based HVA Machinery and Systems

   (see in www.manufuture.org the “Manufuture Best Practice - Sintesi.doc” in /Consultation Section/MANUFUTURE Examples)

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Annexes

Annex 1

MANVIS

The FP6 Specific Support Action "Manufacturing Visions – Integrating Diverse Perspectives into Pan-European Foresight (ManVis)" (Contract No NMP2-CT-2003-507139) started in early 2004. Its aim was to accompany the ongoing policy process of enhancing European competitiveness in manufacturing industries and to include views of more than 3000 European manufacturing experts collected through a Delphi-survey in 22 countries as well as views of stakeholders and overseas experts collected at workshops and in interviews.

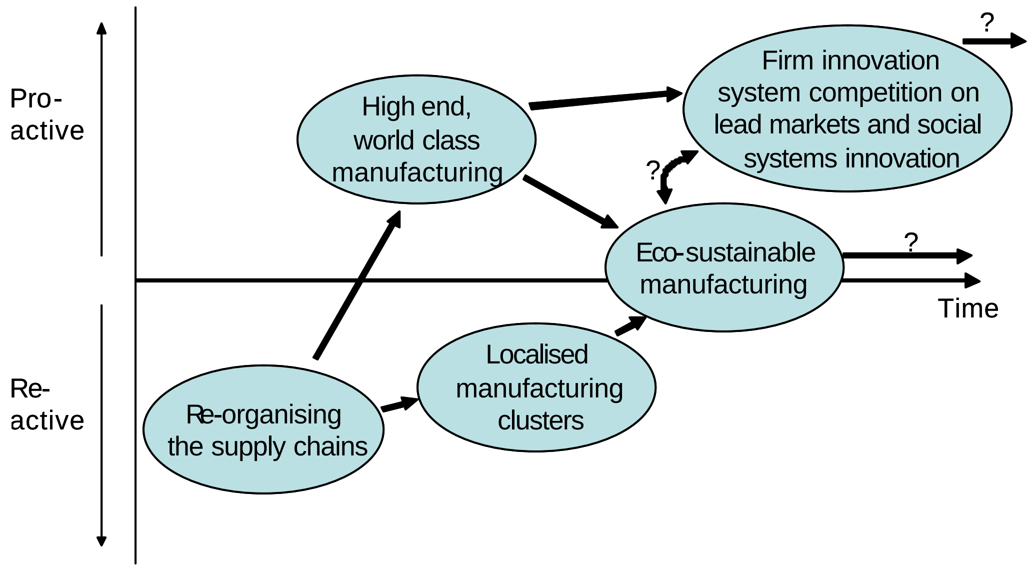

Figure: The ManVis trajectories for Manufacturing of Tomorrow

Several trajectories for developments of the manufacturing of tomorrow came out of the ManVis findings:

- The struggle on labour cost competition will prevail in the next years. Basically there are two dimensions: the loss of operations to countries outside the European Union and the movement within the European Union. The strategies emerging from the ManVis expert consultation are mainly reactive i. e. cost reduction through automation and enhanced labour productivity. The New Member States will exploit in the very near future an existing cost advantage but will loose it faster then competitors outside Europe. Without own innovative capacity for absorption and enhancement this Foreign Direct Investment will just pass through these Member States in a decade. In any way, both developments are characterised by losses of employment in manufacturing.
- Local manufacturing operations and local R+D excellence – as general options – are reactive patterns as well. Very often based on concepts originating from the sustainable development debate this vision is characterized by local operations and development based upon very close interaction with local users – who still have to have purchasing

power. The consulted manufacturing experts were quite sceptical on the prospects of this option because of their assessments on the weak ties of modern manufacturing into its environment, contrary to the consulted stakeholders who value this concept as feasible and competitive.

- Eco-sustainable manufacturing based on new products, new materials, energy efficiency, and last but not least on advanced product service systems could be developed into a competitive advantage for Europe – in the view of both experts and stakeholders. Regulations creating a technology pull, e. g. as outlined in the FuTMaN policy scenarios could be successfully mastered because of the excellent R&D position in this field.
- High end manufacturing will be based on the efficient use of sophisticated manufacturing technologies, which will enable world class highly automated operations for new products. This high ambition requires an exploitation of the expected potentials for micro electro-mechanical systems, related nano-technologies, closing gaps in automation, and research on manufacturing with new materials. But this high efficiency approach will reduce or only maintain existing employment in European manufacturing.
- The most ambitious and far-reaching vision is the European best practice in competing all over the firms innovation system. This comprises user interaction, product development, production, supply chain, and logistics. The successful mastering of this "system" is considered the most promising way to ensure long-term competitiveness. But innovative and adaptive lead markets have to give European companies the chance to be the first to learn if they have effective user/customer interaction mechanism in order to exploit this advantage. Nonetheless, high-end manufacturing with sophisticated technologies is a pre-requisite for any employment creating option.

