The Royal Academy of Engineering

# Industrial Systems:
## capturing value through manufacturing

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*Professor Steve Garwood FREng*

## Foreword

Does manufacturing matter to the UK in a modern, globalised context? This question was at the core of this study. The answer is a resounding 'yes' but with an interesting new dimension. Modern manufacturing is not so much an industrial sector in itself as an activity that influences and is often an integral part of many industrial sectors and all parts of the economy. And, far from being outdated, the UK's manufacturing base can provide an efficient and flexible foundation on which to build new global industries.

In an increasingly interconnected world, however, the challenge for the UK is to understand, marshal and deploy the assets and capabilities necessary to create and capture value. This report seeks to make a contribution to the promotion of a broader view of the value of manufacturing and the industrial systems in which it operates We hope that this will, in turn, help stimulate new opportunities for capturing economic value.

As part of our project, we undertook an extensive review of the literature with the help of the Institute of Manufacturing in Cambridge, which produced a background analysis to further our understanding. We undertook face-to-face structured interviews with 18 senior business and academic leaders, both to influence the initial scope of the study and inform its final content. To them, to the members of the working group and the Academy's Engineering Policy Committee who gave me an enormous amount of support in the project, I should like to extend the Academy's and my own deep thanks.

Our plan is to use the themes and findings of this report to stimulate discussion and debate in partnership with a range of stakeholders. We would welcome comments and ideas from our readers on how we might take this forward.

Professor Steve Garwood FREng
Chair, Working Group

## Executive summary

There is a growing recognition within government, industry and the media that the UK needs to 'rebalance' its economy, moving the emphasis towards capturing value from wealth-creating products and services and away from 'financial engineering'. The tone and content of recent government policies and announcements explicitly recognises the need for economic recovery based on high-value, high-technology manufacturing. However, capturing value from modern manufacturing not just about capturing the implicit value in making and selling products – it is about capturing value throughout the lifecycle of those products, benefiting many companies and requiring many different kinds of skills throughout the value chain.

Engineers and engineering (including design) are key elements of the manufacturing process. The role of manufacturing in creating value makes the modern manufacturing industrial arena an exciting place to work. Manufacturing is successful where engineering meets, and to some extent blends with, creative and design roles, marketing, finance and services. The skills needed by this type of industrial system, with manufacturing as a key source of wealth creation, naturally evolve as the industrial system develops. It is apparent, however, that advanced manufacturing is a knowledge-based activity, with the balance shifting from manual assembly work to design, organisation and other higher-level skills.

The Academy's deliberations on the subject of manufacturing have led to the view that the distinctions currently drawn between service industries and manufacturing industries are not always helpful. Some have sought to deal with this by thinking in terms of a new emerging 'manu-services' sector, but taking an industrial systems view, the distinctions between the activities are not important – just the way in which value is captured and enabled by manufacturing activity. Dealing with manufacturing as a topic in isolation of the services that support – and are supported by it – does not provide the full picture. Support for manufactured products throughout their useful lives right up to and including their disposal and recycling is as integral to the business of manufacturing as sales strategies and supply chains. The Academy therefore has seen the opportunity to develop a systems-level view of manufacturing and how it can best contribute to the economy of the UK. This industrial systems view provides a common understanding of the systems level interactions around manufacturing and, thus, provides a basis on which to build a policy framework that allows greater capture of value for the UK from production-based economic activity.

There are many and varied arguments about the relative merits of value creation in industry versus wealth manipulation in the finance sector, which emphasise the importance of a manufacturing- and export-led economic recovery. It is important to recognise, however, that the finance sector plays a critical role within the industrial system, providing access to finance and assuming risk.

The industrial system is constantly evolving, as is the way in which it is interpreted. Since the industrial revolution, industry in the UK has been involved in manufacturing goods (and latterly services) with the purpose of capturing value from the work done and the processes involved. This now has a far more international dimension as the free flow of information globally and the ease of doing business internationally mean that questions of how best to create and capture value within the UK economy do not automatically assume production itself should be in the UK.

Today, the system is complex with a large number of actors on a global stage. Those actors interact with each other in complex, interlinked value chains, exchanging data, goods (raw materials, components and products), services and, of course, money.

Historically, manufacturing was frequently a largely integrated process, often on a single site. For example, locomotive and railway carriage construction from the mid-19th century was a highly vertically integrated business with railway companies designing their own rolling stock for their own use. It would not have been uncommon for the locomotive works to have its own coking plant, manufacture its own glue and paint, and have its own sawmill. Effectively, the works were able to accept raw materials at one factory gate and deliver working steam locomotives from the other. While these manufacturers did operate within an industrial system, the concentration of so much activity within single facilities meant that understanding interactions at the system level was less important to success. With this model, it was appropriate for governments to develop manufacturing policies that considered all production to occur in a single homogeneous process.

Manufacturing today is, in some respects, no more complex than the locomotive works of the 19th century. However, the unbundling of supply networks so that tier two manufacturers can supply many tier one manufacturers across several industrial sectors has radically increased the number of actors and interlinked the majority of supply chains across industrial sectors. The assumption that manufacturing policy need only concern itself with what happens between the factory gates or solely within defined industrial sectors no longer holds true.

In conducting this study, the Academy has sought to understand and explain the modern industrial system. In order that policies can be developed and implemented that can make a real difference and provide the UK with a competitive edge, government, industry and economists must be able to engage with a common language and common understanding of the system. This common understanding of how the modern industrial system differs from classical manufacturing provides the potential to develop new policy tools and approaches.

### The future

It is clear that production is a strategic part of the value chain. As the industrial system evolves, so the drivers for capturing value change as well. Already, the manufactured product itself has become an enabler to capturing value rather than the creator of value itself. Business models that create markets for other services to support particular products are becoming more common and, in some cases, significantly more value can be captured from the sale of related services than the product itself. Sony's strategy of selling PS3 console gaming machines to consumers at close to or below cost brought Sony's Blu-Ray technology into millions of homes which then became a *de facto* high-definition DVD standard ahead of any rivals. This enabled the capture of significant value through Sony's studio and media businesses.

Social, as well as technical, trends are becoming more dominant in driving innovative products and services. The opportunities for value capture will evolve as the ways in which the consumer uses products and services change. Some trends will be well signposted. Others, as proved to be the case in the explosion of the use of SMS for texting between mobile phones, may not be. Understanding these future trends will be as important to the future of manufacturing as advances in technology.

## The study

The study was conducted by a working group under the chairmanship of Professor Steve Garwood FREng, a member of The academy's Engineering Policy Committee.

To scope the study, the working group held a number of roundtable discussions with senior executives from a wide range of companies. The views expressed at those discussions strongly influenced the initial scope of the study. Key conferences, meetings, lectures and published documents, particularly in the fields of industrial systems and value creation and capture were reviewed. The working group is grateful for the support of the Institute for Manufacturing at the University of Cambridge who, under the guidance of Professor Sir Mike Gregory CBE FREng, provided the academic research and groundwork for the report.

A series of structured interviews were undertaken with leading industrialist to gather expert opinion on and understanding of industrial systems. The views expressed in these interviews are captured in the commentary of Chapter Two as well as informing the main body of the study. This material is supplemented by a number of case studies into particular aspects of businesses which further illustrate the thinking of the study working group.

## Conclusions

In conducting the study, the Academy sought evidence from a wide variety of sources through an academic study, literature searches, discussion events, interviews and case studies. A number of themes became apparent on examination of this wealth of information.

