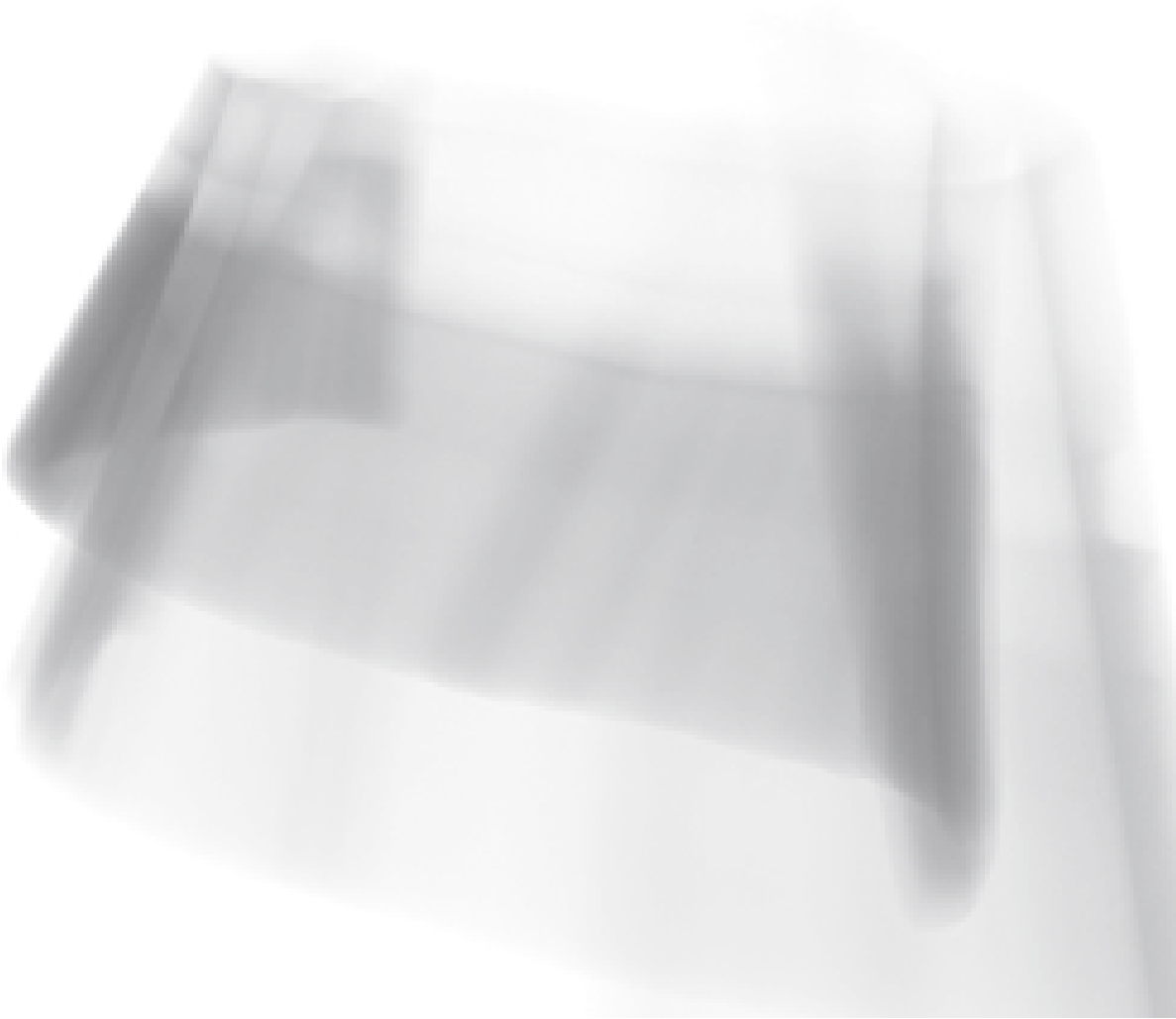
Technology Strategy Board
Driving Innovation

High Value Manufacturing

Key Technology Area

2008-2011



The vision of the Technology Strategy Board is for the UK to be a global leader in innovation and a magnet for innovative businesses, where technology is applied rapidly, effectively and sustainably to create wealth and enhance quality of life.

Our three-year strategy for 2008-2011 is to drive innovation by **connecting** and **catalysing**. To achieve this we are focusing on three themes: challenge-led innovation, technology-inspired innovation and the innovation climate. For more information on the overall strategy see **www.innovateuk.org.**

We have identified a number of key application areas and key technology areas on which to focus, and for which we are developing specific area strategies.

This document presents the strategy for the key technology area of **High Value Manufacturing.**

Foreword

The Technology Strategy Board is a new organisation with a new vision and ambition to make the UK a global leader in innovation. Our job is to ensure that the UK is in the forefront of innovation enabled by technology.

Our task at the Technology Strategy Board is to "Connect and Catalyse". As part of our challenge-led approach to innovation we treat societal and economic challenges of the future not just as threats but as opportunities for innovative solutions that enhance the quality of life and increase wealth.

The world is changing. Globalisation, digital communications and the growth of emerging economies present profound challenges to UK manufacturing sectors. Yet where there are challenges there are also opportunities. Open access to global supply networks and emerging markets is easier than ever before; the highly skilled UK workforce, world class science base and open-market philosophy also puts us in a strong position.

UK manufacturing is also changing. Manufacturing is no longer the simple production of goods for one time sale but is now a complicated network involving many high value but sometimes less tangible activities spanning the whole product life-cycle, these include: design, R&D, marketing, logistics, lifetime services and disposal. The UK is world class in many of these activities and we must exploit this fact through the manufacture of high value products, processes and services that focus on current and future global opportunities. For instance, the UK is now at the forefront of developing low carbon technologies that address climate change; this is reflected in activities already underway at the Technology Strategy Board such as our Innovation Platform in Low Carbon Vehicles.

The High Value Manufacturing Technology Strategy presented in this document recognises these changes and identifies those technology themes which will help UK manufacturing companies to collaborate and transition towards high value activities. I welcome its life-cycle emphasis and recognition that all parts of what have become global value networks within manufacturing organisations offer great opportunities for UK wealth creation.

This High Value Manufacturing Technology strategy will provide the foundations for our work in this area in the 2008-2011 period. We are looking forward to working in partnership with key players in innovative manufacturing businesses and contributing to wealth creation in the UK.

Iain Gray
Chief Executive, Technology Strategy Board

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Executive summary

Manufacturing globally is a key provider of wealth and employment, accounting for $4.4 trillion of value- added world-wide. Using the conventional international definition of manufacturing, the United Kingdom is the sixth largest manufacturer by Gross Value Added (GVA) in the world and has an industry which accounts for 14% – 15% of Gross Domestic product (GDP) and 50% – 55% of exports, as well as employing 3m people. A wider definition, including industrial services, construction and oil & gas, results in a GDP contribution closer to 27%. Manufacturing is also one of the primary mechanisms for realising wealth from new technologies and is therefore critical to the UK.

With the lowering of economic barriers to trade, the reduction in transport costs and the enabling effect of communications technology, manufacturing is highly competitive and gravitates to countries of lowest overall cost. Manufacturing in comparatively high wage economies such as the UK, has therefore had to change radically to remain globally competitive. Rapid change will continue for the foreseeable future and the continuing development path for manufacturing in the UK is one where:

- Its composition will continue to move away from the traditional areas, towards high-value, knowledge-intensive goods
- The emphasis of activities will not just be on production, but will embrace provision of lifetime service, around a manufactured product
- Continued automation of physical and information processes will drive efficiency improvement
- The business model will be increasingly specialised, with outsourcing of non-core activities
- The value chain will be increasingly complex and international resulting in global value networks

The challenge for UK manufacturers is to remain competitive in this environment, which in turn translates into being continually innovative. Against this background, the Technology Strategy Board's broad aim is to invest in UK manufacturing companies to maintain and develop their international competitiveness. This aim will be achieved by focusing on innovation in four broad areas, entitled the four "pillars" of high value manufacturing:

- Products
- Processes
- Service Systems
- Value Systems

These pillars must then be underpinned by innovative technologies, applicable across the lifecycle, and scoring highly against the Technology Strategy Board's four criteria. The technologies chosen in this respect are:

- Modelling, analysis & simulation
- High value products
- Resource efficient and sustainable processes
- Disposal & recycling
- Whole life planning
- Innovative service solutions & condition diagnosis
- Design & innovation process
- Collaboration within extended operations & resulting in global value networks
- Materials & metrology

In more specific terms, the key recommendations of this strategy document are that the Technology Strategy Board should, over the period 2008 – 2011, invest in the development of UK manufacturing industry by:

- Running broadly-based collaborative Research & Development programmes, as well as scoping studies, proof-of-concept and demonstration projects, covering a wide range of industries
- Investing in knowledge transfer through engagement with business, the Knowledge Transfer Networks (KTNs), Knowledge Transfer Partnerships (KTPs), Research Councils including the Innovative Manufacturing Research Centres (IMRCs), Government Departments and the Regional Development Agencies/Devolved Administrations (RDAs/DAs)
- Supporting skills development directly through the KTP programme and indirectly through the BERR Ministerial Advisory Group on Manufacturing and through the National Skills Academy for Manufacturing
- Promoting international engagement by investing in scoping studies which identify issues and barriers to the global success of UK manufacturing

This approach will be promoted actively to industry and academia to maximise the coverage and impact.

