The Royal Academy of Engineering

SCIENCE AND INNOVATION INVESTMENT FRAMEWORK 2004-2014: Next Steps

Consultation Document: Response on behalf of the Royal Academy of Engineering

June 2006

Summary

1. The response from The Royal Academy of Engineering expresses the opinion that the existing framework for supporting science and innovation does not encourage an appropriate level of risk-taking. The document proposes a strategy that focuses on short-term deliverables, rather than more sustainable resources that underpin innovation. Strategies of this type are likely to discourage researchers and funding bodies from curiosity-driven, blue sky as well as risky and long-term research.

   The barriers to more risk-taking in research are mainly financial. Due to the high risk involved, raising the necessary funding in the early stages of exploitation of a novel idea may prove difficult. There is widespread consensus on the need for Government to provide financial support to advanced long-term projects at such stages and to an extent that business would be able to join in without taking excessive risks.

2. It is believed that a bias exists that unfairly favours established research fields over innovative ones. This lies within the dual support system for the allocation of research funds to higher education institutions. More specific factors that impede the development of innovative research fields lie in the structure, functioning and objectives of the Research Councils, Research Assessment Exercise (RAE), responsive mode funding mechanism and the peer review system, all of which rest on the sharp divide between disciplines. Innovative research spans across multiple fields, including the “cracks” in between them, and is therefore hindered by such a divide.

   Funding mechanisms can be made more responsive to new research challenges through several measures. Research Councils could be compelled to ring fence a percentage of their budget for high-risk research: such funds would not be in competition with those dedicated to basic or applied research. Two other possible measures include the allocation of more funds via the Quality Related (QR) mechanism (while reducing the responsive mode distribution of resources) and the diversion of some of the Research Councils’ budget to the Technology Strategy Board (TSB) for use in supporting high-risk and/or innovative projects.

3. Barriers limiting business innovation identify mainly with lack of financial resources. Whilst significant funds are being spent on science, further investments are needed if innovation in business is to be encouraged and improved. Another barrier is the difficulties that Small and Medium Enterprises (SMEs) may face in gaining access to academic knowledge and expertise, which in turn contributes even further to slowing down their innovative developments.

   The barriers that limit business-university collaboration are plentiful, but some that deserve particular attention are: ownership and use of Intellectual Property Rights (IPRs); scarcity of Research Council spending on industry-led research; universities’ reluctance to engage in industrial projects (whose output is less likely to be published on high impact journals); Regional Development Agencies’ (RDAs) policies.

   Innovation needs to be underpinned by “sustainable resources” that only talented people can provide. Thus, addressing some of the existing barrier requires a focus on equipping scientists and technologists with the “hard” and highly specialised skills and knowledge as well as with “softer” competencies than can be easily transferred from academic environments to business and back. Other measures include: better metrics for measuring innovation (also in the service sector); more effective Government policies (e.g. public procurement); allocation of more funds to the TSB and a better definition of its remit and identity; allocation of more resources to UK Trade and Industry (UKTI); a user-inspired research agenda and a better coordination between all the parties involved (Government, Research Councils, RDAs etc).

4. Good practice models for business-university collaborations are provided by: the Massachusetts Institute of Technology and its partner companies, the Technical University of Eindhoven & Philips, Science Parks, Enterprise Parks, University Technology Centres, Visiting Professorships and Industrial Secondment Schemes.

   Business can be encouraged to initiate collaborations with academic institutions through different forms of financial incentives (e.g. government contracts, tax credits linked to R&D spending etc.) and, in general, larger availability of public funds for industrial research.

5. The Academy strongly supports the integration of large facilities operations under a new Large Facilities Council, providing that there is a genuine economy of scale and not a distancing from important sectoral knowledge. The Council should act as a Research Council and not simply a management facilitator.

6. In the event of a merger, PPARC's grant-giving functions should not move to EPSRC since the types of funding and research are different in the two Research Councils. PPARC provides focused support to key research teams on the basis of long term strategic planning, whereas EPSRC's policy and planning are formulated so as to deliver in a relatively short timescale.

7. It is felt that the Research Councils are already effective. However, a few measures could be taken to improve their function. Widely criticised is, for instance, the responsive mode funding mechanisms. This favours a silo mentality that impedes innovative research while also prescribing the areas where researchers are more likely to obtain funds. A large consensus exists on the need for allocating more resources through the QR mechanism, which would allow more freedom to individual universities and their researchers, and consequently favour the creation of an academic ecosystem for innovation.

   Other factors that should be examined are: committees' structure and function, cross-council coordination, knowledge transfer and Research Councils' strategic plans.

1. **The Government would be interested in views about whether the existing framework for supporting science and innovation enables an appropriate level of risk-taking, and if not, suggestions of how any gap might be addressed.**

1.1) General considerations on Science & Innovation

The UK needs a more effective system to encourage and reap the benefit from innovation and maximising the impact of public investment in science on business innovation is one of the main targets set by the framework.

Scientific creativity and excellence are important inputs to innovation but should not be conflated with it, nor should it be assumed that they automatically translate into innovation: less than 10% of all innovative ideas derive from scientific discovery[1] (Fig. 1[2]). "The idea that a single person can *invent* a new technology is out of the question"[3] in many cases. "Creative ideas of course come from individuals but their ideas must fit into the matrix of creativity being generated by individuals and teams all over the world". Innovation builds on existing technologies, products and processes, and not least on the acquisition of additional knowledge that allows progress. However, while on the one hand "working from first principles is not effective as it opens up too many alternatives", on the other, "with most modern technologies the solution generally requires an intimate knowledge of the science that underpins the technology.". Thus, whilst an excellent science base undoubtedly underpins technological innovation, it does not translate directly into significant profits.

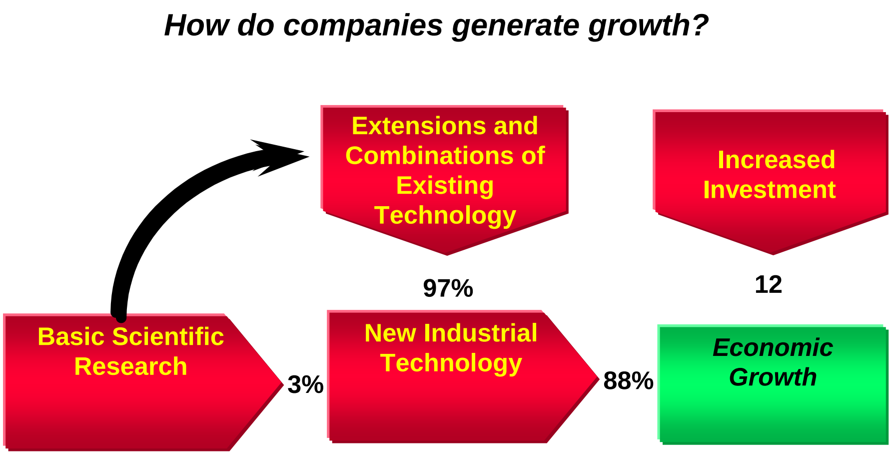

Fig. 1: The reality is that the ability to *combine* existing technology is far more important for value creation than the ability to *invent* new technology

1.2) Enabling high-risk research

The existing framework for science and innovation focuses on benefits to society, industrial exploitation, economic growth and the like, and it is tailored to foster research projects that are likely to turn into deliverables in the short term. This also implies a focus on the final product that directly affects the market, rather than resources that can underpin innovation in a more sustainable way. In this respect there appears to be a consensus on the importance of training and development of the right skills that can sustain an innovative culture and have long lasting effects. A strategy that focuses on short term deliverables may discourage researchers and funding bodies

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[1] Edwin Mansfield, *Academic Research and Industrial Innovation*, Research Policy 20, 1991, pp 1-12. See also *Innovation, Technology and the Economy*, The Selected Essays of Edwin Mansfield, Vol. II, Edward Elgar 1995, ISBN 1858980356.

