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Department for Business Innovation & Skills

Our plan for growth:

science and innovation

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December 2014

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science and innovation

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Foreword

Scientific endeavour is inherently worthwhile. It expands the frontier of human understanding. Whether exploring the first moments of the universe, or the deep structure of matter, or the power of genetic code, Britain will continue to take the lead in pursuit of the fundamental scientific challenges of our time.

Science and innovation are also at the heart of our long term economic plan. The UK's science base is extraordinary – our cutting edge research base is world leading, our universities are world-class, we develop and attract the world's brightest minds and we are second in the world when ranked by Nobel prizes. Science is one of our clear comparative advantages in the global race.

However, we have to build on these advantages. The UK has historically invested less in research and development than our competitor nations. Addressing this crucial challenge requires both public and private sector commitment as we continue the broader work of economic recovery and rebalancing. Businesses that invest in research and other forms of innovation have higher productivity, create high quality jobs and are more likely to export. Our mission is to establish the UK as a world-leading knowledge economy.

The UK's ability to capitalise on its cutting edge science base will be critical to our future prosperity and societal wellbeing. There are big opportunities (such as the burgeoning potential of genomics) but also big challenges (such as around antimicrobial resistance). We must rise to these challenges by supporting innovation and the transformation of our cutting edge science into new products and services. This will create new jobs, innovative businesses and allow the UK to take the lead in new markets.

That is why we have prioritised science and innovation spending in difficult times. But for the UK to stay ahead, we must plan ahead. So we are committing £5.9 billion capital to support scientific excellence out to 2021: the most long-term commitment to science capital in decades. And that is why we are strengthening our partnerships between the public and private sector, epitomised by the Industrial Strategy and the 8 Great Technologies.

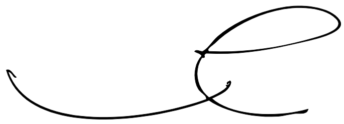
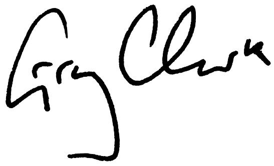
We are making a conscious choice of priorities for the UK, building on our core strengths. So excellence is at the heart of this strategy. So too are the core principles which will help meet the challenges ahead – agility; collaboration; the importance of place and of openness.

We therefore commit a total of £2.9 billion to fund large scale investments in science. Following the science capital consultation, this grand challenges fund will be used to deliver a first wave of projects worth a total of £800 million. We are funding new facilities in advanced materials centred in Manchester, a new high performance computer collaboration with IBM at the Hartree Centre, and we are taking the lead in the next European Rover mission to Mars. These are just three examples where we are backing our priorities to stay at the cutting edge of world science.

We must also recognise the vital role that commercialisation of science and new technologies play in our future growth. We will continue to provide businesses with the environment and infrastructure necessary to generate large scale innovation in areas where there are higher risks and wider benefits. The investment required to keep us at the forefront globally must be a Government priority, but it must also be a priority for our businesses. So we will expand our network of elite technology and innovation centres with two more Catapult centres in Energy Systems and Precision Medicine next year. We are also providing over £60 million to our established High Value Manufacturing Catapult centre and creating a £28 million National Formulation Centre. We will continue to expand the network gradually as the fiscal position improves. And we are renewing our efforts to help high growth businesses access finance by boosting our flagship British Business Bank with additional funding.

Of course, our science and innovation strategy can only be as good as the people that it can attract, educate, train and retain. That is why we are investing across the skills pipeline, from primary school to university. In particular, we are announcing bold new support for postgraduates in order to address the next frontier in higher level skills.

But the government cannot do this alone. Science and innovation is the result of partnerships with business, with charities, individuals, and with our global collaborators. This strategy will only be effective if all of these partners work individually and collectively to deliver its common aims. We welcome the many contributions that these partners have made through the consultation and wider engagement, and we look forward to working with you to deliver this strategy together.

		
George Osborne	Vince Cable	Greg Clark
Chancellor of the Exchequer	Secretary of State for Business, Innovation and Skills	Minister of State for Universities, Science and Cities

Executive summary

The United Kingdom has a proud history in science and innovation. Over many years British scientists have made discoveries that have opened the eyes of humanity to secrets about ourselves, our world, and places and times beyond what we knew before. British innovators have applied these ideas – and those of others – to transform the way we live now.

We are one of the most prolific nations on earth for scientific discoveries, and we regularly attain a level of excellence, and therefore influence, beyond what others achieve. Although we collectively invest less than some other nations in research and development, we have become one of the countries recognised as a particularly fruitful place in which to innovate and we obtain high returns for every pound invested.

While the importance of science and innovation go beyond the economic – they elevate and improve mankind and offer rewards that are beyond price – any nation should ask itself how it will earn its living in the future. The answer must be to build on our strengths, where those strengths are likely to be sources of advantage in the future. That is why science and innovation are at the heart of our long-term economic plan.

Our aim is to be the best place in the world for science and business. Our plan to achieve this has 6 elements:

1. Deciding priorities
2. Nurturing scientific talent
3. Investing in our scientific infrastructure
4. Supporting research
5. Catalysing innovation
6. Participating in global science and innovation

Looking ahead requires that we identify the themes that a plan must address if it is to be successfully aligned to the changing possibilities that emerge. These themes underpin each of the elements set out above:

- the importance of achieving excellence
- the imperative to operate at a quickening pace and show agility to seize new opportunities
- the need to accommodate and foster higher levels of collaboration between disciplines, sectors, institutions, people and countries
- the need to recognise the importance of place, where people and organisations benefit from mutual proximity
- the modern demand for openness and engagement with the world

Deciding priorities

The wealth and breadth of possibilities in science and innovation mean that we cannot hope to do everything equally well. We need to choose our priorities.

This choice will not be made mainly by Government, but we will have an important role to play in securing the UK's strengths. We will make strategic choices and bring together the best minds, research institutions and businesses to help solve the great challenges of the day.

Looking forward, the 8 Great Technologies and the Industrial Strategy will continue to support science and innovation, and our growth ambitions.

Nurturing scientific talent

Our science and innovation can only be as good as the people that it can attract, educate, train and retain. We set out here a range of measures which will develop and support the brightest minds through the pipeline from primary and secondary school, further and vocational education, undergraduate and postgraduate study, and training into the workplace.

Schools: We will take action to increase the quantity and quality of STEM teachers through £67 million of new programmes. These will train up to 17,500 maths and physics teachers over the next Parliament, on top of existing plans: adding to the skills of up to 15,000 existing non-specialist teachers and recruiting up to 2,500 additional specialist maths and physics teachers.

Vocational education: We will deliver more Higher Apprenticeships at the levels and in the sectors where employers believe the need is greatest. We will also ensure the right provision is in place to deliver the training these apprentices and other students will need, by establishing National Colleges in key STEM sectors such as Digital Skills, Wind Energy, and Advanced Manufacturing.

Higher education: We will take new steps to support those who wish to attain a postgraduate qualification. We will introduce a new offer of income contingent loans for those aged under 30 wishing to undertake a postgraduate taught masters in any subject. These loans, of up to £10,000, are planned to be available from 2016-17 and will be repaid concurrently with undergraduate loans. The loans are designed so that, on average, individuals will repay in full, in recognition of the high private return to individuals, but they will beat commercial rates.

Workplace: We will develop a dedicated platform to match female STEM graduates to return to jobs in industry following career breaks, and to provide them with advice and information about the support on offer.

Investing in our scientific infrastructure

Cutting edge science cannot happen without modern infrastructure. That is why we have committed £5.9 billion to science capital from 2016 to 2021. This is the longest commitment to science capital in decades. We have consulted broadly in order to determine how best to allocate these funds, following the principles set out in this strategy.

We will therefore invest £2.9 billion towards scientific grand challenges. We have already committed £1 billion of this to projects such as the new Polar Research Ship and Square Kilometre Array. And we will invest a further £800 million to fund new projects. These include, subject to satisfactory business cases, investments of up to:

- £235 million in the Sir Henry Royce Institute for advanced materials

- £113 million towards big data at the Hartree Centre, Daresbury
- £95 million for European Space Agency programmes, including Britain's lead role in the next European Rover mission to Mars
- £31 million for a new Energy Security and Innovation Observing System, including a subsurface centre at the former Shell site in Cheshire
- £60 million to extend the capabilities of the National Nuclear Users Facility
- £20 million towards an innovation centre on ageing, in Newcastle

We can also confirm the £42 million Alan Turing Institute will have its headquarters at the British Library in London.

We will launch a process of international peer review on further proposals received through the consultation, and will take a decision on whether to fund them at Budget 2015. We will introduce a capital agility fund, to respond to grand challenges as they emerge. This will allocate a further £900m to address the great mysteries and opportunities of our time, whether domestic, international, or in space.

On top of this, we will invest £3 billion to support individual research projects and our institutions' world class laboratories, and provide funding for our international subscriptions. Over half of this will be subject to competition, to ensure excellence is rewarded wherever it is found.

Of course, capital investment alone is not sufficient to ensure our research infrastructure is able to continue to deliver world class outputs. We recognise that our science base requires adequate resource funding, and will give full consideration to these requirements when we take a decision at the Spending Review next year.

Supporting research

Any strategy for science and innovation needs to consider the core principles which underpin the UK's approach to supporting research, the distribution of funds and the funding mechanisms.

There is an opportunity for us – both the Research Councils and UK Universities - to build on our existing strengths.

We have asked the Higher Education Funding Council for England (HEFCE) to assess higher education institutions' (HEIs') performance in knowledge exchange activities to identify examples of good practice.

We have also asked Sir Paul Nurse to lead a review with the Research Councils in order to build on their firm foundations. This will report to the Chancellor, the Business Secretary and the Minister for Science. It will look at how Councils can evolve to support research in the most effective ways by drawing on a range of evidence, including international comparisons and the views of the scientific and business communities, and will report by summer 2015.

Greater collaboration also has to be built on a basis of greater openness and transparency. HEFCE will be considering how to reward open data as part as part of the future REF assessments subject to the evaluation of the REF 2014 review.

We also need to consider the R&D needs of government departments. These needs are commissioned from their individual R&D budgets. We will examine how to ensure that R&D spending by departments is properly prioritised against other capital investment spending,[1] for example by considering controls that can be placed on this spending to ensure that valuable R&D is not unduly deprioritised in favour of short-term pressures. We will report on this by the next Spending Review.

Catalysing innovation

The UK's research base and business environment, with its open, competitive market and trusted institutions, supports the growth of all businesses, especially those that innovate. We will build on this strength by reinforcing each element of this innovation ecosystem.

The Catapult network will expand with two more Catapults for Energy Systems and Precision Medicine due to open next year.

We will provide £61 million funding to the High Value Manufacturing Catapult to meet increasing demand and provide outreach and technical support to SMEs.

We will invest £28 million in a new National Formulation Centre as part of the High Value Manufacturing Catapult in Sedgefield, to drive manufacturing-based growth and help rebalance our economy. We will continue to expand the Catapult network gradually as the fiscal position improves.

Centred around the British Business Bank, we will continue to make finance markets work better for innovative smaller businesses. For instance, the Venture Capital Catalyst Fund, which increases the availability of later stage venture capital, was extended by £100 million this year. And at Autumn Statement this year we announced a new commitment of £400 million over three years to extend the Bank's flagship venture capital programme, Enterprise Capital Funds, which will allow Funds to make larger investments of up to £5 million in innovative smaller businesses.

We will invest an additional £9 million towards driverless car testbeds, enabling four locations to trial the technology from next year.

Participating in global science and innovation

Science and innovation are increasingly international endeavours. That is why this strategy must have a global reach.

We will continue to promote the Newton Fund to support the development of scientific excellence and build scientific partnerships of the future.

We will use our participation in the European Research Agency, the G7, G7+5, G20 and our Presidency of the EU in 2017 to demonstrate our leadership on topics such as open access and infrastructure where the UK is at the forefront.

We will provide further support to UK universities and research institutions to access some of the research elements of the $140 billion international aid funding from multilateral banks, UN agencies and other donors.

[1] Following the implementation of ESA10 accounting standards by the ONS in September 2014, all R&D expenditure will be treated as capital in the national accounts

Introduction

Excellence. Agility. Collaboration. Place. Openness.

"Great discoveries and improvements invariably involve the cooperation of many minds. I may be given credit for having blazed the trail, but when I look at the subsequent developments I feel the credit is due to others rather than to myself".

Alexander Graham Bell

The United Kingdom has a proud history in science and innovation; from Turing to ARM, from penicillin to GSK. This 10-year strategy for science and innovation builds on the great traditions of British science and enterprise. It comes at a critical juncture for science, technology and our economy. The opportunities are extraordinary but so are the challenges. In basic science, our scientists, working in international facilities such as the large hadron collider, are revealing the inner secrets of the atom and the first milliseconds of the universe. Genome science is exploring another 'big bang': how humans colonised the planet. We are learning in unprecedented detail the evolutionary relationships of the extraordinary diversity of life on earth, revitalising the science of taxonomy. Information technology underpins all of the sciences and is revolutionising how we do business, communicate, share knowledge and navigate the world.

However, the challenges are also extraordinary. They are challenges of large numbers. The effect of seven billion human beings on the planet is depleting natural resources. At the same time, we are emitting more than 10 gigatonnes of carbon into our atmosphere each year by burning the fossil remains of ancient organisms, which accumulated over millions of years, in the form of coal, oil and gas.

There is also a challenge of pace. Bacteria and other infectious agents, that can divide every 30 minutes or so, have a huge competitive advantage over human organisms with a generation time of approximately 25 years. So the risks of pandemic infections and the development and spread of antibiotic resistance are dramatically increased by large human populations that can travel round the world at unprecedented speeds and by the other species that we transport around the world, deliberately or accidentally.

Seven billion humans can only live on this planet because we have modified our environment by the application of science, engineering and technology. To sustain our way of life and improve it, we need to continue to develop and apply all of the sciences. This requires all of the sciences, what the Germans would call Wissenschaft, the natural, physical and social sciences, engineering, technology, the arts and humanities. From this point this strategy uses the word science to encompass all of the above.

There is a challenge of collaboration. Science and innovation are global and have transformed the world economy since the industrial revolution. Steam power, electrification, information and communication technologies have changed the way we live and underpinned the fastest period of economic growth in recorded history. But the new economic order presents a new set of challenges. The competition for the best scientific minds and entrepreneurial talent is global. We have much to gain from working with other countries, but we must also build on our own strengths and tackle our weaknesses so we can compete with them.

If we are to become a flourishing knowledge economy, we have to build on our long-standing scientific advantages and innovate. But innovation requires investment. Countries around the world recognise that science and innovation is the right path for sustainable growth. Emerging economies, like China, have been steadily increasing investment in their knowledge base, already reaching 1.8% of GDP in research and development 2012. The US invested 2.8% of GDP, the OECD average is 2.4% and the EU average is 2%. In the UK, total investment was 1.7% of GDP in 2012, and this level has been stable since the early 1990s. Our ability to develop and commercialise new ideas, products and services is critical to our economic future and to providing jobs. Investment in our knowledge base is a crucial challenge for both government and business.

These opportunities and challenges provide the wider context that frames the science and innovation strategy for the UK for the next 10 years.

Principles

The fact that we have a strong record in science and research, and in many areas of its application, does not mean that we can be complacent about the future.

The challenge for any forward look is to build on the things that have contributed to our strengths that are likely to endure into the future, but at the same time to be open to the emerging demands and new possibilities that will determine future success.

The responses to the capital consultation from individuals and institutions in almost every area of science and research were characterised by five pervasive themes. These have greatly influenced the policy directions we set out here.

These themes are:

- Excellence
- Collaboration
- Agility
- Place
- Openness

Excellence

The standing of British science, and the individuals and institutions that comprise it, is rooted firmly in excellence. The fundamental sources of that excellence are timeless: the brightest minds, given the best education, in environments that enable the pursuit of important questions and the application of the results.

Insisting on excellence has become a more marked feature of our scientific and innovation landscape over recent years. The Research Excellence Framework and its predecessors are an example of how our institutions have been geared to compete according to the contribution to excellence. Much of the confidence in standards of excellence promoted comes from decisions being informed by peer-review: leading experts assessing the quality of proposals and work. The contribution to excellence must be robustly maintained at every level of UK science and innovation, through the work of the Research Councils, Learned Societies, Industrial Sector Leadership Councils, and Boards of the Catapults.

Excellence cannot be achieved without resources. In industry, in government and in independent institutions, pressures for cost savings are always present – and efficiency and effectiveness must always be pursued. But we recognise that investment, from all sources, in science and innovation must continue to be a priority.

Collaboration

If excellence has a strong element of robust competition in its essence, there is also a growing role for cooperation.

Science increasingly does not respect boundaries. That is true of traditional disciplines – many of the most exciting discoveries defy categorisation into the established specialisms. It is true of departmental or institutional boundaries – different universities and research institutions are working with each other in collaborative initiatives and projects.

The scale of many of the best experiments now demands extraordinary collaboration between scientists because infrastructure needed to undertake many experiments costs so much that national, or in some case international, facilities are the only affordable solutions.

It is true of sectors – universities and public research institutions are increasingly working jointly and closely with industry on particular technologies and through science parks and incubators and catapults.

It is true between nations – almost half of UK research articles involve authors of more than one country; many of our leading academics and industrialists have served in positions overseas, and foreign nationals occupy many positions of leadership in our own institutions. We must ensure that our policy and institutional arrangements advance, and do not constrain, opportunities for cooperation.

Agility

Much of science, research and innovation depends on confidence in long-term arrangements. Scientific infrastructure and many research projects endure not just for years, but often for decades. One of the purposes of this strategy is to commit to the continuation of the long-term arrangements that the UK enjoys, and for which there has been a broad political consensus for several years.

However, in most scientific disciplines and in the field of innovation, the pace of discovery and application is palpably quickening. We must be able to respond quickly and effectively to the array of opportunities and challenges that face us, from emerging infectious diseases to emerging financial technologies. New discoveries made today may offer opportunities for research and applications and education that could not be envisaged before such breakthroughs had been made. Our arrangements – institutional, funding, educational and collaborative – must include the agility to be able to respond positively and at pace to emerging opportunities. This need for agility is accompanied by a competitive imperative: if we fail to move quickly to secure our position in a globalised world, then it is highly likely that other countries, other institutions, or other companies will do so ahead of us. We not only run the risk of missing out on new opportunities, but also of losing the positions of strength that we have today.

