Technology Strategy Board

Driving Innovation

High Value Manufacturing

Strategy

2012-2015

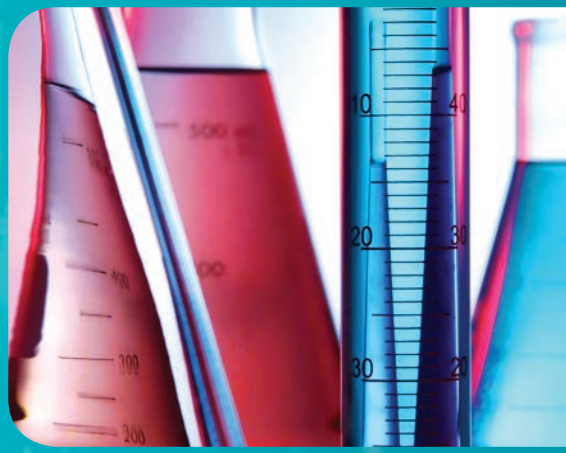
EXECUTIVE SUMMARY

Manufacturing contributes over £6.7tr to the global economy[1] and the UK is a major competitor. In terms of manufacturing Gross Value Added (GVA), it is in the world's top 10[2], generating 10% of UK GVA[3]. UK manufacturing directly employs 2.5 million people, generates half of UK exports and accounts for three quarters of business R&D conducted in the UK[4]. The UK ranks second only to the US in the aerospace industry[5], and two out of the top six pharmaceutical companies are headquartered in the UK[6], where they also support significant manufacturing assets.

The resurgent UK-based auto industry exported a record-breaking 84% of production in 2011[7]. Underpinning these important statistics is an average annual productivity increase of 3.6%, two and a half times greater than the UK economy as a whole[4].

Despite these strengths, globalisation has continued to drive production activities towards countries with the lowest labour costs and/or the largest markets, and the UK remains vulnerable to eroding manufacturing investment and capability. This, coupled with the financial crisis highlighting the UK economy's over-dependency on service sectors, has led the UK Government to aim to increase the role that manufacturing plays in the growth of the economy. Innovation in manufacturing, through commercialising the world-class output of the UK science base, is fundamental to these long-term growth ambitions.

As part of the process of reviewing our existing strategy we have drawn extensively on the findings of the Institute for Manufacturing (IfM) study, *A landscape for the future of UK manufacturing*, that we commissioned and subsequently published in February 2012[8]. In working with IfM to progress this study, we have consulted extensively with industry, academia and other organisations. Our corporate strategy *Concept to Commercialisation*[9] also underpins this work.



Our strategy

We aim to ensure that high value manufacturing is a key driver of UK economic success.

We will help accelerate businesses on their innovation journey from concept to commercialisation by:

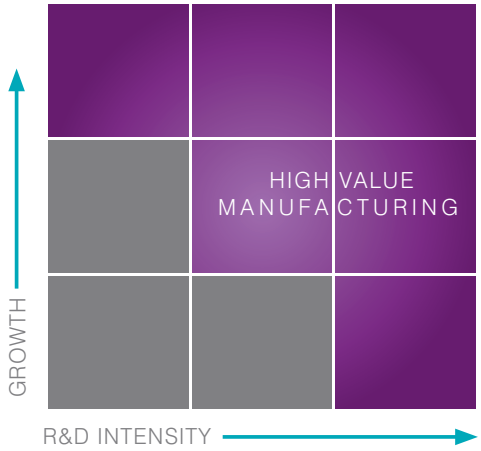
- **doubling our direct investment in high value manufacturing innovation to around £50m a year (a number of other sectors and technology areas in the Technology Strategy Board, e.g. advanced materials, biosciences, transport and energy will also invest in manufacturing innovation specific to their target areas).**
- **focusing our investment in the most attractive technologies and market sectors where the UK can become an important player in large global markets**
- **making our investment choices using a set of 22 manufacturing competencies (as identified and defined in the landscape study) to ensure our support is focused on where there is the greatest potential to deliver high-value economic impact across multiple global market sectors**
- **investing in the High Value Manufacturing (HVM) Catapult to provide the cutting-edge equipment and the skilled resources our businesses need to commercialise their world-class technologies**
- **providing open access to the most effective platforms for knowledge exchange, such as the Knowledge Transfer Networks, Knowledge Transfer Partnerships, Special Interest Groups and HVM Catapult, that will help businesses combine the best manufacturing innovations to create world-beating products, processes and services.**

‘High value manufacturing accounted for 35% of all UK exports in 2010, contributing £151bn to the UK balance of payments.’[10]

Why high value manufacturing?

High value manufacturing is the application of leading-edge technical knowledge and expertise to the creation of products, production processes, and associated services which have strong potential to bring sustainable growth and high economic value to the UK. Activities may stretch from R&D at one end to recycling at the other. Such potential is characterised by a combination of high R&D intensity and high growth (see right).

What makes a sector attractive for our investment?



EXECUTIVE SUMMARY continued

What are the challenges to innovation?

To innovate in manufacturing, new knowledge must be applied to generate a new product, process or service, or new technology utilised to improve an existing process. In each case, businesses face the challenges of securing the supply of resources as well as the need to take risks to achieve significant impact. Manufacturing new products or adopting new manufacturing processes both require demonstration at commercial scale and this step up is often expensive and risky. This so-called 'Valley of Death' – where many innovations fail – represents a significant barrier to innovation in manufacturing, and one which the new Catapults are designed to address.

Small and medium-sized enterprises (SMEs) will play an increasingly important part in achieving economic growth, and connecting these companies to the global players who often represent valuable routes to market is a specific challenge.

We believe that, in order to tackle such challenges, businesses need to acquire certain 'competencies' that will equip them with the means to meet the challenges head-on, turn them to their own advantage, and enable them to exploit the opportunities.

What are the opportunities for business?

Opportunities for UK high value manufacturing may arise in new markets, new technologies, and through addressing the challenges above. But if we were to analyse them purely in this way we would inevitably come to a very narrow view of what the opportunities are for innovative businesses.