The overall aim is for the Technology Strategy Board to invest in the development of the UK to maintain its place as one of the world's leading manufacturing locations. The UK has a broad range of world-class manufacturing companies, both small and large, and has demonstrated how a nation can evolve from a traditional manufacturing base by applying modern manufacturing philosophies and by applying technology. In particular, the aim is to present the UK as a country where high value manufacturing can prosper and where business can develop sustainable solutions for all aspects of the product or asset lifecycle.

1. Background and context

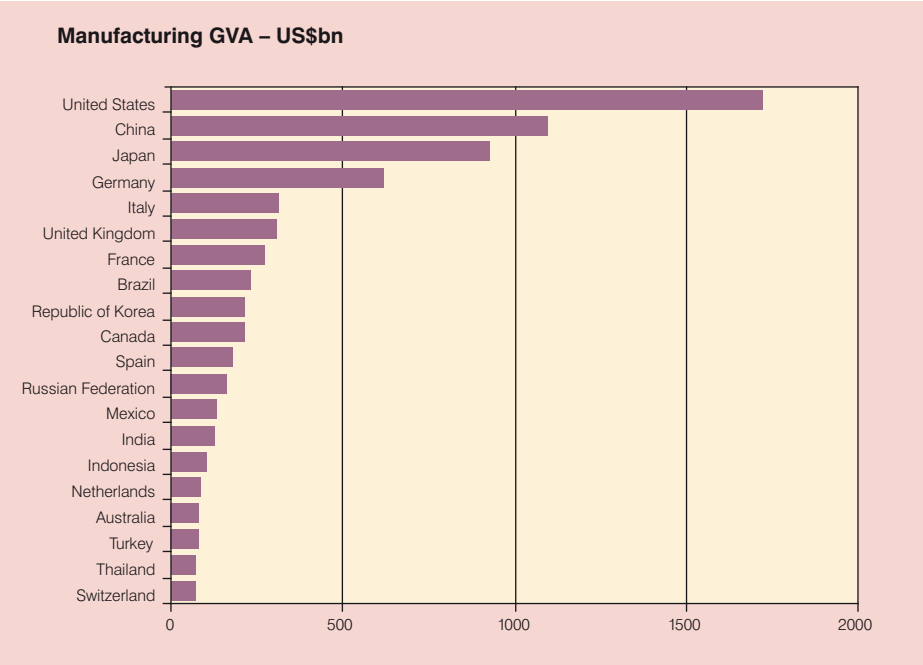
Manufacturing represents an important strategic element of the UK economy, forming 14 – 15% of GDP and over 50% of exports [1]. On a wider definition (including industrial services, construction and oil & gas), it represents up to 27% of the economy. Output is about 20% higher than it was 25 years ago and the UK has the world's sixth largest manufacturing sector [2], comparable in size with those of France and Italy but smaller than USA, China, Germany and Japan. Since 2005, growth in UK manufacturing output has resumed after a static period in the previous five years.

The past 25 years have also seen unprecedented change in manufacturing. For example, in the vehicle sector, 1.8m cars and commercial vehicles are still produced annually in the UK but manufacturing principles have changed radically and the real cost of production has fallen substantially. Other industries have almost ceased to exist but more specialised high-value operations, or completely new industries, have grown to replace them.

The definition of manufacturing has also changed over this period. An increasing number of manufacturers now define themselves as: providers of lifetime service around a manufactured product [3]. There is thus a blurring of the distinction between manufacture and service, leading to multiple revenue streams, an emphasis away from the initial sales revenue and a concentration on "High Value Manufacturing" (HVM).

The key change in the overall environment for manufacturing over this period has been the globalisation of industry. This has created a highly competitive environment within which every manufacturing economy has to operate. Capital tends to come from global sources and most end markets can be considered global, with local variations. Reductions to the barriers to flow of capital, goods, people, information and know-how mean that

Fig. 1 – Manufacturing GVA by Country – UN Statistics Division – Aug 2007



manufacturing is gravitating towards countries of lowest overall cost. These changes have been made possible by political factors, which have reduced barriers to trade and by technology, particularly in communications, which has made it possible to operate companies on a global basis.

Global companies now run quite complex international value and innovation networks, made up of R&D, production and sales/service centres. Individual countries have, in effect, to compete for these centres which may serve a country, a region, or the world as a whole. Given that most value is realised locally, even in global networks, manufacturing industry is seen as a route to creating employment and prosperity for growing populations in developing countries. Hence it receives significant levels of government attention, tax treatment and support, in both developing and developed countries.

This international environment has led to some fundamental changes in UK manufacturing. Many operations, particularly in the traditional industries, have had to close because they were no longer competitive. Their replacement by higher-value activities has just kept pace in terms of output, but not in terms of employment. There have been numerous changes in ownership, with many businesses becoming members of international groups, either UK-led or foreign-owned. There has also been a greater specialisation and concentration on core activities, leading to outsourcing of services and uncompetitive operations, sometimes to low-cost countries.

A further factor which is likely to be a more important driver of change in the future, is the environment itself, in the context of climate change, which creates both threats and opportunities for UK companies. Carbon-intensive production processes, and transport of goods, are clearly likely to become more expensive. However, the world will place a premium on low carbon products and processes, favouring those companies which are innovative in this respect.

ROLLS-ROYCE – Environmentally Friendly Engine

Project No. TP20012

The Challenge: To meet the challenging environmental goals for air transport to be achieved by 2020 as set down by the European ACARE organisation.

The Solution: The Environmentally Friendly Engine (EFE) project is a 4 year, £95m programme started in January 2006. It is aimed at enhancing UK competitiveness in the fields of high temperature materials, high efficiency turbines, low emissions combustion, manufacturing technologies, engine controls, and nacelle aerodynamics. This technology is being taken from the basic research stage to a higher validation level via a series of tests on UK demonstrator vehicles. The work is an agreed part of the AeIGT National Aerospace Strategy leading to the achievement of the ACARE goals. It is a collaborative venture led by Rolls-Royce with four key UK partners: Bombardier, Goodrich, GE Aviation UK (formerly Smiths) and HS Marston. The UK supply base will develop components for the programme within their area of expertise. Various funding sources have been established – Technology Strategy Board, MoD and the RDAs – but at least 50% of the cost is being borne by industry

Alongside changes to the political and economic environment, there has been rapid development in the technologies used in manufacturing. It is difficult to single out any particular technology as the source of fundamental change, although digital technologies have probably been the most influential overall. More specifically, technology has developed in the areas of: discrete product manufacturing, process industries, biologically-based industries, new materials, modelling and simulation, digital representation of data and asset condition monitoring. The overall effect of these developments has been to generate higher performance products or services, at lower overall cost, provided to customers in a more responsive manner over the life-cycle. These moves by successful operations into higher-value, knowledge-intensive goods, place greater emphasis on innovation and are less-readily replicated by competitors.

The opportunities for technological development show no sign of diminishing so rapid evolution of manufacturing can be expected to continue and there is a role for Technology Strategy Board to play in stimulating this change, enabling UK firms to earn the right to compete in the global marketplace. Finally, it should also be appreciated that the production, sale and service of manufactured products is one of the principal routes by which wealth is realised from new technology. The continuing development and broadening of manufacturing is therefore strategically important to deriving benefit from the technology which the Technology Strategy Board will promote over the period from 2008 to 2011.

2. Industry overview

2.1 Manufacturing – the world context

Despite the changing face of manufacturing, the USA has been quite resilient and remains the world's largest manufacturer [4], producing 25.5% of global output in 2006. World output, in GVA terms, is estimated at $4400Bn [5] and is growing at c.3.5% annually. Western Europe collectively produces 26.1%, Japan 13.9% and China 12.1%. The expectation is that China will overtake the USA by about 2020 and that the developed world's share will gradually decline, but that output will still grow in developed countries, provided that constant attention is given to innovation and competitiveness.

2.2 Economic development of UK manufacturing

Taking a relatively long-term perspective, output of the UK manufacturing sector has grown by about 25% since 1970 [6], as shown on Fig. 1. Output over the period 2000 – 2005 was static but growth resumed in 2006 and 2007. Over the same period, productivity grew at 3.5-5% pa. [7] and consistently outstripped output growth. Hence, employment in manufacturing has fallen, year-by-year, contributing to the impression that manufacturing is declining.

These figures are for the UK manufacturing sector as a whole. Within the sector, some quite radical changes have taken place. In particular, there has been substantial shrinkage of the older, traditional industries and their replacement by higher-value, or completely new activities [8], as shown on Fig.2.

