EPSRC
Engineering and Physical Sciences Research Council

ROYAL ACADEMY of ENGINEERING

INTERNATIONAL PERCEPTIONS OF UK ENGINEERING RESEARCH

Report of an International Study

This document represents the conclusions of an International Study Panel of eminent engineers drawn from 10 countries.
The views are entirely those of the Members of that Panel.

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STUDY PANEL ON INTERNATIONAL PERCEPTIONS OF UK ENGINEERING RESEARCH

EXECUTIVE SUMMARY

The following Executive Summary provides a précis of the principal findings of an international panel of experts, drawn from 10 countries, chosen by their own National Academies of Engineering for their familiarity with academic research both in their own countries and abroad. The panel provided a broad coverage of engineering disciplines including mechanical, civil, electrical, chemical, computer science (ICT) and materials, and combined experience of industrial and academic backgrounds. The findings are based on access to data, meetings with senior academics and industrialists from a broad range of engineering disciplines, plus visits to six sample Universities.

The panel was given a series of presentations on the dual support system, operated by the Higher Education Funding Councils and the Research Councils, and had a number of detailed discussions with members and Chairmen of the Research Assessment Exercise (RAE) panels that rated the quality of British University research in Engineering. They fully appreciated the value of longer-term infrastructure support to underpin the separate shorter term funding from individual projects and noted that variants of this exist in several other countries.

Since the RAE rating of research is widely seen as the UK "official" measure of research quality it was inevitable that this process should be used as the yardstick for international comparisons and that there was considerable debate on the criteria adopted in the RAE process. This topic came to the fore in most of our discussions and visits. It has therefore appeared strongly in our recommendations. The results of questionnaires sent to about 100 international referees produced a rather limited response. However, their responses show (not surprisingly) a very high correlation between perceived research quality and the average RAE rating in engineering subjects. This suggests that this approach could be of more value if it were based on larger numbers.

1. The panel perceives the quality of engineering research in five and five star rated departments in UK universities as ranking alongside the quality of the world's best. (The rating referred to here relates to the RAE process operated by the Funding Councils and it is appreciated that this is based upon subject units of assessment which do not always correspond to boundaries of University departments.)

2. In general the panel found that engineering research in the UK was in good health and was impressed with the quality and international diversity of the young researchers we met. Research of good international quality and often strong regional relevance was also found in lower rated departments. Although we encountered departments with a range of research assessment ratings we do not believe it is realistic to try to make multi-level international comparisons where no comparable ranking scales exist. We encountered departments whose research quality was changing (in both directions) demonstrating the dynamic nature of the process. Panel members, academics and industrialists, all commented on the increasing requirements for interdisciplinary research projects. Compartmentalised engineering functions inhibit flexibility and creativity. The UK funding system is not yet ideally organised for stimulating the multidisciplinary research co-operation which international companies are seeking, though the Universities visited are clearly moving in this direction.

3. The panel supported the process adopted by Engineering and Physical Sciences Research Council (EPSRC) to adjust the balance of funding among different subject areas and to encourage collaboration with industry. There are many good schemes offered by EPSRC, The Royal Academy of Engineering and other bodies designed to encourage collaboration with Industry (and other supporters of research). We saw a significant scale of research collaboration with industrial and government bodies during our visits. We also saw several examples of the above schemes during our visits. We commend them but note that there may be room to extend such concepts better to cover small and medium size organisations.

4. The panel wishes to stress its view that engineering research is fundamentally different from curiosity-driven basic science research, since it is driven by direct relevance to applications for wealth creation and quality of life. Engineering research (and interdisciplinary research in particular) is essential to obtain new knowledge bases, technological as well as scientific, for the design of innovative processes, products and services capable of major improvements in performance.

5. The assessment criteria for engineering research should therefore reflect the different nature of that

research. The panel has major reservations about the heavy emphasis that has been put on publications in journals, notably in scientific journals, as a principal method of evaluating quality in engineering research within the Higher Education Funding Councils' Research Assessment Exercise (RAE). Journal publications are not a normal depository of key design data information and in many instances may not reach the desired audiences. These comments relate both to publications used for the RAE and for bibliometric analysis. We note that The Royal Academy of Engineering is currently producing a report of a working party analysing criteria for evaluating engineering research and intends to comment on the significance of bibliometric techniques in their report.

6. The panel has therefore suggested some new criteria which it believes would offer a more realistic method of quality evaluation for engineering research. It strongly supports incorporating some of these into the quality assessment process **at a significant weighting level** despite the fact that they are more judgmental and less transparent. These factors include potential for wealth creation and contribution to quality of life through: innovative designs, sustained collaboration with industry, patents leading to licences, spin-off venture companies, software products and work on the establishment of national and international standards.

