

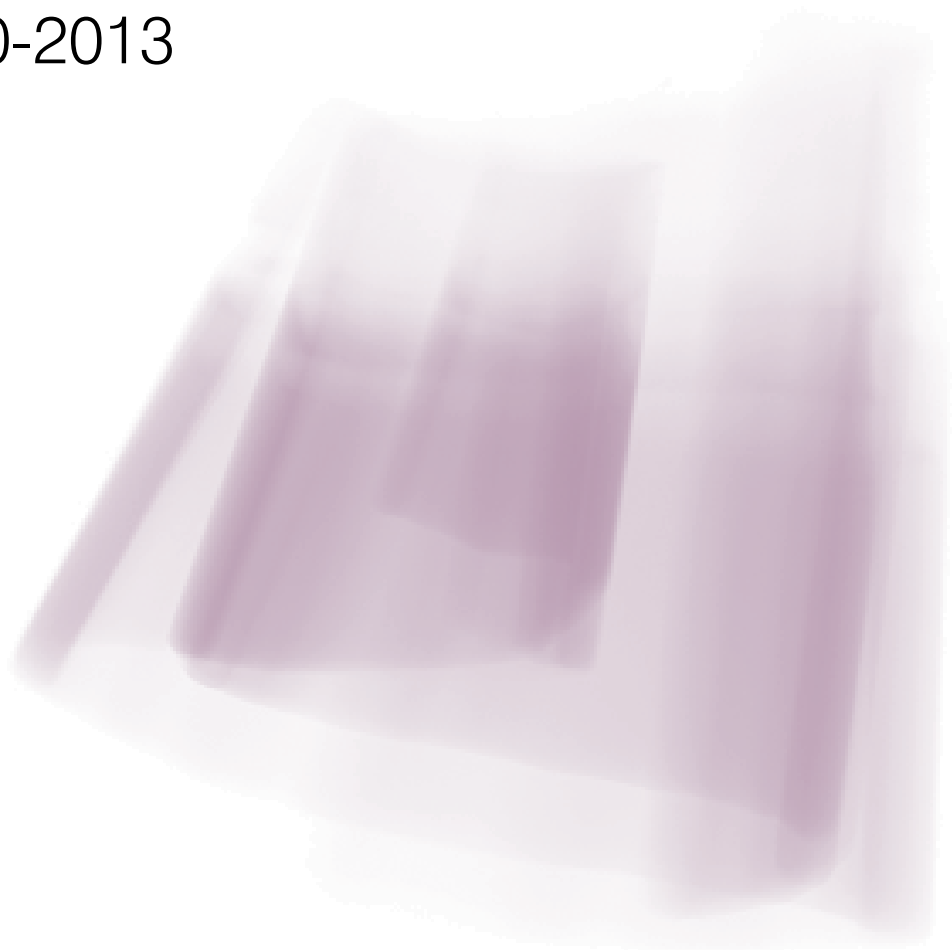
Technology Strategy Board

Driving Innovation



Emerging Technologies and Industries

Strategy 2010-2013



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

Our three-year corporate strategy for 2008-2011 is to drive innovation by **connecting** and **catalysing**. To achieve this we are focusing on three themes: challenge-led innovation, technology-inspired innovation and the innovation climate.

For more information on the overall strategy see **www.innovateuk.org**.

We have identified a number of application areas and technology areas on which to focus, and for which we are developing specific area strategies. This document presents the strategy for **Emerging Technologies and Industries**.

Acknowledgements

Many individuals have generously contributed their time and thoughts to help formulate this strategy. We are grateful to all of them for their advice and support.

Foreword

The Technology Strategy Board aims to make the UK a global leader in innovation. Our job is to ensure that the UK is in the forefront of innovation enabled by technology.

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

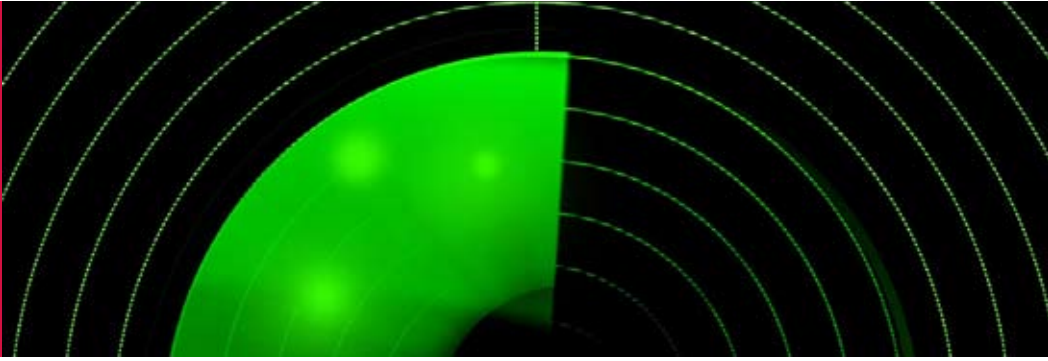
The world is changing. Globalisation, digital communications and the growth of emerging economies present profound challenges to UK business sectors. Yet where there are challenges there are also opportunities. Open access to global supply networks and emerging markets is easier than ever before; the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

The UK already has an exceptional record of successful innovation. We excel in many business sectors: our creative industries are outstanding, our aerospace sector is the second largest in the world, two of the top five pharmaceutical companies globally are based in the UK. And there are many more examples. Many of these industries have been built on the world-class science and technology carried out here. The UK is home to four of the top 10 universities in the world and has produced around 90 Nobel Prize winners, second only to the US in number.

This strategy is concerned with identifying and developing the early-stage technologies that will lead to the new products and services, or even completely new industries, of tomorrow. Its scope is those disruptive technologies that enable something to be done that was previously impossible, or possible only in theory. These are the technologies that lead to completely new markets, or new value propositions, and our ambition is that the value from these technologies should be realised in the UK.

The technologies could come from any branch of science, and be commercialised in many different sectors. Given that breadth of scope, a strategic approach is essential. This strategy describes that approach. We invite businesses, academia, national bodies and other organisations with an interest in this area to join us as we seek to help turn exciting prospects into commercial realities.

Iain Gray
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Executive summary

This executive summary is an updated version of the *Emerging Technologies Strategy Executive Summary* published in October 2009 (T09/087). Changes have been made to better articulate the ambition of this programme – to help create entirely new UK industries from emerging technologies.

