THIRD REPORT
FROM THE
SELECT COMMITTEE
ON
SCIENCE AND TECHNOLOGY

UNIVERSITY—INDUSTRY RELATIONS

Session 1975-76

Ordered by The House of Commons *to be printed*
26th October 1976

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Thursday 21 *November* 1974

Science and Technology,—*Ordered,* That there shall be a Select Committee t consider Science and Technology and to report thereon from time to time.

Ordered, That the Committee have power to send for persons, papers an records, to sit notwithstanding any Adjournment of the House, to adjourn fror place to place, and to report from time to time the Minutes of the Evidence take before them and any Memoranda submitted to them.

Ordered, That Five be the Quorum of the Committee.

Ordered, That the Committee have power to appoint Sub-committees and t refer to such Sub-committees any of the matters referred to the Committee.

Ordered, That every such Sub-committee have power to send for persons, paper and records, to sit notwithstanding any Adjournment of the House, to adjour from place to place, and to report to the Committee from time to time.

Ordered, That three be the Quorum of every such Sub-committee.

Ordered, That the Committee have power to report from time to time th Minutes of the Evidence taken before such Sub-committees and any Memorand submitted to them.

Ordered, That the Committee have power to appoint persons with technica or scientific knowledge for the purpose of particular inquiries, either to suppl information which is not readily available or to elucidate matters of complexit within the Committee's order of reference.

Ordered, That these Orders be Standing Orders of the House until the end c this Parliament.

Ordered, That Mr Ronald Brown, Mr Ray Carter, Dr John Cunninghar Mr Alex Fletcher, Mr David Ginsburg, Mr Frank Hooley, Mr Ted Leadbitte Mr Ian Lloyd, Mr Neil Macfarlane, Mr Airey Neave, Mr Arthur Palme Mr Norman Tebbit, Mr Christopher Tugendhat and Mr Kenneth Warren b members of the Select Committee on Science and Technology.

Ordered, That the members of the Select Committee on Science and Technolog nominated this day shall continue to be members of the Committee for th remainder of this Parliament.

Ordered, That this Order be a Standing Order of the House.

Tuesday 25 *February* 1975

Ordered, That notwithstanding the Order of the House of 21 November relatin to nomination of members of the Select Committee on Science and Technolog Mr Airey Neave be discharged from the Committee and Mr Anthony Nelson b added to the Committee for the remainder of this Parliament.

Ordered, That this Order be a Standing Order of the House.

Thursday 27 *March* 1975

Ordered, That notwithstanding the Order of the House of 21 November relatin to the nomination of members of the Select Committee on Science and Technolog Mr Christopher Tugendhat be discharged from the Committee and Mr Peter Ro be added to the Committee for the remainder of this Parliament.

Ordered, That notwithstanding the Order of the House of 21 November in the ›t Session of Parliament relating to nomination of members of the Select ›mmittee on Science and Technology, Mr Alexander Fletcher and Mr Ray ırter be discharged from the Committee and Mr Nigel Forman and Mr Roderick acFarquhar be added to the Committee for the remainder of this Parliament.

Ordered, That this Order be a Standing Order of the House.

Tuesday 7 July 1976

Ordered, That notwithstanding the Order of the House of 21 November in the last Session of Parliament relating to nomination of members of the Select Committee on Science and Technology, Sir Alexander Fletcher and Mr Ray Carter be discharged from the Committee and Mr Nigel Forman and Mr Roderick MacFarquhar be added to the Committee for the remainder of this Parliament.

Ordered, That this Order be a Standing Order of the House.

NOTES

References

In the Report references to answers given by witnesses in evidence to the Science Sub-committee in Session 1975–76 are indicated in the form " Q 957 ". References to answers given in Session 1974–75 are indicated in the form " Q 957 (1974–75) ".

References to Memoranda printed with the Minutes of Evidence in Session 1975–76 are indicated in the form " p. 121 ".

References to Memoranda printed in the periodical volumes of Memoranda submitted to the Science Sub-committee in Session 1975–76 are indicated in the form " Memorandum 6 ".

Publications

The Minutes of Evidence taken before the Science Sub-committee in Session 1975–76 have been published in series as House of Commons Paper No. 23—i–xx (1975–76).

The Minutes of Evidence taken in Session 1974–75 were published as House of Commons Paper No. 260 (1974–75).

The Memoranda submitted to the Sub-committee in Session 1975–76 have been published in series as House of Commons Paper No. 136—i–v (1975–76).

The Memoranda submitted in Session 1974–75 were published as House of Commons Paper No. 261 (1974–75).

1. The training of engineers and applied scientists suitable for employment in productive industry should be given much higher priority in the Government's educational policy **(paragraph 3.77).**

2. The concept of Special Institutions for Scientific and Technological Education and Research, first proposed by the Robbins Committee in 1963, should be revived and implemented. A number of universities, possibly including the engineering and applied science departments of the University of Cambridge, should be so designated **(paragraphs 3.78, 3.25–6, 3.43).**

3. The University Grants Committee should be instructed to regard engineering and applied science training as a privileged area, for which additional earmarked funds should be provided **(paragraph 3.80).**

4. The content and form of undergraduate courses in engineering should be the subject of a thorough and urgent review, and the universities and engineering institutions should examine methods of achieving greater collaboration in the control of standards and the content of degree courses **(paragraphs 3.82, 3.75).**

5. Employers and universities should give greater support to sandwich courses for undergraduates in engineering and science. They should become a normal feature of undergraduate studies in the Special Institutions **(paragraph 3.83).**

6. The proposals of the Science Research Council for improvements in the training of postgraduates should be pursued with vigour and sufficient earmarked funds should be allocated at the expense, if necessary, of less pressing demands on the higher education sector. The Department of Industry should be prepared to commit their own funds to the development of " Teaching Companies ", and such schemes should be launched with greater rapidity **(paragraphs 3.84, 3.70, 3.68).**

7. Serious consideration should now be given to the introduction of higher maintenance grants for undergraduate and postgraduate students in the applied sciences and engineering. Preferably these should be provided in the form of bursaries distributed from the Department of Industry Vote **(paragraph 3.85).**

8. A Minister of State should be appointed within the Department of Education and Science with special responsibility for Science and Technology. He should be principally concerned with scientific and technical education at all levels of the educational system, and with the activities funded from the Science Budget. It is also hoped that the Secretary of State will devote more attention to the scientific aspects of her job than have most of her recent predecessors **(paragraphs 3.86, 3.74).**

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* Note: the full text af these Recommendations may be found in the paragraphs stated.

EMPLOYMENT

9. The triennial surveys of the employment of qualified scientists, engineers and technologists (QSE's) should be revived, and British measurement standards for scientific and technical activities should be compatible with OECD Frascati classications **(paragraph 4.14).**

10. Industry should take steps to ensure that qualified personnel are not only offered attractive salaries, but also the opportunity of moving into senior management with as much ease as their counterparts in Germany, France or the USA and as their contemporaries in Great Britain who have chosen to study law or accountancy **(paragraph 4.32).**

11. If the Government is serious in its desire to rebuild British productive industry it must create an environment in which there are adequate incentives to attract the ablest young people into industry and away from non-producive public and private services **(paragraph 4.35).**

12. The Government should establish an independent review body to examine the personal incomes, etc, of qualified scientists, engineers and technologists in British industry, and to compare them with the incomes of graduates in the public services and the independent professions and with their industrially-employed counterparts in major competitor countries. The review body should make recommendations concerning the desirable future relationship between the personal incomes of QSE's in industry and of QSE's and graduates in the public services and the professions. They should make provisional recommendations before agreement is reached on an incomes policy to replace Stage II of the Social Contract **(paragraphs 4.35–4.38).**

13. The Government should institute an urgent inquiry into the advice given to young people by school and university careers advisory services and should, if necessary, be prepared to issue guidance on ways of improving advice on industrial careers **(paragraph 4.40).**

COLLABORATION BETWEEN UNIVERSITIES AND INDUSTRY

14. Every encouragement should be given to bringing the higher education system and industry generally into closer alignment **(paragraph 5.5).**

15. There is a good case for devising financial incentives—possibly in the form of generous tax allowances—to encourage companies to place research contracts with universities **(paragraph 5.9).**

16. Both universities and industry should ensure that time is available for those of their employees who wish to improve collaboration to do so, and should take account of such work when promotion is considered **(paragraph 5.14).**

17. Public funds should be made available to encourage the development of liaison bureaux, consultancies and industrial units in *between the activities of the Science Research Council and the National Research Development Corporation, and urgent action taken to correct it, along the following lines :—*

(i) the SRC Engineering Board's "pre-development" grants scheme should be extended, where appropriate, to other areas within the Council's remit ;

(ii) NRDC's patent rights in respect of Research Council funded university research should be terminated and universities should be free to exploit the results of research carried out in their laboratories in any way they choose ;

(iii) university industrial liaison bureaux should act as local agents for NRDC ;

(iv) NRDC's responsibilities should be redefined ; its interest rates should be at or below market levels ; and its obligation to break even should be regarded as secondary to its obligation to encourage innovation **(paragraph 5.58).**

19. The functions proposed for NRDC may well be better performed by a new institution without the accumulated scepticism and indifference which NRDC appears to have generated **(paragraph 5.59).**

20. The Government should undertake a thorough review of the level and nature of the research undertaken in their own research establishments and should attempt to transfer to universities work of a more basic nature, not requiring major physical research facilities, wherever this is possible **(paragraph 5.62).**

MISCELLANEOUS

21. Whether by interventionist or non-interventionist means, the Government must seek to release industrial management from a situation in which, because of the low added-value of their activities, they have insufficient funds to invest in technological innovation, and without such innovation they are unable significantly to increase their added-value. The stimulation of wealth-creating innovation should be the principal activity of the Department of Industry **(paragraphs 6.18–6.20).**

22. Consideration should be given to the transfer of a proportion of the funds of the Science Research Council to the Department of Industry, which is the natural "customer" department for the applied research supported by the Council **(paragraph 7.8).**

23. The new Advisory Council on Applied Research and Development (ACARD) should review the relationship between government-supported applied R & D and government-funded basic research with a view to ensuring that effective machinery exists for relating basic science policies to long-term departmental R & D strategies **(paragraph 7.14).**

24. ACARD reports should normally be published; and the Lord Privy Seal, as Chairman of ACARD, should make annual reports to Parliament on the work of the Council **(paragraph 7.15).**

25. Given effective guidelines, the Research Councils are efficient instruments for providing selective support for research in the higher education system. It is the responsibility of the Government to provide such guidelines. The Research Councils should not be expected to perform the strategic and policy-making roles which belong to the Government and, finally, to Parliament **(paragraphs 7.19–20).**

26. The Science Research Council should be prepared to provide more adequate and regular information about the distribution of research grants and studentships, and should welcome attempts to evaluate the practical effects of their policies for research support. There should, however, be no departure from the principles of the peer-review system **(paragraphs 7.21–22).**

27. One of the central aims of Government policy should be the creation of an environment in which the undoubted scientific and technical expertise of the people of Britain can be directed towards the re-creation of a health and expanding industrial economy **(paragraph 8.1).**

THIRD REPORT

The Select Committee on Science and Technology have agreed to the following Report:—

UNIVERSITY—INDUSTRY RELATIONS

1. INTRODUCTION

Origins of the Inquiry

1.1. The Science Sub-Committee was appointed by the Select Committee in December 1974 to "examine the needs of scientific research in British universities and the funding of such research from public and other sources". An interim Report on *Scientific Research in British Universities* was approved by the Committee in July 1975[1], and a Second Report with the same title was approved by the Committee in December of the same year[2].

1.2. In the process of taking evidence on university research in 1975, and in particular when examining the effects of inflation on the universities' scientific research effort, it became apparent to the Sub-Committee that there was cause for concern not only about the financial situation in the universities and the machinery for allocating resources for academic research, but also about the rationale behind the organisation and funding both of that research and of the higher education in the sciences with which it is invariably and naturally associated. It was also evident that the concern which we felt was not merely the predictable reaction of lay politicians confronted with substantial public expenditure and demands for more of the same, but was shared by many of those within the academic community who were beneficiaries of the existing system, and of those outside the academic community who might hope eventually to be beneficiaries of that community's labours.

1.3. In our last Report we indicated that in the current session we hoped to concentrate our inquiries on:—

"(1) the relationship between the development of ideas, the inculcation of skills, the creation of new technologies and the output of new and saleable products;

(2) the mechanisms for identifying and implementing a coherent national science policy; and

(3) the mechanisms for relating science policy to the general social and economic objectives of the community"[3].

We also made clear that underlying our concern with university science were the beliefs that scientific endeavour "should contribute to the social and economic wellbeing of the community", that scientific funding institutions should bear in mind the "social and economic benefit of the community" and that politicians had a responsibility to ensure that a "continuing and fruitful dialogue is

[1] HC 504 (Session 1974–75).
[2] HC 87 (Session 1975–76).
[3] HC 87 (1975–76), para 32.

maintained between the social and economic decision-making machinery and the scientific decision-making machinery"[1].

The inquiry

1.4. During this part of the inquiry the Science Sub-Committee have held 20 public meetings and have taken oral evidence from:

The Chemical Society's Standing Advisory Committee on Relationships between Higher Education and Industry

The Engineering Board of the Science Research Council

The National Research Development Corporation

The University of Cambridge (School of the Physical Sciences)

The Cambridge Science Park

Patscentre International

Mr John Diebold

Hewlett-Packard Ltd

The Cambridge Instrument Company Ltd

The Oxford Instrument Company Ltd

Dr Frank Jones, FRS

EMI Ltd

The British Steel Corporation

The Plessey Company Ltd

Swan Hunter Shipbuilders Ltd

Y-ARD Ltd

Lucas Industries Ltd

The Lord Bowden

The Secretary of State for Education and Science

The Secretary of State for Industry

The Lord Privy Seal

A full list of witnesses is attached as Appendix I. The Sub-Committee have also received a considerable number of written submissions from other individuals and groups. The Memoranda are listed in Appendix II, and have been published in periodical volumes during the Session[2].

1.5. The Committee are grateful for the help and guidance of all those who have given up their time to submit oral and written evidence to the Science Sub-Committee during their inquiry. They are also grateful for the assistance of Professor Michael Gibbons of the Department of Liberal Studies in Science at the University of Manchester, who acted as Specialist Adviser to the Science Sub-Committee between May 1975 and the conclusion of their inquiry.

on 17 December 1974 with the following membership: Mr Airey Neave (Chairman), Mr Ray Carter, Mr David Ginsburg, Mr Neil Macfarlane, and Mr Norman Tebbit. Dr John Cunningham was appointed in place of Mr Ginsburg on 19 February 1975. Mr Ian Lloyd was appointed Chairman in place of Mr Neave on 26 February 1975. Mr Anthony Nelson was appointed to the Sub-Committee on the same date. Mr Ronald Brown was appointed in place of Mr Carter on 14 June 1976. Mr Roderick MacFarquhar was appointed on 14 July 1976. Dr Cunningham ceased to participate in the activities of the Sub-Committee in September 1976 on his appointment as Parliamentary Under-Secretary of State for Energy.

The nature of the Report

1.7. The normal inclination of Select Committees is to choose subjects of inquiry which admit precise questions and equally precise recommendations for executive action, but there are occasions when problems present themselves which are by their nature more diffuse. The present inquiry is of the latter kind. Although there are undoubtedly some areas, such as educational policy, where new prescriptions may be expected to lead to beneficial changes in the performance of institutions and in the relationships between institutions, much of the inquiry has been concerned with matters where most desired improvements will only arise from quite fundamental changes in attitude and behaviour which will not be easily achieved and which are relatively insensitive—and even resistant—to manipulation by financial or administrative levers. This is the overwhelming opinion of those who have given evidence, and is reflected in the present Report.

1.8. The Committee welcome the recent speech by the Prime Minister at Ruskin College, Oxford, in which he raised a number of questions about the role of the educational system, including its relationship with industry. This Report, which is concerned with the purposes of the institutions of advanced scientific education and research, can be regarded as a contribution to one important aspect of the debate which will inevitably follow that speech. There is a very real sense in which the organisation of higher education, and our attitudes towards both eduaction and industry, continue to be determined by the debates of our Victorian forbears[1]. It is essential that we should be prepared to re-examine the organisation of science and scientific education in terms of our current needs. We believe that the large volume of evidence which we have received—much of it unsolicited—bears ample testimony to the widespread concern in Britain about the contribution of the higher education system to the nation's industrial future.

1 In a speech at the end of last year Mr Edward Heath commented that "Although the sun has set on the British Empire, we still seem to be producing a stream of administrators to govern the colonies which no longer exist" (*Times Higher Education Supplement*, 19 December 1975).

2. R & D TO WHAT END?

The significance of R & D

2.1. Throughout the twentieth century Britain has been one of the biggest spenders, in both absolute and relative terms, on all kinds of research and development. Although overtaken in the postwar period by a small group of other countries, Britain remained in 1971 (the last year for which comprehensive OECD statistics are available) the fifth largest spender in absolute terms among OECD Members, the third largest employed of R & D manpower, and the second largest spender and employer relative to total national resources, exceeded only by the USA[1]. Yet throughout the post-war period Britain's industrial and general economic performance has declined relative to that of her major competitors.

2.2. On the other hand the share of basic research in total current national R & D expenditure in 1971 was less than 11 per cent in the United Kingdom, compared with 28 per cent in Japan and 27 per cent in West Germany (but only 18 per cent in France and 15 per cent in the USA), and the share of basic research performed in the higher education sector was only 38 per cent in the United Kingdom, compared with between 74 per cent and 93 per cent in Belgium, Norway and Sweden, and between 60 per cent and 65 per cent in West Germany, Japan, France and the USA[2]. According to a somewhat different OECD classification the funds received by British universities in 1969 for the "advancement of science" (ie funds deriving from the UGC and the Research Councils for academic research) represented approximately 10 per cent of total government R & D spending compared with 33 per cent in West Germany, 44 per cent in Holland, and 61 per cent in Japan[3].

2.3. Any consideration of the social and economic contribution of the universities must therefore have in mind a number of overriding questions:

What is the explanation for the relatively high British investment in R & D and the relatively poor British performance in industrial production?

What is the relative importance of R & D in determining industrial performance, compared with other factors?

What is the relative importance of "basic" research (as compared with applied R & D) in determining industrial performance?

What is the importance of relating the performance of "basic" research to higher education?

The figures quoted above suggest that the industrial problems of the UK cannot simply be attributed to an over-emphasis on basic research. Indeed, the high proportion of British R & D effort devoted to applied research and development emphasises the importance of examining more closely the nature and organisation of the education of those destined to carry out such work, and the allocation of resources to applied research of relevance to productive industry.

1 These and following figures are taken from OECD, *Patterns of Research and Experimental Development in the OECD Area*, 1963–71 (Paris, 1975).

2 OECD breakdowns of R & D by type of activity are notoriously difficult; but, even allowing for the admittedly wide margin of error, the comparison is striking enough.

2.4. The present Report is not about public attitudes towards economic growth. It is, however, concerned with one aspect of the economic process—namely the transmission and application of scientific and technical knowledge—where individual and collective attitudes are of some importance. The channels along which knowledge flows, from one generation to another, or from one institution to another, are essentially individual. It is not institutions which instil knowledge in the young, but individual teachers. It is not universities as institutions which feed ideas into industry, but individuals within universities and within individual companies who recognise the potential relevance of ideas and seek to apply them. The attitudes of these individuals are therefore a significant factor in the efficient transmission of knowledge. Unless they are both ideologically sympathetic towards economic growth and sufficiently motivated—not only by the prospect of financial reward, but also by considerations of status and esteem—to make a personal contribution towards achieving such growth, no amount of government exhortation will have much effect.

2.5. Britain is often regarded as a country which is good at research but bad at translating the results of research into production. This view is shared by the majority of our witnesses, although their explanations of why this may be so differ quite widely. And, as we point out later, not only is Britain's expenditure on scientific research relatively high, but by many conventional indicators of scientific achievement Britain is rated as successful: we have many Nobel Prize Winners to our credit, our scientists have been exported throughout the world, as have many major fundamental scientific discoveries.

2.6. Achievements at the frontiers of scientific knowledge cannot be lightly dismissed, and the British scientific community has perhaps not always been accorded the praise which is its due. But although we respect the advancement of knowledge as a process to be valued in its own right and supported for its own intrinsic merit, we nonetheless regard the *ultimate* aim of scientific discovery as being the enrichment of the life of the community at large. That is not to say that scientific research for which there is no discernible application should not be supported from public funds. It does imply, however, that those engaged in scientific research should not regard themselves—or be regarded by the rest of the community—as in any way divorced from the productive process.

2.7. The contrast between Britain's scientific success and her currently disappointing industrial performance arises partly, in our view, from the extent to which pure science has been dignified as a profession—or an art—requiring no external justification and with no external aim. The elevation of science as a mystery leads not only to a somewhat myopic view on the part of many scientists but also to a failure on the part of many in productive industry to appreciate the economic benefits which may accrue from the utilisation of scientific expertise.

2.8. The failure fully to integrate the process of scientific discovery into the process of industrial production cannot be regarded as the sole cause—or even the principal cause—of Britain's relative industrial decline, but it is undoubtedly a significant contributory factor. This Report is concerned with institutional problems which mainly derive, in our view, from the failure of different groups in the community to appreciate the extent of their interdependence. Any improvements which can be made in the attitudes of students, teachers, researchers, industrial managers and government officials will be of undoubted benefit to the community as a whole.

2.9. While an explanation for Britain's poor industrial performance may be found in bad industrial management, bad industrial relations, ill-judged investment decisions by government and industry, inadequate education and training, or the innate conservatism of industry, government, and the universities alike, it may be that Britain—that is to say, the British people—has simply "opted out" of the race. Although the Committee do not believe that the latter explanation is necessarily true, the question must be asked: does Britain any longer wish to be an industrial leader? There is little doubt that many overseas observers long ago concluded that that was no longer the case[1], as have some social scientists[2]. Nor do the reported attitudes of students within the higher education sector, or the reluctance of students to study subjects relevant to the needs of industry, indicate any widespread enthusiasm amongst the better educated and potential opinion-leaders for a society made prosperous by industrial growth.