[2] Terence Kealey, *The Economic Laws of Scientific Research*, Palgrave Macmillan 1997, ISBN 0312173067.

[3] Lord Broers, BBC Reith Lecture 2005 (Lecture 1).

from curiosity-driven, blue sky as well as risky and long-term research. The framework is therefore perceived as one that does not enable high-risk research.

Before discussing the nature of the barriers that impede a positive attitude toward high-risk research, it is important to clarify that high-risk research and high-impact research are not the same. Projects rated as high-risk have a high probability of failure, which usually becomes apparent after much time and resources have been spent on the project, hence the risk of losses. High-impact, instead, means that the outcome of the project, be it a device, system or process has significant potential for commercial exploitation[4]. The outcome of some high-risk research may, if positive, have a high-impact as well. But, in most cases, it doesn't for the reasons explained above.

1.2.1) Barriers to high-risk research: finances

The main barriers to risk-taking are financial and cultural. Availability of finance can be a major obstruction particularly in the early stages of exploitation of a novel idea. The demonstration of an adequate return on investment at this stage can prove difficult and the lack of necessary funding severely limit progress. The transition from promising research to innovative products and processes often needs a full commercial-scale demonstration unit in order to convince potential users of the new development that it is a safe, practical proposition. This unit may be a plant, an equipment item, a system or process, etc., but in engineering based product development cases it is likely to be by far the most expensive stage in the development chain, will need a suitable venue and will involve a high degree of risk. If the demonstration unit fails to perform satisfactorily, the consequential loss or damage may be many times the cost of the unit itself. This market failure occurs in new start-up companies as well as in large ones, particularly where product introduction time-scales are long. Circumstances such as these are neither suitable for businesses nor attractive to venture capital firms: consequently companies tend to focus on proven technology that can directly improve their business.

Interestingly, companies are very supportive of universities conducting farsighted research rather than near term projects, but they see this as the role of government funding alone. Business intervention comes later when the fruits of the research have ripened, thus avoiding those that have withered. There is widespread consensus on the need for Government to intervene more boldly in the funding of advanced long-term research to an extent that business would be able to join in without taking significant risks[5]. The science and innovation investment framework does not indicate that the division between the funding of "safe" research and support for high-risk projects is fully appreciated. Government assistance in the latter is far lower than required and therefore needs to be increased if the science base generated within UK Universities is to be fully exploited.

However, Government support for high-risk science does not necessarily exclude incentives that encourage businesses to undertake more speculative research. A method of taxation that divorces high-risk from high-impact research, for example, may be considered. The Government should share the cost of innovation by loans, repayable on market success whereas companies claiming R&D tax credits should have to show that a proportion of their R&D projects (say 10% for example) are high risk. However, the practical implementation of this mechanism may be difficult as it would depend on the criteria used to define "high risk".

1.2.2) Barriers to high-risk research: culture

Cultural barriers, if resistant, can hinder progress even in the presence of generous financial resources. It is fully acknowledged that the attitude and practices of the UK culture need to evolve in a way that an "ecosystem" that fosters innovation can be created. This can be achieved in many ways. For instance, new training regimes and research styles should be encouraged, for example through development of Enterprise Research Fellowships. In Yorkshire, through RDA funding,

[4] This kind of impact should not be confused with that associated with the score that places scientific journals in the excellence league. That factor only reflects the "academic" excellence of the study regardless of its potential for a practical impact.

[5] "SET and the City: financing wealth creation from science, engineering and technology", The Royal Academy of Engineering, in preparation.

examples of BioScience Enterprise Research Fellowships have been effective and provide good role models in changing culture within higher educational establishments. Learned Societies, Academies and charitable foundations would also be well placed to develop strategic schemes of such type.
In addition to financial and cultural impediments, several other obstacles lie on the path to the realisation of high-risk research. Among them are the structure and function of Research Councils, the RAE, the peer review process and the training of PhD students. The first three issues are addressed in the answer to question 2, whereas comments regarding the doctoral training are provided in the following paragraphs.

1.3) How to address the gaps

1.3.1) Doctoral training
Increasing the number of PhD students and much better support for graduate research training in the UK are perceived to be very effective ways of encouraging more innovative research. Students usually have more freedom to pursue new ideas and therefore are frequently the source of real innovation. However, at present there is a worrying shortage of UK students undertaking PhD programmes. The reasons are complex but include the rather low levels of grant support. This means that even if a research grant is obtained, it is increasingly difficult to find any UK post doctoral staff to undertake the project. Hence, a large number of personnel working on research grants are from overseas with the long term effect that UK plc is missing out on training more and well prepared researchers, and is helping to create overseas competitors. Another increasing trend is to make use of research grant income to employ personnel who are also registered for a higher (normally PhD) degree. The effect of this practice is to short-change the research training and decrease the opportunity for innovation. It also means that we are not producing enough research post-graduates to start changing business culture which is still often reluctant to engage in research innovation for the reasons described above.

In addition, business does not adequately reward PhD holders and their skills, often opting for a graduate with 3-4 years of work experience in preference to a PhD graduate. Hence, measures should be taken in order to:

- make all PhD programmes much more attractive to UK graduates by creating many more and better paid research studentship support schemes;
- ensure more rewarding career prospects for UK PhD students;
- educate UK companies of the value of a PhD;
- encourage more links between UK companies and PhD graduates (also see section 4.1.3 on Science Parks).

1.3.2) Allocation of research funding: the "dual support system"[6]
The responsive mode mechanism used by the Research Councils to allocate research funds is perceived as being too prescriptive and leading researchers to adopt conservative research approaches that are more likely to provide secure outputs. Innovation, by definition, implies a certain degree of risk and these circumstances surely hinder the development of an innovative research culture. It would be worth considering whether more funds should be allocated through the QR mechanism while also bearing in mind that not all basic research output can be exploited commercially. Then researchers would be more willing to undertake high-risk projects (also see answer to question 2 and section 7.1 on Response Mode Funding).