The Government has assigned us the role of promoting the rapid and successful commercialisation of emerging technologies in the UK. Creating wealth from new technologies is recognised as being difficult and risky, and for this reason we are taking a new strategic approach.

This document outlines our strategy for emerging technologies in the UK, and the role of the Technology Strategy Board and our partner organisations to promote their rapid commercial exploitation. It builds on our earlier Interim Strategic Assessment consultation document of October 2008.

What are emerging technologies?

By 'emerging technologies' we mean those technologies that are still emerging from the science base, that are at an early, pre-commercial stage, and that have the potential to enable innovations that will truly disrupt the marketplace. The digital camera and PET medical imaging systems are good examples of such innovations. Emerging technologies:

- enable something to be done that was previously not possible, or was possible only in theory
- lead to new products and services
- may be adopted by existing industries or may result in new industries, and
- may arise from:
 - a major scientific breakthrough, like radar or the transistor
 - the integration of several technologies, like the 5.25 inch disk drive, or
 - a single advance that enables a much bigger innovation, such as switching circuits for mobile phones.

The technologies within the scope of this strategy could be as much as 7-15 years from market, and we will only invest in those where there is evidence that the UK can compete. This strategy provides support from the first technical demonstration to the early stages of commercialisation, in terms of lead application development and early market adoption.

This work forms part of the 'technology-inspired' element of our overall strategy for business innovation in the UK, outlined in our 2008 *Connect and Catalyse* corporate strategy.

Exploiting emerging technologies

We aim to help turn the emerging technologies of today into the growth sectors of tomorrow for UK business. We will work with our partners to develop some of these new and exciting technologies into new industries or into completely new markets for existing industries in the UK. In 10 years' time we want to see the UK poised to lead the world in a major new growth sector that is comparable in size and impact with mobile phones, digital cameras and internet searching. In the process we wish to strengthen considerably the UK's capability and reputation for successfully commercialising new technology.

In developing this strategy we have reviewed the literature in the area and consulted widely with key players including business, academia, technology transfer organisations, the investment community, government departments, the Intellectual Property Office, the research councils, the regional development agencies, the devolved administrations and UK Trade and Investment. The strategy is therefore based on the best available understanding of the landscape in the UK and the best thinking on the ways to promote the early commercialisation of new technologies.

Key issues

Much has improved in the last few years in the UK in terms of technology transfer and exploiting research investment. However, we believe that more can be done to promote and accelerate commercialisation. We have identified the following issues that limit the pace and scope of early commercialisation of emerging technologies:

- finding the best route to market for disruptive ideas is inherently difficult
- there is insufficient support for early-stage, pre-investment, proof-of-concept work (a rate-limiting step for technology demonstration and commercial development)
- existing support is not aligned across the various agencies so investment is not focused on the technologies that have the greatest national potential
- an equity gap particularly affects new entrants (start-up and spin-out companies) that typically spearhead the difficult early stages of commercialisation
- the skills required are in short supply and they change during the commercialisation process.

Our strategy

Our strategy addresses these issues within the context of our role of promoting the rapid and successful commercialisation of emerging technologies, and within the approach of 'connect and catalyse'. It is designed to help accelerate the early stages of technology demonstration and commercialisation, and from there to lay the foundation of new industries for the UK. It recognises that commercialising this type of technology can be a lengthy, high risk and complex process, and that it straddles the interface between business and the science base.

Commercialisation is also costly and despite our undoubted strengths the UK will not be able to compete successfully in every area. At some point we will have to choose which areas to support.

Our overall approach is therefore to catalyse the emergence and commercial application of more new technologies, and to connect all the key agencies involved to focus support on those technologies that have the greatest potential to create value in the UK.

The strategy and associated activities are designed to fit with our later-stage support such as knowledge transfer networks and collaborative research and development schemes, which are available as technologies become more mature and as the business opportunities move closer to market. This strategy will therefore build a greater continuum of support for technologies with disruptive innovation potential that may take many years to reach the market.

Our thinking and our activities will be guided by the view that **people don't buy technologies; people buy what technologies do for them.** Our experience of the process of commercialising technology is that it is long and difficult. It takes energy and commitment. It takes longer than you think it will. It often impacts where you didn't expect it to, so unless you are flexible you are unlikely to survive. And unless you can explain clearly what you are doing you are unlikely to attract investment and your business will die.

The four elements in our strategy are to:

- invest in technology demonstration
- build critical mass
- create a coordinated programme
- build and nurture capability.

Invest in technology demonstration

One of the rate-determining steps in commercialising technology is the transition between the different phases of emergence.

We will: invest in demonstrators to speed up the transition between the different phases of technology emergence, to accelerate commercialisation, and to increase the likelihood of creating major new industries. We will focus on three main types of demonstrator known to catalyse the transitions from applied science to the technology-dominated phase, and from technology to the application-dominated phase:

- technology demonstrators
- application demonstrators
- commercial application demonstrators.

We will: work closely with agencies that support related activities, such as the Research Councils Follow-on Fund and regional schemes, to ensure that we provide the best overall framework for technology demonstration.

We will: support early market and business involvement to ensure that the outputs have the greatest chance of attracting investment and moving forward to commercialisation.

Build critical mass

We will: take steps to bridge the gap between the various types of technology demonstrator and the market. Innovation and knowledge centres (IKCs) are a good vehicle for driving technology and matching innovations with customers in high potential, broad areas of technology.

We plan, in partnership with the Engineering and Physical Sciences Research Council, the Biotechnology and Biological Sciences Research Council and other research councils, to increase the number of IKCs and align them more closely with emerging technology areas of major strategic importance for the UK.

These IKCs will form the basis of innovation 'ecosystems', bringing together people with the right technical, business and commercialisation skills in a flexible, highly entrepreneurial environment. They will create strong connections with potential customers, existing industry and investors, and will develop compelling market-led strategies for commercial exploitation.

We will: identify, with the Ministry of Defence, Department of Health and other government departments, key areas of future procurement that are aligned with emerging technologies, and these will be targeted within the Small Business Research Initiative (SBRI) scheme.

In this way we will support small new companies, which play a special role during the early stages of commercialising disruptive innovations.

We will: work closely with the investment community to encourage greater early-stage investment in companies driving disruptive innovations.