In aiming to look at the 'bigger picture' we have identified a set of high value manufacturing competencies necessary to deliver innovation across a broader range of applications. Each competency represents a group of technology-related capabilities which, if held by a number of companies/organisations, will enable high value manufacturing across several different market sectors. An example is the development and application of advanced coatings which impacts many sectors – from food and healthcare, to aerospace, oil and gas.

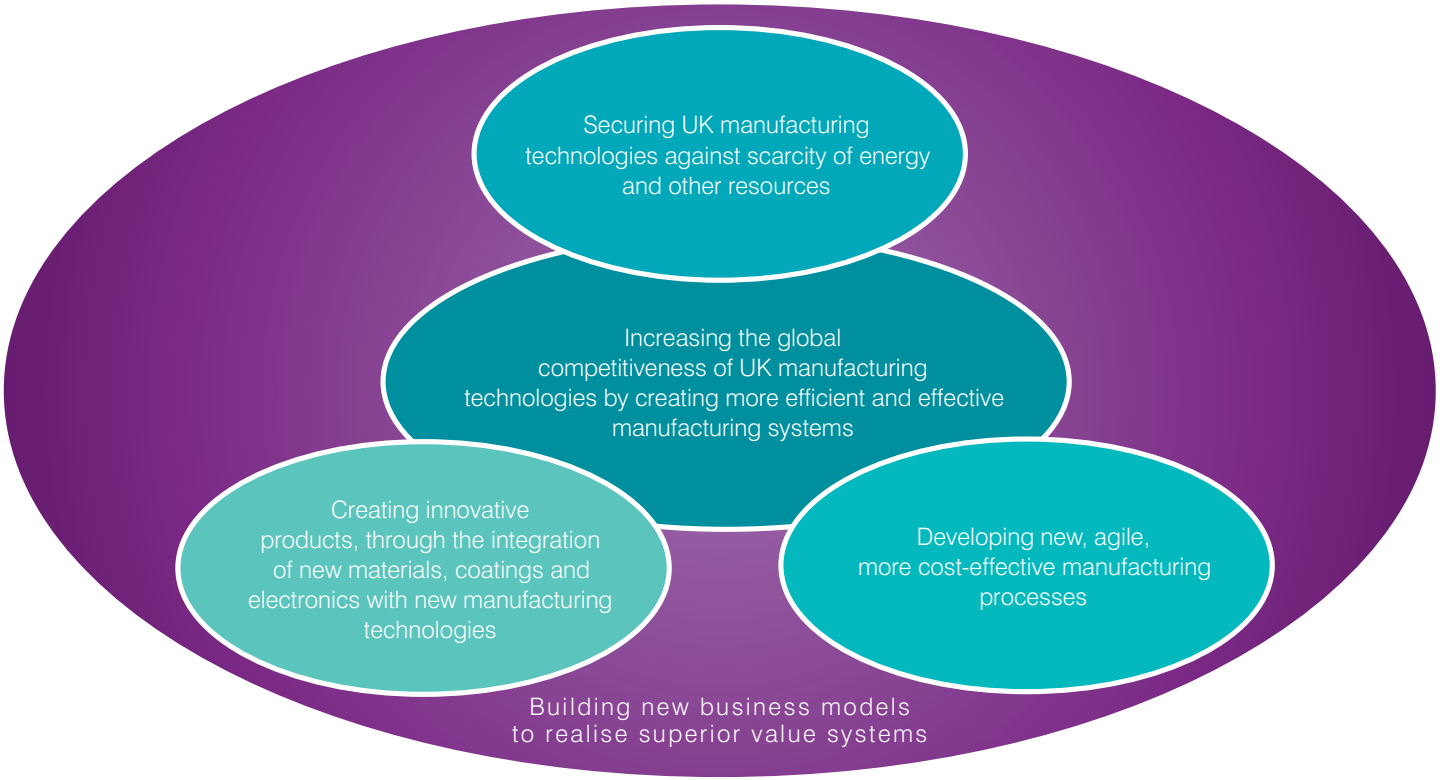
The set of 22 competencies is grouped around five strategic themes:

- **resource efficiency**
- **manufacturing processes**
- **materials integration**
- **manufacturing systems**
- **business models.**

These strategic themes offer pivotal opportunities for businesses and we will use them to inform our investment decisions for high value manufacturing over the coming years.

The five strategic themes reflecting business opportunities.

There is strong overlap between these themes. Global competitiveness underpins all the themes and new business models are essential for the realisation of value.



Making choices

We will focus our investment and support activities where we believe UK businesses stand to gain most success and where our funding will make the most difference.

We will focus our innovation support on the pre-competitive stages of technology development between proof of concept and commercial demonstrators, through investment in collaborative R&D projects and the core capabilities of the HVM Catapult.

We will invest about half of our budget in the Catapult. This will assist businesses requiring higher levels of investment in equipment and expertise in 'platform' technologies than is possible through our collaborative R&D programme, and make such resources more affordable to SMEs.

In making choices we will use:

- **sector attractiveness**
- **the 22 national competencies**
- **technology readiness level**
- **additionality (the potential for the Technology Strategy Board investment to make a difference).**

as our key selection criteria.

Specific investments in high value manufacturing will be detailed in the Technology Strategy Board annual *Delivery Plan* published at www.innovateuk.org

WHY IS HIGH VALUE MANUFACTURING

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ECONOMIC IMPORTANCE AT A GLANCE

- **Manufacturing contributes over £6.7tr to the global economy and the UK is a major competitor.**
- **In terms of manufacturing Gross Value Added (GVA), it is in the world's top 10, generating 10% of UK GVA.**
- **UK manufacturing directly employs 2.5 million people, generates half of UK exports and accounts for three quarters of business R&D conducted in the UK.**
- **The UK ranks second only to the US in the aerospace industry.**
- **Two out of the top six pharmaceutical companies are headquartered in the UK, where they also support significant manufacturing assets.**
- **The resurgent UK-based auto industry exported a record-breaking 84% of production in 2011.**

Why is high value manufacturing a priority for us?