2. The Government invites views on measures to remove any remaining bias which unfairly favours established research fields over innovative ones. The Government also invites views on how funding mechanisms can be made more responsive to new research challenges.

[6] Quality related and responsive mode funding mechanisms

2.1) Bias that unfairly favours established research fields over innovative ones

It is believed that a bias exists that unfairly favours established research fields over innovative ones. This lies within the dual support system for the allocation of research funds to higher education institutions.

2.1.1) Research Councils

The boards and standing committees of many Research Councils tend to have a low and slow turnover of members. These are usually senior academics with a background in established and traditional disciplines that makes them ideal judges of research proposals that fall within their area of expertise. However, high-risk research is becoming increasingly interdisciplinary and such research projects may often be under-rated not only because, being high-risk, they may not deliver, but also, and more worryingly, because they cannot be fairly judged by panels lacking the competence needed to assess this type of research. Boards and committees should therefore consist of members selected from industry as well as from academia: in this respect EPSRC sets a good example. The members coming from industry should not be middle rank managers but talented entrepreneurs for these only will be able to make an informed assessment of the risk involved in the proposal. Among the academic members, the number of senior figures, who will have an expertise in one of the traditional disciplines, should be counterbalanced by members that have an interdisciplinary background. These are obviously likely to be less senior, although not necessarily less prepared. Further, the assessment of high-risk applications should be done in consultation with leading higher education institutions overseas that have the expertise and competencies to assess more speculative proposals.

Another issue is the remit of the Research Councils, their strategic priorities and commitment to deliver in the short term, and the lack of co-ordination between Councils with a close remit (e.g. BBSRC and MRC). There needs to be more effective mechanisms for ensuring that good quality innovative research that crosses Research Councils boundaries can be properly considered. If the current divisions among Research Councils are to be maintained, a clearly defined and fair system should be set up for considering cross-council research applications, which may not necessarily be in line with the Councils' strategic priorities.

High-risk research, by definition, has a low success rate, and even when successful, it may take much longer before the researcher and the funder enjoy the rewards. The return on investments in high-risk research is extremely uncertain and, unless Research Councils are reassured that farsighted research will not impact upon their performance, they will focus their resources on what is most effective in the short term, that is applications that are most likely to deliver high quality publications and/or patents.

Funding of high-risk research in a manner that does not have a negative impact on the performance of Research Councils can be achieved through dedicated, directed funding programmes for multidisciplinary research and for research crossing traditional discipline boundaries. In addition, dedicated funding programmes for emerging areas of science and technology should be established. Non-conventional funding mechanisms, such as platform grants and portfolio awards, give freedom to academics to pursue both innovative and new research challenges. It is essential that each Research Council maintains a balanced portfolio which could be imposed if Research Councils were required to devote a certain percentage of their budget to high-risk projects. Hence, "risk" would become a criterion for the selection of applications.

2.1.2) Peer review and responsive mode funding

The standard peer review process for responsive mode research tends to favour incremental and safe research. High-risk projects are often received with scepticism by referees and therefore rated poorly. This adds to the strategic objectives of most Research Councils that tend to minimise high-risk investments. It is felt that the review process for the assessment of proposals needs major revision: experienced review panels should be given the freedom to take risk and accept that some failures are inevitable. The review process for the DTI "Innovation" programme sets a good example.

2.1.3) Research Assessment Exercise

High-risk research is characterised by a significant number of ideas and projects that will fail to deliver. The RAE discourages risk-taking because failure to deliver has very damaging consequences for the individual as well as his or her department. However, if high-risk research is to be carried out, universities should adapt their own rewards for staff to encourage development of new research areas and innovation-led activities. There is some evidence of this happening and Government, through HEFCE, should strive to accelerate this. Further, the proposed metric-based system that will replace the RAE should not penalise those who embark in high-risk projects. Appropriate metrics, based on a positive perception of risk, should be formulated to assess and encourage specifically this type of research.

2.2) How to make funding mechanisms more responsive to new research challenges

Funding mechanisms can be made more responsive to new research challenges in a variety of ways:

- Research funding schemes should be created to encourage collaborative (including international) creative work, with shared IPRs yielding more radical innovation. RDAs are well placed to manage this activity with Universities and there is opportunity to stimulate such activities alongside those of the HEIF but these must be coordinated.
- A dedicated RCUK funding stream for innovation and collaborative applied research with industry and commerce: this should be kept separate from the normal Research Councils responsive mode funding so as not to compete with basic research or to skew it to matters that are wholly commercially focused. This system would also ensure that Research Councils have a balanced portfolio.
- Alternatively, such funds should be diverted and allocated through the TSB.
- Research funding could be allocated on a project by project basis to allow the more innovative and risky projects to go forward. This is particularly the case for large established research groups at the top of their field, where, of necessity, peer review has to be undertaken by those further down the tree of excellence. In these circumstance seeking the views of international referees, who do not have the same conflict of interest, would be helpful.
- The assessment of proposals should place far greater emphasis on a person's track record in developing innovative ideas than on the details of proposed programme of work. Hence, the funds would be allocated to the person, not the project. However, a different system would have to be set up in order to avoid penalising applications by young researchers who do not have a track record.
- Even when high-risk research does not require large grants and is funded without difficulties, the sometimes large and expensive gap needs bridging between finishing a research project with some interesting commercial application and getting the funds to build a small prototype that may attract industrial support or the interest of venture capitalists. Thus, the funding allocated to high-risk projects should also include a sum for the realisation of innovative research outputs (see section 1.2.1 on Barriers to high-risk research: finances).
- More attention should be given to co-joined initiatives with RDAs, some of which are already major players in research translation from universities and industry, but whose processes can be opaque to Research Councils.

3. The Government would welcome views on the barriers limiting greater business innovation and business-university collaboration in the regions, and on what more could be done on a national and regional level to tackle these barriers effectively.

3.1) Barriers limiting business innovation

In many industries it is important that participants keep their skills and knowledge up-to-date with new techniques. An area where this is especially true is Information Technology where the landscape is changing continuously. Part of this continual learning needs to include the topic of innovation. This would cover lateral thinking and problem solving, risk taking, the process of assessing and adopting new technology, IPRs, funding acquisition, etc. This type of education is necessary for individuals and organisations to have the curiosity and skill to collaborate and exploit innovation.

However, even in well-established companies, it is often the case that the availability of and access to scientific and technical literature, essential to keep up-to-date with new developments, is very scarce. One enormous strength of universities is the access to the most up to date literature, and industry should make an effort to make use of these resources. But universities also have another more important and unique function: their scholarship (i.e. breath and depth of knowledge) and the training of technologists who may act as an intellectual bridge between the repository of knowledge and the company, especially if they are completing a PhD, and that will be absorbed by the industry in the years to come. Thus, an effective way to ensure access to latest scientific and technological developments is through involvement of senior academic staff and PhD students. Companies may offer part-time appointments on their executive board to a professor that would act as an advisor and that would bring his/her academic competencies into the company. PhD students, on the other hand, are an excellent source of in-depth knowledge and fresh ideas, and an effective way to transfer innovation from the laboratory to business. In support of these considerations it is felt that the UK needs many more research compatible staff to be employed or to participate via secondment in its business. This will require many more of the best students to be encouraged to go on to pursue higher research degrees (and therefore the need for more support – see section 1.3.1 on Doctoral Training). Some of the big companies do fund PhD studentships and employ senior academics on their executive boards, but for SMEs this is more difficult and inevitably affects their access to excellent knowledge base.