2.10. If Britain has "opted out" of the industrial race it faces disaster, North Sea Oil notwithstanding. For there is no sign that it has opted out of the race to possess the fruits of industrial growth either in the form of personal possessions or of public services. If we are concerned with attitudinal problems, we must recognise that they may derive not only from the traditional jealousies of rival groups in a class-ridden and status-ridden society, but also from conceptions of society and of life which are hardly conducive to the achievement of greater prosperity. It is arguable that our society's greatest need is to re-examine the relationship between production and consumption. A concerted attempt to clarify in the public mind the distinction between the "unacceptable face of capitalism" and the fundamental processes of wealth creation may well be an indispensable condition of survival.

1 President de Gaulle was perhaps the most eminent to articulate this view.

3.1. Since the last World War numerous studies have dealt in whole or in part with the character of scientific and technical education in the higher education sector, with the nature of British postgraduate education, or with the flow of trained scientists and engineers into industry. Recently, however, there has been a spate of publications dealing particularly with postgraduate education, and we acknowledge the debt of gratitude which we owe to their authors. We have examined with particular interest the reports of the Expenditure Committee[1], the Committee of Vice-Chancellors and Principals[2], the Science Research Council[3], and the joint SRC/Social Science Research Council Committee[4]; and the Joint Report of the SRC and the Department of Industry on a concerted approach to postgraduate training and advance in manufacturing engineering[5].

The Drift from Science

3.2. The total numbers of university students in Britain have increased considerably in all subjects and at all levels, particularly since the early 1960's. The increase in student numbers and graduates, however, has been generally much lower in the sciences, engineering and technology areas than in non-science subjects. The supply of all first degree graduates from all institutions of higher education rose by 170 per cent between 1963 and 1974, but the increase was only 110 per cent in science and 120 per cent in engineering. Comparable growth rates for higher degrees were 285 per cent for all subjects, 150 per cent for science, and 300 per cent for engineering[6]. The figures are set out in Table 1.

3.3. Consequently, despite the optimistic hopes of the Robbins Committee[7], the proportion of graduates awarded first degrees in science and engineering fell from approx 55 per cent in 1963 to approx 46 per cent in 1974, and the proportion of higher degrees in science and engineering together fell from approx 67 per cent to approx 51 per cent. In 1974–75 there were an estimated 18,000 vacant undergraduate places in science and allied subjects in the universities[8], while an increasing proportion of postgraduate places in these subjects was being filled by graduates from overseas[9], the average proportion of British science and engineering first graduates going on to research or higher degree work falling from 26 per cent to 18 per cent between 1963–65 and 1972–74 (see Table 2).

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1 *Postgraduate Education*, Third Report from the Expenditure Committee, Session 1973–74 (HC 96).

2 CVCP, *Postgraduate education: Report of a Study Group*, July 1975.

3 SRC, *Postgraduate training: SRC Working Party Report*, September 1975.

4 SRC/SSRC, *New Postgraduate Patterns: Blending the Natural and Social Sciences*, September 1975.

5 SRC/DI, *The Teaching Company*, December 1975.

6 Memorandum 24. Science and engineering are here defined according to DI classifications and therefore exclude medicine and agriculture.

7 Cmnd 2154 (1963), paras 505–8.

8 See *Second Report from the Select Committee on Science and Technology*, Session 1974–75 (HC 504), para 64. See also paragraph 3.5 (below).

9 *ibid*, para 90.

TABLE 1

SUPPLY OF GRADUATES WITH FIRST AND HIGHER DEGREES IN SCIENCE, AND ENGINEERING AND TECHNOLOGY

ic year ending ...	...	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	
gree														
iversity	Science	7,559	8,580	9,357	10,259	11,155	12,935	13,611	13,935	14,116	14,716	15,100	15,000	
	Engineering ...	3,466	3,723	4,195	5,899	6,665	7,300	7,239	7,933	8,233	8,097	7,989	8,100	
AA	Science	426	510	554	230	190	259	484	706	892	1,080	1,313	1,513	
	Engineering ...	1,281	1,357	1,510	658	546	1,002	1,167	1,440	2,002	2,154	2,293	2,313	
tal	Science	7,985	9,090	9,911	10,489	11,345	13,194	14,095	14,641	15,008	15,796	16,413	16,513	
	Engineering ...	4,747	5,080	5,705	6,557	7,211	8,302	8,406	9,373	10,235	10,251	10,282	10,413	
	Total	12,732	14,170	15,616	17,046	18,556	21,496	22,501	24,014	25,243	26,047	26,695	26,926	
tal all Subjects ...	...	23,235	25,653	27,879	34,638	37,101	43,742	46,909	50,494	55,159	55,467	57,294	59,327	
degree														
	Science	1,878	2,125	2,334	2,725	3,126	3,869	4,117	4,344	4,549	4,534	4,770	4,683	of which c.400 are CNAA Higher Degrees
	Engineering ...	775	878	977	1,300	1,824	1,969	2,178	2,546	2,742	2,670	2,828	3,087	
	Total	2,653	3,003	3,331	4,025	4,950	5,838	6,295	6,890	7,291	7,204	7,598	7,770	
tal all Subjects ...	...	3,949	4,356	4,898	5,891	7,396	9,193	10,238	11,538	12,535	13,067	14,074	15,191	

PERCENTAGE DISTRIBUTION OF FIRST AND HIGHER DEGREE GRADUATES FROM GB UNIVERSITIES FOR SCIENCE-BASED SUBJECTS

Academic years	Average 1962/3–64/5		Average 1971/2–73/4	
	First	Higher	First	Higher
Nos.	12,611	3,130	23,988	8,016
TOTAL GRADUATES	100	100	100	100
Destination:				
FURTHER EDUCATION AND TRAINING ...	40	12	31	17
of which research or higher degree ...	26	11	18	16
teacher training	11	—	10	1
all other	3	—	3	—
FIRST PERMANENT EMPLOYMENT IN UK ...	46	42	44	32
of which public services	5	5	7	5
industry	31	15	26	14
commerce	2	—	7	1
other	8	23	4	12
ALL OTHER DESTINATIONS OR UNEMPLOYED...	11	42	16	38
UNKNOWN	3	4	9	12

3.4. The proportions of students entering different courses of higher education is to a large extent influenced by the qualifications acquired by potential students during their years in secondary schools, and the provision of university places is similarly determined. The Committee commented on the latter feature of British higher educational policy, in the context of the financing of university research, in 1975[1], but it is a characteristic which the Science Sub-Committee also noted during their visits to West Germany, France, Canada and the USA last year. It would, of course, be irresponsible for any government consciously to plan the provision of places in excess of likely qualified demand. The trend away from the sciences has indeed been as marked in the schools as in the universities. Between 1963 and 1973 there was an increase of 69 per cent in all Avanced level GCE passes in England and Wales. In the principal science subjects, however, the increases were markedly lower: 14·3 per cent in Physics, 22·2 per cent in Chemistry, 41·3 per cent in Mathematics and 59·2 per cent in biological sciences[2]. This compared with increases of 119·5 per cent in English literature, 121·7 per cent in Art, 164·9 per cent in Economics and 100·9 per cent in Geography (but only 26·1 per cent in French and 42·3 per cent in German)[3].

3.5. So sharp has been the drift away from science and technology in the schools that there now exists a serious imbalance between the provision of university places and the supply of students to fill those places, despite a general easing of entry standards in science and engineering departments in the universities. In our first Report we quoted a figure of 18,000 vacant undergraduate places in science and engineering subjects[4], based on a calculation of departmental space provision. The University Grants Committee have since

[1] *ibid*, para 65.
[2] Although there was an increase of 135 per cent in other scientific and technical subjects (including geology, engineering etc) these passes totalled only 7,783 in 1973 (compared with 119,859 in the other sciences) and the increase, although very welcome, does not conflict with the generalisation made here.
[3] DES, *Statistics of Education* 1973 (Vol 2) (1975), Table 36.
[4] *Second Report*, Session 1974–75, HC 504, para 65.

pointed out the partial nature of this basis of calculation, but estimate on that basis that the shortfall in 1976–77 would be nearer 24,000[1]. There are similar serious shortages of research postgraduates in most science and engineering departments, partly disguised by an increase in numbers of postgraduate students from overseas[2].

3.6. Although precise calculations of vacancies are frustrated by the complex factors involved, it is clear that the crisis facing science and engineering education is not the result of failures by the Government or the University Grants Committee to make adequate financial provision for such education in the universities. To an unsympathetic observer, indeed, the Government might appear open to criticism on the grounds of over-optimism and wasteful expenditure. The problems relate rather to the quality of the education provided by the universities and to the relative unpopularity of science and engineering amongst potential students.

3.7. This chapter is largely concerned with the nature and quality of university education in science and engineering. Some of the factors which may contribute towards the unpopularity of these subjects are discussed in Chapter 4.

Attitudes towards University Education

3.8. The Sub-Committee have discussed with representatives of a number of individual companies and industrial organisations their attitudes towards the suitability of university training in science and engineering as a preparation for employment in industry, and have also received many written submissions on this subject. Although a number of witnesses have expressed satisfaction with the manpower output of the universities, the overwhelming impression of the evidence is one of concern both about the nature of the training provided by universities at undergraduate and postgraduate level, and about the quality of the individual graduates seeking employment in industry.

The CBI

3.9. In their recent evidence to the Sub-Committee the CBI repeated an earlier view expressed to the Expenditure Committee in 1973 that postgraduate education was "something of a mixed blessing in so far as industry and commence are concerned"[3]. Many in industry considered that the research-based postgraduate system was "producing a body of specialists in science and technology, the relevance and originality of whose research work is often questionable" and the CBI thought that that opinion had, if anything, been strengthened since 1973. Graduates were needed in industry for a wide range of jobs "for many of which specialist academic research experience is of no direct benefit and may even, if it has narrowed the graduate's perspective on life, be a handicap"[4].

3.10. The CBI also reported the concern expressed by many of their members about "the decline in quality of recent graduates". On the basis of a survey

1 Memorandum 26.

ment, the CBI say that

> "While employers report that the top strata of QSE's[1] is still of excellent calibre they indicate with disturbing frequency that there is a growing proportion of those with only poor or mediocre talent. This is illustrated in terms of such factors as poor personal motivation and little professional commitment; a lack of flexibility, breadth of vision and creativity in problem solving; need of close supervision; and deficiencies in inter-personal and communicative skills".

These latter characteristics, it may be noted, are precisely those which the British higher education system is generally thought to encourage. The CBI add that while they accept that the mix of the graduate output will be different as total output increases, "employers do not seem to have experienced a similar fall in the quality of Arts graduates".[2]

Individual companies

3.11. The views expressed above are corroborated by those of many individual witnesses. Hewlett-Packard Ltd. (UK) referred to "a decline in the quality of new graduates" which might reflect a change in the type of student who studied for a science-based degree or "a decline in teaching standards at either the university or secondary school", and criticised the "cook-book" approach of university teaching (p 134). Their R & D Manager told the Sub-Committee that in 1975 they had interviewed about thirty graduates (including some postgraduates) and had "not come anywhere near employing anyone" (Q 376). He found that "more and more graduates are coming to us having followed the course material, knowing the formulae and the principles, but they do not have an understanding of what is taking place" (Q 377). Similarly, the Oxford Instrument Company thought there was "a considerable diminution in the quality of graduates presenting themselves to us for employment" and speculated as to whether this reflected a lowering of university standards or the relative unattractiveness of industrial jobs. They believed, however, that it took "several years of actual job experience for a UK graduate to grasp the commercial aspects of their work" and commented that new engineers arrived in industry with "considerable formal analytical skills, but no understanding of the importance of designing to meet cost limits, or of ease of manufacture and service" (p 155-6).

3.12. EMI Ltd commented that the expansion of higher education had "lowered input standards; there are more graduates, but they have a lower average standard" and criticised "a basic weakness of lack of industrial orientation" which was accentuated at higher degree level where "research objectives are often far removed from the requirements of industry". Postgraduate research was too frequently "so closely guided by a senior member of the University that the scope for imagination and original contribution is small". The result was that "after three years the postgraduate is inferior to the first degree man who has spent three years working directly in the industrial research laboratory" (p 175–6). The decline in academic ability was, moreover, compounded by a decline in "drive and motivation and interest" (Q 524–5).

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[1] Qualified scientists and engineers.
[2] Memorandum 29.

3.13. Representatives of Lucas Industries Ltd, another major employer of engineering and electrical engineering graduates, acknowledged that in 1976 ("a rather exceptional year") there had been no shortage of good graduates seeking employment with them, but said that "for the last half-dozen years or more there has been a distinct shortage, primarily of quality" (Q 790). This was not necessarily because of a lowering of standards as such as because, for a very long time, a career in industry had been frowned on in many University departments as somewhat "money grubbing" and had ranked below university research, the scientific civil service or even teaching (p 264). So far as postgraduate training was concerned their Chief Engineer, Mr Ewen M'Ewen (now President of the Institution of Mechanical Engineers), admitted that in some pure science disciplines "the amount of knowledge is so vast that only by some degree of postgraduate specialisation do you get the kind of man you really need". On the other hand, a PhD in engineering was a "non-asset" in industry, "although it may be an asset to one who wishes to remain an academic". The engineering PhD did a "disservice" to industry both by keeping the student away from industry for three or four years and by not preparing him to enter industry" (Q 789).

3.14. Some industrial witnesses were not so critical of the universities, however. The Deputy Chairman of the Cambridge Instrument Company, for instance, acknowledged that his company had been "very lucky indeed in obtaining very bright people from universities all over the UK", although "some of the very bright physicists who come in and take charge of research teams do have an inbuilt arrogance . . . to commercial and marketing practice" (Q 419–20). Representatives of Y-ARD Ltd were in general "well satisfied" with undergraduate training, although graduates were not all as literate as they would have liked (Q 713). In any case Y-ARD did not very often recruit directly from the universities and polytechnics, "because in our business we tend to need a modicum of sensible practical experience" (Q 715). On the other hand the Y-ARD representatives had concluded after a meeting with their senior staff that although "we do have need for people to be taught at a higher level, and very often this is conveniently aggregated into an MSc course", they saw "no advantage at all in the PhD type of training so far as our work is concerned" (Q 726). The Managing Director of Swan Hunter Shipbuilders regarded PhD's as valuable because they had gone to "the frontiers of knowledge" and had acquired "a certain independent view and a certain maturity" (Q 673). And in the opinion of the Managing Director of Plessey Microsystems, the idea that young people were being ruined by university and "If only we could get them at the age of fifteen everything would be marvellous" was "absolute nonsense" (Q 613). Plessey had no difficulty in getting science graduates, but it was much more difficult in engineering, which he thought was a reflection on the tendency of the educational system to put the brighter schoolchildren into the pure sciences (Q 602).

Chemistry

3.15. The high regard in which academic chemistry—both as regards research and education—is held by the chemical industry is well known, and has not gone unremarked by the Committee. Chemistry is an area where there is higher than usual alignment between the academic discipline and the industrial practice of that relationship below. At this point, however, we note the view of the Education Policy Committee of the Chemical Industries Association that "The Chemical industry has a high regard for the contributions of the universities and in particular for the existing immediate post-graduate courses", although they too comment on "the use of well-established and sometimes purely repetitive research techniques" (Appendix 100 (1974–75)). Evidence of the respect in which academic chemistry is held by the chemical industry is to be found not only throughout the evidence given by representatives of SACRHEI[1] but in the very existence and vitality of that Committee.

Government Departments

3.16. Despite the exceptions noted in the two preceding paragraphs, the general tone of the evidence from industry indicates a considerable degree of dissatisfaction with the current educational performance of the universities, and tends to confirm the impression gained by the Expenditure Committee in 1973 that industry was not well-disposed towards the type of PhD at present produced by the universities[2]. This impression of industrial attitudes is shared by the two Government Departments principally concerned. In a recent speech[3] the then Secretary of State for Education and Science spoke in language very similar to that of the CBI quoted above. Amongst other things, Mr Mulley remarked that

> "What industry seems to be saying is not that they are dissatisfied with the 'high fliers'. They willingly admit that the top strata of new graduates are the equal of any in the world. But they say that the graduate output, of engineers especially, has a very poor 'tail'. The quality in terms of motivation and breadth drops away more sharply than in other areas."

3.17. Similarly, the Department of Industry, in evidence to the Science Sub-Committee, commented that "The overall picture at the higher education level is one of below-average standard of entry to engineering and technology compared with other subjects, and difficulty in filling some industrial posts requiring graduate qualifications", and concluded that "**The overall trend is a decline in the numbers and quality of QSE's and supporting staff in key areas of manufacturing**"[4].

3.18. Neither Department, however, is tempted to attribute blame for this situation to the higher education sector alone. In the Industry Department's view, "There needs to be a better understanding, within industry and the educational system and in the world at large, of the vital contribution of qualified scientists and qualified engineers to the national economy"[5]. And in the speech quoted above the Secretary of State for Education and Science stressed that the "status, career prospects, and the deployment of QSE's in industry" was an aspect of the problem as important as the nature of higher education courses and the teaching of science in the schools.

1 The Chemical Society's Standing Advisory Committee on Relations between Higher Education and Industry (QQ 1–41).

2 Third Report from the Expenditure Committee, Session 1973–74 (HC 96—I), para 80. Although we have gained a similar impression of industrial attitudes, we have not, as will be clear from this Report, reached the same conclusions.

3 To the Association of British Science Writers (14 June 1976).

4 Memorandum 23 (paras 33 and 35).

5 *ibid*, para 45.

Professional Engineers

3.19. It is also worth noting the attitudes of professional engineers towards the academic education and formal training which they received prior to entering their profession. In a survey carried out in 1975, the Council of Engineering Institutions asked professional engineers under the age of 40 (the large majority of whom are graduates) for an assessment of the quality and appropriateness of their education. 54·4 per cent were satisfied with their pre-graduation training, and only 42·4 per cent with their post-graduate training. The CEI comment that "neither of these figures can be considered satisfactory . . . attention should be given to ways of increasing the provision of suitable training, possibly by improved financial inducements"[1].

New Institutions in Higher Education

3.20. Concern about the higher education of scientists, and more particularly of engineers, is evident not only amongst the potential consumers of the products of the higher education system, but also amongst many of those involved in the operation of that system. During the last decade or so, a number of institutional changes have been implemented as a matter of national policy to seek to improve the supply of well-trained QSE's, attempts have been made by individual educational institutions to marry their courses to the needs of employers, and the Science Research Council has studied, and in some cases launched, new programmes for the encouragement of more industrially-oriented postgraduate education.

3.21. The two most important changes in the higher education structure effecting scientific and technical education have been the elevation of the former Colleges of Advanced Technology (CAT's) to independent university status, and the creation of the Polytechnics.

Technological universities

3.22. The elevation of the CAT's to university status was recommended by the Robbins Committee in 1963[2]. The CAT's had been created from 1956–57 onwards, largely growing out of existing local technical colleges of high standing. The Robbins Committee pointed out that the great majority of full-time CAT students were by then taking advanced courses, and noted the development of sandwich courses in connection with the Dip. Tech., which was "perhaps the most notable example of the orientation of the Colleges of Advanced Technology towards industry, a connexion which is proving of particular value". The Committee considered it "anomalous" that the CAT's did not have power to award their own degrees (a power granted immediately to the new universities), and thought that "the present powers and status of the colleges are not commensurate with the work they are now doing".

3.23. The Robbins Committee therefore recommended that the CAT's should in general become "technological universities". Although some might wish to merge with existing universities they pointed out that such a move might "lessen the present predominance of technology" and therefore thought that "the colleges are more likely to preserve the new look and the new approach to education on which they pride themselves if they develop independently".

accordingly granted independent university status, one (Cardiff) became a constituent part of the University of Wales and one (Chelsea) became a College of the University of London.

3.24. The Robbins Committee hoped that the new technological universities would retain "teaching and research in the sphere of technology" as their central feature, although this should not prevent developments in the area of pure science and "social and humane studies". They also wished to see an increase in the proportion of postgraduates from 4 per cent to 15 to 20 per cent. By December 1972 the average size of the nine ex-CAT's (excluding Chelsea) was about 2,800 full-time students (roughly the minimum recommended by Robbins) of whom 14 per cent were post-graduates. About 79 per cent of the full time undergraduates were studying science-based subjects, approx. one-third of whom were studying pure science as opposed to engineering and technology[1].

3.25. The Robbins Committee also recommended[2] the designation of five institutions as "Special Institutions for Scientific and Technological Education and Research" (SISTERS). Three of these were to be based on the Imperial College of Science and Technology, the Manchester College of Science and Technology and the Royal College of Science and Technology at Glasgow. A fourth was to be based on an existing CAT, and a fifth was to be a new foundation which "could experiment boldly, unfettered by existing affiliations either with universities or with further education". In practice the first three institutions were already heavily biassed towards technology, and have remained so, the Manchester College becoming the University of Manchester Institute of of Science and Technology, and the Glasgow College, amalgamated with the Glasgow College of Commerce, becoming Strathclyde University.

3.26. The purpose of these "special institutions" was to provide a "striking innovation" to demonstrate that Britain "is perpared to give to technology the prominence that the economic needs of the country will surely demand". Although the Government originally expressed sympathy with the concept of "SISTERS", the University Grants Committee opposed the development of such institutions on the grounds that it would impose rigid uniformity, would stifle growth elsewhere, and would "introduce unhealthy considerations of status and title into what should be conceived and planned as a coherent and balanced development of growing points in the university field as a whole"[3] The Government announced in 1965 that they had rejected the designation of any institutions as "SISTERS" because "they wish to prevent the false impression arising that a first-class technological education is only available in a small handful of institutions". They allocated a supplementary grant of £1 million over two years to Imperial College, UMIST and Strathclyde, and an additional £400,000 for the rest of the university sector[4]. Nothing further was heard of the "SISTERS".

3.27. The only other major change flowing from the Robbins Report was the creation of the Cranfield Institute of Technology out of the former College of Aeronautics at Cranfield. Cranfield, which now awards its own higher degrees

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1 *Statistics of Education* 1972 (Vol 6, Table 7).
2 Cmnd 2154, paras 383–8.
3 UGC, *University Development* 1962–67 (Cmnd 3820), para 225
4 *ibid*, paras. 226–8.

but is funded by the DES, not the UGC, is perhaps the single most successful outcome of the Robbins Committee's desire to improve higher education in engineering and the applied sciences.

Polytechnics

3.28. Not long after the creation of the technological universities, the Government announced, in May 1966[1], the designation of a number of new institutions in the further education sector as polytechnics. Like the CAT's[2], the polytechnics were to be based on existing further education colleges under local authority control, and although courses would be subject to approval on academic grounds by the the Council for National Academic Awards, and the broad lines of development laid down by DES directives, the polytechnics were to remain primarily under local control.