- *The UK exists within a highly complex, global industrial system:*

  There are no national boundaries to business today. Decisions on where and how to do business are taken on a number of bases including, cost of a particular activity in a particular area, stability and robustness of legal and policy frameworks. Value chains cross borders in such a way that the value of any industrial activity can be captured locally or elsewhere.

- *Production is important to the UK for its role in international competitiveness:*

  Production leads to enhanced research and design capacity and enables commercialisation, infrastructure for other businesses, protection of intellectual property, and innovation. Co-location of these activities is often beneficial and, if the environment is right, the presence of one in a particular location can attract the other activities.

- *The skills base is critical to the sustainability of a location-specific and/or niche-based industrial system:*

  Some localities have a tradition of particular skills or crafts. This, in itself, can be attractive to businesses in need of those skills. The emergence of clusters both naturally and under certain RDAs capitalised on this effect and sought to provide a pool of skills in a particular geographical location as well as facilitate the establishment of new companies in the area.

- *The government should monitor the socioeconomic system and engage in areas where markets are not functioning in the best interests of the wider UK economy:*

  It is clear that an open market serves the UK well. However, there are a number of strategic reasons why the government might intervene in the

market, including: to protect a strategic skills base in the UK; to preserve a local community; or to ensure availability of key strategic materials or products to UK based businesses.

- *The government needs to identify key strategic policy areas, such as education, research, health, energy, transportation, defence and communications, and maintain a long-term, evidence based, approach to support these important system components:*

  Certain activities in the UK provide the key infrastructure and certainty on which industrial systems can build. The provision of the right underpinning policies and economic infrastructure is a key enabler for the generation and capture of value through manufacturing in the UK.

- *The UK academic network is a global player and is, in itself, a system on the same scale as the industrial system. More mechanisms need to be developed to maximise the leverage that UK manufacturing can derive from this strength and facilitate the interactions between industry and academia:*

  Further development of the Advanced Manufacturing Centres and a coordinated national skills agenda for engineering and manufacturing apprentices and graduates could help promote such interaction. The establishment of Catapult Centres provides a new opportunity to promote industry academia interaction in pre-commercial R&D.

*"There are only three ways to create wealth – you can dig it up, grow it or convert something in order to add value. Anything else is just moving it about."*

**Sir John Rose, in an address to the Royal Society for the Encouragement of Arts, Manufactures and Commerce, November 2009**

## 1 Industrial systems: an overview

An industrial system includes the context, resources, activities, processes, actors, and interdependencies that support the creation and delivery of products and services. A clearer understanding of industrial systems – a holistic view – can identify those 'levers' which are available to generate and, crucially, capture value.

A century ago, an industrial system would have been simple. In businesses of many kinds, raw materials went in at one end of a factory and finished goods – ships, clothes or food products, – came out of the other end.

Many of today's companies operate quite differently. Their alliances and relationships are fluid and forever changing; their supply chains and customer bases may be global. The linear view of innovation and product development is now mostly seen as too simplistic; the different activities of research, design, production and lifecycle service can operate together as an integrated operation, or separately, unconstrained by either geography or history.

Systems thinking has become the norm within industry when considering supply and distribution chains or networks. Modern manufacturers are able to identify and protect critical areas of the networks they operate within. They are also able to take a sophisticated view of value where the benefit the company can derive from manufacturing a product is measured in strategic terms rather than simple cash value.

The same techniques that companies use to determine the strategic importance of production to their organisations can be used by government to understand the strategic importance of activities within the UK economy, and values other than cash can be used in evaluating them.

Policies directed at point interventions in single sectors or processes can sometimes have limited effect or have unintended consequences elsewhere in the system.

Historically, it was convenient to think of the manufacturing and service sectors as being entirely separate in their operation within the economy. Again, this is no longer the case. In our view, such distinctions between sectors are becoming less useful in a system where large retailers are able to capture value from manufacturing processes just as well as any traditional manufacturing business.

*"The UK is best served by a diverse economy, manufacturing, financial, retail, etc. Increasingly manufacturing is global."*

**Brian Cantor, York University**

In the complex, globalised world of modern manufacturing, companies are finding new ways to capture value. Much value (and employment) is now enabled by the production process rather than coming from production itself. Throughout the lifecycle of a product, opportunities for creating value are increasingly being taken by manufacturers rather than allowing other organisations to capitalise, so production can become a strategic activity within businesses rather than an end in itself. An example of this type of operation can be seen in Rolls-Royce's aero gas turbine business, where an engine service package is provided to an airline to support its aircraft. The airline simply pays for the number of hours it flies.

Decisions on what to produce or buy therefore become strategic decisions for manufacturing businesses and the drivers are less likely to be directly linked to the cost effectiveness of in-house or out-sourcing production. Protection of intellectual property, process know-how, and supply-line security, for example, can have more importance than the economics of production itself. This points to the importance of measures of value other than hard cash.

In an article for the *Financial Times*[1] in January 2011, Pascal Lamy, Director-General of the World Trade Organisation, talked of how the globalisation of manufacturing has led to simple measures of GDP being meaningless when examining the value that a country derives from manufacturing. He argues that the concept of finished goods having a country of origin is no longer helpful because of the international and highly interlinked supply chains with value no longer necessarily accruing to those countries producing the goods in the same way as used to, but to those holding the intellectual property. He takes as his example, the Apple iPhone: "According to a recent Asian Development Bank Institute study, the phone contributed $1.9bn to the US trade deficit with China, using the traditional country of origin concept. But if China's iPhone exports to the US were measured in value added – meaning the value added by China to the components – those exports would come to only $73.5m."

It is clear that the role of people and their interrelationships within complex industrial systems is vital.

The critical links between the education system, the availability of skills within the economy and ability of the industrial system to create and capture value mean that strategic decisions within the education sector can have wide-ranging implications of the industrial system.

At its simplest level, there are already efforts to predict and supply certain skills to the workforce and industry by providing capacity through education and training provision ahead of industrial requirements. This has recently been seen in the re-establishment of nuclear engineering courses at a number of Higher Education institutions in the UK.

The link between the needs of the industrial system and people brings a further link to 'place' and community. There have been many well documented cases of companies moving to, or being established, in particular locations in order to access particular skills. For example, Rolls-Royce went to Derby early in the 20th century originally to access the skilled coachbuilders employed by the then dominant railway industry there (further incentivised at the time by Derby Council).

***"The UK population needs to engage in manufacturing for emotional, psychological and sociological reasons in addition to purely financial reasons."***

**Dame Sue Ion FREng, consultant.**

A recent parallel would be the establishment of Advanced Manufacturing Research Centre in Sheffield filling the void left by the coal and steel industries and building on the local clusters of skills and established knowledge from previous businesses.

A symbiotic relationship between community and company can grow to such a significant extent that it must be taken into account in company strategy and this is most evident where a company (such as BAE Systems in Barrow, described in the case study in Annex 2) is the dominant employer in an area. It can also happen as natural clusters spring up, such as the concentration of companies associated with motor racing around the Silverstone circuit in Northamptonshire.

*"The UK cannot compete with China, India and Eastern Europe in low cost manufacturing. There is a need for the UK to be niche and high-end; based on innovation and research."*

**Alan Cumming, EDF.**

### 1.1 Key themes

As outlined in the section on the study (page 6), the Academy sought evidence from a wide variety of sources through literature searches, research papers, discussion events, interviews and case studies. A number of themes became apparent on examination of this wealth of information. We took as our main themes and points for further investigation the following:

1. **The UK's businesses exists within a highly complex, global industrial system**

   There are no national boundaries to business today. Decisions on where and how to do business are taken on a number of bases including cost of a particular activity in a particular area and economic stability and robustness of legal and policy frameworks. Value chains cross borders in such a way that the value of any industrial activity can be captured locally or elsewhere.