However, Universities will allow companies to benefit from their resources only if such interaction benefits the academic institution as well. Stronger recognition and reward for innovation in universities is an obvious need to which some universities are responding (through changes in role analysis and criteria for promotion, local salary rewards, significant cash prizes etc) but the practice needs to be encouraged.

Barriers in the business framework also exist: the financial encouragement to be innovative in the UK is not competitive whether it is tax credits, technology support grants, small firm and start up company enhancement schemes and the whole (very cautious) approach of the City to technology based companies. Further, the role of the RDAs in creating science parks and technology based business clusters in their areas particularly with facility and infrastructure grants is not yet evident.

3.2) Barriers limiting business-university collaboration

3.2.1) Ownership and use of IPR

Universities wish to publish the results of their research: this is a measurement of their status within the system (RAE), and the means whereby the individuals concerned further their career. Industry would rather keep potentially profit making results to itself and negotiating a position between these two objectives is extremely time consuming. The Lambert model contract agreements have the potential to simplify contract negotiation on IPR but there is still a lot to be done and it is still too early to assess whether the new agreements have had an impact on the economy. In Germany, for instance, policy ensures that a university inventor is entitled by law to profits of his own invention, and it has been observed that this plays a direct role in stimulating innovation and has resulted in a high number of University patent applications[7].

3.2.2) Funding for industrial-type research

The type of work that industry would wish the university to undertake is often too short-term to be accepted by the peer review process and may therefore not be funded by the Research Councils. The alternative approach, the university being funded by the DTI within industry-led projects, means that the universities can be funded to undertake the work that industry is interested in. In the UK, both the company and the university are funded at 50%. However, this is not the case in

[7] Arie Rijlaarsdam, Octrooi en Dienstbetrekking (Patents and Employment), PhD Thesis, VSSD Delft 2005.

EC projects, where industry is funded at 50% and universities at 100%, and may be one of the factors underlying the development of strong relations between universities and industry in some European countries.

As a further alternative, there are also some emerging examples of vehicles to enable shorter term engagement of larger corporations and SMEs such as via the Centres of Industrial Collaboration models (WDA, Yorkshire Forward). These locate specialist brokers and dedicated technical capability alongside internationally known research peaks of excellence. They have achieved significant outcomes measured in terms of engagement of industry and impact. To date these mechanisms have been RDA funded and the model appears to be effective. Work is done at commercial rates but the nature of the work package can be tuned to specific needs of the company and is normally of a duration much shorter than a conventional Research Council - industry research programme.

3.2.3) Research Productivity and Assessment
Currently, academics are measured and rewarded by their research and teaching performance whereas their research work is important to maintaining the RAE ratings of their institutions. There is therefore reluctance on the part of universities to release academics to pursue business activities and disinclination on the part of academics to reduce their research output by getting themselves involved with business. There is additionally reluctance on the part of academics to abandon a relatively secure academic post for a risky existence in an embryo business. Government could consider (a) funding temporary posts so that research output can be maintained and, with it, the RAE rating of the institution, while allowing academics to explore the prospects for a successful business venture, and (b) encouraging universities to recognise the involvement in business activities, alongside teaching and research, as an integral part of the personal reward system for academics. Similarly, research assessment mechanisms should take into account and reward the extent to which the institution engages with business.

If lacking adequate financial support from the host institution, spin-out businesses may require the assistance of external investors. This inevitably brings some consequences that may not be desirable when they identify with dilution of university involvement; changes in the business mission and disillusionment of the academic staff. In order to minimise such circumstances, Government could examine the rules concerning charitable status such that universities are encouraged to provide loan and/or equity capital to spin-out businesses (other than through University Challenge Funds) as an integral part of their role as a university.

There have emerged some professional spin-out service providers to universities (currently two main companies) and these appear to show effectiveness in focusing resource on building good quality propositions. The largest of these companies acts for about 8 major universities. This model and others could be further encouraged, according to the specific circumstances of the universities.

3.2.4) Business – University Collaboration and RDAs
University expertise is embodied in individuals and therefore is not stationary. To further their career researchers move around the university system and an institution that is regarded as a centre of excellence in a specific discipline may not maintain such status if the expertise moves to another institution. Business collaborates with universities that specialise in the technologies that are relevant to its objectives but these universities are not always in the same region as the business as defined by the RDA boundaries. It may thus be necessary to allow regional funding to be traded across boundaries but not necessarily like for like. However, RDAs are protective of their funds and have incentives to fund within their region. Hence, there appears to be little scope for RDAs to fund across these boundaries although they may collaborate with neighbour regions. RDAs are however good catalysts for engaging leading teams within a region and thus build on national capability. With joined up thinking and processes it is possible to overcome some of the potential pitfalls and ensure that excellence is maintained as a primary criterion. For example, excellence in a region with few research centres may be very different from national excellence, which in turn may not match up to international values. It is well established that those RDAs in

less wealthy regions have funds to support business - university collaborations, while those in well-off regions (such as the Southeast) do not. As a nation, we should focus on excellence wherever it may be found.

3.3) How to tackle existing barriers

3.3.1) Talent and skills

The science and innovation investment framework conflates innovation with the product of the science base and R&D. Although these two components are relevant to technological innovation, they do not represent a complete picture of wealth creation. R&D is just a component of innovation and is only relevant to companies that do R&D as defined by accounting terms. Therefore, setting the target of R&D spending at 2.5% of the GDP may not address the UK's innovation needs.

It is important to question the motives for doing research. Contribution to new product ideas is an important factor but, above all, training of scientists and technologists, and development of the right skills and knowledge is of paramount importance. In particular, focus is needed on equipping scientist and technologists not only with the "hard" and highly specialised skills and knowledge, but also with "softer" competencies than can be easily transferred from academic environments to business and back. Innovation needs to be underpinned by "sustainable resources" that only talented people can provide. Lucrative and revolutionary technologies are created by talented people (e.g. Tim Berners-Lee and the World Wide Web) and investments should be directed to create and develop their skills, not the technologies. These will come from the skills we foster. A very logical consequence of the concepts above is that when assessing research and measuring innovation, people's talent and skills should be captured along with more "tangible" indicators, such as publications, patents, R&D etc. It should be noted that the 2002 OECD Labour Force Survey showed that nearly 35% of all science and technology graduates are employed in banking and financial services, wealth creating sectors for UK, which use the talent of the science graduates.