Manufacturing in general represents an important strategic competence within the UK economy, but it is high value manufacturing specifically where we see the most opportunities for innovative businesses to succeed long-term.

'High value manufacturing is the application of leading-edge technical knowledge and expertise to the creation of products, production processes, and associated services which have strong potential to bring sustainable growth and high economic value to the UK. Activities may stretch from R&D at one end to recycling at the other'[11].

World-class

The UK retains a world-class science and technology base and this is particularly important for high value manufacturing which is becoming increasingly knowledge-based. Recent research indicates that a country's ability to innovate in manufacturing is strongly linked to the presence of an indigenous manufacturing base, where the opportunities for innovation can be quickly identified and acted upon, ensuring that local manufacturing technologies remain globally competitive (the learning curve effect), as we still demonstrate today in our aerospace and pharmaceutical industries. This is a model on which we need to build in other market sectors.

SMEs in the value chain

Of the 4.5 million businesses in the UK, approximately a quarter of a million (5%) operate in the manufacturing sector, with manufacturing SMEs representing a third of total manufacturing turnover[12]. Large manufacturing companies often have a multitude of SMEs in their supplier base and together companies large and small operate in a connected value chain structure.

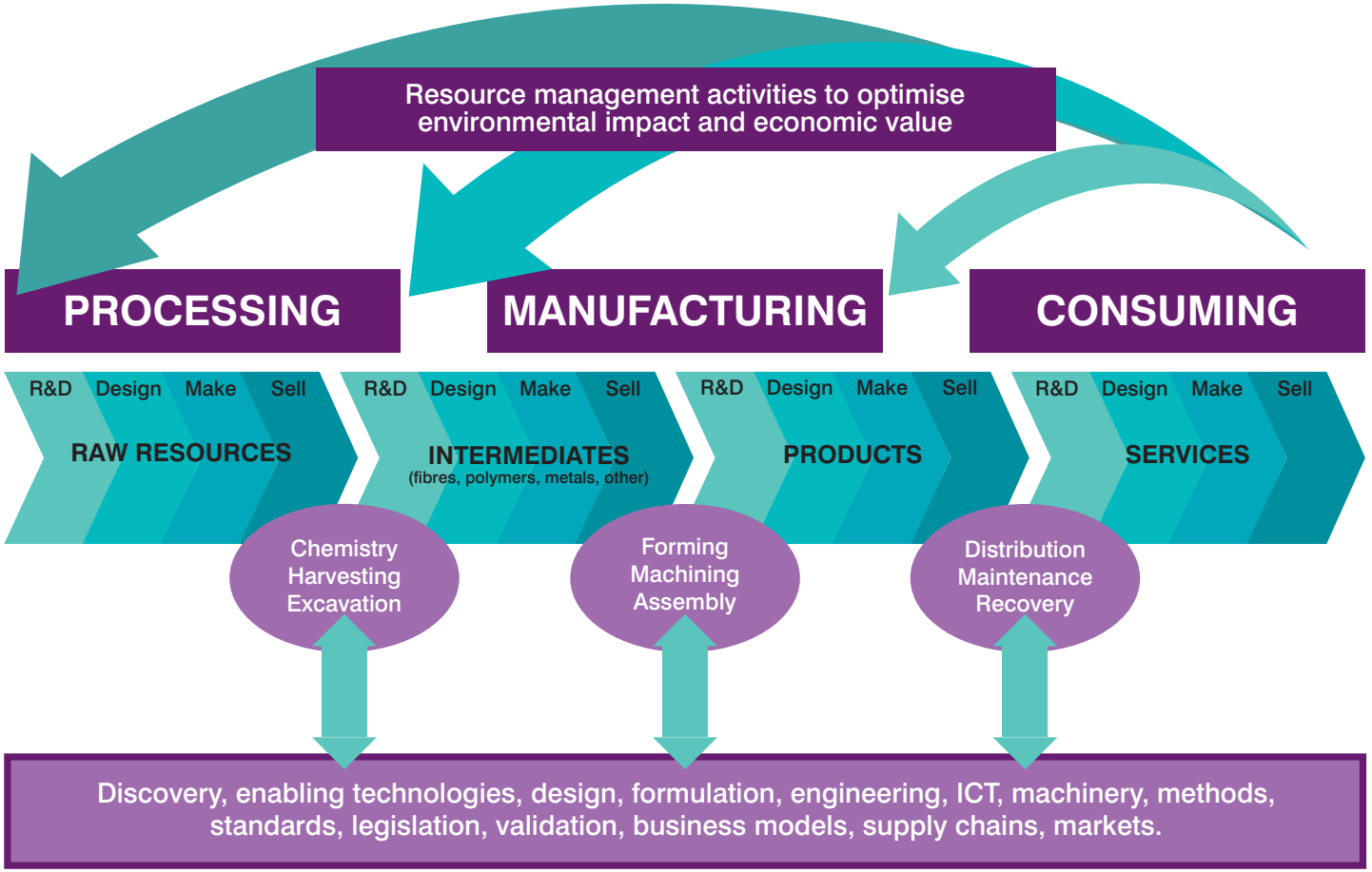
Manufacturing represents a number of value chains and is itself part of a wider industrial system for value capture[13] enabling new ideas to reach their markets, with each stage adding value to the output of the previous stage. These value chains have become complex global systems with the sequential stages often being carried out in different countries.

A PRIORITY FOR US?

Sustainable high-value manufacturing

In reviewing the basic design/make/sell model for a product lifecycle we have worked with Forum for the Future[14] to develop our extended view of the product lifecycle as shown on the right, which illustrates how recycling and retrieval of products and materials should be an integral consideration at all stages of processing, manufacturing and consumption. We believe that the emphasis of activities in the UK should extend beyond the core competencies of design and production increasingly to encompass the provision of a lifetime service around the manufactured product, designing in options to manage the material resource over multiple product lifetimes.