Place

Science and innovation, and the education and training of future academics and practitioners, is about ideas and thought. But, for the most part, ideas and their application and exploitation are not formed in the ether, but in particular institutions and companies which are physically present in particular towns and cities. Place can make a difference – the clustering of resources and industries in specific locations can provide a conducive – and, in some cases, essential – context for success. Cities, like universities, exist to bring people together so that they collaborate with each other and make advances that would not be possible in isolation.

Science and innovation policy has not always recognised the contribution that place can make to fostering and sustaining excellence. Likewise, policies for local growth have not always recognised the contribution that science, research and innovation can make to local and regional economies.

Increasingly that is changing. The old 'town-gown' divide is receding into history. The unarguable success of Cambridge, for example, illustrates the shared interests of the local economy and institutions of research, education and innovation contained within it. Significantly, every one of 39 Local Enterprise Partnerships (LEPs) has a Vice Chancellor or a senior Higher Education representative on its board.

An approach that encourages such collaboration is strongly in the interest of institutions and places – and the nation as a whole.

Openness

As boundaries between disciplines, institutions and sectors dissolve, science and innovation is becoming, as in the title of a Royal Society report, 'an open enterprise' – less and less a closed community and more and more engaged with the world. Public interest in science and innovation is high and rising, thanks to public and private programmes supporting public engagement, and brilliant high-profile successes such as the Rosetta mission. 'Citizen Science' is making important contributions to fields in astronomy and epidemiology, by crowd-sourcing data collection and the analysis of everything from the structure of galaxies to the spread of ash-dieback disease.

Huge numbers of people are participating as research subjects in population studies such as the longitudinal cohorts for which the UK is famous – like the UK Biobank, which has half a million participants.

Technology allows openness and public scrutiny of research that was not possible until now – going far beyond the ability to share a published paper through open access; the data and the information behind the paper can be made available to all.

The public fund research through their taxes and, without public support, many technologies and scientific ideas would not fulfil their potential. Researchers and innovators must be prepared to engage in discussion with all those who support their work.

These changes open up science to democratic scrutiny in new and exacting ways. Science can benefit from coming under challenge. For instance, less latitude is now given to non-reproducibility of scientific studies, driving greater rigour. However, in the words of Sir Paul Nurse, it can also be true that "society wants clear and simple answers when it is not possible to provide them".

The vision

This government and its predecessors have done much in recognition of the crucial role that science and innovation play in our economic prospects and well-being.

In the course of this government, the tax regime has been strengthened by increasing the competitiveness of our R&D tax credit schemes, expanding the tax-advantaged venture capital schemes, and introducing the Patent Box. Alongside tax incentives, and despite the difficult fiscal period, the ring-fenced £4.6 billion per annum funding for science and research programmes has been protected in cash terms. Science capital funding was raised in real terms, from £0.6 billion in 2012-13 to £1.1 billion in 2015-16, and the long-term capital budget for science has been committed into the next Parliament, which will grow in line with inflation to 2020-21. The budget of Innovate UK (formerly the Technology Strategy Board) was increased by £185 million, taking it to more than £500 million for 2015-16. A concerted and sustained effort has been made to improve the study of STEM subjects across the education pipeline, increase the rigour of the curriculum and accountability in schools, make vocational education and apprenticeships more responsive to the needs of employers, and reform investment in undergraduate education.

This commitment to science and innovation has been strategic and long-term. 8 Great Technologies where the UK has the potential to be world leading have been identified and significant investments have been made. The Industrial Strategy has set a whole of government approach in partnership with business and the voluntary sector. A network of elite technology and innovation centres, the Catapults, has been created and is progressively bringing together this national ambition. These efforts have started to pay off. The existing seven Catapults are widely supported by the business community.

Our vision is for the UK to be the best place in the world for science and business. The next sections set out the action plan that will deliver this vision. This strategy is about getting the best possible outcomes from science and innovation. Further decisions on public investment in science and innovation, building on those made by this government, will be made after the General Election. This government is committed to delivering a sustained and balanced level of investment, having regard to the fiscal challenge.

The actions are not for government alone because, while our actions are necessary, they are far from sufficient to achieve the vision. This strategy is for government, for business, and for the education system. It can only deliver if it is owned and supported by the science and innovation communities in academia and business, and by all those who work alongside them.

1 Deciding priorities

Identifying and responding to scientific, economic and social challenges

"Most modern technologies are created by bringing together and evolving capabilities which already exist. The genius lies in the way they are brought together and improved. There are innumerable examples to illustrate the process. The long sought mobile phone was made a reality by bringing together mathematical concepts of cellular networks, advanced ultra-high frequency radios, low power microprocessors, and improved batteries. It was not invented, although buried within it are innumerable inventions".

Lord Broers, 2005 Reith Lecture.

The UK's position:

- The UK ranked 9th in Global Competitiveness Index (ranking 12th on the Innovation pillar) in 2013-14, up from 13th in 2009-10
- However, the UK ranks 7th in the world in terms of its overall level of R&D spending, with 3% of the global total
- Of the productivity growth that took place in the UK between 2000 and 2008, nearly one third was attributable to changes in technology and other forms of innovation

Key actions taken by this government:

- Identified 8 Great Technologies where there are significant opportunities for the UK
- Invested £600 million new investment in these 8 Great Technologies, £90 million in graphene and £270 million in quantum technologies
- Developed sector strategies for innovation-intensive industries, in partnership with business, through the Industrial Strategy
- Set up a network of elite technology and innovation centres, the Catapults, that focus on sectors or challenges with large market potential and where the UK has a global research lead
- Supported universities in a 3rd mission to deliver economic growth, alongside their traditional roles of teaching and research

Next steps:

- The government will continue to have an important role to play in securing the UK's strengths. We will make strategic choices and bring together the best minds, research institutions and businesses to help solve the great challenges of the day
- We will help catalyse long term investment and transmission mechanisms between the science and the industrial strategies to operate effectively
- Looking forward, the 8 Great Technologies and the Industrial Strategy will continue to support science and innovation, and our growth ambitions

Introduction

1.1 It is not the job of a strategy for science and innovation that will last for 10 years to specify in detail the scientific questions to be answered. And when it comes to fundamental research it remains the case that those at the 'coal face' of research are best placed to identify the key questions and opportunities to advance knowledge. However, many of the 'grand challenges' for society, the ultimate customer for research, are obvious: developing cost effective low carbon power sources and storage solutions for energy-hungry economies; harnessing and managing scarce resources; improving human, animal and plant health.

1.2 Grand challenges, by their nature, rarely have simple or single solutions. Their solution almost invariably requires advances in techniques and technology, and the commercialisation of these advances. So the revolution in biological understanding of the 20th century was underpinned by new techniques to sequence proteins and nucleic acids, and ever more powerful microscopes and crystallography to visualise the structure of organisms at the level of the organ, the cell and the molecule. It was scientists working at the interfaces between biology, chemistry, physics, engineering and mathematics who made these great advances.

1.3 So how should government, academia and business identify the key questions and priorities for research and for innovation? The answer is by collaboration, horizon scanning and foresight work, pulling together and sharing intelligence. Any decent scientist is always scanning the horizons of science, to see what others are doing and what is appearing in the distance. And every good business must be aware of the competitive environment and new market opportunities or disruptions. The government and policy makers must scan many horizons if we are to do their best for our citizens.

1.4 Intelligence sharing on emerging topics, opportunities and challenges is co-ordinated in government through joint working by the Research Councils, Innovate UK, and the Government Office for Science. The best policymaking requires the best analysis and evidence. There are many areas where science impinges on government policy, and whilst it is not the job of scientists to make public policy, it is important that they provide the best evidence to support horizon scanning and to help policy makers make the best decisions. As part of this strategy all of those involved in the research endeavour are expected to work together to define key challenges for science and society and to collaborate to tackle them.

Backing emerging technologies

1.5 New technologies continue to be developed and we have worked with the research and innovation community in the UK to identify 8 Great Technologies, which were selected by analysing UK scientific and business capabilities and are central to our Industrial Strategy. Each technology is an area in which the UK has world-leading research, a range of applications across a spectrum of industries and the potential to be at the forefront of commercialisation.

The 8 Great Technologies

At Autumn Statement 2012, the Chancellor of the Exchequer announced the investment of an additional £600 million in supporting 8 Great Technologies, where the UK could lead the world in their development – drawing on advice from the Research Councils, Innovate UK and the foresight exercises of the Government Office for Science.

1. Big data and energy-efficient computing: The data deluge will transform scientific inquiry and many industries too. The UK can be in the vanguard of the big data revolution and energy-efficient computing.
2. Satellites and commercial applications of space: There is a surge in data coming from satellites which do not just transmit data but collect data by earth observation. We have opportunities to be a world leader in satellites and especially in analysing the data from them.
3. Robotics and autonomous systems: There are particular challenges in collecting data from a range of sources in designing robots and other autonomous systems. We can already see that this is a general purpose technology with applications ranging from assisted living for disabled people through to nuclear decommissioning.
4. Synthetic biology: Modern genetics has emerged in parallel with the IT revolution and there is a direct link – genetic data comes in digital form. The future is the convergence of "dry" IT and "wet" biological sciences. One of the most ambitious examples of this is synthetic biology – engineering genes to heal us, feed us, and fuel us.
5. Regenerative medicine will open up new medical techniques for repairing and replacing damaged human tissue.
6. Agri-science: Although genetics is above all associated with human health, advances in agricultural technologies can put the UK at the forefront of the next green revolution.
7. Advanced materials and nano-technology: Just as we understand the genome of a biological organism so we can think of the fundamental molecular identity of an inorganic material. Here too we can increasingly design new advanced materials from first principles. This will enable technological advances in sectors from aerospace to construction. Quantum photonics is an exciting area where advanced materials and digital IT converge.
8. Energy and its storage: One of the most important applications of advanced materials is in energy storage. This and other technologies will enable the UK to gain from the global transition to new energy sources.

Each of these technologies has very high potential for global markets and long-term benefits for society, and capable of wide-ranging application across industries and sectors to create new products and services.

1.6 These 8 Great Technologies are summarised in the box above. Throughout this strategy, we propose further actions which entrench our continued commitment to these priorities.

1.7 But this list is neither exclusive nor exhaustive. There are many other important areas in which the UK excels such as graphene, where we have invested more than £90 million across the country to support existing research and create new infrastructure including three new graphene centres and two Centres for Doctoral Training. We have invested £270 million in quantum technologies to develop a national network of research hubs that will provide postgraduate skills, research and infrastructure, including a £50 million innovation programme to support business-led feasibility and demonstrator projects.

1.8 Not every scientific question requires new technology. There are many challenges that face the UK and nations around the world where new evidence is required to facilitate good policy making. Current infectious disease challenges include Ebola in Africa, tuberculosis in both humans and cattle and ash dieback. There are many other diseases of humans, animals and plants that are important for our health, wealth and the environment. Indeed the natural environment offers an vast array of scientific challenges varying from improved meteorological and climate prediction, to understanding the differing contributions of surface and ground water to flooding, or predicting and understanding the consequences of effusive volcanic eruptions. The digital revolution is generating an array of scientific questions varying from understanding the consequences of social networks to the implications of the World Wide Web for privacy and security. The list is endless.

Enabling the opportunities from emerging technologies to permeate all disciplines and sectors

1.9 Developing a new idea and technology provides the means to do new things, but it is not an end in itself. The scientific community around the world usually adopts new technologies at great pace and competes fiercely to apply these to hitherto intractable research questions. New technologies create new businesses and transform existing ones. Although we have an outstanding record of development of new technologies, the pace at which we exploit and commercialise the best of what is invented here and elsewhere in the world must increase. In the field of medicine, ultrasound scanning, CT scanning, MR scanning, protein and DNA sequencing, and monoclonal antibody technologies were all first developed in the UK.

1.10 Innovation requires much more than novel technology or research. Good ideas are the starting material, but progressing these needs a team of smart people with the right skill mix, and access to resources, expertise and facilities. Intellectual property and know-how need to be managed. Finance and financial skills are essential. And whether it is a manufactured product, software or a service, this needs excellent design, marketing and distribution.

1.11 It is industry, and organisations in the public sector, that generate economic benefit from science and technology investments, and creates jobs. We have worked with business and industry through Industrial Strategy sector councils to create 11 specific sector strategies, which are detailed further in the following chapters (see box on nuclear sector). All of these depend on science and innovation to develop and compete effectively in national and global markets, and attract investment to the UK. This needs long term investment, and for the transmission mechanisms between the science and the industrial strategies to operate effectively. This requires catalysis.

Nuclear

The UK was one of the early pioneers of the science and engineering of nuclear energy, but reductions in research and development in recent years had meant we were losing ground.

Nuclear has been an important contributor to our energy mix for decades, contributing up to 20% of our electricity supply. However, in recent years the position of the nuclear power industry in the UK has changed radically. The need for low carbon power sources, coupled with the need for energy security and reliable provision of electricity base load, has revitalised our need for long term nuclear power as part of a sustainable energy mix.

The revitalisation of the nuclear power industry offers important economic opportunities for the UK, which require unprecedented cooperation between government, industry and academia to be realised. This cannot be achieved without a clear strategy and leadership. The government and industry-led Nuclear Industrial Council (NIC) is driving forward an ambitious strategy for the sector, the flagship success of which will be the creation of the first new build plant in 20 years, Hinkley Point C. Knowledge management and an integrated approach can help enable the success of the Nuclear Industrial Strategy. Recommended by a review led by Sir John Beddington, the Nuclear Innovation and Research Advisory Board (NIRAB) brings together industry leaders, academics, government scientific advisors, Research Councils, Innovate UK, and the Nuclear Decommissioning Authority to provide a coherent view about future research priorities.

On the science side, we need to train new generations of scientists, technicians and engineers to design, regulate, build and operate new generations of nuclear power stations. We need to support research to develop the fuel cycles and the material and manufacturing science necessary to work safely with hazardous substances at high temperatures and pressures. The capacity of the UK Nuclear Regulator will need to be sufficient to meet the demands of assessing and approving the new designs for future reactors. On the industrial side, there are opportunities for design innovations, for example exploration of the technical and financial feasibility of the development of small modular nuclear reactors but businesses need to have confidence that there will be a predictable long term policy environment for nuclear power.

Industrial strategy and sector partnerships like the NIC are providing this long term stability and a forum for the timely information-sharing and coordination which are allowing UK businesses to position themselves as technology leaders.

2 Nurturing scientific talent

Ensuring that the world of science and innovation continues to attract and develop the brightest minds

"It [science] can arouse and satisfy the element of wonder in our natures. As an intellectual exercise it disciplines our powers of mind. Its utility and applicability are obvious. It quickens and cultivates the faculty of observation. It teaches the learner to reason from facts which come under his own notice. By it, the power of rapid and accurate generalisation is strengthened."

Natural Science in Education, The Thomson Report 1918

The UK's position:

- Take up of GCSE single sciences has increased from 112,000 in 2010 to 129,000 in 2014 in Physics, from 113,000 to 130,000 in Chemistry and from 116,000 to 133,000 in Biology
- STEM numbers in higher education have increased over recent years. For example, total UK domiciled first degree enrolments at English Higher Education Institutions (all years between 2003-04 and 2012-13) have increased in biological sciences (from 85,300 to 122,000), in physical sciences (from 37,700 to 52,700), and in maths (from 17,100 to 26,500)
- In 2011, the UK was ranked 2nd for graduation rates (out of 25 OECD countries) and the 2013 National Student Survey found that 85% of students were satisfied with their course
- However, in the 2012 PISA survey, the UK ranked 26th in mathematics and 21st in science out of 65 countries. England continues to perform at the OECD average in mathematics and reading, but significantly better in science. There has been no significant improvement in the UK's absolute performance in mathematics and science since 2006
- Only one in five A level physics students is female – a figure that has remained unchanged in the last 20 years

Actions taken by this government:

- The National Curriculum improved with new programmes of study for science at Key Stages 1 to 3 (a new programme for Key Stage 4 is to be introduced in September 2016)
- New GCSE content criteria for science changed to include an introduction to the human genome, life cycle analysis and space physics
- New science A level specifications to strengthen mathematical and quantitative content so that students have the necessary numeric skills for undergraduate study
- Bursaries increased for postgraduate teacher trainees in STEM subjects
- £7.2 million funding over 2014-16 to provide support to science teachers through the National Science Learning Network

- Implementation of the Richard Review to reform apprenticeships and introduced Higher Apprenticeships at levels 4-7 to deliver the higher-level technical skills employers need
- Establishment of high-status National Colleges, led by employers to deliver high level vocational education in strategically important sectors
- Cap lifted on student numbers, and provided £185 million funding to support the teaching of high cost Band B subjects (science, engineering and technology) in higher education – to increase the flow of highly skilled graduates going into strategically important sectors of the economy

Next steps:

- We have set out an ambition for the overwhelming majority of young people in England to study mathematics at least to age 18 by 2020
- We are allocating £67 million for new programmes to train up to 17,500 maths and physics teachers over the next Parliament, on top of existing plans
- We will encourage and support employers to develop and offer more Higher Apprenticeships in STEM areas
- We are establishing National Colleges in further key STEM sectors such as Digital Skills, Wind Energy and Advanced Manufacturing
- We will provide funding to HEFCE to work with the engineering profession to develop and pilot engineering conversion courses for non-engineering graduates
- We will fund independent reviews of STEM degree accreditation arrangements to improve quality and graduate employability, starting with Computer Science accreditation
- We will introduce a major new loan system for postgraduate students. For the first time ever, anyone under 30 who is accepted to study a postgraduate taught masters course will be able to access a £10,000 income contingent loan to help them to do so
- We will provide dedicated support for women to return to jobs in industry following career breaks

Introduction

2.1 Our science and innovation strategy can only be as good as the people that it can attract, educate, train and retain. Rigorous education and training add value to both individuals and the economy. Getting this right requires elements of both 'push' and 'pull'. On the push side we need to ensure that we provide the best education, training and career opportunities for future scientists. On the pull side, we need to ensure that these opportunities take into account the major trends in the requirements of the workplace. We need to ensure that we make the best of all our talents – dismantling the sometimes invisible barriers faced by women and other underrepresented groups.