Besides improving skills and knowledge, a greater engagement with, and employment of, engineers and scientists may favour innovation. As employing practicing scientists and engineers is an investment by a business (whether what they do is counted in the R&D or not), the numbers of scientists and engineers employed in the UK is likely to be the best measure of the input to the innovation process. Clearly, it is not a measure of the output, but because businesses do not invest lightly, one should assume that there is some correlation between input and output.

3.3.2) Value Chain

The value chain is created by the value that a product gains during its life cycle (from design through product production to the services provided relating to its use). The consultation document (Par 1.1) implies that innovation is more likely to materialise when moving up to the top of the chain. This concept is questionable[8] as in many instances the added value is at the pinch points at some intermediate point in the value chain. Indeed, China and India, used as examples of emerging economies, are mostly investing in skills (i.e. see the high numbers of engineering graduates in India, for instance), not in creating a final product. The UK is good at working with complex systems, for instance, and this gives it some distinctive offerings.

Innovation from the creative industries follows a different path as some of the drivers for change occur via different mechanisms (policy development is often tender based).

3.3.3) Innovation metrics

The impact of investments in fundamental research on innovation is not well tracked and the current reliance on R&D intensity is inappropriate as measures of research spend do not correlate to drivers in innovation. Research Councils and government departments should examine the practices of US funders and also develop more appropriate metrics that capture risk-taking, know-how, culture and pull through, and focus on the short and longer term impact of their research by means of innovation scoreboards. In this respect, we commend the start made in this area by the

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[8] Clayton Christensen, *Skate to where the money will be*, HBR November 2001

European Innovation Scoreboard and the suggestion made by the Confederation of British Industries (CBI) for appropriate metrics. Additionally, RCUK should co-fund collaborations with the RDAs: this will take effort and consideration of proposals to develop innovation metrics in a European context would be worthwhile.

3.3.4) Innovation in the service sector

Innovation occurs in every sector of the economy. Indeed, while Government has been pushing university-business collaboration to exploit scientific research in the hope that this would drive innovation, the financial services sector has been innovating successfully without scientific research but using the talents of STEM graduates. However, it is not clear to what extent such developments are being measured and contribute to official statistics. Appropriate metrics are needed to capture innovative trends in the service sector.

3.3.5) Procurement

Innovation implies a certain amount of risk that a large company may be able and willing to afford but that SMEs may find difficult to accept. Public procurement could be used very effectively to ensure that SMEs do have a return on their investment as well as satisfying the unmet demand for certain goods and services. Unfortunately the UK Government cannot claim a good record on this. All too often major works, such as the recent orders for new aircraft carriers, are awarded to foreign companies even though the savings, if any, are marginal. A good example is set by the US public procurement system. Many more contracts for work are placed with SMEs: these are not "research" contracts but revenue generating contracts for the SME to produce analysis or prototype products. As such they enhance the SME cash flow and development substantially. The present UK SBRI scheme is only related to government department research budgets and any contracts are subject to "peer review" on the research: this does not stimulate SME development. In this context the US Defence Advanced Research Projects Agency (DARPA) has proven a very effective model and, even though its remit is perhaps too broad for the UK, the Government may want to consider a similar agency to help business innovation. The transport infrastructure, for instance, is an area where public procurement could drive innovative developments. It is felt that the UK target of 2.5% of public sector extra-mural R&D to be invested in SMEs is too low to make a difference and, by limiting it to research activity, it does not stimulate exploitation of new technologies.

Government procurement can play a big role in stimulating innovation and new technology provided that Government policies are modified to allow the inclusion and encouragement of innovation in procurement from UK companies instead of going to the lowest cost overseas bidder.

3.3.6) The Technology Strategy Board and the Technology Programme

The consultation document states that the TSB will become a body that operates "at arms length from Government". However, the TSB is a Non-Departmental Public Body (NDPB) and it is not clear if the plan is to make it an Executive NDPB, the status assigned to Research Councils. It is unclear whether the function of the TSB will come to resemble that of Councils or whether there is any plan to incorporate the TSB in one of them (the obvious one would be the EPSRC).

The TSB has delivered significant targets but it is acknowledged that its impact should be made more incisive. This intention has triggered changes in its function but it is difficult to predict whether its new identity as a body that functions at arms length from Government, or the opposite alternative as a cross-departmental body, is more appropriate to make it fully functional.

Regardless of the TSB's identity, its Technology Programme is a very powerful tool but the funds that have been allocated (£178M) are too limited. France, for instance, is allocating €2bn to their Innovation Agency to commit over the next two years.

3.3.7) UK Trade and Industry

The new role assigned to the UKTI is a very important one: however, we have reservations as to how effective this will be since the funds allocated (£9M) are modest and it is unclear how this will be allocated. More resources are needed if the UK science base is to be marketed to businesses effectively and strategically.

3.3.8) User-inspired research agenda

A minority of Academy Fellows who responded believe that the framework does not focus enough on potential customers for the output of the research. Whilst not wishing to compromise the intellectual independence of research ideas, when there are otherwise equivalent “competitors” for funds, it seems logical to favour those that have clear (commercial or societal) customers for the potential outcome, since this provides the soundest economic model for UK plc overall. Within business – university collaborations fora are needed that allow input and challenge to research concepts, programmes and proposals, and an opening of the minds of the academic community to the customer-oriented approach, i.e. research proposals should require a statement on the commercial or societal potential of the possible outcome of the research. The innovation pipeline needs to be fully developed in UK universities by providing space to enable the incubation and development of start-up ventures. This should be aided by specific initiatives to assist in the transfer and secondment of research staff to start-up companies, and the provision of feasibility funds for academic staff with track records in exploitation. This could be part of an enhanced role for the TSB. On the other hand, business should be open to academic input (see section 3.1 on Barriers limiting business innovation).

Some feel that the funding allocated to blue-sky research in the UK is excessive. The implication of such a statement is that a larger percentage of the whole research budget should be allocated to research that has more practical applications. However, the problem may not necessarily lie in the proportion of funds invested in blue-sky and applied research respectively, but in the effectiveness and promptness with which the output of basic research is translated into applications. In the UK the transfer of knowledge into developments that impact upon society and the economy is not very effective. HEFCE and DTI should be praised for having succeeded in establishing best practices (e.g. Knowledge Transfer Partnerships); however, the several existing initiatives are too fragmented, need co-ordinating and more funding.

3.3.9) Timescales

The best industry-university collaborations tend to be based around long-term relationships rather than individual research contracts. Unfortunately the move to full economic costing will have the effect of reducing the level of activity and, in some cases, could lead to existing relationships being terminated. Thus, any support that provides more attractive incentives for industry to invest in research would be useful.

