The Royal Academy of Engineering

Engineering

House of Commons Committee on Innovation, Universities, Science and Skills

March 2008

Summary of recommendations

1a) Engineers have expertise that is highly valuable to policymakers. We recommend that the committee consider ways to ensure that engineers are called on to advise Government on issues of significance to policy making, in particular, climate change.

1b) The importance of engineering to society is not always understood. We recommend that the committee consider how engineers can be supported in communicating better their contribution to society.

2a) We recommend that the committee consider how DIUS and BERR can encourage businesses to use engineering solutions to create better business models.

2b) 'Open Innovation' is essential to the UK's success in innovation. The committee should consider how DIUS can promote open innovation.

3a) There is a pressing need to attract women into engineering education and to retain more women in engineering careers. The committee should consider what action can be taken to change the current situation.

b) There is a pressing need to attract more young people in general to engineering education. The committee should consider whether the DCSF / DIUS STEM Programme is doing enough for the engineering and technology elements in STEM alongside what it clearly does for the science and maths elements. At university level, Lord Sainsbury's recommendation for a review of engineering education should be taken up swiftly.

4a) Engineering research differs from pure science. The committee should consider how to ensure that engineering research is adequately funded and properly assessed, especially through any assessment criteria developed by HEFCE.

4b) The committee should consider how Government can stimulate UK R&D and knowledge transfer through its procurement strategies.

5a) Coordinated effort is required to raise the profile of engineering and to attract young people into engineering roles that are essential for the welfare of society. The committee should consider how to ensure that all of the sectors above work together to encourage young people of leadership potential to begin an engineering career.

5b) The Academy recommends the appointment of a Chief Engineer to ensure that engineers have input to policy formulation and that issues relating to engineering are dealt with by Government in a strategic way.

1) The role of engineering and engineers in UK society

1.1 Suppose that an unknown and fatal virus swept the UK, rapidly killing off all who it affected. Suppose that the virus struck only professional engineers – but somehow spread through all engineers, from graduate and chartered engineers to engineering technicians. How would society cope with this sudden and tragic loss? Society, as it is now, would not cope at all, for without any engineers there would be:

- No clean water delivered to homes or businesses and no used water or sewage flushed away;
- No public transport, from the tube to trains to international flights;
- No telecommunications – no mobile phones or landlines, no television, radio or internet, generally not much fun;
- No emergency services or health service, which rely on communications and on life-saving electronic devices;
- No electronic payments – no salaries and no payment for goods or services;
- No military vehicles or defence technologies to support and safeguard British troops on operations;
- No gas or electricity to homes or business – the country would be in the dark (in fact, purely by virtue of this most of the above infrastructure would fail);
- And there would be no energy production in the first place, therefore no electricity or gas to distribute.

1.2 It is quite clear just how *crucial* engineers are to society's functioning. The UK, and every other developed society is highly dependent on engineered infrastructure and therefore dependent on engineers of all grades to design, construct and maintain the physical fabric that supports our quality of life. The UK infrastructure is engineered in such a way that it provides optimal services with as little waste as possible, meaning it is often required to function at close to capacity. Therefore, the input of engineers is needed constantly to ensure the reliability of infrastructure when patterns of demand change and even when it is threatened by accident or attack.

1.3 Engineers not only support the current quality of life in the UK, they offer promise for the future. Engineers have brought significant innovations in medical care – since engineers design and produce all manner of medical equipment and devices from robotic surgery equipment, to imaging devices for the brain and body, to replacement hips. They are the source of innovation in consumer electronics, from mobile phones to televisions and have brought about huge changes in the world of entertainment. We are currently in desperate need of sustainable solutions to energy production and of ways to cut emissions through increasingly energy efficient transport, buildings services and electronic goods. Engineers offer the best hope for these solutions; without engineers we have little promise of strategies to save us from a frightening future, and no hope of deploying those strategies.

1.4 It is clear then that engineers have an absolutely critical role in supporting current and shaping future society. Yet the perception of engineers in UK society does not match their role, nor does it match engineers' perceptions of themselves. The success of engineering means that it is often taken for granted, and as a result engineers are themselves taken for granted and undervalued. Not only is their importance to society not recognized, but the nature of their role is not widely appreciated.[1] The creative or innovative aspects of engineering are often overlooked,

[1] See The Royal Academy of Engineering and Engineering Technology Board Report 'Public Attitudes to and Perceptions of Engineering and Engineers 2007':

yet engineers have applied their abilities to create devices and systems from ipods to the internet. In exploiting the possibilities of technology and science, engineers use their inventiveness to give us things we never imagined we needed but can no longer live without.