2.2 Both 'push' and 'pull' speak to the importance of STEM skills. Producing more graduates and technicians with excellent STEM skills, including through apprenticeships, adds value to both the individual and the economy. Higher level skills both fill and create higher productivity jobs, and this is reflected the wage premium of those with STEM skills. However, despite increases in the number of people with these skills over the last ten years, a number of studies suggest that demand for STEM skills will grow, and that there remains a risk of a shortfall in supply.

2.3 So starting with the 'push', the recipe for attracting and developing the people to support the science and innovation strategy is as follows. The metaphor of the 'pipeline' is useful. This starts with primary education, proceeds through secondary and tertiary education, and continues with skills training into the workplace. Each of these will be considered in turn.

Schools

2.4 To meet demand for STEM skills over the next decade, we need a significant increase in the number of young people achieving high grades in maths and science at GCSE, so that more young people are better equipped for further study and work. We therefore need to start at the beginning of the pipeline: school age education.

2.5 Primary education provides the foundations of literacy and numeracy, combined with the social skills, curiosity and engagement necessary for good citizenship. Young people form preferences and aversions for particular subjects based on a mixture of aptitude and the quality of their educational experience. High quality exposure to STEM subjects must start at primary school and the options and opportunities should become increasingly 'tailored' at secondary school and through skills training, further and higher education.

2.6 A strong mathematics education is vital for all pupils in enabling them to take advantage of the opportunities available in today's fast-moving education and employment market. To support this, we are establishing a network of Maths Hubs across England backed by £11 million of funding. As centres of excellence, we intend that these outstanding schools and colleges will raise the standard of mathematics education by implementing elements of the Asian-style 'mastery' approach that has achieved world-leading success.

2.7 We have also set out an ambition for the overwhelming majority of young people in England to study mathematics at least to age 18 by 2020. We are developing Core Maths qualifications to support this ambition. These qualifications will be aimed at those students with a grade C or above in GCSE mathematics who choose not to take AS-A level mathematics as part of their 16-18 programme. These qualifications will build young people's confidence and competence in mathematical thinking and problem solving and build on new GCSE mathematics courses. Students will develop skills that industry and higher education have said are essential to future success and give them the chance to earn better salaries. We hope that, as these qualifications grow in popularity with students, universities and employers, they will pave the way for a future in which all students study maths until the age of 18.

2.8 Good teaching is vital if students are to achieve highly in STEM subjects. Subject knowledge for teachers in secondary schools is important for good quality teaching. However, last year, 26% of single physics hours taught to pupils in years 7-13 were taught by a teacher without a degree or PGCE in physics or a related subject. The corresponding figure for maths lessons was 17%.

2.9 For this reason, we are announcing £67 million of new programmes to train up to 17,500 maths and physics teachers over the next Parliament, on top of existing plans. This will include programmes to recruit up to 2,500 additional specialist maths and physics teachers, through new schemes to attract more graduates, postdoctoral researchers and career-changers into teaching, and to add to the skills of 15,000 existing teachers through funded sector-led subject specialism training. We will also pilot a new scheme to offer A-level students financial support through their maths or physics degree and a place in employment-based teacher training so that they will earn a salary from their first day in the classroom, in return for a commitment to teaching. These schemes will be on top of existing policies to attract top graduates into maths and physics teaching - which include a £25,000 tax-free bursary for graduates with a first-class degree.

2.10 We are supporting Your Life, a three-year industry-led campaign, to ensure the UK has the maths and science skills it needs to succeed in a competitive global economy. It will do this by inspiring young people to study A level maths and physics as a gateway to exciting and wide-ranging careers; and by helping employers recruit and retain talent, particularly women. More than 200 organisations have pledged to take action to increase the representation of women in the engineering and technology sectors.

2.11 We also expect that the further and higher education sectors will take more account of the shortages of skilled and well-educated people in STEM subjects that are in high demand by employers. Of course government accepts that good education, in and of itself, is beneficial, indeed vital, to individuals and to society. But education must also be responsive to the needs of future generations, and those needs include the ability to progress within and between different stages in the education pipeline and to learn through employment. In particular, the education system needs to respond to shortages of engineers, vocationally trained and technical staff, and workers with the business and entrepreneurial skills to support new and innovative companies.

Technical and vocational education, including apprenticeships

2.12 We have already done a great deal to improve the quality of vocational education: simplifying funding; reducing bureaucracy; and reforming qualifications and apprenticeships to ensure that they are rigorous and respond to the needs of employers.

2.13 A core element of our strategy is to establish a high status system of vocational education, an area where as a country we have historically been weak. In order to fill skills gaps in critical STEM sectors we need to provide business led training with a direct line of sight to work, which young people will aspire to alongside traditional higher education. Our strategy will be driven by (a) rapidly expanding higher apprenticeships up to degree and postgraduate level, and (b) creating National Colleges as high status, employer led institutions.

2.14 Employer-led apprenticeship trailblazers are putting funding and control over standards in the hands of employers. Trailblazers are developing many Higher Apprenticeships to deliver the higher-level technical skills that employers need, including in STEM areas, such as manufacturing engineering. Around 40% of the reformed apprenticeships published so far are Higher Apprenticeships. The government is also providing additional funding to support their growth and the latest figures show a 40% increase in the number of those on a Higher Apprenticeship (18,100 in 2013-14 compared to 13,000 in 2012-13). However, only 1,000 of those participating in higher apprenticeships last year were training in STEM professions. We need to significantly increase these volumes in order to address the gaps that employers tell us exist at level 4 and above, particular in technician skills. Budget '14 made available £20 million funding over 2014-16 for new support for employer investment in apprenticeships that include higher education, up to postgraduate level. This complements the £40 million funding over 2013-15 for 20,000 more Higher Apprenticeships announced in the previous Autumn Statement.

2.15 We will now work with STEM sector businesses to develop more Higher Apprenticeships in the areas business tell us are a priority. The UK Commission for Employment and Skills will undertake a review of STEM occupations at levels 4 to 7 and advise government where to prioritise this investment, and it will report in January 2015. Employers will be able to apply for funding from the Gatsby Foundation to develop new Higher Apprenticeships in STEM areas (as earlier employer-led trailblazers have been able to). This approach will include degree apprenticeships, which we have already announced as a new Higher Apprenticeship model for the digital sector, integrating paid work and study for an honours degree and co-designed by employers and universities specifically for apprentices. This model could have considerable applicability for other sectors and we will work with further trailblazer employers to consider where that might be the case.

2.16 The establishment of a new generation of National Colleges (see box) will target skills gaps in priority STEM sectors – we have already announced National Colleges for High Speed Rail, Nuclear Skills and Onshore Oil and Gas, and we are now going further and introducing National Colleges in Digital Skills, Wind Energy, and Advanced Manufacturing. The colleges will be employer led, delivering training up to full degree and post-graduate level, as well as professional qualifications. They will bring together skills and innovation to develop training programmes which anticipate future technological development – ensuring that their students are prepared to adapt new approaches as they are developed, and that the UK is well placed to be at the cutting edge of innovation.

2.17 We must make sure that the incentives for both individuals and institutions make vocational education in STEM subjects an attractive choice. In order that the newly created National Colleges can be truly national institutions, the best and brightest from across the country must be able to attend them. These opportunities cannot be restricted to only those students who can afford to support themselves. We are therefore keen to work towards the introduction of maintenance loans for students from around the UK wishing to study at these colleges. However, given the challenges of delivering a new loans scheme in the short to medium term, we will provide competitive, time-limited maintenance scholarships (from a total pot of £5 million) to support the very strongest candidates from across the country to attend the new National Colleges in 2016-17.

National College pathways at the Manufacturing Training Centre

The Lloyds Advanced Manufacturing Training Centre is being established by the Manufacturing Technology Centre to deliver more than 1,000 engineering apprenticeships over 10 years.

The apprentices will spend the first year of their apprenticeship in full time education at a local Further Education College. They will then spend their second year at the Lloyds Advanced Manufacturing Training Centre, with years three and four either spent at the Manufacturing Technology Centre or in a placement at a manufacturing company, when they will also spend a day a week at the Training Centre.

The Manufacturing Technology Centre, part of the High Value Manufacturing Catapult supported by Innovate UK, is a collaboration between four of the leading universities and technology organisations in the UK; the Universities of Birmingham, Loughborough and Nottingham and TWI Ltd, and has industrial members ranging from small businesses to large multi-national corporations.

Higher education

2.18 Changes in technology are increasing the demand for high skilled workers in the UK and internationally. The UK Commission for Employment and Skills estimates that by 2022 over half of jobs will require higher education (51.3%), with one in seven jobs (14.1%) requiring postgraduate qualifications.

2.19 Our higher education system is one of our greatest strengths: the UK has 29 out of 200 of the world's top universities. It must be at the heart of our plan to deliver the skills that tomorrow's scientists and economy will need.

2.20 Since 2010, the government has transformed higher education to put students at the heart of the system. Funding has been rebalanced from the taxpayer to graduates in order to create a sustainable and fair funding system. Because loans are income-contingent, this ensures that graduates pay only according to what they can afford, and only when they enter the labour market.

2.21 We have removed the student numbers cap at undergraduate level in order to meet increasing demand for university places and ensure that all those with the qualifications and the aspirations to go to university can do so. These reforms have had a positive impact: the application rate for all English 18 year olds has increased in 2014 to the highest ever level (35%); and a higher proportion of students from disadvantaged backgrounds are applying to university than ever before. The application rate for disadvantaged young people from England has increased to the highest ever level (21%). This means that 18 year olds living in the most disadvantaged areas in England are nearly twice as likely to apply as they were 10 years ago.

2.22 In terms of those accepted onto a course, there was a 25,500 (5.6%) increase in university acceptances between 2010 and 2014. And the number of acceptances for students from most disadvantaged backgrounds has seen a 17% increase.

2.23 Students now also have access to better information to enable them to make informed choices about what and where to study.

2.24 But while STEM course applications have been increasing, we also need to enable non-STEM graduates to enter and qualify in STEM professions. Therefore, we will provide funding to HEFCE to work with the engineering profession to develop and pilot engineering conversion courses for non-engineering graduates.

Postgraduate education

2.25 The talent developed in our postgraduate education system is essential to maintaining a world class research base in the UK and is highly prized by business and the public sector. The skills of postgraduates are critical to tackle major business challenges and drive innovation and growth. The ability of our industrial sectors and businesses to respond to change and technological development with swiftness and agility depends on these skills. Recent initiatives to introduce Centres for Doctoral Training (CDTs) are aiming to raise training standards for postgraduate research, encourage closer multi-institutional working and align institutional research strengths with Research Council priorities.

2.26 But we need to do more to support those who wish to study a postgraduate taught masters. There is a strong economic rationale for this: the wage premium for those with a postgraduate masters has risen over the last 10 years to £5,500 a year, which corresponds to £200,000 over the course of their career. Individual postgraduates benefit through higher wages, but business also benefits through more innovative employees and from knowledge and productivity spill-overs. As the UK labour market evolves and as ageing skilled workers approach retirement, demand for highly skilled individuals is projected to grow. In order for the UK to remain competitive at an international level, the domestic supply of workers with higher level skills needs to increase, both to meet current demand from employers and to stimulate future growth in an innovation-led economy.

2.27 Postgraduate taught study also provides core research skills, the advancement and specialisation necessary to undertake original and independent research that lead to academic and research careers, and feeds the pipeline for research-intensive businesses.

2.28 But there is also a strong social mobility argument too: currently, because of limited government support, 72% of postgraduate students under 30 fund their studies themselves. The Alan Milburn independent review on social mobility in 2012 highlighted that many professional careers now require postgraduate qualifications, and that the ability to pay up front, rather than a student's potential, risks becoming an increasingly strong factor in determining who can access postgraduate education.

2.29 That is why we are introducing a major new loan system for postgraduate students. For the first time ever, anyone under 30 who is accepted to study a postgraduate taught masters course will be able to access a £10,000 income contingent loan to help them do so. These loans will be structured so that, on average, graduates repay them fully, in recognition of the high private return to individuals for these courses, and will be repaid concurrently with undergraduate loans. However, they will beat commercial rates.

2.30 We will consult on the detail and confirm the delivery plan. These loans will support individuals and our economy to grow, and they will also support individuals who want to progress further in research specifically following their Masters course. We expect these loans to benefit 40,000 students, enabling around 10,000 more individuals to take advantage of the opportunity to undertake postgraduate study each year.

Working with employers

2.31 It is one thing to provide sufficient places in the STEM subjects for apprenticeships, further and higher education. It is another to ensure that these are of the highest quality in terms of the experience and opportunities that they provide. It should be taken for granted that at the core will be rigorous content in the STEM subjects. But, while this is necessary, it is not sufficient. People trained in STEM disciplines should have the opportunity to receive a rounded education with exposure to other disciplines. An intrinsic part of the educational and vocational training experience should include opportunities for exposure to leadership, entrepreneurial training, internships and other workplace experiences, and careers guidance. Institutions should be held to account by their students for the quality of the delivery of these elements of education and training.

2.32 Moreover there is clear benefit to students of the arts and humanities who improve their knowledge of the sciences. For example they will gain the quantitative skills to allow them to take best advantage of important advances, such as the availability of big data.

2.33 This is not an attempt to over-engineer the planning and delivery of education, because this type of workforce planning always fails. Nor is this a call for education to take on the role of providing the specialised training that can only be realistically delivered in the workplace and is a responsibility for employers. It is, however, a call for much more effective partnership between education and business.

2.34 Strong employer engagement should happen at all levels of education with employers taking a more active role in schools through, for example, engaging in curriculum and careers guidance, through to further and higher education. Reform of apprenticeships and other vocational education will put employers at the heart of these programmes.

2.35 Employer engagement is key in higher education too, where increasing provision and uptake of work experience is fundamental to improving employment outcomes.

2.36 We will fund independent reviews of STEM degree accreditation arrangements to improve quality and graduate employability, starting with Computer Science accreditation.

Helping students to make the best choices

2.37 We need to provide better information to help students make the important choices that will influence the rest of their lives. It is very hard to make the best decisions about educational and skills choices without information about the possible outcomes of those decisions. Equally the opportunities within the system of education and training need to take into account the opportunities in the workplace.

2.38 We will facilitate the provision of data that shows the links between educational achievement in schools and subsequent employment using administrative datasets. In turn we expect that further education and higher education will provide much clearer information to prospective students on the career outcomes associated with different programmes and courses.

Careers in science and innovation

2.39 We also need to ensure that researchers receive the best career support and professional development to maximise the value of the enormous investment in their education and training. This means working to increase the permeability between jobs in academia, the public sector and industry and embedding the Concordat to support the Career Development of Researchers. This has cross-sector support from major funders – Universities UK, Research Councils, Wellcome Trust and the Higher Education Funding Councils. It can help ensure that all the participants in scientific endeavour receive the best mentorship, career support and professional development so that their education, skills and training can be applied in many different walks of life. We particularly need to enhance the diversity of the research workforce and correct the under representation of women in senior roles.

2.40 It is also important to be able to reskill individuals whenever possible when scientific advances have made their current jobs obsolete and to enable people to return to science after an interval in scientific employment. This is particularly true for women. In 2010 nearly 100,000 female STEM graduates were either unemployed or economically inactive. While there is currently support for them to return to research jobs through the Daphne Jackson Trust, there is no support to return to jobs in industry.

2.41 We will provide support for a dedicated platform to match STEM trained women graduates to return to jobs in industry following career breaks and to provide them with advice and information about the support on offer to them.

2.42 Finally, a vibrant scientific environment requires a vibrant mixture of talents. The opportunity is to ensure that UK science remains an environment that makes the most of the talents of the diverse community within the UK and that imports similarly diverse talent from around the world.

2.43 The UK is open for students from all parts of the world; there is no limit on the number of overseas students studying at UK institutions. Overseas graduates have up to 4 months to find a graduate level job and many UK employers value this deepening of the graduate talent pool.

2.44 Work visas are available for established scientists and engineers; the rules provide that UK businesses must first look to fill vacancies locally, but where there are skills shortages or a lack of suitable applicants, hiring from overseas is possible. There is a simplified process for those specialisms where there is a shortage in the UK. The Exceptional Talent route is available for the world's best, or those with the potential to be the world's best.

3 Investing in scientific infrastructure

Investing in our scientific infrastructure, landscape and equipment so that it equals the best in the world

"The UK's international stature in research is founded in part on the availability of internationally competitive scientific infrastructure. For many areas of science, it is vital that both UK researchers and industry have access to scientific infrastructure, enabling them to be at the forefront of scientific discoveries and pioneering innovation.''

House of Lords Select Committee on Science and Technology
2nd Report of Session 2013–14

The UK's position:

- The UK has 29 universities among the top 200 according to the Times Higher Education World Rankings
- Our research base is world-class and is second only to the USA for number of citations. We have the most productive research base in the G8
- The Global Competitiveness Index ranks the UK 3rd for the quality of its research institutions
- We have world-class research institutes, including the Diamond Synchrotron, ISIS, the Rutherford Appleton Laboratory, the Sanger Institute
- We participate and co-fund laboratories such as the European Molecular Biology Lab, CERN and the Large Hadron Collider, and astronomical facilities such as the developing Square Kilometre Array

Actions taken by this government

- £1.9 billion of capital funding announced in 2010; an additional £1.6 billion of capital and £300 million resource investment has so far been announced to 2014
- We have funded and developed major research facilities such as the Francis Crick and Alan Turing institutes, the Royal Research Ship Discovery, and the new polar research vessel announced in April 2014
- A consultation on proposals for long-term capital investment in science and research was launched this year to identify strategic priorities and the appropriate balance between investment at different levels (i.e. project level, institutional, national and international)

Next steps:

- We will invest £5.9 billion into the UK's research infrastructure between 2016 and 2021 – the most long term commitment to science capital in decades.
- Of this, £2.9 billion will go towards large capital projects to support scientific grand challenges

- £1 billion of the grand challenges fund has been committed to projects such as the new Polar Research Ship and Square Kilometre Array
- £800 million was announced at Autumn Statement to fund new projects, subject to satisfactory business cases. These investments include up to £235 million in the Sir Henry Royce Institute for advanced materials in Manchester, and £113 million in big data at the Hartree Centre, with IBM.
- We will also invest £3 billion to support individual capital projects and maintenance at our universities' and institutes' existing world class laboratories, and provide funding for our international subscriptions. Over half of this will be subject to competition.