In order to move along the different paths and create employment severe *challenges* have to be mastered:

- creating manufacturing based on sophisticated technology,
- developing knowledge based and learning companies and industries,
- competing through the firms individual innovation systems,
- re-defining and innovating demand,
- keeping Europe economically united.

Because the science base is of growing importance in manufacturing, topics and issues have to be included into the funding mechanism of the planned European Science Council. Other existing mechanisms on transfer and mobility of researchers have to be maintained as well as international cooperation.

Excellent research projects in manufacturing topics are needed (see box). It is important to notice not to concentrate on technological developments only but the whole system of innovation in the firms has to be considered. This implies tools, strategies, methods, procedures etc. for product development, logistics, innovation management, business concepts etc. had to be added to the technological research agenda. The main barrier towards more pro-active strategies lies in the implementation of successfully learning companies which can adapt their innovation system fast.

Imminent technological research needs

Paving the way for new technologies in manufacturing

- roadmapping and foresight on manufacturing relevance of nano- and (white) bio-technology
- measurement, workplace safety for nano-technology and bio-technology
- applied basic research for white bio technology and nano-manufacturing

Industrializing technologies

- processing and manipulation of new materials
- incorporating smart materials into components for process technologies
- combining new materials with micro electrical mechanical systems (adaptronic)
- exploring new modelling knowledge and high power computing for simulation of product development, of material behaviour, and of virtual experiments

Exploiting technology advantages

- micro-systems in machine tools and products
- intelligent mechatronic systems for automation and robotics (e.g. self adapting components)
- new automation technologies considering advanced human-machine interaction by considering diverse workers capabilities
- ICT-tools for traditional sectors

Technologies for customizing products/services

- tagging Technologies
- approaches towards product customisation via software or electronic components that allow for maximum flexibility and user integration
- technologies and concepts facilitating user integration into innovation processes
- technologies and concepts facilitating personalisation and build to order concepts

Enhanced funding mechanisms should focus on the integration of user-interaction mechanisms. Accompanying measures should ensure the transferability of the results e.g. by feeding them into other policies (e. g. standards, regulation) as well as preparing diffusion.

A harmonized policy approach is absolutely necessary if societal requirements and existing competences should converge into a lead market. First mover advantages could be only obtained if quick and decisive moves in demand shaping and competence building are made. In order to be successful, a thorough analysis of long-term demand and interactive participation of stakeholders and users is decisive for policy makers and industry, both. Hence, while closing the loop, exercising these practices in the R&D projects and efforts in manufacturing becomes of crucial importance.

Annex 2

FUTMAN

The future of manufacturing in Europe 2015-2020 - the challenge for sustainability (FuTMaN) project sought to examine what technological, knowledge and organisational capabilities might be required by European manufacturing, if it was to remain both competitive and sustainable by the year 2020. Particular attention was to be paid both to technological priority areas and to any policy changes required.

Three cross-cutting approaches to exploring the problem were adopted.

Scenarios were developed to provide imaginative, coherent views of the threats and opportunities which manufacturing might face in the years to 2020. Three broad strands of manufacturing were studied – **Materials, Transformation Processes** and the **Structure of Industry.** Four sectoral case-studies were undertaken in the **Automobile Industry – Personal Cars**, **Measuring, Precision and Process Control Instruments (MPPCI)**, the **Semiconductor Industry** and **Basic Industrial Chemicals**. In addition, a separate integrating study examined the implications which **Governance, social attitudes and politics** might have on the transformation of industry.

The **Scenarios** were not predictions, but sought to establish what common, robust traits European manufacturing must acquire or possess, in the event of a variety of possible futures coming to pass. Four individual scenarios were developed, based on the extent to which socio-economic attitudes and governance became either more individualised or more collectivised. Taking two contrasting examples, *Global Economy* was the most individualised, ungoverned scenario: under it global competition is cost-driven, with R&D helping to sustain leading-edge products. But the uptake of nanotechnology disappoints and progress on sustainability and the environment is incremental. In contrast, the *Sustainable Times* scenario contains both a high degree of acceptance by individuals of the need for sustainability and sophisticated public pricing mechanisms to cope with "externalities". Some pointers as to how European manufacturing might become robust enough to cope with such apparently contradictory futures emerged later in the study, as the experts in the broad strands and the case studies identified four pressures which manufacturing would have to adapt to in all circumstances. These were **Time** (conflation), **Knowledge** (intensification), **Costs/competitiveness** and **Resource use/Sustainability.**