7. The panel noted that the latest draft guidance documentation for the next RAE has been circulated for consultation. We were pleased to see that they recommend full weighting of industrial research support since we believe that this represents a very important criterion and one which also reflects past performance. We remain concerned that the currently suggested future criteria remain strongly focused on publications - this measuring technique is adversely modifying behaviour in universities, by directing research away from the most relevant engineering problems with applications to industry towards projects which are more suited to journal papers. Although clearly important, we feel these are overemphasised for engineering research. The panel hopes that the views expressed in this report can be taken into account in the current consultation exercise.

8. We have a real concern that the value of post-graduate studentships and the salary of research workers and academic staff in engineering have fallen far below the levels associated with potential employment in the commercial market in the UK and comparable countries. Innovative schemes such as the engineering doctorate clearly help research students but more needs to be done to prevent a rapid collapse in the ability to recruit and retain quality research workers in engineering research.

9. The panel found that its visits to see engineering research activities in a number of universities were essential complements to documentary material reviewed beforehand. In consequence, and in recognition of the practicalities entailed, the panel strongly supports the concept of visits to 5 and/or 5 star departments as an essential part of the RAE process. The quality ranking (based upon international criteria) of individual departments is a dynamic process which would be better validated through the inclusion of international experts in visits as is the practice in many other countries.

1. Introduction

1.1 The UK Government spends substantial sums in support of research, mainly undertaken in the university sector. Infrastructure support for Universities is provided through the "dual support system" in which the funding (for laboratories, libraries etc.) is channelled via the Higher Education Funding Councils for England, Scotland and Wales and the Department of Education for Northern Ireland (DENI). The allocation of these funds makes use of the national Research Assessment Exercise (RAE). Direct support for research programmes is provided by six Research Councils, on a UK-wide basis. The Research Council funding is provided by the Office of Science and Technology.

1.2 The Research Council with prime responsibility for engineering is the Engineering and Physical Sciences Research Council (EPSRC). As part of its role to support UK research, EPSRC undertakes evaluations of quality for the research it funds. It does this in a number of ways which include reports from assessors on individual projects and statistics from its database plus relevant information available in the public domain such as the Higher Education Statistics Agency Ltd (HESA) and the RAE mentioned above. This latter process classifies each subject area (defined as a subject unit of assessment) into different categories with 5 and 5* representing the highest quality of grouping.

1.3 To further develop this process EPSRC decided to join with The Royal Academy of Engineering to undertake a study into the quality of engineering research in the UK, using a Panel of international experts to benchmark that quality on an international scale. Very deliberately the findings of the Panel are titled Perceptions of UK Engineering Research. They amount to a snapshot view of people well equipped to recognise excellence.

1.4 This study is an extension to the normal in-house evaluation techniques employed by EPSRC. To undertake the study The Royal Academy of Engineering set up an international panel of experts (membership details are shown at Appendix 1). The panel was established by approaching Academies of Engineering in several other countries, inviting each to nominate a senior member of their Academy able to contribute to such an international panel and capable of commenting on the quality of engineering research on an international scale.

1.5 The Terms of Reference of the panel are set out at Appendix 2. The international panel was augmented by two Fellows of The Royal Academy of Engineering, (one industrialist and one academic) and chaired by the President of The Royal Academy of Engineering. EPSRC provided the panel with significant background information from their database but chose not to appoint a member of the group. The panel met in the UK for 7 days, commencing on 8th October 1999. They received presentations from senior staff of EPSRC and received information on the Higher Education RAE. They met with a selection of Chairmen and members of the RAE Panels concerned with engineering quality evaluations, together with a number of Heads of 5 and 5*-rated University Engineering Departments. The panel visited 6 universities (namely Imperial College, City, Cambridge, De Montfort, Edinburgh and Heriot-Watt) and received responses from a limited number of international referees who were asked for their views on quality issues (Appendix 3). The panel also had the benefit of discussing these issues with a group of senior industrialists who are currently involved in supporting university research both in the UK and on an international scale.

1.6 As a consequence of its many meetings and visits the Panel became very conscious of the enormous amount of work that had already been put in to the RAE process which is undertaken jointly by the four UK Higher Education Funding Councils and managed by the Higher Education Funding Council for England (HEFCE). This was clearly seen to be a national ranking exercise with a dominant and pervasive influence but it was felt that the Panel could add to this by providing an international benchmarking at least of the top ranking levels associated with the RAE.

1.7 In determining the criteria which it should adopt in evaluating the quality of engineering research the Panel took advice from a number of sources. The Panel was conscious of the ideal need for a broader assessment in the form of an evaluation of cost effectiveness for such research and how this varied with other methods of evaluating quality. It was acknowledged from the outset that this was a particularly difficult task, however it was considered imperative that it be addressed.