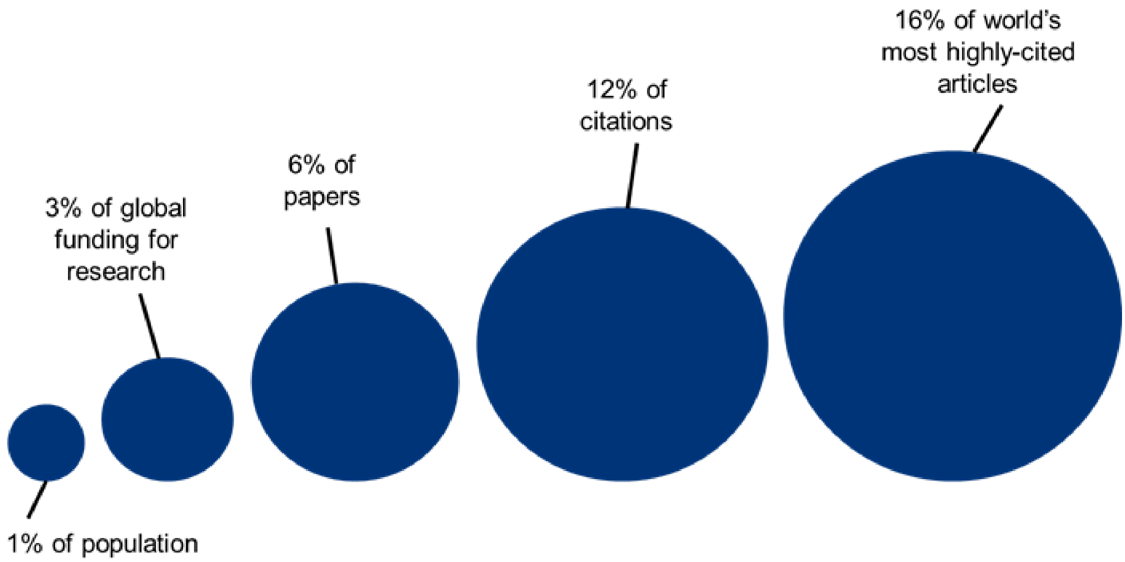
Introduction

3.1 As the House of Lords' Select Committee on Science & Technology recognise in their 2013 report, Scientific Infrastructure,[1] "sustained and efficient future investment in scientific infrastructure [is essential] to ensure that UK research is able to remain internationally competitive" and "efficient investment in scientific infrastructure requires long-term planning and transparent decision making". This infrastructure is wide-ranging, including medium-scale facilities shared across universities as well as facilities such as the Diamond Light Source and research ships.

Research infrastructure

3.2 The UK has an exceptional scientific landscape. Our universities and research institutes are the envy of the world. With 3% of global funding for research, the UK produces 16% of the world's most highly-cited articles (see figure below).

Chart 3.A: Performance of the UK research base



Source: Elsevier (2013)

3.3 We have over 150 universities carrying out different combinations of teaching and research, including 29 of the top 200 universities in the world. They produce highly skilled people. With less than 1% of global population the UK is 4th largest global producer of PhDs (over 21,000) and has 3.9% of global total of researchers. Our universities and research institutes also have a significant impact on our economy. In 2011-12 universities contributed £3.4 billion through commercialisation of new knowledge, delivery of professional training and consultancy. The University of Cambridge, Imperial College London and the University of Oxford have 3 of the top 5 of the world's most highly-regarded university-based entrepreneurial environments.

3.4 Our universities are only part of the story. The UK is the home of an array of other world-class research facilities supported by the public and private sectors. There are the research institutes such as the Diamond Synchrotron, ISIS, the Rutherford Appleton Laboratory, the Sanger Institute, the developing Francis Crick and Alan Turing Institutes.

3.5 British scientists also participate in and depend on a series of European and global research institutes and facilities. We host the European Bioinformatics Institute and the Elixir

[1] http://www.publications.parliament.uk/pa/ld201314/ldselect/ldsctech/76/7602.htm

bioinformatics infrastructure; we participate and co-fund laboratories such as EMBL, CERN and the Large Hadron Collider, and astronomical facilities such as the developing Square Kilometre Array.

3.6 There is a strong industrial research and development landscape in large firms such as GlaxoSmithKline, AstraZeneca, BT, Unilever, Royal Dutch Shell and Rolls-Royce. Our innovative SMEs (small and medium enterprises) are wide ranging and growing. There is an increasing network of science parks, each providing an environment for a range of companies, from nascent companies to medium size enterprises. The United Kingdom Science Park Association has 100 members supporting 4,000 tenant companies which employ 42,000 people.

3.7 There are public sector research establishments such as the National Physical Laboratory, AWE, DSTL, the British Geological Survey, the Health and Safety Laboratories, the Met Office, and the Ordnance Survey which provide direct scientific support not only to the government but also to innovative businesses through access to specialist facilities and data, expertise and know-how. For example, the rock cores stored by the British Geological Survey are a unique national asset used by scientists as well as by industry.

3.8 A BIS research paper highlighting the multiple roles of these organisations in our system will be published shortly.

Research facilities

3.9 Science cannot happen without infrastructure. That is why, at Spending Review '13, we set out a long-term capital commitment of £1.1 billion per annum until 2020-21 to support scientific infrastructure, rising with inflation. Over the period 2016-17 – 2020-21, this totals £5.9 billion. This represents the most long term commitment to science capital in decades.

3.10 However, as infrastructure is increasingly expensive, this forces tough choices. The consultation on proposals for long-term capital investment to 2020-21 asked about these choices: "What balance should we strike between meeting capital requirements at the individual research project and institutional level relative to the need for large scale investments at national and international levels?" and "what should be the UK's priorities for large scale capital investments in the national interest, including where appropriate collaborating in international projects?"

3.11 It is clear that the UK needs to balance funding across these different priorities. We need to ensure funding is available at scale for large new international facilities which will allow us to rise to the world's grand challenges. But we also need to ensure funding at institution and project level in order to keep our infrastructure world class, and ensure the best minds are able to explore new ideas.

3.12 Following the consultation, we therefore commit a total of £2.9 billion to fund large scale investments. £1 billion of this has been committed to projects such as the new Polar Research Ship and Square Kilometre Array. This fund will also be used to deliver a further wave of projects worth a total of up to £800 million, to address scientific grand challenges.

3.13 These were chosen following the capital consultation and informed by an expert working group comprising research funders and representatives of the science community. This capital roadmap has been selected according to the published criteria of affordability (including revenue costs), excellence, impact, skills development, and efficiency and leverage of other funding sources. Additionally the projects were judged to be suitable for funding in the short term and support government's wider priorities: the 8 Great Technologies; the Industrial Strategy; and developing collaboration across disciplines and boundaries.

3.14 These projects include 6 major new investments, subject to satisfactory business cases, of up to:

- £235 million investment in the Sir Henry Royce Institute for advanced materials, which will be based at the University of Manchester with satellite centres at Leeds, Liverpool, Sheffield, Cambridge, Oxford and Imperial College. The institute will drive collaborations between academia and industry, to commercialise the UK's world-leading research in this field.
- £113 million investment in a Cognitive Computing Research Centre in the Hartree Centre, Daresbury, which will enable non-computer specialists to gain insights from big data in order to enhance and design products, services and manufacturing processes
- £31 million investment into Energy Security and Innovation Centres to develop home-grown energy supplies through sub-surface testing facilities
- A £95 million investment into European Space Agency programmes, including taking the operational lead on the first European Rover mission to Mars which will search for life, past and present
- £20 million towards a Centre for Ageing Science and Innovation in Newcastle, utilising academic research to tackle many of the challenges faced by an ageing population and, in doing so, ensuring optimum health and quality of life whilst reducing health and social care costs
- £60 million to extend the capabilities of the National Nuclear Users Facility, supporting research across the full nuclear lifecycle

3.15 The full details of this capital roadmap are published alongside this document in the formal response to the capital consultation.

3.16 In addition, we can confirm the location of the £42 million Alan Turing Institute. This will be based in the British Library alongside the Francis Crick Institute, in the centre of London's Knowledge Quarter.

3.17 It is envisaged that there will be a wide network of partners across the UK forming the institute. Named in honour of the wartime code breaker, it will help position the UK as a world leader in the analysis and application of big data. This will ensure that we are at the forefront of data-science in a rapidly moving, globally competitive area, enabling first-class research in an environment that brings together theory and practical application.

3.18 Through the consultation, further potential high impact proposals to tackle grand challenges were put forward. In order to ensure these are subject to proper scrutiny, we will put these through a robust process of international peer review, and will take a decision on whether to fund them at Budget 2015. As part of any final decision to commit funds, we would expect to see substantial industrial or other co-funding.

3.19 Clearly we need to preserve the agility to respond to further challenges down the line. In order to do this, we will introduce a capital agility fund to provide the flexibility to respond to grand challenges as they emerge. This fund will allocate a further £900 million to tackle the great questions and opportunities of our time, both domestic, international, and indeed in space.

3.20 However, we also need to ensure funding at institutional and project level to keep our infrastructure world class, and allow our top scientists the agility and autonomy to explore new ideas. We therefore commit £3 billion towards World Class Labs. This funding will support the concept of the "well found" lab, equipped with the instruments and facilities to support the science that we need in the future. And it will fund our international subscription to facilities such as CERN. Over half of this funding will be subject to competition.

3.21 Of course, equipment sharing is a vital part of maximizing the value for money of this new investment. We welcome the excellent efforts made already by EPSRC and groups of universities such as N8 and SE5. We will assess carefully the work commissioned from N8 by Professor Ian Diamond and Universities UK with a view to supporting a sector-led, national approach to equipment sharing which benefits both academia and industry. We will clarify Research and Technology Organisation and Independent Research Organisation eligibility for capital funding via the Research Councils. At present for rules for this are not clearly articulated (unlike resource funding where eligibility criteria are clearly set out). We will also continue to support projects that drive collaboration with industry.

3.22 But capital investment alone is not sufficient to ensure our research infrastructure is able to continue to deliver world class outputs. The House of Lords Science and Technology Committee reviewed the funding of scientific infrastructure and in the words of its Chairman Lord Krebs, noted that capital is often funded "batteries not included", by which he meant that capital committed was often not accompanied by the additional necessary revenue to achieve the most impact from the capital investment.

3.23 We recognise that staffing, running and maintaining our scientific infrastructure requires adequate resource funding, and will give full consideration to these requirements when the government takes a decision at the Spending Review next year.

The Big Data revolution

We are experiencing a paradigm shift in the conduct of research and innovation as profound as the Industrial Revolution or the development of the internal combustion engine. The ability to generate, collect and process almost unthinkable quantities of data for exploitation by industry, academia, and government is rapidly changing the basis of comparative advantage and competition in science and innovation.

Leading industrial and commercial organisations are using supercomputing and Big Data analytics to take time and cost out of the research, development and innovation process. Big data analytics is the process of extracting useful information from very large amounts of data. Tackling this huge amount of data is now a key challenge for businesses, and the countries that address this challenge well will have the opportunity to gain competitive advantages. Organisations using computer generated modelling and simulations and Big Data analytics create better products, get greater insights and gain competitive advantage over traditional development processes by getting to market sooner and with more innovative designs.

For example, for a fast moving consumer goods company, speed counts, especially when it needs to put on the market hundreds of new products every year. Just one example is the challenge of formulating a new fabric conditioner. This product tends to be unstable, especially when it is shipped to very cold or very hot countries. Traditional stability tests, on the laboratory bench, tend to be very time consuming, typically taking 8 to 12 weeks. However, the comparable test on a supercomputer takes only about 45 minutes.

Addressing the challenge of Big Data is not a "nice to have": it is now a fundamental enabling competence.

The UK starts from a position of strength because of our open data policy, the skills of the existing UK research community, and previous investments. Since 2012 government has invested over £400 million to equip UK researchers in academia and industry to meet this challenge and take advantage of the opportunities. Centres of expertise have been established, such as the Hartree Centre at Daresbury, a collaboration with IBM to give UK industry access to cutting edge skills and high performance computing (HPC). New training courses have been designed to equip researchers for this new era of data driven discovery, and BIS has published the UK's Data Capability Strategy. Most recently, funding for the Alan Turing Institute was announced for research into the underpinning mathematics and algorithms for advanced HPC modelling and simulation.

The Hartree Centre will soon expand significantly to establish a global research centre in Data Centric and Cognitive Computing. Data centric systems can enable higher speed computation due to a dramatic reduction in data movement throughout the computer system. Cognitive computing enables systems that can learn, more like people do, and can be deployed to address complex and challenging problems.

The Hartree Centre and the Alan Turing Institute will provide world-class environments for academia and industry to work collaboratively to develop algorithms and leading edge applications to harness Big Data for the benefit of society as a whole.

4 Supporting research

Supporting research excellence whilst keeping pace with a changing environment

"There are basically just two central questions regarding the organization and administration of science. These questions present themselves at many different levels of aggregate scientific activity, from the individual laboratory or university department, to multinational research institutes and collaborative programs, including research and development programs which are nationally funded.

The first question is how to organize, staff, and direct the search for knowledge so as to obtain the greatest rate of scientific progress for a given investment of human and material resources. The second question is how to couple the existing body of knowledge, as well as the search for new knowledge, to existing needs for policy or action, including those felt by education and technological innovation."

Harvey Brooks, The Dilemma of Science Policy in the 1970s

The UK's position:

- The UK is the leading research nation amongst core comparator countries with a large research base (G8 plus China)
- The UK has a breadth of excellent research across the sciences, social sciences and humanities
- With 3% of global level of spending, 0.9% of global population and 4.1% of the world's researchers, the UK produces 9.5% of article downloads, 11.6% of citations and 15.9% of the world's most highly-cited articles

Actions taken by this government:

- Science and research resource funding has been protected at £4.6 billion per annum from 2011-16, within a ring-fence
- We launched the Catalyst programmes in biomedical, agri-tech, biotech and energy research
- We are pushing through open access to publicly funded research in response to the 2010 Finch Review and as part of the wider government agenda on open data
- The Research Excellence Framework (REF) is the largest ever quality and impact evaluation of the UK's investment in science – which will, by early 2015, have assessed over 55,000 researchers, 191,000 research outputs and 7,000 case studies
- The UK Charter for Science and Society, setting out principles for public engagement. has been developed in collaboration with the science community, business, educators, media and civil society groups

Next steps:

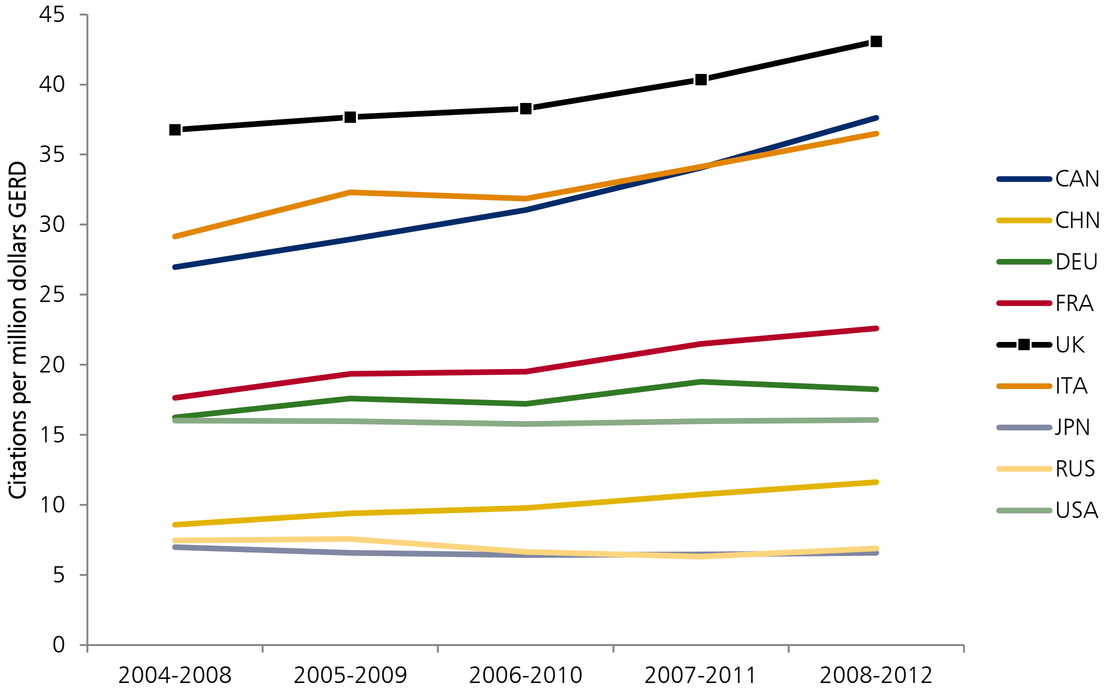
- We will maintain stability and commitment to the core principles as advocated by stakeholders – this includes the dual support system

- At the same time we will find further efficiencies – ministers have commissioned UUK to carry out a further review of university efficiencies, to be chaired by Professor Sir Ian Diamond. This will look at areas such as asset sharing, estates and the higher education workforce. The report will be delivered in February 2015
- We have asked Sir Paul Nurse to lead a review with the Research Councils in order to build on their firm foundations. This will report to the Chancellor, the Business Secretary and the Minister for Science. It will look at how Councils can evolve to support research in the most effective ways by drawing on a range of evidence, including international comparisons and the views of the scientific and business communities, and will report by summer 2015
- We will continue to push forward on implementation of open access to research publications and the underlying data. HEFCE will be considering how to reward open data as part of future REF assessments subject to the evaluation of the REF 2014
- We have asked HEFCE to develop a robust, evidence based framework to assess HEIs' performance in knowledge exchange
- Research Councils, Innovate UK and Higher Education Funding Bodies will draw on the evidence collected from their activities, case studies from the REF and similar exercises to make a proposal, by summer 2015, on the development of a whole system approach to research impact

Introduction

4.1 The UK is a highly productive, collaborative and efficient research nation with high research outputs relative to government investment levels. We are top of the G8 in article citations per pound (see graph below). We have a unique breadth of research capability across disciplines and the discovery-applied spectrum. This helps maintain a balance between investing in innovation now and the ideas which will lead to the innovations of the future, reflects the unpredictable nature of discovery and ensures we have the capability to respond to the full breadth of priorities including the unexpected.

