Science & Innovation Strategy

Submission from the Royal Academy of Engineering

31 July 2014

About the Royal Academy of Engineering

As the UK's national academy for engineering, we bring together the most successful and talented engineers for a shared purpose: to advance and promote excellence in engineering.

Royal Academy of Engineering Submission to the Science & Innovation Strategy

1. Introduction

1.1 The Royal Academy of Engineering welcomes this opportunity to contribute to the development of the Science and Innovation Strategy. The Academy is responding both individually and in conjunction with the other three UK National Academies. Since the joint response covers fundamental research in detail, the emphasis in this response is on innovation and the relationship between the research base and industry. The inputs should therefore been seen as complementary and collectively reflect the Academy's position.

Investment in R&D

1.2 The UK has world-class universities, an extraordinary history of invention and innovation and many world-leading science and engineering-based companies. However, international competition is stronger than ever and is set to increase in years to come. The UK's R&D investment levels lag behind those in many key competitor countries (1.8% GDP c.f. 2.7% in US, 2.8% in Germany, 3.4% in Japan and 4.0% in Korea), and it is especially troubling that our business R&D investment levels are persistently low.[1] In respect of the latter, boosting the innovation performance of, and R&D engagement by, SMEs is a particular challenge.[2]

1.3 Whilst the UK has maintained the science 'ring-fence', the science budget has been falling in real terms since the last Comprehensive Spending Review, with inevitable consequences. The Strategy needs to reaffirm and fortify the Government's commitment to investment in science and innovation as a key driver of economic success and to provide new and better tools to address societal challenges. This requires maintenance of the science ring-fence as a minimum and a recognition that UK investments in R&D must be commensurate with the scale of its ambition as a knowledge-driven economy.

1.4 Within the context of a thriving research and innovation system, engineering has a specific role to play in creating new and better products and services that can generate wealth and improve quality of life. Strategic investment in engineering can yield a significant return on investment for the UK since engineers draw on scientific advances produced all around the world in developing innovations that create wealth for the UK.

Systems approach

1.5 If the Strategy is to have real impact, it needs to adopt a systems approach to the treatment of the UK's research and innovation base. This entails taking a holistic view of the incentive structures, interventions and policies that impact on the research and innovation system. It is essential, for example, that the Science and Innovation Strategy and the UK's industrial strategy are coordinated effectively: the investments being made through the sector strategies and Eight Great technologies in skills, R&D and innovation are substantial and provide real opportunities for UK researchers and innovators to achieve leading positions in the global market.

1.6 The Strategy also needs to connect with relevant policy areas beyond those which BIS is directly responsible for, with important interfaces to policies on

---

[1] Gross Expenditure on R&D (GERD) as percentage of GDP in 2011, OECD

[2] Insights for International Benchmarking of the UK Science and Innovation System, BIS, January 2014 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/277090/bis-14-544-insights-from-international-benchmarking-of-the-UK-science-and-innovation-system-bis-analysis-paper-03.pdf

infrastructure, education and skills, immigration, procurement, energy, tax etc. If the support of other Government departments could be secured, the potential impact of the Strategy would be amplified significantly. The Strategy should also provide a framework to achieve coherence across R&D investments by different Government departments and agencies.

Stability

1.7 Continuity and consistency is widely seen as being more important than the specifics of any one policy, as noted in the recent Wright Review of Advanced Manufacturing.[3] We understand that the Strategy is focussing on the period until 2020. It is very welcome that the Government is taking a longer-term approach to policy making in this area and would favour the Strategy looking beyond this five-year horizon. A ten-year horizon with periodic review would provide stability with flexibility. In view of the forthcoming General Election, it is also important that there is broad-based support for the Strategy within the science and innovation community and across political parties. The Strategy should therefore establish principles for good stewardship of the research and innovation system that would be broadly accepted across the political spectrum.

Promotion of the Strategy

1.8 In developing this Strategy, due attention needs to be given to how it can be utilised as a tool to market and promote the UK as a world-leader in research and innovation. Germany, for example, has utilised *Industrie 4.0* to promote the merits of German industry extremely effectively, and there has been considerable international interest in the UK's adoption of a modern industrial strategy. Coordinated and well-designed communications material that can be shared across key UK agencies, including UK Trade & Investment, will help to ensure that a consistent and compelling message about the strength and stability of the UK research and innovation system is transmitted to potential international partners, investors and talent.

Recommendation: The development of the Strategy provides an excellent opportunity to help create a stable and positive policy framework for the UK research and innovation system that will give businesses and others the confidence to invest and position the UK as an attractive destination for international talent and investment.

2. Infrastructure

- *How to strike the balance between meeting capital requirements, at the individual research project and institution level, and the need for large-scale investments at the national and international levels?*
- *What are the UK's priorities for capital investment in the national interest, including potential collaboration in international projects?*
- *How to make the most of the existing research and technology organisations, in both the public and private sectors, and their infrastructure to strengthen science capability and support for businesses?*

2.1 The approach to determining capital expenditure needs to recognise that capital, skills, research and innovation, as well as the cost of running and maintaining the capital equipment, are all integrated and cannot be easily separated. Core

[3] *Making the UK a Globally Competitive Investment Environment: The Wright Review of Advanced Manufacturing in the UK and its Supply Chain*, Mike Wright, June 2014, http://thewrightreport.net/report.html

infrastructure is the foundation on which the next generation of leading researchers are trained. The state of the art equipment is only as good as the skilled professionals running the equipment, accessing the facilities, interpreting the results and providing the intellectual challenges for the future.