Supply networks have become more "tiered". Original Equipment Manufacturers (OEMs) have placed more responsibility in the supply network and SMEs have assumed more importance. This has resulted in a manufacturing

Figure 1 – UK Manufacturing Output, Productivity & Employment

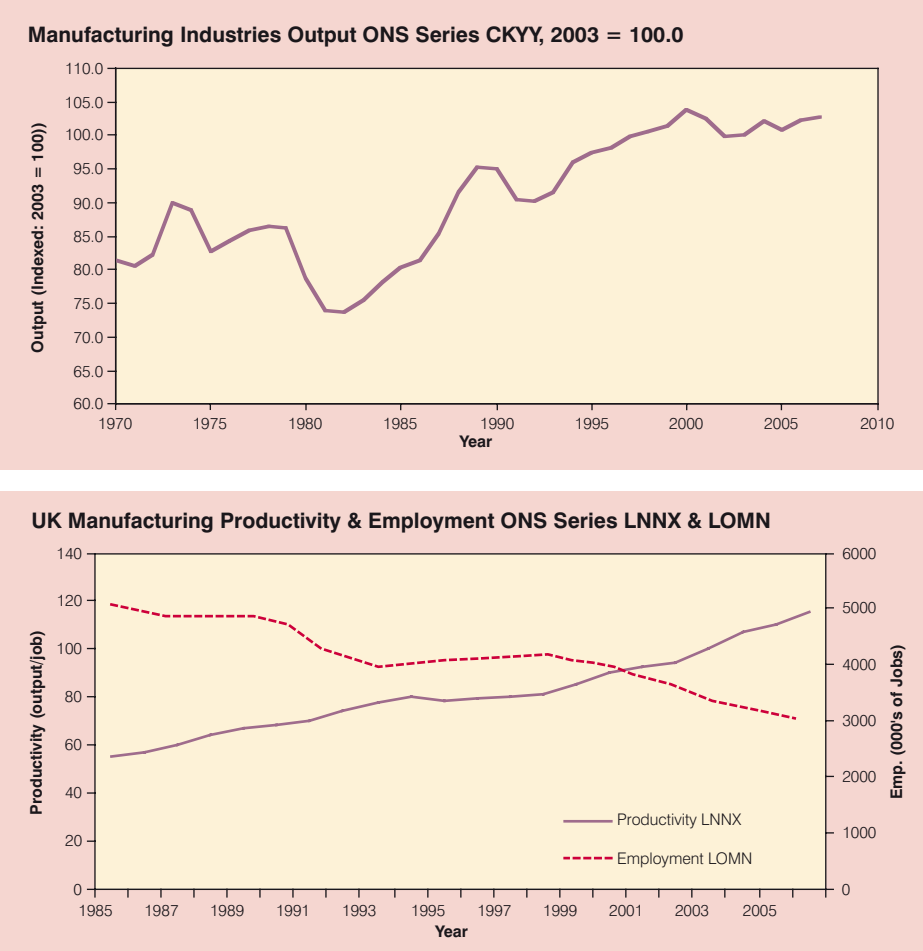
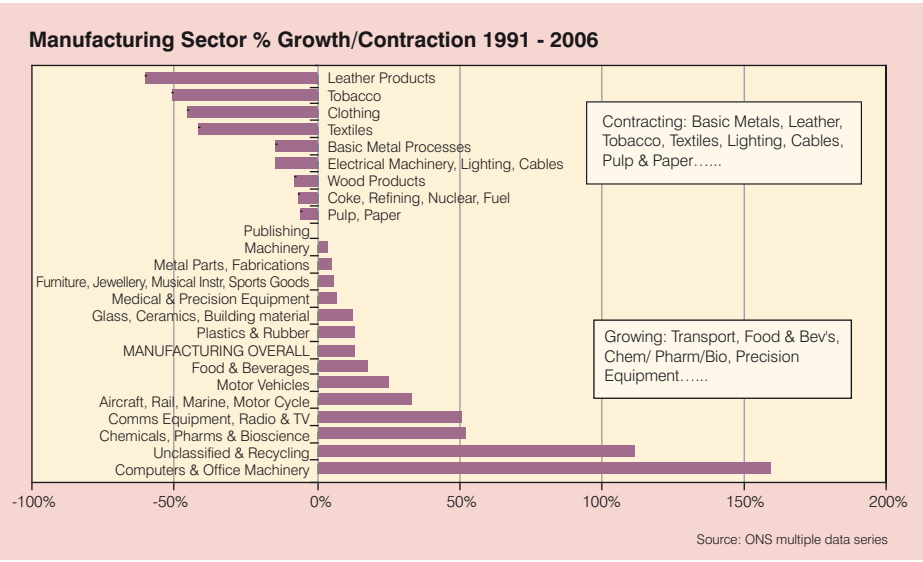


Figure 2 – Sectoral Composition of UK Manufacturing



sector which is increasingly made up of high-value activities.

These comments are based on the ONS definition of "manufacturing" which excludes extractive industries (such as oil & gas), utilities, and some industrial support services. The UK has a flourishing sector in the services area. In some cases, these firms have been spun out of manufacturing companies and these are included in the Technology Strategy Board's manufacturing programme. In addition, there is convergence between manufacturing and construction where modern manufacturing approaches are being adopted. Collectively, these additional sectors represent c. 13% of the UK economy [9].

2.3 Development of individual sectors

Against this background, there is merit in the UK focusing its attention towards manufacturing sectors which are likely to give better results in terms of wealth and job creation. An analysis of UK manufacturing has been undertaken to assess which sectors (both by Standard Industrial Classification – SIC – code and by Industry Classification Benchmark – ICB) are particularly important to UK manufacturing. In performing this analysis, a number of reports and stakeholders were consulted [10,11]. Sector attractiveness for UK wealth creation was then assessed by reference to:

- Global market size and growth
- Market share of UK companies and UK strength in that sector
- Profitability
- Efficiency in exploiting value for wealth creation
- Technical intensity

Based on SIC classification, the table below suggests the areas which should be targeted:

In broad terms, therefore, the areas where intervention is likely to be most effective in terms of UK wealth creation are:

- Transport
- Pharmaceuticals and bioscience

Fig. 3 – Analysis of Sectoral Attractiveness

- Speciality chemicals
- High-value, precision equipment, systems and machinery for all sectors
- Specialised materials
- Oil & gas
- Construction (particularly off-site manufacture, advanced materials, systems engineering, and process efficiency)

This does not imply that other sectors should be ignored but rather that those proposed should be the focus for engagement, or for establishing large projects or initiatives, whereas a more reactive stance should be taken in other areas.

2.4 Development of supply and global value networks

The most fundamental definition of manufacturing, based on processing raw material into a finished product, has changed. Traditionally, manufacturing grew from companies where the majority of costs and revenue were production-based and companies undertook most activities in-house. In a comparatively high wage economy, such as the UK, the way companies based on this model continue to compete is to reduce costs. This has led to an increase in UK manufacturers setting up offshore facilities and an apparent 'decline' in UK manufacturing.

However, far from declining, many UK manufacturing companies are experiencing increased revenue streams by exploiting alternative opportunities within the value network, whether it is from specialised high-value products and intellectual property, or through developing offerings in alternative parts of the product lifecycle. The landscape has therefore become much more complex with value being taken from different parts of the supply or value network, sometimes from low cost countries or sometimes from very specialised sources. Value can

be realised either from initial sale or, as a continuous stream by providing the product through a service arrangement. Managing these alternative business models is a considerable challenge for the future.

2.5 Development of high value activities

To understand value generation more thoroughly, the Engineering Employers Federation (EEF) recently published a report on High Value Manufacturing asking some 600 manufacturing companies what they perceived as their competitive strengths today and in the future [12]. The companies surveyed came from a range of industry sectors.

Figure 3 shows companies' responses on their top three competitive strengths today versus what they anticipated in five years' time. At the present moment, production and assembly is most frequently ranked as the number one source of competitive advantage, ranking highest for 29% of companies, followed by design & development (23%) and service provision (18%). Only 2% of companies saw research as their top source of competitive advantage. This suggests that most of the innovation taking place within manufacturing extends well beyond basic research into areas such as services and design but may also confirm a view that UK companies are less research-oriented than those in, for example, Germany or America.

The key development over the next 5 years is that design & development is expected to overtake production as the number one source of competitive advantage. This probably illustrates that it is increasingly taken as read that manufacturing, in terms of cost, quality and delivery, will be fully competitive. This being the case, design of the product becomes an important differentiator, but still linked to efficient manufacturing. In addition, the increase in the number of firms seeing services as their key competitive advantage closes the gap with production and assembly considerably [12].

2.6 Low carbon manufacturing

Climate change and the environmental "agenda" will have a fundamental effect on manufacturing. Looked at negatively, it could be argued that energy, transport and materials will become more expensive, as is happening already, driven by demand rather than environmental factors and that this will stifle growth. However, there is clearly a more positive aspect to the situation in developing solutions to problems. Opportunities exist for UK companies to develop renewable energy generating systems, low carbon products, less energy-intensive processes, and services to support individuals, companies or governments in their journey to low-carbon activities. Overall, the Technology Strategy Board sees low carbon manufacturing as more of an opportunity than a threat and will support companies in developing their capabilities in this area.