1.8 The Panel was very aware that despite the senior level of the Panel, and the significant time devoted by its members, its review was inevitably a far smaller effort compared with the RAE or even the in-house evaluation undertaken by EPSRC. Nevertheless, the Panel believes that its findings represent a genuinely valuable addition to the other mechanisms, due to both its independence and international background.

1.9 The Panel fully accepts that the duration of the study has meant that it has undertaken a very limited sample of UK universities, however it has included: Cambridge and Imperial College - representing two of the highest quality group of Departments; Edinburgh - representing one of the UK's most distinguished civic universities; two former colleges of advanced technology (City and Heriot-Watt), converted to universities in the 1960's; and, one university recently converted from former polytechnic status (De Montfort). The Panel believes that this has enabled it to pick up some flavour of the UK situation together with the broadly based information from EPSRC Assessment Exercise statistics, referees and chairmen of research assessment panels. No such sample is perfect or even comprehensive but we believe it is a useful contribution to the debate on quality and cost effectiveness of national investment in major engineering research programmes.

2. Methodology

2.1 The issue the Panel had to address, namely that of assessing engineering research, can be separated into two major questions:

a) how should the quality of engineering research be defined; and
b) how should this be measured.

2.2 In addressing the first question, the Panel took as its starting point the 1993 Government White Paper "Realising Our Potential". Whilst acknowledging that 6 years have elapsed since publication of that paper, under the previous administration, it is nevertheless considered a useful reminder of the defined role of the Office of Science and Technology (OST):

"... to ensure that Government expenditure on Science and Technology is targeted to make the maximum contribution to our national economic performance and quality of life".

2.3 Before attempting to evaluate quality in engineering research it is essential to be clear about the overall objectives of university research from a national standpoint.

2.4 Since the largest single source of funding for engineering research in the UK is the Government, we have taken the objectives directly from the Mission Statement of the EPSRC as specified in the 1993 White Paper "Realising our Potential":

"To promote and support high-quality basic, strategic and applied research and related post-graduate training in engineering and the physical sciences (chemistry, physics and mathematics), placing special emphasis on meeting the needs of the users of its research and training outputs, thereby enhancing the United Kingdom's industrial competitiveness and quality of life."

2.5 The Group considered that this Mission Statement could equally well describe the objectives of most other sources of research funding such as charities, government departments, the European Union and industry.

2.6 Evidently, any research assessment in the field of Science and Technology should be performed in accordance with the above general statement and mission of the EPSRC. Contributions to quality of life would in our opinion include:

a) improvement of human health, economy and social infrastructure
b) sustainability of natural environment
c) satisfaction of human curiosity.

2.7 Basic research is mainly curiosity driven and therefore governed primarily by criterion (c). Furthermore, it is often argued that this should be the only criterion for all kinds of research, this argument being firstly that the outcome of research cannot be predicted and even less dictated and secondly that the result of all high-quality research will - sooner or later - be beneficial to society. Applied or engineering research, on the other hand, is often governed by the criterion of economic growth. Economic growth is to a large extent a prerequisite for improved quality of life, but used alone it is not necessarily in accordance with some of the other criteria, such as (a) and (c).

2.8 The panel believes that the criteria mentioned above could be used in assessing all kinds of applied research within science and technology (including in particular interdisciplinary research). Quality of research should then be defined in relation to these criteria and interpreted as the degree to which these criteria are being fulfilled. It is obvious, however, that the various criteria have different relevance and therefore should be given different weights in different areas of research. In basic science quality of research is usually measured by means of publications in refereed journals and similar bibliographical measures. In engineering research, on the other hand, it is our definite opinion that other measures have to be used. Such research must be assessed primarily from its expected or demonstrated contribution to society. Obviously, the quality of research in a scientific sense is also an important factor here - and likely the most important one. However, other factors have to be taken into account, concerning the extent the research is expected to fulfil any of the other goals.

2.9 It is often argued that it is very difficult to measure such things as the expected influence of the research on society. This is certainly true, but it is our firm opinion that efforts should nevertheless be made in order to develop mechanisms for such assessments. Some indications will be given in 3.7 below regarding how we believe that this can be done in a reasonably objective way. However crude and inaccurate such mechanisms may be, we are convinced that they will lead to a better result than applying a well-developed scheme that measures items of less direct relevance to engineering research.

2.10 Prior to this study, The Royal Academy of Engineering had established a Working Group under the Chairmanship of Mr P C Ruffles RDI FREng FRS to examine possible ways of Measuring Excellence in Engineering. At the time of preparing this report the Working Group had not finalised its report. However it had provided details of its initial conclusions to assist our evaluation process.