2.2 It is important for the capital investment decisions to align with the needs of the UK's industrial sector strategies and enhance opportunities for exploitation of the Eight Great technologies. Within this, the UK requires a balanced portfolio of capital investment at different levels which incorporates:

- A high degree of support for underpinning local infrastructure;
- Targeted regional, mid-range provision, with incentives to maximise academic and industrial access and collaboration;
- An appropriate balance between existing facilities and emerging areas of strategic importance to the UK; and
- The creation of research and innovation clusters, co-located across academia and industry, which can contribute to UK jobs and growth.

2.3 The Academy recognises the need to identify strategic priorities for capital investment in a financially constrained environment, where Government, industry, academia and policy makers working together can make a significant difference. Some examples include: advanced materials and manufacturing, cross-cutting infrastructure, energy security and resilience, high-performance computing, big data and software dependability. In addition, consideration should be given to large-scale facilities which enable laboratory research (in technologies such as robotics and autonomous systems) to be scaled up to higher Technology Readiness Levels through trials in representative environments.

2.4 For international investments, it is vital for there to be a long-term vision for the UK's priorities in major projects and for the Government to reinforce its commitment to areas where substantial investment has already been made. Capital investment, providing it is well planned and operated, can be a 'sticky' form of public investment working as an attractor for inward investment and skilled people flowing to the UK. It is also important that once international commitments have been made, the UK should engage positively and lead thinking in international projects, rather than being a reluctant or ambivalent partner.

2.5 Whilst the Academy is supportive of the principle that RTOs and other types of organisations could be considered as recipients of capital investment by Government, the Academy advises that any extension must be based on the quality of the research that would be enabled by the specific capital investment and a previous track record of delivery in the relevant organisation. Decisions on the most appropriate delivery organisations should be based on merit, within the context of the UK's wider Science & Innovation and industrial strategies.

Recommendation: Capital investment decisions need to be informed by and aligned with the Science & Innovation Strategy as well as the UK's wider industrial policy (including the growth sector strategies, Eight Great technologies and Catapult centres). They must also be integrated with resource planning and skills development.

3. Business Investment

- *What more could be done to catalyse business investment in R & D and close the gap with other leading economies?*
- *How to ensure that more SMEs develop new products and services and bring business innovation performance at the level of other leading economies? How can the science and innovation system better support SMEs?*
- *How can the science and innovation system better contribute to support innovation in services, a large part of the UK economy?*

3.1 The UK's performance must be considered in the context of a highly internationalised research and innovation system. The globalised nature of business now means that the choice of where to develop and manufacture products is strategically and commercially very important and the UK has to compete with many other countries for business investment in R&D. Recent research commissioned by the Campaign for Science and Engineering has highlighted the importance of public investment in R&D as an attractor for business investment in R&D, including from overseas,[4] and there is growing consensus that public investment 'crowds in' rather than 'crowds out' investment by other actors. In addition, access to skills, markets and other parts of the innovation system, as well as labour costs, tax and fiscal policy and political considerations, all have a bearing on where companies choose to invest.[5] Selected examples of collaborative investments in R&D in the UK involving the public and private sector are provided at Annex 1.

3.2 The development of industrial strategy in the UK is an important step, providing a welcome and much-needed signal to business (both domestic and overseas) that the Government is committed to providing a stable policy framework for key sectors and technologies. The aerospace and automotive industries provide excellent examples of what can be achieved through effective sector leadership councils with strong political and industry buy-in, creating business confidence and a clear vision for the sector. In these sectors, dominant OEMs actively encourage innovative supply networks to form and help drive up-skilling in the supply chain, in the knowledge that a quality supply network is a competitive advantage for the business.

SMEs

3.3 Mechanisms that encourage large companies to involve small companies in their collaborations with universities can be effective ways of encouraging engagement by SMEs. Policies intended to promote SME engagement in R&D are therefore likely to be most effective if they incentivise the whole supply chain. Industrial strategy also provides opportunities to improve UK performance in this area and more could be done to build on the relationships in the sectoral clusters that form around leadership councils to promote engagement between SMEs and the research base and build innovative capability in SMEs.

3.4 The majority of SMEs in the UK are at the smaller end of the spectrum and greater thought needs to be given to how Government initiatives and instruments (e.g. KTPs) can be made accessible to such micro-companies as opposed to SMEs in general. In addressing this, consideration needs to be given to both the ability of the SME to engage and the attractiveness of the proposition to the academic researcher.

---

[4] The Economic Significance of the UK Science Base, Campaign for Science and Engineering, March 2014 http://sciencecampaign.org.uk/UKScienceBase.pdf

[5] Here or There: A survey of factors in multinational R&D location, Report to the Government-University-Industry Research Roundtable, National Academies Press, 2006

3.5 Procurement is a powerful lever available to Government to stimulate innovation in SMEs. The US Small Business Innovation Research (SBIR) procurement model provides one route to promoting collaboration within a supply chain and has been far more successful than the UK Small Business Research Initiative (SBRI) scheme in this regard. Regrettably, procurement in UK Government Departments still tends to favour 'faster and cheaper' over 'smarter and better value': too often, the outcome is neither faster nor cheaper.