Key elements of sustainable manufacturing



WHAT ARE THE CHALLENGES FOR HIGH

Responding to global megatrends

We consider sustainability in its broadest (economic, social and environmental) sense to be the most important challenge for high value manufacturing. The increasing cost and scarcity of some materials is highlighting the importance of security of supply and driving the search for replacement, renewable raw materials. At the same time, there is a drive to develop products and processes requiring less energy and/or greater conversion efficiencies and a greater use of other renewable resources.

The ageing population is another major challenge facing the developed world. As people are living longer, whole markets are facing new challenges around healthcare provision and independent living. This is having a significant impact on these markets as well as offering major opportunities for high value manufacturing.

The UK's ability to respond to these trends will depend on us having the skilled workforce necessary to innovate in HVM. The skills shortages in science, technology, engineering and mathematics disciplines represent a significant challenge to highly innovative businesses being able to take their innovation forward and compete globally.

Innovating to compete in global markets

The UK's innovation capability is critically dependent on manufacturing as the route to achieving rapid and profitable commercialisation of new products, processes and services. In many cases this innovation will involve the assembly of new supply chains or the adoption of new business models.

Manufacturing new products or adopting new manufacturing processes both require demonstration at a commercial scale. This step up in scale from prototyping is often expensive whilst still representing significant risk – often referred to as the Valley of Death – a significant barrier to innovation in high value manufacturing.

Continuing higher economic growth rates of the BRIC (Brazil, Russia, India and China) economies represents a major challenge and, at the same time, an opportunity. However, anecdotal evidence suggests that increased transport cost and decreased security are encouraging repatriation of some manufacture back to Europe, and the UK must position itself to exploit this change.

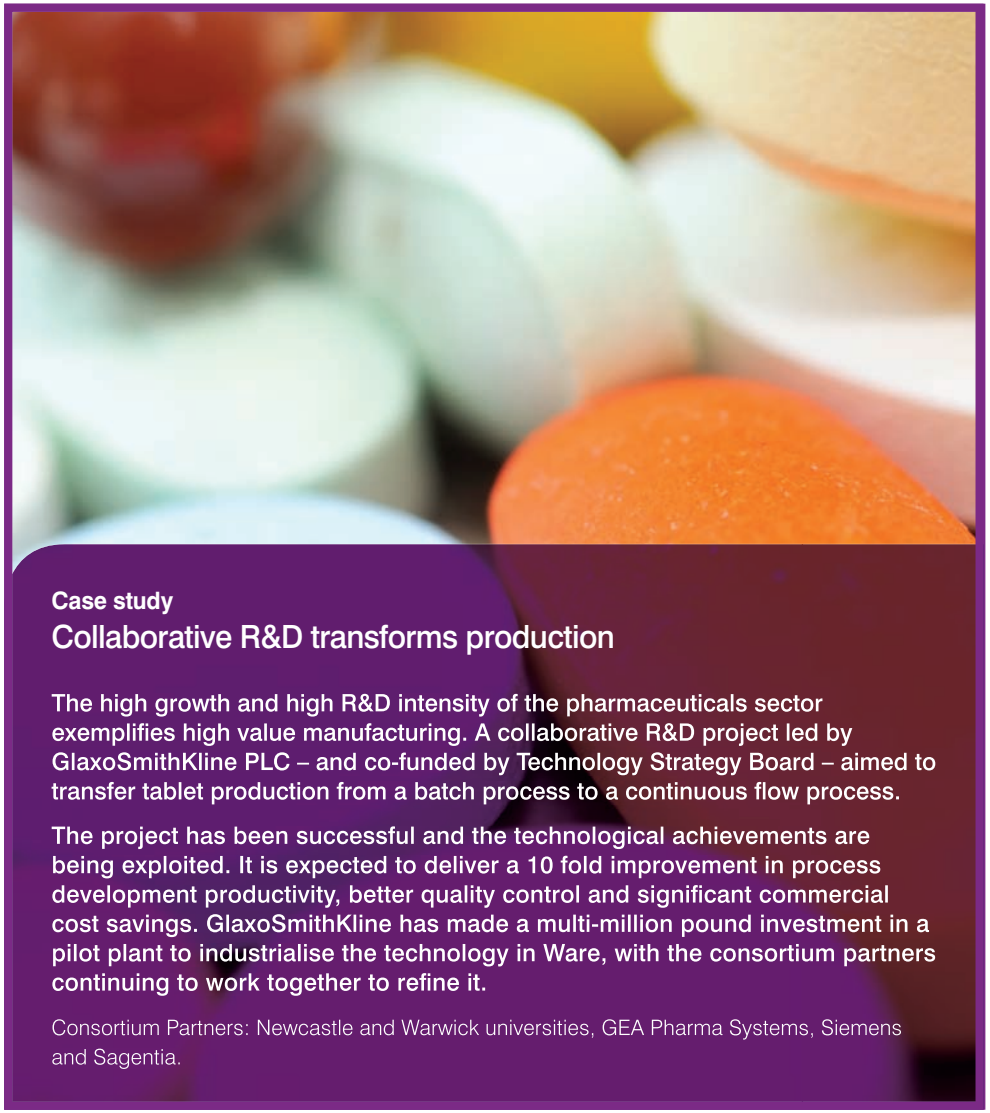
Government too plays a vital role in this – in ensuring consistent and supportive fiscal policy and legislation that creates the best environment for UK business to optimise the potential of its high value manufacturing capability both at home and abroad. This is critical to the process of de-risking investment in new ideas.

VALUE MANUFACTURING INNOVATION?

Restoring the health of the UK supply chain

A progressive depletion or 'hollowing out' of the UK-based supply chain over recent decades represents a long-term threat to our manufacturing capability and its future prosperity. An everyday example of this would be to lift the bonnet of a British-built car: many of the major components come from overseas. This means that an SME with an innovative new technology developed for one of these components needs to find an overseas client to sell its product. Given the key role of SMEs in the supply chain, the need to actively re-build and sustain SMEs is a major structural challenge for the manufacturing industry.