The best way we can contribute to tackling the equity gap is through making such investments more attractive, not through setting up a new source of capital. Our approach will therefore be to help lower the risk and increase deal flow by supporting high-quality demonstrator and IKC programmes. While it is important to increase the availability of equity funding, other organisations are better placed in terms of expertise to do this. We will consult the investment community to ensure that the outputs of these programmes are aligned with their expectations in terms of the degree of confidence and understanding of the business proposition required at this stage.

Create a coordinated programme

We will: build a coordinated Emerging Technology Programme bringing together different elements of UK activity to establish a competitive position and create significant value for the UK in new high-growth markets and industries based on emerging technologies.

The programme will bring together public and private sector expertise to coordinate the actions of the various agencies involved and progressively focus support on areas of greatest national significance. The programme will stretch from the science base to wealth generation by business.

We will: establish an Emerging Technologies and Industries Steering Group to build consensus across agencies on decision-making and allocating resources.

The steering group will coordinate work to agree, prioritise and oversee a national portfolio from which future nascent industries will arise.

Build and nurture capability

Our aim is to make the UK a leading practitioner of commercialising emerging technologies, and to build its strength as a centre of excellence in this sphere. We believe that not only will this help us build entirely new UK-based industries and strengthen existing ones, but it will also help attract overseas investment.

It is not enough to have the most exciting technology ever invented. It is people, and the right sort of people, who turn great ideas into commercial successes. A set of diverse skills is required, from market analysis to technology development, and from intellectual property management to business modelling.

We will: define the types of skills that are critical for success at different stages, and will identify important gaps and ways to improve capability in the UK.

We will: monitor and study the impact of our interventions on the development of future industries from emerging technologies.

1. Background and context

Although the Government is focusing on short-term business needs and opportunities for innovation because of the global economic situation, it also recognises the importance of laying the foundation for longer-term value creation based on today's emerging technologies.

The importance of new technology for economic growth and national competitive advantage is well recognised and was highlighted in the *Sainsbury Review (2007)* [1]. This is the most recent report on the UK's position in terms of the critical factors affecting innovation, and makes recommendations on how to improve it. The report speaks of the need to shape innovation 'ecosystems' where companies, universities, investors and government agencies interact effectively. When such ecosystems work well, as for example in Silicon Valley in the US, the result can be the creation of new industrial sectors on a global scale.

1.1 The position in the UK

Much has improved in recent years as a result of the Government's focus on the economic exploitation of investment in science. The UK has in place many of the elements needed to create more ecosystems in the future around today's emerging technologies.

Three of these elements are:

- the science base
- technology transfer and commercial exploitation
- finance.

1.1.1 The science base

We have a flourishing, inventive and strong science base, which we can expect to be a powerful source of emerging technologies. A report from the Department of Innovation, Universities and Skills (2008) shows that the UK is maintaining its excellent position globally, as assessed by output of

publications and citations (it is second overall behind the US) [2]. This position is reinforced by the 2008 ranking of the world's universities prepared by analysts QS for *Times Higher Education*, which shows that the UK has four universities in the top 10, and 17 in the top 100 [3].

1.1.2 Technology transfer and commercial exploitation

Technology transfer and the commercial exploitation of university research have improved dramatically in the UK over the past 10 years. Increased UK government investment in science, programmes such as the 'third stream' agenda (where the Higher Education Innovation Fund allocates funding preferentially to those universities with the strongest links to industry), as well as various research council initiatives, have greatly helped to bring this about.

There are many local and regional proof-of-concept schemes; follow-on funding is available at a national level to explore the commercial potential of ideas arising from research council grants; and pilots such as the Engineering and Physical Sciences Research Council's (EPSRC) innovation and knowledge centres (IKCs) are breaking new ground in commercialising major new technologies. Most universities now have an in-house technology transfer function or employ commercial organisations to handle the business exploitation of their intellectual property.

The impact of these changes is reflected in a recent international comparison of commercialisation where the UK was ahead of Australia, Canada and the US in five out of seven metrics [4]. One measure of successful commercialisation is the number of new companies that have started up. UK universities create three times more spin-outs than US universities for each dollar spent on research, and the quality of the spin-outs, in terms of attracting investment, is comparable [5].

1.1.3 Finance

Another major element is finance. The availability of early-stage seed, angel or venture capital investment for business start-ups or spin-outs is particularly important. These small 'new entrants' can play a significant role in taking technologies to market by further mitigating risks, demonstrating possible applications for potential customers, and establishing a route to market. New entrants are often the most effective way for larger companies to engage with new technologies.

The UK has a well-developed venture capital industry; it is the largest in Europe although much smaller than that of the US. However, funding for high-tech businesses has declined from a peak of around £500m in 2000 to about £200m in recent years [1].

It is generally recognised that many small high-tech companies seeking capital of around £250k to £2m face an 'equity gap'. The share of venture capital going into early-stage investments has fallen from 11% in 2000 to less than 4% in 2007 (figure 1), according to research sponsored by the National Endowment for Science, Technology and the Arts (NESTA) [6]. This is against a backdrop of rising demand for the critical sub-£2m type of capital.

The research also found that the public sector is becoming an increasingly important source of venture capital in the face of these trends. NESTA has recently called for the establishment of a £1bn co-investment fund of funds to address the equity gap and support early-stage, high-potential innovative businesses.

It is crucial to provide start-ups with the right kind of investment in infrastructure and other support during the first five years or so. Success rates after that are high (over 80%) [7]. The key factors for success in the early years of a new enterprise include having a clear

competitive technological advantage, an able management team, and strong customer demand. The public sector can contribute to customer demand by acting as an intelligent customer in its own right. We took this into account when leading the reform of the Small Business Research Initiative (SBRI) in line with the *Sainsbury Review*. The reformed SBRI is a procurement programme: government departments buy research and development services, helping to bring new technologies to market and leading to the possibility of future commercial procurement in the public sector.

1.2 The challenge

Although the UK is punching above its weight in terms of spin-outs and start-ups, it has had less success than the US at growing high-technology enterprises into businesses and industries on the scale of Genentech or Google. This is a major challenge for the UK in a very competitive world.

The underlying causes of this lack of success are in part linked to the scale and duration of investment. The UK Government has also spelled out the need to develop a more focused strategy to develop industry, and to do more to build clusters where there is a critical mass of science, enterprise and investment [8].