Experts consulted in the **Materials** report identified 27 high potential materials technologies. Three potential technology development paths were identified i.e. *Specialisation, Convergence* and *Integration.* The *Specialisation* technology path is the present position, *Convergence* would add pluri-disciplinary thinking and new interfaces with industry, while *Integration* would call forth a new paradigm of technology priorities, R&D organisation and interfaces with industry. The US is more advanced than Europe on technological priorities and on R&D organisation, while Japanese research has a long tradition of a better interface with industry. For Europe to move to move up from the *Specialisation* to the *Integration* technology path will require both substantially increased investment in real and in financial resources and a re-structuring of research practice and organisation.

The **Transformation Processes** study covered all manufacturing design, planning and production processes (including disassembly and re-manufacture) as it affected both Traditional

Manufacturing and Electronic Manufacturing. Traditional manufacturing would require new styles of team leadership and greater adaptability from all team players. Electronic manufacturing would require more research-related resources and a clearer identification of manufacturing's core competences. The report confirmed that Europe has a strong manufacturing base rooted in a well skilled workforce, a good and comprehensive infrastructure and a strong cohort of competitive companies – particularly in the provision of productivity-enhancing manufacturing equipment. The report went on to make five policy recommendations viz. cross-cutting and competing technological trends should be geared towards sustainability, sustainability should be made an effective driver of manufacturing innovation, manufacturing itself should become more pro-active in process improvement, continuous improvement in skills and competencies, and Europe must build on its capability to service a diverse range of markets without falling prey to fragmentation.

The **Structure of Industry** report concluded that *"human capital will replace physical capital at the core of competitive advantage".* This suggests that enterprise, incorporated in the whole of the labour force and not simply in its managers or its entrepreneurs, will be the main bulwark against the commoditisation of products made in high-labour-cost/high-value-added economies such as the EU. The report identified three key influences on the structure of manufacturing. Firstly, *servation*, or the need to incorporate a greater service element into the product, both during design and during after-sales. Secondly, pressure towards *closed loop* systems, in which waste outputs from one process are used as an input to other processes. And thirdly, the growth in *virtual enterprises via B2B*, which will radically alter the organisational structure and the competitive positioning of firms.

The four **Case Studies** provided an interesting mix of the differing capabilities and challenges which different sectors of European manufacturing possess or are exposed to.

The Automobile Industry is one of the EU's major success stories. In Japan, Carlos Ghosn's matching of products to markets and his views on the shortening of product life cycles provide headlines for non-auto manufacturers in Europe. The automobile case study identified seven drivers of change: three were related to demand, two to resource inputs, and two concerned the production process. Unlike the scenarios, the case study experts did not see individual car ownership being ousted by some servation-type concept such as "mobility services".

The Measuring, Precision and Process Control Instruments (MPPCI) sector is comprised of a small number of large firms and a large number of small firms that either collaborate with the large firms or service niche markets. Developments in demand and technology are forcing a much greater degree of adaptability on the sector, particularly in relation to modularisation of product design, concurrent engineering and simulation. Nanotechnology and the spread of sustainable practices will increase pressures/opportunities on MPPCI in future. Policy must help the sector upgrade its knowledge base and its capability in networking and in innovation.

Products produced by the Semiconductor Industry are high-value/low-bulk and thus prey to competition from low-wage Asian countries. The case study considered that opportunities exist for Europe to consolidate its current capabilities and to establish itself as a prominent player in emerging technologies, which will challenge the current dominant technologies. However policy measures will need to support measures to improve the industry's attractiveness, to develop entrepreneurship, to commercialise new technologies and to exploit niche markets.

The Basic Industrial Chemicals sector faces strong pressures towards commodification, with little scope for adding value through customisation or servation. The main technology trends identified for the sector concentrate on the impact of new materials, new catalysts and improved processes. Expert views on the future fall into two groups. One sees the future as incremental with gradual improvements in materials and processes and the second view sees a more rapidly increasing shift towards bio-processing and green chemistry. There was also a North-South division of opinion on environmental issues. The industry is very concerned to better its reputation with citizens. It advances a number of policy recommendations in relation to regulation, innovation, education and realistic visions of sustainability.