2.7 Challenges for UK manufacturing firms

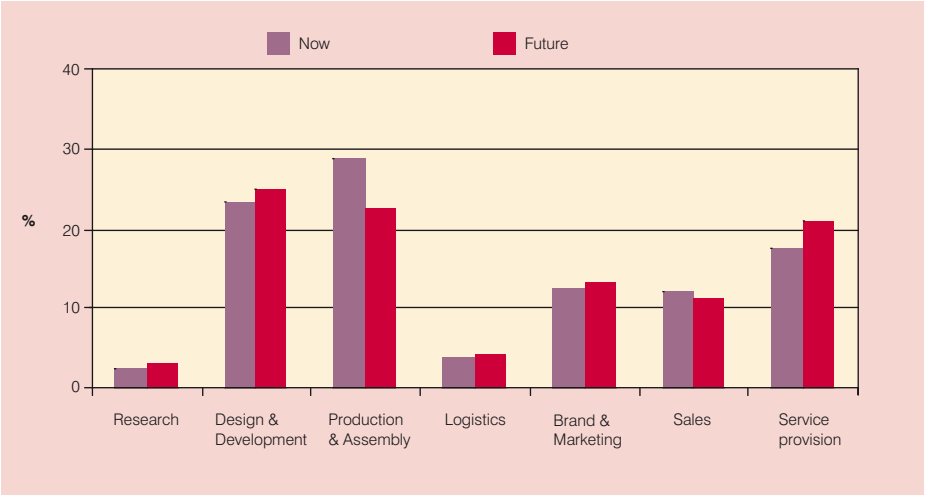
Against this background, it could be argued that the most fundamental challenge at the level of the UK economy is to accelerate the process of change so that output grows more quickly and manufacturing maintains its share of the economy, as well as its position in the world rankings.

At the company level, the biggest challenge for firms based in high-cost economies is maintaining sustainable competitive advantage over international competitors. This requires revenues to be grown and costs to be controlled through best practice. To achieve this, firms must:

- Develop innovative business solutions which give a continuing competitive edge
- Optimise performance over the lifecycle of the product or service
- Manage the increasing complexity of companies, supply networks & projects
- Adapt to environmental issues
- Develop intellectual property

The next section considers how the trend of UK manufacturing towards long term relationship building with customers and the extra provision of services around the product offering can be utilised to focus technology and innovation on areas that may best address these challenges.

Figure 3 – % of companies citing particular activities as their top competitive strength
Source: EEF Business Trends Survey



3. Technology Overview

3.1 Previous design, engineering and advanced manufacturing (DEAM) strategy

The Technology Strategy Board has contributed over £120m to Collaborative R&D projects, based on priorities identified in the previously published *Design Engineering and Advanced Manufacturing (DEAM) Strategy* document (13).

A large number of successful projects have been funded under this strategy in areas as diverse as environmentally-friendly aero engines, novel medical devices and battery-powered cars (see case studies).The HVM strategy recognises the successes of the previous DEAM strategy and seeks to build upon them by developing an additional focus towards the changing nature of UK manufacturing, covering service support and full life-cycle responsibility, including environmental impact. The previous DEAM strategy technology priorities are listed below:

- New business models
- Design
- Modelling
- Validation
- Advanced manufacturing technologies and processes

In light of the current global environment, and the forces acting on UK manufacturing described in the previous section, the new HVM UK strategy will seek to take forward the previous manufacturing strategy by placing a new emphasis on the value network, the life-cycle and a new definition of High Value Manufacturing, as indicated in section 3.2. Re-emphasising the previous DEAM priorities within a new context recognises the needs identified by other high level strategic documents and KTN roadmaps reviewed during the development of this strategy (see Appendix 2), other specific reports on issues for UK manufacturing and the internal analysis, consultation and roadmapping activities that have taken place during the development of this document. It also recognises that the often perceived threats of globalisation, environmental sustainability and shorter product life cycles actually offer significant opportunities for the UK in terms of access to global markets and technology innovation.

3.2 The four HVM pillars

Traditionally, manufacturing has been concerned with the one-time sale of a product. However, there is now a trend towards long term relationship building with customers, and servicing their needs around the purchased product [3]. The Technology Strategy Board recognises this trend and the need to continue restructuring the UK economy in favour of high value, knowledge-based design, manufacturing and services[14]. In view of this objective, and building on successful previous DEAM calls in manufacturing, a new definition of manufacturing – High Value Manufacturing (HVM) – forms the core of the HVM UK strategy in this area.

Figure 4 builds on a simple matrix definition of modern manufacturing that was developed for the CBI and DTI by the Institute for Manufacturing, Cambridge. The original definition uses the matrix to position manufacturing companies according to whether the majority of their costs and revenues are in or outside products and production. The four HVM categories within the matrix are described below:

- Service led producers – provide customers with services based on a significant production capability. A company of this type will have in-house production capabilities where most of its costs accrue and will generate the majority of its revenues from services related to those products
- Product manufacturers – focus on generating value through production. A company of this type will have in-house production capabilities where most of its costs accrue and will generate the majority of its revenue from the sale of those products

BBC – iview Project
Project No. TP15515

The Challenge: To reconstruct a 3D model of the action in an event such as a football or rugby game thereby allowing the play to be viewed from locations where it would be impossible to place a real camera.

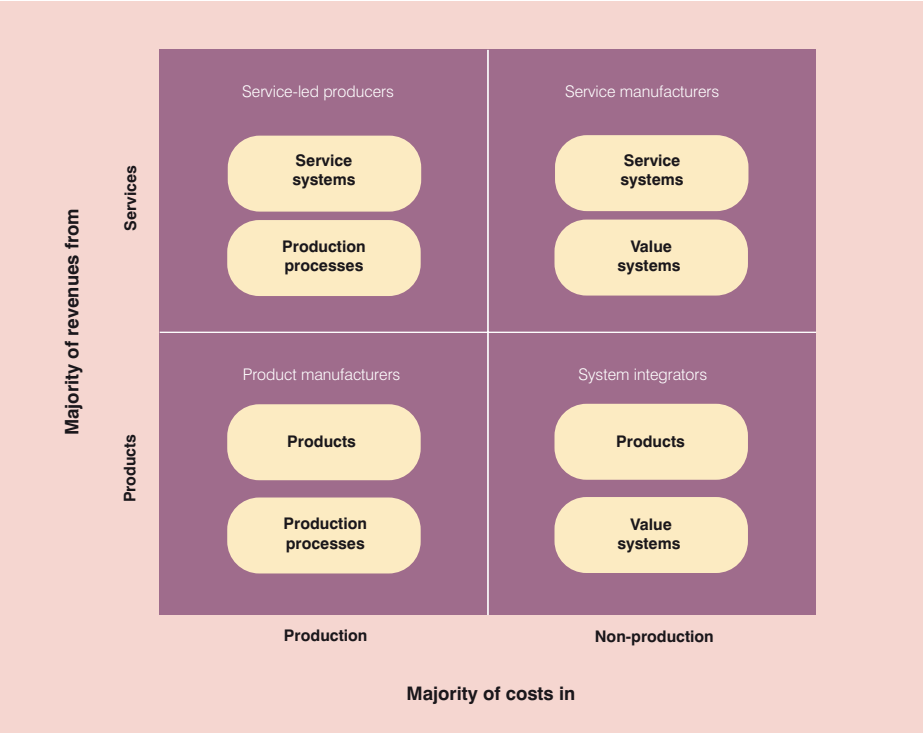
The Solution: This three-year project is being led by the BBC, the other partners being Snell & Wilcox (a broadcast equipment manufacturer), Hawkeye (supplier of ball tracking technology for sports events) and the University of Surrey.

The technical goal of the iview project is to develop a free-viewpoint system that allows the capture and interactive replay of live events using multiple cameras. The technology uses multi-camera images as an input and is based on algorithms for 3D reconstruction, texture mapping and view-synthesis at interactive refresh rates. Although the techniques could be used for many applications, a sport scenario will be used to demonstrate these techniques. It is hoped the technology developed through the project will allow TV pundits to analyse incidents from the point of view of the goalkeeper, the referee, or a player. Ultimately, the technology may allow a game to be streamed in 3D to a device such as a games console. The project, started in Autumn 2005 and is due to finish in Spring 2009 but is already generating some exciting results.

- Service manufacturers – have little or no production and generate value from services which are based around a product. A company of this type will not have significant production related activities and will generate the majority of its revenues from services that may directly support a manufactured product or provide services (e.g. consultancy, management etc) within manufacturing industries
- System integrators – who control the channel to customers and manage an external production network. A company of this type will not focus on in-house production capabilities but will likely manage outsourced production activities and generate the majority of its revenues from the sale of those products. Companies in this category will often have strong brand value and add considerable value through activities such as design, R&D, logistics etc. Many branded electronic goods companies and increasingly automotive manufacturers are following this strategy

The Technology Strategy Board has used this definition to identify key, overarching areas or 'pillars' where the drive for innovation is deemed to be most appropriate for the companies operating within one of more of the HVM categories. The overall challenge for each pillar is to create sustainable competitive advantage with a focus on the opportunities that global supply networks, environmental sustainability and shorter product life cycles now offer. The pillars are shown in Figure 4 and a description of each is listed below that:

Figure 4 A new definition of high value manufacturing and the overarching pillars for innovation within each sector



1. Products

The product pillar is focused on the design and development of innovative products or systems which provide improved performance, functionality, reliability, service life and reduced environmental impact whilst at the same time being designed for efficient manufacture and service in a global supply and market environment.

2. Production processes

The production processes pillar is focused on the development of production technologies that, within a global marketplace, can create high value through novel processes, advanced product manufacture, resource efficiency and greater product customisation. It will also focus on technologies that will facilitate greater environmental sustainability through efficient disposal, re-cycling or remanufacture of assets at the end of their useful life.

3. Service systems

The service systems pillar is focused on the development of solutions which complement product offerings by adding value through support services before, during and after manufacture. In particular, the channels offered by global supply networks and ICT present considerable opportunity for sustainable competitive advantage gained through differentiated service propositions.