1.5 Of course it is uninteresting to hear engineers complain about a lack of recognition and better to take action to get the positive message across. This is, to a large extent, down to engineers themselves – engineers have an increasingly important role in communicating with society. Most importantly, they need to explain clearly and impartially the technical possibilities for dealing with problems like climate change so that society can choose the best solutions (for example, engineers should automatically be invited to contribute to bodies such as the Climate Change Committee in order to communicate just what engineering can do to address this critical problem, and to ensure that mooted solutions are technically and practically deliverable). Engineers need to engage better on the issues that grab society's attention – and the Academy has taken steps in this direction by looking at engineering's contribution to tackling issues like climate change, international poverty, and the impact of engineering on privacy[2], as well as implementing a general public engagement strategy. Engineers have a great deal to contribute to public debate and policy development, and organizations like The Royal Academy of Engineering should be seen as a resource that Government can use.

a) Engineers have expertise that is highly valuable to policymakers. We recommend that the committee consider ways to ensure that engineers are called on to advise Government on issues of significance to policy making, in particular, climate change.

b) The importance of engineering to society is not always understood. We recommend that the committee consider how engineers can be supported in communicating better their contribution to society.

2) The role of engineering and engineers in UK's innovation drive

2.1 One of the main roles that engineering has in society is in creating wealth for UK plc and it does this through innovation. Often the role of engineering in innovation is not appreciated – for example, Google is one of the most significant successful innovations of our time and its success is based on engineering methods – from the application of algorithms to create the search function to the successful scaling up of the process using a large network of computers. This was all a matter of engineering, and it should be appreciated that lots of innovators are engineers as well as entrepreneurs.

2.2 Engineering is fundamental to innovation in many sectors. The recent Nesta report, *Hidden Innovation*, shows how engineering and technology are key to facilitating innovation in a wide variety of sectors – from the obvious examples of construction to less obvious areas like retail banking. Technology has been exploited to a significant degree in the banking sector to improve processes which in turn improve services. In the City innovation is supported by engineering in virtue of the vast computing power that supports modern trading and by the engineering

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http://www.raeng.org.uk/news/publications/list/reports/Public_Attitude_Perceptions_Engineering_Engineers_2007.pdf

[2] See *Dilemmas of Privacy and Surveillance*, published by The Royal Academy of Engineering in March 2007: http://www.raeng.org.uk/policy/reports/pdf/dilemmas_of_privacy_and_surveillance_report.pdf

graduates who chose to apply their specialised skills to careers in the financial sector.

2.3 Business and marketing innovations frequently depend on the results of engineering. The internet has supported new business models that have been proved successful in examples like Easyjet and Ryanair; and even Tesco's Clubcard system, credited as key to its huge growth, is dependent on sophisticated databases made possible by engineering and exploited by marketers.

2.4 Advantages are available through even closer collaboration between engineering and business. For example, if a business considers the design of its offices and premises in terms of its overall business model, it will have to consider the lifecycle and not just the capital costs of those premises. This will be a spur toward using engineering to create more sustainable office space and generally exploiting the ways that engineering can be used to change the way we work.

2.5 It is essential that the UK's innovation drive is considered in the global context. International collaboration and 'Open Innovation' (in which industrial, start-up and academic partners combine their strengths to competitive advantage) are essential to the UK's competitiveness. Engineering innovation is all about exploiting technology and research. This depends on taking a global perspective and exploiting the best science and technologies that are available across the world. UK engineers will need to develop new skills and strengths to support this collaboration – skills in road-mapping and horizon-scanning; skills in knowledge management. If these collaborative skills are fostered engineers and engineering can have an increasing role in the UK's innovation drive.

a) We recommend that the committee consider how DIUS and BERR can encourage businesses to use engineering solutions to create better business models.

b) 'Open Innovation' is essential to the UK's success in innovation. The committee should consider how DIUS can promote open innovation.

3) The state of the engineering skills base in the UK, including the supply of engineers and issues of diversity

3.1 The cataclysmic scenario painted in the first section is just the extreme end of the steady drop in numbers of trained engineers that is currently the reality in the UK. In recent years, surveys of engineering employers (including those carried out by Cranfield University, the CBI and the IET) all provide the same indication: that looking forward, the majority of employers expect to find it difficult to fill engineering vacancies.