The report on **Governance** looked at the increasing dispersion of power and authority beyond the apparatus of the state. Indeed The EU's White Paper on Governance in 2000 looked for a greater downward distribution of governance, to allow more participation in decisions leading to major technological change and also to allow for a greater diversity in European culture and society. In future major developments or decisions in relation to manufacturing will probably have to be taken within a "*socio-technical constituency*", perhaps using some "*transition framework*" so as to allay disquiet in the move from the old to the new. The report outlines research in a number of areas which might secure a better insight into how this might be achieved.

FuTMaN sets forth a bold agenda for sustainable manufacturing to 2020 – echoing perhaps the Lisbon Declaration of 2000. And the experts consulted under FuTMaN's many elements considered that such a great hope could be realised:

there were no insurmountable social or technological barriers. **However it would mean the development and adoption of new paradigms of production and consumption. These in turn would require a quantum leap in resources to enable manufacturing to research and implement these paradigms, and also a willingness and capability by Europe's leaders to persuade its own people and the rest of the world that sustainability was worth pursuing seriously. Neither of these conditions is in place at present.** Great change can deliver great rewards, but in the process usually incurs great disruption. The main fear underlying FuTMaN is that European manufacturing, its customers and their political leaders, may be dissuaded from making the great efforts required to reach long-term sustainable development because of the medium-term disruption this would cause to individuals and to society.

The United States' growth as a *hyperpower* since 1990 has been paralleled by a divergence in values between the US and Europe. Baseline economic forecasts to 2015 suggest a growing increase in the US's hyperpower status and an increase in the EU's dependency. Only if the EU throws off the lassitude of the 1990's and replaces it with the economic and social vigour it displayed during the 1960's, can sufficient resources be made available to turn the FuTMaN programme into reality.

FuTMaN made six overall recommendations for policy viz.

1. Manufacturing must attract and hold on to able people: A repeated theme in many areas of the study was the concern expressed about the possibility of shortages in adequately qualified and skilled personnel. Demographic trends of ageing raise the first fear in this regard but the perceived unattractiveness of manufacturing industry as a career poses a bigger problem. Solutions require collective actions by all parties.

2. Continue building European systems of Innovation: In addition to optimising the harmonisation of standards, FuTMaN looked continuously for policies to strengthen entrepreneurship through broader education curricula.

3. Networking takes time. Be Patient: The new instruments of FP6, integrated projects and networks of excellence all have a long learning curve.

4. From Specialisation to Integration in New Materials: The Integration technology path of materials development will require a multidisciplinary skills base among S&T personnel, new organisation forms for S&T, for education, and for interaction with industry. Above all it will need strong economic growth among Europe's core economies in order to provide the necessary financial resources.

5. Sustainability needs Champions both from Manufacturing and from Governments: Manufacturing acknowledges its need to be pro-active in this area, but it cannot do it alone.

6 "Transition Management" may allow for improved governance. Recently developed concepts like "transition management" may provide a process for dealing with the combination of slower incremental developments and rapid disruptive dynamics, which would better allow manufacturing and its policymakers to systemically cope with change.

Annex 3

Minutes – Manu*future* 2004 Workshop, 1st July 2004

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Annex 4

IST Workshop final report. June 2005**.**

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Annex 5

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Annex 6

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Annex 7

MACHINE TOOL TECHNOLOGIES FOR DISTRIBUTED MANUFACTURING SOLUTIONS

(Example of roadmap in the Machine Tool sector)

This following is an example of the technology roadmaps developed by the MANTYS[15] FP5 thematic network. MANTYS has produced several foresight studies that are relevant to manufacturing industry concerning technology, markets, and business models. MANTYS used the best of machine tool researchers in Europe and systematically discussed and validated its findings with industry, giving a prominent role to machine tool builders and users.

[15] MANTYS Proceedings of the Final Conference in EMO, Hanover – 19th September 2005; http://www.mantys.org

This technology roadmap concentrates on the technological steps that will enable an efficient usage of machine tools in the context of global and distributed manufacturing operations and supply chains. The technological content and the timing were determined during the "Next Generation Machine Tool" Delphi study, the second of nine foresight exercises conducted within MANTYS. The time span is limited to 2011, as this was, according to the NGMT Delphi study, the most sensible materialisation date for a majority of technologies.

Other technology roadmaps were developed, focussing on the technological developments leading to more competitive machines (reliability, precision and intelligence being the core attributes) and more productive machines (as a way to reduce manufacturing costs and counterbalance high labour costs in Europe).