This strategy is designed to help meet the challenges of successfully exploiting emerging technologies within existing, or completely new, wealth-generating industries in the UK. It outlines the role of the Technology Strategy Board and our partner organisations to promote their rapid commercial exploitation. This strategy builds on our earlier Interim Strategic Assessment consultation document of October 2008 [9] and forms part of the 'technology-inspired' element of our overall strategy for business innovation in the UK, outlined in our 2008 *Connect and Catalyse* corporate strategy [10].

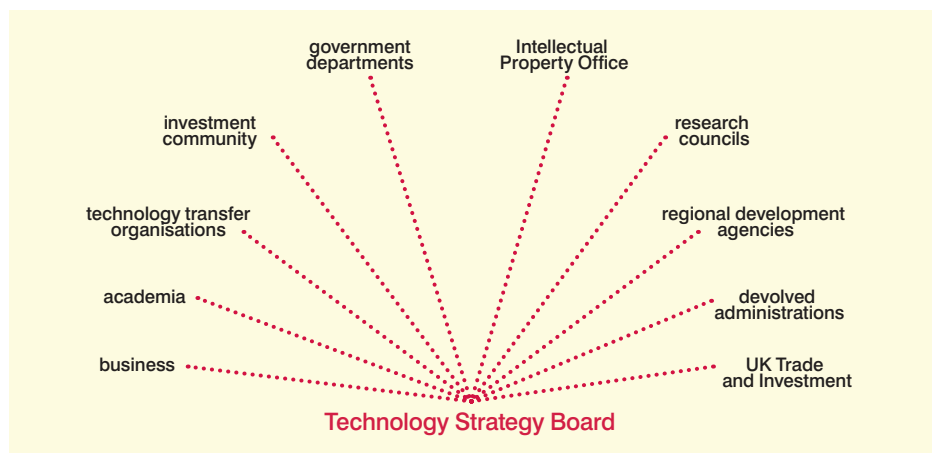
Figure 1: Percentage of UK venture capital investment going to early-stage businesses [6]



We aim to help turn the emerging technologies of today into the growth sectors of tomorrow for UK business. We will work with our partners to develop some of these new and exciting technologies into new industries or into completely new markets for existing industries in the UK. In 10 years' time we want to see the UK poised to lead the world in a major new growth sector that is comparable in size and impact with mobile phones, digital cameras and internet searching. In the process we wish to strengthen considerably the UK's capability and reputation for successfully commercialising new technology.

In developing this strategy we have reviewed the literature in the area and consulted widely with key players including business, academia, technology transfer organisations, the investment community, government departments, the Intellectual Property Office, the research councils, the regional development agencies, the devolved administrations and UK Trade and Investment (see figure 2). The strategy is therefore based on the best available understanding of the landscape in the UK and the best thinking on the ways to promote the early commercialisation of new technologies.

Figure 2: In developing this strategy we have consulted widely with key players



2. Emerging technologies overview



2.1 Definition

It is important to define what we mean by 'emerging technologies' and the types of activities involved in the early stages of their development and commercialisation. This will help to understand today's landscape, the major barriers, and where and how we should intervene. It will also help to show how the emerging technologies programme relates to other Technology Strategy Board activities and how it fits within our overall portfolio [10].

As set out in our Interim Strategic Assessment [9], our focus is on new technologies; those that are still emerging from the science base, that are at an early, pre-commercial stage, and that have the potential to enable innovations that will truly disrupt the marketplace. The digital camera and medical imaging systems are good examples of such innovations. Emerging technologies:

- enable something to be done that was previously not possible, or was possible only in theory
- lead to new products and services
- may be adopted by existing industries or may result in new industries, and

- may arise from:
 - a major scientific breakthrough, like radar or the transistor
 - the integration of several technologies, like the 5.25 inch disk drive
 - a single advance that enables a much bigger innovation, such as switching circuits for mobile phones.

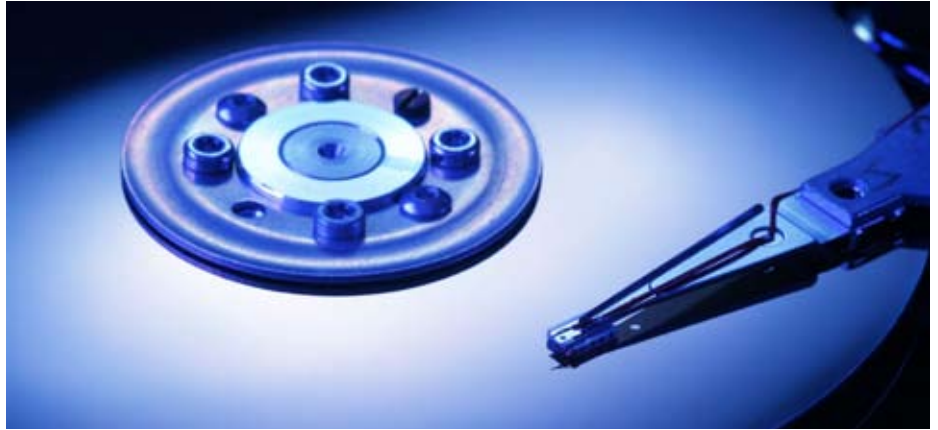
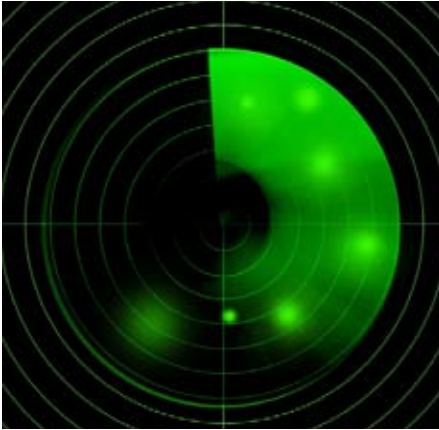
By their very nature such technologies might be some way upstream of the Technology Strategy Board's current technology areas and application areas. In fact, they could be as much as 7-15 years from market. This focus on emerging technologies therefore complements our existing priority areas, and indeed may generate the priority areas of the future.

The work will benefit UK business by providing a springboard for completely new industries as well as new products and markets for existing industries. Based on the strength of the UK science base, we expect there to be a significant number of technologies at an early stage of development with this potential for disruptive innovation.