3.29. The thirty polytechnics in England and Wales have as yet an ambivalent and ill-defined role in the further and higher education structure. They perform not only the principal functions of the commercial and technical colleges which they replaced—providing local vocational and non-vocational courses of non-degree standard—but also functions in many ways similar to universities, with an increasing number of full-time and sandwich-based students reading for CNAA first degrees[3], and a developing postgraduate sector. In 1975 polytechnic students were spread roughly equally between science and technology subjects, business and social studies, and arts and vocational courses (Q 344 (1974–75)). They are now being further enlarged by amalgamations with Colleges of Education. The polytechnics therefore do not enjoy the independent status of universities, but perform many functions similar to those of the universities in addition to those functions which have traditionally belonged to the further education sector managed by local government. According to the former Chairman of the Committee of Directors of Polytechnics (Sir Alex Smith), these new institutions are intended to form "a strong, distinctive sector, complementary to the universities, conducting work which is comprehensive in range and character and which has closer, more direct relations with industry, business and the professions" (Q 343 (1974–75)).

Comments on the new institutions

3.30. Since 1963, therefore, eight new technological universities have been created in England and Wales, two "Institutes of Science and Technology" have been attached to universities in Manchester and Cardiff, and thirty polytechnics have been formed out of the remaining further education colleges[4]. None, however, are entirely new institutions.

3.31. The creation of all the new institutions was motivated, in part at least, by the desire to increase the quantity and quality of higher education in the applied sciences, engineering and technology, and other professional and vocational fields. It is perhaps still too early to assess the full impact of

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1 *A Plan for Polytechnics and other Colleges* (Cmnd 3006).

2 The CATs were in fact put on a direct-grant basis in 1962.

3 About half the polytechnic students in 1975 were CNAA undergraduates (Q 344 (1974–75)).

4 In Scotland the situation is somewhat different. Two Colleges (Glasgow and Heriot-Watt) achieved university status. The Scottish equivalent of the polytechnics are the "central institutions", first created in 1902, which are directly funded by the Scottish Office. They vary in

scientific and technological education at a standard equivalent to universities, as witnessed by their desire to expand their research and post-graduate activities while retaining their more practical, commercial and industrial orientation[1]. It is also encouraging that some large employers, such as EMI, appreciate the "attractive alternative" offered by the polytechnics in terms of industrially-oriented syllabi and work-related training (p. 176, Q524).

3.32. So far as the ex-CAT's are concerned, there is little doubt that they have profited as institutions by the acquisition of independent university status and the relative freedom to innovate and experiment which that status grants them. They have largely succeeded in retaining their emphasis on applied science and technology, while at the same time expanding in other socially-relevant fields such as business and social studies, town and country planning and modern languages. They have also succeeded in sustaining within the university system the principle of the sandwich-course, which was formerly regarded as the characteristic of the less academic further education sector. It is important to add however, that as Table 3 below indicates, there has been no widespread adoption of sandwich courses in other universities, and no increase in sandwich course numbers in the ex-CAT's during the 1970's.

TABLE 3

NUMBERS OF SCIENCE AND TECHNOLOGY UNDERGRADUATE SANDWICH COURSE STUDENTS IN UNIVERSITIES IN ENGLAND AND WALES IN 1971 AND 1974

University	At 31 December 1971	At 31 December 1974
Aston	1,226	1,085
Bath	718	1,266
Bradford	1,843	1,831
Brunel	1,255	1,293
City	1,132	793
Loughborough	1,452	1,494
Salford	1,418	959
Surrey	1,158	1,279
UWIST	555	470
All ex-CAT's	10,757	10,470
Other universities	147	177
Total in England and Wales	10,904	10,647

Notes: (1) Includes students in subject groups 2 (Medicine etc), 3 (Engineering etc), 4 (Agriculture etc) and 5 (Science).

(2) There were no sandwich courses in universities in Scotland and Northern Ireland.

(3) Compiled from information supplied by the University Grants Committee. No information is available for years prior to 1971.

3.33. Despite some successes, and despite the tremendous effort and upheaval —and not inconsiderable cost—of reorganisation, the new institutions have not prevented the development of a situation in which the quality of the scientific and technical manpower going into industry is under fire, and the output

[1] See eg evidence from the Committee of Directors of Polytechnics (QQ 343–390 (1974–75)), and Memoranda from the Committee of Heads of Polytechnic Chemistry Departments and the Association of Polytechnic Teachers (Appendices 93 and 94, 1974–75).

of such manpower has failed to keep pace with the graduate output in traditional university disciplines.

3.34. The reasons for this paradox are admittedly complex, and in the following chapter we discuss, amongst other things, the career factors which may deter students—and particularly the better able—from studying science and technology in the first place, and from seeking industrial employment if they do. But in our view the nature of the institutional reorganisation which has taken place has not been entirely conducive to the achievement of a higher output of scientific and technical manpower of an acceptable standard.

3.35. Throughout the post-war era, educational policy at national level has reflected an ambivalence towards the aims and philosophy of higher education which has done much to undermine the good intentions which underlay the reforms in technological education outlined above. At least since the Report of the Barlow Committee[1] in 1946, an improvement in the supply of trained engineers and technologists has been an accepted aim of government, and the university sector has been expected to play a role in achieving that aim. Such an ambition implies an obligation on the universities not only to provide more students with a higher education but to fulfill output norms, however vaguely defined, in the form of graduates with a higher education of a particular kind. Although detailed manpower planning is generally eschewed (with the notable exceptions of medical and teacher training) there is an overall obligation, which unfortunately is not fully accepted by some of the universities themselves, to relate their educational services to " social and economic needs ", and that was clearly one of the factors in creating universities of a " technological " character.

3.36. On the other hand, as we noted in our first Report in 1975[2], the financing of the universities is largely determined in response to student demand and the notion of encouraging, let alone directing, students into one field rather than another is anathema. We have already indicated[3] that we accept the principle that there should be no direction of individuals into particular courses. But the aim of providing a particular pattern of technical manpower must always be in conflict with freedom of choice.

3.37. This conflict was exacerbated in the 1960's by the parallel development of the technological universities and the other " new universities ". The latter institutions were in the process of creation before the publication of the Robbins Report. A considerable amount of political and financial capital was invested in them, and they offered the multiple attractions of the excitement of entirely new institutions, architect-designed buildings and green-fields campuses. They also offered the intellectual excitement of a new approach to higher education which, through novel multi-disciplinary courses, appeared to provide a refreshing alternative to the rather humdrum specialisation of sixth-forms and most of the existing universities. Academics of high standing flocked to the University of Sussex, which rapidly became one of the most popular first choices for university applicants. And while Sussex, with its ease of access to London and the Home Counties and the prestige of Sir Basil Spence's buildings, was in a rather special position, much the same

[1] *Scientific Manpower* (Cmd 6824, 1946).

In fact, of course, the new universities were if anything an idealisation of the traditional 'humane' university. They embodied in an extreme form the principle of freedom of choice cherished by the traditional universities; and although, because they were popular, they demanded high entry standards, they also imposed fewer specific entry qualifications.

3.38. The truly 'new' universities were the old Colleges of Advanced Technology, and they could not compete. They grew out of existing institutions and were initially housed in old and unsuitable buildings on city-centre sites. Because they were built on existing institutions, they did not have the freedom to develop from scratch the new teams of young high-calibre academics which were attracted to Sussex or to Warwick. New degree students were obliged to rub shoulders with HND students who started life as industrial apprentices. They offered courses which, superficially at least, sounded all too similar to the applied science courses available in the redbrick universities. They could not offer the intellectual and social glamour of the other new institutions. And before they had been in existence for long, and had time to make the radical contribution expected of them, governments were already looking for new ways of achieving the aims which the technological universities had been intended to serve.

3.39. In our opinion the transformation of the CAT's into universities, and the present tendency of the polytechnics to seek 'parity' with the universities, reflect the distressing British habit of attempting to bestow status and prestige on institutions and individuals by changing their names rather than by encouraging them to do well the things for which they are best suited. In much the same way as the teacher training colleges enthusiastically pursued in the 1960's their ambition to bestow a qualification with the magic title of 'degree' on their students in the hope that this would somehow improve their status in society, so the CAT's became universities, and the technical colleges became polytechnics.

In the opinion of the Group Chief Engineer of Lucas Industries,

> "The polytechnics (thank God!) are still producing some technicians, but, unfortunately, they are tending to go the way of the CAT's and turning themselves into yet another set of univerities producing yet more graduates. What we are getting desperately short of. . . is the necessary supporting staff to back up the graduates, and a bad graduate is no substitute for a good technician. It is like having a hospital manned entirely by doctors and no nurses" (Q 810).

The elevation of the CAT's was well-intentioned, but the effect in our view has been to convert them from potentially excellent specialist colleges of technology into universities with a technological bias which are regarded by many traditional academics as second-rate. The university system has extended its aristocratic embrace and has attempted to eliminate a potential threat to its traditional freedom and independence by turning that threat into an asset to be deployed in defence of the freedom of universities from direct state control.

3.40. While we accept that it was necessary to give the CAT's the power of self-government if they were to be free to develop, we do not believe that it was necessary to rebuild them in the image of the institutions which were regarded as having failed to provide the manpower which the nation required.

3.41. The reported comments of several of the first generation of Vice-Chancellors of the technological universities and institutions, many of whom have retired during the last year, indicate the sense of frustration which they have felt in carrying out their tasks. Professor Elfyn Richards, the first Vice-Chancellor of the Loughborough University of Technology, reflected this frustration in an interview with the *Times Higher Education Supplement* last year[1]. Professor Richards believed that the ex-CAT's had never had the public recognition which they deserved. He summarised their history as follows:—

> "In 1950, the government said it would provide extra money to build up technology in the universities, but many of them said 'Oh no, we are not going to get out of balance, technology must not dominate the situation'. The government therefore established the colleges of advanced technology just when the universities were really getting into their stride in technology, and that created competition for places."

> "With another change of government it was decided that the universities still were not doing their stuff: the ex-CATs had become universities in accord with Robbins in the meantime and ceased to be appreciated. The government therefore decided to formulate still another kind of body from those which had not become CATs and these were to become polytechnics."

Professor Richards regarded the creation of the polytechnics as a "thoroughly bad idea", partly because "by emphasizing university equivalence they are going to expand the grave middle-level sparsity of effort . . . In any teaching system, the teachers will always want to teach the top level". He believed that "the ex-CATs were doing well and could have been expanded cheaply to deal with any shortage of places for engineering students. He thought, however, that university status had been good for the CAT's because it was easier to take the initiative in the "private sector" of education.

3.42 Lord Bowden, the retiring Principal of UMIST, told the Science Sub-Committee that although UMIST had expanded and had "much to be thankful for in the provision of new buildings and equipment", he had come to realise "that we have not, in fact, fulfilled the ambitions with which we began thirty years ago. We are eating Dead Sea fruit and very bitter it is". It was "only too clear that Englishmen no longer want to study those disciplines which would fit them for a career in productive industry". He thought that the most important reason was the lack of prospects of a "reasonable career in industry". But he also regarded as significant the views of Midlands headmasters on the status of industry in society, and "the contempt with which society at large so obviously regards those who create the wealth which everyone wants to spend" (pp 278–9).

34. In the Committee's view these status considerations are of importance, and the attempt to solve them by placing applied engineering and technology education in the university system appears, in retrospect, to have been misguided. **We believe that it is regrettable that more effort was not made to establish a parallel system of technical institutes or colleges, excellent in their own right, offering potential students and staff the excitement of an entirely new concept (for Britain) in higher education, and untrammelled by the accumulated**

would have been funded by government according to somewhat different criteria and would have espoused different, but no less excellent aims. We also believe that the designation of "SISTERS" and the creation of at least one entirely new institution might have done much to concentrate public interest and to popularise the concept and enhance the status of such a new higher education sector. We recognise that the clock cannot be put back, but such considerations have been in our minds when formulating recommendations about the future of applied science and engineering education, set out later in this Chapter.

New Initiatives in Education

3.44. We noted above (paragraph 3.2) that there has been a modest growth in the output of new science and engineering first degree graduates from the universities, although it has been far less considerable than the growth in other subjects. It was also clear from much of the evidence taken from universities in 1975 that there was an appreciation of the need to relate undergraduate education, particularly in the engineering and technology areas, to industrial practice and some attempts to achieve this were being made.

3.45. We also acknowledge, as the Nuffield Foundation, amongst others, have suggested that we should[2], the important contribution which many university engineering departments have made both to the advancement of engineering science and to the education of graduate engineering scientists. Representatives of the principal technological departments at the University of Cambridge told us that

> "We aim to teach mainly basic principles and we recognise that our graduates need several years in industry to develop their full potential. We are convinced that any attempt to produce in three years a 'ready-to-use' technologist can only provide graduates with limited horizons" (p 74).

We believe that that view would be shared by many engineering departments in universities and we acknowledge that within the confines of a three-year undergraduate course it may well be better to concentrate on fundamentals.

3.46. Given the limited possibilities of the three-year undergraduate course, however, the nature of the postgraduate education available to British graduates is of added importance. As Professor A W J Chisholm of the University of Salford has pointed out in a valuable comparison of engineering training methods in Britain and Europe[3], the practice in the best continental engineering schools is to concentrate first on the foundations of engineering practice. In Germany, according to Professor Chisholm this change is "analogous to the way that medical courses distinguish between pre-clinical and clinical studies", and the courses are necessarily longer than the British undergraduate course. The analogy with pre-clinical and clinical medical studies in the training of engineers and scientists destined for industrial employment is in our view a

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[1] We note that according to the Vice-Chancellor of the Cranfield Institute of Technology, that Institute was so-named because "there was a general feeling that the former Colleges of Advanced Technology in becoming universities had failed to produce new styles of university education appropriate to technological industry, and there was a general interest in a new title which would give greater scope to these new styles". We also note his view that direct funding by DES in no way inhibits Cranfield's activities (Memorandum 41, Annex).

[2] Memorandum 30.

[3] Memorandum 44.

fruitful one. It is a concept which enters increasingly into the discussion of reforms of the postgraduate system and is to some extent embodied in the idea of the "Teaching Company", which we discuss below.

Existing SRC schemes

3.47. The Science Research Council (SRC) is the chief source of support for British postgraduate students in engineering and the natural sciences. Its support is provided in the form of academic fees and maintenance grants for the students and a small "bench fee" for their departments to help to cover the additional research costs invoved in training the students. SRC studentships are generally either Research Studentships, usually lasting for three years and leading to a PhD, or Advanced Course Studentships, usually lasting one year and leading to a Master's degree (p 23). For the most part studentships are allocated to university and polytechnic departments by the SRC Boards and Committees, who "use their knowledge of the quality and extent of the research and training in the different schools and departments". Advanced Courses have to be accepted as suitable before SRC studentships are allocated. Awards not taken up by the end of July in each year (usually about 10 per cent) are returned to a pool and allocated direct to individual appellants (Evidence (1974-75) p 317).

3.48. During the 1970's there was a small decline in the total number of studentships awarded by the SRC, mainly accounted for by a decline in applications in engineering and for advanced course studentships, with result that in 1973, for instance, the SRC were able to give awards to all qualified applicants[1]. In 1975 there was a slight upturn in engineering, and the SRC awarded 1,462 engineering studentships (approx. 40 per cent of the total), equally divided between advanced courses and research.

3.49. In adition to the usual awards described above, three new schemes have been "superimposed", in an attempt "to broaden the nature of a research student's training, and to increase the relevance of this training to the student's subsequent employment". They are

(*a*) *the CASE scheme:* Co-operative Awards in Science and Engineering[2] are awarded to research students undertaking projects jointly formulated by an academic department and an outside organisation. The outside body provides a minimum of resources in cash and kind and allows the student to work on site for at least three months during the three years of the award. The scheme aims to produce greater academic-industrial collaboration, but there is no financial incentive for the student, who receives only the standard studentship;

(*b*) *Industrial studentships,* whereby the SRC pay the usual grant to an employer, who releases an employee to undertake a research or advanced course degree course at his normal salary. This scheme reduces the cost of secondment to both employer and employee; and

(*c*) *Total Technology awards:* under this scheme the SRC provides awards for PhD students to pursue a research project on an industrial theme, supplemented by group activities such as design projects and lecture marketing and industrial relations. In 1975 seven approved Total Technology schemes were operating at the Cranfield Institute of Technology, Sheffield Polytechnic, and the Universities of Aston, Lancaster, Loughborough, and Strathclyde, in subjects such as production engineering, industrial metallurgy, and marine engineering (p 23-4).

3.50. Not all these schemes have been as popular as might be expected. In 1974, the SRC approved 309 CASE projects, but only 162 awards were taken up. In the same year Total Technology awards represented only 2 per cent of the total new research studentships in engineering, and new industrial studentships declined marginally to 262, compared with 269 in 1973.

3.51. During the last eighteen months the Science Sub-Committee have received numerous comments on the above schemes from university and industrial representatives. On the whole these comments have been sympathetic to the schemes in principle, but sometimes doubtful about their effectiveness. This applies in particular to the CASE scheme, the Total Technology scheme being regarded as somewhat too recent to admit detailed appraisal (Q 803).

3.52. The UDIL Group[1] regard CASE awards as providing "one of the most effective ways for ensuring that academic-industrial collaboration increases" and comment that "the value of this collaboration probably greatly exceeds that which might be expected from the low percentage (1 per cent) of all SRC student time since the student and his university and industrial supervisors are all committed to the success of the project". On the other hand, Professor Sir Brian Pippard, of the Cavendish Laboratory, thought that the scheme could lead to "complacency on the part of the industry and the university concerned—the belief that they are making contact with one another by this and doing nothing at all to cement that contact". He also thought that if a department had too many of these awards there was a danger of "your whole research effort becoming fragmented and subject too much to the whims of the individual industries". He hoped that the CASE scheme would become unnecessary as more permanent developments took effect (Q 212). Critics of the scheme amongst members of the Standing Conference of Professor of Physics referred to "too many failures springing from loss of interest by the firm involved", but welcomed as encouraging those cases where "enterprising departments, considered by the SRC as not reserving even a single quota studentship, have established successful research programmes with the aid of CASE awards".[2]

3.53. The Nuffield Foundation believed that the CASE scheme had "not been a success", because the numbers involved have been too small and the scheme is funded on the misconceived belief "that industrial employment would be more attractive for university graduates if the prestige of a PhD qualification were accessible to them".[3] The Vice-Chancellor of the University of Bradford believed that whatever its merits the scheme was "faltering through lack of sufficiently positive support from all three sides and insufficient planning".[4]

1 University Directors of Industrial Liaison (Memorandum 34).
2 Memorandum 2.
3 Memorandum 30.
4 Appendix 7 (1974–75).

3.54. In addition to the SRC schemes described above a number of other initiatives in this field should be mentioned. The SRC themselves have collaborated with the Social Science Research Council (SSRC) in a modest scheme to develop postgraduate training in cross-disciplinary areas of interest to both Councils. The programme has been handled by a joint SRC/SSRC Committee, initially established in the wake of the Swann Report in 1968[1], and the number of studentships awarded by them increased slowly over the years to 1974, when a total of 119 studentships were awarded, divided equally between research and advanced course studentships, and involving 29 different approved schemes and courses at a wide variety of universities. The joint Committee urged a further enlargement of this scheme in their recent Second Report,[2] which we discuss below.

3.55. Similarly, the University Grants Committee devoted considerable sums of money between 1967 and 1973 to provide " pump priming " grants for specific projects, including teaching programmes, aimed at providing collaboration with industry. The Final Report on this scheme, which was terminated in December 1973 because of financial shortages, is annexed to the UGC's Memorandum on University-Industry Collaboration (Memorandum 5). Of the 58 projects supported, 46 were regarded as " wholly or partially successful ", and it was the Sub-Committee's impression in taking evidence from the universities last year that there was considerable support for the scheme and disappointment that it had been abandoned. Many of the schemes supported were for short post-experience programmes for graduates already in industry, provided on a fee-paying basis. It is important to note that although the " pump priming " scheme is now in abeyance, many universities continue to organise courses of this kind, some with notable success, as at the Cranfield Institute of Technology.

3.56. It is clear to the Committee that the initiatives by the SRC and other bodies described above have all contributed in a constructive manner to the development of broader postgraduate studies and industry-related courses. Although the Committee, like the SRC, recognise that more positive initiatives are now needed in this field, they believe that the organisations responsible, including many individual universities, deserve congratulations on the progress already made. Many of the programmes have been of an experimental nature, and there have inevitably been some failures. Experimentation in solving these very difficult educational problems has been necessary, and will continue to be necessary, if more substantial efforts are to be based on experience, rather than on mere hunch. Accordingly, whatever new and more ambitious proposals may be adopted, we see no reason why the existing programmes should not continue and develop as appropriate to meet specific needs.

New SRC proposals

3.57. During 1975, three Reports were published by the Science Research Council containing proposals for reforms in the organisation and methods of postgraduate education in the sciences and engineering. The Science Sub-Committee have discussed these Reports with a number of witnesses and received written views from several other individuals and groups.

3.58. We referred above (paragraph 3.54) to the joint SRC/SSRC programme of postgraduate studentships for cross-disciplinary courses and research. In their Second Report[1] the joint Committee administering this programme describe the various experimental schemes which they have supported as "exercises in the solution of problems arising in industry and government which require judgments based on the blending of information from science and technology with information from other disciplines". They say that "in some centres clear patterns of training are emerging" in cross-disciplinary areas, and note that the courses provided attract students of high quality who subsequently have no difficulty in obtaining appropriate jobs, "despite the conservatism of some employers". They nonetheless point out the difficulties in developing cross-disciplinary courses, particularly those arising from the novelty of the subjects and the resulting absence of a "codified body of knowledge or even recognised channels of communication for research results", the lack of defined career structures for teachers in interdisciplinary fields, and the reliance which has to be placed on teachers from established disciplines, who are unable to offer prime loyalty to cross-disciplinary studies".

3.59. The joint Committee believe that they should now be empowered to grant not only studentships but also grants to departments for research assistance, administration, travel and the preparation of postgraduate teaching material. They recommend the introduction of fellowships for teachers who need to re-train themselves for interdisciplinary work, and of "package deals" for institutions wishing to set up new interdisciplinary postgraduate courses. Finally, they recommend a three-fold increase in studentships awarded to about 400 in 1980, which would represent $6\frac{1}{2}$ per cent of total SRC and SSRC studentships in that year.