3.2 In the electrical power and distribution industry specifically, 20% of current power generation engineers will retire in the next 10 years and 50% will do so in the next 20. At the same time the number of 18 year olds is dropping, meaning that the sector will face significant competition in attracting a new generation of workers from a shrinking pool. Other areas feel the dearth even more strongly – nuclear engineering and materials are areas where recruitment is a serious challenge but which provide engineers with skills essential for the sustainable development and support of our infrastructure.

3.3 Skills shortages are not restricted to graduate engineers. With organizations like Transport for London and Network Rail re-launching their apprenticeship programmes the shortage of technicians is made evident.

3.4 The greatest risk to the engineering skills base in UK comes from the poor progression with science and mathematics in schools, colleges and beyond. Engineering, at whatever level of practice, is underpinned by mathematics and science. However, 9 out of 10 students that complete GCSE science give up science at that point. They are thus, perhaps unconsciously, closing off the option of an engineering career at a very early age. The Academy supports the current Government interventions in this area (particularly in the recruitment of more specialist science teachers) because the future health of engineering depends on them.

3.5 The issue of diversity among engineering students and professional engineers is a somewhat mixed picture. HESA statistics on the makeup of engineering Higher Education courses in the UK reveal that women are greatly under-represented at 14% of the engineering student body. The situation amongst registered engineers is worse with 96% of engineers being male. However, the proportion of UK students from all minority ethnic backgrounds applying to engineering courses stood at 21% in 2005, slightly better than the 18% average for all subjects.[3] And the number of engineering students from the lowest socio-economic groups is at least as high as in other subjects (though still a considerably lower proportion than found in the general population). The Royal Academy of Engineering's London Engineering Project, funded by HEFCE, has engaged in a wide range of activities to attract students from a broader range of socio-economic groups to an engineering education.

3.6 The proportion of female students varies significantly across the engineering disciplines – the best sector being chemical engineering and the worst being mechanical engineering. The worst performers in terms of gender diversity would do well to learn lessons from the best on attracting talented female students. In terms of encouraging a better gender balance in professional engineering, it seems that the problem is self-perpetuating – the male dominance in engineering being a barrier to female engineers. If so, this may only be solved by a step-change, which may involve *engineering* more women into engineering. There is often a business case for doing so. For example, in user-centred design there is a need for a diverse workforce to represent diverse user groups. Actively encouraging more women in to engineering design – perhaps from product design, might bring about a step-change that will create a virtuous circle.

3.7 Making stronger links between engineering and design may in fact encourage more young people generally to engineering. As will an emphasis on the engineering component of issues that engage young people – such as climate change and poverty reduction. The engineering degree curriculum needs to be revisited to ensure that it is current and attractive to young people. Lord Sainsbury's recommendation for a review of engineering education should be taken up swiftly.[4]

3.8 Despite the problems of lack of engineers, the engineering profession must not mourn those students who move to other careers, such as jobs in the city and

[3] Mailardet, Martland, Morling: 'Attracting More Students into Engineering: The UK Perspective', Presented at IEEE conference on Meeting the Growing Demand for Engineers and their Educators, 2010-2020, Munich, Germany, 9-11 November 2007

[4] *The Race to the Top*, recommendation 7.17: "A leading member of the engineering profession should be asked to set up a working group of experts from academia and industry to review current approaches to engineering education. The group should develop, with a number of leading engineering universities, an experience-led engineering degree which integrates technical, operational and business skills."

management consultancy. A great virtue of an engineering education is that it gives students skills in systems thinking, skills that are valuable in a wide range of roles. Indeed, a useful way to promote engineering education is to bring attention to the fact that it makes a student a good candidate for a wide range of careers.[5]

a) There is a pressing need to attract women into engineering education and to retain more women in engineering careers. The committee should consider what action can be taken to change the current situation.

b) There is a pressing need to attract more young people in general to engineering education. The committee should consider whether the DCSF / DIUS STEM Programme is doing enough for the engineering and technology elements in STEM alongside what it clearly does for the science and maths elements. At university level, Lord Sainsbury's recommendation for a review of engineering education should be taken up swiftly.