2.11 Although this current study is sponsored jointly by The Royal Academy of Engineering and EPSRC, the scope of engineering research will in practice incorporate programmes funded by sources other than EPSRC. These include charities, other government departments, industry and the European Commission. Detailed statistics were obtained for the Panel from HESA together with a substantial quantity of research statistics from EPSRC and the Higher Education Funding Councils. It is clear that EPSRC remains the dominant source of overall funding but the distribution is by no means constant across universities or subject areas.

2.12 Quantitative forms of quality criteria take the form of, for example, research income, research student numbers, patents and evaluations of publications on the basis of journal quality citations. The citation index data are often regarded as unaffected by subject area and national characteristics. That said, there have been a number of significant criticisms of this approach by expert bodies such as the Science Policy Research Unit (SPRU) at Sussex University which suggests that they are only valid within specific contexts and not as relevant in engineering subjects. Research income is more correctly a measure of input but a track record of funding from a source that employs a rigorous evaluation of proposals also represents an output quality criterion.

3. Evaluation

3.1 During discussions with representatives of the EPSRC the panel noted that the criteria adopted by EPSRC for funding university research fully reflected the above Government policies and were aimed to promote and support excellence in research achieved by a peer review process which also judged quality and engineering relevance. EPSRC also described a range of schemes they operate to encourage closer collaboration between universities and industry. We encountered several examples of the application of these schemes in the universities visited; we believe they are effective and to be encouraged. There is however probably room to try and extend such approaches to smaller regionally based companies with less well developed university contacts.

3.2 There are fundamental differences between basic research and engineering research as outlined in the previous section. Engineering is more concerned with developing and exploiting knowledge for innovation and design aiming at sustainable development for the benefit of society. This includes the acquisition of knowledge for the specific application to design of new systems for various challenging applications. Nevertheless, engineering research is increasingly dependent on cross-boundary input from other technical disciplines.

Quality Evaluation

3.3 In evaluating quality it is logical to start from the existing RAE since it is a major assessment process which is based upon a form of peer review within defined criteria. Clearly our own study can only deploy a small fraction of the effort of the RAE applied to engineering but we do believe that we can add to the existing RAE process in terms of an international dimension. This might be expressed as a form of international benchmarking of the RAE process.

3.4 We discussed the research assessment process with many people, including the Chairmen of the relevant engineering research assessment panels, to understand the application of their criteria and their mechanisms of operation. It is evident that the output of this process is widely regarded as an official mechanism for measuring and ranking research excellence. The process makes use of a number of parameters of research performance and we noted that despite some flexibility in the way that these parameters could be combined to produce an overall research rating for each subject area, the dominant criteria (as laid down) always related to publications in a few selected "high quality" journals. One very significant observation made by this group was that "relevance of engineering research was not included in the measure of quality" in terms of the criteria laid down by the RAE.

3.5 The Panel had severe reservations about this emphasis which did not represent the best way to evaluate quality in engineering research since it is less likely to cover those aspects of research of relevance to industry or society. We further concluded that this measuring technique is adversely modifying behaviour in universities, by directing research away from the most relevant engineering problems with applications to industry towards projects which are more suited to journal papers. This came across during several of our visits and also seems quite out of line with the objectives of the EPSRC Mission Statement. The Panel however does not deny the freedom of researchers as related to risk or curiosity.

New Assessment Criteria

3.6 We received many suggestions on the possible criteria that might be adopted to more effectively evaluate engineering quality in line with government policy and discussed this further at the universities visited. In addition we were helped by input from The Royal Academy of Engineering's separate Working Party on this topic (see 2.10).

3.7 We concluded that there are several possible parameters that could be adopted to provide additional information on the quality of engineering research and in particular evaluate the relevance of the work to industry and the benefit to society. However, we do recognise that many of these are difficult to quantify and analyse in a numerical, transparent and auditable manner. Despite this, we do believe that it is important to try to evolve the RAE to a form which can take more account of these additional parameters for engineering research. In this regard we recommend that the following principal measures be taken into account as a whole. Each of them has a number of possible components as detailed in the table below. A more detailed list is given in Appendix 4:

Potential Assessment Parameters for Engineering

Measure	Example of Possible Components
Publications	Academic and conference publications
Peer recognition	Professional recognition eg FREng, FRS, prizes, premiums
Consultation	Membership of Advisory Committees
Evidence of partnerships, industrial support and partnering activities	LINK, conferences chairs, consultancies, interdisciplinary research projects
Patents and practical research outputs	Patents, licences, spin-off companies, innovative projects and processes
Core capability indicators	Number of trained researchers
Support capability indicators	Infrastructure, record of past quality and relevance
Involvement with society indicators	Number of staff involved in professional society roles and public understanding activities
Strategic programme and resource planning indicators	Research strategy relevant to chosen mission and purpose

3.8 The period of our study also coincided with the consultation phase for the guidance to the panels for the next RAE in 2001. These appeared to offer an increased degree of flexibility to move in the direction of more dependence on information from industrial sources along the lines of our recommendations. We therefore hope that the panels evaluating engineering in subsequent research assessment exercises will take advantage of this increased flexibility in drawing their conclusions for the next set of ratings.