3.60. Although there has been a general welcome for courses of this kind, we believe that the inherent difficulties in interdisciplinary teaching to which the SRC/SSRC Report refers are such as to counsel caution against any very rapid build-up in the number of studentships until sufficient action has been taken to ensure an adequate supply of teachers qualified to supervise the students concerned. Accordingly, we recommend that priority in the further development of the programme should be given to the provision of research grants and re-training fellowships in order to assist the establishment of centres to which increasing numbers of postgraduate students may be naturally attracted in the longer term. For similar reasons it would appear to us to be sensible to restrict the number of centres where such projects are being developed to a number small enough to concentrate the available academic expertise in groups of a viable size. It might well be a waste of resources to spread too thinly the modest sum of £1 million per annum which the programme is expected to cost.

The Edwards Report

3.61. We gave a warm welcome in our last Report[2] to the Report of the SRC Working Party on *Postgraduate Training*, chaired by Sir Sam Edwards[3], whose principal recommendations were

(1) that there was a need to provide courses up to doctoral level of the quality and intensity of those provided at the Massachusetts Institute of

[1] SRC/SSRC, *op cit*.
[2] HC 87 (Session 1975–76) paras 29–31.
[3] SRC, *Postgraduate training*, September 1975.

Technology for scientists and engineers whose subsequent careers would be in management and other activities outside research;

(2) that there was a similar need to provide a formal teaching structure beyond the first degree even for those postgraduates who were primarily destined for careers in research, in order to overcome the tendency towards over specialisation, and accordingly that a Master's degree based primarily on compulsory course work during the first postgraduate year should eventually become a prerequisite for admission to a research-based PhD training;

(3) that in order to achieve these aims there should be a greater concentration of staff and facilities in regional consortia of universities in collaboration with non-university scientific and technological bodies and the business schools;

(4) that a new qualification at doctoral level, possibly called a Doctorate of Technological Studies, should replace the traditional PhD for postgraduates pursuing training for careers outside research; and

(5) that the SRC should be able to offer postgraduate studentships at a substantially higher value for students in areas of economic importance, and that students should be able to earn modest additional sums from collaborating bodies without deductions from their SRC grants.

3.62. Many of the criticisms which we have received of the Edwards Report are aimed at the Working Party's use of MIT as a model for their own proposals. Several critics have pointed out that American postgraduates need further formal instruction after graduation simply because of the comparatively low standard of American first degrees. According to the Nuffield Foundation, for instance, "'Taught courses' are a necessary means by which American graduates may be given the specialised knowledge necessary for a career in research. In Britain the corresponding need is for an element of more general education, especially for those intending to—or destined to—follow careers outside the higher education system" (Memorandum 30). Similarly, Professor R M S Smellie, of the University of Glasgow, points out that in many instances in the UK "the level of understanding attained by students in undergraduate courses is considerably higher than the level of attainment of comparable students in undergraduate courses in the United States. It is partly for this reason that the United States system of postgraduate education contains a substantial amount of broadly-based course work" (Memorandum 20). Sir Brian Pippard thought the MIT system was not one to be emulated because "the students are taught too much before they get their hands dirty" (Q 213).

3.63. These criticisms may result largely from a certain ambiguity in the Edwards Report as to the nature of the taught courses to be provided for students intending to read for research-based PhD's and we think it might be helpful if the SRC Working Party were to spell out in more detail precisely what they intend in this area. Our own interpretation is that the "broadly based compulsory course work" proposed in paragraph 34 of their Report is intended not only to continue to postgraduate level the formal teaching of the flow of primarily specialised postgraduates is maintained (see, eg, Q 40). We do not believe that the Edwards Report is seeking to undermine the ability of the universities to produce first-rate specialists and we are confident that the universities would not allow that to happen.

The Teaching Company

3.64. The third SRC Report was produced by a joint working party of the SRC and the Department of Industry[1]. Arguing from the premise that " British manufacturing industry is not getting the qualified engineers it must have to maintain its historically strong position in world markets ", The Report proposes that " selected well-managed and successful manufacturing firms should, in partnership with university and polytechnic departments, become ' teaching companies ' ". Three pilot schemes have already been launched (Q 964).

3.65. This scheme appears to be an attempt to recreate by artificial methods the kind of practical postgraduate training for engineers which existed before World War II at the Metropolitan Vickers Research Department at Trafford Park or at Rolls Royce in Derby, the demise of which is regarded by Lord Bowden as " the greatest disaster that has befallen education in England during my lifetime " (p 279). In those cases, however, the companies concerned were carrying out training functions for their own purposes, and in one version of the " teaching company " idea the company concerned would be one " doing a normal job of training for its own purposes but which is publicly funded in order to train more people than it really needs so that it can do a good job of training people for other companies as well " (Q 801).

3.66. The SRC/DoI proposals are, however, more academically-based: " The departments that teach and do research in manufacturing engineering have no systematic access to their material; it is as if English departments had no libraries, or medical departments no teaching hospitals "[2]. The principal analogy is with the teaching hospital. Young postgraduate engineers (and other graduates) would " take an active and direct part in an integrated programme of company development "; their research would be supervised in the company by academic staff in partnership with company staff; and their research would be complemented by instruction in the university or polytechnic forming the " home " institution. A majority of the Working Party recommended that the trainee should be paid a realistic salary, instead of a maintenance grant.

3.67. These proposals go a long way towards meeting the arguments of those, like the Nuffield Foundation, who believe that the first degree should be regarded as an opportunity for broader more generalist education, and that the notion of postgraduate vocational training should be extended to a much wider range of disciplines and careers.

3.68. We believe that there is great potential merit in the idea of the teaching company. We share the concern of the Director of the Cranfield Unit for Precision Engineering that the present progress with small pilot schemes " is insufficient to make a significant impact on industry in the next five to ten years "[3]. **We therefore hope that, although the Department of Industry at**

[1] SRC/DoI, *The Teaching Company* (December 1975).
[2] Para 4.
[3] Memorandum 41 (Annex).

present regard the scheme as an experiment (Q 966), they will be prepared to back it more extensively as quickly as possible, particularly in view of the fact that they "already have a short queue of quite eminent companies that are anxious to join in and strong indications of a very much longer queue outside the door" (Q 964). There can be little doubt that if the scheme can attract companies with positive enthusiasm to join in it is already a long way down the road to success.

3.69. All the existing and proposed schemes outlined above have in common the aim of broadening the base of postgraduate studies in science and engineering and are generally welcomed by the Committee. We believe in particular that the SRC proposals for the establishment of regional consortia for postgraduate studies, and the SRC/DI proposals concerning the Teaching Company, could, if developed with vigour, produce significant and beneficial changes in the orientation of postgraduate studies. Both schemes imply the development of specialised centres with some of the characteristics of the Special Institutions proposed by the Robbins Committee.

3.70. **If any of these proposals are to make more than a marginal impact on the output of postgraduate engineers and scientists, they will require more than marginal injections of capital into the higher education structure.** Throughout this inquiry we have been loth to propose changes which would involve unrealistic expenditure increases. **We nonetheless believe that substantial funds will be required to enable these schemes to be launched at the required pace, and therefore recommend that sufficient earmarked funds be allocated to the SRC and the UGC to launch them immediately, at the expense, if necessary, of other desirable but less pressing demands on the higher education sector. The principle of equal sacrifices, however attractive it may be to the Treasury, should not be allowed to impede developments which are crucial to the future industrial health of the nation.** Just as the Government have been prepared to increase the flow of funds into industrial development in the latest Expenditure White Paper, so they should be prepared significantly to increase their support for the training of the next generation of industrial managers. **So far as the Teaching Company is concerned, we believe that there would be merit in cementing co-operation between the Industry Department and the SRC by carrying a substantial proportion of the costs on the Industry Department Vote.**

Departmental proposals

3.71. We were impressed by the degree of concern expressed by both the Secretary of State for Industry and the former Secretary of State for Education and Science, about the relative decline in student numbers in certain science and technology areas, the decline in student quality, and the difficulty of filling some industrial posts requiring graduate qualifications.

3.72. The opinion of both Ministers appears to be that the primary causes of these developments relate to the image and status of industry and hence of those scientific and technical subjects which are regarded as a preparation for industrial employment. According to the then Secretary of State for Education and Science, of industry has been, on the whole, something that is not greatly admired. . . . In ways that we can we are trying to help, but it is much wider than any Government Department, or the Government itself; it is a question of attitudes " (Q 880).

These views were echoed in evidence by the Secretary of State for Industry, who ascribed the unattractiveness of industry not only to relatively poor salaries, but to the attitude of students to industry, " the image of industry, the structure of the profession and also the status of scientists and technologists within the community " (Q 957).

3.73. We welcome the fact that the Industry Department, as consumers—at least as proxies—of the technical and scientific output of the educational system, are turning their minds to the consideration of changes in that system which may help to improve the situation. They note in their Memorandum Memorandum 23) a number of collaborative schemes in which they are involved to improve liaison between schools and industry, but note that there is a need for more attention to be paid to improving the availability of " school teachers and careers advisers with enough knowledge of industry and technology to use the material provided effectively ". Apart from their participation in the Teaching Company scheme, the Industry Department also canvass a number of proposals worth considering to improve the situation in the higher education sector, including

> " consideration of the case for fewer first-degree places, perhaps coupled with some courses on a 4-year basis to increase breadth and include vocational elements . . . assessment of the value of HNC courses compared with degrees for people who will become employed as technicians . . . the provision of financial incentives for first-degree students on courses of particular relevance to industrial competitiveness and to the economy ".

Not all these proposals may be as attractive as they seem at first sight: we believe, for instance, that the doubts raised by the Institution of Mechanical Engineers about four-year degree courses deserve careful study[1]. But we are encouraged that the Department of Industry recognise their own responsibilities in this field and have not been constrained by considerations of inter-departmental solidarity from discussing their views in public.

3.74. On the other hand we were not convinced, from the evidence available to us, that the Department of Education and Science are as yet adopting a sufficiently vigorous approach to the solution of problems which they acknowledge to be of great seriousness. The evidence given by the then Secretary of State and his officials, while emphasising their concern, revealed very few concrete proposals for reforms. We understand their reluctance to interfere too directly in the work of agencies, such as the UGC and the Research Councils, which have been set up to distribute funds to the higher education sector, but their attitude is far too passive. If they believe, as they claim, that the situation is serious, they should be prepared to take the initiative by indicating

[1] The IME say: " Given the current poor image of the engineer in schools, the fact that he is paid far less than his contemporaries in other EEC countries, his relatively poor chance of reaching top management, it is questionable whether the more able sixth former is likely to go for a four year degree, when he can see that the rewards are much greater from a three year course in a non-scientific discipline " (Memorandum 45).

clear guidelines to assist such agencies in developing policies aimed at improving the situation. The Secretary of State believed that it might not be "thought to be within the rules of the game" for him to give precise directions to the UGC (Q 861). Similarly he thought that "you do not get together a very distinguished body of people willing to serve on a science research council or medical research council, or whatever, and then try to tell them from Whitehall how they ought to go about their job" (Q 864). As we understand the situation, these are all bodies acting as agents of the Government in distributing funds to higher education. They should of course be allowed freedom of action, but that does not absolve the Secretary of State from the responsibility for proposing measures to alleviate particularly critical problems when they arise. While this may not involve giving detailed instructions, it does require greater determination on the part of the Secretary of State. We believe that a more vigorous approach would be welcomed by the UGC and the SRC, whose efforts to improve matters in the higher education sector do not seem to have received the degree of political support which they need. **It is to be hoped that the Prime Minister's recent initiative will lead to a greater pre-occupation with the scientific aspects of her job on the part of the new Secretary of State than was evident in the performance of most of her recent predecessors.**

The Engineering Institutions

3.75. The Committee are aware of the important role performed by the fifteen institutions which comprise the Council of Engineering Institutions in the education and examination of engineers and in the recognition of academic qualifications for the purposes of professional registration. We have not examined this role because we have been primarily concerned with the work of the universities. We share the increasingly prevalent view that there may now be a need for an inquiry into the work of the engineering institutions, including their educational functions. However, in view of the fact that the great majority of professional engineers now obtain their basic qualifications through the higher education system[1], the need for close collaboration between the institutions and the universities and polytechnics in determining the basic ingredients of undergraduate and postgraduate engineering studies is self-evident. **We therefore recommend that, pending the outcome of any inquiry which may be established, the universities and polytechnics and the engineering institutions should examine methods of achieving greater collaboration in the control of standards and the content of courses for first and higher degree students.**

Conclusion

3.76. The Committee share the concern of our witnesses about the apparent shortcomings of the higher education system in supplying qualified scientific and technical manpower to industry in the right quantity and the right quality and with training relevant to industrial needs. We welcome the many schemes which have been or are proposed to be implemented to seek to solve some of these shortcomings. We nonetheless recognise that changes in educational practice cannot in themselves provide a complete answer. In the ment of qualified scientists and engineers which may also need to be resolved.

Recommendations

3.77. **The training of engineers and applied scientists suitable for employment in productive industry should be given much higher priority in the Government's educational policy.** This applies not only to graduate and postgraduate training, but also to the training of technicians and designers at the HNC and HND level.

3.78. **The concept of SISTERS (" Special Institutions for Scientific and Technological Education and Research ") should be revived and implemented.** A number of university institutions should be designated as SISTERS. These are likely to include the Imperial College of Science and Technology, the University of Manchester Institute of Science and Technology, and the University of Strathclyde, and some of the former Colleges of Advanced Technology. Consideration should also be given to the separation of the engineering and applied science departments at the University of Cambridge and their designation as a SISTER to ensure that the high status of SISTERS is recognised by the academic community at large.

3.79. SISTERS should continue to be regarded as university institutes, but should be issued with revised Charters limiting their functions to training and research in engineering and applied sciences.

3.80. The University Grants Committee should be instructed by the Secretary of State for Education and Science to regard engineering and applied science training as a privileged area in which, in particular, the normal staff: student ratios should not be expected to apply. **Additional earmarked funds should be supplied to the UGC for the support of technological education, and in particular for the development of facilities in the Special Institutions.**

3.81. New degree qualifications in applied science and engineering subjects should be introduced in the Special Institutions and in conventional universities offering courses in those subjects: we suggest that they might be described as BEn, MEn, and DEn.

3.82. **The content and form of undergraduate courses in engineering should be the subject of a thorough and urgent review.**

3.83. **Employers and universities should be encouraged to give greater support to sandwich-courses for undergraduates in science and, in particular, in engineering subjects.** Sandwich courses should become a normal feature of undergraduate studies in the new Special Institutions, but should also be adopted for appropriate subjects in other universities.

3.84. **The proposals of the Science Research Council for improvements in the training of postgraduates should be pursued with vigour. In particular the Department of Industry should be prepared to commit their own funds to the development of " teaching companies ".**

3.85. **Serious consideration should now be given to the introduction of higher maintenance grants for students, at both undergraduate and postgraduate levels, in the applied sciences and engineering.** In principle the Committee believe that **such higher grants might be provided in the form of supplementary bursaries distributed according to criteria laid down by the Department of Industry, and from that Department's Vote.**

3.86. In order to ensure that due attention is paid to these problems in the Department of Education and Science **the Committee recommend that a Minister of State should be appointed within the Department with special responsibility for Science and Technology.** His principal concerns should be with the activities funded from the Science Budget, and with scientific and technical education at all levels of the educational system.

Employment Trends

In manufacturing industry

4.1. Recent overall trends in the employment of QSE's in manufacturing industry are summarised in the Memorandum submitted to us by the Department of Industry[1]. Between 1961 and 1971 the number of QSE's employed in manufacturing industry rose from 94,000 (64,000 engineers and technologists and 30,000 scientists) to 139,000 (88,400 engineers and technologists and 50,300 scientists). During the same period the supply of new graduate engineers and technologists rose from 2,800 to 6,700, but the proportion entering industry and commerce declined from 84 per cent to 65 per cent. The supply of new science graduates rose from 3,800 to 7,700, and the proportion entering industry and commerce fell from 55 per cent to 44 per cent[2].

4.2. The Department of Industry believe that 1971 marked a low point for scientists and engineers generally and that there has since been some increase in the numbers entering industry and commerce. They nevertheless point out that the supply of engineering and technology graduates remained constant between 1971 and 1974, whereas the supply of graduates in all subjects increased by 11 per cent[3].

4.3. At the non-graduate level, the Department conclude that there has been a fall of 23,000 (approximately 46 per cent) in the annual rate of enrolment for HNC and HND courses in engineering and technology between 1965 and 1973 and "a substantial fall-off in apprentices, particularly in the private sector". Even though the Department say that "an increasing number of graduates are taking jobs hitherto filled by technicians with HNC and similar qualifications" (which explains the very low rate of unemployment amongst graduate engineers), the increase in the supply of graduates goes no way towards making up the very large fall in the supply of HNC and HND engineers.

4.4. The Industry Department note that "the overall proportion of QSE's in industry in relation to the number of employees is significantly lower in the UK than amongst our competitors", and, in view of the decline in numbers and quality of QSE's and supporting staff in manufacturing industry, they suggested that "action may be necessary to improve the position"[4].

Research and Management

4.5. The Department of Industry also provided some information about the balance of employment of QSE's in industry between R & D functions, on the one hand, and management functions on the other hand. They asserted that "the proportion of QSE's in R & D to other QSE's is much higher in the UK than elsewhere". They referred to a survey of 576 top companies in Britain, France, West Germany, Italy, Belgium and the Netherlands in 1969, which showed that "**only 40 per cent of Britain's top executives had a**

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1 Memorandum 23.
2 *ibid*, para 28–9.
3 *ibid*, para 30.
4 *ibid*, para 35.

university degree as compared with 55 per cent in the Netherlands, 80 per cent in Germany and Italy, 85 per cent in Belgium and 90 per cent in France ". Another French survey in 1970 had reported that " the proportion of graduates among senior executives was about half the number in the UK as compared with France, West Germany and Italy ". The Department's conclusion was that " there are fewer QSE's in top management of British manufacturing industry than on the continent "[1].

Employment Statistics

4.6. The data presented by the Department of Industry are disturbing in themselves. We are also disturbed by the inadequate statistical information on which they are based. In their Memorandum to us the Department comment that: " Interpreting employment trends poses some difficulties "; " data are not always entirely comparable, either in time scale or in definition of qualifications and occupation " ; " only very limited information is available on employment in the research and management areas " ; " in the management field it is not easy to distinguish the spread between the various levels of management or to establish the ratio of QSE's to other disciplines undertaking management training " ; and " Statistics comparing the share of top industrial management posts in the UK occupied by graduates generally, or QSE's specifically, with other countries are sparse and unreliable "[2].

4.7. For a Department which " has a deep and direct interest in ensuring that the manpower resources available to industry are adequate in both quantity and quality "[3] the absence of adequate statistics on the employment of QSE's must be very distressing indeed. Allegations about the quality and quantity of QSE's entering industry, and about the deployment of QSE's in industry, are now the daily diet of the national press. Universities, industry and government departments are, as our evidence has shown, uniformly unhappy about the present situation. And yet, when questioned about these matters, the Department of Industry have to rely largely on hunch.

4.8. The last comprehensive survey of the employment of QSE's in Great Britain was published in 1971[4]. It was based primarily on the returns from a survey of central government, research councils, research associations and establishments, local authorities, nationalised industries, manufacturing industry, construction firms and management and engineering consultants carried out in January 1968, and on similar surveys carried out in 1956, 1959, 1962 and 1965. These triennial surveys provided detailed information about the employment of QSE's by subject, nature of employment, employment sector and so forth.

4.9. Despite subsequent discussions between the CBI and the former Department of Trade and Industry[5], the triennial surveys were discontinued after 1968 and have not been revived. Since 1968, therefore, national statistics of employment of QSE's have been based either on the updating of the 1968 statistics by reference to subsequent census data (Q 951), or on the partial

[1] *ibid*, paras 36–39.
[2] *ibid*, paras 26, 36, 37 and 39.
[3] *ibid*, para 23.
[4] DTI [illegible]

First Destination of University Graduates[1], surveys of individual members of the professional institutions[2], or sectoral surveys conducted by Industrial Training Boards[3]. Some information on the employment of QSE's and others in R & D functions only has also been gathered from the 1972 survey of industrial R & D[4].

4.10. All the partial surveys mentioned above are of value, and we have drawn on most of them for information in the compilation of this Report. None of them, however, presents an overall picture of the pattern of employment of QSE's, and the abandonment of the former triennial surveys is to be greatly regretted. According to the Secretary of State for Industry, who himself regrets the inadequacy of the statistical information available, the triennial surveys were terminated "on the basis that it would probably be a good thing to withdraw some of the form-filling that companies had to engage in at that time". His Chief Scientist, Sir Ieuan Maddock, explained that the forms were a "burden" on industry, that the results took a long time to analyse and were therefore often out-of-date, and that statistics "hardly ever give you a sense of the quality of the input" (Q 951). While estimation of quality is inevitably and always a problem, the explanation advanced for the discontinuation of the triennial survey seems to us quite ludicrous. The value of the surveys was that they provided a means of examining trends over an extended period of time, trends which, in this instance, are fundamental to any appraisal of the efficiency, as opposed to the quantity, of employment in an advanced industrial society.

4.11. Without an adequate statistical base it is impossible accurately to assess the seriousness of the present situation, particularly insofar as it affects individual industrial sectors. It is equally impossible to consider the need for palliatives to assist individual sectors, and all but the crudest and most generalised manpower forecasting is ruled out. This applies not only to the nation as a whole, but also to the individual employer. The requirement to make regular detailed returns is itself an incentive to the individual firm to analyse its own performance in respect of the function concerned. It is clear that many British companies at present do not carry out such an analysis because they are not required to produce the figures on which such an analysis could be based. The Plessey Company, for instance, appear to have little idea how many QSE's they employ or how these QSE's are deployed[5]: how then, can they assess the contribution which such employees make to their performance as a company?

4.12. In September 1968 the Swann Report pointed out the "need for more information and further research" on the flow of qualified manpower into employment, and listed a number of individual areas where more information

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1 See, for instance, *Economic Trends*, No 269 (March 1976) (article on "New Supply of persons qualified in engineering, technology and science and first employment of those who were university graduates 1958–1974").

2 eg *The Survey of Professional Scientists* 1971 (HMSO, 1973); *The* 1975 *Survey of Professional Engineers* (CEI, 1976).