3.6 The Catapults represent an important mechanism provided by the Technology Strategy Board (TSB) for supporting collaborations involving multiple institutions and companies, including SMEs. Catapults have been helpful for reducing investment capital requirements for companies entering key markets by offering open access prototyping, scale up and demonstration facilities. It is encouraging that there has been continuity of support by successive Governments for the Catapult model (even if the name has changed), and that Dr Hermann Hauser CBE FREng FRS has been asked to review progress following his report in 2010, since the tendency of Government to introduce new initiatives and funding instruments (or to rebrand existing ones) has certainly not been of benefit to the research and innovation system in the UK. The existing Catapults are already demonstrating their worth and need to continue to receive appropriate Government support to enable their potential to be realised. Notwithstanding the differences between the two systems, the Fraunhofer network in Germany, which has grown organically with consistent public support over a sixty year period, serves to illustrate the tremendous benefits that can be derived from stable and sustained investment.

Recommendation: The Strategy should recognise the role that larger companies can play in acting as traction engines that pull through the development of smaller companies in their supply chains. Procurement remains a key and under-utilised tool available to Government for stimulating innovation and improving the value and quality of public services. Growth sector activity also provides an excellent opportunity to facilitate engagement between SMEs and the research base.

Classifications

3.7 It is unhelpful that Government policy often seems to assume that SMEs can be treated as a coherent group. In fact, the needs of a company with two people are fundamentally different from those of a company with 200. In addition, many firms in the SME category may never wish to or be able to engage with the wider research and innovation community so policy interventions need to be targeted at the high-growth potential, innovation-driven companies within the category. Work is needed to find a more appropriate way of defining this group and then promoting its adoption within (and beyond) Government.

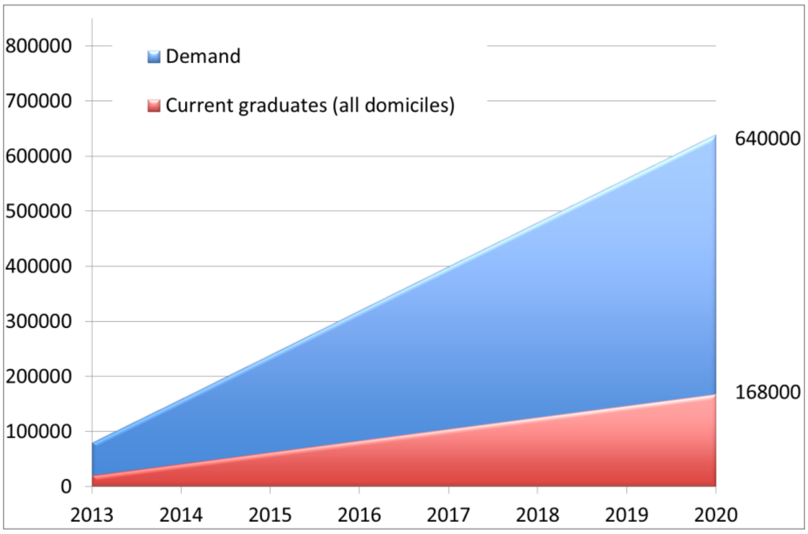
3.8 Current classification systems (including Standard Industrial Classification codes) also greatly oversimplify and distort the relationship between manufacturing and services, which can mean that the contribution that engineering and technology makes to the service economy is underplayed. Such classifications fail to take account of key trends such as the servitization of manufacturing and the significance of engineering consultancies for the service economy. This matters because it hampers the ability to collect meaningful evidence about the performance of the research and innovation community and to target policy interventions appropriately.

Recommendation: The Strategy should address the need to update definitions and classification systems used to identify types of company and sectors.

4. Talent

- *How to expand in the UK the number of people in science, technology, engineering and maths (STEM) disciplines at all levels of qualifications?*
- *How to raise awareness in the UK of science careers and opportunities and maximise the chances of people fulfilling their potential?*
- *Have we got the right balance of skill levels and disciplines for the future of science and innovation? Which are the areas to grow?*
- *Do we have masters and postgraduate degrees that prepare well to take up technological and managerial roles in UK businesses?*

4.1 The UK's ability to develop, attract and retain people with the right skills and capabilities will be one of the most critical factors in determining our future competitiveness. The Academy and EngineeringUK estimate that the demand for engineers in the UK will be between 1.28 and 1.86 million technicians and professionals in science, engineering and technology roles by 2020.[6,7] This means approximately 640,000 graduate engineers will be required by 2020 across all sectors of the economy. Seven out of 10 of these jobs will be to replace the ageing workforce. However, UK higher education institutions currently produce only 21,000 graduates each year, resulting in a shortfall of some 470,000 graduates (as shown in the figure below).[8]



4.2 The Academy and the Engineering and Physical Sciences Research Council (EPSRC) are undertaking a detailed review of the economic impact of engineering research and training, due to be published in the spring. A crude analysis of the major engineering sectors suggests that engineering now accounts for 24.5% of the turnover of all businesses in the UK. Easily identifiable engineering activity totals some £370 billion and contributes around 30% to Gross Value Added

---

[6] Jobs and Growth, Royal Academy of Engineering, October 2012 https://www.raeng.org.uk/news/publications/list/reports/Jobs_and_Growth.pdf

[7] EngineeringUK report 2014 www.engineeringuk.com/Research/Engineering_UK_Report_2014/

[8] Ibid

(GVA). The 2012-13 Adult Population Survey estimates 2.73 million engineers working in the UK. EngineeringUK identifies some 565,000 engineering businesses in the UK employing 5.4 million people.