Chart 4.A: International comparative performance of the UK Research Base – 2013



Source: Elsevier (2013)

4.2 Our goal is to build on our strengths and deliver a research sector that is highly flexible, responsive and ambitious. This requires strong foundations, a long term investment horizon and a stable delivery system to keep the UK at the cutting edge and to attract the top research talent.

Renewing our commitment to independence and excellence, whilst reflecting the priorities of society, taxpayers and government

4.3 Any strategy for science and innovation needs to consider the core principles which underpin the UK's approach to supporting research, the distribution of funds and the funding mechanisms. The existing funders supported by the government include the Higher Education Funding Councils and the Research Councils, which form the dual support system for university research. In addition the government-funded UK Space Agency, the National Academies, Innovate UK and the research and development budgets of individual government departments all form part of the wider funding environment. So how can these funders provide even greater impact for taxpayers' pounds?

4.4 Form should follow function. That is why the Haldane Report of 1918 on the Machinery of government is so important, because it set out to re-engineer the structure of government based on consideration of function. As part of this it set out the reasons for the funding or research and innovation by government and the basic principles of how this could be achieved.

4.5 As set out by this government in 2010 and earlier this year, the way in which decisions are taken on what research to fund should reflect a focus on excellence alongside both the strategic priorities and challenges of the government and society, and the advice from the scientists best placed to judge where and on what issues the most excellent research can be done.

4.6 However, it is important to recall all the principles of the Haldane Report, which argued: 1) that research and evidence was important to the development of government policy; 2) that each government department should provide funds to answer specific policy questions; 3) that there should be a department of government charged with funding general research questions; 4) that the choice of how and by whom that research should be conducted should be left to the decision of experts; 5) that the questions and topics to be tackled should be considered as a result of close collaboration between the administrative and the general departments; and 6) that there should be a department that supports research applied to trade and industry. The fourth of these points is the one that has been designated the "Haldane Principle", but all six are as pertinent now as they were in 1918; these are the six Haldane Principles.

4.7 One of the reasons that UK science is at the global forefront is because of the longstanding freedom provided to researchers to pursue fundamental research questions. The government recognises and respects this freedom, which will continue to be supported through the grant schemes of the Research Councils and the flexible support mechanisms of the Funding Councils. But UK science has also led the way in response to challenges posed by government and society, from the Longitude Prize of the 18th century that resulted in Harrison's chronometer, to its 21st century counterpart to find solutions to the global threat of antimicrobial resistance to antibiotics. Freedom to explore the secrets of nature must be combined with a more strategic, directed approach to solving the pressing needs of society. The whole endeavour, whether driven by the curiosity of scientists or by the needs of society, only achieves fulfilment when the outcomes of research are turned into impacts for society. The key policy questions here are not a binary choice between top-down and bottom-up decision making structures, or between basic and applied research. Rather they are about the achieving the most effective balance.

4.8 The Research Councils are at the heart of the mechanisms for allocating money, particularly to universities in support of academic research. The Medical Research Council, the oldest was founded just over a hundred years ago - and the newest, the Science and Technology Facilities Council, formed in 2007. The Research Councils are highly respected organisations here and around the world. They provide leadership in the face of new opportunities and challenges, from changing regulatory frameworks to creating global companies and supporting international efforts to test a new Ebola vaccine (See box).

Research Councils work together to advise on changes to regulatory processes:

Through the Rural Economy and Land Use programme, NERC, BBSRC and ESRC funded a ground-breaking multidisciplinary research team led by Professor Wyn Grant at the University of Warwick to understand the barriers to commercialising and regulating biopesticides. The researchers provided expert advice and training for UK and European regulators, as well as biopesticide manufacturers and food retailers. As a result, regulatory frameworks designed for controlling synthetic chemicals were adjusted to encourage biological control and integrated pest management. The expert advice and more amenable regulation helped manufacturers, many of which were relatively small and not set up to deal with the regulatory process, to achieve a higher registration rate for new biopesticide products. Food retailers such as Marks & Spencer used the research findings to revise their pesticide strategies.

Research Councils working together with Innovate UK can help turn research success into business success

Joint BBSRC, EPSRC and Innovate UK investment enabled the University of Durham and Oxford Chemical Ltd, (now Frutarom Ltd), to commercialise the use of enzymes in the development and production of new natural flavour and fragrance compounds for the food industry. Frutarom Ltd is now one of only two companies producing natural versions of methylmercaptan compounds found in all savoury vegetable or meat-based flavours – and is one of the largest flavour and fragrance companies in the world, with profits of $63.6 million in 2013.

Responding with speed: The west African Ebola crisis

Professor Adrian Hill, Director of Oxford University's Jenner Institute is leading international efforts to test a new Ebola vaccine, critical to tackling the growing crisis in west Africa. With £2.8 million funding from the MRC, the Wellcome Trust and the Department for International Development received within two weeks of applying, and trials approved in four days, the first person was vaccinated in Oxford on September 17th. With sufficient data obtained in the UK, the consortium including the Jenner Institute, the WHO, the NIH, the Center for Vaccine Development in Mali, and GSK Vaccines, was able to begin testing safety and immunogenicity in Bamako, Mali on October 8th, and hope to start testing efficacy among health workers in Liberia and Sierra Leone by the turn of the year. Speed of response is critical, with GSK beginning manufacturing while testing is in train. It has been forecast that if current trends in west Africa continue, we may not be able to be eliminate the epidemic without a vaccine.

4.9 However, all organisations need to keep pace with the changing environment within which they operate. As the recent triennial review of the Research Councils found there are important questions about their structure and function. Key conclusions included that "individually [they] are operating from a position of strength", but also that the Councils might take a more proactive role in "challenging and shaping the government's research agenda, in areas of long-term strategic importance". It also stated that "the strong arrangements to ensure good use of public money at individual council level are not yet as effective at a cross-council level".

4.10 The opportunity is for the Research Councils to build on their success. They must inspire and raise the levels of aspiration of the scientific community. They must empower and support the brightest minds to tackle the most important problems. They must make it easy for UK scientists to collaborate across institutions, across disciplines, across the boundaries between academia and industry, and across national boundaries. All of this is essential to ensure that we can continue to lead and to compete on a global stage in the face of the new opportunities and ways of conducting science. The Research Councils must deliver with ever-greater pace, flexibility and agility. And all of this must continue to be delivered with rigour because excellence must remain a fundamental value of UK science. To achieve these aims the Research Councils may require new capabilities and structures.

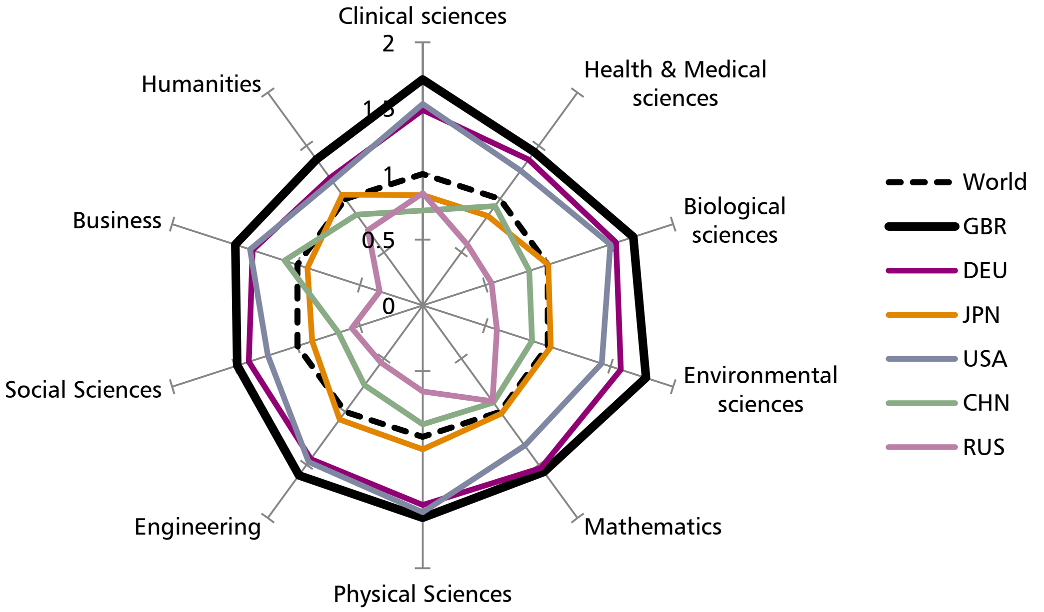
4.11 We have asked Sir Paul Nurse to lead a review with the Research Councils in order to build on their firm foundations. This will report to the Chancellor, the Business Secretary and the Minister for Science. It will look at how Research Councils can evolve to support research in the most effective ways by drawing on a range of evidence, including international comparisons and the views of the scientific and business communities, and will report by summer 2015. We will publish terms of reference shortly.

4.12 In addition to the long-standing commitments to the independence of the scientific process, the focus on excellence with impact means funding allocations right through the system are highly competitive and made primarily on the basis of quality as assessed by expert peer review of proposals and outputs. Maintaining the quality of UK research is vital to driving subsequent impact, serves to attract international investment and increases the absorptive capacity of the UK.

Breaking down barriers between disciplines and building partnerships between business, the public sector and civil society

4.13 Our research landscape is complex and increasingly interdisciplinary. The UK's breadth of scientific excellence across different academic disciplines is unrivalled in the world. To better understand key linkages, the Prime Minister's Council for Science and Technology is developing a map of the UK's scientific landscape, its dependencies and interdependencies. This will assist government and others in planning strategic investments for science and innovation during the next ten years.

Chart 4.B: Field-weighted citation impact for UK and comparators across research fields in 2002 and 2012



Source: Elsevier (2013)

4.14 We are also known for our open and collaborative system both within the UK and internationally. Building collaboration and promoting international mobility are established drivers of UK research excellence, increasing impact and attracting external investment. Almost half of the scientific articles we produce have an international co-author, more frequently from Europe, North America and Australia.

Chart 4.C: Share of articles for the UK by co-authorship type, 2008-2012

Bubble size is proportional to field-weighted citation.

Source: Elsevier (2013)

4.15 Research Councils work with more than 2,500 businesses including large corporates and more than 1,000 SMEs. UK university collaboration with external partners including business has risen 45% in real terms since 2003-4 and continues to grow, reaching £3.6 billion in 2012-13. In the last 2 years the UK overtook Germany as the number one recipient of EU Framework Programme 7 funds. UK excellence in research is one of the most significant factors attracting high-value investment to the UK, bringing infrastructure, staff and revenue to the research and development laboratories of multinational companies.

4.16 Charities are another major contributor to UK research, contributing £1.3 billion funding in the health research sector. This funding is dependent on our excellence and infrastructure in universities and in the NHS. Charities are also important partners in major collaborative partnerships such as the Francis Crick Institute and the Alan Turing Institute.

4.17 We have supported universities in developing partnerships and knowledge exchange through HEFCE's Higher Education Innovation Funding (HEIF). HEIF ensures that universities have the capability to engage effectively with a wide range of partner organisations and businesses. It has been successful in delivering a return on the public investment in knowledge exchange of £6.30 gross additional income generated for universities from every £1 invested over the period 2003-2012. In recognition of this important role, the government made, in its response to the Witty Review, a long-term commitment to supporting universities in knowledge exchange, which will help deliver economic growth, and is committed to supporting a fully rounded approach to funding all forms of knowledge exchange, with all forms of partner, including recurrent funding for knowledge exchange through HEIF.

4.18 We have also used funding mechanisms and incentives to encourage much greater collaboration between the research community, business and government. The Catalyst grant funding schemes, run jointly by Innovate UK and the Research Councils, are a good example of supporting research in priority areas where there is clear commercial potential. In the Biomedical Catalyst, for example, Innovate UK and the Medical Research Council have invested £185 million in grants to date, which has leveraged nearly £100 million of additional investment from the private sector. Other current Catalysts focus on agri-tech, biotech and energy.

4.19 Another example is the Research Partnership Investment Fund (RPIF), which gives awards to large-scale projects and can attract at least double the level of public investment from private and charitable sources. It has been a success, so far securing more than £1.3 billion of new investment in world class research facilities that benefits both universities and their business partners.

4.20 One example of success from RPIF is the collaboration, worth more than £35 million, between the University of Surrey and many of the mobile communications global industry leaders to build a new collaborative international research centre to support the development of 5th Generation cellular communications. The 5G Centre will provide real-time experimental facilities to underpin the development of new mobile broadband internet products and services. This partnership has already secured over £43 million private co-investment.

4.21 We have asked Professor Dame Ann Dowling, the newly appointed President of the Royal Academy of Engineering, to advise on how best to strengthen the relationship that allows industry to share the long-term strategic needs of their business with the UK's world leading researchers.

4.22 The performance of UK Universities in partnerships and knowledge exchange can be further promoted through sharing of best practice and by assessment of performance. The government has asked HEFCE to develop a robust, evidence based framework against a suite of key knowledge exchange activities to assess performance and identify examples of good practice.

4.23 Using Higher Education – Business and Community Interaction Survey (HE-BCI) as the key data set, this will assess performance in terms of discrete areas of knowledge exchange activity which share common performance features, and within which performance can be normalised and contextualised. Within this framework, it will also be possible to identify key elements of strong, good practice within each of these discrete knowledge exchange activities, which can be highlighted.

Open science, research and citizen engagement

4.24 Greater collaboration has to be built on a basis of greater openness and transparency. The UK is committed to the principle that publicly funded academic research is a public good and that making it openly available with as few restrictions as possible will realise more effectively the social and economic benefits of spreading knowledge.

4.25 The government remains fully committed to open access to research publications in line with the recommendations of the Finch Group Report, and whilst our ultimate objective remains gold open access, we will continue to work, nationally and internationally, with partner organisations and other research funders on the implementation of open access to achieve a sustainable and affordable model. HEFCE will be considering how to reward open data as part of future REF assessments subject to the evaluation of the REF 2014.

4.26 Further, access to underlying research data and meta-data is recognised as a complementary need to access to research papers. We will take forward cross-sector discussions on implementation through the Research Sector Transparency Board.

4.27 HEFCE commissioned Professor James Wilsdon to lead an independent review looking at the role of metrics broadly in research assessment and considering how well metrics can be used across different academic disciplines to assess the excellence of research undertaken in the higher education sector. The review will report in 2015.

4.28 The social and cultural context of scientific enquiry is also changing. At present, citizen engagement is typically about collecting data or providing capacity. But the potential is much greater. Citizen engagement in science brings with it a wider range of influences on what research questions might be tackled in the future and how. It blurs the distinction between the laboratory and the home or the street. Meanwhile the spread of prize and challenge-led funding creates opportunities for more diverse consortia of investigators and entrepreneurs, and can even lead to public participation in setting the goals, as with the Longitude Prize launched in May 2014 by Nesta. The £10 million prize aims to find a major innovation in the field of Anti-Microbial Resistance by 2020. Since 2012, BIS has supported successful prizes in the areas of assisted living technology, open data and energy efficiency through the Centre for Challenge Prizes at Nesta, and will continue to do so.

4.29 The British public is strongly supportive of research and sees scientists and engineers as making a valuable contribution to society and to economic growth. But we cannot take this support for granted – we must earn it. We are committed to encouraging scientists to engage with the public on their work and to the greater use of dialogue with the public on science and technology policy issues, as part of open policy making.

4.30 The government led the development of the UK Charter for Science and Society in collaboration with the science community, business, educators, media and civil society groups. Signatories to the Charter commit to the core principles of improving the relationship between science and society, enabling organisations and individuals to participate in activities and have appropriate training, support and opportunities. To date 22 signatories are committed to monitoring and evaluating impact in order to continuously improve the relationship between science and society across the UK.

Ensuring government policy is underpinned by the best scientific advice

4.31 Every government department requires specific evidence, including public views, in support of its policy and delivery requirements. Some of the research and development (R & D) needs of individual departments have been provided historically by laboratories and institutes, public sector research establishments (PSREs) that have been both owned and largely funded by government. Over many years the scope and scale of many of these has changed and some have been converted to trading funds or been transferred in whole or in part to the private sector. There is no single right answer for the ownership and governance model of these institutions. What is critical is that they should be able to function in the most effective fashion to provide the advice that government needs, and to do this they need to be able to recruit the best scientists and provide an excellent environment for their work. The functions that enable them to serve government departments effectively often mean that they can also undertake valuable work for the private sector. Indeed, some of these institutions are fully part of our innovation landscape.

4.32 Data and expertise from organisations such as the Met Office, the Ordnance Survey, the Environment Agency, the British Geological Survey and the Health and Safety Laboratory comprise a key part of our national scientific infrastructure. This is of particular importance in the management of national emergencies when scientists from these and similar organisations play a key role as members of the Scientific Advisory Group in Emergencies (SAGE), a group that co-ordinates and brings the best scientific advice to the centre of government, often at very short notice.

4.33 The government Chief Scientific Adviser, individual Chief Scientific Advisers and the Civil Contingencies Secretariat play a key role as the expert customers for government when it comes to national security and resilience issues. There is also an important role for the Council for Science and Technology in providing independent advice to the Prime Minister and the Cabinet.

4.34 Other R&D needs of government departments are commissioned from their individual R&D budgets. Comparison of these budgets between government departments shows a diverse picture. The Ministry of Defence and Department of Health both have large R&D budgets in comparison with much smaller budgets in other government departments. However, in some cases budgets have reduced in recent years and there has been a trend over many years for a reduction in the scope and scale of 'government laboratories'. A good customer function accompanied by strong inter-departmental governance is crucial.

4.35 We will examine how to ensure that R&D spending by departments is properly prioritised against other capital investment spending, for example by considering controls that can be placed on this spending to ensure that valuable R&D is not unduly deprioritised in favour of short-term pressures. We will report on this by the next Spending Review.

Enhancing the effective impact of UK research

4.36 Our universities are a vital part of our innovation ecosystem, as highlighted by the Witty Review. This strategy strongly reflects the role of universities in supporting economic growth, complementing the traditional role of teaching and research. Many of the Review's recommendations are now within the core programmes of BIS and the Review's principles have become an intrinsic part of our strategic direction. We will continue to take forward actions in concert with partner organisations.

4.37 The benefits of research impact beyond academia, including collaborative working between UK universities and business are well known, and UK has a strong track record of success: (i) delivering highly skilled people to the labour market, (ii) improving performance of business, (iii) creating new businesses, (iv) improving public policy and services, and (v) attracting foreign direct investment in R&D from global businesses.