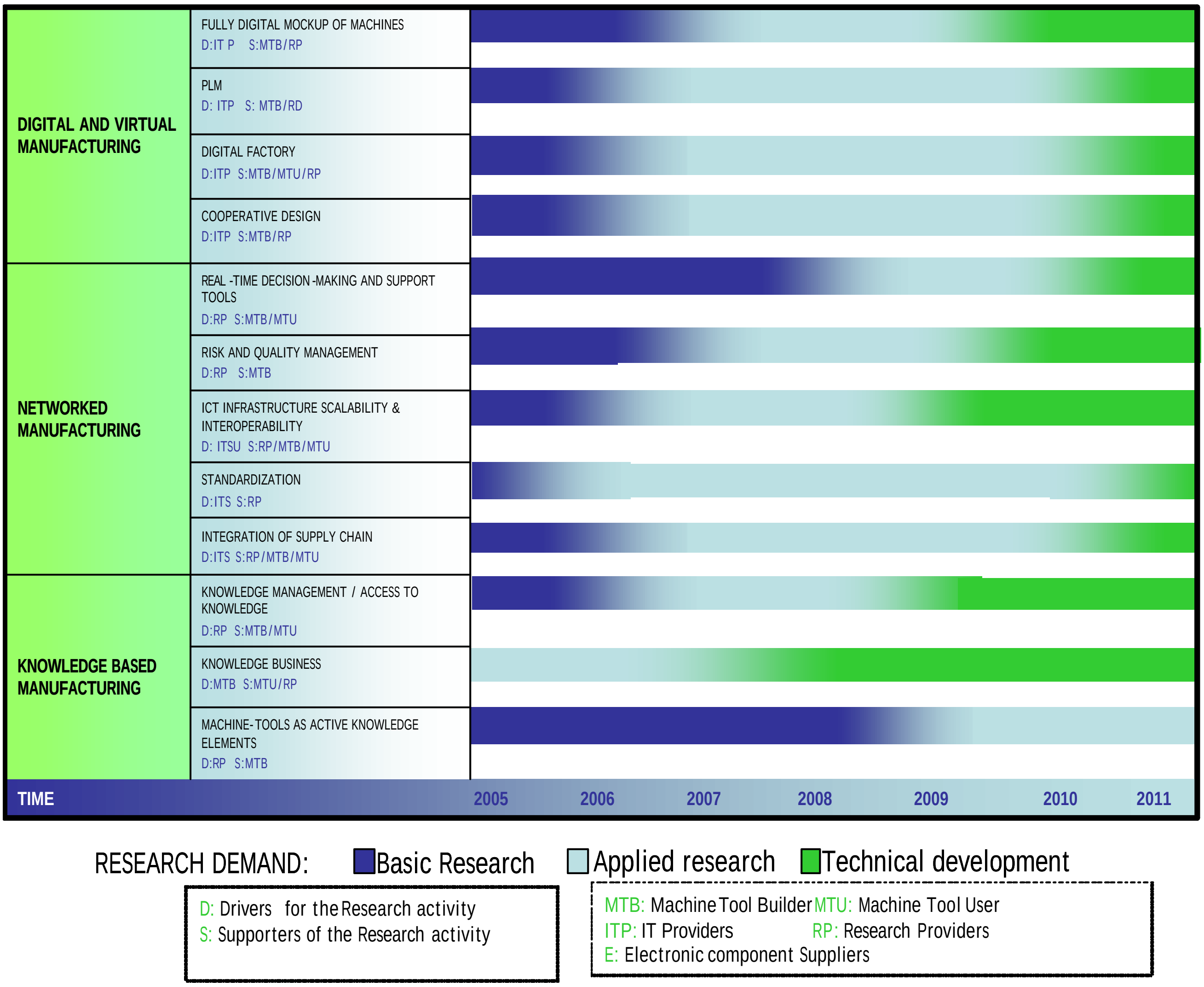
These technology roadmaps are meant to steer research in useful directions, and to give manufacturing companies a tool to assess their positions and possibilities in terms of product or manufacturing process development. They were presented to industry during a MANTYS Conference at the EMO Hanover Trade Fair in September 2005.

The machine tool technology developments necessary to achieve efficient distributed manufacturing operations are classified in three categories: digital and virtual manufacturing, networked manufacturing and knowledge-based manufacturing. They are then organised on a graphical timeline.

1. Digital and virtual manufacturing New engineering methods and tools based on planning tools, software and ICT to integrate new technologies into the design and operation of manufacturing processes, covering the whole product life cycle.	
1.1 Fully digital mock-up of machines	Mechanical structure simulation. Process simulation. Prediction and validation of final pieces' optimal results in design-time. Global dynamic simulation of machines. Validation of the fit between control approach and mechanical structure.
1.2 PLM	Tools to design, analyse and manage machine tool products from the stage of initial conception to the retirement stage (Product Lifecycle Management).
1.3 Digital factory	Planning and modelling. Improving cooperation between the enterprises, and internally-the base for outward cooperation-.
1.4 Cooperative Design	Tools and methods to improve the design phase in a global scenario (e.g. secured engineering networks between project partners).