4.3 The strong message from industry is that, welcome though the many initiatives to address skills shortages are, they do not address the issues at the scale and pace required. With skills shortages already affecting business performance and outlook, several companies have stated that if they cannot obtain the skills they need from UK domiciled people they will either import skilled people from overseas or the work will be exported. The UK therefore risks giving away massive value in the form of skilled jobs for young people and technology-led growth in the economy.

4.4 Initiatives to attract more young people into engineering careers are necessary but not sufficient to address the skills crisis: a systems treatment must be applied. For example, activities such as the Government's 'Your Life' campaign provide very welcome opportunities to increase uptake of maths and physics A-level and thus demand for engineering degrees. However, insufficient consideration has been given to the issues of specialist teacher shortages in STEM subjects in schools, league table pressures on schools creating disincentives to increase participation in STEM post-16, and the capacity of the Higher Education system to absorb increased demand. In fact, Academy research has highlighted a shortfall in capacity, with a clear divide between engineering provision in pre- and post-92 universities.[9] Pre-92 universities are full and increasing UCAS tariffs for entry; in some instances they are unable to make a business case for expansion of high capital cost courses. Post-92 universities meanwhile face a threat to provision based on a lack of demand.

4.5 It is also essential that STEM professionals have the right types of skills and qualifications to equip them for the needs of industry. The Academy's analysis of STEM in Further Education shows the majority of courses being taken in the UK are at Level 2 (GCSE equivalent) and there is little progression to the higher skill qualifications that industry needs.[10] In Higher Education, schemes such as the Visiting Professors and Visiting Teaching Fellows programmes run by the Academy have brought practising industrialists into universities to enrich the student experience and update curricula, thereby ensuring that graduates emerge ready to enter the world of work. This model is now widely used in engineering but is perhaps less common in some other STEM subjects. Taught Masters courses can make a particularly valuable contribution to developing skilled personnel of value to industry. The aerospace MSc bursary scheme, which the Academy helps to deliver, provides a good example of a coordinated approach to developing the higher skills needed across the sector that could easily be transferred to other sectors.

4.6 Critically, if the skills shortage is to be addressed, the lack of diversity in engineering will need to be tackled. In the UK, 13% of applicants to engineering undergraduate degree courses and 5.5% of the professional engineering workforce are female, placing the UK at the bottom of the league within Europe for gender diversity in engineering.[11] The Academy is leading a programme to address this issue in partnership with other key stakeholders in the engineering profession. It should be noted that intervention is required at multiple stages in the skills pipeline, from increasing the uptake of maths and physics A-levels by

---

[9] Skills for the nation: engineering undergraduate in the UK. Royal Academy of Engineering 2013

[10] FE STEM Data report 2012 www.gov.uk/government/statistical-data-sets/fe-data-library-other-statistics-and-research#stem

[11] WISE UK Statistics 2012 www.wisecampaign.org.uk

girls in schools to working with employers to make engineering careers more attractive. Developing more flexible career paths for engineers and increasing the ability of technically-qualified individuals to enter the engineering profession at later stages (e.g. through Masters courses) may also improve the appeal of engineering careers to other under-represented groups.

Recommendation: The Strategy needs to acknowledge that the UK is facing an engineering skills crisis. It must commit the Government to taking urgent and effectively-targeted action to address this. This will involve inspiring, engaging, recruiting and retaining more young people in engineering careers, as well as building an education and training system that is designed to convert aspiration into attainment and the skills that industry needs.

Immigration

4.7 Engineering is a global profession: UK engineers are in demand internationally, UK universities educate many foreign students and a majority of the large engineering firms active in the UK employ significant numbers of engineers from overseas. It is therefore a source of concern that the Government's immigration policy and, importantly, messaging have had a detrimental impact on the attractiveness of the UK as a destination for international talent. The recent House of Lords Science and Technology Select Committee Inquiry into International STEM students heard extensive evidence regarding the negative impact of UK immigration policy on the ability of universities to recruit STEM students from some countries, most notably India, and on employers.[12] While the picture is complex, it is widely agreed that the main impact on universities has been to postgraduate taught courses (which, as noted above, are of particular importance to industry). In addition to the policies themselves, confounding factors include uncertainty over what the rules are and a widely held perception that the UK does not provide as warm a welcome as some competitor countries.

Recommendation: The UK's immigration policies and messaging have had a detrimental effect on the attractiveness of the UK for international talent. The Strategy needs to ensure that the Government's approach to immigration helps rather than hinders the national growth agenda.