4.38 UK university collaboration with external partners including business has risen 45% in real terms since 2003-4 and continues to grow, reaching £3.6 billion in 2012-13. The UK is now 4th for university-business research collaboration, rising from 11th in 2008-9. A recent study by MIT identified that the UK has 3 of the top 5 of world's most highly-regarded university-based entrepreneurial ecosystems. However, it remains important that, in a harder and more competitive economic environment, we ensure the best exploitation of research for public benefit.

4.39 UK SMEs that cooperate with universities or public sector research establishments are twice as likely to introduce new products to the market. But while two thirds of SMEs cooperate with private sector partners, only one third do so with public sector organisations. This imbalance needs to be addressed if we are to gain the most competitive industrial advantage and boost British exports.

4.40 None of this detracts from the importance of the pursuit of fundamental research, which underpins the great advances in our understanding of ourselves, the other species that cohabit the earth, and the earth and cosmos.

4.41 The public is entitled to expect that the scientific enterprise will be organised in the most efficient and effective fashion to explore these questions, with at least as much collaboration as competition, and with rigorously designed and powered studies that offer the best chance of delivering robust results.

4.42 The UK is the world's leading nation in assessing the impact of research. The recent Impact Stocktake study, undertaken by Research Councils, HEFCE and Innovate UK, examined the measures that contributed to changing the culture and behaviour of research organisations and positively affected the quantity and quality of research impact. We have an opportunity to further enhance the effectiveness of our research and innovation system by developing an improved impact policy framework.

4.43 Research Councils, Innovate UK and Higher Education Funding Bodies will build on the evidence collected from their activities, case studies from the REF and similar exercises to make a proposal by summer 2015 on the development of a whole system approach to research impact. It will further our understanding of the impact relationships between research outputs and economic and societal outcomes, greater effectiveness and agility, and better awareness of systemic risks and opportunities.

5 Catalysing innovation

Investing in knowledge exchange and innovation to catch up with the best competing nations

"In seeking innovation-led growth, it is fundamental to understand the important roles that both the public and private sector can play. This requires not only understanding the different ecologies between the public and private sector, but especially rethinking what it is that the public is bringing to that ecology"

Professor Mariana Mazzucato

The UK's position

- The UK is in 2nd position in the Global innovation Index, up from 14th in 2009-10
- The UK ranks 2nd in the world on investment in knowledge-based capital
- However, total UK investment in R&D has been stable and relatively low at around 1.8% of GDP since the early 1990s. In contrast the US spends around 2.8% of its GDP on R&D per annum
- Private rates of return on R&D investment are estimated at between 20% and 30%, with social rates of return two of three times larger

Actions taken by this government

- We have set up the British Business Bank, helping finance markets work better for businesses undertaking cutting edge innovation
- We have expanded the existing tax-advantaged venture capital schemes (the Enterprise Investment Scheme and Venture Capital Trusts), and introduced a new seed enterprise investment scheme, to encourage private investment into smaller, higher-risk companies, that would otherwise struggle to raise finance
- We have provided an additional £185 million funding for Innovate UK – which supports and connects a full range of innovators including start-ups, SMEs, large companies, academics and Research and Technology Organisations
- We have established a network of Catapult Centres – currently there are seven, specialising in High Value Manufacturing, Transport Systems, Digital, Cell Therapy, Offshore Renewable Energy, Satellite Applications and Future Cities
- The UK's intellectual property (IP) system has been reformed to improve enforcement and to establish the right framework of incentives for creators and investors
- We have agreed Growth Deals with each of the 39 LEPs to provide investment in innovation and growth, based on local priorities
- We are piloting four University Enterprise Zones in Bradford, Nottingham, Bristol and Liverpool designed to develop stronger partnerships between universities and business

Next steps:

- We will continue to invest in the Catapult network and expand it gradually as the fiscal position improves
- The Catapult network will expand with two more Catapults for Energy Systems and Precision Medicine due to open next year
- We will provide £61 million funding to the High Value Manufacturing Catapult centres to meet increasing demand and provide outreach and technical support to SMEs
- We will invest £28 million in a new National Formulation Centre, as part of the High Value Manufacturing catapult, to drive manufacturing-based growth and help rebalance our economy
- Centred around the British Business Bank, we will continue to make finance markets work better for innovative smaller businesses. For instance, the Venture Capital Catalyst Fund, which increases the availability of later stage venture capital, was extended by £100 million this year. At Autumn Statement this year we announced a new commitment of £400 million over three years to extend the Bank's flagship venture capital programme, Enterprise Capital Funds, which will allow Funds to make larger investments of up to £5 million
- We will signpost opportunities for businesses to exploit available patented technologies and we will undertake a review of schemes for IP markets

Introduction

5.1 Innovation drives productivity and growth: of the productivity growth that took place in the UK between 2000 and 2008, one third (32%) was attributable to changes in technology resulting from science and innovation. Innovative businesses grow twice as fast as non-innovative ones. They create new jobs, new products, access export markets and attract inward investment. We are starting from a good base and have made excellent progress in recent years. But we need to do more.

5.2 On some indicators the UK already does well. But on others the UK has to do more to be a leading knowledge economy. To meet the ambition set out in this strategy it is essential that, overall, the public and private sectors invest significantly more.

5.3 We know that every one pound we spend delivers a social rate of return i.e. a return to wider society beyond the agent spending the money, of between 20 and 50 pence per year. Investment by Innovate UK to support business-led innovation has generated a return to the economy of between three and nine pounds of additional value (Gross Value Added) for each pound of public money invested.

5.4 There is potential for public investment to drive virtuous circles of private investment, as high quality research and development attracts international talent, which in turn attracts global businesses and fosters innovative new businesses, all of which results in further advances in both new knowledge and exploitation. Thanks to the Catapult network, and the progress made by Innovate UK through its various programmes, we now have the innovation infrastructure capable of helping us scaling up our public and business investment.

Creating the right environment and infrastructure

5.5 Creating the right business environment is a crucial foundation for private investment. The UK has a highly competitive overall tax system. From April 2015 we will have a 20% corporation tax rate, the joint lowest in the G20.

5.6 In addition, there are generous incentives specifically for R&D and innovation. The Patent Box offers a 10% rate on profits derived from patents encouraging innovation to take place in the UK. R&D tax credits provided £1.4 billion of relief to over 15,000 businesses, supporting around £13.2 billion of investment in 2012-13. R&D relief reduces the cost of qualifying expenditure by around 46% for a profit-making SME, 33% for a loss-making SME, around 29% for a large profit making company and 9% for a large loss making company. These reliefs put money into the hands of businesses making investment decisions.

5.7 But the right tax environment is only part of the story. Businesses gain confidence to invest from having world class institutions that underpin the innovation infrastructure. These institutions provide essential support to business and research organisations looking to develop, progress and protect their ideas. Here the UK has strong foundations on which we have been building. For example, the UK is world renowned for its design capability – capability that is championed nationally by the Design Council as a means to create better places to live, better products to use and healthier living. Our strong presence among the global standards bodies – through the work of the British Standards Institution (BSI) and the UK Accreditation Service - maximises the ability of our businesses to influence and access international markets. In 2013, BSI signed a memorandum of understanding with the Standardization Administration of China that will enable British standards to be more widely accepted in China. This is the first such agreement signed by China. The many measurements needed to support research and innovation are supported by our world-leading national measurements institutes. Here the government has taken action to strengthen further the National Physical Laboratory (NPL), developing a new strategic partnership with the Universities of Surrey and Strathclyde. This partnership will strengthen both the science undertaken in NPL and encourage greater interaction with business, driven by closer integration of existing innovation infrastructure and commercial activity.

5.8 The UK Intellectual Property Office is a crucial part of the innovation infrastructure. UK businesses are already among the most 'knowledge intensive' measured by intangible investment among OECD countries. This government's reform of the UK's IP system has helped establish the right framework of incentives for creators and investors, as well as focusing on effective enforcement through a small claims track in the IP Enterprise Court which will significantly reduce the cost for SMEs of pursuing IP infringement cases.

5.9 The new Intellectual Property Act has simplified design and patent protection and introduced new exceptions to copyright law which will bring cost savings to businesses through reduced complexity. A new scheme for dealing with 'orphan works' will unlock the value of copyright works which cannot currently be used because the owner is unknown, and the introduction of extended collective licensing for copyright will allow the clearance of multiple rights quickly and cheaply.

5.10 But we need to do more to help businesses recognise and understand the value of their intellectual property. Besides access to IP audits, local hubs of expertise will be developed with partners such as Chambers of Commerce, Patent Libraries, Business and IP Centres, and local authorities. The Intellectual Property Office, in collaboration with the CBI, banks and IP professionals will also look at bridging the gap in information and understanding between smaller firms which have IP as an asset and potential investors.

5.11 Creating markets for IP rights is an important element for ensuring that knowledge is effectively exploited. The IPO already makes public data on the ownership of patents whether in force or ceased. It also currently offers a Licence of Right scheme, which allows patent holders to signal that they are willing to grant a licence to anyone who wishes to use their patent in return for a reduced renewal fee on the patent. The IPO maintains a database of patents available under these rules. We will explore how this can be made more user friendly. We will improve the visibility of the scheme and of wider patent ownership data to make sure that more businesses are aware of their options. This will signpost opportunities for businesses to exploit available technologies and for patent holders to reduce their costs, generate licensing income and see their innovations developed.

5.12 Recognition of the need to create value from IP through markets and exchanges has prompted public and private sector initiatives around the world. For example, the Danish IP Office has developed the 'IP Marketplace', an online market where entrepreneurs and innovators can seek out trading partners. IP rights, including patents, designs and trademarks are offered for sale or licensing. In the UK 'Easy Access IP' offers free, licensed access to university IP not currently used, in return for some form of recognition for the originator. We will undertake a review of schemes for IP markets, and the open data information systems essential to support them to assess which are most likely to add to growth.

Shaping an informed debate

Modern democracies looking to exploit research rapidly, sustainably and safely also need well-informed debates, smart regulation and effective governance of research and innovation. In particular, a clear understanding of risk is essential to facilitate evidence-led debates and to inform regulation. The Government Chief Scientific Adviser recently published his 2014 annual report "Innovation: Managing Risk, Not Avoiding It". He said that:

a) it should be normal practice for those responsible for leading the analysis and discussion supporting innovation to be informed by independent evidence;

b) discussions about a new technology should be founded around specific possible uses of the technology, their respective alternatives, and the costs of inaction as well as action;

c) the multi-disciplinary academic community that works on risk and risk communication in the United Kingdom is small. This community, the UK Research Councils and universities should all collaborate to fund and support the development of this capacity. The scope of the work should range from undergraduate to postgraduate courses, doctoral training and support for the next generation of leaders.

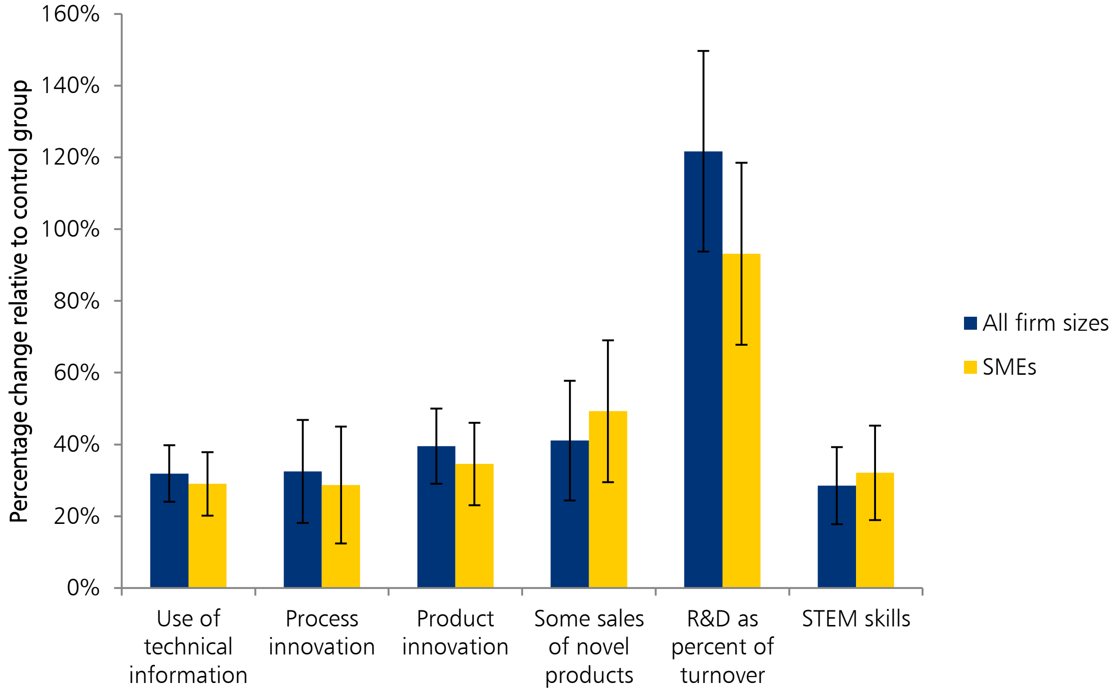
Supporting innovative businesses

5.13 Innovation is inherently a risky business. Many businesses, particularly SMEs, consider that risk more than they are willing to absorb. But they are risks that we need businesses, big and small, to take to ensure growth in the UK increases and is sustained. Through Innovate UK, we seek to reduce barriers to innovation for businesses, by providing access to equipment, skills, networks, and funding.

5.14 Almost 60% of grant funding from Innovate UK goes to SMEs. This ranges from £5,000 of funding for expert support on a novel idea through Innovation Vouchers, to Smart awards of up to £250,000 to develop a new product, service or process, to a Collaborative R&D grant of up to £5 million for a consortium of organisations working together. This might be to prove or demonstrate a concept.

5.15 The impact of this support on business innovation is positive. Businesses that receive public funding for innovation are significantly more innovative than comparable non grant-holding businesses. Receiving a grant increases a business's own spending on R&D by 30% and makes them over 40% more likely to introduce novel products to market, 40% more likely to engage in product innovation and almost 30% more likely to employ STEM graduates (see graph below).

Chart 5.A: Impact of direct government support: percentage change in likelihood



Source: BIS (2014). 'Estimating the Effect of UK Direct Public Support for Innovation'

5.16 The impact is even higher where a business collaborates with other partners, whether businesses or universities. The government has recognised the importance and impact of this support to innovative businesses. It has – despite the fiscal environment – continued to increase the funding to Innovate UK. The budget will reach over £500 million in 2015-16.

5.17 The opportunity is greater than grant funding. Innovate UK provides access to knowledge and partners through the Knowledge Transfer Network, and connects SMEs with talented people in universities through Knowledge Transfer Partnerships. It supports business to find customers through trade missions run jointly with UKTI. And it finds business customers and government solutions to problems through the Small Business Research Initiative (SBRI).

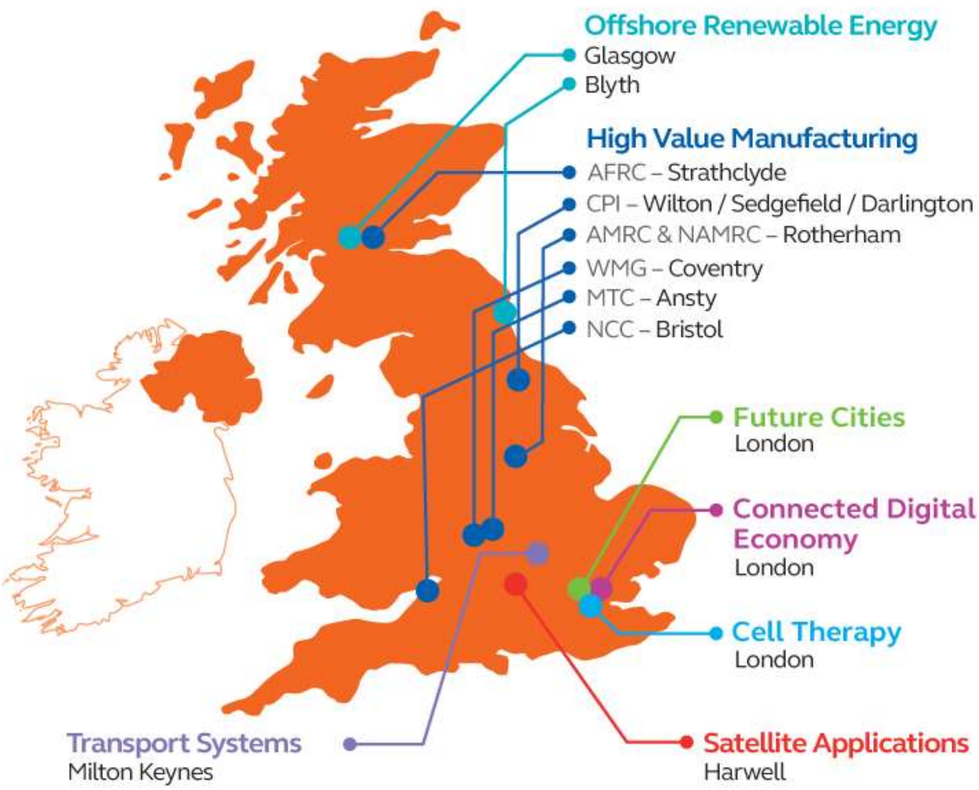
5.18 Since 2009, SBRI has delivered 215 competitions from 70 public bodies, including the Department of Health and the Home Office and resulted in 1,850 contracts worth £210 million. This is a substantial increase, but the government is committed to expanding this further. There are good examples of successful outcomes delivered for departments through SBRI and significant scope for further expansion. Over the next 12 months we will improve awareness and understanding across departments and agencies of how SBRI can help solve their policy challenges, and we will improve communication of successful outcomes, tracking of SBRI projects, and sharing of best practice and networking between departments.

5.19 Continuity in the available support schemes for innovation is important but Innovate UK is working with partners to find new ways of maximising exploitation of our research base. This includes the £3.2 million ICURe pilot programme informed by schemes such RAE fellowships in the UK and international models such as those found in the US (ICorp). Targeted at the "Valley of Death" this programme will help identify and commercialise interesting university research, by supporting market validation and, where appropriate, company formation. A jointly funded pilot has been developed with HEFCE and SetSquared that will start in 2015-16.