High Quality Research

3.9 On the basis of our visits to 6 universities, including several departments given 5 and 5* RAE ratings, we judged that the groupings of the highest quality departments (5 and 5*) were clearly fully comparable to top quality departments seen in an international context. We also note that these top departments are very well connected to industry, both in terms of strategic partnerships and the generation of high value spin-off ventures. They would doubtless also be highly regarded under the revised criteria outlined in this report. However, we suspect that were revised quality assessment criteria operated in a wider context the process could well change the value and ranking of departments lower down the RAE scale.

3.10 During our visits we saw a range of departments varying in quality between 3 and 5*, and clearly it is not realistic to compare all departments on an international scale since there is no corresponding numerical scale outside the UK. We were, however, convinced that the process does produce a viable ranking system though based on the imperfect criteria adopted. We believe the system would be improved if it were able to take more account of those factors which would bring it more into line with engineering criteria, and the stated objectives of EPSRC, even if this resulted in some reduction of precision of evaluation and transparency in the process. We also saw departments who were in the process of strengthening their position and others who appeared to be weaker than that suggested by their previous ranking, thus emphasising the dynamic nature of the process.

3.11 Although we visited a very sparse sample of UK universities we were struck by the clear advantages of a visit compared with the perusal of statistical information (much of which we had in advance). The quality ranking of individual departments is clearly a dynamic process. We would also stress the value of using international teams in the visits and assessments of universities. The method of funding research benefits from a diversity of approach and it would be a mistake to develop national policies which force universities into a common response to a single funding formula. There is some evidence that the current RAE structure has achieved that undesirable result. When visiting departments in the “middle ranking” region we encountered a rather different attitude: some would prefer quality criteria which better fitted their own profile of strengths, while some others did not worry about the criteria, but about their consistent use - so that they could develop their own strengths towards this “consistent goal”.

Personnel Issues

3.12 During the visits, the Panel made a point of meeting with young researchers and were very impressed indeed by their vitality, quality and international diversity. However, in virtually all departments visited we were told of the problems of attracting the highest quality research students, research assistants (RAs) and academic staff into engineering as a result of research student stipends, RA salaries and lecturers salaries. These were so critically out of line with comparable careers in other forms of engineering that we were rather surprised that university research programmes continued at their current high level in the absence of adequate financial rewards. Universities have adopted a variety of approaches to mitigate this problem. We would strongly encourage any mechanisms designed to help this situation - for example the development of engineering doctorate programmes being pursued by the EPSRC which aims to help with research student stipends and machinery that takes account of market conditions. This is clearly an area justifying further study and the problem is clearly subject dependent.

Appendix 1

Panel Membership

1 Mr Martin Thomas, Vice President, Australian Academy of Technological Sciences and Engineering, Australia

2 Professor Paavo Uronen, President, Helsinki University of Technology, Finland

3 Sir David Davies CBE FREng FRS, President, The Royal Academy of Engineering, UK (Chairman)

4 Professor Hiroaki Yanagida, Professor Emeritus, University of Tokyo, and Director General, Japanese Fine Ceramics Centre, Japan

5 Professor Philippe Bovy, Director, Institute for Transportation and Planning, Swiss Federal Institute of Technology Lausanne, Switzerland

6 Professor Ron McCaffer FREng, Senior Pro Vice-Chancellor, Loughborough University, UK

7 Professor Simon Ostrach, Home Secretary, National Academy of Engineering, USA, and Director, National Center for Microgravity Research on Fluids and Combustion, Case Western Reserve University, USA