5. Reaping the benefits

- *How to get the right balance between curiosity driven research and applied research?*
- *How to take forward the progress already made on maximising the impact of research?*
- *What are the most effective models of Government support to catalyse innovation and technology transfer?*
- *Is the Catapult approach as set out in 2010 working? What should be the future direction of the Catapult network in scope and scale?*
- *How to identify the technologies that are priorities investment? How to build the evidence base to make these decisions?*

[12] International Science, Technology, Engineering and Mathematics Students, House of Lords Science and Technology Select Committee, Fourth Report of Session 2013-14, April 2014

Support for innovation

5.1 There have been a number of positive developments in recent years in the Government's support for innovation – the TSB in particular has made a very valuable contribution and we are encouraged by the extent of business engagement in the shaping of its strategy and programmes. Despite the recent increases in funding for innovation, we remain concerned that the scale of resource available impedes the ability of the TSB to meet national need effectively. It is increasingly accepted that the UK Government has tended to withdraw support for technology development too early in contrast to the US where public support has been provided much closer to market.

5.2 While increased Government investment in innovation is essential, it needs to be appropriately targeted. The UK has sometimes tended to 'spread the jam thinly' rather than focus investment on a more limited number of priorities to achieve critical mass in those areas. High-performance computing is often cited as an area where the UK has lost out on the opportunity to have a truly world-leading facility by distributing the funding across too many centres. Access to world leading facilities can play an important role in influencing business decisions regarding R&D investment.

5.3 The Academy is strongly supportive of the focus brought by the identification of the Eight Great technologies and, as noted above, would argue that the principle is more important than the specific selection. However, we would also note that the Government might benefit from broader engagement with the academies and other key stakeholders in future prioritisation exercises to ensure that the selection is as robust as possible. It is equally important to engage appropriate experts in guiding decisions around implementation: effective targeting must extend to the oversight of progress and programme steering, not just resource allocation. The US Department of Energy's approach to programme management is worthy of further investigation as a model of good practice.

5.4 In addition to the Eight Great technologies, the Academy would welcome clearer identification of areas where the UK needs to maintain strategic national research capabilities, for example in relation to security, energy and health. The loss of the UK's nuclear skills base provides an example of our failure to do this successfully in the past.

Recommendation: The UK needs to boost public investment in innovation in order to match the scale of both national need and global opportunity. While it is crucial that the UK has a vision for innovation that is ambitious in scale, it needs to take a focussed approach to scope, with clearly defined priorities and targeted investment to ensure critical mass and impact. The Government should call on appropriate external expertise to ensure robust identification of priorities and successful implementation.

Collaboration vs Competition

5.5 The UK is a relatively small country with a high concentration of talent. It is therefore critical that effective connections are made between local and regional centres of excellence and clusters. Whilst recognising that there are examples of excellent practice, the Academy remains concerned about the lack of funding for and clarity about the role of Local Enterprise Partnerships (LEPs), including their relationship with the TSB. There appears to be significant variation in capability, activity and engagement with the public and private sectors and academia amongst LEPs and their role in stimulating innovation remains largely unproven. The quality of staff is likely to be a key determinant of success and there may be a role for Central Government in supporting capacity development within the LEP teams. In addition, the granularity of LEPs is such that coordination will be essential to ensure that they can be effective in serving the national interest.

5.6 It is also important that the innovation system promotes collaboration between other key groups. Equipment sharing between universities and businesses can facilitate collaboration and help to ensure that maximum efficiencies are derived from public investment in research capital. Catapults and vehicles such as the ETI have provided other valuable mechanisms to facilitate collaborative research and innovation activity.

5.7 As the UK's innovation system evolves, it will become increasingly important to consider the architecture of the instruments available to support innovation and, in particular, the connections between instruments provided by different agencies, including the TSB, Research Councils, HEFCE, LEPs, the devolved administrations and the EU. Further work is needed to improve the navigability of the innovation support architecture, particularly for small businesses, and any new instruments introduced should support cooperation with and innovation flow across existing instruments.

Fundamental and use-inspired research

5.8 Innovation is not a linear process: it requires feedback from the market, timely and appropriate investment at critical development points and the interaction of a variety of actors. There is a complex interplay, including multiple feedback loops, between fundamental research and use-inspired or application-focussed research. They can both play key roles in driving innovation and provide rigorous intellectual challenges. The Strategy provides a welcome opportunity to raise awareness of this.

5.9 However, incentive structures in and for universities (including those used by the Research Councils) tend to provide greater reward and recognition for achievements in fundamental research. Incremental improvements in the efficiency of a particular manufacturing process can have significant impacts on a company's bottom line and even the competitiveness of a sector but will rarely result in a metric that will help advance an academic's career, in the near term at least. Experience within universities also suggests that success in innovation and entrepreneurship will have little impact on career progression within the academic system and can even be considered a hindrance. In addition, while most innovation takes place through the activities of teams, many forms of recognition focus on the achievements of individuals. Prizes such as the MacRobert Award and Queen Elizabeth Prize for Engineering, which are awarded to teams responsible for ground-breaking innovations, provide important opportunities to counterbalance this tendency.