4. Value systems

The value systems pillar will focus on value networks that extend beyond individual companies or countries. It focuses on the delivery of a mix of products and services within extended global innovation, supply and distribution networks. The value system is likely to include the company's internal value chain, created with suppliers and the product or service distribution channels and market access. Efficient synchronisation of these networks for lower environmental impact and economic advantage offers great opportunity for future operations management within UK manufacturing businesses. The value system pillar will also focus on how individual parts of global networks interact and add to the

manufactured product or activity. This may include aspects that are less tangible such as social or environmental value and services designed to add value to manufactured products.

3.3 Supporting technologies and innovations

To gain sustainable competitive advantage the 4 HVM pillars must be underpinned by innovative technologies. The HVM strategy takes a holistic lifecycle and value-network view on the technologies required for the 4 pillars and recognises that the technologies applicable to one type of industry will be different to another. Each technology area listed below has been chosen for its applicability to two or more of the HVM pillars and for its ability to score highly against the four Technology Strategy Board criteria of:

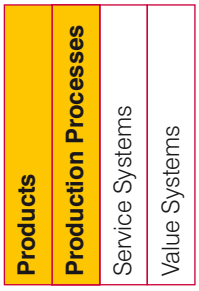
- Does the UK have the capability?
- Is there a large market opportunity?
- Is the idea ready? (timeliness and impact)
- Can the Technology Strategy Board make a difference? (added value)

The strength of the technologies chosen for development in relation to the 4 Technology Strategy Board criteria is summarised by the four boxes immediately below:

Fit against criteria for investment	
UK Capability	High
Market opportunities	High
Timeliness & Impact	High
Added value	High

Modelling, Analysis and Simulation Methods

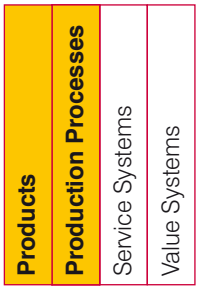
Technology will be developed to facilitate analytical modelling and analysis solutions which enable the prediction of system behaviour from a set of initial parameters and conditions. Innovation in computer simulation will also be developed as a means to create new products and predict processes with less financial risk, less time to market and optimised solutions in terms of performance and environmental sustainability.



Primary 4 Pillar feed-through (bold text and yellow fill denotes applicability to that pillar)

High Value Products

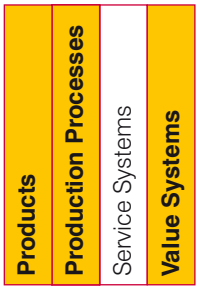
Technology will be developed for well designed, high value products that may offer global market opportunities for UK manufacturers where the value margin is such that the manufacture of the product is feasible in high cost economies. Products that exploit new global and environmental markets are likely to provide particular opportunities for UK wealth creation.



Primary 4 Pillar feed-through (bold text and yellow fill denotes applicability to that pillar)

Resource Efficient and Sustainable Processes

Technology will be developed for advanced production and operational processes that may take advantage of the future drive towards resource efficiency and environmental sustainability within a global context. Areas for technology development may therefore include: novel chemical processes, near net shape forming, advanced automation, renewable feedstocks, custom manufacture and advanced control of processes which require less scale and can therefore be placed closer to the user.



Primary 4 Pillar feed-through (bold text and yellow fill denotes applicability to that pillar)

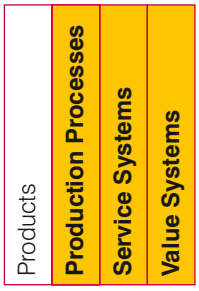
Disposal & Recycling

Technology will be developed to support the drive towards a low-carbon economy and assist UK manufacturing as it becomes increasingly required to change its products and operations in line with regulations and new directives. Early innovation in this respect is likely to present significant global opportunities; technologies should focus on developing designs and processes for efficient disposal, re-cycling or remanufacture of assets at the end of their life.

Primary 4 Pillar feed-through (bold text and yellow fill denotes applicability to that pillar)

Whole Life Planning

Technology will be developed to improve the planning and execution of complex projects, set up of global supply chains and modelling of whole-life financial costs so that business offerings can be designed and evaluated accurately in these respects. Innovation in this area should be set within a global context and be aimed at delivering optimised workflows, reduced waste and environmental impact, better information management and faster time to market.



Primary 4 Pillar feed-through (bold text and yellow fill denotes applicability to that pillar)

Innovative Service Solutions and Condition Diagnosis

UK manufacturers are increasingly looking at opportunities for creating and capturing value through service offers based around the manufactured product. Significant opportunities exist for innovation within globally dispersed service systems and technology will be developed for analysing asset performance data from the field and diagnosing condition – information which is then used to manage inspection, maintenance or repair regimes.

Primary 4 Pillar feed-through (bold text and yellow fill denotes applicability to that pillar)

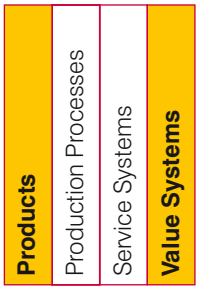
Design and Innovation Processes

Technology will be developed for innovation in design and innovation processes that exploit the opportunities digital technologies offer for globalised design and innovation processes. Areas for development may therefore be aimed at digital technologies that support innovation in design, knowledge management, reduced prototyping costs and new innovation philosophies such as 'open innovation' and 'open source'.

Primary 4 Pillar feed-through (bold text and yellow fill denotes applicability to that pillar)

Collaboration within Extended Operations and Global Networks

Innovation will be developed that looks to exploit opportunities from global networks and operations. Globalisation means that conventional supply-chains have become replaced by complex networks of collaborating suppliers and customers that make up extended value-systems. The UK has considerable strengths to exploit this shift including close multinational trade links and a global language. Areas for development should include business tools for success within global networks and extended systems with a focus on best practices.



Primary 4 Pillar feed-through (bold text and yellow fill denotes applicability to that pillar)

Materials and Metrology

Technology will be developed that addresses the growing global demand for raw materials and its impact on sustainability. The strength of the UK in advanced materials and associated disciplines such as surface engineering and metrology offers significant opportunity for creating new advanced materials that may replace or supplement those in most demand. Specific areas for development may include materials and chemicals made from sustainable feedstock, materials with modified surfaces, validation of materials data, measurement of properties and development of new standards.

Primary 4 Pillar feed-through (bold text and yellow fill denotes applicability to that pillar)

Given the wide range of industries and activities covered by the manufacturing sector, the number of particular technologies which companies could develop in the future is very high. For illustration, examples of candidate technologies for some of the industry sectors of interest are listed in Appendix 2. As well as listing technologies, in a "hard" sense, reference is also made to broader, "soft" capabilities which firms must develop if they are to exploit the new technologies effectively. If technologies are developed without the supporting infrastructure of supply networks, standards, regulations and investment to bring such technologies to consumers, then the investments in such technologies are likely to fail.

The future UK research activities promoted by the Technology Strategy Board will address both the needs and the solutions noted above. Future intervention activities including Knowledge Transfer Partnerships (KTPs), Knowledge Transfer Networks (KTNs), Collaborative R&D and Scoping Studies, will be measured against these challenges and priorities, with the overall aim of supporting UK manufacturing companies in their journey to remain internationally competitive.

UNIMATIC LIMITED Direct Writing of Bioceramics

Project No. TP22300

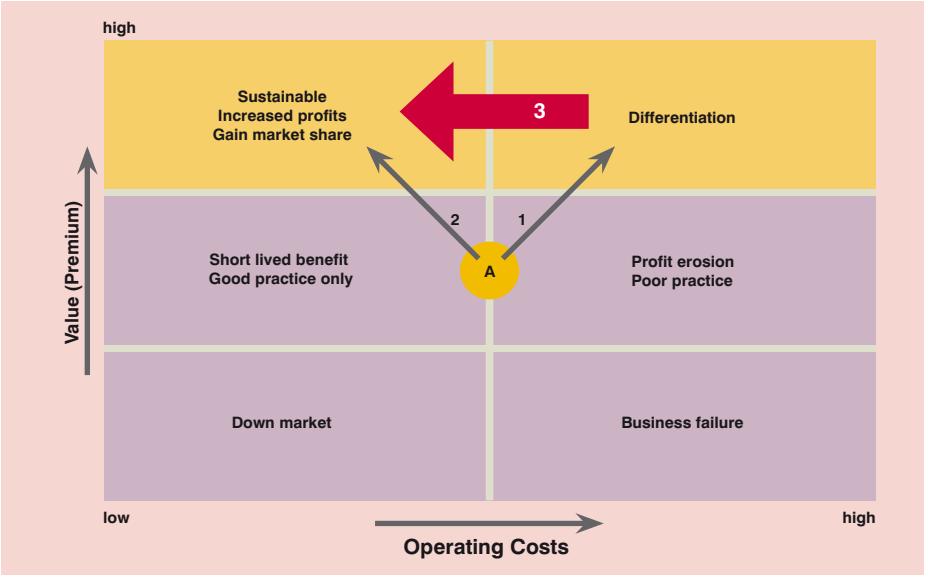
The Challenge: To develop an efficient, reliable, and cost-effective system for producing customised bioceramic implants in place of bone or metallic implants

The Solution: The aim of this project is to develop a procedure that will enable a patient in A & E to undergo a scan, the data from which can then be converted into a computer model and used to drive a machine which builds the implant' layer by layer' using a thin stream of ceramic ink. The process employs high ceramic content inks which are formulated to set strongly when frozen – a process known as freeze casting. The project is led by Unimatic Engineers Ltd, with the following consortium of partners: Sheffield University, De Montfort University, Horizon Ceramics Ltd, Eurodyne Ltd, Strahl Ltd, Ceramisys Ltd

This project aims to enhance the quality of human life whilst simultaneously providing a sound economic contribution to the UK medical market. It is hoped that implants manufactured using this process can potentially be produced in 1 day and implanted in relatively short procedure times with minimal trauma leading to faster patient recovery.