'We believe that, in order to tackle such challenges, businesses need to acquire certain national competencies that will equip them with the means to meet the challenges head-on, turn them to their own advantage, and enable them to exploit the opportunities.'



Case study

Collaborative R&D transforms production

The high growth and high R&D intensity of the pharmaceuticals sector exemplifies high value manufacturing. A collaborative R&D project led by GlaxoSmithKline PLC – and co-funded by Technology Strategy Board – aimed to transfer tablet production from a batch process to a continuous flow process.

The project has been successful and the technological achievements are being exploited. It is expected to deliver a 10 fold improvement in process development productivity, better quality control and significant commercial cost savings. GlaxoSmithKline has made a multi-million pound investment in a pilot plant to industrialise the technology in Ware, with the consortium partners continuing to work together to refine it.

Consortium Partners: Newcastle and Warwick universities, GEA Pharma Systems, Siemens and Sagentia.

WHAT ARE THE OPPORTUNITIES FOR

The study on *A landscape for the future of UK manufacturing* identified some clear areas of consensus on trends and drivers, challenges and opportunities which are set out and explained in the report in further detail.[15] Business opportunities for UK manufacturing may typically arise in new markets or new technologies, but analysing them in this way can lead to a very narrow view of innovation opportunity and miss the 'bigger picture' provided by looking at opportunities that can be exploited through high-impact, cross-cutting manufacturing innovation. In our strategy, we address this by considering the 'competencies' necessary to deliver innovation across a broader range of market sectors.

By a competency, we mean a group of technology-related capabilities held by a number of companies/organisations enabling high value manufacture across several different market sectors. The 22 key competencies detailed opposite are grouped into five strategic themes in the panel below.

- **resource efficiency**
- **manufacturing systems**
- **materials integration**
- **manufacturing processes**
- **business models.**

The landscape study suggested that acquisition of key competencies is likely to be a critical factor in equipping UK manufacturing companies for future success in exploiting the big opportunities of tomorrow. We would expect successful companies to have, or acquire, a world-class manufacturing capability focused on one or more of the competencies listed here.

The UK possesses a unique set of opportunities. This is due to its large and diverse markets, potential to establish high-technology clusters as a result of close geographical locations and networking advantages and a unique combination of challenges and capabilities. Investing in competencies that have an impact on multiple market sectors will ensure maximum leverage of every pound of our investment to yield better results in terms of stronger and wider business impact and greater value for money.

1. Resource efficiency: Securing UK manufacturing technologies against scarcity of energy and other resources

Energy generation, storage, management and security

Energy storage, energy management and transport focusing on energy cost, security and novel generation technology. New energy sources including next generation nuclear and energy transmission with low loss and low visual impact.

Design and manufacture for sustainability and through-life

Design and manufacture of sustainable and innovative products including cleaner processes, low-carbon outcomes and less waste. Robust assembly for disassembly (recycling) and through-life engineering.

Design and manufacture for lightweight vehicles, structures and devices

Light-weighting to reduce energy consumption and emissions, reduce costs and increase efficiency. Composite, new and hybrid structures design, fabrication, joining and assembly. Multifunction component design and manufacture.

Biotech, biological and synthetic biology processing

Alternative bio- and synthetic bio-based sources for new and existing products and processes. Processing of biologics for pharmaceutical and medical applications.

2. Manufacturing systems: Increasing the global competitiveness of UK manufacturing technologies by creating more efficient and effective manufacturing systems

Process engineering capability across food, pharmaceuticals and chemicals

Development and application of common capability across food processing, pharmaceuticals and chemicals. Redesigning processes to increase yields and operational efficiency.

Design and manufacture for small-scale and miniaturisation

Miniaturisation, design and manufacture of smaller products such as specialised drugs, batteries and electronics. High precision and micro/nano-engineered products and processes and integration with macro-scale.

Systems modelling and integrated design/simulation

Systems modelling and simulation tools, integrated system design, simulation and validation. Virtual prototyping, materials models, functionality and design. System integration of high-complexity products.

Automation, mechanisation and human/machine interface

Process automation and human/machine interface. Autonomy applications, particularly in production and servicing.

BUSINESS?

‘Plug and play’ manufacturing

Application of modularity to develop a high-volume production environment, where the production units can be combined in a flexible manner and serviced more effectively.

Novel mechanical conversion processes for scale, economy and efficiency

The application of new primary and secondary mechanical conversion technologies and processes, for example, low-energy forming/forging, tool-less and one-shot manufacturing, new machine tool technologies and welding processes/applications including, for example, welding to titanium and magnesium.

Understanding, designing and manufacturing formulated products

Understanding design and manufacture of all formulated products for relevant sectors across the supply chain.

3. Materials integration: Creating innovative products, through the integration of new materials, coatings and electronics with new manufacturing technologies

Smart, hybrid and multiple materials

Design, modelling and manufacturing processes of multi-metallic components and high-performance materials. Structures and components with integrated functions and tailored material properties and location-specific properties. Enhanced, faster joining capability with a range of materials.

Intelligent systems and embedded electronics

Robust ‘live’ data capture and comprehensive capture and use of product/process information. New sensor/non-destructive testing (NDT) devices and smart and multifunctional components which are embedded and/or intelligent. Large-area, printable, cheap electronics, integrated with other manufacturing processes for energy management, security, packaging and light-weighting. Integration of electronics into product and materials design.

Development and application of advanced coatings

Development and application of advanced coatings across multiple sectors.

4. Manufacturing processes: Developing new, agile, more cost-effective manufacturing processes.

Flexible, adaptive manufacture

Flexibility of production and manufacture supporting customised and rapidly reconfigurable manufacturing. Adaptive manufacturing including single-step, flexible reconfiguration and process technology that can adapt to feedstock of different types and compositions and mass customisation techniques.