4) The importance of engineering to R&D and the contribution of R&D to engineering

4.1 Engineering is crucially important to R&D. A huge proportion of scientific research is completely dependent on technologies produced, maintained and improved by engineers. The scanning electron microscope was developed by engineers in Cambridge and is essential to the research carried out in laboratories across the world. The human genome project would have been impossible without the sequencers which were produced by engineers. Across the sciences research is very often facilitated by the increases in computing speed and power that have made ever more complex data processing, calculations and predictions possible – climate science is particularly dependent on engineering in this way.

4.2 R&D is essential to engineering in that an increase in research is necessary to reverse the decline of high value-added manufacturing in the UK. Sir John Rose spoke recently about the importance of high value-added manufacturing to the balance and health of the UK economy and its skill base.[6] He used the manufacture of turbine blades as an example. Others could include magnetic storage devices, fuel cells, optical components and aircraft wings.[7]

4.3 However, the contribution of R&D to engineering is a complex matter. An easy assumption is that engineering is all 'D' – exploitation of research for engineering application. However the examples above show areas where engineering precedes scientific research, where in fact science is exploiting the engineering for research purposes. There is thus a spectrum of activities between research and development, and between science and engineering.

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[5] For further comments relevant to the state of the engineering skills base, and to the discussion under point 5, the committee may wish to consult The Royal Academy of Engineering report, 'Educating Engineers for the 21st Century': http://www.raeng.org.uk/news/publications/list/reports/Educating_Engineers_21st_Century.pdf

[6] Imperial College London Annual Gabor Lecture - 15 November 2007

[7] Victrex PLC, now a FTSE250 company but originally a spin-out from ICI, is the world leader in its high performance polymer niche, exporting 97% of its production. Because of the cost of the product it is only used in the most demanding environments (at the bottom of oil wells or in car gearboxes) and all of these sales are dependent on devising engineering solutions for these mission critical applications. This is an example of how R&D in engineering can lead to profitable manufacturing companies that boost the UK economy.

4.4 Nevertheless, engineering research can often be quite different to that in pure science. It is focused more on specific outputs and much less on the publication of papers for scholarly journals. As a result, it is difficult to measure science and engineering research on a commensurate scale. This can be harmful to engineering when it competes in the Research Assessment Exercise. Hefce's proposed move to research metrics on the basis of Treasury directives is a threat to engineering as engineering research has quite different impact to that of other sciences and does not fit well with such a measure. Hence, it is essential that a good measure of the quality of engineering research is established so that engineering research is adequately supported – if it is not, then engineering cannot have the impact on innovation that is described under question 2.[8]

4.5 Collaboration between industry and academia is essential for R&D, and university-industry links must be strengthened and supported by stakeholders on both sides. There are some good examples of this in the UK. For example, Rolls-Royce does a great deal of research in collaboration with universities through their university technology centres, which focus on different aspects of research into engine design. Rolls-Royce has said that this has been crucial to the world wide success of their products and has also helped to create world class UK university departments.

4.6 However, in general the UK engineering industry is risk averse, and tends to work within the well-trodden path. More incentives for industry to engage in R&D would be of great benefit. The Government could take advantage of the power it holds in relation to public procurement in order to stimulate innovation across domains as diverse as defence, transportation and the NHS. There are good examples in other countries, notably in the US, to show what can be done to stimulate R&D and innovation by means of carefully calculated procurement practices. This is an opportunity already recognised by Lord Sainsbury.

a) Engineering research differs from pure science. The committee should consider how to ensure that engineering research is adequately funded and properly assessed, especially through any assessment criteria developed by HEFCE.

b) The committee should consider how Government can stimulate UK R&D and knowledge transfer through its procurement strategies.

5) The roles of industry, universities, professional bodies, Government, unions and others in promoting engineering skills and the formation and development of careers in engineering

5.1 Each of these sectors have a significant role in the formation and development of engineering careers, from attracting students into the profession to supporting young engineers. The Royal Academy of Engineering, which does not fit neatly into any of these sectors, also has an important role and has devoted significant effort into encouraging young people into engineering. One example of its efforts is its work on the Engineering Diploma. The new 14-19 Diploma in Engineering is significant because, for the first time in most schools, engineering will be part of the mainstream curriculum. Therefore, young people will not only learn more about the realities of engineering, but also have an obvious pathway into the profession. The Royal

[8] See The Royal Academy of Engineering response to the Hefce consultation on the research excellence framework:
http://www.raeng.org.uk/policy/responses/pdf/Research_Excellence_Framework.pdf

Academy of Engineering has made a particular contribution for the Advanced (Level 3 diploma) in the field of engineering mathematics by driving the development of a bespoke Additional Specialist Learning qualification. The qualification sets mathematics within a realistic and authentic engineering context.