5.20 Innovate UK is also looking to enhance our approach to identifying the most exploitable emerging technologies. The initial markets for disruptive technologies are often uncertain. Waiting for markets to become clearer can lose the competitive time advantage that exists in our research base. In the US, DARPA has demonstrated notable success in accelerating commercialisation through early stage system demonstrators and stage gating. Learning from this, Innovate UK are investigating new ways of working with the Research Councils to develop a more holistic approach to the identification and exploitation of disruptive technologies. The first pilot is in Quantum Technologies where Innovate UK are working with DSTL, NPL and EPSRC. RCUK and Innovate UK will also launch a new joint initiative on Urban Living. Further pilots are under discussion.

5.21 One of this government's major achievements is the setting up of the Catapult Centres. This network of technology and innovation centres focuses on sectors or challenges that have large global market potential and where the UK has a global research lead. The Catapults aim to assemble the best facilities and talent nationally to provide open access to businesses new to the technology areas. They provide an opportunity to build new collaborative activities between business and universities. Seven centres are currently open: High Value Manufacturing, Cell Therapy, Offshore Renewable Energy, Satellite Applications, Digital, Future Cities and Transport Systems. Two more – Precision Medicine and Energy Systems – will open in 2015.

Chart 5.B: Catapult locations across the UK



Source: Innovate UK (2014)

5.22 The government commissioned Hermann Hauser to conduct a review into the future scope and scale of the Catapult network. His independent report was published in November. The government welcomes Dr Hauser's findings. The Review highlighted the progress and difference Catapults are making and recommended Innovate UK work closely with Catapults to build on their SME engagement strategies. It also recommended that we should grow the network of Catapults, at no more than 1-2 centres per year, with a view to having 30 Catapults by 2030.

5.23 Gradual expansion of the Catapult network is right for the UK. That is why we will continue to expand the network of Catapults as the fiscal position improves. We also welcome Hermann Hauser's recommendations to strengthen the impact of the current network through improved SME and research base engagement, and the development of sophisticated performance indicators.

5.24 We will expand the Catapult network with two more centres, focused on Energy Systems and Precision Medicine, due to open next year. We will also support and invest in the existing Catapult network to secure the impact of the network in key markets into the future. We announced £61 million further core funding for the High Value Manufacturing Catapult at Autumn Statement, to maintain the funding balance which will allow the Catapult to invest in expertise and new cutting edge equipment, and to engage with more SMEs.

5.25 We are also creating a £28 million world-class National Formulation Centre, specialising in formulated products such as medicines and chemicals, to help UK companies research areas which would otherwise be too high risk or technically challenging.

5.26 The performance of the individual Catapults and the network will continue to be measured so that their effectiveness and relevance can be demonstrated and maintained. We will consider the case for further expansion of the network at the next Spending Review.

5.27 Decisions on the sectors and challenges for future Catapults will be taken transparently, using the current criteria of the potential for a large global market, UK research excellence and absorptive capacity in UK businesses. We will ask Innovate UK, working with others, to establish a "bottom up", flexible approach to identify, seed and nurture potential new technologies, to ensure that the right options are identified for the UK.

Catapults are trusted neutral conveners and facilitators of collaboration. They enhance knowledge dissemination and increase SME involvement.

The Offshore Renewable Energy Catapult's SPARTA project has created a database for sharing anonymised offshore wind farm performance and maintenance data in collaboration with the Crown Estate and off-shore wind owners-operators. The resulting increased yield, better operations and management strategies and improved reliability should lead to £200-£300 million of financial benefits in the next 5 years.

The Digital Catapult has partnered with the Copyright Hub company and industry competitors to build a pilot platform for easier licencing of creative content. This new copyright marketplace could deliver benefits of up to £2 billion to the UK economy by 2020.

Catapults anchor investment in the UK in key strategic sectors. Public investment crowds in industry investment, including on an international level.

The Cell Therapy Catapult has collaborated with ReNeuron to help secure a £33 million financing package, cementing the company's position in the UK, and enhancing its competitive edge. New expertise has been developed at the Catapult to accelerate the growth of the industry.

Catapult facilities are often one of a kind in the UK. SMEs could not afford them and larger companies would not take the risk of investing in such high level facilities.

The High Value Manufacturing Catapult worked with PolyPhotonix, an SME, to develop a therapeutic device for macular degeneration, which is now in phase 3 clinical trials and will save the NHS £1 billion per annum. Using the facilities at the Centre for Process Innovation meant that PolyPhotonix did not need to try and invest in prohibitively expensive equipment.

Catapults are having international impact through their coordinating role.

The Satellite Applications Catapult has brought together international organisations based in the US and Norway, with a satellite data services company to develop a prototype global fishing monitoring tool. The aim is to eliminate illegal fishing in 10 years, an illegal trade currently worth $23.5 billion annually.

5.28 Alongside the Catapults we will identify technological opportunities that will be important to the future of the UK, and also globally. These technologies have the potential to dramatically change the way we engage with our environment, and government support has included funding, but also regulatory reform and other interventions. They include:

- Ultra Low Emission Vehicles (ULEVs) – finite resources and pollution mean the development of Ultra Low Emission Vehicles is essential for continued sustainable mobility, as well as providing an opportunity to attract inward investment to UK manufacturing. Through the Office for Low Emission Vehicles, we are incentivising consumers to adopt the technology, supporting Research and Development and launching initiatives to increase uptake by cities, bus providers and taxi services. The government has committed £900 million between 2010 and 2020 to investment in ULEVs.

- Shale – with the potential to transform our future energy supply, shale gas could increase our energy security, support thousands of jobs, reduce our carbon emissions and generate substantial tax revenue for the country. We have put in place world-leading regulation and a competitive fiscal framework to kick-start exploration for shale gas in a safe and environmentally sound manner. But to ensure there is public support we will provide a new £5 million fund to provide independent evidence directly to the general public about the robustness of the existing regulatory regime.

- Driverless Cars – these have both social and economic benefits. They have the potential to increase mobility, for example for the elderly, and to increase productivity, through enhanced logistics and the transformation of cars into mobile offices. The government is investing in four driverless car testbeds from next year, allowing the technology to be trialled in real-time to increase technological development whilst building social acceptance. We will also publish a regulatory review at the end of January 2015 and, instead of implementing regulatory changes which may hinder the technology's development in the long term, will also set out a 'code of best practice' for trialling – allowing regulation to evolve with the technology, making the UK the best place in the world to test and use driverless cars.

Joining up the business support landscape

5.29 Access to finance for innovative businesses has remained a challenge. The two main financing gaps that have historically affected innovative firms are at the seed stage, during the first commercialisation of innovation, and then the 'equity gap' as innovative firms grow. We have taken significant steps on both counts.

5.30 We have introduced the new Seed Enterprise Investment Scheme. In its first two years (April 2012 to July 2014), this scheme supported over 2,000 companies to raise over £175 million. It has also significantly strengthened both the Enterprise Investment Scheme and Venture Capital Trusts, increasing the limits so that larger companies with up to 250 employees and £15 million of gross assets could benefit from up to £5 million of investment a year. Earlier this year, the British Business Bank announced that it would be extending its Venture Capital Catalyst Fund scheme to provide up to £125 million to increase the availability of later stage venture capital funding to businesses with high-growth ambition.

5.31 The Financial Conduct Authority introduced a new regulatory regime in April 2014 to support the growth of crowdfunding. This industry has grown rapidly, providing an estimated £80 million of equity finance both at the seed stage and the venture stage.

5.32 But there is still more to do. At Autumn Statement we announced a new commitment of £400 million over three years to extend the Bank's flagship venture capital programme, Enterprise Capital Funds, which will allow Funds to make larger investments of up to £5 million. Going forward, BIS and the British Business Bank are going to publish an 'equity tracker' providing a much more detailed view of how much equity finance is reaching small businesses to demonstrate better the evolution of the 'equity gap' that affects innovative businesses. The British Business Bank will also shortly publish its analysis of the latest trends in small business finance, including an analysis of venture capital markets for growing innovative businesses.

5.33 In 2002, publicly-funded research organisations and BIS created the Rainbow Seed Fund (RSF), which is a £24 million, early-stage venture capital fund dedicated to kick-starting promising technology companies. The Fund holds investments in some of the UK's most innovative companies in areas as diverse as novel antibiotics, research into Alzheimer's disease, "green" chemicals and airport security. For example, RSF has invested in Cobalt Light Systems, an early-stage company based in Harwell, Oxfordshire which was set up to exploit technology spun-out from the Science and Technology Facilities Council Rutherford Appleton Laboratories.

Since January 2014 certain liquids must be screened in EU airports and Cobalt's Insight 100 product has been selected at many key hubs including Heathrow, Gatwick, Paris and Schiphol largely due to its very low false alarm rate and high threat detection capability.

5.34 We are also making it simple and easy for businesses to get the right support at the right time. This has already led to Innovate UK, Growth Accelerator, and the British Business Bank forging strong links to connect innovative businesses to the right sources of finance. This includes the new GrowthShowcase portal which showcases the most exciting Innovate UK-funded and Growth Accelerator-supported companies to investors through an online platform, with the Bank raising awareness amongst its fund managers. We are now going further and have recently launched a single service – the Business Growth Service – for businesses with ambition and potential to grow. This brings together the full range of expert advice to improve and grow in one place. This is part of our work to simplify the government offer of support for all businesses, with a single place to go for help – GREATbusiness.gov.uk – supported by a national helpline with expert advisers, and local growth hubs.

The power of place

5.35 Amongst the most innovative environments are geographic clusters of businesses in the same industry or clusters of organisations that offer complementary activities, enhanced by opportunities for training, development and collaborative research. Such clusters are being backed across the UK. We need all parts of the country to flourish and fulfil the potential of their people, businesses and specialisms. LEPs have been created to empower local business and university leaders to engage directly with government and drive decisions that help their economies to grow. The government welcomed the fact that many local growth strategic plans had strong innovation elements.

5.36 LEPs will also have a key role in operating the next round of the European Structural and Investment Funds across England. During the programme period, around £600 million from these funds will be applied to research and innovation activities in the 39 LEP areas. LEPs have been encouraged to take a 'smart specialisation' approach to developing their plans. This has meant working with business and other stakeholders to develop a clear understanding of the sectors and technologies in which they have a comparative advantage and selecting from these a small number of key priority areas on which to focus their investments for maximum impact.

5.37 To help LEPs in gathering, assessing and understanding the data needed to develop a complete and accurate understanding of their strengths, we have commissioned the National Centre for Universities and Business to develop an advisory hub. This hub will provide LEPs with the information they need to make good investment decisions and uncover opportunities for collaboration and partnering with projects in other areas.

5.38 Further opportunities to strengthen local engagement in innovation are also now in place. In January 2015, Innovate UK will lead the Enterprise Europe Network in England, Wales and Northern Ireland, with a network of expert advisers connecting local and national, as well as international agendas by helping businesses find partners globally. The Enterprise Europe Network will work closely with Growth Hubs and LEPs to deliver enhanced support to innovative businesses. In Scotland, it will be led by Scottish Enterprise.

5.39 Researchers and business leaders need access to the best expertise and infrastructure wherever it is located. We are supporting innovative clusters by connecting them with partners such as Catapults, Research and Technology Organisations, universities, science campuses and science parks. Barriers between organisations are dissolving.

Oxford: how a city with ambitions to grow is using design to stimulate innovation and the local economy

Oxford is world renowned for education and, as a centre for technology research, is a key part of the UK's knowledge economy. There are 1,500 high-tech firms in Oxfordshire, employing 43,000 people and the city's labour force has the highest proportion of graduates anywhere in the UK, other than Cambridge. Managing a successful, growing city while maintaining its character and enhancing its reputation requires careful consideration. A city's built environment can either facilitate or hinder local ambitions for growth. The City Deal for Oxford and Oxfordshire sets out clear ambitions by supporting a new wave of innovation-led growth to maximise the area's world-class assets. These include "big science" facilities such as Harwell Oxford Campus and the Oxford Innovation Campus. Public and private funding is combining to invest in a network of innovation and incubation centres in Science Vale Oxford (Oxfordshire's Enterprise Zone), to develop major sites in Oxford, and to enable the growth of small and medium-sized enterprises.

The City Deal identified transport improvements and the provision of high-quality housing as fundamental to the delivery of innovation-led growth. To help meet these challenges, Oxford City Council commissioned the Design Council to provide design support services across the city to blend world-class expertise and local knowledge to accelerate the necessary development. This approach brings together councillors, council officers, developers, investors and other key stakeholders to debate and set a benchmark for design in the city. In combination with the adopted Local Plan, this is enabling Oxford to set out a clear vision and strategy for the city's development. It gives investors confidence and secures a vibrant, prosperous future for the city. The support is helping the City Council develop the confidence it needs to demand high-quality solutions and to ensure they can be delivered.

5.40 The government has increased UK support for clusters that foster collaboration. Earlier this year, the government piloted University Enterprise Zones (UEZs). Four UEZs have been established in Bradford (the Leeds City Region), Nottingham, Bristol and Liverpool. These partnerships between universities and LEPs will provide strong support to small high tech businesses.

5.41 Innovate UK is running competitions for Launchpads to accelerate the development of technology based business clusters that have potential for further growth. These have included Tech City in London, Motorsport Valley around Oxford and to the Digital and Creative Clyde in Glasgow. Each Launchpad focuses on a specified technology and Innovate UK provides grant funding, a structured programme of business support and access to finance.

6 Participating in global science and innovation

Participating in science and innovation as a global enterprise and realising the full benefits of international collaboration

"One of the UK's not-so-secret weapons for growth is its world-leading research community. Global companies set up in the UK in order to participate in a world-class research environment that can help give them a decisive lead against global competition"

Professor Andrew Blake, Microsoft Research Cambridge

The UK's position

- The UK has become a partner of choice for research collaboration, with 48% of all UK articles in 2012 resulting from international collaboration
- Almost 72% of active researchers were internationally mobile (meaning that they have published articles while working at institutions outside of the UK) in the 1996-2012 period
- The UK attracts the 2nd largest number of international students after the USA. Roughly one in six students come from overseas, of these nearly 70 per cent are from outside the EU
- The UK has strong presence in international university league tables, with 3 in the top 10 and 29 in the top 200
- In 2011, the UK attracted almost $7 billion of overseas-financed R&D. This is the same as Canada, Finland, Japan, China, and Russia combined, more than either France or Germany ($4 billion each) and just under half that of the USA (with $16 billion)
- Since 2008, the percentage of business R&D financed from overseas has remained comfortably above 20% for the UK, which compares to less than 14% of all our comparator countries

Actions taken by this government:

- The UK-hosted G8 Science Ministers meeting in 2013 and Carnegie in 2014 has put international science – and the agendas the UK cares about – more firmly on the international agenda
- Progress has been made in bilateral science collaborations with China and India. Since 2007, the value of UK-China Research Council programmes has risen to £130 million. In India this has risen from £1 million in 2008 to £150 million in 2013
- The £375 million Newton Fund was launched this year as the first truly significant UK bilateral international science and innovation fund. Through this the UK will use its strength in research and innovation to promote the economic development and social welfare in 15 partner countries. This will also enable us to build strong,

sustainable and systemic relationships with these countries that will support the continued excellence of the UK research base

- In the last two years of the EU's flagship Seventh Framework Programme for Research and Technological Development (FP7) the UK moved from second to first position, receiving more money than any other European country in applying for this instrument
- In negotiating the €80 billion successor programme (Horizon 2020), we successfully pushed for the programme to be more relevant to business and societal needs – thereby making funds available to support the UK's Industrial Strategy
- To help small businesses access EU research funds, we successfully argued for a dedicated instrument for SME research. Horizon 2020 has allocated €3.2 billion for this and in the first round of funding applications the UK was the second most successful country

Next steps:

- We will continue to promote the Newton Fund to support the development of scientific excellence and build scientific partnerships of the future
- We will use our participation in the ERA, the G7, G7+5, G20 and our Presidency of the EU in 2017 to demonstrate our leadership on topics such as open access and infrastructure where the UK is at the forefront
- We will provide further support to UK universities and research institutions to access some of the research elements of the $140 billion international aid funding from multilateral banks, UN agencies and other donors
- We will help small and medium-sized UK businesses to take their first steps into export and we are launching a new £20 million package of support

Introduction

6.1 Science and civilisation are inseparable, and the history of civilisation is, at least in part, a history of science. Scientists have always sought out like-minded partners with whom to argue, to debate, to collaborate and to compete. These partners have come from all around the world. The Royal Society from its earliest days promoted a global scientific outlook. In 1723 it appointed an assistant secretary for foreign correspondence. Individual Fellows and the Royal Society itself have had enduring relationships with their counterparts in countries such as Russia, India and China. These relationships have endured, even through times when political and economic relationships between our respective governments have been strained. The shared values of science can be important in diplomacy and keep doors ajar even at times of the greatest divisions between nations.

6.2 So the first part of the global elements of the science and innovation strategy is obvious. That is the importance of maintaining and growing the UK's participation globally. We must continue to encourage the interchange of UK scientists with their counterparts from around the world. Science and Innovation must continue to be an integral and essential part of the UK's diplomatic efforts. In one way this is easier than it has ever been, because communication via the Internet is easy and nearly instantaneous. Sharing results and ideas is easier than it has ever been.

6.3 But the Internet is not a substitute for direct contact. A visitor to almost any laboratory, institute, university or business research department that is world class in quality will discover that it is home to researchers from many countries. The Science and Innovation Network embedded in UK missions around the world, which works closely with partners such as UKTI, the British Council and FCO Prosperity Officers, will continue to play an important part in connecting UK scientists, innovators and businesses with their counterparts around the globe.

Funding global scientific infrastructure

6.4 Nations around the world have recognised that the price of the most advanced scientific infrastructure and facilities is so high that the financial burden of these should be shared. There is also a particular type of infrastructure that can only be located in certain parts of the world, which forces scientific international collaboration. Astronomy is one example of this, where large optical instruments need to be located in regions of the world with low light pollution or in space, and large radio telescopes require low levels of electromagnetic pollution, which similarly can either be achieved in space or in a few remote parts of the planet.

6.5 There is an excellent track record of international collaboration in the building and running of large facilities – and to some extent, this is an area that is a victim of its own success, as the scale, scope and costs of international facilities have increased during recent decades.