3 eg Engineering Industry Training Board, *Professional Engineers, Scientists and Technologists in the Engineering Industry* (Research Report No 4, 1975).

4 *Trade and Industry*, 13 February, 1975, "Employment on scientific research and development in British industry".

5 According to one of their senior staff, we should "disregard figures that you get from our Personnel at the centre" (Q 630).

was needed. They believed that "statistical studies should be refined and extended" and argued that "If information on all these subjects can be collected on a regular basis . . . a more complete picture of the flow of qualified manpower and its deployment will be available as a basis for guiding future policy"[1]. It is evident that the Government have paid little or no attention to a recommendation which was crucial to any further and more detailed analysis of a complex problem of great national importance. We hope that the Department of Industry's own alarm at the inadequacy of the statistical base will lead to a more serious effort to improve the flow of information in this area.

4.13. Detailed and regular analyses of the deployment of qualified personnel are not only valuable in assessing changes over time in the employment characteristics of sectors of British industry, and therefore of identifying areas where action is desirable. They are also an essential aid in comparing the employment characteristics of British industry with those of competitior countries. The comparability of data from different countries is notoriously difficult, and to achieve a high degree of comparability involves collective action by numerous governments. Nevertheless it is evident from OECD publications that the statistical data on employment are markedly less adequate from the UK than from many other OECD countries. In one recent OECD survey, for instance, total R & D manpower data were unavailable from the UK and were therefore "boardly estimated" by OECD, and figures for R & D manpower by broad sector were completely excluded in the case of the UK[2].

4.14. **We recommend that the Department of Industry should immediately revive the triennial surveys of QSE's**; and that the Government should in future ensure that British measurement standards for scientific and technical activities are wholly compatible with OECD Frascati classifications[3] and take whatever further steps are necessary to explain to industry the reasons why such information is required.

The Unattractiveness of Industry

4.15. Despite the inadequacy of existing statistics, it is clear from the evidence submitted to us that many in industry regard the quality and quantity of the flow of qualified scientists, engineers and technologists from universities and polytechnics into industry as inadequate. It is equally clear that industrialists recognise that the inadequacies are due not only to the nature and quality of the courses provided in the higher education sector, but also to the fact that industrial employment is regarded by many potential employees as relatively less attractive than employment in other sectors. Although there is some divergence of opinion about the reasons for the unattractiveness of industrial employment, the consensus view seems to be that industry is unable to compete with the public services in terms of salaries and career prospects, and that the image of productive industry and the status of applied sciences

[1] *The Flow into Employment of Scientists, Engineers and Technologists* (Cmnd 3760, 1968) paras 196–9 and Chapter XII.

[2] OECD, *Patterns of Resources devoted to Research and Experimental Development in the OECD area*, 1963–1971 (Paris 1975).

[3] The OECD methodology is laid down in *The Measurement of Scientific and Technical Activities:*

and engineering amongst the general public discourages the ablest students from considering employment in industry or studying the subjects which would equip them for such employment.

Pay etc

4.16. In evidence to the Science Sub-Committee in November 1975 representatives of the CBI said that their members frequently complained that "the Civil Service offers higher salaries and more attractive conditions and that makes it very difficult for industry to recruit in competition with the Civil Service" (Q 893, 1974-75). The principle of parity with the private sector on which the civil service pay review system was based means that "if industry puts up its rate to attract people it merely pushes the price up generally" (Q 894 (1974–75)). In a subsequent Memorandum the CBI point out that the pay of scientists in the civil service is related not only to that of scientists in industry but also to the pay scales of civil service administrators, and that the effect has been to raise the pay scales of the scientific civil service "to a level which is widely regarded in industry as being too high". Industrial salaries were also restrained by the fact that "industry has to relate pay to the value of the work done, and to the funds available, whereas the civil service can draw on tax revenues to pay salaries agreed by negotiation and comparison". The situation was exacerbated during the period of pay restraint by the fact that civil service scientists were on fixed incremental scales (which were allowed to operate under the pay policy) while many in industry were paid merit increases (which were forbidden under the pay policy).[1]

4.17. The CBI also pointed out that competition between employers was "considerably effected by perceptions of security". In the 1960's industry had faced stiff competition from the expanding university sector; since then university expansion had slowed down, and competition was now coming particularly from the civil service and local government. In the opinion of Dr Duncan Davies of ICI, there was "no doubt that conditions of high inflation support arguments that the industrial sector may have a weaker base in terms of long-term security than the public sector . . . in the public sector, on paper at any rate, stability and security is built in" (Q 895 (1974-75)).

4.18. These views were widely echoed in evidence from individual companies. The Managing Director of EMI Ltd. pointed out that whenever industry tried to offer comparable conditions and salaries the Civil Service "upped" the stakes. Private industry was working on an "escalating ladder" (Q 515): "if it is money that you are seeking, you will have a better opportunity and better job security if you go to, for example, the Post Office, who will offer fifty per cent higher salaries than industry, but with the added benefits of job security."[1] Moreover, the civil service not only offered better pay and security but also offered "the best research facilities in this country" (Q 514). The Chairman of EMI summarised the situation as follows:

> "If it is security you are after, you are unlikely to choose an industrial environment in which to work. If it is wealth you are after you are very

[1] Memorandum 29.

you are unlikely to choose an industrial career".

He believed that men went into industry for job satisfaction and a "reasonable reward". The reward was unavailable because of pay restraint and economic depression and job satisfaction was "exceedingly difficult to get" (Q 526).

4.19. Representatives of Lucas Industries Ltd. thought that "civil service rates of pay in recent years have been in the middle ranks considerably beyond what industry pays" largely because "industry tends to have had a lot of instructions telling it what it can do about its pay levels over the years, and this has not necessarily applied to the Civil Service" (Q 791–3). Hewlett-Packard Ltd. thought that "careers in science, particularly in the UK, do not offer rewards commensurate with the demand" (p 134) and private industry could not do much to improve the situation because if they paid scientists more "they would be very heavily taxed" (Q 385). Similarly representatives of the Oxford Instrument Company believed that "The whole problem of attracting and keeping the staff of companies like ours, and other companies in general, happy in the industrial environment in England in this decade is not an easy one" (Q 449). There were "no young men between the ages of 18 to 23 who want to follow in our footsteps" and, according to the company's Chairman, the erosion of the "entrepreneurial environment" was such that if he were twenty years younger he would "have to think very hard—and I am not at all sure of the outcome—as to whether I would do the same as I did twenty years ago" (Q 461).

4.20. The explanations offered by many industrial representatives for the unattractiveness of industrial employment in terms of pay and conditions tend to be of a rather short-term nature. There is little doubt, of course, that average incomes of QSE's in industry have declined over recent years relative to average incomes in the public service. The recent survey of professional engineers, for instance, revealed not only a decline in the real incomes of engineers between 1973 and 1975, but also that in salary terms "all State-related enterprises have overtaken industry and commerce".[1] We welcome, and have no doubt that industry generally will also welcome, the recognition by the Secretary of State for Industry that "to be a technologist or a manager within industry has been a pretty lousy job" and of the need to ensure that "whatever follows the present pay policy will be flexible enough to ensure that technologists and scientists who work in industry are adequately rewarded" (Q 955).

4.21. On the other hand the figures which the Secretary of State presented to the Committee (see paragraphs 4.4 and 4.5) indicate that, compared with other countries, British industry is not merely going through a period of temporary difficulty in attracting qualified manpower: in comparison with other countries British industry employs "significantly" fewer QSE's. If there is some direct correlation between the employment of qualified manpower and industrial performance—and such a correlation is implied in all the evidence from industrial witnesses—the easing of pay restraint is not likely to effect any immediate cure to industry's problems. It may well assist in improving industry's competitive position as an employer, but the process of strengthening the intellectual muscle of British industry is going to take time.

[1] *The 1975 Survey of Professional Engineers* (1976), p 3.

Image and status

4.22. Perhaps more serious in the long term than relatively unattractive rates of pay is the image of productive and manufacturing industry and the status of engineers and applied scientists in the community at large.

4.23. In his Memorandum to us Lord Bowden, the retiring Principal of UMIST, asks

> "Why should anyone want to go into industry these days, if he remembers the hazards of life there, the rather unpleasant environment in which people have to work, and the contempt with which society at large so obviously regards those who create the wealth which everyone wants to spend?" (p 279).

It is clear from the evidence submitted by industrial witnesses that the belief that their activities are poorly regarded by the community, if not regarded with contempt, is widely held and causes great concern to industrial management.

4.24. A number of witnesses believed that the trouble began in the schools. The Deputy Chairman of the Cambridge Instrument Company thought that attracting able people into industry was "a very significant problem indeed, but I do think it goes right back to school and the persuading of people to go into engineering, physics or electronics in universities" (Q 401). Mr J J Righton, of Lucas Industries, believed that "manufacturing industry in general has a very bad name in this country" and laid part of the blame on school careers masters, who "seem to think that going into manufacturing industry is to do a dirty job rather than a nice, white-collar, clean job in one of the other things" (Q 787). The Technical Director of Plessey Radar commented that "The main problem that we face is a lack of appreciation in schools of the interesting work and the opportunity that exists for university graduates in engineering in industry. There is a lack of encouragement in the schools, particularly the State schools, for people to go into engineering as a career now" (Q 614). He speculated as to whether the attitude which he claimed to see in the State schools might arise from "inverted snobbery" (Q 615). According to the Institution of Mechanical Engineers, the image of engineering in schools has for some years been "extremely poor" and "it is still all too common to meet the spanner and boiler suit syndrome and the situation is not helped by the abuse of the word 'engineer'"[1].

4.25. It is questionable, however, whether the schools—or, for that matter, the universities—can be held to blame for attitudes which are deeply entrenched in society. According to the Director of Patscentre International,

> "the status of an engineer in Europe is higher than it is in the UK. . . . A continental engineer is addressed as 'Engineer'. His letters would be addressed to 'Engineer Gordon Edge' or whoever it was. In other words, there is a deliberate attempt by the society to raise the status of the engineer so that being an engineer is perhaps more important than the job he is doing, and you do not mind doing high advanced production engineering, whereas in this country it is a shop floor job and is looked on with rather less priority" (Q 296).

more forcefully recently by HRH The Duke of Edinburgh. His Royal Highness wrote in *The Guardian*[1] that " the fact is that we suffer in this country a great deal more from intellectual snobbery than from social snobbery . . . Engineering, except for that short period in the middle of the nineteenth century, has been looked upon as a second-class intellectual activity not really fit to be compared with the arts, classics, finance or even science. I suspect that the trouble is that the discipline of engineering is absolute. It either works or it does not ".

4.26. In the opinion of most industrial witnesses, the situation has been made worse by the failure of British governments to emphasise sufficiently the importance of manufacturing industry and by the tendency to invest an increasing proportion of national resources in non-productive, albeit socially desirable, services. As a result of these tendencies there is a far greater national preoccupation with patterns of consumption than with patterns of production and, quite apart from the effect of relative salary scales, the resulting pattern of priorities inevitably affects the attitudes of individuals within the society. Government Ministers are now openly admitting the validity of this view of past government policies. The Secretary of State for Industry told us that " I think that successive Governments have not given sufficient attention to manufacturing industry, and it is a source of great concern to me that we have seen the contraction taking place in manufacturing industry " (Q 958). In his view, " unless we get the manufacturing investment decisions properly in order, we are not going to be able to pursue some of the cherished social schemes that all political parties in this country subscribe to " (Q 963).

The deployment of QSE's

4.27. Having listened to and read with great care the views of industrial representatives about the attitudes of government and society towards industry and engineering, about the difficulties faced by industry in competing with the public sector, and about the inadequacies of higher education, the Committee are not convinced that the problems can be regarded as wholly external to industry, as constraints placed on industry by a malevolent or unsympathetic society. In particular, even if the higher education system is not producing enough QSE's of the right calibre, and even if industry is currently unable to offer competitive salaries or career prospects, one might expect that industry would be making every effort to ensure that there is sufficient penetration of the senior management and decision-making structure of industry by highly qualified technical manpower. The record of British industry does not substantiate this expectation.

4.28. We referred above (para 4.5) to the Department of Industry's conclusion that " there are fewer QSE's in top management of British manufacturing industry than on the continent ". Although comparative information is scanty, all the analyses of which we have knowledge tend to confirm the impression that QSE's in British industry are more concentrated in R & D functions than elsewhere and that there is a much lower proportion of QSE's in senior management, particularly at board level. Mr Ian Glover, writing in *The Chemical Engineer*, in January 1976, concluded from a survey of much of the available information that " British engineers may fill management posts, but

[1] 13 July 1976.

they do not reach top positions nearly as often as do their Continental counterparts ".

4.29. In 1967–68 the CBI carried out a survey of qualified manpower in industry as part of their inquiry into relations between universities and industry. Their report (the CBI Docksey Report)[1] revealed wide variations between companies of different size and in different sectors. 13 per cent of all the companies surveyed (including 27 per cent of companies with less than 200 employees) had no qualified scientists, engineers and technologists on their staff. In the remaining companies 33 per cent of " senior management " (which was not defined) were QSE's (20 per cent engineers and technologists and 13 per cent scientists). The Report commented that " Chemicals, pharmaceuticals and scientific instruments score high, whereas food, drink and tobacco, motor vehicles and paper and printing have less qualified staff in senior management "[2]. The Report also revealed that 22 per cent of all companies (including 14 per cent of companies employing more than 5,000 people) had no qualified staff on their main boards. Of those which did have qualified mainboard directors, 24 per cent were engineers and technologists, and 12 per cent scientists. In the paper and printing industry 45 per cent of companies had no qualified directors, and there were also high proportions in the textile industry (41 per cent), food, drink and tobacco (36 per cent) and the metallurgical industry (30 per cent)[3]. The survey also established that only 9·5 per cent of all QSE's employed in industry were employed in senior management[4].

4.30. With the " sparse and unreliable " information available[5] it is difficult to know whether any major changes have taken place in the deployment of QSE's since the CBI Docksey Report was published, but none of our witnesses has suggested that such changes have taken place. Most of our evidence has been taken from science-based companies, where the position has been better historically and where there appears to be an awareness of the need to ensure penetration by scientific and technical manpower at the top management levels. Even in science-based sectors, however, the proportions of senior management and board members who are QSE's appear to be much lower than the figures for " top executives " in other European countries quoted by the Department of Industry[6].

4.31. It is is not our purpose here to denigrate the efforts which may be made or may have been made by individual companies or whole sectors of industry to improve the penetration of qualified staff into senior management positions. It is important nonetheless for those inside and outside industry to recognise that the low standing of applied science and engineering in society at large is likely to be reflected also in the attitudes of many in industry, since industry is not isolated from society at large but is a part of that society. If, as industrialists frequently claim, too many of the ablest scientists and engineers are

1 CBI, *Industry, science and universities*, July 1970.
2 *ibid*, page 26.
3 *ibid*, Table 10 and Annex E.
4 *ibid*, Table 9.
5 Memorandum 23 (Department of Industry).
6 The Director of Patscentre International told the Sub-Committee that it was very much easier to sell his research services in Europe because he would be selling to senior management with technical expertise. In his view continental management was more aware of the advantages of

government research establishments, it may also be true that too many of the ablest scientists and engineers recruited into British industry are retained exclusively for R & D work and are therefore also isolated from production and management. This is a criticism often made of the civil service, but there is evidence to suggest that it may apply with equal force—and perhaps with less justification—to industry.

4.32. Just as we have heard many criticisms of the higher education sector from industry, so there are suspicions in the universities that many in industry do not appreciate the valuable role which qualified manpower could play in their organisations[1]. **Industry must make it clear not only that they want salaries, but also the opportunity of moving into the top echelons of management with as much ease as their counterparts in Germany, France or the USA and as their contemporaries in Great Britain who have chosen to study law or accountancy. Similarly, if industrialists want to attract the best postgraduates they must be prepared to pay for them.** Students who have spent three extra years on a small maintenance grant to acquire additional skills are unlikely to be attracted into companies who will pay a PhD no more than a BSc.

4.33. Mr John Lyons, the General Secretary of the Electrical Power Engineers Association, recently summarised the problems relating to the employment of qualified engineers as follows:

> "First, while we probably have the largest stock of scientists and technologists with some kind of higher qualification as a percentage of the total labour force, other countries have a considerably higher proportion at graduate level.
>
> Second, we have a disproportionately low proportion of engineers in manufacturing industry, and third, a disproportionately high proportion of our engineers are in research and development as compared, for example, with production and marketing.
>
> Fourth, a much smaller percentage of industry's top management have an engineering or technical background than in other major industrial countries.
>
> Fifth, we pay our engineers less, at every level, than in other countries, including even Italy."[2]

Most of these remarks apply equally to scientists as well as to engineers and technologists. We have already indicated (paragraph 3.75) our sympathy with the proposal from Mr Lyons and others that the time may have come for a national inquiry into the engineering institutions. In the meantime we believe there is much which industry could do unaided to begin to meet points two, three and four in Mr Lyons' list. While much depends on the creation of an economic environment in which industry can thrive, much also depends on the sincerity of industry's desire to improve its deployment of qualified personnel. That cannot be achieved by government edict.

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[1] See, for instance, para 6 of the Memorandum from the Committee of Vice-Chancellors (Memorandum 33).

[2] *The Guardian*, 19 July 1976.

The need for government action on pay

4.34. Nonetheless, the restoration of flexible pay limits is an essential precondition of the policies which we are asking industry to follow, and the evidence on all sides supports the view that substantial advances in productivity, on which, ultimately, the validity of all money incomes depends, will not be achieved unless this occurs. Moreover, such flexibility is unlikely to be conducive to the desired result unless differences in money incomes are permitted by the fiscal system to effect significant differences in real incomes.

4.35. There is therefore one area in which the Government's responsibility is clear and unmistakable. Although private employers probably have more room for manoeuvre so far as marginal adjustments of salaries and fringe benefits are concerned than they would readily admit, the overall pattern of pay and the relative pay scales of different categories of employees is now a matter of government policy, not of private initiative. The salaries and other rewards of scientists and engineers in British industry have, by the Government's own admission, been held down in recent years and are worse than those offered overseas, or by British public service employers (Q 954). **If the Government is serious in its desire to rebuild British productive industry it must create an environment in which there are adequate incentives to attract the ablest young people into industry and away from non-productive public and private services.** The terms of Stage II of the current pay policy offer no element of flexibility in this regard, and we recognise the overriding need to ensure that Stage II is successful.

4.36. The Industry Secretary told us that he hoped that "whatever follows the present pay policy will be flexible enough to ensure that technologists and scientists who work in industry are adequate rewarded" (Q 955). Such a development, to be effective, will involve a substantial departure from the principle of equal sacrifices, and, to be acceptable to other groups, will have to be justified by very clear evidence of the overriding need for unequal treatment. In order to meet the latter aim, and to give some encouragement to those qualified people already in industrial employment (as well as those young people contemplating such employment) we believe that **the Government should establish a high-level independent review body with the following terms of reference:**

(i) to examine changes in recent years in the personal incomes (including fringe benefits, pension provisions etc) of qualified scientists, engineers and technologists in British industry compared with those of similarly qualified employees in the civil and other public services;

(ii) to compare changes in the personal incomes etc of all QSE's with those of other graduates and graduate-equivalents in the civil and public services and the independent professions;

(iii) to compare the personal incomes etc of industrially-employed QSE's in Britain with those of their counterparts in major competitor countries; and

(iv) to make recommendations concerning the desirable future relationship between the personal incomes of QSE's in industry and of QSE's

tunity, and should be provided with sufficient professional staff and funds to be able to make at least some general provisional recommendations before agreement is reached on a policy to replace Stage II of the Social Contract.

4.37. The means of implementing changes in the relative incomes of industrial QSE's will be matters to be decided in the context of any future overall government pay policy, and it would be inappropriate to entrust the implementation of any one aspect of a pay policy to a separate agency. Whatever methods and timescale are adopted, however, we urge the Government to give public recognition to the importance of the problem by establishing the review body recommended above; and to adhere to the principles of the review body's recommendations when formulating future pay policies.

4.38. Whether or not the Government accept the recommendations outlined above, they must now give urgent consideration to the pay of qualified industrial personnel. It is essential for the future industrial health of Britain that they move beyond the stage of sympathetic platitudes.

Educational attitudes towards industry

4.39. As we have pointed out above, it is not only low pay which discourages able young people from considering a career in industry. Suggestions have been made to us—and are often repeated in the press—that schools, colleges and universities do too little to encourage a positive attitude towards industry, and even that they actively encourage antipathy towards industry. These are very serious charges and, if they are true, the Government have a right to intervene to correct the balance.

4.40. Accordingly, **we recommend that the Secretary of State for Education and Science should institute an inquiry into the attitudes of school teachers and careers officers, and into the nature of the advice given to young people by school and university careers advisory services.** On the basis of the results of that inquiry **the Government should if necessary be prepared to issue guidance to the education system on ways of improving advice on industrial careers.**

5. ACADEMIC-INDUSTRIAL COLLABORATION IN RESEARCH

5.1. The Evidence taken by the Science Sub-Committee during the current session was published in weekly parts under the title "Industry and Scientific Research"[1], which indicated the Sub-Committee's concern, arising out of their earlier inquiries, with the nature of the input from the research carried out in the universities into productive industry. From the start of the inquiry, however, it was obvious that research collaboration was intimately tied up with collaboration in educational matters and that one area of collaboration could not be completely isolated from the other. Research and teaching in the universities proceed in tandem and are not regarded by the universities—or funded by the University Grants Committee or even the research councils—as separate activities.

5.2. The interlocked relationship between research and training at the postgraduate level in particular is one of the key characteristics of university science and engineering departments: the availability of postgraduate research students with particular specialisms influences the ability of departments to undertake particular kinds of research, and the nature of departmental research programmes influences the subject and character of the postgraduate education which they provide. It follows that whatever the intrinsic advantages of collaboration in the research field, such collaboration will also have a considerable influence on the educational work of the university departments concerned. The following discussion is largely concerned with methods of collaboration aimed at improving the take-up of university research results by industry. The foregoing remarks should, however, be borne in mind.

Why collaborate?