5.10 The Academy has found through the research programmes it delivers in partnership with industry that bringing prestige and an association with excellence to application-focussed research can help ensure that high quality researchers are not discouraged from working with industry. Such de-risking of the relationship is especially important for academics at an early-stage in their career. While the Research Excellence Framework (REF) now provides a mechanism for recognising and rewarding impact at the level of a department, there may be value in broadening the interpretation of impact to include, for example, businesses created by researchers who have been trained within a department but who have left to set up the company. It should also be noted that there are few incentives, and some potential disincentives (including the REF), for universities to recruit industrialists to join their research staff. In countries such as the USA and Germany, there is far greater interflow of researchers between academia and industry and it is commonplace for senior academic staff to have spent significant periods of time working in industry. This model brings benefits to academia, industry, the researchers themselves and the students they interact with.

Recommendation: The Strategy should emphasise the fact that innovation is not a linear process and relies on complex interactions between fundamental research and use-inspired research. There are insufficient incentives to encourage academics to engage in application-focussed research and entrepreneurial activity and to reward those that achieve excellence in these endeavours. There is also a need to increase the permeability between academic and industrial research careers.

University technology transfer

5.11 The emphasis on the third mission of universities in knowledge transfer has had many benefits but there is growing concern regarding the approach taken by universities to the protection and exploitation of IP. For example, the Academy's enterprise activities have highlighted several instances of universities taking equity stakes in spin-outs that are so high that they may damage the likelihood of the company succeeding. There can also be a tension between the objective of ensuring that IP generated from publicly funded research is exploited and the expectation that the universities should derive income from it. Businesses frequently complain that academics overestimate the value of the IP they have generated and underestimate the cost and risk involved in taking it to market. There are a number of interesting examples of new approaches to technology transfer being developed by universities, including easy access, open access and 'golden share' IP models and joint technology transfer offices for consortia of universities. We believe that this is an area that merits further investigation.

Recommendation: The Strategy should highlight the need to identify and promote best practice in the protection and exploitation of IP by universities.

Investment and regulatory environment

5.12 The wider investment and regulatory environment can have a major impact on the ability of the UK to reap the benefits of its investments in research and innovation. Regulations and standards can act as either brakes on growth or drivers of innovation so it is vital that Government recognises the importance of these as factors influencing competitiveness. OECD analysis has also shown that well-functioning product, labour and risk capital markets and bankruptcy laws that do not overly penalise business failure can raise the returns to investing in knowledge-based assets.[13] The same analysis noted that in countries that had repeatedly changed their R&D tax policy, the impact of R&D tax credits on private sector investment in R&D was greatly diminished, reinforcing the importance of a stable and consistent policy environment.

5.13 The UK's investment environment for innovation and entrepreneurship has both strengths and weaknesses. The Enterprise Investment Scheme (EIS) and Seed Enterprise Investment Scheme (SEIS) have been broadly welcomed by the entrepreneurial community as helping to make the UK one of the most favourable environments for Angel investing. However, a lack of access to debt financing for SMEs remains a concern and there is limited availability of venture capital for technology-based enterprises. Furthermore, companies backed by investors under the EIS and SEIS schemes can have difficulty in securing venture capital

[13] Supporting Investment in Knowledge Capital, Investment and Innovation, OECD, October 2013

funding compatible with the tax breaks enjoyed by EIS and SEIS investors, which can contribute to the likelihood of such companies being sold early. Recognising the challenges facing UK engineering and technology-based SMEs, the Academy has recently established an Enterprise Hub to harness the expertise and networks of its Fellows, who include some the UK's most successful engineering entrepreneurs, business leaders and investors, to build the capabilities of the next generation of engineering enterprises and to connect them more effectively with potential investors and routes to market.

Recommendation: The Strategy should position the UK as having the best regulatory and investment environment for innovation in priority sectors and technologies. This should include ensuring that Government policies support the development of a continuous and effective 'funding escalator' for risk capital.

International dimension

5.14 If the Strategy is to be effective, it must consider the position of the UK's research and innovation base within a highly interconnected global system. Research endeavours draw on and generate international networks and knowledge and large companies and their supply chains are becoming ever more international in nature. The EU provides a major source of funding and partnerships for UK research and innovation, as well as being a critical market for UK businesses. While UK academics have been exceptionally successful in attracting European funding, the picture is less positive for UK businesses: income drawn down by UK businesses from FP7 is 63% of that achieved by German industry and tends to be clustered in smaller, niche themes rather than the larger, better-funded themes.[14] This underlines the importance of establishing an architecture for innovation support within the UK that facilitates access to international instruments, funding and expertise.

5.15 The global landscape for research and innovation is changing, with several emerging powers now prioritising investment in research and innovation as a key determinant of future economic and geopolitical influence. The Strategy needs to include a commitment to building partnerships at scale with the countries whose investments, talent, infrastructure and industry will make them world-leaders in research and innovation in the future, as well as with the scientific and engineering superpowers of today. The Newton Fund has the potential to provide a powerful mechanism for strengthening relationships with several of these countries, as well as building capacity and delivering knowledge and innovations that will help address the needs of poor people in developing countries. However additional mechanisms are needed to allow UK businesses as well as academics to collaborate with international counterparts in lead sectors and technology areas (as defined within the industrial strategy). It is also important to ensure that the UK has clear metrics that will enable it to understand the performance of its research and innovation system – including with regard to the wider regulatory and investment environment – against international comparators, and takes targeted action to intervene where performance is lagging.