*The engine room of an economy is production."*

**Adrian Bull, Westinghouse.**

*"The UK has an industrial nation perspective but the industrial base for mass employment has disappeared. The industrial make-up is now focused on design and innovation; being at the leading edge drives wealth creation."*

**Geoff Robins, Atkins.**

2. **Production is important to the UK for its role in international competitiveness**

   Production enhances research and design and enables commercialisation, infrastructure for other businesses, protection of intellectual property, and innovation. Co-location of these activities is often beneficial and, if the environment is right, the presence of one in a particular location can attract the other activities, making the system more robust and sustainable.

   The future will require the early recognition of new opportunities for complex packages of manufacturing and service provided by integrated and flexible industrial systems. Increasingly, these opportunities are going to be driven by social as well as technical trends.

*"For wealth creation the UK must develop indigenous skills that are aligned to a strong industrial sector."*

**Geoff Robins, Atkins.**

3. **The skills base is critical, both on a national level and for the sustainability of a location-specific and/or highly specialised industrial system**

   There is a widespread concern to nurture, retain and develop the UK's skills base to meet the needs of industry. There is also a responsibility to ensure that the next generation has the right perception of manufacturing, its value, and the attractiveness of working in the modern industrial environment.

   Some localities have a tradition of particular skills or crafts. This, in itself, can be attractive to businesses in need of those skills.

*"Large companies are … reducing apprentice numbers so a national approach is needed to maintain skills as this will be a time bomb [set to go off] in 10 years' time."*

**Frank Hayden, Rolls-Royce.**

4. **Government should monitor the socioeconomic system and engage in areas where markets are not functioning in the best interests of the wider UK economy**

   It is clear that an open market serves the UK well. However, there are a number of strategic reasons why the government might intervene in the market, including: to protect a strategic skills base in the UK; to preserve a local community; or to ensure availability of key strategic materials or products to UK-based businesses.

   The government needs to identify key strategic policy areas, such as:

   - education
   - research
   - health
   - energy

*Training and developing graduates takes five years or more, therefore we need to ensure education and research investment is maintained in all states of the economy and intervention can be useful in this regard."*

**Frank Hayden, Rolls-Royce.**

- transportation
- defence and
- communications.

It also needs to maintain a long-term, evidence-based, approach to support these important system components.

Certain activities in the UK provide the key infrastructure and certainty on which industrial systems can build. The provision of the right underpinning policies and economic infrastructure is a key enabler for the generation and capture of value through manufacturing in the UK.

**5. The UK academic research network is a global player and is, in itself a system on the same scale as the industrial system**

More mechanisms need to be developed to maximise the leverage that UK manufacturing can derive from this strength and facilitate the interactions between industry and academia.

Further development of the Advanced Manufacturing Research Centres, Catapult Centres and a coordinated National Skills agenda for Engineering and Manufacturing apprentices and graduates could help promote such interaction. The establishment of Technology Innovation Centres, now Catapult Centres, provides a new opportunity to promote industry academia interaction in pre-commercial R&D.

*"The UK is good for start-up companies but the complex legislation around employee share ownership is a real challenge,"*

**Alan Hoy, Risktec.**

## 2 The views of industrial leaders and influencers

Drawing on the key themes, the working group set out eight key questions that were put to a number of leading industrialists, academics and policymakers both in face-to-face meetings and remotely. In this commentary, the main themes from the individuals' responses are extracted and grouped according to the eight questions used in the structured interviews.

### 1. What are your reasons for investing in the UK?

The study team was told by many of those interviewed that an open market approach has served the UK well. However, in certain circumstances, there are strategic reasons why the government might wish to influence the market. These reasons include;

- to protect a strategic skills base in the UK
- to preserve a local community
- to ensure the availability of key strategic materials or products to UK based businesses
- to serve national security.

The diverse pool of knowledge and skills is seen as the UK's prime source of competitive advantage for retaining its position as a significant player in global manufacturing.

Although many industrialists would welcome a 'level playing field' approach between the UK and global markets in their arena, the key requirement is stability and consistency of government policy.

Some interviewees stressed the importance of a high level of international engagement, in part a result of the English language, as being one of the key discriminators for the UK in the global marketplace.

### 2. What do you understand by an industrial system?

*"An integrated network of people/parts create an end product."*

**Steve Yianni, Network Rail.**

*"Bounded by input at one end and output at the other."*

**Geoff Robins, Atkins.**

*"All the processes which surround the design and life cycle of a manufactured product."*

**Chris Kirby, Magnotronics.**

*"An integrated set of local companies and the wider system of competitors and suppliers of goods and services."*

**John Parnaby, BPSE.**

Among the industrialists interviewed, some were very familiar with the concept of the industrial system; others had a general understanding but did not use the concept regularly within their business; and some had a very restricted perception limited by their position in the supply chain.

A strong theme was that industrial systems do not recognise national boundaries. Systems will extend across many jurisdictions and the location of particular elements is always subject to change. Companies operating globally are not necessarily focused on enhancing their position in the UK – they are interested in their total business position on the international stage.

Creating and sustaining a vibrant and competitive industrial system is a classically wicked problem in that intervention can change the nature of the problem being tackled. Policies and policy levers need to adapt to changing situations and this is to be expected as long as the general direction of policy is maintained.

Some felt that the complex and dynamic nature of industrial systems means that it is impossible to influence the system in any conventional sense. Policymakers are not the only decision makers and their role should reflect the need to coordinate and mediate between other stakeholders' demands and needs.

*"Industrial systems cover everything from design capability through supply management, sales, production, and services with feedback on the products back to design and production. It requires continuous improvement feedback to have a successful industrial system."*

**Dr Regis Matzie, consultant to the nuclear industry.**

*"A system of systems thinking must now be applied to industrial systems."*

**Geoff Robins, Atkins.**

There was a sense of the critical role finance can play within the industrial system providing access to finance and assuming risk. The relationship between the financial services industry and 'productive' industry needs to be understood.

### 3. Is production important in the United Kingdom?

Production is at the heart of all industrial systems and the sheer range of what it supports and influences underlines its importance. Production activities are seen as key to not only capturing value directly, but also for enabling the capture of value elsewhere in the product lifecycle.

Manufacturing is not a sector on its own. It is linked to all other aspects of the economy involving finance, design, marketing and services, and needs to be seen as a central component of the larger industrial system.

Controlling production enables a company operating in the industrial system to create a barrier to entry for competitors providing competitive advantage. High value-added production is recognised as particularly important to the UK industrial environment.

The adoption of advanced manufacturing developments in production means that further investment in UK manufacturing is no longer a provider of mass employment. However, via its crucial role in the industrial system, investment in manufacturing will result in significant job creation for the UK (in such areas as R&D, design, marketing, service and support).

Even where financial value is not the main driver to keep production in the UK, the skills base and quality processes are significant reasons for companies to manufacture in the UK.

### 4. What are the sources of value in industrial business?

Financial performance was the strongest measure of value. However, wider concepts of value appear to be well-recognised in business. These include: skills, reputation, capabilities, social value and environmental quality.

Another message was that manufacturing in the UK, as opposed to outsourcing, protects the value of intellectual property in both design and manufacturing know-how.

In many cases, manufacturing adds value in the industrial system because it enables the creation of value in other parts of the system.

Advanced manufacturing processes are seen to add significant value and are generally protected by the organisation whereas 'build to print' activities can be outsourced, often offshore with little or no penalty.