2.2 Scope and investment criteria

We will consider technologies arising from any field of scientific or technological research, and we will assess whether technologies are suitable for investment against our existing criteria, namely:

- Does the UK have the capability to develop and exploit the technology? (In emerging technologies we will pay particular attention to the UK's competitive position globally, and to the ability to realise value from the resulting innovations.)
- Does the technology have the right potential for impact in the right timeframe? (We will seek technologies that can enable disruptive innovations with market impact within 7-15 years.)
- Is there a large global market opportunity? (Technologies should have the potential to lead to completely new value propositions of global significance.)
- Is there a clear role for the Technology Strategy Board to add value? (The framework for our intervention is set out in chapter 5.)



The focus of this strategy is on the early stages of commercialising emerging technologies. The scope includes activities from the first demonstration of technology feasibility through to the development of applications and business models, early market adoption and wealth creation. In terms of technology readiness levels (TRLs) these activities will typically span TRLs 2-6.

We are leading a survey to identify technologies in the UK that meet these requirements and are in the early stages of development. This survey will build on and

widen an initial scan by the research councils for the Technology Strategy Board in 2006 that suggested quantum technologies, smart optics and nanomedicine as areas with disruptive potential. As well as bringing our own perspective and seeking the latest input from the research councils, we are also requesting help from the regional development agencies, devolved administrations and the Intellectual Property Office. We will also seek the views of the Horizon Scanning Centre and

the Ministry of Defence (MoD), which have a close interest in emerging technologies. This survey will complement the 2007 report by the Council for Science and Technology, which highlighted the most promising technology areas in which a larger-scale focus by Government could speed up returns for the UK within five years [11].

3. Commercialisation

3.1 The commercialisation process

It is important that our strategy for promoting the early stages of commercialisation is consistent with our goal of creating major new growth sectors for the UK. Our strategy must feed into, anticipate and help drive the later downstream activities that are essential for building emerging industries. Our thinking and our activities will be guided by the view that **people don't buy technologies; people buy what technologies do for them.**

Our experience of the process of commercialising technology is that it is long and difficult. It takes energy and commitment. It takes longer than you think it will. It often impacts where you didn't expect it to, so unless you are flexible you are unlikely to survive. And unless you can explain clearly what you are doing you are unlikely to attract investment and your business will die.

These challenges become more difficult the further from market the technology is, and the more disruptive its potential.

Commercialising such technologies is likely to be an iterative, non-linear process that involves demonstrating the technology, generating prototypes, and evaluating them against possible markets and business models, which will lead to increasingly clear and compelling applications and paths to market. It is a continuous process of identifying and mitigating risks. It needs the right levels of investment and people with the right skills. It often needs early adopters to help pioneer and shape applications. The early stages have the greatest number of uncertainties and challenges, and are therefore the most complex and highest risk. We can expect a high failure rate and that only a few technologies will become the basis for new industries.

The characteristics of the commercialisation process and some of the factors that influence it are starting to be understood. The main points (based on the work of Christensen [12], Schmoch [13], Maine and Garnsey [14], and Phaal and O'Sullivan [15]) are:

- Science and technology are closely intertwined at the earliest stages because technologies are first realised at the lab level.
- Success requires space and time to match technical possibilities and market opportunities. This process is lengthy, complex and can be costly. A long-term perspective and continuity of finance and support are therefore important, particularly for the new entrants that typically spearhead the difficult early stages.
- Patent activity can develop in two phases. The first is related to the generation of the initial concept, and the second to the development of specific applications. Value creation follows the second phase and support is most required in the lag between the two phases.
- Technologies must cross several critical transition points on their journey to the market. These transition points mark the boundaries between the four main stages of technology emergence: science-dominated, technology-dominated, application-dominated and market-dominated.
- Demonstrators play a major role in helping to catalyse the transition from one stage to the next. For example, an application demonstrator may help to identify possible end-uses, and a commercial application demonstrator may help to win potential customers and refine the marketed product.
- New regulations and standards may be needed for radical technologies to be exploited effectively.

- Disruptive innovations may have social or ethical dimensions that need to be explored to address public concerns about their impact on society or the environment.

3.2 Obstacles and opportunities

There is more to learn about the process of commercialising technology, but there are some clear gaps and barriers that we can start to address. We have identified the following issues that limit the pace and scope of early commercialisation of emerging technologies:

- finding the best route to market for disruptive ideas is inherently difficult
- there is insufficient support for early-stage, pre-investment proof-of-concept work (a rate-limiting step for technology demonstration and commercial development)
- existing support is not aligned across the various agencies so investment is not focused on technologies that have the greatest national potential
- an equity gap particularly affects new entrants (start-up and spin-out companies) that typically spearhead the difficult early stages of commercialisation
- the skills required are in short supply and they change during the commercialisation process.

Our strategy addresses these issues within the context of our role of promoting the rapid and successful commercialisation of emerging technologies, and within the approach of 'connect and catalyse'. It is designed to help accelerate the early stages of technology demonstration and commercialisation, and from there to lay the foundation of new industries for the UK. It recognises that commercialising this type of technology can be a lengthy, high risk and complex process, and that it straddles the interface between business and the science base.

Commercialisation is also costly, and despite our undoubted strengths the UK will not be able to compete successfully in every area. At some point we will have to choose which areas to support.

3.2.1 Technology demonstrators

Demonstration is a critical, rate-limiting step that determines whether a technology will move from the scientifically possible to the technologically real. This type of activity is eligible for support by pre-investment proof-of-concept funds, of which there are many in the UK. Even so, the amount of funding available for technology demonstrators is low.

Proof-of-concept funds are not usually dedicated to technical demonstration; the term 'proof of concept' covers other activities such as developing a business plan, assessing commercial feasibility, and conducting pre-clinical studies. A recent survey by the Technology Strategy Board in collaboration with Unico and Research Councils UK revealed a fragmented picture, with availability of funding for pre-investment proof of concept being highly dependent on geographical location [16].

Less than 1% of government spending on scientific research is allocated to proof-of-concept work. The amount available to support technology demonstrators is presumably even lower given the range of activities that the various funds cover.

Many different agencies at both local and regional levels are involved, but there is currently no UK national strategy or coordination. A greater level of investment in, and focus on, technology demonstrators would allow more ideas originating in the science base to be evaluated.

3.2.2 The need for aligned support

Related to the fragmented availability of funding is the absence of a mechanism at the national level to identify emerging technologies, track their progress and evaluate their potential as emerging industries.