Recommendation: The Strategy must give due consideration to the global context of the UK research and innovation system. This should include action to support substantive business and academic collaboration in priority sectors and technologies with key international partners, as well as monitoring the UK's international performance against the full range of relevant indicators.

[14] http://raeng.org.uk/societygov/policy/responses/pdf/RD_Joint_National_Academy_Submission_Final.pdf

6. Summary of Recommendations

- The development of the Strategy provides an excellent opportunity to help create a stable and positive policy framework for the UK research and innovation system that will give businesses and others the confidence to invest and position the UK as an attractive destination for international talent and investment.
- Capital investment decisions need to be informed by and aligned with the Science & Innovation Strategy as well as the UK's wider industrial policy (including the growth sector strategies, Eight Great technologies and Catapult centres). They must also be integrated with resource planning and skills development.
- The Strategy should recognise the role that larger companies can play in acting as traction engines that pull through the development of smaller companies in their supply chains. Procurement remains a key and under-utilised tool available to Government for stimulating innovation and improving the value and quality of public services. Growth sector activity also provides an excellent opportunity to facilitate engagement between SMEs and the research base.
- The Strategy should address the need to update definitions and classification systems used to identify types of company and sectors.
- The Strategy needs to acknowledge that the UK is facing an engineering skills crisis. It must commit the Government to taking urgent and effectively-targeted action to address this. This will involve inspiring, engaging, recruiting and retaining more young people in engineering careers, as well as building an education and training system that is designed to convert aspiration into attainment and the skills that industry needs.
- The UK's immigration policies and messaging have had a detrimental effect on the attractiveness of the UK for international talent. The Strategy needs to ensure that the Government's approach to immigration helps rather than hinders the national growth agenda.
- The UK needs to boost public investment in innovation in order to match the scale of both national need and global opportunity. While it is crucial that the UK has a vision for innovation that is ambitious in scale, it needs to take a focussed approach to scope, with clearly defined priorities and targeted investment to ensure critical mass and impact. The Government should call on appropriate external expertise to ensure robust identification of priorities and successful implementation.
- The Strategy should emphasise the fact that innovation is not a linear process and relies on complex interactions between fundamental research and use-inspired research. There are insufficient incentives to encourage academics to engage in application-focussed research and entrepreneurial activity and to reward those that achieve excellence in these endeavours. There is also a need to increase the permeability between academic and industrial research careers.
- The Strategy should highlight the need to identify and promote best practice in the protection and exploitation of IP by universities.
- The Strategy should position the UK as having the best regulatory and investment environment for innovation in priority sectors and technologies. This should include ensuring that Government policies support the development of a continuous and effective 'funding escalator' for risk capital.
- The Strategy must give due consideration to the global context of the UK research and innovation system. This should include action to support substantive business and academic collaboration in priority sectors and technologies with key international partners, as well as monitoring the UK's international performance against the full range of relevant indicators.

Annex 1: Collaborative Research and Catalysing Business Investment

1. This Annex provides examples of the importance of collaborative research between academia and industry. As noted in the Wilson Review, universities are an integral part of the skills and innovation supply chain to business.[15] The benefits of university-business partnerships are substantial, ranging from challenging industrially-inspired research to the delivery of novel commercial products across a range of sectors.

2. A key strength of the UK's innovation system is the excellence of its research base. With only 0.9% of the global population the UK punches above its weight, with 15.9% of the most highly cited articles.[16] This excellence is cited by business as a key reason for continued engagement in the UK higher education sector and attracts major investment from international companies.

3. The UK Research Councils and Technology Strategy Board are instrumental in providing research and innovation opportunities for UK business and researchers. Such commitment to long-term collaborative research and innovation, working in partnership with multinational companies, has been shown to pay dividends.

4. Some examples follow which are **only illustrative** of the contribution that engineering makes, recognising that it would be impossible in a short document to provide a fully comprehensive picture. The examples demonstrate the impact of collaborative research across a number of sectors. It is important to stress the time it can take to go from research output to commercial benefit (which reinforces the need for a sustained strategy and support structures). The examples highlight the importance of large companies, a range of SMEs and specialist contributors working with public sector funders within different innovation systems.

Collaborative Research and Innovation

5. A 10 year partnership between Rolls-Royce and EPSRC is supporting leading-edge research in priority areas for the aerospace industry. The £51M public-private initiative has helped ensure that Rolls-Royce and companies in its supply chain continue to invest heavily in UK science and engineering. In another area, Jaguar Land Rover is leading a five-year research programme with EPSRC and Loughborough University, University of Leeds, University of Cambridge and Warwick Manufacturing Group. The £10M collaboration between Jaguar Land Rover and some of the UK's leading academics will develop the capability of the virtual simulation industry in the UK and give manufacturers access to new, world-class simulation tools and processes, enabling them to deliver more complex new vehicle programmes more quickly and save costs in product development by reducing the reliance on physical prototypes.