4. Technology Strategy

Figure 5 – Value vs. Cost Map for UK Manufacturing (Adapted From Ref. [15])



4.1 Strategy overview

The most fundamental challenge facing UK manufacturing is that of maintaining competitive advantage in a comparatively high wage economy. Over the past twenty years, UK manufacturing has endured increasing financial pressures and decreasing profit margins due to global competition. In an attempt to maintain margins, many UK manufacturers have strategies focused on cost reduction whether through best practice (Lean, 6-Sigma etc) or by off-shoring labour intensive, often low skilled production operations.

Whilst recognising best practice as fundamental to UK manufacturing competitiveness, the HVM strategy will also recognise that margins may also be maintained through high added value or in other words a value premium over product offerings sourced from global competitors. High added value products can create and capture value in a number of ways other than the most basic production and once only sale of a product. This fact is reflected by the 4 HVM pillars and their underlying technologies.

Figure 5 is a simple illustration to show the possible strategic directions in which a UK manufacturing company may move with regards to cost and customer value proposition. It also highlights what is meant by a 'high value' strategy. For this illustration, value can be regarded as directly linked to the price premium and is therefore a direct driver for wealth generation although it is recognised that other forms of value such as environmental and social value are also important.

Imagine a UK manufacturing company being in the cost/value position represented by A in Figure 5. Even remaining static in this situation requires a considerable amount of business effort. For instance, allowing operating costs to increase without any increase in product value is likely to result in profit erosion at best, or business failure at worst, i.e. a move south-east or east in the diagram.

On the other hand, a strategic move to reduce costs may seem like an obvious winner. However, if such a move does not simultaneously add value to the product then the competitive advantage may not be sustainable, particularly in a high cost economy. Worse still it may result in a move to a more 'down-market' position, i.e. west or south-west respectively.

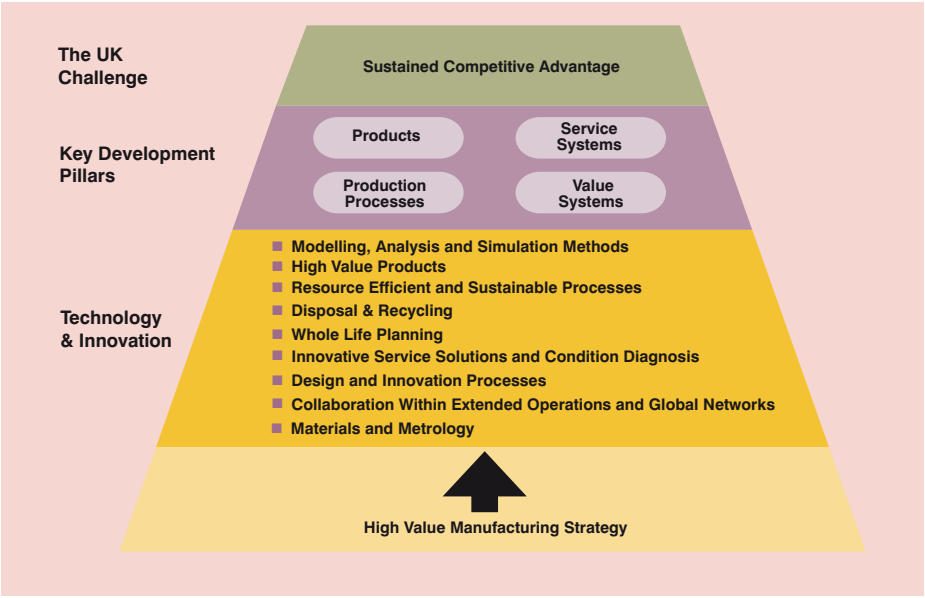
With the High Value Manufacturing strategy and its focus on technologies and innovation to underpin the 4 pillars of products, production processes, service systems and value systems, the Technology Strategy Board wishes to encourage a move into the high value space shown by arrows 1 and 2 in Figure 5.

This strategy is appropriate for UK manufacturers as it allows a company to operate profitably in a space where labour costs may be comparatively high. For instance, if moving into a high value area actually adds to the operating costs (a move north-east along arrow 1) then, as long as that premium value generates higher profits, it is a strong position to be in. This position is the classic strategy often followed by manufacturers that may be able to leverage value created within a cluster of companies operating in a similar technology space or/and a manufacturer of differentiated products, brands or products with enhanced value such as social or environmental value. This position is strong as it also presents the opportunity to reduce operating costs in the future, a move along arrow 3 in Figure 5 whilst maintaining the high value offer.

An obvious strategy in this type of scenario is for a company to actually move north-west where the product is of premium value but also has lower costs. Such a move may result in sustainable competitive advantage, increased profit margins and may even allow the company to gain market share over competitors through enhanced value of the product.

This basic understanding of value and cost is key for UK manufacturers and the 4 HVM pillars are aimed at moving into the high value space whilst understanding how this impacts on costs. A move towards high value should be set within the context of the opportunities presented by

Figure 6 – Summary of how the HVM strategy aims to encourage new technology and innovation in specific areas to underpin the 4 HVM pillars and achieve sustainable competitive advantage through high value manufacturing



globalisation and the shift towards a low carbon economy. Figure 6 summarises how the HVM strategy aims to encourage the new technology and innovation outlined previously in section 3.3 in specific areas to underpin the 4 HVM pillars and achieve sustainable competitive advantage through high value manufacturing.

4.2 Linkages of the HVM strategy to Technology Strategy Board Key Technology & Application Areas

The stated vision for the Technology Strategy Board is *"for the UK to be a global leader in innovation and a magnet for innovative businesses, where technology is applied rapidly, effectively and sustainably to create wealth and enhance quality of life."*

In the area of High Value Manufacturing, it achieves this mainly by initiating and sponsoring collaborative R&D projects. These involve manufacturing companies and often academic partners. Since 2004, about 100 projects have started with a total value (including the partners' financial contribution) of approximately £300m, in the area previously designated as "DEAM". These have involved about 250 companies and 50 academic partners. Many projects in the other Key Technology and Application Areas also have a manufacturing content.

The bulk of the collaborative research work supported by the Technology Strategy Board in the area of manufacturing is with established companies in established markets. Most R&D projects are incremental in terms of their technological or market impact but help to maintain the long-term competitive position of the companies involved. More detailed linkages between the HVM programme and the other Key Technology & Application Areas are listed in Appendix 3. The general approach has been to take particular account of the priority issues within each area.

Another mechanism through which the Technology Strategy Board drives innovation is through Innovation Platforms. The concept of these is that they pull together policy, business, government procurement and research perspectives and resources to generate innovative solutions to societal challenges. Examples of these include Low Carbon Vehicles and Low Impact Buildings. Manufacturing will be key to the successful commercial exploitation of projects undertaken by many of these platforms and Appendix 3 lists how and where the Innovation Platforms may link to the HVM programme.

4.3 Linkages of the HVM strategy to other government programmes

(i) Research Councils:

EPSRC – The Innovative Manufacturing Research Centres are an EPSRC initiative that are supported through the Innovative Manufacturing Programme (IMP). A key objective of the programme is to create, deliver, disseminate and exploit a coherent programme of novel research in innovative manufacturing and to generate significant world-class knowledge and support for the UK manufacturing sector, in its broadest sense. In summary the IMRC programme takes university/industry collaborative research to a readiness level of circa Technology Readiness Level (TRL) 3 [16] from which typical Technology Strategy Board projects could then develop. Close links therefore need to be maintained with the IMRCs and they should be encouraged to develop their existing workstreams into collaborative R&D projects, when they reach this stage of maturity.

ESRC sponsor research in the industrial management field, which is relevant to the Service and Value Systems pillars. The possibility of joint funding of work in this area is being explored further. Particular opportunities may exist for collaboration with the ESRC-funded Advanced Institute of Management (AIM). AIM was established in 2002 with the mission to 'Significantly increase the contribution of and future capacity for world class UK research on management'. To date, AIM has had a considerable focus on manufacturing management issues and in particular the UK's competitive position in respect to productivity.

BBSRC sponsors strategic and applied research into biological systems. The BBSRC Technology Strategy document [17] has a focus on underpinning industrial needs and its key priorities fit well with the Technology Strategy Board focus on UK wealth creation. There is considerable crossover between the priority sectors identified within the BBSRC strategy document and those identified within section 2.3 of this document, specifically the pharmaceuticals & biotechnology, food producing, beverages and healthcare sectors. Given the emerging nature of many of the technologies within these sectors, the HVM team will seek to find appropriate intervention mechanisms with the BBSRC to leverage funding for UK wealth creation.