5.3. The Committee believe that collaboration in research which achieves a greater level of industrial orientation in the universities can be regarded as beneficial for that reason alone, whether or not there are demonstrable returns in terms of direct improvements in industrial performance. This view contradicts to some extent those of our witnesses about the value of collaboration in research. Although there appears to be agreement amongst witnesses that the general level of collaboration is lower in the UK than in the United States of America or in West Germany, and that such a situation is "far from satisfactory" (eg p 75), many also believe that collaboration should be "need" related, and not "artificially created" (eg p 134). This view is repeated in the recent SRC Report (the "Richards" Report) on collaboration in engineering research: "It needs to be recognised that one of the conditions for fruitful collaboration is a sufficiently strong overlap either in motivation or purpose"[2].

5.4. We recognise that there is little to be gained from compelling university departments and companies with few mutual interests to collaborate on research projects which will be of little benefit to either. But if mutual understanding and identity of interest are to be regarded as preconditions of successful collaboration, we cannot see how the situation is going to improve with any semblance of the urgency which is required. For, as the Richards Report acknowledges, "the stereotyped views held by each side of the other are as standing between the two " sides ". The Richards Report concludes that greater understanding " can best be brought about by increasing the volume of collaboration ". That must imply the need for a certain degree of forceful persuasion, if not of compulsion, going beyond measures designed merely to facilitate cooperation between mutually sympathetic partners. Measures of the latter kind are of course desirable and can be expected in the long run to have a beneficial effect across the spectrum of higher education and industry. But the situation appears to us to be such as to demand more urgent measures to bring industry and universities into closer alignment in order to ensure both that educational courses take appropriate cognisance of industrial manpower needs and that the many companies who totally disregard the need for trained manpower are quickly persuaded of the value of utilising the skills and knowledge available in the higher education system.[1] To overemphasise the need for " mutual understanding " as a precondition of collaboration will result in allowing the existing laissez-faire system to continue, and even if it continues at a higher volume it will not solve a situation which is universally regarded as damaging to the performance of British industry.

5.5. **In the Committee's view, therefore, every encouragement should be given to bringing the higher education system and industry generally into closer alignment, and it may well be necessary for that encouragement to include an element of positive discrimination hitherto uncharacteristic of British government aid policies in either the educational or the industrial sectors. Collaboration is desirable because it is the only way in which one of the worst and most damaging examples of British obtuseness can be undermined.**

Methods of collaboration

5.6. In their Report in 1970, the CBI's working party on universities and industrial research published a list of the various methods by which universities and industry do—or could—collaborate. Although there have been some minor institutional changes since then, the CBI summary provides a useful checklist of the activities which we are discussing here, and is reproduced in Table 4.

TABLE 4

Ways in which universities and industry can collaborate

1. Personal assistance from industry with university activities

Lectures by industrialists at universities.

Industrialists serving on university and faculty committees etc.

Industrial advice on, and provision of problems for, research.

University staff and students visiting industry.

Industrial advice on curricula.

Use of industrial laboratories for higher degree work.

Secondment of industrial staff to work at universities.

Technical advice or assistance.

Use of equipment or facilities in industry.

Instrument development.

2. Use of university staff and facilities

Industry using more consultants.

Industry sponsoring research at universities.

Provisions of special advisory or consultancy services.

Secondment of university staff to work in industry.

Refresher or retraining courses.

Industry sponsoring sandwich students and also providing suitable training.

An increase in multidisciplinary projects.

Use of facilities or equipment at universities by industry.

3. Joint activities

Joint research programme with work at university and in industry.

Interchange of staff.

Joint supervision of students.

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1 *ibid*, para 5.

Local "science-based" industry developing from university departments.

Joint meetings or colloquia.

Joint appointments.

4. Positive role of "third parties"

Industrial Liaison Centres run by universities.

Science Research Council Schemes for improving contacts:

(*a*) Co-operative Awards in Pure Science (CAPS);

(*b*) Industrial studentships and fellowships;

(*c*) Awards for science, industry and school teaching (ASSIST);

(*d*) "Instant" awards;

(*e*) Graduate schools;

(*f*) Support for collaborative research grants.

Research Associations translate research into technology for smaller firms and feedback to universities.

Ministry of Technology Industrial Units.

University Grants Committee "pump-priming" support for schemes of assistance to industry.

Professional institutions encourage joint activities and influence curricula by professional requirements.

MinTech industrial liaison officers encourage university-industry links.

5. Financial (or similar) support from industry for university activities

Grants for research without a fixed timescale or agreed programme.

Grants for studentships, fellowships etc.

Loans or gifts of equipment.

Endowment of a chair or university post.

Source: CBI, *Industry, Science and Universities* (1970), Table 64.

Industrial money

5.7. During the previous session we asked a number of universities to give us information about the extent to which their research activities were funded by industry, and in the present session we have asked a number of companies about the level of their direct cash support for research in the universities. The overwhelming consensus amongst our witnesses was that the questions were irrelevant. The important considerations were personal contact and cooperation, and there was, if anything, a movement away "from patronage to participation" (Q 865, 1974–75). The CBI quoted figures for 1969–70 which showed that industry contributed £3·6 million to research in universities and further education, compared with a total industrial R & D spend of £409 million and a total spend in universities and further education of £91 million and they thought that industry's cash payments to universities had since declined further. They argued that "industry as a whole discharges its general obligation to support university research through the tax system" (Evidence p 391, 1974–75). Similar views were expressed by representatives of a number of individual companies.

5.8. Although the Committee are in complete agreement with the view that collaboration which consists solely of disinterested payments out of the "Chairman's vote" is unlikely to lead to any great increase in the industrial relevance of university research, we are not convinced that British industry should be complacent about the very small proportion of university funding which derives directly from industry. Money is as good a lubricant as any in improving contacts between individuals or between institutions, and we doubt whether the most academic of departments would refuse to re-orientate their activities to some extent if offered sufficient financial inducements for doing so. If only 2·2 per cent of the value of total research contracts with the science departments of the University of Oxford derive from industry (Evidence p 369, 1974–75) it would hardly be surprising if 98 per cent of the research carried out in these departments was of little relevance to industry. By way of contrast the industrial relevance of much of the work of the Cranfield Institute of

Oxford[1].

5.9. Industry does not, of course, want "all university research, even in engineering departments, to become "applied" in the Rothschild or administrative sense of being directly commissioned by a user" (Evidence p 392, 1974–75). Neither do the universities, nor do this Committee. On the other hand, by not making larger contributions to university departments industry is making little effort to buy in to the research effort and hence to influence the postgraduate—and undergraduate—training in the universities. Whatever procedures are devised at a national level to encourage a greater orientation of university research and training towards industrial needs will require positive back-up at the level of the individual university department and the individual company. It may well be that many companies are reluctant to put up cash for university research from which the short-term commercial return is likely to be small. **We therefore believe that there is a good case for devising financial incentives—possibly in the form of generous tax allowances—to encourage companies to place out-of-house research contracts with universities.**

Personal contacts

5.10. There are already numerous and varied contacts between individual university departments and companies covering all the possible areas of collaboration listed in Table 4. Because many of these contacts are developed informally and on a person-to-person basis they are largely unquantifiable, particularly because many involve no exchange of funds and are not therefore noticed in the accounts of the universities or the companies concerned. There is a great preference on both sides for contacts of an informal nature. According to Professor W A Mair, of the Department of Engineering at the University of Cambridge, we should not be talking about relations between universities and industry at all, but about "relations between people in the departments and people in the industry" (Q 183). The Chief Scientist of the British Steel Corporation thought that the most important points of contact were "just a matter of dropping in, meeting at conferences, and things of that sort" which might eventually lead to formal research contracts (Q 557). And the Managing Director of NRDC thought that the major obstacles to bringing universities and industry into closer collaboration were "just people". All the arrangements for improving liaison were steps in the right direction but in the end "it really comes down to people". He did not think that "setting up a lot of new committees is the answer" (Q 170).

5.11. Obviously the aim must be to re-orientate the attitudes of people, and not just of institutions, but too great a reliance on purely informal contacts may result in the neglect of those areas of industry and those university departments where the need for collaboration is greatest. Companies and university departments who place their confidence in informal contacts are probably for the most part those which are already collaborating with some success and will continue to do so.

5.12. A widespread device for producing informal, person-to-person contact is the personal consultancy between a company and an individual academic. There is a particular predilection on the university side for such arrangements,

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1 Memorandum 41.

in which the universities are not involved as institutions, partly, of course, because personal consultancies are of financial benefit to the individuals concerned. An increase in consultancies was recommended by the CBI's Docksey Report in 1970[1]. Although they noted the absence of any widespread demand in industry for more consultants, they considered them to be a valuable stimulus to companies of all sizes. The Richards Report, on the other hand, pointed out that consultancies were a method of using existing knowledge, but "research is usually not involved" and noted that the benefits to universities as institutions were limited and could "occasionally turn to embarrassment"[2]. It is certainly true that occasions can arise when senior members of departments are deeply involved in personal consultancies, leaving their more junior colleagues to carry on the routine work of their departments. Apart from the element of unfairness, such a situation does not do much to orientate the activities of the departments as a whole towards industry. There is therefore much to be said for the more widespread use of younger academic staff for consultancy purposes, and for departmental consultancy arrangements which are of benefit to departments as a whole, rather than individual departmental staff.

5.13. During their visit to the United States of America in September 1975, Members of the Science Sub-Committee were impressed by the quite widespread practice of appointing senior academic scientists and engineers as non-executive directors of industrial companies. This was regarded by those whom we met in the USA as a useful device for ensuring that a relatively objective scientific voice was heard when major company policy and investment decisions were being taken. This practice is much less common in the United Kingdom, except in those relatively small science-based companies which have sprung directly out of university departments. Witnesses from large companies were not altogether enthusiastic about this practice (eg QQ 656, 778). Although the Managing Director of EMI, for instance, thought it would have advantages, he thought it would be difficult to identify individuals with the right mix of skills. There was "more a tendency towards the academic on the professorial side in this country than there is in America" and from his own experience at Oxford he did not think that in general there were the skills amongst professors there "for which one would be looking to add real strength to the board room" (Q 509–10). We realise that it is impossible to lay down any firm rule about this but we believe that companies should give serious consideration to the possibility, particularly those companies which are major users of university products in the form of manpower and research ideas. It is perhaps significant that one company which has retained a university professor as a main board director is Hewlett-Packard Ltd (Q 352) who in many ways have followed the practice of their American parent in fostering contact with universities at all levels of the company.

5.14. The Committee are very much in favour of the development of ad hoc relations between companies and university—and polytechnic—departments at all levels, since this kind of interpenetration must provide the long-term key to fruitful co-operation. We welcome the tendency to recruit people from industry to work as part-time lecturers or professors (eg Q 653) or as directors of industrial liaison units (eg Q 340) which are the universities' equivalents such arrangements will only develop spontaneously where the level of mutual understanding is high, which will not lead to rapid short-term improvements in relations across-the-board, we believe that every encouragement should be given to university and industrial employees to make contact in this way and any obstacles should be removed. In particular we agree with the CBI Docksey Report that **employees who are willing or eager to collaborate should be given the time to do so,** and that **both universities and industry should regard such work as part of their normal activities, success in which should be taken into account when promotion is considered.**

Liaison bureaux, industrial units, etc.

5.15. In recent years many universities have established separate organisations either to foster liaison and collaboration between their departments and outside organisations (usually called " industrial liaison bureaux "), to provide general consultancy and research facilities, often of a multi-disciplinary nature, for outside organisations (" university consultancies ") or to exploit the results of research in a particular area on a commercial basis (" industrial units "). On occasions the work of these organisations overlaps.

5.16. A large number of universities—perhaps the majority—now have small *industrial liaison bureaux* designed to foster collaboration with outside organisations. They often consist of only one or two full-time officers and are not directly concerned in research or teaching activities. They visit industrial companies, advertise in industry the research services available in university departments, assist in arranging industrial projects for postgraduate students, and, in some cases, advise departments on patenting techniques. Some, such as the University of Manchester Research Consultancy Service, publish periodical magazines and newsletters aimed at their potential industrial clients. Two have recently acted as local agents for NRDC[1].

5.17. Many of these liaison bureaux were established with the help of " pump-priming " grants from the University Grants Committee between 1967 and 1973[2], but have now been taken over by their parent institutions. They are clearly regarded as a success both by the UGC and by those who now have responsibility for their management. The latter, represented in the UDIL Group, regard " this low-cost operation " as " one of the most effective ways of helping to improve mutual understanding ". We agree. We believe that the Government should revive the practice of making ear-marked grants for this purpose, either to assist in the establishment of new bureaux, or to help out those universities which face difficulties in maintaining existing bureaux because of pressure on their general funds. It might be appropriate for these grants to be made in future not by the UGC, as in the past, but by the Department of Industry. We do not believe that liaison bureaux should be expected to be self supporting or to earn a large income for the university. Their primary purpose is to improve academic-industrial understanding and co-operation.

5.18. A smaller number of universities have established general *university consultancies,* which operate on a commercial basis to provide research and consultancy services to external clients. Some, such as those at Edinburgh

1 Memorandum 34, para 3.
2 See para 3.55 above, and Memorandum 5.

and Bath, were also established with the help of UGC grants, but were expected to become self-supporting. It is usual for consultancies to be established as limited liability companies with a board of management drawn from the parent university and industry. Examples include ULIS (the University of Leeds Industrial Services Ltd) and Loughborough Consultants Ltd.

5.19. It may well be that not all universities have research activities on an appropriate scale or of an appropriate nature to support a commercial operation of the kind described above. In principle, however, we believe that commercial operations of this kind are desirable not only as a means of achieving a financial return from the expertise available in the universities, but also as a means of accustoming academics and administrators to work according to commercial criteria and within the kind of commercial and time restraints usual in industry, since ignorance of industrial conditions is one of the charges often levelled against universities by industrial critics. In cases where individual universities could not support such consultancy companies there would be advantages in arranging for them to buy in to existing consultancies in neighbouring universities, or to form consortia for this purpose. There is no reason why such consortia should not also include local polytechnics.

5.20. *Industrial units*, operating with their own research and engineering staff, have been established in a number of universities with particularly strong research teams in particular academic areas. These were largely started with the help of substantial funds from the former Ministry of Technology or the Wolfson Foundation. Perhaps the most well-known and successful of these units are the Cranfield Unit for Precision Engineering (CUPE), which received a MinTech grant in 1968 and now has a staff of about 50 and is self-supporting on an annual turnover of more than £300,000; and the group of Wolfson Units at the University of Southampton, including Noise and Vibration Control, Electrostatics, Electronics, Materials and Marine Craft.

5.21. Whether supported by the UGC, the Ministry of Technology or the Wolfson Foundation these units appear to have been generally very successful, and it is to be hoped that further funds will be made available from public funds for such ventures in the future. The Committee regard the work of the Wolfson Foundation, all of whose industrial units have proved financially viable[1], as particularly praiseworthy, and as an example to other industrial organisations, as well as to government departments, of the effective stimulus which can be provided by the imaginative use of sizeable, but not enormous funds. We urge the Government to make further funds available for activities of this kind. Although we agree with the Director of the Swansea Tribology Centre that "it is probably unimportant which Government Department should act as the agent for such funding"[2], we believe that the Department of Industry could use this method as a means of intervening to stimulate collaborative research in selected industrial sectors.

Science parks etc

5.22. Members of the Science Sub-Committee visited the new Cambridge Science Park and took evidence from the organisers and tenant companies at Trinity College in December 1975[3]. They have also received Memoranda

Lancaster[1].

5.23. The concept of the Science Park has been borrowed from the United States of America where, in May 1974, there were 82 science parks in 28 different states. On average the American parks are large (about 650 acres) and employ large numbers of qualified staff[2]. Most American parks are not restricted to science-based companies, and some have tended to become general industrial agglomerations located near universities (Q 229).

5.24. The present developments associated with British universities are very much smaller. The Cambridge Park, opened in June 1975, had only four tenant companies by the end of that year, employing about 150 staff, on a 13-acre site. Its activities are limited by a planning agreement to scientific research associated with industrial production, light industrial production dependent on regular consultations with local university or other scientific institutions, and ancillary buildings. It is planned eventually to provide employment for about 1,000 people (Q 220).

5.25. The Heriot-Watt Research Park at Riccarton is on a 20-acre site donated by Midlothian County Council within the University Campus. This park is also intended to be used only for research and development and the manufacture of prototypes and specialist high technology apparatus. The first tenant contract was negotiated in 1971, and the Park now has five tenant organisations, including the University's Department of Petroleum Engineering. The Park was established as " an act of faith on the part of the University, aimed at encouraging industry to establish research and development activities on the Research Park as a means of strengthening the interface between the University and Industry " (Memorandum 6).

5.26. The University of Lancaster have not established a science park as such but have collaborated since 1968 with the City of Lancaster in a scheme (called " Enterprise Lancaster ") to attract small science-based companies into the area, the City offering sites, buildings and assistance with housing, and the University offering access to equipment, library and computer facilities, and liaison with the science, engineering and management departments of the University. Eight of the twenty companies established in Lancaster under the scheme are regarded as " science-based" and a further eight as " engineering/technical based "[3].

5.27. The Cranfield Institute of Technology have also acquired a number of tenant organisations, including a Research Association, and branches of two private companies. Although the Institute say that they see themselves " as a federation of interests relevant to the advancement of industry " and not as a science park[4], there appear to be close similarities between the grouping of interests at Cranfield and developments taking place at Heriot-Watt and Cambridge.

5.28. The Committee are very much in favour of these developments. They symbolise the awareness of the universities concerned of the need to collaborate with industry ; they assist in the creation of an environment in which collaboration becomes a normal activity in both the academic and industrial environ-

1 Memoranda 6 and 7.
2 Unreported evidence.
3 Memorandum 7.
4 Memorandum 41, Annex.

ments ; and they provide the basis of organisations capable of providing facilities to university researchers to establish their own science-based companies to exploit the results of their research.

5.29. The Committee feel that facilities of the latter kind are particularly desirable in order to assist in the growth of awareness amongst young research workers of the advantages of taking their research down the line to product development. Both the Science Park at Cambridge and the Heriot-Watt Research Park already have small private tenant companies established to exploit spin-off from high-technology research within university departments (Laster-Scan Ltd, and Edinburgh Instruments Ltd). At the University of Lancaster imaginative use has been made of the University's original building in the city centre by converting it into a multi-occupancy building " to provide high quality accommodation at low cost to assist new firms to get established ". The organisers of both the Cambridge Park and the Heriot-Watt Park aim to establish similar multi-occupancy buildings.

5.30. The developments at Cambridge and Heriot-Watt have been launched with enthusiasm and are regarded by the small number of tenants already on site as successful. Significantly, they have had little direct help from the Government, and have suffered from the economic recession which has made the establishment of new companies more difficult. They are, however, long-term ventures, and it is to be hoped that their activity will pick up as the economy begins to expand again. Although it is difficult to believe that sufficient capital or appropriate sites are likely to be found for such developments on a large scale in the UK in the foreseeable future we believe that more active encouragement should be given by government departments to those universities wishing to start such enterprises. We believe in particular that the Government should seriously consider the provision of specific financial help to Heriot-Watt and Trinity College Cambridge to enable them to build and offer at peppercorn rents multi-user facilities for small science-based companies established to exploit the results of university research projects. We also believe it to be undesirable that the essential development and growth of companies in such science parks should be unduly inhibited by excessively restrictive and unimaginative planning conditions.

The transfer of technology

5.31. We argued above (paragraph 5.3) that university-industry research collaboration is desirable as a means of improving mutual understanding, whether or not it leads to immediately discernible returns in terms of improved industrial performance. Nonetheless one of the main reasons for wishing to improve relations between the two " sides " is to produce improvements in the translation of ideas and discoveries into marketable products.

5.32. In the following Chapter we discuss the process of innovation as a factor in achieving success in industrial production. In this Chapter we are concerned with the existing mechanisms for transferring knowledge and the effectiveness, or otherwise, of the institutional machinery devised to assist such transfers.

5.33. There are dangers in generalising about this subject. The first is to nor even the major executer of fundamental research in the UK. A very much larger volume of fundamental and applied research is carried out in government research establishments, industrial research associations and in individual companies, and the process of "technology transfer" from and between these sources may well be of much greater importance than whatever direct transfer may take place between the higher education sector and industry.

5.34. The second danger is to assume that the transfer of knowledge from universities—or indeed, from GRE's, research associations and industrial laboratories—is the main key to industrial success, and that, if only a situation could be created in which ideas and men moved freely between different organisations, the nation's industrial problems would be solved. As we point out below[1] industrial innovation is a complex activity in which the crucial variable is more likely to be money than ideas. While ease of transfer is of importance, therefore, it is not a substitute for resources or commercial acumen.

5.35. A third danger is to assume that the characteristics of the potential transmitters and receivers of ideas, on both sides, are generally similar, and that a uniform degree of effort is required—or desirable—to transmit ideas from higher education in general to industry in general. That is obviously not the case. There are some industries—such as the chemical, pharmaceutical, and advanced electronics industries—which are undoubtedly science-based and where product improvement often stems directly from quite fundamental advances in knowledge. There are other industries—particularly in the general manufacturing sector—where the need for advances on the frontiers of knowledge may be much less, and product improvement is much more dependent on applied development work and better engineering design. Similarly, some academic disciplines (such as computer science or pharmacology) will require a more intimate awareness of industrial practice for purposes of both teaching and research than will some others, such as mathematics or pure physics.

5.36. Despite the above qualifications, it can nevertheless be argued that it is desirable to ensure that the best possible climate and conditions should be created to facilitate the transfer of knowledge wherever the potential exists. It cannot be the function of Parliament or Government to require the transfer of knowledge where there is no knowledge to transmit or no application to which it can be transmitted. It is a function of Parliament and Government to ensure that conditions exist to allow the potential for transfer to be perceived and that there are no unnecessary obstacles to prevent it.

The example of chemistry

5.37. We have already remarked (paragraph 3.15 above) on the high regard in which academic chemistry is held by the chemical industry. This high regard extends not only to the educational functions of university and polytechnic chemistry departments, but also to their performance as sources of knowledge for use in the chemical industry. In his evidence to us, the Chairman of SACRHEI[2] emphasised the "relative ease of technology transfer" in

[1] Chapter 6.