6. Within the Chemicals and Process industry, innovation underpins the continued success of world-leading multinationals such as Procter & Gamble (P&G). By strengthening its portfolio of consumer products and the processes behind them,

---

[15] *A review of business-university collaboration,* Professor Sir Tim Wilson, 2012 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/32383/12-610-wilson-review-business-university-collaboration.pdf

[16] *International comparative performance of the UK research base*, Elsevier, 2013 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/263729/bis-13-1297-international-comparative-performance-of-the-UK-research-base-2013.pdf

scientific breakthroughs sharpen the company's competitive edge helping to create jobs and ultimately drive growth. However this cannot be achieved without a solid platform of world-class research and innovation. The Technology Strategy Board has helped to negotiate the 'valley of death' between the laboratory and the marketplace leading to real-world solutions to tough industrial problems. For example, fundamental collaborative research into cold water cleaning (i.e. effective low-temperature detergents), has now led to the creation of the Centre of Excellence in Methods and New Technologies for Surface Modification and Cleaning (CEMENT), a £14 million Regional Growth Fund initiative involving P&G, Durham University, Peerless Systems and the Centre for Process Innovation (part of Technology Strategy Board's High Value Manufacturing Catapult).

Commercial Products and Economic Impact

7. The impact of Rolls-Royce's long-term investments through its University Technology Centres (UTCs) is visible in many of the company's products today. For instance, the highly-efficient wide-chord fan blade, seen at the front of the Trent 900, drew on technology developed in partnership with at least six different UTCs, covering disciplines as diverse as materials properties, manufacturing capabilities, aerodynamic design and noise modelling. Many other patents have arisen from the collaborative research, enabling significant savings for the aerospace sector as a whole.

8. The UK economy loses £24 billion (1.6 per cent of the country's GDP) every year because of problems with friction, wear and lubrication in transport, manufacturing, energy and life sciences. Researchers at the national Centre of Advanced Tribology (nCATS) at the University of Southampton are exploring ways of reducing this damage. Led by Professor Robert Wood, the Centre hosts 39 multidisciplinary researchers carrying out fundamental research in collaboration with industry. Findings which combat damaging friction and wear are already being used by British Nuclear Fuels Ltd and Sellafield. A further collaboration with the US Office of Naval Research, Chevron Oronite and GE Aviation has resulted in the development of advanced sensors that can detect signs of wear on surfaces and also monitor the oil condition in running machinery. GE Aviation has now integrated this technology into their commercial sensor systems.

9. Robotics and Autonomous Systems have had commercial impact in a number of areas and the potential for greater impact across diverse sectors is substantial. The timescale from basic research to commercial product is sometimes measured in decades, underlining the importance of a long-term investment and policy framework from Government. As an example, a RCUK funded feasibility study in 1979 led to the UK's first autonomous underwater vehicle at Heriot Watt in 1981. A series of RCUK-industry managed programmes in the 1980s had substantial impact in subsea automation and underwater technology. These were led from Heriot Watt in collaboration with Strathclyde, Newcastle, Cranfield and UCL. Coda Ltd was created in 1995 becoming the first commercial enterprise to build economic value from RCUK-funded underwater technology research in Edinburgh. In 2001 SeeByte Ltd, a spin-out company from Heriot Watt became a global leader in software for unmanned robotic systems building on EU, MOD and some underpinning EPSRC support. Finally, in 2012 and 2013 EPSRC, in collaboration with a number of companies, supported a Centre for Doctoral Training and capital investment creating an internationally leading cluster across Edinburgh and Heriot Watt. This will train the next generation of 'innovation ready' leaders and act as a magnet for inward investment.

10. The Centre for Process Innovation (CPI) is the UK's national technology and innovation centre to serve and support the process manufacturing industries. CPI works with key UK universities and academic spin-off companies to develop, prove, prototype and scale up the next generation of products and processes. In addition to

the CEMENT example above, other impacts include: (i) the Northern Way Printable Electronics Technology Programme which has stimulated near-to-market applications of printable electronics; (ii) CPI start-up company PolyPhotonix Ltd, a bio-photonic research company which has developed light therapy treatments for macular eye disease; (iii) advice to Applied Graphene Materials, a spin out from Durham University, on the design and build of their Graphene Demonstration plant; and (iv) helping PragmaticIC, a University of Cambridge spin-out out company, to move its logic circuits prototyping technology to pilot scale production.

Emerging Areas

11. Intelligent Energy is the world's largest independent fuel cell company and one of the fastest growing companies in Europe with major global partnerships in sectors including automotive (Suzuki), consumer electronics (Cable and Wireless) and stationary power (Microqual – a global telecommunications company with a strong presence in India, China and South America). Their fuel cell technology is behind the first manned flight of a fuel cell powered aircraft by Boeing, the first European approved fuel cell vehicle, and the zero carbon London taxis used in the 2012 Olympics.

12. The core of Intelligent Energy's knowledge and expertise is a group of ten researchers and students from the automotive engineering and chemistry departments of Loughborough University. When four of these researchers (Dr Paul Adcock, Tony Newbold, Dr Jon Moore and Dr Phil Mitchell) created the spinout Advanced Power Systems in 1995 on the back of EPSRC funded research, the group moved from the university to the spinout which later became Intelligent Energy. It is their knowledge and expertise in fuel cells, developed over 20 years, that gives Intelligent Energy a sustainable competitive advantage, resulting in revenue of £44m in 2012 with a net profit of nearly £8m. Based in the UK with offices in California, India and Japan, the company now employs 350 people worldwide and continues to work closely with UK academics with half of its research and development team made up of talented PhD graduates.