Within the regions it is necessary to increase the interaction between large and small companies and universities. The RDAs are beginning to foster these relationships through their Science and Innovation Councils but additional support through funding would provide the catalyst for these groups to come together. However, as yet, the amount of money available for innovation in the regions is very limited and more resources for innovation led activities would be beneficial. In particular, Government should provide funding for developing long-term sustainable university-industry strategic partnerships. RDAs have in part addressed this through, for example, Centres for Industrial Collaboration (Yorkshire Forward) with some effect. Short-term subsidies tend to be ineffective for long-term sustainability so any actions such as those suggested must draw on regional clusters. For example, the Knowledge Exchanges established in parallel with HEIF2 could fulfil a continuing and ongoing role of developing and maintaining awareness of universities’ expertise and capabilities among regional SME communities, and from there establishing longer term relationships.

3.3.10) Alignment

There is an urgent need for proper alignment of Research Councils, government departments and RDAs in planning policies more effectively and undertaking bidding processes that encourage coordinated action. Alignment is also needed at the sub-regional level where universities are usually approached simultaneously to participate in competing and similar schemes (in some regions universities may be faced with up to eight different national/regional/sub-regional organisations seeking partnerships in the area of innovation). Instead, great value and efficiency would be gained by adopting an integrated approach.

Universities would be more effective in encouraging businesses to work with them in responding to the range of programmes available if planning and communication of bidding processes and their timescales were better coordinated. The development of more creative schemes could also be envisaged: an example is the *open innovation platforms,* which are under active development at the University of Leeds to enable the creation of more radical innovations in specific sectors.

The use of business-to-academic and academic-to-business cluster models to open up opportunities is welcomed but may be less effective until the culture within universities is addressed more thoroughly. Pilot schemes would be welcome but alignment with regional and national agenda would be essential for success.

4. The Government would welcome views – in particular from outside Higher Education - which can be taken into account in developing best practice models for business-university collaboration. In addition, the Government would welcome views on how to encourage businesses to work with universities for the first time, perhaps by introducing short-term, low-cost mechanisms for business-university interaction.

4.1) Best practice models for business-university collaboration

4.1.1) Massachusetts Institute of Technology (MIT)

MIT sets an example of good practice. The Institute works with whole sectors at a time, and requires the sector players to agree among themselves on the objectives to be pursued. It is in the context of that agreed vision that MIT chooses what, where and how to research. The UK should adopt similar practices. In part, the process is a refinement of the US mission-agency phenomenon: someone somewhere has a clear vision and mission, and research funding is allocated to support the advance of that mission. The key factor is to secure critical mass projects that draw in the complete supply chain in certain areas, so that the businesses help each other while working together with the universities. The target is to build a community that integrates knowledge (mission research, pedagogical reform and industrial outreach) around an issue and projects that go to the heart of future prosperity.

4.1.2) Technical University Eindhoven & Philips

Another example is the Technical University Eindhoven, which has established a strong link not with a sector but with a leader in a sector: Philips. Together they have arranged a large area for laboratories, start-up firms, etc. that is growing and functioning very well.

4.1.3) Science Parks and Enterprise Parks

In addition to the tax credit that UK business can claim if investing in R&D, there also should be incentives for business and academia to collaborate in terms of setting up science parks as already exist at some universities. Incentives should come in the form of significant financial awards for research and innovation that turn into practical application that benefit the country and its inhabitants. Generic Enterprise Parks and Specialists Science Parks would create the ideal habitat for knowledge transfer to take place swiftly and effectively. Here, researchers (including PhD students) would have the opportunity to gain an adequate understanding of industrial realities by spending some time with the industrial sponsor. Companies, on the other hand, may play a role in the training of young researchers that they may want to employ later on, thus saving time and resource on further in-house training. Finally, companies could complement this arrangement by allowing an appropriate member of the firm's staff to be attached to the university, possible on a part-time basis.

4.1.4) University Technology Centres and University Alliances

Alliances and University Technologies Centres (UTC) appear to work well with larger established companies (e.g. Rolls Royce, BNFL/Nexia & BAE) that already recognise the value and necessity of continuous R&D as a precursor to innovation and market leadership. Determined efforts should be made to establish similar UTC for groups of smaller and perhaps newer companies within UK industries that have a common interest or need. Grouping could centre around themes such as: new materials (metallic, plastic or composite), new manufacturing techniques, advanced control methods, application of electronics and electronic devices, evolution and utilisation of environmentally friendly sustainable energy sources, and others. Existing literature such as Eureka, Global Watch and the Publications and Conferences of Learned Institutions and Societies could be utilised to encourage participation. There are also examples of such alliances for smaller companies too but sometimes these are less well known although evident from examining RCUK data of industrial partnerships.

4.1.5) The University of Greenwich and the Cutty Sark Conservation Project

The Cutty Sark Conservation Project is a £22m project, principally funded by the Heritage Lottery Fund, to arrest decay in the Victorian fabric of the ship and to present the ship in a dramatic new way to make it one of the best visitor attractions in the UK. As part of their knowledge-transfer programme, DTI has enabled Cutty Sark to benefit from state-of-the-art academic resources provided by the University of Greenwich. The University has acted as a specialist and independent resource to the Office of the Project Director and in particular to its Chief Engineer. Their work has concentrated on both complex structural finite element analysis and computational fluid dynamics, using the University's intellectual capability, access to very powerful computers and a world-class library of software. The University has been deliberately kept in the role of informing and educating the client, rather than being employed in the design production as a nominated sub-consultant. This approach gives additional strength to the client, as well as avoiding possible contractual liabilities for performance.

4.1.6) The Royal Academy of Engineering (RAEng) Industrial Secondment Scheme

The Industrial Secondment Scheme enables academics to gain experience in industry. A case study is provided by the University of Southampton and the secondment of a senior lecturer in Aerospace Engineering to Surrey Satellite Technology LTD (SSTL). The secondee left university for six months. During his time in the company he gained knowledge of the working practice and state-of-the-art software and hardware technologies used in the development of spacecraft structures. He also gathered up-to-date material for his courses and student projects. On its part, SSTL had the opportunity to draw upon Southampton's expertise and the development of structures and mechanisms suitable for low costs space mission, which was the secondee's area of expertise. As a result of such experience the university has maintained strong links with the company while the secondee is supporting the development of a new course on Spacecraft Structural Design, for which most of the examples and case studies that complement the lecture will be drawn from the real design issues faced during the secondment.

The Scheme started in 1995 and provides a number of benefits to the secondee, the student, the university department and to the host organisation. The secondment enhances credibility of lecturing staff, meets the requirements of some accreditation panels for academic staff to have recent industrial experience and, most importantly, can initiate or enhance the development of long-term relationships between the university and the company. Many secondments have also resulted in the acceptance of students for employment, and research and consultancy contracts.