Overall, the UK economy does not capture as much value as it should from the innovation developed from research. There should be a more strategic link through the advancing technology readiness levels to maximise value development throughout the product lifecycle.

*"In the UK, we have to capture value by exploiting our strengths such as our highly educated population."*

**Neil Burns, Loughborough University.**

### 5. How can value be captured from an industrial system?

Capturing and retaining innovation and developing a highly qualified skills base are ways of increasing the value of production. In many industries, manufacturing enables value creation in other parts of the product lifecycle such as services and support.

In the UK, the indigenous skills base is a key enabler in the creation of value. This base crosses many industrial sectors. A systems approach to skills policy decisions is therefore essential.

The government should use the mechanisms at its disposal (such as regulation) to capture the maximum value for the UK from private and public investment.

*"If an open competitive global market is available, it shouldn't matter to the UK if it imports: it encourages UK manufacturers to be globally competitive and it enables us to secure products at the most competitive price from a secure international supply chain."*

**David Boath, AMEC.**

### 6. Does production in the UK provide an advantage for competing in global markets?

The study team was told that production enhances research and design development and that co-location of these activities is beneficial.

Whether the location of production in the UK is important depends on how manufacturing connects with the larger industrial system. Sometimes it is essential (such as with IPR connectivity), but in other cases the logical decision is to outsource to other markets.

Competitive advantage can be derived from factors such as: providing the local capability to exploit the UK expertise in research/knowledge base; enabling a design-make function to keep the local skills base competitive and developing a source of innovation to influence future products.

*"It is the responsibility of government to provide a stable and supportive environment for the industrial systems to fully develop and for new industries to emerge."*

**Neil Burns, Loughborough University.**

### 7. Should the UK government intervene in industrial policy?

Although the industrialists to whom the study team spoke called for a 'level playing field' with international competition, most identified that a consistent long term approach from government as the most important policy factor.

While there is an appreciation of the hands-off, open market approach to business in the UK, most of those interviewed recognised instances where it was expected that the government would intervene both to protect 'crown jewels' and parts of the industrial or wider systems that are critical to the capturing of value elsewhere. How to determine what the UK crown jewels are therefore becomes essential – a better approach is needed and the process needs to be transparent.

It is not always apparent that the setting of a target will lead to a stable regulatory environment for business. A policy built around the desire to increase manufacturing output which does not link closely with other policy areas is likely to be hampered by unforeseen effects within the overall system. At the very least, a policy for industrial systems needs to encompass the availability of energy to industry, the provision of skills, enabling regulation and state of markets. At a more detailed level, it is possible for wider policy objectives to be antagonistic towards one another.

*"Doing nothing shouldn't be an option; there should be a focus on winners with objective criteria for selecting them."*

**Frank Hayden, Rolls-Royce.**

In recent times, governments have emphasised that they are not in the business of 'picking winners'. A policy of not picking winners needs to be recognised and its impact worked through as part of a long-term approach to policy. However, choosing to identify a focus on critical areas of technology where the UK has an advantage is an appropriate strategy for a systems approach: in particular leading to a focus on companies with high growth potential with innovative

*"It is the responsibility of government to provide a stable and supportive environment for the industrial systems to fully develop and for new industries to emerge. It can do this by encouraging education, improving the infrastructure and tax and financial benefits. The government has not got a good history for picking winners and the level of knowledge in government about modern methods and products is not great so I do not think, even with expert advice, the government should attempt to pick winners."*

**Neil Burns, Loughborough University.**

*"Universities alone cannot breathe new life into UK engineering. A focused advanced manufacturing research centre approach works better for manufacturing development."*

**Frank Hayden, Rolls-Royce.**

*"The academic research base in the UK is strong, but less linked to industrial needs than in other countries. Consequently this is currently a minor factor in the decision to locate in the UK, but is an area that is being actively addressed by AREVA with such initiatives as the Nuclear Advanced Manufacturing Research Centre."*

**Robert Davies, Areva.**

technologies. This approach is emerging through such initiatives as Advanced Manufacturing Research Centres and Catapults.

A closer working relationship between government and companies with well-developed strategic approaches would enhance the understanding and influence of the industrial system on the UK economy and benefit policy making in these areas.

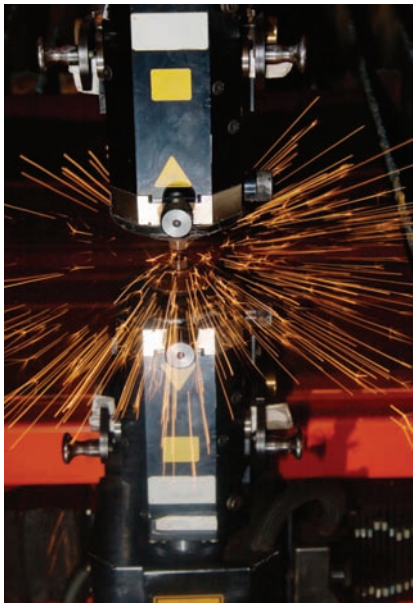
**8. What is the importance of the UK research and academic infrastructure?**

The UK academic network is a global player and is, in itself, a system with some of the same qualities and drivers as an industrial system.

Although linkages exist between industrialists and academics, more mechanisms of using the strength and global impact of the UK academic sector need to be developed to enhance UK manufacturing. Examples cited were the further development of Advanced Manufacturing Research Centres and the introduction of The Royal Academy of Engineering Visiting Professorships.

Further development of the Advanced Manufacturing Research Centres and a coordinated national skills agenda for engineering and manufacturing apprentices and graduates could help promote such interaction. The establishment of Catapults provides a new opportunity to promote the interaction of industry and academia in pre-commercial R&D.

The UK influence on global skills via the academic sector is vital, but there is also a responsibility to understand and meet the needs of national industries and to ensure that the next generation has the right perception of manufacturing, its value and the attractiveness of working in the modern Industrial environment.



## 3 The policy context

In the wake of the financial tumult across the world, vibrant manufacturing industries are increasingly seen as essential for advanced as well as emerging economies. They provide the means of capturing value from ideas, goods and services and a critical route to participating in the global economy.

This renewed focus on the importance of industry – and more specifically manufacturing – is echoed across the world. Closest to home, and including some of the most comparable economies, a 2010 EU report[2] placed industry at the heart of its vision for 2020. In the United States, there is evidently a strong emphasis on the importance of manufacturing, while in China, despite some internal concerns that there is an excess of manufacturing in the economy, industrial production continues to grow apace.

Over recent years, the structure and dynamics of industry have changed in response to improvements in communications, transport, and the international diffusion of skills and capabilities. Early movements of production were stimulated by the relatively high cost of labour in industrialised countries. Japan led the way in developing sophisticated production capabilities on the back of an early low-cost labour advantage. This, in turn, led to increasing design capability and eventually to leading international positions in, for example, the automotive and electronics sectors. Korea followed a similar path, and Chinese and Indian growth shows many of these characteristics.

In the UK, increasing awareness of the importance of manufacturing – even before the recent financial crisis – was reflected in the publication of a series of national manufacturing strategies. A series of government policy statements in 2009/10 set out clear priorities for government support to manufacturing and led to substantial investments in advanced manufacturing, including high-potential technologies.

The UK government has highlighted the importance of manufacturing in rebalancing the economy. Developments during the life of the current government include a 'Growth' White Paper[3], a *Growth Review framework for Advanced Manufacturing*[4] publication and the announcement of £200 million for Catapults designed to bridge gaps between science, technology, and industry and accelerate the commercial exploitation of new ideas.