Combining product development steps in parallel/concurrent engineering

Real-time market analysis and response and systems to reduce development time. Combining marketing, design, manufacturing, standards, regulations and procurement and early user engagement.

Additive manufacture

Application of layer manufacturing techniques or other freeform techniques for joining materials to fabricate intermediate and end-use products including direct digital manufacturing methods.

Net and near net shape manufacture

Initial production of items very close to the final net shape, reducing the need for surface finishing. Tool-less manufacturing with single actions to produce final parts or one toolset for full production system with one-pass production.

5. Business models: Building new business models to realise superior value systems

Managing fragmented value chains to support HVM

Managing complex value delivery across the value chain in multiple locations and exploiting ‘economies of small scale’ to develop and produce close to the customer.

Building new business models to support HVM

New business models, with flexible arrangements to create new value.

Developing and retaining skills to support HVM

Associated training and skills in HVM, provision of employees with cross-disciplinary skills and the ability to combine knowledge.

Managing risk and resilience to support HVM

Mechanisms to ensure HVM strategy and associated product strategies are inherently compliant with necessary standards across the value chain. Governance to ensure HVM product, service and process outcomes meet strategic intent.

OUR STRATEGY

Scope

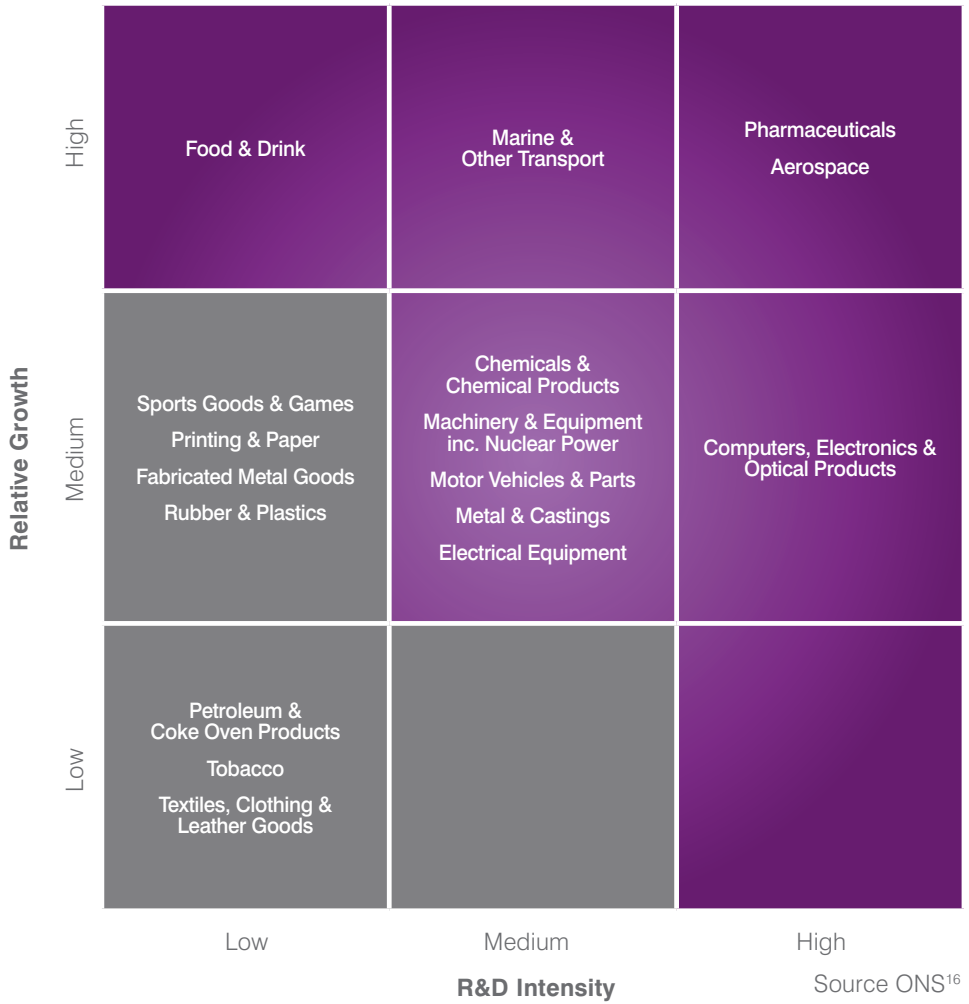
Our focus is on innovation – the commercial exploitation of new ideas – within high value manufacturing. In making choices we will use:

- **sector attractiveness**
- **the 22 national competencies**
- **technology readiness level**
- **the potential for the Technology Strategy Board to make a difference (additionality)**

as our key selection criteria.