(ii) Regional Development Agencies and Devolved Administrations – RDAs and DAs

The RDAs and DAs have an active involvement in the development of manufacturing companies in their regions and have a network for linking together the manufacturing coordinators for each region. This is a natural engagement channel as well as a route to identifying projects which RDA/DAs might jointly fund.

ZYTEK GROUP LIMITED – Energy Efficient Electric Urban Transport
Project No. TP10167

The Challenge: To achieve low, or zero emissions in personal transport.

The Solution: Zytek was awarded a grant in the April 2004 competition to develop an electric driveline in conjunction with three partners: Sheffield University (machine and battery modelling), Beta (batteries) and Mira (practical heat management and EMC test work).

The aim of this project is to develop a brushless DC permanent magnet drivetrain, using the **smart fortwo** city car as a validation platform. Targeted research and development has been in progress to produce an electric vehicle with optimised energy utilisation. Improved efficiencies are sought from optimisation of the powertrain by exploring machine parameters which have a significant effect on field-weakening capability, research into battery chemistry technology to increase energy storage density, and waste heat management for climate control within the vehicle.

Exploitation of the technology has already started. Zytek were awarded a contract by Mercedes UK to convert 100 Smart cars to electric propulsion. The first vehicle was delivered to Coventry City Council in December 2007. Coventry will be using the electric Smart within their fleet of pool vehicles.

There is a strong emphasis in each region on identifying the industrial sectors where the region has strengths and on supporting these. There is a priority for bringing SMEs into this process and it is therefore another route to increase engagement with SMEs. The Sainsbury Review requires that £180m of RDA funding should be aligned with the Technology Strategy Board over the 2008 – 2011 period and the HVM group will work actively with the RDAs/DAs to find projects, small and large, where regional and national objectives can be jointly achieved.

(iii) Manufacturing Advisory Service – MAS

The Manufacturing Advisory Service (MAS) is a BERR initiative that seeks to improve productivity and share knowledge across UK manufacturing. The services offered by MAS focus on best practice training, consultancy on key manufacturing issues (e.g. lean manufacturing techniques, design advice, product and process improvement etc), free on-site diagnostic reviews of the entire manufacturing operation and a helpline delivered through regional centres. In the future it is likely that the MAS will also extend into supply network management. The focus of MAS on these services has obvious overlap with the four

HVM pillars and therefore offers another route for disseminating the strategy and implementing its recommendations.

4.4 Promotion and placement

Against this background and in order to stimulate interest from a broader range of industries, an active programme of promotion is required to achieve the Technology Strategy Board's broader mission. The target industries of the HVM programme employ in the region of 4m people and the number of companies who could participate is measured in thousands. Splitting the target audience into two groups:

(1) Large Companies – there is a small number of large companies, with a history of engagement who can be targeted directly, through named individuals in those companies. At the present moment, 90% of the "DEAM" investment goes to 50 companies many of which are large. There is likely a similar number of large companies who do not have this history but who could also potentially benefit from strategic investment in the HVM pillars and underlying technologies.

(2) SMEs – there is then a much larger group of small companies who would have to be made aware of the support available from the Technology Strategy Board by indirect means: through KTNs, trade associations, RDAs & DAs, MAS and university links. Large companies should also be encouraged to take on SMEs as partners in projects to encourage knowledge transfer and exploitation of novel technology.

Through these routes, these companies need to be made aware of the fact that:

(1) There is funding available in principle for collaborative research

(2) There is a very positive climate towards high-value manufacturing and a good understanding of its national benefits

(3) There is technical and management support available to take new ideas forward from conception to demonstration.

The Technology Strategy Board needs to mount an active programme of marketing to make these different communities aware of the funding which is available.

5. Implementation

The Technology Strategy Board will invest in UK industry to develop activities that are aligned with the 4 HVM pillars and the underpinning technology and innovation priorities. The following recommendations are grouped under R&D, Knowledge Transfer, Skills and International Engagement:

5.1 Collaborative R&D

Collaborative research projects have occupied a central role in delivering the Technology Strategy Board's mission over the four years of its existence and have clearly had a good measure of success. However, feedback from the business and academic community has suggested some areas for improvement:

- Time – the timescale from initial call to initial submission gives limited time to form consortia, unless they are already in existence, at least in embryonic form
- Consistency – having a set of business and technical challenges, consistent over time, would encourage effort being invested ahead of calls
- Scale – there may be situations where an idea does not have sufficient momentum behind it to warrant a full-blown project but where some initial funding might be more appropriate.

It is therefore proposed that a flexible range of approaches, addressing the varying needs of manufacturing businesses, should be adopted for the future and, on this basis, the Technology Strategy Board will:

- Run broadly-based CR&D programmes, appealing to a wide range of industries, focused on the four pillars of: product technology, process technology, service systems and value systems and the associated underpinning technologies
- Recognise that the service and value based pillars require business model innovations and CR&D calls in these areas will require appropriate assessment and financial investment
- Invest in scoping projects and proof-of-concept to encourage firms with limited experience of R&D work to be more active in this area
- Encourage large projects to address major issues in key sectors such as aerospace, pharmaceuticals and automotive
- Invest in demonstrators to encourage industry adoption
- Encourage collaboration between large companies and SMEs on collaborative R&D projects

5.2 Knowledge Transfer

- Invest in transferring research from centres of UK academic excellence into industry and work with the Research Councils to ensure appropriate intervention and alignment of priorities
- Work with businesses to transfer established good practices from one industrial sector to another
- Encourage the formation of new KTPs and shorter, more flexible schemes to help companies develop their technical skills in manufacturing technology.
- Work with KTNs and RDA/DA's to act as a channel between the HVM programme and industry, particularly SMEs

5.3 Skills

- Encourage and support skills development of KTP associates that aligns with the 4 HVM pillars and therefore equips the associates with the new skills required by UK manufacturing companies
- Make recommendations concerning skills development and the culture of manufacturing to the manufacturing Ministerial Advisory Group in line with the BERR review of the UK Manufacturing Strategy
- Engage with the National Skills Academy for Manufacturing as an awareness channel for knowledge transfer and R&D opportunities

5.4 International engagement

- Invest in international benchmarking activities against the 4 HVM pillars and align with UK Trade and Investment (UKTI) activities
- Work with UKTI to invest in scoping studies that identify issues and barriers for the global success of UK manufacturing companies
- Support the European Manufuture, SusChem and e-Tranet initiatives to increase the volume of research funding potentially available to UK companies

Appendix 1 – UK Government & European reports and programmes

Recent Key UK Government Reports

Document	Key information for the HVM Technology Strategy	Strategic fit with the Technology Strategy Board – High Value Manufacturing Strategy
The Government's Manufacturing Strategy 2002 [18] and **Review of the Government's Manufacturing Strategy 2004 [19]**	The 2002 document was aimed at developing a strategy to narrow the productivity gap between the UK and its major international competitors, concluding that there are 7 pillars for strategic development in the UK: 1. Macroeconomic stability 2. Investment 3. Science and Innovation 4. Best Practice 5. Raising Skills and Education Levels 6. Modern Infrastructure 7. The Right Market Framework	This strategy document is aimed at Pillar 3 and the specific foreword from the then Secretary of State – 'To help more manufacturers move up the value chain and to reap the benefits of high-skilled, knowledge-intensive manufacturing operations'. The 2004 Stakeholder Review document states that the boundary between manufacturing and services is becoming increasingly blurred and that – 'For every factory producing machine tools, there is demand for collaboration with designers, software specialists, financial experts, caterers and other service providers'. It is clear that this increased pull on services should be an essential component of this strategy and its emphasis on product life cycle and the value chain.
The Foresight Manufacturing 2020 Panel document – 'We Can Make It' [3]	The Foresight Manufacturing 2020 Panel document – 'We Can Make It' [3] – was published in 2000. It sought to identify key issues shaping the future of UK manufacturing and the actions that should be taken. The document raised a number of questions regarding how the UK should best exploit the opportunities the medium term future brings, including 'how the UK can make the most of this shift in emphasis towards becoming a customer-driven, service-led industry'.	The HVM strategy, based on a new definition for manufacturing, implicitly links this change in emphasis within the UK by focusing on interactions between all aspects of the value chain, for instance, the design and production of a product for in-life servicing. The HVM strategy also recognises the future vision of the Foresight Panel that mass customisation, shrinking supply chains and simultaneous processes will be key in the medium term.

The Sainsbury Review

Document	Key information for the HVM Technology Strategy	Strategic fit with the Technology Strategy Board – High Value Manufacturing Strategy
The 2007 Sainsbury Review – The Race to the Top, A Review of Government's Science and Innovation Policies, October 2007 [20]	This is a key document for UK manufacturing and the Technology Strategy Board. This document also recognises the changing face of UK manufacturing and the challenge of moving towards high-value, knowledge-based production and service activities. The report specifically states that there is 'a need to build up the skills in the management of fragmented manufacturing chains' and that 'research into the structure and dynamics of value chains should be supported across the Research Councils'.	The HVM strategy recognises these needs and the further recommendation (Recommendation 2.4) that the Technology Strategy Board should work with the Research Councils to identify the complex, high-value-added production technologies that current and emerging industries require and which are likely to flourish in high-cost economies.