Entrepreneurs need a continuum of support through the different stages of commercialisation. Given the scale of resources required to progress from an emerging technology to an emerging industry we will need to make informed and coordinated decisions about which areas to invest in. This will ensure that we focus resources on those areas where the UK has the greatest potential to compete.

This is particularly true given the much larger levels of investment being made in some other countries. For example, spending on proof-of-concept work in the US through schemes such as the Small Business Innovation Research fund (\$2bn) far exceeds comparable activity in the UK [5]; and countries such as Singapore are starting to make large strategic investments in areas like quantum technology [17].

3.2.3 Equity gap

The shortage of funding available to early-stage, high-potential innovative businesses has already been mentioned. It is real, but it isn't solely due to a lack of available investment finance. It results from a complex set of decisions made by investors as they evaluate their risk-return options. These decisions take into account, among other things, the capability of the business management team, the business model, the analysis of the potential market and the evidence of serious intent from customers as much as the performance of the technology itself.

We believe that poor commercialisation skills and limited early market awareness and connections with customers are barriers that reduce investment into emerging technologies. In addition, the limited pre-investment proof-of-concept funding may result in low-quality technical demonstrations that do not attract investment.

3.2.4 Innovation and knowledge centres

For broad areas of emerging technology where many applications are possible and the choice of target markets is uncertain, the process of matching the technology to market opportunities requires patience and effort. Few forms of investment support this process at present. An exception is the IKC scheme, which offers support for five years in areas of emerging technology based on world-class research where the first technical proof of concept has been made.

The EPSRC established two pilot IKCs in 2007, in the areas of ultra-precision and structured surfaces, and plastic electronics manufacturing. In 2009 it established two more, in data and network security, and regenerative medicine, with support from the Technology Strategy Board and the Biotechnology and Biological Sciences Research Council (BBSRC).

The prime goal of an IKC is to accelerate and promote business exploitation of an emerging research and technology field. An IKC is expected to:

- create a shared space and entrepreneurial environment in which researchers, potential customers and skilled professionals from both academia and business can work side by side to scope applications, business models and routes to market
- have the resources, freedom and flexibility to explore different prototypes and business models

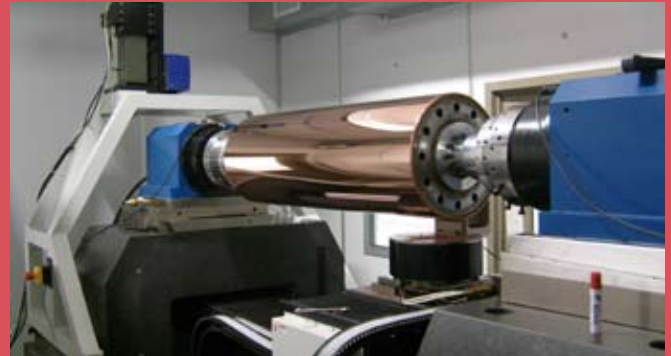
IKC in Ultra-Precision and Structured Surfaces

The IKC in Ultra-Precision and Structured Surfaces was launched in 2007 and is based at Technium OpTIC in St Asaph, Denbighshire. This location was chosen to be close to potential customers of the optics business cluster in North Wales.

The IKC was set up to bring together and commercially exploit two complementary technologies that emerged from University College London and Cranfield University. Prototype equipment for the large-scale manufacture and finishing of ultra-precision surfaces had already been demonstrated, funded by the EPSRC. The IKC was set up to explore the many possible applications and markets for this technology, including large, very-high-precision mirrors.

Since its inception the IKC has:

- established laboratories and manufacturing capabilities
- recruited a team of 10 people including an independent chairman and business development manager
- developed its first product for which it is seeking a sales/manufacturing partner
- won a €5m contract with the European Southern Observatory to make mirrors for the European Extremely Large Telescope.



Micro surface structuring of drum moulds

This will prove the IKC's capability and enable it to bid for a larger contract worth about €150m

- started projects for US and UK companies developing moulds for next-generation display films
- established and run courses in high-precision surfaces for industrial employees and students.

The director of the IKC, Professor Paul Shore, said: 'The pilot IKC we are running is seeking to help bridge the gap between proving functionality of an emerging technology and establishing a firm basis for a wealth-generating opportunity. It is an area that the UK in particular needs to address. The Cranfield-led IKC is testing new approaches and our initial results look highly promising.'

- provide a clear strategy for technology-based, market-led innovation in a new area of technology where there is potential for major growth and evidence of a strong business and/or customer need. IKCs are expected to establish and exploit strong connections with potential customers and markets
- provide a focus for many different strands of industry-relevant activity, including pre-competitive collaborative research, postgraduate research training, contract research and consultancy, commercialisation, vocational training and continued professional development

- contribute to learning about driving effective commercialisation.

So far the IKC scheme has invested in four new centres. More centres will be established to capitalise on the number and global competitiveness of emerging technology areas in the UK.

4. Strategic framework

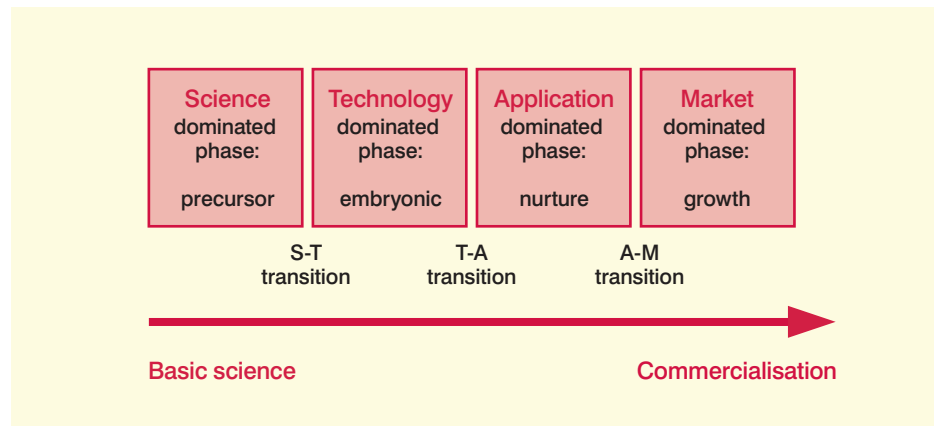
Phaal and O'Sullivan [15], at the Institute for Manufacturing, University of Cambridge, have recently developed a conceptual framework for the stages and activities that take place from scientific discovery to industrial emergence. This framework resulted from a retrospective analysis using interviews and technology roadmapping techniques of the key steps and dynamics in the emergence of about 20 major global industries.