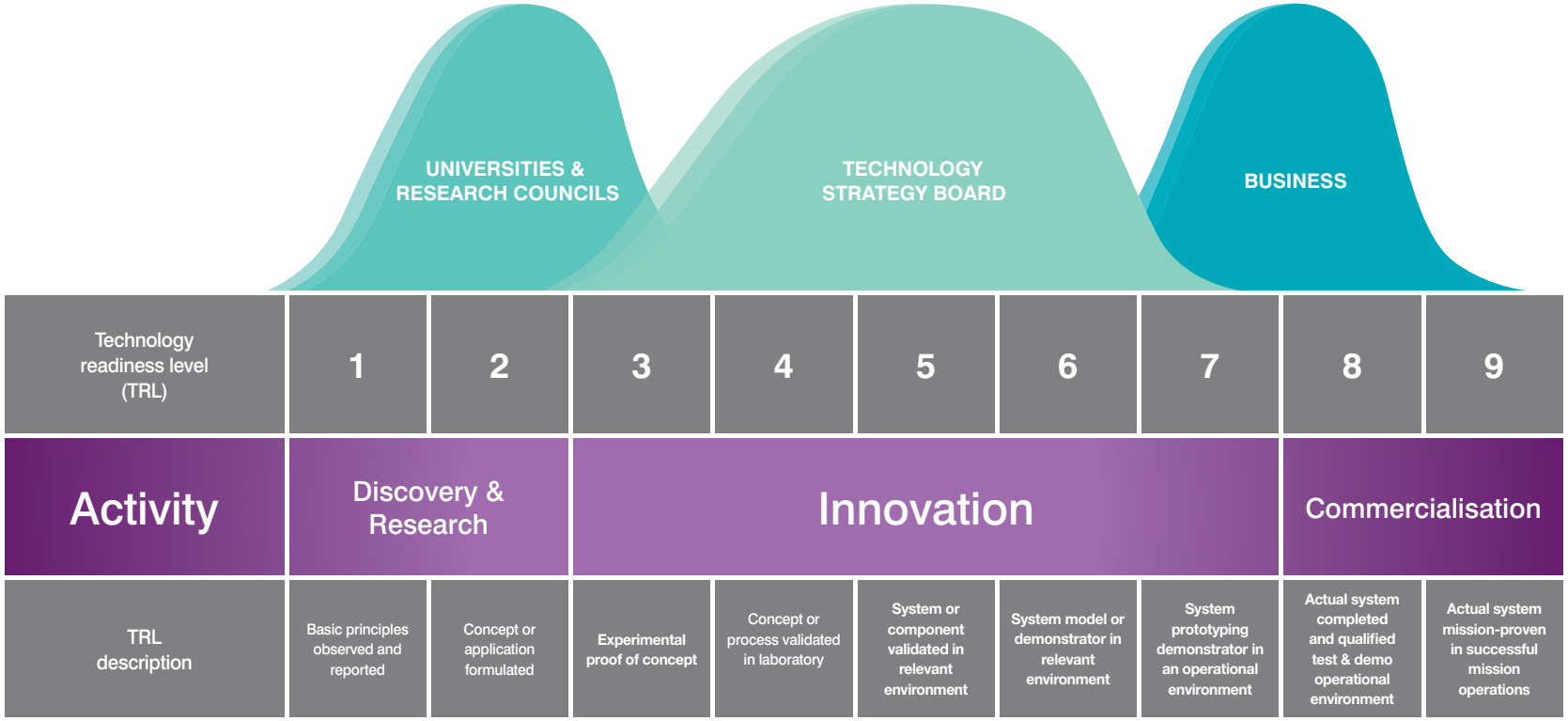
Using the competencies and sector attractiveness gives us two different but complementary perspectives for investment allocation. Technology readiness level is an internationally recognised guideline for describing the maturity stages of innovation activities; this helps ensure that our funding does not significantly overlap with the other main UK funding sources.

Sector attractiveness – defining the industry sectors with the most potential

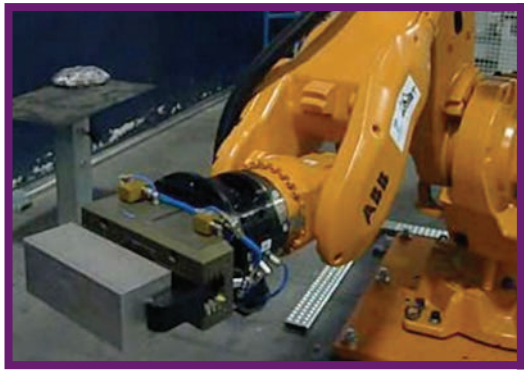


Source ONS[16]

We fund innovation from proof of concept to demonstration



Source: The NASA-developed Technology Readiness Level model[17]



Case study

Pan-European project targeting better 'bots'

The European high-end manufacturing industry demands production systems that can quickly switch between diverse machining operations with short changeover, programming and set-up times, without compromising quality, reliability or life-cycle costs. Industrial robots seem ideally suited but have their limitations – such as the need for absolute positioning accuracy and the lack of reliable programming and simulation tools to ensure right-first-time machining.

The 30-month COMET project, initiated by Delcam plc and funded with €8m in Factories of the Future EU funding, aims to overcome these limitations. So far there are seven COMET robot 'cells' testing the project's innovations across Europe.

OUR STRATEGY continued

Technology Strategy Board investment criteria

In line with the investment criteria set out on page 21 of our corporate strategy *Concept to Commercialisation*[9], assessment of all HVM project funding applications will be made against these criteria:

- **is there a large market opportunity?**
- **does the UK have the capability?**
- **is the idea ready?**
- **can the Technology Strategy Board make a difference (additionality)?**

The Technology Strategy Board will invest in core or platform technologies within the HVM Catapult based on a further set of criteria. These serve to differentiate projects which need the specialised resources of the Catapult. Such proposals will progressively need to demonstrate that their 'capability need' meets the additional HVM criteria outlined below:

1. **State-of-the-art, high-cost capital equipment and related infrastructure not available/accessible to them elsewhere in UK.**
2. **Specialist technical skills and elements of future supply chains associated with the application of this equipment, able to develop innovative manufacturing technologies and capabilities.**
3. **Engagement and application of the above resources for significant and sometimes intense cycles of innovation activity, over an extended period (longer than 18 months, typically more than two-three years).**
4. **Business leadership in the UK with proven ability to deliver an innovative, pre-competitive manufacturing capability or 'technology platform' which is capable of subsequent commercialisation.**
5. **Strategic help to link up a new supply chain with potential impact going well beyond the participating companies.**

Due to the nature of this investment, lead times for establishing new capabilities in the HVM Catapult will generally be measured in years not months. Therefore, assessment of current and new capabilities will be carried out at least once a year against a time window of what is needed approximately three-five years ahead.

Implementation

We expect to invest at least £50m a year to deliver the HVM strategy, with at least £25m allocated to HVM Catapult core funding and around £25m for business investment in process and product-related collaborative R&D projects and other innovation support activities.

Our implementation framework on the right reflects the five main focus areas set out in our corporate strategy *Concept to Commercialisation* to ensure alignment with the overall aims and objectives of the Technology Strategy Board.