The *Strategy for Sustainable Growth*[5], published in July 2010, recognised that sustainable growth in the UK economy needs to come from private investment in the UK's productive capacity. This signalled the current government's intention to encourage the creation and capture of value through production and a wish to see a framework that allows the balance of payments deficit to be reduced through the export of goods. The Growth Review Framework for Advanced Manufacturing reinforced this approach and indicates how the government expects manufacturing businesses to improve the capture of value from production.

Among the most significant trends are the increasing pressures to create environmentally sustainable industrial systems. As well as the need to mitigate climate change, there is a growing awareness of the need to reduce the environmental damage caused by human activity, including industrial activity. This, along with increasing scarcity of some critical materials, is likely to require moves towards more sustainable design of products, recycling and reuse of materials, growth of local production capability, significant improvements in the energy efficiency of production systems and a focus on services associated with

products. In this view of the 'industrial system', manufacturing is increasingly not an industrial sector in its own right, but a process within the system which allows wider opportunities for the creation and capture of value in economic, strategic and social terms.

There has been a tendency in analysing the manufacturing and process industries to make a distinction between 'manufacturing' and 'services'. In a systems-driven analysis, this is not helpful to understanding the dynamics and opportunities for value creation and capture. Dealing with manufacturing as a topic in isolation of the services that support and are supported by it does not provide the full picture. Support for manufactured products throughout their useful lives and their disposal and recycling is as integral to the business of manufacturing as sales strategies and supply chains.

Recently, there has been more discussion in the UK about proactive industrial policy. It has also been noted that many countries already adopt industrial policies designed to improve national competitiveness. France, for example, has assembled world-class aerospace capability through systematic government intervention. The US pursues active programmes of industrial development such as DARPA and the Small Business Innovation Research programme through the defence and health budgets.

Other national level initiatives over recent years have had direct impact on manufacturing including the establishment of the Technology Strategy Board (TSB) and the Engineering and Physical Science Research Council's (EPSRC) network of Innovative Manufacturing Research Centres. The TSB's *High Value Manufacturing report*[6] and subsequent programmes reflect renewed appreciation of the importance of manufacturing. The EPSRC, meanwhile, has extended its network of Advanced Manufacturing Research Centres and has highlighted manufacturing as one of its key priorities in its forward plan.

## Annex 1 Industrial systems: a deeper dive

This section pulls together some of the further material that can form the basis of discussion on the modern industrial system and value chain.

### An industrial systems approach

An industrial systems approach highlights the connectedness of the key elements that go to make up an industry. It is important to differentiate between relatively 'established' industries and 'emergent' industries. In the first case, the basis of competition may be broadly understood and the emphasis might be on efficiency and cost reduction. In emerging industries, the emphasis might be on innovation, rapid scale-up, and the creation of supply networks.

Large companies operating within global industrial systems generally have quite complex and sophisticated strategy systems that involve activities such as:

- strength, weakness, opportunity and threats (SWOT) analyses
- technology 'road mapping' with lead-lag analyses against the market to identify where 'fast following' is an economically sound position
- structured processes for R&D investment linked to product technology readiness levels which in turn relate to manufacturing readiness levels where development funds are employed to de-risk production and raise skill levels.

In particular 'make-buy' strategies are continually being developed to maximise the effectiveness of the product lifecycle and protect the 'long-term' key discriminators for the company, often termed 'crown jewels'. A simple Boston matrix approach which could be employed for the UK is shown in Figure 1.

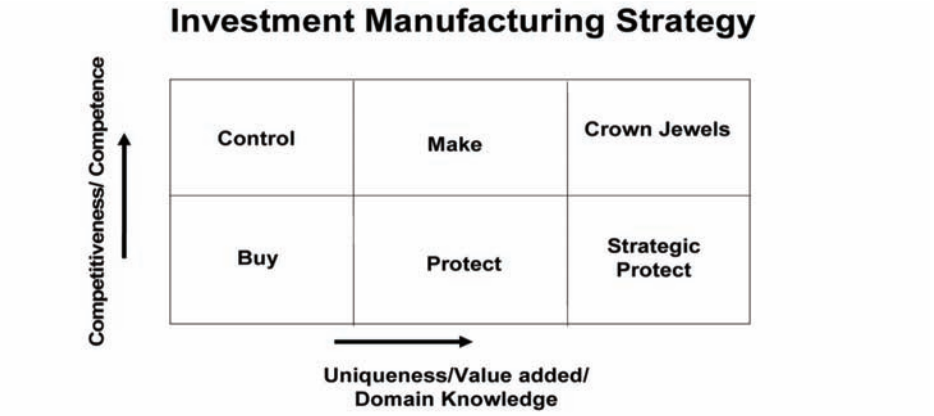



**Figure 1: Simplified Boston matrix**

A generalised view of an industrial system has a range of actors involved and a large number of potential interactions between them. One of the limitations with systems approaches is that they make it difficult to illustrate definitive solutions or to assess the potential implications of change, such as new functions or players entering the system. Each actor in the system needs to have an understanding of the immediate environment. Figure 2 shows how a company might envisage its immediate surroundings within the system and it could be perfectly adequate to operate at a certain level.

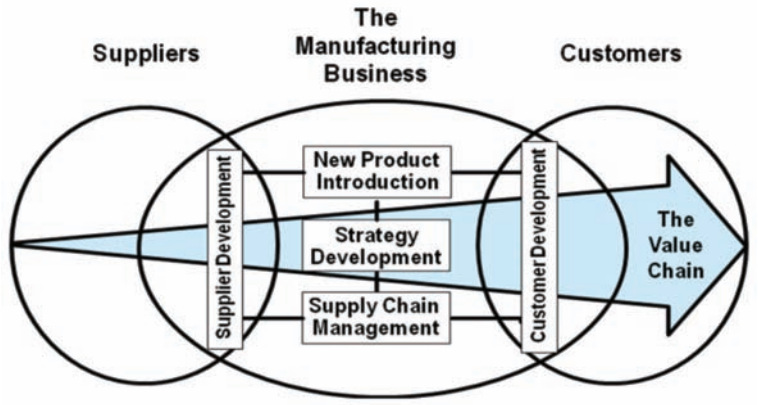



**Figure 2 A company level system**

Figure 3 highlights the range of other factors relevant to the operating environment of the firm showing the range of the agents, enablers and processes influencing the behaviour and performance of the firm. Environment and economy are particularly important, reflecting the increasing importance of environmental concerns and the increasing strength of global competition which requires much more sophisticated evaluation of economic contexts and opportunities.

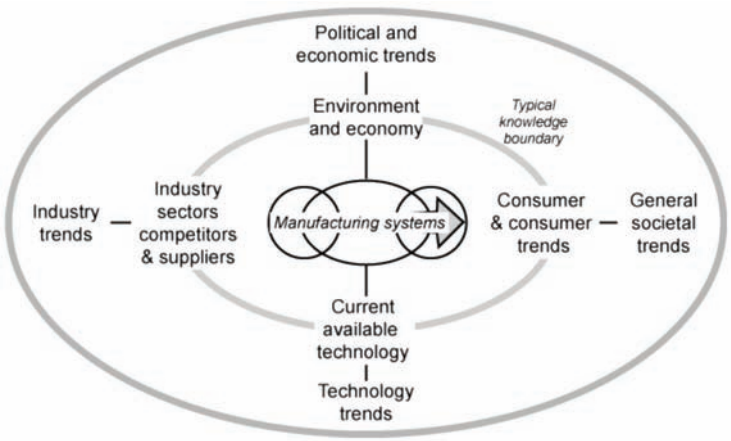



**Figure 3 A business context.**

The range of responses from the structured interviews in the study showed differing horizons, with some interviewees having a systems-wide appreciation of the landscape around them and others being concerned with only a few layers of the network around them. The results of the interviews showed that successful, multinational companies had the widest systems view and deployed it as part of their strategy for sucess.