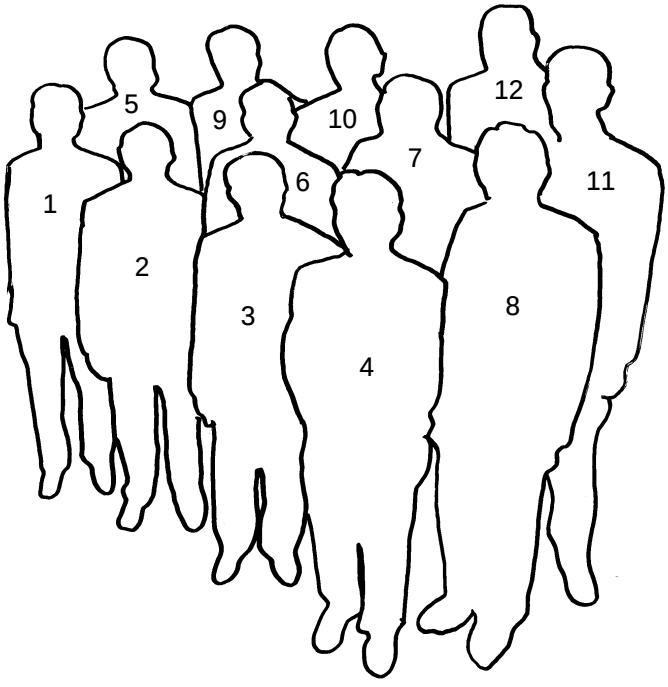
8 Professor Gordon Slemon, President of the Canadian Academy of Engineering, Canada

9 M. Valentin van den Balck, President, Belgian Royal Academy Council of Applied Sciences, Belgium

10 Professor Ingvar Lindgren, Professor Chalmers University of Technology, Former President Swedish Foundation for Strategic Research, Sweden

11 Dr Robin Paul CBE FREng, formerly Chief Executive, Albright & Wilson plc, UK

12 M. Pierre Fillet, Délégué Général, Council for Applied Sciences of the French Academy of Sciences, France



Appendix 2

Terms of Reference

As part of its role to support UK Research in Engineering and the Physical Sciences, EPSRC undertakes evaluations of quality for the research it funds.

It does this in a number of ways including reports of assessors on individual projects and statistics from its database plus relevant information available in the public domain such as the Research Assessment Exercise undertaken by the Funding Councils.

To further develop this process EPSRC has now decided to join with The Royal Academy of Engineering to undertake a study into the quality of engineering research in the UK, using a Panel of international experts to benchmark that quality on an international scale.

The Panel will:

- consider the available data
- assess research quality through visits to specific Academic Institutions
- discuss assessment procedures and current research activities with senior academics and industrialists
- comment on the scale of activity and quality of facilities in academic engineering in the UK
- comment on the degree of collaboration of academic researchers with industrial and other users
- report on the outcome of their assessment

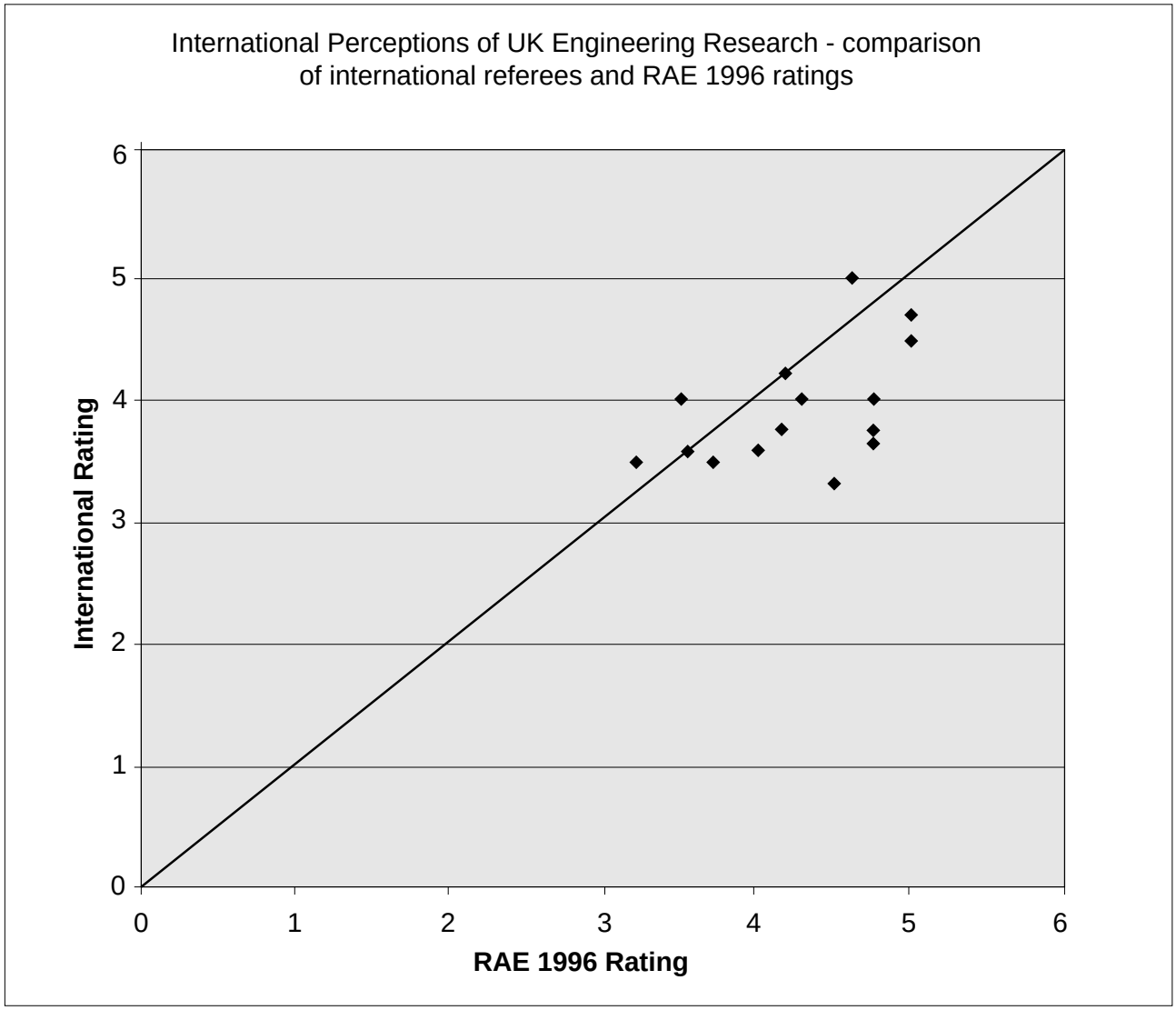
Sir David Davies/Professor Richard Brook
5 August 1999