4.1 Four phases

The analysis revealed that although the new industries arising from these disruptive technologies were all different, there were some similarities in the way they evolved. In particular, the technologies passed through four phases on their route to commercialisation (see figure 3):

- **Science-dominated phase:** this is the precursor phase to everything. Here work in the basic science dominates activity and provides the basis for identifying potential applications and stimulating interest and investment.
- **Technology-dominated phase:** this is an embryonic phase, in which work to develop the technology dominates the activity. Here the technology is developed and integrated with other technologies to produce early demonstrators that can be shown in the field or to potential customers. The performance of the technology improves, and it becomes more reliable.
- **Application-dominated phase:** during this phase the technology is nurtured and extended in the context of the potential applications. The work involves improving the functionality, performance and price of potential products, processes or services in line with early customer needs.

Figure 3: Emerging technologies pass through four phases on their route to commercialisation



- **Market phase:** this has a growth phase where the focus is on increasing revenue and sustaining business growth to fully realise the market opportunities. This is followed by a maturity phase, with a focus on product, manufacturing and business model refinement.

An emerging technology has to negotiate a path through these phases, and overcome the barrier of moving from one phase to another – the transition points. The emergence of new technologies and industries can be accelerated by speeding up the transition between phases, and there is compelling evidence that demonstrators enable this process [15].

4.2 Demonstrators

This strategy will focus on three types of demonstrator known to catalyse the transitions from science-dominated to the technology-dominated phase, and from technology-dominated to the application-dominated phase:

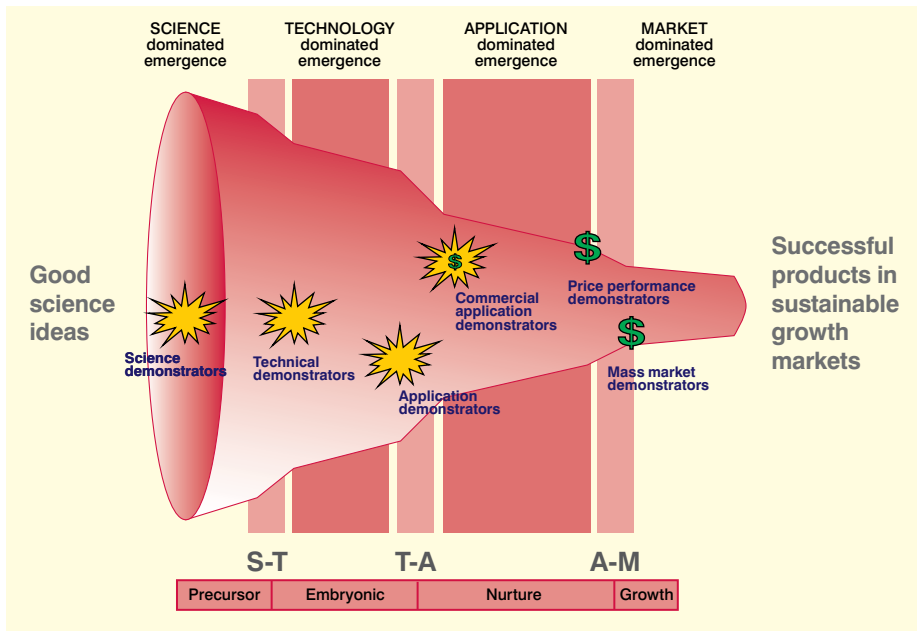
- **Technology demonstrator:** a prototype that shows that the technology is robust enough to be integrated into a functional system. It is associated with the end of the science-to-technology transition, and the start of the technology-dominated phase.

- **Application demonstrator:** this demonstrates the potential functional benefits of a system under non-laboratory conditions to internal and/or external investors. This is linked with the end of the technology-dominated phase and the start of the transition to the application-dominated phase.

- **Commercial application demonstrator:** this shows performance and functionality to customers/early adopters, and demonstrates the potential to create a sustainable business venture within a growing market. This is associated with the end of the technology-to-application transition, and the start of the application-dominated phase.

Depending on the complexity of the system environment of the technology and/or application, one or more prior 'technical demonstrators' may be necessary during the technology-dominated phase. This could be to address system deployment issues (for example, systems components and modules). Similarly, in the application-dominated phase one or more prior application demonstrators may be needed to address environmental or real-world performance.

Figure 4: The Industrial Emergence Funnel [18], showing the key demonstrators at the transitions between emergence phases



During the commercial application-dominated phase, additional commercial application demonstrators (for example, demonstrating issues such as manufacturability, market acceptance and regulatory compliance) may be needed to address customers' and investors' concerns about commercialisation and market readiness.

4.3 Evaluating emerging technologies

We have a clear opportunity, working with partner organisations, to help drive faster and more effective commercialisation of emerging technologies by investing in demonstrators within the phases and at the transition points.

With so many opportunities arising from such a strong science base it will be impossible for us to support everything. We will need to evaluate the candidate technologies quickly and ensure that those that fail do so at low cost.

We will use the 'funnel' model proposed by O'Sullivan and Phaal [18] to progressively evaluate and select from the candidate emerging technologies, and focus on those with the greatest potential to create value for UK businesses. Over the next few years, as we implement our strategy, the funnel will become populated with real technologies and possibilities for future growth. Figure 4 shows the Industrial Emergence Funnel that results from this evaluation, with the main phases and transition points highlighted.

5. Strategy implementation

This *Emerging Technologies and Industries Strategy* addresses the challenges to commercialising emerging technologies within the context of the strategic framework.

The four elements in our strategy are to:

- invest in technology demonstration
- build critical mass
- create a coordinated programme
- build and nurture capability.

Our overall approach is to catalyse the emergence and commercial application of more new technologies, and to connect all the key agencies involved to focus support on those technologies that have the greatest potential to create value in the UK.

The strategy and associated activities are designed to fit with later-stage support such as knowledge transfer networks and collaborative research and development schemes, which are available as technologies become more mature and as the business opportunities move closer to market. This strategy will therefore build a greater continuum of support for technologies with disruptive innovation potential that may take many years to reach the market.