[2] The Chemical Society's Standing Advisory Committee on Relations between Higher Education and Industry.

chemistry and claimed that "we have been unable to find significant examples of industry failing to take up ideas developed in university chemistry research". This was largely because the chemical industry was well-defined, whereas "There is not in the same way a physics industry or a biology industry", and because of "the long-standing, close, personal, often Christian-name relationship between the chemical industry and the universities" (Q 1). To make quite certain that this desirable situation continues, SACRHEI were considering "the extent to which industrial advance may be held up in areas where technological exploitation has reached the limit of knowledge" (p 3) and were considering the establishment of "a small advisory body which would be available for anyone in universities who has made a chemical advance which he thinks has not been adequately assessed by British industry" which would be "a court of last resort" after direct approaches to industry and NRDC (Q 22).

5.38. Such a situation does not and cannot exist in most other industrial sectors or academic disciplines, although it may be hoped that a closer alignment of much university teaching and research may in the long run produce new academic divisions which may more closely resemble the divisions between industrial sectors. If for instance the teaching of manufacturing technology is successfully implanted in the universities (through the "Teaching Company" or other devices) the day may come when university departments of production engineering relate naturally and easily with general manufacturing industry. But that day is a long way off.

5.39. Nevertheless, we believe that the example of chemistry deserves careful study by other industries and other academic disciplines and that attempts should be made to establish similar bodies in other areas. We are especially attracted by the prospect of such a joint Committee performing the function of assessing industrial needs for new areas of basic research and of marrying the output of the universities to the requirements of the industry. It is preferable, in principle, for such activities to be performed through bilateral channels than through the agency of third parties, whether they be government departments or research councils, although government agencies cannot be excluded, even in the case of chemistry, since they provide many of the funds.

The gap between research and development

5.40. Our evidence has led us to conclude that the principal weaknesses in the existing mechanism for transferring the results of research from the higher education sector to industry are:—

(1) in the identification of the stage in the process when a piece of research ceases to be speculative and becomes a potential product or process; and

(2) in the allocation of funds to support a potential development through that stage.

5.41. This conclusion confirms the findings of the Richards Report on *Academic-Industrial Collaboration in Engineering Research,* that there is what that Report describes as a "pre-development gap" which arises from

"the [illegible]

process or piece of equipment). The academic engineer sees it to be possible once the conceptual ideas have been elucidated and some rough indication is available of marketability and production problems. The industrialist on the other hand, and to a lesser extent the NRDC, sees a marketable product as worth developing only if it is already being demonstrated in pilot form, and has a predictable time-scale to profitability "[1].

Although the Richards Report is concerned only with engineering research—and stresses the need to consider engineering separately from scientific research—our evidence suggests that the gap to which they refer applies equally to any piece of academic research with potential application. Naturally the majority of examples are likely to occur in engineering or applied science subjects but steps by the Government to improve the situation—apart from any which may be taken by the SRC Engineering Board—should not be confined to engineering alone.

5.42. As the Richards Report suggests the gap arises from understandable differences in the attitudes of academics and industrialists towards the commercial potential of a piece of research. The academic researcher may envisage a product as soon as he has demonstrated that the potential product can be made; the industrialist may well be unable to envisage a product until he knows how he will make it, what it will cost to make it, and whether there are customers to buy it.

5.43. This difference of view would not be of much importance if the academic had funds to spend on designing and building prototypes and assessing the market, or if the industrialist had funds to spend on the support of potentially high risk R & D. Generally speaking neither situation is likely to obtain. The industrialist will normally not put up money for work which is still, in his view, speculative unless he is more or less certain that there will be an outcome, or unless he is authorised by his company to be philanthropic. The academic, on the other hand, is likely to be funded by a Research Council primarily concerned with the support of research which conforms with purely academic criteria of " excellence " and " timeliness and promise ". A Research Council is unlikely to support work which they regard as development, rather than research.

5.44. This situation has been spelt out to the Committee in categorical terms by the Science Research Council. In their view, if " the main purpose of the proposed research is specifically to develop a machine or process, or is directly related to the achievement of the objectives of other Government Departments, then it is not normally appropriate for SRC to fund the project ". Although the Council's Charter gives it wide powers to support research and development, its role is limited " by administrative understandings of what it is appropriate for SRC to support and what is the responsibility of other bodies " (p 20).

5.45. The other public body particularly concerned is the National Research Development Corporation (NRDC). The Chairman of the SRC explained that the point of the statement quoted above was that " if a particular investigator has in mind inventing . . . a machine, or perfecting a machine, which is then a marketable product, if it is something which he intends to produce or get a

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[1] SRC, *op cit*, para 17.

firm to produce, then the actual avenue for this is the National Research Development Corporation. We have a situation where the SRC is supposed to abut on NRDC" (Q 45).

5.46. The explanation of the respective roles of the Research Councils and NRDC given by Sir Sam Edwards accorded with our understanding of the system, but since it is was clear from all our previous evidence that there was some doubt in the university system whether the practice bore any resemblance to the theory, we decided to seek further views, particularly from industry, on the NRDC's performance as the supporter of potential innovations across the gap from research to development.

NRDC

5.47. NRDC described the functions laid down for it under the Development of Inventions Act 1967 as follows:—

> "Broadly, the Corporation is permitted (*a*) to secure the development and exploitation of inventions resulting from public research and of any other invention which, in the opinion of the Corporation, is not being sufficiently developed or exploited; (*b*) to acquire and to license rights in such inventions; (*c*) to promote and assist research for satisfying specific practical requirements and likely to lead to an invention; and (*d*) to assist the continuation of research that is likely to lead to inventions of practical importance. In all of these sectors, the Corporation can act only where the public interest so requires".

The Corporation added that it was required by the Act "to attempt to match income with outgoings, insofar as that can be done consistently with the fulfilment of its functions" (p 51).

5.48. NRDC therefore has very wide potential powers, and also some rights. Most notable amongst the latter is the right to exploit the results, if it wishes, of inventions from certain Government establishments (but not all) and of certain categories of inventions from the universities. This situation is rather confusing, and was not made any less so following Mr Peter Docksey's report to the DTI in 1971 on *The Government Role in Developing and Exploiting Inventions*[1]. Although some of Mr Docksey's main recommendations (including the establishment of an "overlord" Government Development Council) were not accepted, his report led to the principal multi-purpose civil government research establishments (including the National Engineering Laboratory, the National Physical Laboratory and Warren Spring Laboratory) acquiring the freedom to exploit inventions without reference to NRDC. Mr Docksey's report left untouched the existing situation in which rights in inventions arising from university research sponsored by Government Departments and Research Councils are the property of the sponsoring body and are normally offered to NRDC for exploitation: whereas rights in inventions arising from research supported by the universities' general funds remain the property of the universities.

5.49. In view of the fact that almost all university funds derive from the Exchequer, the unequal treatment of Research Council-sponsored and univerboth to respect the notional independence of the universities [illegible] certain flexibility. As we made clear in our first Report[1] the gradual erosion of the universities' ability to support research and the increasing cost of most individual research projects has made university research generally more dependent on Research Council support and the volume of unsponsored research likely to lead to exploitable inventions is therefore relatively smaller, and NRDC's potential role relatively larger. In the case of research not sponsored by Research Councils and Government Departments, NRDC may be approached by university departments for help, or may itself offer help on a royalty-sharing basis. In recent years "academic institutions have replaced Government Departments as the biggest single source of public-sector inventions offered to NRDC" (p 51). This is hardly surprising in view of the absolute increase in the scale of university activities, the greater dependence of universities on the Research Councils, and the independent position of most of the major government research establishments.

5.50. The Corporation has also, since 1965, concentrated more on joint venture activities with industry (Q 104) in which NRDC contributes a fixed proportion of development costs in return for a levy on sales or some other form of return reflecting the risk-bearing nature of the support, ownership and development responsibility remaining with the industrial firm concerned. In these activities NRDC is acting in many ways as an alternative source of venture capital for industry.

5.51. NRDC is financed by Treasury loans but has a statutory duty to attempt to break even on its revenue account. Between 1949 (when it was set up) and 1972 the Corporation accumulated borrowings of well over £20 million (out of a maximum permitted of £50 million) but in the last few financial years has managed to repay some of these borrowings, and is now able to service them without interest relief (QQ 107–9). The Corporation's financial position is therefore very healthy. Nonetheless, so far as its business with universities was concerned, £12·8 million of the total cumulative income of £14·3 million between 1949 and 1975 derived from only one invention (the cephalosporin drugs), the patents on which will soon be running out.

5.52. Although the Corporation is described by the Industry Department as a "highly autonomous body" it is in fact required to refer a number of relatively trivial decisions to the Departments. These include "the taking of equity in a company, promoting or assisting research, and the provision of financial assistance to any person or company in excess of £20,000 per annum"[2]. Until the passing of the Industry Act 1975 the latter figure was only £1,000. The Secretary of State said that "there is no breathing down NRDC's neck as far as I am concerned" and pointed out that approval had been refused for only four NRDC projects since the Corporation was set up (Q 902). But the Managing Director of NRDC, while admitting that there was not a great deal of interference from the Department (Q 117), told us that he saw no relationship "between the £20,000 and what we would regard as a reasonable industrial project" (Q 116).

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1 Second Report, Session 1974–75, HC 504.

2 Memorandum 23 (Department of Industry).

5.53. We asked our witnesses to comment on NRDC's effectiveness in "bridging the gap". A selection of replies is set out below:—

"NRDC is an enormous organisation and the inertia to get through there is impossible. Unless someone is extremely articulate and very good at putting together a financial package, and unless he is very fortunate in raising someone in NRDC who can comprehend the idea—and that is a very great difficulty in NRDC—he has not got a chance" (Q 245, LKB Biochrom).

"I believe [NRDC] is greedy in that it wants more than its pound of flesh for everything it gives you . . . I am far from certain that the channelling of all university patents through the NRDC is in the interests of either the university or of industry . . . we have had considerable difficulties about property rights when we wanted to finance a job for a university" (Q 795, Lucas Industries).

"Too often their own technical scientific staff are dominated by a fiscal policy which plays for safety and demands guarantees of success which cannot be given until feasibility studies are done" (Memorandum 9, Professor D E Hughes).

"We have had limited help from the NRDC but have to state that the terms so far offered have been quite useless for a small development Company" (Memorandum 6, Edinburgh Instruments Ltd).

"NRDC was not particularly effective: its remit appeared too narrow, it was slow, it tended to be too timid, and its staff were not as closely in contact with industry as those of the NPL" (Memorandum 11, Scientific Instruments Manufacturers' Association).

"NRDC has not been as effective as it should have been in helping to develop new technologies and facilitating the application of the results of research. It does not seem to be popular with industry and many firms find its terms and conditions too onerous. Thus it provides only a very tenuous link between industry on the one hand and university or Government research on the other" (Memorandum 15, Machine Tool Industry Research Association).

"There are signs that in its relations with innovators in university departments, the NRDC is at once too slow and too monopolistic" (Memorandum 30, the Nuffield Foundation).

"The staff of the Corporation should be more actively engaged in searching out potentially viable innovations and in applying sound marketing techniques to their development. . . . We agree with other submissions that the requirement that expenditure of more than £20,000 on any one project must be approved by the Minister is unrealistic [and] often leads to delays which industrial collaborators are not prepared to accept" (Memorandum 33, Committee of Vice-Chancellors).

5.54. We find these comments most disturbing, particularly because there is no sign in our evidence of much outright support for NRDC in other quarters. The University Directors of Industrial Liaison believe that those who, like themselves, have most to do with NRDC, are "conscious of its value" and of commercial success", and that the Corporation's "knowledge of companies most able to manufacture and sell artefacts resulting from a given invention is not as comprehensive as we would wish it to be" (Memorandum 34). The CBI, although they claim that there is no support among their members "for abolishing NRDC or for making any major change in its functions", admit that their ranks are divided and note the "fairly high return on its successful investments" which the Corporation seeks in order to fulfil its financial obligations (Memorandum 29).

5.55. There was little indication in the evidence of either NRDC or the Department of Industry that they were aware of the extent of the criticisms levelled against the Corporation. There was, indeed, an air of complacency about their evidence. This is a matter for concern in itself. The Managing Director of NRDC said that "we have never yet been limited by funds, we have always been limited by opportunity. . . . We have been stuck for opportunities", although he admitted that "This may be a reflection on the extent to which we are able to winkle out these opportunities" (Q 123). The Corporation was "in an extremely healthy position" from a financial point of view (Q 112). And they knew of no conspicuous examples of the Corporation's judgment having been proved wrong (Q 158). The Secretary of State for Industry thought that NRDC "has been a success and has contributed significantly to developing inventions" (Q 903). He had been "told" that the Corporation was not inhibited in any way in taking up ideas, "but because so many are very risk-taking and because of its break-even responsibilities it has to turn a good many down" (Q 904). He "would like to know whether NRDC would like to become a more risk-taking body" (Q 906) and was "very ready to consider representations from the NRDC" if they thought themselves to be financially inhibited (Q 902). The Department's Chief Scientist, replying to questions about the comments of SIMA and the MTIRA (quoted in para. 5.53 above), said that "this kind of general criticism, of course, generally comes from people who have had their projects turned down. . . . It is like the rejected suitor who then starts criticising his erstwhile fancied lady" (Q 918).

5.56. We face a strange situation. The Government is happy with NRDC, probably largely because the Corporation is now paying its way. The Corporation is satisfied with its own performance, probably for the same reason. But the potential clients of the Corporation, from both the university and industrial side, regard the Corporation as unadventurous, unwilling to take sufficient risks, imposing excessive interest rates, and out of touch.

5.57. The situation we face is also a damaging one. The Science Research Council's Charter permits it to support research *and development,* but by administrative agreement it will only support research. NRDC is empowered by statute to "promote and assist *research* for satisfying specific practical requirements and likely to lead to an invention" and to "assist the continuation of *research* that is likely to lead to inventions of practical importance" but is dominated by the need to break even financially. Even when the Corporation took the initiative in April 1975 to invest an extra £1 million in applied research in universities and polytechnics the criterion that "there should be a prospect that the Corporation's investment will be recoverable" (p 53) continued to apply. Perhaps not surprisingly, therefore, by the end of the year the Corporation had authorised expenditure of only about £120,000 attributable to their widespread publicity campaign (Memorandum 43).

5.58. The "pre-development gap" to which the Richards Report refers is exacerbated by the mis-match between the activities of the SRC and NRDC and by an overemphasis on profitability in the operation of NRDC. Urgent attention should be paid by the Government to this problem and urgent action taken to correct it. The Government should certainly not wait for NRDC to take the initiative. There are a number of specific steps which we believe could go a long way to help:

(i) As recommended by the Richards Report[1], **the SRC should institute a separate "pre-development grants scheme" in engineering, with a view to extending this, where appropriate, to other areas within the the Council's remit ;**

(ii) **NRDC's patent rights in respect of Research Council-funded university research should be terminated ;**

(iii) **universities and polytechnics should be free to exploit the results of research carried out in their laboratories in whatever way and with whatever partners they choose ;** in the event of any unusually large income accruing to a university or polytechnic, the situation can, if necessary, be corrected by adjustments in the level of the institution's general funding from DES sources ;

(iv) **universities should be encouraged to establish liaison bureaux, where these do not already exist, and to form industrial consultancies either independently or in collaboration with neighbouring institutions ;**

(v) **university industrial liaison bureaux should act as local agents for NRDC ;** this practice was recomemnded in the Docksey Report[2] and has been taken up on an experimental basis in two universities recently ;

(vi) **NRDC's main responsibilities should be redefined as**

(*a*) **the support of high-risk applied research for which no industrial or commercial sponsor is available ;**

(*b*) **the provision of advice to universities and polytechnics, through local liaison bureax, on patenting techniques and on potential industrial and commercial markets ;**

(vii) **NRDC should not support low-risk R & D if other sponsors are available ;**

(viii) in joint ventures with industry **NRDC's interest rates should be at or below market rates in order positively to encourage the take-up of university inventions ;** and

(ix) **the obligation on NRDC to break even should be regarded as secondary to its obligation to encourage innovation.**

5.59. The recommendations above would if implemented result in a quite fundamental re-orientation of NRDC's work. It would cease to be a body funded research, and would concentrate instead on providing advice and assistance to those seeking to exploit research results. It would have no particular rights with regard to university research and would act only when asked to do so. **It may well be that these functions would be better performed by a new institution without the accumulated scepticism and indifference which NRDC's policy and activities appear to have generated in some quarters.**

5.60. Whatever action is taken by the Government, we regard the present activities of NRDC—and the priorities given to its various functions—as in no way conducive to encouraging the exploitation of academic research. Its control of many university patent rights reduces the scope for initiative in the universities and opportunities for bi-lateral cooperation; and its imposition of high interest rates reduces its chances of collaboration with industry. Moreover we believe that if the State is to take a major initiative in assisting the exploitation of the results of university research, it should do so not in low-risk areas which can finance themselves, but in those areas which the private sector, or other parts of the public sector, cannot afford to support. There is in other words a need for a public body which will take higher risks than the market will normally allow. Such a body may not always make a profit. We do not believe that it should aim to do so, even if its success over a period of years enables it to break even. **It should rather be judged by the number of high technology enterprises which can claim to have come into existence only because of imaginative and enterprising sponsorship at the outset by NRDC.**

Government research establishments

5.61. We have argued that it is intrinsically desirable to orientate the work of university science and engineering departments towards industry. One method of achieving this is open to the Government and is not directly dependent on industrial cooperation. The Government could, if it chose, transfer to the universities and polytechnics a proportion of the work currently undertaken in their own research establishments, much of which can be regarded as of a "basic but relevant" character. The case for such a transfer is forcefully argued by the Nuffield Foundation. The Foundation say that "it is inconsistent that the universities should on the one hand be blamed for the predominantly academic character of their research while, on the other, publicly sponsored applied research should be considered the responsibility of the public laboratories". They point out that such applied research "could enliven and make pointed the vocationally oriented postgraduate courses which the Foundation considers to be necessary in precisely the way in which more academically oriented research is known to enliven undergraduate teaching and the training of traditional PhD candidates in research"[1].

5.62. We have not studied this question in depth, but the principle appears to us to be a very sound one. The Government is the largest single sponsor of research of all kinds. The policies which the Government pursues in placing research of different kinds in different institutions is therefore a major factor in determining the nature of the work undertaken by the different sectors.

[1] Memorandum 30.

We therefore recommend that the Government should undertake a thorough review of the level and nature of the research undertaken in their own establishments and should attempt to transfer to universities and polytechnics work of a more basic nature, not requiring major physical research facilities, wherever this is possible. If one effect of such a transfer would be to reduce the staffing of government research establishments, we would regard this as a gain, since we accept the view of the CBI, in particular, that these establishments are over-staffed with the best scientists, engineers and technologists.

Conclusion

5.63. We regard collaboration between universities and industry in the research area as desirable both because of its beneficial effects on the universities as teaching institutions and because of the need to maximise the input of new ideas into industry. Such collaboration is already widespread and ought to grow naturally.

5.64. To assist the process industry should be encouraged to place more research contracts with universities, if necessary encouraged by tax concessions; industry and universities should be encouraged to establish bilateral bodies to assist in the identification of industrial research needs; public funds should be made available to encourage the development of liaison bureaux, consultancies and industrial units in universities and to support the growth of science parks or their equivalents; consideration should be given to the transfer of work from grovernment research establishments to universities; and the activities of SRC and NRDC should be reorganised so as to actively encourage the exploitation of the results of university research.

6.1. In this Chapter we attempt briefly to assess the significance of the university-industry relationship in the process of industrial innovation, and of such innovation as a factor in determining industrial success. Although much of our inquiry has been concerned to determine the nature and effectiveness of relations between universities and industry, it is clearly relevant also to consider the extent to which the functioning of such relations may contribute to wider economic and social goals. For although it is clear that many witnesses regard university-industry relations as unsatisfactory, it is not at all clear how far relations which were more satisfactory would significantly enhance the achievement of economic goals, or to what extent the achievement of such goals could be more significantly enhanced by action on other fronts.

6.2. It is generally accepted that the British economy is performing less well than it should be, or, at least, that economic growth in Britain is sufficient neither to meet popular expectations nor to allow Britain to compete on favourable terms in world markets. Diagnoses of the situation vary considerably, but there seems to be a consensus that the root of the problem lies in the performance of British manufacturing industry since the Second World War, if not earlier. And amongst the many individuals and groups who submitted evidence to us, there was a general assumption—explicit or implicit—that the performance of manufacturing industry was in some way related to Britain's propensity to innovate, that there was a significant relationship between industrial success and technological innovation.

6.3. More specifically, there was a widespread feeling, particularly among senior industrial management, that the deep-seated problems of industry were closely related to the social and educational role of the universities. As indicated in more detail in preceding chapters, industrial comments on the functioning of the universities tended to agglomerate around a few general themes, concerning the quality of science and engineering graduates, the alledged antipathy of universities towards industry, and the contribution of universities towards the perpetuation of the poor image of engineering as a profession. Although both the criticisms and the prescriptions were normally couched in rather general terms, the industrial witnesses clearly believed that a closer and more sympathetic relationship with the university sector would be of benefit to industry.

6.4. These industrial comments, general as they are, indicate an awareness within the industrial community of the importance of knowledge in the process of technological innovation. Many studies over recent years have indicated the essential correctness of this view. For example, OECD study carried out in 1971 suggested a relatively high degree of correlation between national performance in technological innovation on the one hand, and strength in fundamental research and in R & D performance in industry on the other hand. Yet the same study also suggested that, among OECD members, Britain ranked consistently high in terms of national indicators usually associated with innovative performance—including the absolute level of R & D activity, the output of physical and chemical abstracts, and the number of Nobel Prizes awarded to national scientists[1]. This would seem to suggest either that Britain is not so poor at innovation as is widely assumed, or that other factors are effecting our

[1] *The Conditions for Success in Technological Innovation* (OECD, 1971), See, especially, pages 143-8.

propensity for economic and industrial growth. It also suggests that there is more to industrial success than knowledge generation, and that for an explanation of the outstanding technoligical progress of Britain's competitors—notably in Europe, North America and Japan—one must look further than the normal statistical indicators of innovative performance. In particular, there is a need to look more closely at factors, such as entrepreneurship and the quality of management, which are rather more difficult to quantify.

6.5. This is not to say that the role of science in the innovative process—or the need for government support of scientific endeavour—is unimportant. Although Britain's R & D expenditure is high, so is that of her main industrial competitors. Since 1971, for instance, West Germany, Japan, the Netherlands and Switzerland have all spent proportionately more on industrially financed R & D than has the UK[1], and there is little case for arguing, on the basis of overseas comparisons, that Britain now devotes excessive resources to civilian R & D.