Appendix 3

The following chart is based on the responses of 16 international referees to a questionnaire issued jointly by The Royal Academy of Engineering and the Engineering and Physical Sciences Research Council, to over 100 referees. Each referee was asked to score any known engineering research group in a 1 to 5 scale. The "international score" was achieved by taking the average rating where three or more ratings were given for a University. The RAE score was achieved by taking the average rating for the same University based on that University's rating under all 1996 RAE Engineering-related units of assessment. (This took 3a and 3b as 3 and also 5 and 5* as 5).

The resultant scattergram shows a (not surprisingly) high correlation between the international perception of quality and the RAE average ratings of engineering departments. These results cover a total of 15 Universities. The points all lie close to the 45° line (representing full correlation) but with slightly more below it, suggesting that the international perception is slightly below that of the RAE rating.

This is a small statistical sample but one that does seem to indicate that international perceptions correlate strongly with the results of the RAE and gives further encouraging support to the use of international assessors in any quality judgement system adopted.



Appendix 4

Potential Assessment Parameters

The Group was not short of advice (either from its own members or universities visited) concerning suitable assessment parameters to measure quality in engineering research. It is however far easier to list the relevant parameters than to devise methods to measure them in a quantitative and transparent manner. The list set out below covers many of the criteria suggested to the Group and it is apparent that several of these are also mentioned in the advice given to the RAE Assessment Panels. The critical issue is of course how to judge the qualitative factors and how to weight them together into a single conclusion. Indeed the selection of the most relevant criteria is itself a qualitative judgement which should be made on the basis of the best criteria and not on the basis of the criteria that is easiest to numerically evaluate.

It is of course tempting to use a simpler process (such as counting papers published in quality journals) as a simple numerical transparent process but quality in this area is a very multi-dimensional parameter which is best judged in terms of peer review evaluation in totality.

Suggested criteria:

- Potential for wealth creation
- Contribution to quality of life, both at home and especially in the international arena where the United Kingdom is expected to play a leadership role
- Extent and quantum of real industrial support for quality challenging projects (cash and in-kind) and sustainability of support
- Working research partnerships (industrial and other research centres) which can or will show real results in the achievement of these objectives; evidence of sustained partnerships
- Greater emphasis on conferences and workshops (compared to Journal publications)
- International esteem - contact and co-operation with other top-level universities and researchers
- Collaboration with industry (and society at large outside academia), in particular spin-off IP, patents, licence and development agreements, start-up companies (employees, total turn-over etc.) and commercial joint ventures
- Assessment of prospective value (or estimated NPV) of the benefits of commercialisation,
- Contribution to regional business development,
- Degree of real innovation as distinct from simply derivative work; initiation of innovative research fields or projects, particularly by young and bright or willing researchers
- Extent of interdisciplinary projects
- Credible peer assessments of quality of research plus achievements or prospects
- Relevance of research projects to current and future national priorities and/or social issues (eg Foresight objectives, environmental management, sustainability and clean production, management of pollution, defence, foreign aid programs, health, etc)
- Consultancy work obtained
- Satisfaction of curiosity
- Quality and quantity of undergraduate input and graduate and postgraduate output (as measured by marketability); demand from engineers in industry to follow advanced education courses
- The ‘buzz’ and excitement evident
- Relevance of research to the generation of important engineering knowledge bases
- Development of effective and sustainable models of processes
- Recognition of national and international esteem for research