6.6 So decisions to build new infrastructure must be tensioned against the costs of existing infrastructure. This creates a challenge for the peer review system. All the best scientists in a particular field around the world may have a vested interest in a major facility, meaning that it is hard to obtain dispassionate peer review. Experts should be sought who have the insight without personal interest in the infrastructure under review.

6.7 None of this argues against the importance of the continued development and maintenance of global research infrastructures. But it does argue for the development of robust mechanisms of governance, regular peer review, and for the choice of directors and executive teams based on excellence as the prime criterion.

6.8 It should be a norm for any international scientific infrastructure to be the subject of at least a quinquennial review, including peer review of both the science and operations of the infrastructure and taking likely lifespan and long term revenue costs into account.

Square Kilometre Array

The Square Kilometre Array (SKA) will be the world's largest and most sensitive radio telescope. With the observatory divided between South Africa and Australia, the total collecting area of the telescope, spread across many receivers, will be approximately one square kilometre. This will give 50 times the image resolution of the Hubble Space Telescope and survey speeds thousands of times faster than the best current-day telescopes. The key science projects will focus on: studying the formation of the first objects in the universe – the first stars and galaxies; probing cosmology – understanding Dark Energy and how galaxies evolve to what we see today; and testing Einstein's theories – the search for gravitational waves. Outside astrophysics, SKA will be an exceptionally powerful solar system science tool and a tool for astrobiology, undertaking studies of planetary and space weather, as well as conducting the most sensitive search yet for intelligent life elsewhere in the universe.

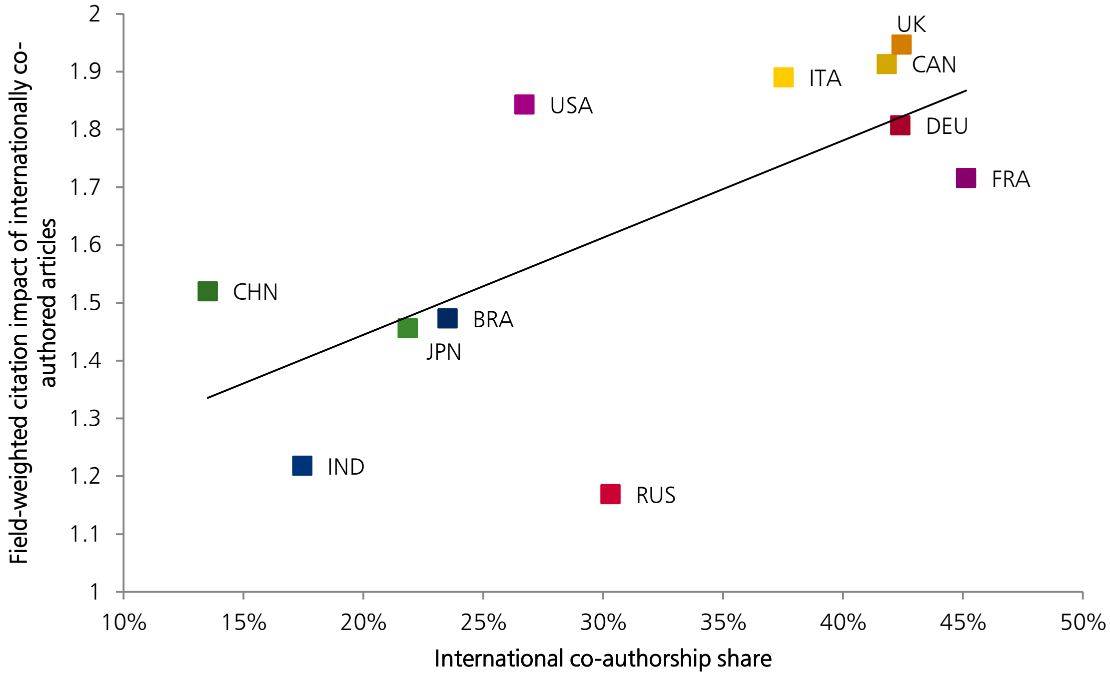
Innovation in electronics, software, and computing are central to realising the SKA. Transformational changes are required in electronics and in computing. The science requirements of the facility are acting as a driver for innovation in components and in associated software development – supported by large ICT industry companies. By 2023, the Square Kilometre Array project will generate 1300 billion gigabytes of data each month, (which is more data than the entire current global internet monthly traffic today). Processing such a flood of data will require computers over a thousand times faster than today's.

The headquarters of the SKA is based in the UK at the University of Manchester's Jodrell Bank Observatory and currently has around 50 staff focused on developing the governance structure (treaty organisation) and the baseline design for the SKA. The HQ is the central hub for the entire design effort, coordinating 11 unique work packages tasked to deliver the site infrastructure, the Science Data Processor (the high performance computing heart of the telescope) and the fast networks to transfer the data. This entire effort involves ~500 scientists and engineers in 20 different countries. The Universities of Cambridge and Manchester are leading key design work packages for the SKA Organisation, the Science Data Processor and the Signal and Data Transport, showing the UK's leadership in high performance computing and ICT.

Promoting the UK as a key partner in global networks

6.9 UK businesses and institutions must be able to operate effectively with international partners and draw on resources around the world. Indeed the UK is highly connected internationally, and has become a partner of choice for research collaboration. Over 40% of articles result from international collaboration, and these deliver higher impact (see graph below).

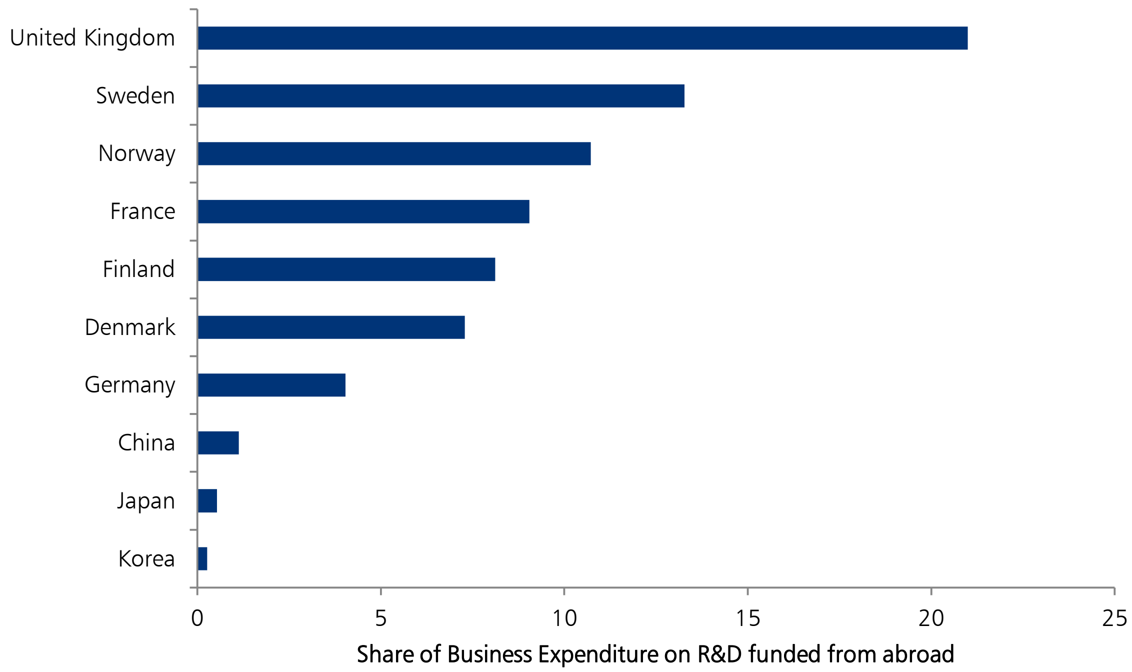
Chart 6.A: Correlation between international co-authorship and FWCI, 2008



Source: Elsevier (2013). 'International Comparative Performance of the UK Research Base – 2013'

6.10 The UK also has a high share of business R&D funded from abroad (see graph below).

Chart 6.B: International comparisons of the UK's position on R&D funds from abroad



Source: Office for National Statistics and OECD Main Science and Technology Indicators

6.11 We need to continue to develop stronger, open and mutually supportive relationships with a range of countries, both to encourage investment in the UK and enable our businesses to export.

6.12 The UK is already the top beneficiary from the EU Framework Programme, particularly in terms of funding received via the European Research Council (ERC) for excellent science. We need to build on this success and increase SME access to Horizon 2020 funding by working with Innovate UK, and the national contact points they are supporting for Horizon 2020. We also need to encourage UK institutions and businesses to prioritise the importance of knowledge and networks in Europe and the world and to access them in ways that are beneficial to them and to the UK economy. UKTI supports businesses in this endeavour.

6.13 There are also opportunities for UK universities and research institutions to access some of the research elements of the $140 billion international aid funding from multilateral banks, UN agencies and other donors, and a number are already taking advantage of these. However, there is more that can be done to support the UK research base here. We will build on the work of the UKTI's Aid Funded Business Service and provide more systematic support to enable the UK to gain further access to these funds.

6.14 It is important that we influence the new EU Commission and the European Parliament on the future of science, innovation and research policy. We are doing this in part by influencing the direction of the European Research Area to maximise the benefits to the UK from participation. The UK is a driving force in the development of the ERA roadmap and, by mid-2015, will set out the priorities for deepening the ERA as a single market for research and knowledge. Looking forward we will seek to work with other Member States, the Commission and business to establish a pro-innovation regulatory framework in the EU.

6.15 We will use our participation in the ERA, the G7, G7+5, G20 and our Presidency of the EU in 2017 to demonstrate our leadership on topics such as open access and infrastructures where the UK is in the forefront. We will also continue to consider how to build capacity in the EU13 and other countries through the sharing of best practice and encouraging excellence.

6.16 However, the international science and innovation landscape is changing. Emerging powers are increasingly becoming global players. We are no longer in a world where the vast majority of leading research and innovation activity is undertaken in North America and Europe. Real growth in gross expenditure in R&D in China from 2005 to 2010 has been ten times as high as in the USA, and sixteen times as high as in the UK. But it is not only the BRIC countries that are developing their scientific bases rapidly. For example, South Africa is planning to increase R&D expenditure to 2% from a base of less than 1% in 2009. Turkey, Malaysia, Colombia and Egypt are others where R&D expenditure is increasingly rapidly. This signals the increasingly competitive environment in which UK research and innovation is operating. It is important that we further build our relationships with these new scientific powers.

6.17 Science is a critical lever to help the UK achieve wider public policy goals. The UK's outstanding science heritage is a source of considerable 'soft power' around the world. Science is an increasingly important element of 21st century diplomacy. The scientific values of rationality, transparency and universality can increase confidence in bilateral relationships through building apolitical partnerships.

6.18 Excellence and leadership in science, technology and innovation can create a range of formal and informal channels of influence and opportunity that transcend national interests. Science can forge political, economic and social links even in politically difficult circumstances. For example, UK scientists are working with counterparts in North Korea to understand Mount Paektu, a volcano responsible for one of the most intense eruptions recorded in human history, which is showing signs of life.

6.19 To ensure that we are able to maximise the benefits from science diplomacy we need a joined-up strategy – working effectively across our overseas networks (the Science and

Innovation Network, DfID, UKTI and prosperity officers) and with key delivery partners such as the British Council and Research Councils. There has been much progress in recent years and the Newton Fund is proving successful in deepening these partnerships further. But there is always more that can be done. We need to continue to strive that the sum of all our activity is more than the parts and that we achieve maximum impact from our strength as a scientific nation.

Attracting inward investment and supporting trade

6.20 Attracting research and development investment into the UK is essential to help to create high-skilled jobs and develop intellectual capital. The UK does well here. In 2011 the UK attracted almost $7 billion of overseas-financed R&D. This is the same as Canada, Finland, Japan, China and Russia combined, more than either France or Germany ($4 billion each) and just under half of that of the USA ($16 billion). However, there is scope to do more. Research commissioned by UK Trade and Investment shows that UK innovation is still seen internationally as excellent in science but weak in commercialisation.

6.21 The UKTI Innovation Gateway has been established to fill this gap and provide an easy front door for international investors. It will create tailored investment portfolios and propositions on science and innovation for large international funds and corporates, whilst supporting innovation-focused UK companies in the 8 Great Technologies to internationalise and grow. As a commercially focused organisation, it will convert more of the latent international economic value in the UK's innovation system into growth for the benefit of UK PLC, working in partnership with Innovate UK, the Research Councils, the Science and Innovation Network, and the wider ecosystem.

6.22 Since its launch in March 2014, the UKTI Innovation Gateway has supported the landing of over £485 million in FDI and R&D investment including significant international businesses such as IBM, Eutelsat, Rockwell Collins, and Lockheed Martin, as well as supporting more than £160 million in business wins for UK companies in the 8 great technologies. It has delivered an international Innovation is GREAT campaign with events across 10 markets supporting more than 1000 smaller businesses, and facilitated more than 60 inward investment leads. UKTI's Venture Capital network, led from the Innovation Gateway, has supported more than £97 million in venture capital investment, driving the growth of early stage innovation-led businesses.

6.23 UKTI is also launching a new £20 million package of support to help small and medium-sized UK businesses to take their first steps into export. It will support over ten thousand new exporters in the next year.

6.24 A strong research base helps us attract international students – the UK attracts more than anywhere other than the US (13% of the internationally mobile student market in 2011). But it is important that mobility goes both ways. We will increase the outward mobility of UK students to strengthen links and share knowledge with Europe, as part of Erasmus+, and with the rest of the world. UK students who spend time overseas gain valuable skills to compete as graduates in an increasingly globalised marketplace. This is why we are supporting a sector led strategy to increase the outward mobility of UK students. The Higher Education International Unit is working to increase the profile of outward student mobility, address barriers and raise awareness of the benefits. To do this, the new 'Go International' website brings together information on studying, volunteering and working abroad. Two separate pieces of new research will establish the value of mobility for employability and academics' perceptions of mobility. We will also grow the number of students spending time overseas through bilateral programmes with a number of countries. The British Council's Generation UK China initiative aims to increase UK students participating in study or work programmes in China. Generation UK India will increase the number of young people from the UK gaining experience in India.

Science, aid and economic development

6.25 Given the importance of science and innovation for economic development, it follows that this should be an important component of overseas development assistance. The UK has a long record of partnership working with scientists and countries in the developing world. There is partnership and participation at many levels. Individuals and groups of scientists in universities, industry and research institutes have formed important collaborations.

6.26 Through the Newton Fund, a £375 million fund over five years, the UK will use its strength in science and innovation to promote the economic development and social welfare of partner countries. By working together on bilateral and multilateral programmes with a research and innovation focus, the UK will also build strong, sustainable, systemic relationships that will support the continued excellence of the UK research base and innovation ecosystem and unlock wider opportunities for collaboration and trade. In its first six months the Newton Fund is already generating significant diplomatic gains. It has delivered a step change in UK-China relations as China has opened up domestic research funding for collaboration on an unprecedented scale to the UK. Similarly the Newton Fund has rapidly positioned us as a partner of choice in South Africa and it is now Chile's most significant international science and innovation bilateral partnership. In the UK it has also leveraged wider funding from GlaxoSmithKline.

6.27 Outstanding UK charities and other voluntary organisations are active throughout many parts of the world. The UK government will continue to support research and capacity building through DfID and the Research Councils.

Science in ungoverned spaces

6.28 Humans only inhabit a tiny fraction of the planet and universe. The oceans and the Antarctic are not subject to the sovereignty of individual countries. And we share our atmosphere and the core of the planet, even though this may be above or below sovereign nations. Similarly space is ungoverned by any sovereign nation. And human technology has created a new form of space, cyberspace. None of these are in the domain of any individual country alone and all are part of the domain of the scientist. The UK is a major player in each of these ungoverned spaces.

6.29 The UK has well developed strategic priorities in ungoverned spaces from the high seas and the Antarctic to space and the cyber world, and we will take them forward. For example, the Space Growth Action Plan published in April 2014 reconfirmed government commitment to growing the space sector and raise our share of the expected £400 billion global space-enabled market to 10% by 2030. Our Cyber Security Strategy set out how the UK will support economic prosperity, protect national security and safeguard our way of life by building a more trusted and resilient digital environment.

Space

The UK space sector is growing at around 7% a year, and has created 5,000 new jobs from 2011 to 2013 – bucking the overall trend in the UK economy during that time. The UK Space Agency believes that, to support this phenomenal growth in the space sector, it is essential to support research and innovation at all stages of the value chain and work in partnership internationally, nationally and locally.

Key achievements include UK participation in Europe's Rosetta mission and the landing of the Philae lander on a comet this year, which opened a new chapter in Solar System exploration.

UK companies have now won contracts to build the Galileo system equalling the contribution that the UK makes to the Galileo programme (around 14%). Surrey Satellite Technology Ltd in Guildford has developed an advanced assembly facility to build the payloads of the 22 Galileo satellites on order.

Large satellite export contracts won in 2014 as a result of technology developed through UK contribution to ARTES (including those secured by Airbus DS UK for the SES 12 and Eutelsat 172b satellites) are worth in excess of £160 million to the UK.

Support for world-class space science includes the Gaia satellite observatory that is accurately mapping the position and motions of a billion stars. We have also provided funding for satellite technologies such as the MicroWave Sounder, which will improve the MetOffice's ability to accurately analyse weather patterns.

More than one hundred highly skilled ESA jobs have been reallocated to the UK from the Netherlands following our commitment to increase in UK funding for ESA. The new ESA facility, the European Centre for Space Applications and Telecommunications (ECSAT), is now being built at the Harwell campus and will be completed in 2015.

We have secured an astronaut flight for Tim Peake on the International Space Station, with corresponding scientific, education and outreach benefits for the UK.

The UK will play the leading role in the Mars Rover, key to the European Space Agency's ExoMars mission – which has the potential to be as significant a source of scientific and engineering advance, and to inspire new generations, as the Rosetta project.

6.30 Ultimately, there is a 'selfish' reason for the UK to take a global approach in this science and innovation strategy. This is fundamentally good for UK science, innovation and international relations. Science and innovation will play an important part in defining the place of the UK in the world in the 21st century. That is why this strategy is so important. But it will only be effective if all of the partners work individually and collectively to deliver its common aims. The UK is a proud leader in the business of science and innovation. To stay there we cannot stand still.

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