2. Networked manufacturing Tomorrow's processes will work in complex, integrated and dynamic networks, often operating across borders of companies and countries maximising their shares within the value chain. Networking will be supported by new-generation modelling, simulation and optimisation tools for the automatic reconfiguration of the value-chain network.	
2.1 Real-time decision-making and support tools	Tools supporting autonomous decision-making when production break-downs take place, maximising machines' productivity, and providing alternative (logistics) ways for maintaining productivity rates.
2.2.Risk and quality management	Tools integrating added-value information (influencing productivity) in management mechanisms concerning manufacturing and production.
2.3 ICT infrastructure scalability & interoperability	Secured ICT tools with global production management information, accessible for the entire set of production entities, from large companies to SMEs. Information addition and update (quality/quantity) in real-time. Improved response times thanks to fast access to the interoperation services.
2.4Standardisa tion	Generation of standards for methods and ICT tools (hardware and software) supporting manufacturing and machine operations. Standards-based tools improving relationships and exchanges between production entities and production processes.
2.5 Integration of supply chain	Management tools and technologies supplying globally structured real-time information related to production operations and internal or external processes (logistics) to the manufacturing network (e.g. machines of automotive Tier 1 supplier linked in RT to ERP system of OEM).

3. Knowledge based manufacturing To respond quickly to changes in a dynamic environment, knowledge from all fields of manufacturing must be integrated – from manufacturing networks down to the individual components of manufacturing systems – by means of ICT-based tools.	
3.1 Knowledge management/access to knowledge	Tools for different profiles around the machine and production (i.e. SAT), with access to global information (stored knowledge, expertise from entire production world), to react quickly in critical situations, improving production times.
3.2 Knowledge business	Knowledge as a product. New business models (pay-per use). IPR protection.
3.3 Machine tools as active knowledge elements	Methodologies and techniques for machines co-operating as intelligent devices in manufacturing networks, with global production objectives. Machines with capabilities related to decision-making on workload balancing.


DIGITAL AND VIRTUAL MANUFACTURING
FULLY DIGITAL MOCKUP OF MACHINES
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PLM
D: ITP S: MTB/RD
DIGITAL FACTORY
D:ITP S:MTB/MTU/RP
COOPERATIVE DESIGN
D:ITP S:MTB/RP
NETWORKED MANUFACTURING
REAL -TIME DECISION -MAKING AND SUPPORT TOOLS
D:RP S:MTB/MTU
RISK AND QUALITY MANAGEMENT
D:RP S:MTB
ICT INFRASTRUCTURE SCALABILITY & INTEROPERABILITY
D: ITSU S:RP/MTB/MTU
STANDARDIZATION
D:ITS S:RP
INTEGRATION OF SUPPLY CHAIN
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KNOWLEDGE BASED MANUFACTURING
KNOWLEDGE MANAGEMENT / ACCESS TO KNOWLEDGE
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KNOWLEDGE BUSINESS
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MACHINE-TOOLS AS ACTIVE KNOWLEDGE ELEMENTS
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TIME
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RESEARCH DEMAND:
Basic Research
Applied research
Technical development
D: Drivers for the Research activity
S: Supporters of the Research activity
MTB: Machine Tool Builder
MTU: Machine Tool User
ITP: IT Providers
RP: Research Providers
E: Electronic component Suppliers

Glossary

DNA	Dynamic Novation of Artefacts
EC	European Commission
EMIRA	European Manufacturing Innovation and Research Area
EMO	European manufacturing fair
ERA	European Research Area
ETPs, TP	European Technology Platforms, Technology Platforms
EU	European Union
EU-15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, Portugal, Spain, Sweden, United Kingdom
FACTORY	EUREKA Umbrella for the generation of RTDI projects
Factory DNA	EUREKA Cluster for the generation of sectoral RTDI projects
FMS	Footwear Market Study
FP5	Fifth European Framework Programme
HVA	High Value Added
ICT	Information and Communication Technologies
IMS	Intelligent Manufacturing System
IP	Intellectual property
IPR	Intellectual Property Rights
IT	Information Technology
K-based	Knowledge based
LC	Life Cycle
MS	Member States
OEM	Original Equipment Manufacturer
R&D	Research and Development
RSE	Research Scientists and Engineers
RTD	Research and Technological Development
RTDI	Research, Technological Development and Innovation
SME	Small Medium Enterprises
SRA	Strategic Research Agenda
TEU	Transformable Enterprise Unit
US	United States

Definitions of terminology mentioned in the document:

Adaptive control – control algorithms in which one or more of the parameters varies in real time, to allow the controller to remain effective in varying process conditions. The method continuously adjusts in an attempt to provide near-optimal processing conditions.