Appendix 5

List of Documents Received

- Measuring Excellence in Engineering Research - draft Report of The Royal Academy of Engineering Working Group
- Hong Kong Research Assessment Exercise 1999 - Guidelines for Panel Members
- Chemical Engineering Science, Vol 52 No 18 pp iii-iv, 1997 - Jean-Claude Charpentier (Elsevier Science Ltd)
- Reports on the Strengths and Weaknesses of European Science - ESTA and EUROHoRCs, April 1997
- Students Seriously Considering Manufacturing as a Career (1990) - extract from "European Students' Attitude to Business", Research Surveys of Great Britain Ltd, Report no JN5896, 1990
- Doctoral Education in Engineering Faculties, August 1999, Royal Belgian Academy Council of Applied Science
- Interdisciplinary Consortia in Materials Science and Materials Technology, International Evaluation, December 1995, NUTEK and NFR
- Manual for the Accreditation of Professional Engineering Programs, October 1999, The Institution of Engineers, Australia
- EPSRC Background Information:
- the SET White Paper;
- the Dual Support system;
- the Research Councils;
- EPSRC's role;
- Evaluation of Research Quality - Research Assessment Exercise; Evaluation of EPSRC Engineering Programmes;
- Summary of Foresight;
- 1996 RAE outcome for Engineering Units of Assessment;
- Engineering for Manufacturing Programme 1999 Evaluation Report - Executive Summary;
- Engineering for Infrastructure, the Environment and Healthcare Programme 1999 Evaluation Report - Executive Summary;
- General Engineering Programme 1999 Evaluation Report - Executive Summary;
- Contextual data related to EPSRC supported research and training
- EPSRC Balance of Programme Criteria 1999
- Extract from Libération - Guide des 1000 Universites
- Imperial College of Science, Technology and Medicine - Overview by Lord Oxburgh; Overview of Environmental Engineering;
- Heriot-Watt University - Responses to "Questions for University Visits"; Abstracts of Posters; University Overview; Strategic Plan, June 1999; Postgraduate Prospectus, 2000-2001
- University of Edinburgh - Overview of the University; Electronics and Electrical Engineering Research Handbook, 1998; Research Grants in Engineering Department, January 1996-September 1999; Overview of Electrical and Electronic Engineering Research groups
- University of Cambridge - Overview of the University; Programme for Industry; Department of Engineering Annual Report 1997/98; CFD Laboratory
- City University - Overview of Engineering
- De Montfort University - Science and Engineering Research Centre Research Information
- 1996 Research Assessment Exercise: The Outcome (December 96) - HEFCE
- 1996 Research Assessment Exercise: Membership of Assessment Panels (December 96) - HEFCE
- 1996 Research Assessment Exercise: Criteria for Assessment (November 95) - HEFCE
- 1996 Research Assessment Exercise: Guidance on Submissions (November 1995, revised February 1996) - HEFCE
- 1996 Conduct of the Exercise: RAE Manager's Report - HEFCE
- About the RAE 2001 - HEFCE
- 2001 RAE Panel Membership
- 2001 RAE Guidance for Panel Members - HEFCE
- 1997-1998 Research Grants and Contracts League Tables, Higher Education Statistics Agency Ltd

The Royal Academy of Engineering

The objectives of The Royal Academy of Engineering are to pursue, encourage and maintain excellence in the whole field of engineering in order to promote the advancement of the science, art and practice of engineering for the benefit of the public.

The Academy comprises the United Kingdom's most eminent engineers of all disciplines. It is able to take advantage of their wealth of knowledge and experience which, with the interdisciplinary character of the membership, provides a unique resource with which to meet the objectives.

Its activities include an extensive education programme, research chairs and fellowships, visiting professorships, industrial secondments and international travel grants. It provides expert advice on engineering matters to government and other bodies and administers the UK's premier annual prize for innovation in engineering, The Royal Academy of Engineering MacRobert Award.

Election to The Academy is by invitation only. Up to sixty Fellows may be elected annually, together with Honorary Fellows and Foreign Members who have made exceptional contributions to engineering. All are elected by their peers for personal achievement of exceptional merit and distinction. Fellows are distinguished by the title "Fellow of The Royal Academy of Engineering" and use the designatory letters "FREng".

The Academy was founded in 1976 as The Fellowship of Engineering on the initiative of HRH The Duke of Edinburgh and a group of distinguished engineers. It was granted its Royal Charter in 1983 and, with the consent of HM The Queen, adopted the present title in 1992.

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