4.1.7) The Royal Academy of Engineering (RAEng) Visiting Professor Scheme

A scheme that complements that described above allows people from industry to spend some time in academia. A case study is provided by a five-year collaboration between Bradford University and Arup. The RAEng have provided seed-corn funding of £20,000pa for three years to Arup for the provision of a visiting professor in Engineering Design for Sustainable Development. The basic requirement is for 40 days of activity per year comprising lectures, support to teaching staff, seminars, industrial visits, workshops, field visits and teaching material to create a permanent shift in the understanding and teaching of sustainable development across the University staff and students, and to broaden and strengthen more permanent links with the company. The input has come from an Arup director who fulfils the role of RAEng Visiting Professor. There is also considerable support from associate directors, associates, senior engineers, engineers and graduates. The Arup relationship has provided a step-change in the appreciation, understanding and teaching of sustainability and has been a major success for all parties. Arup now has permanent representation on the Industrial Liaison Board for the University and are active participants. This scheme has been so successful that an application has been received by the RAEng to extend beyond the initial three years through funding of £18,000 year 4 and £10,000 year 5. This has just been granted. The funding helps to minimise the cost to the industrial partner. Arup has invested in excess of £30,000 in addition to the scheme funding and have a valuable relationship that is already set to continue beyond the pump-prime of the RAEng funding scheme. It is vital that universities develop closer links to current working practice and live projects so that graduates have relevant, practical experience and skills of value. Much of this can be gained through informal discussion, post lecture Q&A sessions and collaborative field courses.

Schemes such as these have proven very effective but it is important to ensure that the number of the schemes is increased and the nature expanded.

The Visiting Professor Scheme has grown into an established network with 150 Visiting Professors in 46 universities. It continues to develop and at present is concentrating on the principles of Integrated Systems Design. More case studies and the overreaching rationale can be found in two Academy's publications "Educating Engineers in Design" and "Engineering for Sustainable Development".

4.2) How to encourage businesses to work with universities for the first time

4.2.1) Focus on business

There appears to be a belief in Government that business - university collaboration is the answer to the poor UK record of research investment by companies. This assertion needs to be challenged and be more evidence based. Rather than trying to address modest business investments in R&D through research funding only, Government should adopt a different approach and consider more incentives for industry. The implementation of the recommendations in the Cox review is very welcome. However, more needs to be done to make best use of tax credits. For instance, an "incremental" tax credit system may be more effective. With this system a company in a given year would be able to apply for tax credits if its R&D spending is larger than the average calculated over, for instance, the last four years. Hence, only companies that gradually increase their R&D (and therefore more likely to contribute to innovation) are rewarded. An alternative and perhaps more practical system, adopted in Canada and perceived as a very good model, is one that involves linking the tax credit to the R&D spending so that the funds that are returned to the company (as the equivalent to the tax credit) are re-invested in further R&D. This system ensures that the financial resources returned to the company are used for the same reason that motivated their return, rather than being spent elsewhere.

However, availability of funds seems to be a key factor and the UK could learn more from the US in this respect. For example, the extensive availability of funds for industrial research in the US through the Small Business Innovation Research (SBIR) programme and a plethora of other government contracts are worth examining (also see section 3.3.5 on Procurement). EPRSC did operate such a scheme a few years ago and the notion is to be encouraged. It is well established that, unlike in the UK, US SMEs can expect as much as 30% or their revenues through these routes. Hence UK SMEs tap into US funding as a consequence.

4.2.2) Business - University Collaboration in the UK

Fellows questioned the evidence showing a poor business – university interaction in the UK in light of the fact that academic groups doing world class work have no difficulty in attracting collaboration with leading companies (where they exist) or spinning out their own start-ups or both. Inevitably some of the research carried out in UK universities is mediocre and, not surprisingly, doesn't attract much interest. That is not because of a failure of collaboration mechanism. Wherever collaborations are possible and useful, business and academia should work together and make sure that the best knowledge is transferred. However, universities should strive to deliver their primary functions consisting in realisation of world-class research, regardless of whether there is a local company to exploit it, while also fostering knowledge and training. The production of IPRs, patents or world shattering discoveries is an additional function that rests on the primary scholarly one. Companies that spin out from universities can certainly "contribute" to the wealth of the nation and are an effective way to transfer knowledge; however, one should not assume that they are levers that can be used to increase the UK plc. The same principle applies to universities' licensing income: exploiting the outcome of research is certainly desirable but such purpose should be secondary to ensuring a sound training of research students and staff.

5. The Government would welcome views on whether all large facilities operations should be integrated under a new Large Facilities Council, or whether there is a case for some facilities to remain under the management of other Research Councils.

The Academy strongly supports the integration of large facilities operations under a new Large Facilities Council, providing there is a genuine economy of scale and not a distancing from important sectoral knowledge. This Council should act as a Research Council and not simply a management facilitator.

However, associated with such a merger, risks exist that should not be underestimated. Facilities are best managed by the people who use them; thus, grouping them may not necessarily produce the desired effects for prioritisation will not be done by the Research Councils using the facilities but by those owing them. The merge may, thus, encourage the formation of a new empire to be protected by its owners. This circumstance would be unfortunate as it would impact negatively on the effectiveness of those Research Councils that need access to the large facilities.

The whole question of large facilities, however, deserves a more radical examination rather than the proposed minor changes of their management. Worth considering is, for instance, the German model with the Max Plank and Fraunhoffer Institutes focussing respectively on advanced and industrial research. But in the UK there appears to be a fear of establishing such centres because of the difficulty of closing them when beyond their sell-by dates. Hence, a clear Government policy is much needed on the establishment of centres together with an understanding that they should not necessarily be permanent fixtures. UK ventures in this direction through, for example, Interdisciplinary Research Centres, were not widely regarded as successful. But the whole question of establishing centres of excellence could be examined in greater detail and a coherent policy established. In is felt that in the UK limited research funds are spread far too thinly. This mitigates against large, well-funded and focussed centres of excellence that are closely linked to industry and internationally competitive.

6. Furthermore, in the event of a merger, should the grant-giving functions of PPARC be moved to EPSRC?

In the event of a merger, PPARC grant-giving functions should not move to EPSRC since the types of funding and research are different in the two Research Councils. PPARC provides focused support to key research teams on the basis of long term strategic planning. Many of the projects supported are by their nature highly ambitious and “innovative”, and require a sustained commitment over several years. In contrast, EPSRC operates in a very different mode whereby strategic planning and policy are formulated so as to deliver in a relatively short timescale. Hence, given such a large difference in the way the two Councils operate, it is difficult to see how a merger could benefit PPARC. However, on the other hand, merging PPARC and EPSRC grant-giving functions would remove the artificial divide in physics funding and allow the innovation agenda to be addressed. Thus, it may be worth considering an inter-council group that views sympathetically research that crosses the boundaries. Cutbacks in overall funding should be avoided.

7. The Government would welcome views on what further measures could be taken by the Research Councils to improve their effectiveness.

Whether there is scope for improving the effectiveness of Research Councils may simply reflect the need for changes at a higher level. It is important to recognise that world-class research requires well-funded centres having critical mass and this in turn requires choices of direction rather than a scatter-gun approach. Major reforms, rather than some rearrangement of the Research Councils may be more effective in making a difference. There are definitely too many Research Councils: their number could be reduced to four grant awarding Councils and the CCLRC. This should reduce costs whilst still maintaining focus.