Automation – the replacement of manual operations by computerised methods. Office automation refers to integrating clerical tasks such as typing, filing and appointment scheduling. Factory automation refers to computer-driven assembly lines. It also relates to automatic operation or control of equipment, processes, or systems, and to techniques and equipment used to achieve automatic operation or control.

Composite – a structure or an entity made up of distinct components, or a complex material such as wood or fibreglass, in which two or more distinct, structurally complementary substances, especially metals, ceramics, glasses, and polymers, combine to produce structural or functional properties not present in any individual component.

Control – a means or device to direct and regulate a process or sequence of events.

Customisation – making or changing something according to the buyer's or user's needs

Design – the act of working out the form of something. Design of products means first planning their structure, operation, and appearance and then planning these to fit efficient production, distribution, and selling procedures. Manufacturing-system design covers all aspects of creating and operating a manufacturing system. Creating the system includes equipment selection, physically arranging the equipment, work design (manual and automatic), standardisation, design of material and information flow, etc.

Digital – a means of encoding information in a communications signal through the use of binary digits. Digital signals consist of a stream of discrete (but not discontinuous) pulses. Discrete might be envisioned as the steps on a set of stairs; discrete pulses are connected, as with the steps being connected with risers. Discontinuous implies total separation and might be envisioned as a graph with a series of horizontal lines separated by blank spaces. Digital is increasingly used as a replacement for analogue technology.

Engineering – a process of design, construction and processing of materials to produce useful objects or processes using scientific methods

Flexibility – the ability to change with minimum effort of time and cost, preserving high performance products

Functional – designed for, or adapted to, a function or use. In manufacturing – relating to functions of a part or assembly to confer desired characteristics such as tensile strength or temperature range.

Improvement – a change for the better, progress in development. In organizational development, performance improvement is the process whereby the organization looks to modify the current level of performance in order to achieve a better level of output. Process improvement is the activity of elevating the performance of a process, especially a business process, with regards to its goal. Process improvement can take the form of an improvement project, or that of a process. Such a process of continuous improvement is part of organization's management processes (as opposed to business processes and support processes)

Integrated – one that (1) efficiently links environmental measurements, data communications and management, data analysis, and applications (to form an "end-to-end" system); (2) provides rapid access to multidisciplinary data from many sources; (3) provides data and information required to achieve multiple goals that historically have been the domain of separate agencies, offices or programs; and (4) involves cross-cutting partnerships among federal and state agencies, the private sector, and academic institutions.

Integration – in the most general sense, integration may be any bringing together of things: the integration of two or more economies, cultures, religions (usually called syncretism), etc. An integration clause in a contract is used to declare the contract the final and complete understanding of the parties. In microeconomics and strategic management, horizontal integration and vertical integration each refer to a style of ownership and control.

Intelligent – having the capacity for thought and reason, especially to a high degree. An intelligent system learns during its existence. It continually acts, mentally and externally, and by acting reaches its objectives more often than pure chance would indicate. For acting, and for its internal processes, it consumes energy. [www.intelligent-systems.com.ar/intsyst/glossary.htm]

Knowledge – understanding something or being able to do something. The things we know are facts, truths or information. Obtaining knowledge is called learning. "Knowledge" is related to such concepts as meaning, information, instruction, communication, representation, learning and mental stimulus. Knowledge is distinct from simple information. Both knowledge and information consist of true statements, but knowledge is information that has a purpose or use. Philosophers would describe this as information associated with intentionality.

Knowledge-based system – an information processing system that provides for solving problems in a particular domain and application area by drawing inferences from a knowledge base. The term is sometimes used synonymously with 'expert system', which is usually restricted to expert knowledge. Some knowledge-based systems have learning capabilities.

Logistics – A set of methods, procedures and means aimed at procurement, transport and distribution of materials and products including purchasing, production and sales service, with full adaptation to the model of information flow in the company. Logistics includes the questions of widely understood integration of all activity areas of the company, where material components required for the company operation are handled and stored (including auxiliary operations).

Life cycle – the description of distinct phases through which each product passes during its life. This includes phases such as requirements definition, concept design, production, operation, maintenance, and disposal of the product.