1. Accelerating the journey between concept and commercialisation

We will:

- utilise the HVM Catapult to provide the industry with access to world-class assets and talent. This will help de-risk investment in innovation and inspire, train and up-skill staff
- use collaborative R&D to support and de-risk projects, promoting the establishment of new value chains from within the collaborative partner companies, and the development of new business models
- carry out feasibility studies to build the readiness of individual companies and consortia for commercialisation of ideas or further collaborative R&D (including the European Framework programme 7 and Horizon 2020) funding, and to enable us to evaluate new ideas more quickly
- consider Smart (formerly Grant for R&D) to support SMEs
- run grand challenges and demonstrator projects where increased scale and additional collaboration is key
- work to achieve optimal alignment between HVM funding and European programmes (especially Nanotechnology, Materials and Production (NMP), Manufuture, Knowledge-Based Bio-Economy (KBBE), and SusChem).

2. Connecting the innovation landscape

We will:

- continue to work across the Knowledge Transfer Networks, including _connect, to enable businesses to find new partners, sources of expertise and investment
- actively encourage new connections with SMEs in support of potential new supply chains and the restoration of lost UK capabilities
- continue to develop 'joined-up' delivery with the research councils, particularly the Engineering and Physical Sciences Research Council (EPSRC), through its *Manufacturing the Future*[18] strategy, and the Biotechnology and Biological Sciences Research Council (BBSRC)
- forge strong links between the HVM Catapult and the appropriate EPSRC Centres for Innovative Manufacture and BBSRC Institutes, as well as with other university-based centres of excellence, so that, for example, strategic investments in EPSRC Centres and the HVM Catapult will be closely aligned, to ensure a connected innovation journey from TRL 1 to 7
- help UK companies to access European funding (Framework Programme 7 and Horizon 2020) more easily, by signposting them to it through our National Contact Points[19] and the HVM Catapult
- encourage UK companies to leverage competencies in other parts of the EU, the rest of the world and supply chains that link these.

3.Turning government action into business opportunity

We will:

- be proactive in connecting manufacturing businesses with opportunities in government procurement, such as through our innovation platforms or our SBRI programme
- work with business, academia and manufacturing organisations to influence the development of regulation and legislation, in order to incentivise innovation where the UK has the capability to establish leadership.

4. Investing in priority areas based on potential, making choices

As set out in this strategy,

We will:

- invest in projects in those areas showing greatest potential to deliver step-change innovation and high-value, sustainable growth
- invest in the HVM Catapult according to our investment criteria plus specific criteria developed for the Catapult.

5. Continuously improving our capability

We will:

- continue to listen to the voice of industry, academia and other organisations to help us understand the changing landscape in which UK businesses must compete to succeed
- hold 'open review' events on this strategy, inviting stakeholders from all areas of UK manufacturing to help us review progress on implementation and impact. This may lead to changes in the 22 competencies over time
- assess the impact of our investments and use this to tailor future approaches.

References and sources

In developing this strategy we have drawn extensively on the outputs from the research study we commissioned from the Institute for Manufacturing, which closely involved the research councils and Department of Business, Innovation and Skills (BIS). We would like to thank all the companies, academics, industry organisations and individuals who have provided valuable input to this strategy.

Source information

1 United Nations Statistics Division, United Nations National Accounts Main Aggregates Database, Value added by Country, 2010

2 UN Main Aggregates Database as above, UK ranks 9th by Manufacturing GVA

3 UK National Accounts, ONS

4 Engineering Employers Federation, UK Manufacturing 2012, The Facts

5 IMechE Publication 2011: Aero 2075: Flying into a bright future

6 ContractPharma Report 2011, World Top 20 Pharmaceutical Companies

7 SMMT Motor Industry Facts 2012

8 A landscape for the future of high value manufacturing in the UK, Published by Technology Strategy Board – Study conducted by The Institute for Manufacturing, Cambridge University, 2012, www.innovateuk.org under Publications/corporate

9 Concept to Commercialistion, Technology Strategy Board 2011, www.innovateuk.org under Publications/corporate.

10 High value manufacturing is here defined as high and medium-high technology manufacturing as defined by the OECD (SIC codes 20, 21, 25.4, 26, 27, 28, 29, 30.2, 30.3, 30.4, 30.6). Exports of these goods totalled £151bn in 2010 - 66% of total UK manufacturing exports (at £228bn in 2010) and 35% of total UK exports of goods and services (£437bn in 2010). Sources: UK Trade in Goods Analysed in Terms of Industry (ONS) and UK Balance of Payments: The Pink Book 2010 (ONS)

11 High value manufacturing as defined by Technology Strategy Board and Institute for Manufacturing

12 Department of Business, Innovation and Skills, Economics Report 10B (December 2010)

13 Royal Academy of Engineering: Industrial Systems report, 2012

14 Forum for the Future, action for a sustainable world. www.forumforthefuture.org/

15 A landscape for the future of UK manufacturing, further details are given on trends and drivers (pages 13-14), challenges (page 15) and opportunities (page 16)

16 Relative R&D intensity measured by 'Research and Development in UK Business, 2010 – Datasets, R&D intensity in manufactured products, R&D as % sales,' ONS; Relative Industry Sector Growth as measured by 'United Kingdom National Accounts, The Blue Book, 2011 Edition, Section 2.4, Gross value added at basic prices: by industry, Chained volume indices,' ONS

17 NASA Technology Readiness Levels defined at http://esto.nasa.gov/files/TRL_definitions.pdf

18 Manufacturing the future, EPSRC Themes, www.epsrc.ac.uk/ourportfolio/themes/manufacturingthefuture/Pages/default.aspx

19 National Contact Points www.ukcds.org.uk/page-National_Contact_Point-67.html

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The Technology Strategy Board is a business-led executive non-departmental public body, established by the Government. Its role is to promote and support research into, and development and exploitation of, technology and innovation for the benefit of UK business, in order to increase economic growth and improve the quality of life. It is sponsored by the Department for Business, Innovation and Skills (BIS). T: **01793 442700 www.innovateuk.org** T12/065 May 2012