7.1) Responsive Mode Funding

The fragmentation of research areas among the Research Councils creates difficulties for researchers as well as for business. A company that deals with more than one Research Council often has to deal with an overload of administration that could easily be reduced by collapsing the overall number of Councils, or by grouping the administration of all of them under the same office. Further, an increasingly high proportion of the most able researchers' minds are being deflected to the rather unrewarding task of preparing research grant applications, the success rate for which is decreasing in inverse proportion to the increasing numbers being submitted. This is wasteful for all involved. It is also requiring an increasingly top heavy administration effort. Thus, it is worth asking whether so much research funding should really be distributed through Research Councils.

Each Research Council currently spends about 3-4% of its budget in administration. To these costs, those sustained by the universities and businesses interacting with Research Councils should be added. It would be really worth looking at how much money could be saved if Research Councils were grouped under the same administration. Through the last few RAEs, it has become fairly clear where research funding is being most effectively deployed. Additionally, at present, the RAE costs less than all the administration needed to support responsive mode funding. It may be more effective to reduce the budget allocated through responsive mode and increase that distributed via QR mechanisms, and leave universities free to spend it on the research they are best placed to perform. At present, it is almost impossible to rely upon funds for undertaking research within the universities without being successful in procuring a research grant. This cannot be good for innovation and it is certainly disastrous for productivity.

However, some policy makers are suggesting the opposite course of action. There are some callings for the scrapping of the RAE and its replacement with a growth in the proportion of total research funding being distributed through competitive bidding. This would exacerbate all the problems outlined above and many more. There is no reason why the RAE should be kept and not be replaced with an alternative, less distorting and wasteful mechanism for the pursuit of excellent research. However, an increase in the proportion of funds selectively distributed by way of direct institutional support for basic research should be seriously considered.

7.2) Other issues

Other issues have been identified that impact upon the effectiveness of Research Councils.

- *Standing committees*: these often introduce conservatism, bias and a “club culture” into funding allocation. Old fashioned committees (such as those in BBSRC and MRC) should be removed and replaced with the adoption of a college system such as that of EPSRC.
- *International committee membership*: committee structures should be reviewed to ensure stronger international representation, which might encourage a less conservative approach and enable more high risk, ground-breaking research to be funded.
- *Cross-council co-ordination*: cross-council priorities are not administered as smoothly as those from a single council. It would help if Councils were more “joined-up” as some areas of research currently fall through the cracks.
- *Innovation and knowledge transfer*: Councils (and their reviewers) should recognise the appropriateness and cost of management resources for complex innovation-led projects, and that such management is essential to translate research to users.
- *Customer-oriented approach*: Research Councils could be more effective if they had an awareness of industry requirements which would enable them to assess the claims of proposals to be meeting industry needs when selecting them for funding. However, industry should not be specifying the technology or approaches the universities should explore since too much steering by industry would stifle the innovation being sought. On its part, industry would benefit from having access to academic knowledge and a range of technology solutions and options to use when exploring solutions to customer requirements.

8) Inspiring the next generation of engineers

A significant proportion of the Academy’s activities are directed at inspiring the next generation to become tomorrow’s engineers and, therefore, the Academy welcomes the Government’s commitment to this work and its belief “that further steps are necessary to meet its [the Government’s] targets”[9]. The main Academy work programmes in this area are: the Best Programme, the National Engineering Programme, the Technology and Engineering in Schools Strategy (TESS) and *Shape the Future*.

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[9] Science and innovation investment framework 2004-2014: next steps (Par 6.28), Treasury 2006.

The Best Programme works in primary schools by building an enthusiasm for science, engineering and technology (SET) subjects. In secondary schools it promotes engineering and related SET careers. In universities it helps support gifted engineering students and then, after university, it works to develop the engineering leaders of tomorrow. The Best Programme is the Academy's longest standing commitment to inspiring the next generation of engineers and participation levels are at their highest levels with a record number of youngsters taking part in hands-on activities designed to excite enquiring minds.

In addition to the ongoing success of the Best Programme and as a response to the challenges identified in the science and innovation investment framework, the Academy has developed a substantial new engineering education outreach programme designed to bring engineering within reach of four target groups: women, students from families with no experience of higher education, minority ethnic students, and adult learners. Funding for the first two and a half years of this 10-year National Engineering Programme (NEP) has been provided by the HEFCE.

The London Engineering Project (LEP), the London phase of the NEP, was launched in September 2005 and, providing continuation funding from HEFCE is secured, will roll out to other cities in England from 2008.

In addition to its leadership of the Best and National Engineering Programmes, the Academy is using its unique multi-disciplinary role in the engineering community to facilitate two new ways of engaging with the young engineers of tomorrow.

The consultation document (Par 6.6) refers to the commitment in the Science and Innovation Investment Framework highlighted the need to “bring coherence to the many science, technology, engineering and maths initiatives across the education system”. For its part and at the Science Minister's request, the Academy has developed and is leading the Technology and Engineering in Schools Strategy (TESS), a mechanism by which the engineering community of institutions, learned societies, charities and industry work together to present a coordinated promotion of engineering and technology careers in schools.

The Academy is also taking part in the development of the new 14–19 specialist diploma in engineering, to be offered through schools and colleges from September 2008. The Engineering Diploma will provide a fresh way of engaging young people in the world of engineering.

Finally, through its *Shape the Future* campaign, the Academy is connecting young people with the engineering that surrounds their daily lives. This campaign invites youngsters to engage with this engineering by participating in activities such as those provided by the Best and National Engineering programmes and those promoted by TESS.

Abbreviations

BBSRC	Biotechnology and Biological Sciences Research Council
CBI	Confederation of British Industries
CCLRC	Council for the Central Laboratory of the Research Councils
DARPA	Defence Advanced Research Projects Agency
DTI	Department of Trade and Industry
EC	European Community
EPSRC	Engineering and Physical Science Research Council
HEFCE	Higher Education Funding Council for England
HEIF	Higher Education Innovation Fund
IPRs	Intellectual Property Rights
LEP	London Engineering Project
MIT	Massachusetts Institute of Technology
MRC	Medical Research Council
NDPB	Non-Departmental Public Body
NEP	National Engineering Programme
OECD	Organisation for Economic Co-operation and Development
OSI	Office of Science and Innovation
PPARC	Particle Physics and Astronomy Research Council
QR	Quality Related
RAE	Research Assessment Exercise
RAEng	Royal Academy of Engineering
RCUK	Research Councils UK
R&D	Research and Development
RDA	Regional Development Agency
SBIR	Small Business Innovation Research
SBRI	Small Business Research Initiative
SET	Science, Engineering and Technology
SMEs	Small and Medium-Sized Enterprises
SSTL	Surrey Satellite Technology LTD
STEM	Science, Technology, Engineering and Mathematics
TESS	Technology and Engineering in Schools Strategy
UKTI	UK Trade & Investment
US	Unites States
WDA	Welsh Development Agency

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