These representations point to another feature of industrial systems – that many, if not all, of the actors in a particular system will also be members of other systems. Customers and suppliers, regulators, standards organisations, investors, sources of technology and other resources are likely to be integrated within numerous other systems. Competitors too, particularly larger ones, are likely to engage in multiple, interdependent, industrial systems. Each of the actors therefore has their own set of expertise and connections beyond those engaged with any particular firm or industrial system and of course their behaviour in each of the systems with which they are engaged may influence the dynamics of the other. It is perfectly possible and normal for individual actors to operate successfully within the system, within their own 'knowledge boundary', but the wider the 'knowledge boundary' the better equipped individuals are to take strategic decisions and capitalise on opportunity.

The industrial systems approach allows a wider approach, extending beyond particular companies and industries to identify and share 'high performance' system elements including, for example, system integration, network design and operation and skilled and flexible staff. Industrial systems are global, with different aspects of the system often being located in different countries. Nevertheless, businesses tend to operate within recognised sectors. Understanding how an industrial systems representation is reflected in key companies in major sectors allows connections to be made from one sector to another that may not be immediately obvious.

### Skills base

Maintaining and enhancing the skills base is critical for the UK to maintain its prominence within this global industrial system. Our discussion with business leaders found that UK labour skills in companies and research capabilities in UK universities evoke pride but also anxiety about maintaining both in the future. Many people interviewed cited labour and research skills as the most significant sources of value for the UK in the global industrial system.

There was also a consensus that general labour and research skills and capabilities need to be maintained for manufacturing in general as well as specific labour and research skills to support specific national priorities. The required skills are in production operations as well as those skills needed for the UK to play a role in the emergence of new industries such as nanotechnology and regenerative medicine. Examples of these types of skills are product and process design, systems integration and business modelling.

The skills base is also critical to the sustainability of a location-specific and/or niche-based industrial system. Some localities have a tradition of particular skills or crafts. The formation of clusters around centres of both research and production was viewed positively in this context.

### Role of government

The governments should identify key strategic policy areas, such as education, research, health, energy, transport, defence and communications, and maintain a long-term approach considering the essential context which these activities provide for industrial systems.

Governments use a range of mechanisms to influence the direction and pace of industry growth, and they tend to use them at different times for different effects. These mechanisms can include:

- macroeconomic policies
- education and skills development
- regulation and standards
- grants, subsidies, and procurement
- intellectual property protection
- investment incentives
- employment incentives.

In the period before a new industrial system is evident, and in the early stages of its existence, government's role is most likely to involve support for basic research with limited emphasis on seeding particular new industries. General areas of research are supported with the focus on ways in which to address technical challenges or the need to expand the application of existing technologies. Support is often provided as grants, subsidies, and procurement contracts but also in the form of intellectual property protection. The government may continue these roles as an industry evolves but interventions may be more targeted at both product and process

improvements and their roles in the establishment of regulations and the setting of standards are likely to become more prevalent as the risks and opportunities of industries are better understood and as competition increases.

Government plays many roles in an industrial system, from investor and customer to service provider and regulator. Governments may invest in research and early-stage firms as well as struggling late-stage firms to encourage the emergence and preservation of industries. These roles are often justified as necessary to address market failures such as inadequate investment due to high risk.

While the risks of governments 'picking winners' are clear, there can be little doubt that policymakers need a clear understanding of those industrial domains in which they might seek to participate. Launch aid for new aircraft, for example, is a widely understood form of intervention, but in complex emerging industries, decisions and priorities may be much less clear. It is in such circumstances that an industrial systems approach, accompanied by detailed mapping, that information for policymakers might be greatly improved, while recognising that the system components are in a constant state of change.

Although few would now suggest that governments should make local commercial decisions, it is now widely accepted that there are some activities within industrial systems where public involvement is appropriate – and, indeed necessary.

### The value chain

Industrialists are naturally aware of the need to create and capture value; typically recognised through business growth and profitability. A broader and more formal understanding of value systems might however:

- encourage critical review of the value of key skills, assets, and activities
- highlight the collaborative and competitive impacts of partnerships
- identify strategic and social as well as financial value as a basis for growth.

From an industrial, as distinct from an economic perspective, value creation and capture can be considered at several levels – operations, systems, and networks. Value can be created and captured at each of these levels.

The debate about the role and value of production continues to engage economists, managers and technologists. In practice, of course, the role of production depends crucially upon the circumstances of different industries, and indeed individual countries. The debate, therefore, should not be an abstract one about whether production 'matters' or not but rather about the ways in which production can generate value. In high volume, labour intensive garment production, for example, it might be very unlikely that production in high wage countries would be appropriate. In biotechnology, however, which depends upon complex, science based production, advanced economies might be extremely well placed to execute the production activity – and indeed to capture financial, strategic, and social value by so doing.

The creation and capture of value is the purpose of most industrial sectors and manufacturing is no different. A simple representation of the process of value creation is the 'value chain' as in Figure 4.


**Figure 4– Simple, linear industrial value chain.**

Of course, value systems are not linear. They typically involve many complex interactions. Nevertheless, Figure 4 does highlight the main activities that are necessary to convert ideas and opportunities into products and services.

An illustrative example of a product life cycle as used by Rolls-Royce for its gas turbine (see case study in Annex 2) is shown in Figure 5. The timescales given are indicative of the life cycle of a commercial aero engine and different products, such as consumer electronics, will have significantly different timescales associated with them.

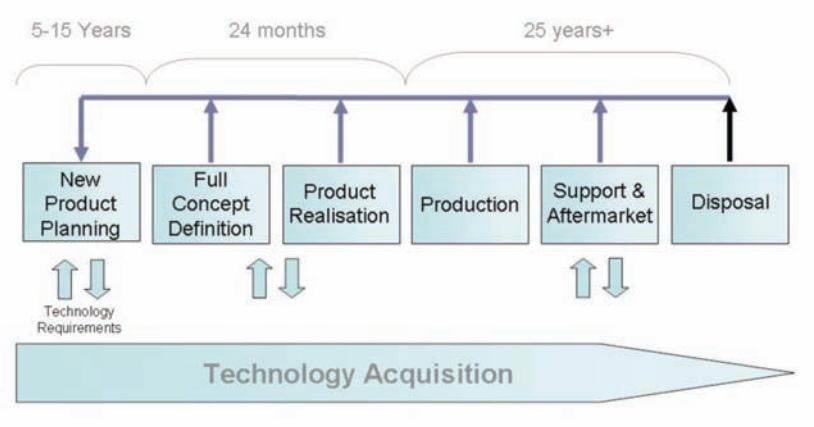



**Figure 5 This approach makes it clear that industrial activities go far beyond physical production, and that it is necessary to recognise the opportunities to create and capture value at each stage in the chain, as well as in the system as a whole.**

This is further illustrated in the modified version of the approach used by the Technology Strategy Board (Figure 6) which brings in the value created and captured in the process industries.