5.1 Invest in technology demonstration

The purpose of this strategy is to accelerate the commercial exploitation of new and disruptive technologies, arising from the science base, for the benefit of the UK. A retrospective analysis of successful disruptive technologies [15] has shown how demonstrators played a crucial part in their journey to market. One of the rate-determining steps in commercialising technology is the transition between the different phases of emergence.

We will: invest in demonstrators to speed up the transition between the different phases of technology emergence to accelerate commercialisation, and to increase the likelihood of creating major new industries. We will focus on three main types of demonstrator known to catalyse the transitions from applied science to the technology-dominated phase, and from technology to the application-dominated phase:

- technology demonstrators
- application demonstrators
- commercial application demonstrators.

Our investment will be in the form of grants tied to specific outputs in terms of actual demonstrators. We expect the level of investment for each award to increase from technical to application demonstration as the challenges become more difficult. We will encourage many ideas to undergo technical demonstration as this is the critical first step, and we expect there to be a high failure rate.

We will: support early market and business involvement to ensure that the outputs have the greatest chance of attracting investment and moving forward to commercialisation.

We will: work closely with agencies that support related activities, such as the Research Councils Follow-on Fund and regional schemes, to ensure that we provide the best overall framework for technology demonstration.

5.2 Build critical mass

As technology demonstrators emerge and their potential can be better judged it is important to take steps to build critical mass in those areas of greatest promise. Matching technologies to markets is now recognised as a key process for successfully commercialising radical technologies [12]. It is through this process that emerging industries are nucleated in the form of companies, clusters of companies, and emerging value chains, and start to generate revenue around early products.

We will catalyse this process in three ways:

We will: take steps to bridge the gap between the various types of technology demonstrator and the market. IKCs are a good vehicle for driving technology and matching innovations with customers in high-potential, broad areas of technology.

We plan, in partnership with EPSRC, BBSRC and other research councils, to increase the number of IKCs and align them more closely with emerging technology areas of major strategic importance for the UK.

These IKCs will form the basis of innovation ecosystems, bringing together people with the right technical, business and commercialisation skills in a flexible, highly entrepreneurial environment. They will create strong connections with potential customers, existing industry and investors, and will develop compelling market-led strategies for commercial exploitation.

We will: identify, with the Ministry of Defence, Department of Health and other government departments, key areas of future procurement that are aligned with emerging technologies, and these will be targeted within the SBRI scheme.

In this way we will support small new companies, which play a special role during the early stages of commercialising disruptive innovations.

We will: work closely with the investment community to encourage greater early-stage investment in companies driving disruptive innovations.

The best way we can contribute to tackling the equity gap is through making such investments more attractive, not through setting up a new source of capital. Our approach will therefore be to help lower the risk and increase deal flow by supporting high-quality demonstrator and IKC programmes as described above.

While we consider that increasing the availability of equity funding is important, we believe that other organisations are better placed in terms of expertise to implement this approach. We will consult the investment community to ensure that the outputs of these programmes are aligned with their expectations in terms of the degree of confidence and understanding of the business proposition required at this stage.

5.3 Create a coordinated programme

The above interventions will stimulate the emergence of new technologies and the early matching of technologies to markets. They will help to create a pipeline of technologies at different stages of development. Using these as a basis:

We will: build a coordinated Emerging Technology Programme bringing together different elements of UK activity to establish a competitive position and create significant value for the UK in new high-growth markets and industries based on emerging technologies.

This programme will bring together, and will be underpinned by, public and private sector expertise, and will coordinate the actions of the various agencies involved to enhance their impact. The programme will stretch from the science base to wealth generation by business and will progressively focus on the areas of greatest national significance.

We will: establish an Emerging Technologies and Industries Steering Group to build consensus across agencies on decision-making and allocating resources.

The steering group will comprise senior representatives from business and the public sector agencies involved, and will include academia and the investment community. It will be chaired by an independent person who is passionate about technology and innovation, and who has outstanding leadership qualities.

The steering group will:

- help identify emerging technologies with the potential for disruptive innovation where the UK has a leading capability
- highlight technology areas with the potential to become IKCs
- provide individual resources and expertise in an aligned way to maximise their collective impact and realise value from new growth sectors for the UK
- help create new industries from the technology advances
- give guidance to the Technology Strategy Board on the wider Emerging Technology Programme.

A major function of the steering group will be to build consensus across the various public and private sector bodies on the prioritisation of emerging technologies. This will enable resources and expertise to be aligned more effectively at different stages to maximise their impact and ultimate value creation. This will lead to the creation of a national portfolio of emerging technologies from which future industries will arise.

The steering group's work and role will span the process of technology commercialisation, from first technology demonstration to the point where there is evidence of a nascent growth sector in the market. The steering group will build shared ownership of technologies across lead agencies and will anticipate future needs so that a continuum of support can be provided. It will put in place criteria and processes to prioritise technologies, monitor progress, adjust support, and realise economic and social value.

The steering group will start by identifying all the technologies that may lead to disruptive innovation and where the UK has competitive strengths (the 'long-list'), and will work towards a prioritised 'short-list' that has shared ownership and will drive the alignment of resources.

The desired outcome from this intervention is that in 10 years the UK will be poised to lead at least one major new industry, worth in excess of £1bn.

5.4 Build and nurture capability

In developing this strategy we have been greatly helped by academic research into the commercialisation process and the barriers and enablers that can be used to guide progress. Our aim is to make the UK a leading practitioner in commercialising emerging technologies, and to build its strength as a centre of excellence in this sphere. We believe this will help to attract overseas investment as confidence in our capabilities grows.

We will: define the types of skills that are critical for success at different stages, and will identify important gaps and ways to improve capability in the UK.

We will: monitor and study the impact of our interventions on the development of future industries from emerging technologies.

It is not enough to have the most exciting technology ever invented. It is people, and the right sort of people, who turn great ideas into commercial successes.

A set of diverse skills is required, from market analysis to technology development, and from intellectual property management to business modelling. We want to have a complete definition of these skill sets and to know when in the process they are needed. We will then work with partner organisations to identify where there are gaps and where we need to build capability through training or other initiatives. We will also use this information to guide IKC directors in the types of people they should recruit into their teams when establishing future IKCs.

This will link into and support the work of the Emerging Technologies and Industries Steering Group. It will help to further develop investment mechanisms, and to evaluate the steering group's work. It will also help to benchmark the UK's activities against best practice elsewhere, and to introduce new insights that may improve future effectiveness.

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