5.2 Although this development is of great advantage to students interested in engineering from an early age, there needs to be effort focused on attracting bright students to engineering later in their education. Universities can help to attract the brightest and most creative students into engineering by making entry routes into engineering more flexible and by making course content more flexible. It should be easier for pure science students to change track to an engineering course part way through their degree, should they discover a particular interest in applied science. And there should also be pulls for students who are not so attracted by a highly technical education. Although mathematics and science skills are essential for engineers, so is an appreciation for the social context of engineering and the users of an engineering product or system. Emphasising the latter aspects of engineering, and giving opportunities for students to focus on this later in the degree, may well attract more students to engineering degrees and careers.

5.3 Attracting the best students is important because the UK does not simply need more engineers, but it needs more engineers with creative ability and leadership potential. It is difficult to identify high-profile, leadership figures such as Bill Gates or Jonathan Ive (senior VP of Industrial Design, Apple Computer) in the UK, and in engineering generally rather than IT. High profile UK engineers such as James Dyson or engineers in high profile companies like Arup or Phillips need exposure to inspire engineering students to strive for leadership level. It is the role of industry and the professional bodies to push these people forward. The Royal Academy of Engineering runs a distinguished visiting professors programme which allows eminent engineers to work in university departments and serve as inspirational figures for students. If prominent engineers are willing to evangelise by speaking to students in schools and universities, they can serve as role-models that will encourage a new generation of engineering leaders.

5.4 There are pushes from various quarters attempting to attract students to engineering, and these would benefit from a concerted collaborative effort. The Academy's *Shape the Future* initiative has been central here and such over-arching programmes should be encouraged and supported. This effort should include the voices of all bodies mentioned above, alongside engineering employers who are often SMEs with no lobbying or media profile. Opportunities to hear their voice in the call for more engineers should be created, with professional bodies having a major role (in particular larger professional bodies like the larger engineering institutions working with more specialised, smaller professional bodies).

5.5 Attracting students to engineering careers can be helped by raising the profile and perception of engineering generally. Stories about engineering and engineers need to be heard more often, and more television coverage of what engineers do and how they change our world would have a great impact. Relationship building and fruitful, mutually beneficial partnerships with broadcasting can lead to a significant increase in programmes with a richer contemporary engineering content which can help raise the profile of engineering significantly.[9]

[9] The Academy is currently working with and building relationships with the broadcast community. Specifically, the Academy has organised networking events between engineering and broadcasters (the "Would Like to Meet the Innovators" event at last year's 'Britdoc' festival brought together documentary film and TV producers with a diverse range of

5.6 Government can have a particular role in raising awareness of engineering by simply talking about engineering more often. The role of science and its contribution to society is often mentioned, but the word 'engineering' is seldom heard. A more conscious awareness of the place of engineering in society should be evidenced by hearing the word issue from their mouths once in a while to show that they understand how central engineering and engineers are to society. It is also important to note that the Government's definition of 'science' may intend to encompass engineering, but the policy context for incubating good science is not necessarily the policy context that will support good engineering.

5.7 There is growing support for the appointment of a Chief Engineer, distinct from the Government Chief Scientist. Engineers have particular skill in the deployment of resources to meet national goals and measures; the management of risk and the assessment of technological solutions to problems like climate change and security of energy supply – all of which are essential to good policy making. Such an appointment would also go a substantial way to ensure that engineering is appropriately represented in Government and that the needs and contributions of engineering are dealt with by Government in a strategic manner.

a) Coordinated effort is required to raise the profile of engineering and to attract young people into engineering roles that are essential for the welfare of society. The committee should consider how to ensure that all of the sectors above work together to encourage young people of leadership potential to begin an engineering career.

b) The Academy recommends the appointment of a Chief Engineer to ensure that engineers have input to policy formulation and that issues relating to engineering are dealt with by Government in a strategic way.

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engineers); it is setting up an endowment fund to provide funding support to encourage the commissioning of engineering-rich programmes (working in partnership with both broadcasters and independent producers); and it is establishing a Broadcast Award (awaiting final confirmation).