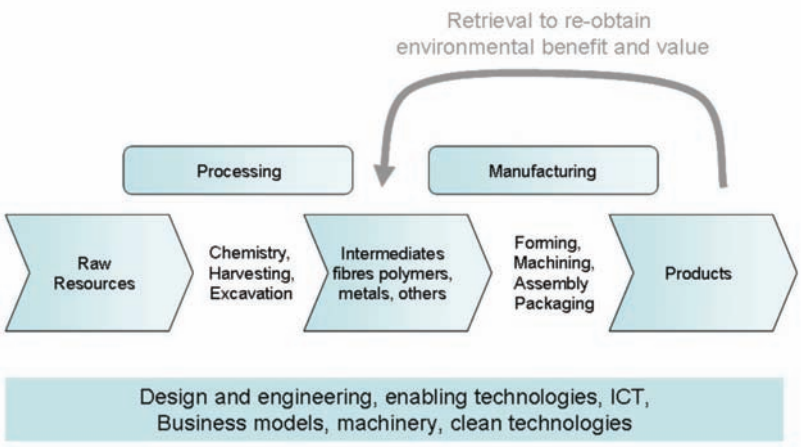



**Figure 6 Combined process and product lifecycle (Technology Strategy Board)**

A recent study of the defence related aircraft industry in Sweden[7] has analysed the macroeconomic, system level benefits of the Swedish government's decision to maintain a strategic national capability in design and manufacture of military fighter aircraft. Although the original analysis (1995) had only attempted to discover if pursuing the Saab Grippen fighter project would be a technology generator of a national prestige project for Sweden, the latter analysis found significant benefits to the wider economy with the Grippen project supporting the wider economy with a 'technology dividend'. While the study makes the case for using public procurement policy as a policy tool to bolster or protect industry, the strategic security-based decision to protect a defence related national capability is acknowledged.

When companies identify which benefits are critical for competitive advantage in their industry, they can use production in different ways, depending upon their context and capabilities, to reap their desired benefits. For example, if a company needs to retain its intellectual property in order to hold and advance its position within its global industry, it can use pilot production to prove the value and feasibility of its innovations and later it may choose to mass produce in-house to continue to retain the intellectual content in its products. Therefore, our findings show that production capabilities offer a plethora of potential benefits that are likely to be company- and nation-specific. As transportation costs and foreign labour costs rise, UK production will become even more valuable.

A study of UK manufacturers that offshored production in 2008-2009 found that 14% of them had already backshored it[8].

### Capturing value

The most common source of value is, of course, financial value. While crude in many ways, financial value is at least widely understood and provides a set of common units through which diverse activities can be compared.

Another way of looking at value, or the sources of value and how it is captured, is in terms of the qualities and attributes of a company and its manufacturing system. In this sense, these values can be thought of as 'assets' and are typically the characteristics and capabilities of an enterprise that are highly valued by people and often regarded as being the essential ingredients for success.

More difficult to assess in financial terms is strategic value, although this may well influence financial valuations. In mergers and acquisitions, for example, companies might seek to acquire assets and capabilities that will complement their own and provide access to broader ranges of capabilities and markets. While more difficult to quantify, strategic value can be a major driver of the configuration of industrial systems.

The differentiation between value creation and capture becomes increasingly significant. Companies at the beginning of the value chain may capture value from their specialised expertise in R&D and design, but if they do not have access to the means of production, may find it difficult to capture the full benefits from their intellectual investments. On the other hand, companies with major investments in production capability may find it difficult to capture the full value unless they have clear routes to market.

The ability to assess and quantify the mechanisms for value creation and capture is therefore critical. There are cases of companies outsourcing production only to find that they have lost the differentiating capability that production gave them and, worse still, that the company to which production has been outsourced is enabled to deliver competing products or services that undermine the original company's business.

Much progress has been made in recent years through the adoption of 'lean manufacturing' techniques that have done a great deal to improve the operational efficiency of manufacturing businesses. Lean production projects typically begin with 'value stream mapping' exercises that break down the production system to its constituent elements and then examine in detail the efficiency of those elements and of the interfaces between them.

Value at this level is typically financial value as efforts are made to reduce unnecessary or wasteful processes. Value is created by enhancing the function of the materials being processed, then captured by using in-house processes to reduce cost and then creating products and services that can command premium prices.

Corporate social responsibility has featured increasingly strongly in company strategies, is an increasingly important consideration in the configuration of industrial systems and must necessarily feature in any comprehensive assessment of value.

As societies and industries develop, new requirements will emerge and industrial systems will have the opportunity to offer different types of value. New lifestyle choices are already opening previously unimagined markets through the internet and social networking. Industry has always been about meeting customer needs but, in a rapidly changing environment, there will be more opportunities and, indeed, premium-priced opportunities to which capable, flexible and responsive businesses must be able to respond. The integration of manufacturing and service can already be seen in a growing number of businesses. The future will require the early recognition of new opportunities for complex packages of manufacturing and service provided by integrated and flexible industrial systems. Increasingly, these opportunities are going to be driven by social as much as technical trends.

### Industry links with research and academia

The strategic links between the research, skills and industrial policy areas have always been recognised, certainly in the sense that industrial policy is a 'customer' of research and skills policies, but the relationship is complex and interdependent.

The strategic policy of preserving and developing a vibrant research sector has direct benefits to industry. The preservation of the research capability within the UK has been a policy objective for successive governments, yet the link between the research agenda and industrial need is still tentative. Strengthening that relevance to industry's needs could bolster the case for inward investment decisions as well as being of significant benefit to UK companies.

The Royal Academy of Engineering invests public funds in research which attracts a high level of additional support from business and industry and which is strategically relevant to business.

In July 2010, the Academy stated that "The overriding consideration for BIS should be the impact of research on the economy in the short to medium term. Investment of research funds into engineering and technology will provide the best return to the country compared with other possibilities. At a time when the state of the economy in the UK is overwhelmingly the predominant concern of government and the nation, the available science and research budget should be targeted where it will have most impact in the foreseeable future, without compromising future potential as far as possible. Future potential will never be realised if the nation has not created the means to exploit it."[9]

The UK academic network is a global player and is, in itself, part of a system of the same scale as the industrial system. While the Haldane Principle dictates a certain hands-off approach by government in setting the research agenda, policy levers are being put in place to exert direction in the balance of curiosity-led and applied research.

More mechanisms need to be developed to maximise the leverage that UK manufacturing can derive from this strength and facilitate the interactions between industry and academia. Further development of the Advanced Manufacturing Research Centres and a coordinated national skills agenda for engineering and manufacturing apprentices and graduates could help promote such interaction. The establishment of Technology Innovation Centres provides a new opportunity to promote industry academia interaction in pre-commercial R&D.

# Annex 2: Case studies

### Tata Motors takeover of Jaguar Land Rover

Historically, Britain has a strong tradition of welcoming foreign direct investment. This is particularly true in the area of manufacturing. With an open economy, Britain is often a magnet for foreign companies which acquire British companies and base their manufacturing operations in the United Kingdom. The UK Inward Investment Report 2010/11 estimated that foreign owners have invested around $1 trillion during the last 10 years for acquiring British companies. In turn, the British have spent around $750 billion acquiring foreign companies.

Jaguar Land Rover, even though owned by the US-domiciled Ford Motor Company since 1990, is primarily a British-based manufacturing company, with three internationally well-known brand names, Jaguar, Land Rover and Daimler. Ford had purchased Jaguar for $2.5 billion in 1990 and Land Rover from BMW Group for $2.9 billion in 2000. Jaguar Land Rover was set up in 2002 as a single joint entity by Ford to manage the operations of both companies. Jaguar has had poor performance since the 1960s and essentially became a burden for the parent Ford, which spent $10 billion trying to revive the Jaguar brand. Ford decided to divest itself of Jaguar Land Rover and other brands like Volvo to concentrate on its North American and Ford brand businesses. Following months of negotiations, Jaguar Land Rover was sold to the Tata Group in 2008 for $2.3 billion.