Management (manufacturing) – the function of directing or regulating the flows of goods through the entire production cycle from requisitioning of raw materials to the delivery of the finished product, including the impact on resources management.

Management information system (MIS) – an information system, typically computer-based, that is used within an organisation. A management information system may also be defined as 'a system that collects and processes data (information) and provides it to managers at all levels, who use it for decision making, planning, program implementation, and control'. An information system comprises all the components that collect, manipulate, and disseminate data or information. It usually includes hardware, software, people, communications systems such as telephone lines, and the data itself. The activities involved include inputting data, processing of data into information, storage of data and information, and the production of outputs such as management reports.

Mechatronic – the synergistic combination of mechanical engineering ('mecha' for mechanisms), electronic engineering ('tronics' for electronics), and software engineering. The purpose of this interdisciplinary engineering field is the study of automata from an engineering perspective and serves the purposes of controlling advanced hybrid-systems.

Micromachining – a process used to produce micromachinery or micro electro-mechanical systems (MEMS). There are two main processes: surface micromachining and bulk micromachining. Unlike surface micromachining, which uses a succession of thin film deposition and selective etching, bulk micromachining defines structures by selectively etching inside a substrate. Whereas surface micromachining creates structures on top of a substrate, bulk micromachining produces structures inside a body of material.

Nanotechnology – technology for microscopic devices: the art of manipulating materials on a very small scale in order to build microscopic machinery; technology on an atomic or molecular scale, concerned with dimensions below 100 nanometres.

On-line – being in progress now; ongoing; under the control of a central computer, as in a manufacturing process or an experiment; connected to a computer or computer network; accessible via a computer or computer network.

Planning – the process of identifying the means, resources and actions necessary to accomplish an objective. In manufacturing, manufacturing planning is the function of setting appropriate levels or limits to the various future manufacturing operations according to sales forecast, economic constraints and resources requirements and availability. Manufacturing Resource Planning is the implementation of management plans that evaluate and predict the demand for each element in the manufacturing process at a given time. Material Requirements Planning is a priority planning technique which is driven by a master production schedule and which relates component demands to the production schedules for parent items.

Processing – preparing or putting something through a prescribed procedure. Process is a particular procedure for doing something involving one or more steps or operations. The process may produce a product, a property of a product, or an aspect of a product.

Productivity – the quality of being productive or having the power to produce. Productivity in economics aspects is the ratio of the quantity and quality of units produced to the labour per unit of time.

Prototyping – manufacturing of the prototype, first version of a part, for new products for their tests and research or improvement. Rapid Prototyping is a group of technologies for fast manufacturing of prototype goods, also known as solid freeform fabrication, automated fabrication, layered manufacturing, and under other terms; it consists of a range of technologies that are capable of taking computer-aided design (CAD) models and converting them to a physical form or part. This process is automatic, generally independent of the model geometry, and does not require special tooling or fixtures. Complex three-dimensional contours are quantized in the form of stacks of two-dimensional, finite thickness layers or cross sections.

Rapid prototyping – This term covers a set of methods and techniques that allow for creating physical models as well as constructional, functional, aesthetic and assembly prototypes from 3D models recorded in CAD systems. A prototype is built from layers of various materials in several techniques: ✍SLA (by laminar hardening of photopolymers), LOM (by welding layers of films), FDM (by melting a plastic and laminar spraying) or ✍SLS (by sintering metallic and ceramic powders with a laser). As a result, a spatially represented geometry of solids modelled in the 3D technique is obtained. Rapid prototyping is used in machine building, medicine, architecture.

Real time – as it happens. Refers to applications which perform tasks without delay. Used to describe for example a transmission or data processing mode in which the data is entered in an interactive session where an application can respond fast enough to affect later data input.

Simulation – Widely applied term related to modelling and analysis (most often numerical) of processes and programmes. In technical applications, the simulation methods are used to examine the effect of numerous parameters influencing the process model, including the parameters forecast or determined by approximate methods. In engineering design practice, simulation is predominantly used in modelling and analysis of static, dynamic and thermal phenomena (✍FEA and kinematic analysis systems), as well as in simulative process analysis. Visualisation of the results proceeds, with regard to time and other important variable parameters, in real time.

Standardisation – in the context related to technologies and industries – the process of establishing a technical standard among competing entities in a market, where this will bring benefits without hurting competition.

Virtual – simulated; performing the functions of something that isn't really there. Virtual Manufacturing is the use of computer models, simulations and realistic visualisations of manufacturing processes to aid the design and production of manufactured products.