European Programmes

Document	Key information for the HVM Technology Strategy	Strategic fit with the Technology Strategy Board – High Value Manufacturing Strategy
Manufuture Strategic Research Agenda – Assuring the Future of Manufacturing in Europe, 2005 [21]	Five priority pillars identified for the European manufacturing industry: 1. New, high added value products and services 2. New business models 3. New manufacturing engineering 4. Emerging manufacturing science and technologies 5. Transformation of existing RTD and existing educational infrastructure to support world class manufacturing	The strategic fit between the Manufuture Pillar 1 and the HVM pillars is high. Both recognise new high added value services and products as a key driver where the influence of the whole lifecycle and the value chain are critical. Manufuture regards Pillar 1 as the only area where the impact on industry is potentially immediate and continuous into the long term on the Manufuture roadmap. The HVM strategy agrees with Manufuture that exploitation of the lifecycle will enable EU industries to stabilise and strengthen their positions in world markets.
Framework 7 (FP7) Theme 4 – Nanosciences, Nanotechnologies, Materials and New Production Technologies (NMP) [22]	The specific areas for development in Theme 4 are: 1. Development and validation of new industrial models and strategies 2. Adaptive production systems 3. Networked production 4. Rapid transfer and integration of new technologies into the design and operation of manufacturing processes 5. Exploitation of the convergence of technologies The Framework 7 NMP programme also recognises the importance of new industries emerging from nano and micro technologies and their potential for high value-added products.	The HVM strategy recognises the relevance of these specific areas for technology development and builds on them by taking a broad view of the value chain both in terms of how value is created but importantly how the value is captured and sustained for competitive advantage. The HVM strategy in this document complements FP7 NMP by recognising that technologies and processes for developing today's emerging technologies in the UK into emerging industries are essential to fully exploit our strong science base and technology development activities.

Appendix 2 – Illustrations of candidate technologies

Pharmaceuticals and biotechnology	Food & beverages	Healthcare equipment	Aerospace	General industrials	Chemicals	Elec/Electronics
Natural active ingredients and micro/ nano materials manufacture	Manufacture of new varieties, genetically modified ingredients etc	Novel polymer manufacture	Advanced & smart structures & materials	Energy efficient materials Alternate materials	Better ways to make small & nano particles	Cost effective, high energy density capacitors with extended operating temperature range
Process and active molecule modelling	Nutrition and shelf life modelling	Better physiological modelling based on in-vivo imaging	Synthetic environments & systems simulation	Use of finite element methods for life prediction	Higher fidelity, easier to use modelling	EMC design tools and design rules
Reduction of hazardous ingredients	Increased nutritional value New ready meals technology	Combination products Novel sensors	Advanced electric drives & distribution	Design of products to minimise environmental impact throughout lifetime	Better routes from olefins to alkanes	Smaller, more efficient high speed motors
New catalyst synthesis leading to reduced waste	Processing to retain nutritional value New sterilisation processes Automation	Manufacture of functional surfaces on implanted devices	Near net shape forming	Novel joining technologies Precision surfacaes	Intensified Continuous Processing	Electronic systems embedded within injection moulded products
New diagnostic products and services	Rationalisation of support services	In-vivo monitoring through wireless sensors Minimally invasive servicing of implants	Health management & prognostics	Remanufacturing Design for servicing	Develop better understanding of down stream chemical use	Prognostics/ diagnostics for power electronics, self testing/condition monitoring
Advanced bio-informatics	The use of the internet for direct sales and marketing	Advanced health-informatics	Network-enabled capability	New information formats and info minimisation through application of information theory and advanced knowledge extraction	Information traceability and maturity	Information overload & value
Implementation of new regulatory & industrial standards Reduction of experimentation	Efficient compliance with a high amount of legislation and accreditation systems	Identifying real clinical and market needs Infrastructure for increased speed to market	Design of service-oriented business models	Production management	Ability to engage with and navigate regulatory & industry standards processes	Strategic re-use of IP
Operation of increasingly fragmented supply chains in a highly regulated industry External partnerships	Identification of new sales channels to replace declining traditional fresh food channels	Integration of supply chain quality systems across raw material suppliers, contract manufacturers and OEMs	Outsourcing by primes to a global network of suppliers	Management of offshore and/or outsourced production	Substitution of non-renewable feedstocks by renewable	Supply chain networks bringing together universities, component suppliers and end users to deliver strategic research

Sources:

National Aerospace Technology Strategy, Crystal Faraday (Chemistry Innovation KTN) Green Technology Roadmap, EEP KTN (Integrated Products Manufacturing KTN) Power Electronics Roadmap 2007, Chemistry Innovation KTN pharmaceutical roadmap, Health Technologies KTN roadmaps, Food Processing KTN roadmaps

Appendix 3 – Linkages to other key technology & application areas

KEY TECHNOLOGY AREAS:	AREAS OF CROSS-OVER:
Materials	• Use of new materials & processes in the fabrication of innovative products • Disposal & recycling of materials at end of product life
Nanotechnology	• Scale-up of current nano-tech production • Production of nano-precision surfaces • Disposal and recycling of nano-scale materials
Bioscience	• Manufacture of pharmaceutical & biotechnology products
Electronics, Photonics & Electrical Systems	• Design & manufacture of systems & equipment in the EPES industries
Information & Communication Technologies	• Running of core business processes • Control of manufacturing processes • Modelling & simulation of products & processes • Analysis of asset condition data
KEY APPLICATION AREAS:	**AREAS OF CROSS-OVER:**
Environmental Sustainability	• Design of sustainable products • Low-carbon manufacturing processes • Re-cycling & re-manufacturing at end of life
Energy Generation & Supply	• Design, manufacture & asset management of energy generation & transmission systems
Medicines & Healthcare	• Design & manufacture of healthcare systems & equipment
Transport	• Design, manufacture & asset management of transport products, equipment & infrastructure: automotive, aircraft, marine, rail, in line with their strategies developed in their IGT's, or equivalent
Creative Industries	• Creative design of industrial products
High Value Services	• Industrial services: consultancy, research, design & development, asset care & operation
Built Environment	• Application of manufacturing system approach to construction
INNOVATION PLATFORMS:	**AREAS OF CROSS-OVER:**
Intelligent Transport Systems and Services	• Little obvious overlap
Network Security	• Little obvious overlap
Low Carbon Vehicles	• Significant overlap in design, manufacture & asset management of transport products
Assisted Living	• Some possible overlap in the manufacture of products and associated services
Low Impact Buildings	• Significant overlap in a manufacturing system approach to construction and the production of building materials

Appendix 4 – Glossary

ACARE	Advisory Council for Aeronautics Research in Europe
AIM	Advanced Institute of Management Research
BBSRC	Biotechnology and Biological Sciences Research Council
BERR	(Department) for Business, Enterprise and Regulatory Reform
CBI	Confederation of British Industry
CR&D	Collaborative Research & Development
DA	Devolved Administration
DEAM	Design Engineering & Advanced Manufacturing
DTI	Department for Trade & Industry
EEF	Engineering Employers' Federation
EPES	Electronics, Photonics and Electrical Systems
EPSRC	Engineering & Physical Sciences Research Council
ESRC	Economic & Social Research Council
FP7	Framework Programme 7
GDP	Gross Domestic Product
GVA	Gross Value Added
HVM	High Value Manufacturing
ICT	Information & Communications Technology
IGT	Innovation & Growth Team
IMP	Innovative Manufacturing Programme
IMRC	Innovative Manufacturing Research Centre
KTN	Knowledge Transfer Network
KTP	Knowledge Transfer Partnership
MAS	Manufacturing Advisory Service
NMP	Nanosciences, Nanotechnologies, Materials and New Production Technologies
OEM	Original Equipment Manufacturer
ONS	Office for National Statistics
R&D	Research & Development
RDA	Regional Development Agency
RTD	Research & Technological Development
SME	Small & Medium-Sized Enterprises
TRL	Technology Readiness Level
UKTI	United Kingdom Trade and Investment

Appendix 5 – References

1 ONS data series ABML & QTPI

2 UN Statistics Division, Manufacturing GVA by Country

3 Foresight Manufacturing 2020 Panel document – 'We Can Make It', 2000

4 Global Insight Report, May 2007

5 World Development Indicators 2007, World Bank, 2007

6 ONS data series CKYY

7 ONS data series LNNX & LOMN

8 ONS data series multiple

9 ONS 1.41 Change in contribution by industry to GVA between 1992 and 2003

10 DTI R&D Scorecard, 2007

11 DTI Value Add Scorecard, 2007

12 EEF Report – High Value Manufacturing, 2007

13 Design, Engineering and Advanced Manufacturing Technology Strategy Report, Technology Strategy Board, 2006

14 Objectives of the Technology Strategy Board, Annual Review, 2006

15 C. Bowman and D. Faulkner 'Competitive and Corporate Strategy' – Irwin – 1996

16 Technology Readiness Levels – A White Paper, NASA, 1995

17 BBSRC Strategy Document – Underpinning Industrial Needs, 2007

18 The Government's Manufacturing Strategy, 2002

19 Review of the Government's Manufacturing Strategy, 2004

20 The 2007 Sainsbury Review – The Race To The Top, A Review of Government's Science and Innovation Policies, 2007

21 Manufuture Strategic Research Agenda – Assuring the Future of Manufacturing in Europe, 2005

22 Framework 7 (FP7) Theme 4 – Nanosciences, Nanotechnologies, Materials and New Production Technologies (NMP), 2007

Left hand picture on front cover courtesy of Stratophase

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