Tata Group, which is the largest private corporate group in India, has 98 operating companies in power generation, telecommunications, engineering, automotive, steel, consultancy and hotels. Its subsidiary, Tata Motors, is the biggest automotive manufacturing company in India. It had hitherto operated primarily in India. Tata's main objective in the takeover of Jaguar Land Rover was to become a global player, and explore new horizons and opportunities in the automotive market.

Access to advanced automotive technology creates synergies between Jaguar Land Rover and Tata Motors cars manufactured in India. At the same time, the Jaguar and Land Rover cars are essentially British-manufactured and jobs of employees are preserved, thus creating a win-win situation for both parties. The onset of the worldwide recession in the automotive industry appeared to cast serious doubts on the timing of the takeover of Jaguar Land Rover by Tata Motors. However, recent events show that the Jaguar Land Rover takeover has been of benefit to both parties with a turnaround of Jaguar Land Rover, manufacturing jobs protected in the UK and a substantial improvement in the profits of the Tata Motors Group. Jaguar Land Rover now accounts for more than half of Tata Motors' business and has been generating profit for last four quarters.

*"A lot of local suppliers depend on ACG being here. Consumables suppliers, local equipment providers, facilities etc."*

**Ebby Shahidi – Advanced Composites**

### Advanced Composites Group Ltd. (ACG Ltd.)

Advanced Composites Group Ltd (ACG Ltd.), part of Umeco Composite Structural Materials (UCSM) – a division of Umeco plc, is a leading manufacturer of advanced composite carbon and glass fibre (CFRP and GFRP) reinforced plastic pre-impregnated materials (prepregs) custom formulated for component, structural and tooling applications in a diverse range of industries.

Markets served by ACG Ltd include: motorsport, aerospace, marine, automotive, construction, wind energy, defence, medical, and sports and leisure.

ACG Ltd. employs approximately 520 professionals across its carbon- and glass-reinforced plastic (CFRP and GFRP) manufacturing facilities in Heanor and Manchester in the UK, its component manufacturing facility in Cape Town in South Africa, and its technology centre, also in Heanor, UK.

Through its own internal product development strategy and significant involvement in a number of national and international collaborative research programmes, ACG provides its partners and customers with innovative, technologically advanced fibre reinforced materials and manufacturing solutions for complex applications, meeting, and often exceeding, the most demanding technical specifications and delivery schedules.

The Group's strength is its ability to formulate customised resin systems for a diverse range of demanding applications and to manufacture and deliver short and long production runs of prepreg materials to a global customer base to demanding timescales.

***"Increasingly now, as the Airline buys a Rolls-Royce engine, we secure a service package with them, sometimes for as long as 20 years, we will provide all the spare parts and make sure they have engines available whenever they need them to support the aircraft, and they simply pay for the numbers of hours they fly."***

**Mark King, Rolls-Royce.**

### Rolls-Royce plc

'How to Build a Jumbo Jet Engine' featured the Rolls-Royce plc - Aerospace business primarily based in Derby but with reference to other plants around the UK including Barnoldswick (fan blades) and Ansty (fan cases). 'How to Build a Nuclear Submarine' featured BAE Systems submarine business in Barrow in Furness.

Rolls-Royce employs around 50,000 people worldwide and is one of the largest employers in the Midlands. The Trent series of engines has been developed for wide-bodied (Jumbo) jets. The Trent 700 was designed specifically for the Airbus A330 and has clocked up more than 13m flying hours. Mark King (President of Civil Aerospace) described the 5 tonne engine as 'worth several times its weight in silver' each module is made from around 1000 components supplied from all over the world. Each engine has 30-40,000 parts.

Phil Ruffles CBE FREng (former Director of Engineering & Technology) described the effect the company going into receivership in 1971 had on the local community in Derby. The continued investment by government in the RB211 project allowed re-privatisation and was the basis of the Trent family of engines. The company now has a £40bn order book and competes with one of the most powerful and competitive companies in the world: General Electric.

As one employee said 'Derby is Rolls-Royce'.

The programme showed the first flight of the new Boeing 787 Dreamliner with Trent 1000 engines which is the 'most efficient engine flying in the world'. This is the first new airliner for 10 years and has some of the most advanced technology with the engines made in 'State of the Art' factories across the UK employing 11,000 people.

*BAE Systems, How to Build a Nuclear Submarine*

***"We play a vital role in the community, we have extraordinary numbers of people working here with all sorts of family relationships, and the business here has a family feel to it ... a lot of salaries and money go back into the community through our shipyard."***

**John Hudson, BAE Systems**

### BAE Systems

'How to Build a Nuclear Submarine' focused on the BAE Systems shipbuilding facility at Barrow where the latest generation (Astute class) of nuclear powered hunter-killer submarines are being constructed for the Royal Navy. Of BAE Systems' 35,000 employees in the UK, 5,000 are at Barrow with 600 engineers working on design. The yard is the backbone of the local economy and as John Hudson (MD) says 'This is the only site in the UK where we design, build, test and commission nuclear submarines for the Royal Navy'.

The programme featured the departure from Barrow of the first-in-class submarine, HMS Astute, on 14th November 2009 with interviewees including Admiral Simon Lister (Director Submarines) who likened the submarine to a 7,400 tonne Swiss watch. This was the first new submarine for 10 years.

### Brompton folding bicycle

In late 1991, production of the UK-designed and built Brompton folding bicycle was at full stretch. Contact from Eurotai in Taiwan opened up the possibility of expanding production by manufacturing bicycles in the Far East under licence. In this way, Brompton manufacture at the existing UK Brentford factory would supply the European and USA markets, and bicycles manufactured by Eurotai would supply the Far East. However, the quality of the Taiwanese models was poor, with shortcuts taken in many aspects of the build: the tube thickness was incorrect, the folding pedal used the wrong material, the jigging was poor and the tooling was appalling. Coupled with this, there were problems associated with marketing and sales. Royalties received were far lower than predicted; the bike was marketed as a leisure machine and not the serious commuting bicycle of the UK brand. Unauthorised sales of the Taiwanese Brompton into other parts of the world, including the USA, made matters worse.

Source: David Henshaw, "Brompton Bicycle", published by Excellent Books, West Yorkshire, 2009.

## Annex 3: Acknowledgement


**Working Group:**

| | |
|---|---|
| Professor Steve Garwood FREng (Chairman) | Rolls-Royce Plc |
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| Professor Keith Ridgeway OBE FREng | University of Sheffield |
| Dr Gregory Theyel | Institute for Manufacturing |
| Frank Turner FREng | |
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| Alan Hoy | Consultant |
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| Ravi Kant | Tata |
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| Ebby Shahidi | Umeco |
| Professor Denis Towill FREng | Cardiff University |
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# The Royal Academy of Engineering

As the UK's national academy for engineering, we bring together the most successful and talented engineers from across the engineering sectors for a shared purpose: to advance and promote excellence in engineering. We provide analysis and policy support to promote the UK's role as a great place from which to do business. We take a lead on engineering education and we invest in the UK's world class research base to underpin innovation. We work to improve public awareness and understanding of engineering. We are a national academy with a global outlook and use our international partnerships to ensure that the UK benefits from international networks, expertise and investment.

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The Royal Academy of Engineering
3 Carlton House Terrace, London SW1Y 5DG

Tel: 020 7766 0600 Fax: 020 7930 1549
www.raeng.org.uk