6.6. Nonetheless, there is growing evidence to suggest that despite the importance of continuing R & D as a feed-stock, the crucial factors in the successful development of new products based on new technologies are related more to market factors than to technological factors. Put in very general terms the evidence suggests (1) that most (though not all) contemporary innovations tend to be stimulated initially by *economic need* rather than scientific and technical opportunity; and (2) that the most important factor in the eventual commercial success of an innovation is the extent to which it has been consciously developed to user needs.

6.7. This view was expressed to the Sub-Committee in forceful terms by Mr John Diebold, chairman of the American Diebold Group. Mr Diebold pointed to the superficial similarities between the R & D patterns in the UK and the USA, including similar proportions of GNP spent on R & D, and a similar balance between government and non-government funding. But he explained the success of the American technology-based industries—including the phenomena of "Route 128" and "Silicon Gulch"[2]—as mainly characterised by "demand-pull" factors, as opposed to "technology-push" factors. A "whole complex of qualitative market and attitude factors" included the creation by the US Government of demand for "task-oriented technology", mainly in the defence and space areas; a buoyant and growing economy; corporate willingness to take risks; and a prevailing mood sympathetic to materialism, profit and industry. His conclusion was not that there was consequently no role for government other than to nurture a healthy economy, or that there was nothing to gain from direct government support for R & D. Rather, there were "a number of fields in which the government can actively stimulate demand factors, directly and indirectly, that would 'auto-generate' the complex of conditions . . . needed to foster technology-based industry". Mr Diebold pointed to the field of environmental control as an area in which more stringent government standards and regulations in the USA "created a market for a great variety of technology based products that promoted the right conditions for significant technological development on a large scale"

[1] See K. Pavitt, "Government policies towards Industrial Innovation: a review", in *Research*

of the objectives" (Q 324).

6.8. Our industrial witnesses were in general agreement with Mr Diebold's emphasis on the significance of demand factors in the innovation process. It was nonetheless clear from their evidence that the process of innovation in high technology could not be regarded as a simple response to market demand, but rather as an interaction between scientific research and market research, scientific research being translated into product development at the moment when a potential market was matched to a technical concept. There are, indeed, outstanding examples of product development in which "technology-push" factors could be clearly identified in the initial stages—instances which conform in many ways to the caricature of the backroom boffin who simply comes up with an idea with inherent market potential. This would certainly seem to apply to the development of the original "Stereoscan" electron microscope by Cambridge Scientific Instruments (Q 413–4) and of the EMI Scanner (Q 532), although in both instances the companies concerned were working in a product area in which their corporate knowledge of the characteristics of the potential market was probably high from the outset, and in neither case was there any question of production prior to an assessment of the market.

6.9. EMI in particular gave interesting evidence on the development of the Scanner, and we were impressed by the importance which they attached to "the freedom to pursue new ideas to feasibility stage in early research work". They emphasised in particular the fact that if their Central Research Laboratory had not been given the freedom to pursue independent lines of research, and if the inventor of the Scanner had been working on 'Contract research', the result might merely have been "another optical character recognition machine". They nonetheless regarded regular contact with customers, identification of markets, thorough planning of market strategies and the "commitment of top management at an early stage of development" as factors of equal significance (p 177) and pointed out that it was only when "the need was created" that resources were poured into the development (Q 542).

6.10. Although the EMI case illustrates the complexity of the interaction between R & D functions and marketing functions, it does not belie the general thesis that the impetus to go down the line from research to product development is financial rather than technological. As the Managing Director of Hewlett-Packard Ltd explained to us, the innovation process was "very much a very careful assessment of what the market needs, and applying ourselves, with the technology that exists in the corporation, to meet those particular markets". Hewlett-Packard had first had to develop an R & D capability in the UK, but had then gone into very detailed assessments of the kind of equipment which their main customers would need to meet long-term developments. R & D and marketing operations were "pretty closely integrated to get a complete understanding of where the future lies from a development point of view" (Q 390).

6.11. It may seem naive to spell out the obvious importance of the demand factor in the process of technological development. Our purpose, however, is to emphasise the extent to which innovation is a complex activity, a complex *management* activity, in which the crucial variable appears to be the willingness or ability of a company's decision-makers to allocate resources to profitable ventures. These decisions will be based on perceptions both of technological opportunity and of market need. Our concern is that in the consideration by government of this complex activity the separate aspects should not be isolated and remedial measures applied to one or other aspect but not to the whole process.

6.12. In our view, there has been a tendency in the UK in recent decades for governments to give undue emphasis to research and development in the process of innovation and to attempt to place R & D in the role of "engine" of industrial success. This is manifested partly in the current debate about the level of R & D most appropriate for a country like Britain (is it too high, too low, or just right?) and more particularly by the very large proportion of government resources devoted to spectacular technological developments. With respect to the former, the available evidence suggests that the level of British R & D spending as a percentage of GNP is not much different from that of our main industrial competitors. More important, if our belief that industrial innovation is critically influenced by market factors is substantially correct, the "most appropriate" level of R & D activity is likely to relate more directly to industrial perceptions of market demand than to any notional proportion of GNP. The fact that the rate of growth of *industrially-financed* R & D throughout the 1960's was much lower in the UK than in the Netherlands, West Germany or France may therefore merely reflect the relatively depressed state of the UK market during that period.

6.13. As far as the latter point is concerned—that is to say, the high proportion of government investment in spectacular R & D—over 80 per cent of Department of Trade and Industry spending on civilian industry-related R & D in 1972–73 was spent on generally very large high-technology projects in the three fields of nuclear power, aviation and space (see Table 5). It is questionable whether this balance of expenditure can have made any great contribution to innovation or competitiveness in British industry. Because of tighter British budgetary controls, moreover, the spin-off into other industries and scientific fields is likely to have been minimal compared with the massive spin-off from the defence and space investment of the American federal authorities in the 50's and early 60's.

6.14. We are not alone in questioning the effectiveness of this high level of investment in big science and big technology. The Chief Scientist of the Department of Industry has gone on record several times in recent months with unequivocal warnings about the implications of the present pattern of resource allocation in government-financed R & D. In a recent speech to the Royal Society he said:—

> "If it is felt that the nation needs to seek to retain a conspicuous place in the world's scientific arena, then a heavy commitment to very large and expensive big science programmes may be inescapable. What I do argue, however, is that a very large proportion of the total Government R & D expenditure is *not* aimed at industrial improvements in any significant way. Where the objective has been an industrial one a significant portion has been aimed at a very small part of the total industrial pattern of the UK

DTI Spending on Civilian Industry—Related R & D 1972–73 (£ millions)

Sector	Type of R & D			
	Basic and applied R & D exploratory development and other STS	Commercial development	Total	Sector as percentage of grand total (including nuclear)
Aircraft	13·9 (14)	86·9 (86)	100·8 (100)	50
Space	7·8 (66)	3·9 (34)	11·7 (100)	6
Nuclear	?	?	49·2 (100)	24
Computers and Automation	3·6 (29)	8·8 (71)	12·4 (100)	6
Other industry	16·1 (60)	10·7 (40)	26·9 (100)	13
Total (excluding nuclear)...	41·4 (27)	100·3 (73)	151·7 (100)	100

Note: Figures in brackets are percentages of sectoral totals.
Source: Department of Industry, *The Economics of Industrial Subsidies* (HMSO, 1975), page 124.

Sir Ieuan Maddock's message is clear: heavy investment in R & D in these spectacular areas of technology may be desirable for other reasons, but it cannot be regarded as a means of stimulating industrial productivity—and hence economic growth—in any significant way. The implication, of course, is not that government investment in R & D is inherently of little value as a means of stimulating industrial growth, but that such investment, if it is to be effective, requires more careful allocation[1].

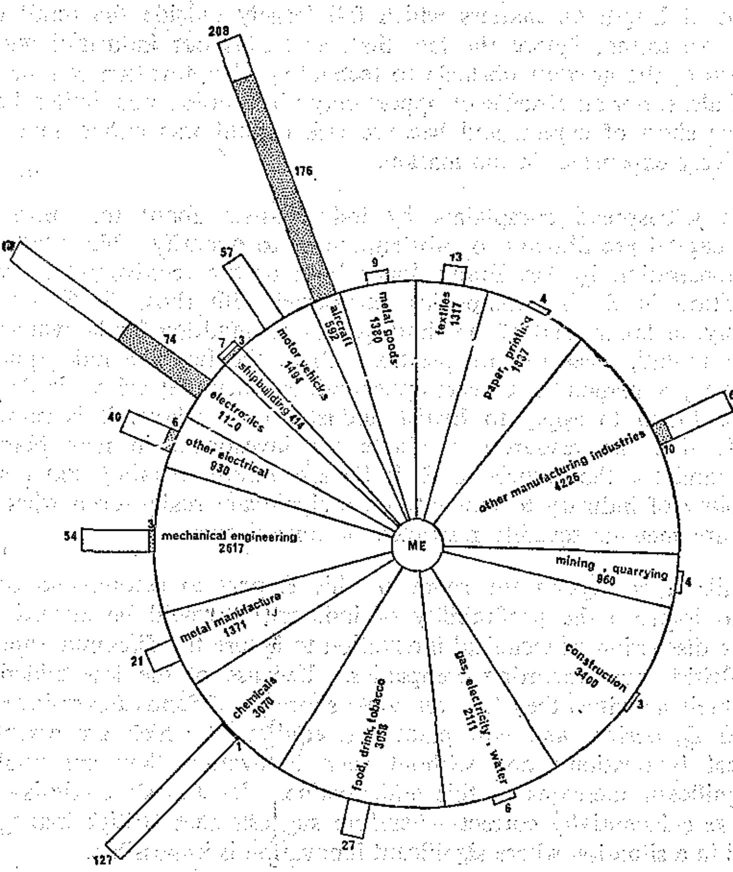
6.15. In our view R & D is better regarded not as the engine of industrial success but rather as an essential prerequisite for innovation leading to increased production and profitability. Seen in this light, the absolute level of overall R & D resources is less relevant than the distribution of those resources. Consequently, a lower level of R & D spending, effectively deployed, could provide greater benefit, in industrial terms, than a higher level of spending deployed in ignorance of industrial needs. But an improved deployment of R & D resources will not in itself stimulate innovation of a profitable nature unless other equally necessary conditions are met. The main conditions are (i) the existence of an R & D capability which is relevant to the needs of productive industry; (ii) the ability of industrial managers to recognise the opportunities for utilising R & D ; and (iii) the availabilty of sufficient capital to enable industrial management to utilise the R & D capability when the opportunity arises and is recognised.

6.16. The first of these conditions will be satisfied partly by the decisions of individual companies to maintain an in-house R & D capability suitable to their own purposes; partly by the provision of industrial R & D capacity on a

[1] We are aware that Sir Ieuan's analysis is not universally accepted. In an interesting recent article, for instance, Professor Berrick Saul has questioned the significance for industrial growth of a reallocation of R & D resources, arguing that " overall efficiency " and " market prospects " are of more importance (*New Scientist*, 23 September 1976).

TABLE 6

UK Net Output and R. & D. (1972, Provisional)



Source: The Seventh Royal Society Technology Lecture, 1976 Net output total £28 897M; R. & D. total £820M (shaded areas indicate government contribution; nuclear £50M. Sources: net output-business monitoring 1000 census of production provisional results 1972; R. & D.-Trade & Industry, 5 September 1974; nuclear-C.S.O.R. & D. expenditure.

vices, or industrially-relevant government research establishments; and partly by the organisation of the nation's capacity for fundamental research and of the training of research personnel in the context of an awareness of long-term industrial needs. The second condition will be met by the training of scientists and engineers to suit them for employment in managerial positions, by the employment in managerial positions of personnel with scientific and technical experience, and by effective channels of communication between the R & D function and the managerial function within individual companies and industrial sectors. Most of these points have been discussed in earlier chapters of this Report.

6.17. The third condition—the availability of capital—takes this Report into the wider area of general economic policy. While it is not our intention to comment at length on matters which fall largely outside the remit of the Committee, we cannot ignore the fact that, as far as our industrial witnesses were concerned, the greatest obstacle to technological innovation was neither a shortage of ideas, nor an absence of opportunity; innovation was limited because industry was short of capital and because risk capital was either unavailable, or prohibitively expensive, in the market.

6.18. The widespread complaints by industrialists about the shortage of investment capital are difficult to substantiate or to quantify. Nonetheless, the recent demonstration by Dr. Frank Jones both of the relatively low level of wealth creation in British companies, compared with those in Europe and, more notably, in Japan, and of the shortage of uncommitted funds available for further investment[1], gives rise to questions about the fundamental capacity of British industry to respond to market opportunities when they arise. If Dr Jones' findings are found to apply to British industry as a whole, it is reasonable to conclude that the resources available for investment in new plant and machinery (and for the associated R & D) are almost certainly too low, and that the ability of industry to innovate on a significant scale—even when other conditions are met—is severely restricted in consequence.

6.19. While it is beyond the scope of this Report to recommend detailed measures to improve the profitability of industry, it would be absurd in the context of a discussion of technical innovation to ignore the dilemma apparently faced by British manufacturing companies. Because of the low added-value earned by their activities they face an acute shortage of funds for re-investment in the R & D, design, and new plant and equipment which are essential to technological innovation; and without such innovation they are unable to achieve significant increases in this added-value. Dr Jones's analysis—which we accept as substantially correct—therefore suggests that British management are trapped in a situation where significant innovation is impossible.

6.20. The implications for government action are clear. **Not only must the Government seek to secure a greater emphasis on industrial relevance in the scientific and technical research and training conducted under government auspices, but they must also seek by taxation and other means to release industrial management from the "innovation trap" which we have described above.** It is a matter for political debate and judgment as to how the latter

[1] See QQ 462–499, *passim*.

aim can best be achieved, and the solution will doubtless reflect the political philosophy of the Government of the day. The interventionist approach—which is increasingly being pursued through the Research Requirements machinery of the Department of Industry—is directly to assist the innovation process by underwriting industrial research and development which will lead to significant increases in industrial production and profitability. The non-interventionist approach would be to increase the availability of funds for investment in new processes by a selective or more general easing of corporate taxes. Both methods are subject to the danger that the funds released by government may not be committed to projects leading to profitable innovation: interventionist methods require machinery sufficiently sensitive to industrial opinion to ensure that funds are invested in wealth-creating projects rather than spectacular technology; and non-interventionist methods must rely to some extent on the good faith of industry to ensure that the extra funds are re-invested, rather than distributed to shareholders. The ultimate solution, which we do not attempt to propound, is likely to be a mixture of measures of both kinds. Whatever these measures may be the Committee are in no doubt that **the stimulation of wealth-creating innovation should now be the principal activity of the Department of Industry.** The support of R & D in its own right, in the absence of the overriding objective of increasing the added-value of industrial operations, will do little to help the economy in the foreseeable future.

7.1. To ask questions, as we have done, about the transfer of knowledge from university to industry is to imply that universities should be expected to make a direct contribution to economic progress. It implies that ultimately universities can be assessed in "value for money" terms. This is not a popular view in the universities. Nor, as far as much university research is concerned, has it been popular with government. Even Lord Rothschild insisted that the "customer-contractor" principle could only be applied to research which was mission-oriented: and that the money transferred from Research Councils to Government Departments should represent only that part of the Research Councils' funds which went on applied research. As a result the Science Research Council was left untouched by the Rothschild reforms[1]. The present Science Budget is therefore intended to be spent by the Research Councils solely for the purposes of maintaining scientific standards and supporting scientific education and research.

7.2. In fact this traditional view of "basic" research is obsolete: the choice of subjects for research in the universities, like the nature, quality and quantity of the scientific education provided, has a direct effect on the nation's capacity to undertake applied research oriented towards specific social and economic objectives. If decisions about the funding of research and postgraduate courses were to be based solely on academic criteria of excellence, timeliness and promise that capacity could not be *guaranteed,* even with unlimited funds and unlimited scientific manpower, although in such a situation the combination of academic decisions and the market place for jobs might produce a basic research and training pattern which approximated to overall national needs. But funds, far from being unlimited, are in decline; and the manpower is going elsewhere and in increasing numbers. A system based on the view that if you provide reasonably competent research workers with adequate funds and facilities then you will produce the knowledge and skills which the nation requires is a luxury which this country has probably never been able to afford, and certainly cannot afford in present circumstances.

7.3. The Research Councils are of course well aware of this fact and therefore no longer claim to base their decisions on academic criteria alone. Indeed, if the published statements from the Research Councils were taken literally, one might even conclude that *all* decisions are now taken by the Research Councils after earnest consideration of "national need". This is an international phenomenon: a recent OECD report on the subject commented that as a result many research projects "profess their relevance to the problems of society or the environment, in order to be 'in the swim', but have scarcely changed their content since the recent days when they were 'disinterested research'"[2]. That may or may nor be fair. But it is certainly fair to ask what agencies like the Research Councils mean in practice by "national need"; and whether they are in any case equipped or qualified to employ such a criterion. To take the extreme case, the "national need" as perceived by high-energy physicists may well be for a sufficiently large stock of accelerators to keep British high-energy physics at the front of the field and to employ all the high-energy physicists who are looking for jobs. A committee of high-

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1 *A Framework for Government Research and Development,* 1971 (Cmnd 4814), para 25.
2 OECD, *The Research System* (Vol I) (1972), page 35.

energy physicists is likely to say just that. A more senior committee composed of biologists, engineers and chemists as well as high-energy physicists will probably conclude that the stock cannot be maintained at that level because the cake at their disposal is not big enough both to provide the stock of accelerators and at the same time to meet the national need as perceived by committees of biologists, engineers and chemists elsewhere in the same building. The logs are rolled and the cake is divided: but nobody challenges the perception of the high-energy physicists. Who is there to ask the prior questions: "Do we want our high-energy physics to be at the front of the field? Do we want to give jobs to our high-energy physicists?" And who is there to answer those questions?

7.4. The case of the high-energy physicists is imagined. It is a caricature. It is almost certainly grossly unfair: in recent years, after all, the high energy physicists have been losing ground: their slice has been getting thinner. But in essence this is the only way decisions can be taken when the people who cut the cake also consume the slices.

7.5. The tendency of the Research Councils to talk in terms of "national need" is an understandable reaction to a situation in which too many individuals and departments are chasing too little money, and when the value of money available is falling. The Councils are compelled in this situation to defend themselves from government and public criticism by justifying their actions in terms which they consider comprehensible to their non-scientific critics: and the criterion of "national need" is a convenient rejoinder to the increasing number of applicants who have to be refused grants because of lack of funds. Their new rôle is evidently not one which the Research Councils particularly relish: they are only too aware that if they make the wrong assessment of national need they will be criticised as irresponsible, and yet they also know that the assessment of national need is not a function for which they are particularly well-equipped. Witness the plaintive remarks of the Science Research Council in their Report on Advanced Ground Transport (October 1975):

> "Not infrequently such reviews are also called upon to strike a balance between the ill-defined, long-term needs of society on the one hand and the importance of encouraging fundamental research which may transform the criteria whereby these needs are judged on the other. In that respect this review has been a particularly awkward one to carry out. In particular, innovation on a national scale involving massive expenditure is necessarily associated with a lengthy time-scale and economic planning operations and reseources which are neither available to, nor the responsibility of, the Council. At the same time, probabilities must be taken into account and due note taken of common tendencies for too precise predictions to be made too early and for necessary technologies to follow rather than to anticipate the recognition of social and economic needs. Furthermore, the Council's primary role is providing advanced training of scientists and engineers and advancing knowledge in science and engineering to form the basis of future developments in technology."

Such a statement makes clear the Council's awareness of the exposed position in which they find themselves: it is inevitable that somebody will ask with what position in the first place. They are academic bodies [illegible] excellence: their decision making responsibility should lie solely in the assessment and support of academic excellence. They may advise on national needs in particular areas—but they should not be allowed to decide. They should also be asked to act in the national interest—but they should not be expected to determine where that interest lies.

7.7. A recognition of the need to isolate the Research Councils from the responsibility for taking decisions about national needs was one of the motivations underlying the reforms in Research Council funding recommended by Lord Rothschild, and accepted by the Government in 1971. Lord Rothschild noted that an appreciable part of the work of the Medical Research Council, the Agricultural Research Council and the Natural Environment Research Council was "applied" and argued that "However distinguished, intelligent and practical scientists may be, they cannot be so well qualified to decide what the needs of the nation are, and their priorities, as those responsible for ensuring that these needs are met. That is why applied R & D must have a customer"[1]. As a result a substantial proportion of the funds of those three Research Councils, representing their "applied" work, was transferred to the appropriate Government Departments, who then assumed responsibility for commissioning applied research from the Councils in accordance with departmental perceptions of national need. No funds were transferred from the Science Research Council because it was largely concerned with "pure, and to a larger extent applied *science*"[2].

7.8. It is arguable whether Lord Rothschild was correct in entirely excluding the SRC from the operation of the "customer-contractor" principle. He drew a distinction between *applied* R & D, which had a product, process or method of operation as its objective, and *basic* research, which was concerned with "the discovery of rational correlations and principles"[3]. It is curious that Lord Rothschild did not regard that part of the SRC's budget directed to research in engineering as falling within his definition of "applied" research and therefore subject to the customer-contractor principle. The Richards Report describes research in engineering as an activity which "achieves its culmination in some evident way at a later date—a new product or process, a decision to pursue or not to pursue a line of development, a modification to an existing piece of equipment, a more accurate means of assessing performance, etc"[4], a definition very close to Lord Rothschild's description of applied research. In view of the fact that some 12 per cent of SRC's expenditure is now devoted to engineering[5] we believe **there is a good case for the transfer of a proportion of the Council's funds to the Department of Industry, which is the natural "customer" department for the applied research supported by the SRC.** This would help to bring the funding of the SRC into line with that of the other major Research Councils.

7.9. Our objective is not to restrict the freedom of the Science Research Council to take the decisions which they are qualified to take. Rather, we are

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[1] Cmnd 4814, para 8.
[2] *ibid*, para 25.
[3] *ibid*, para 7.
[4] SRC, *Academic-Industrial Collaboration in Engineering Research*, para 15.
[5] SRC, *Annual Report 1975-76*, October 1976 (HC 635, Session 1975 - 76.

concerned that the scientific decision-making structure should be constructed according to rational principles which ensure that decisions are taken at the appropriate level by people with the appropriate skills and responsibilities. A coherent structure for scientific decision-making should aim to ensure

(i) that politicians determine policy objectives and priorities

(ii) that government departments identify the R & D and manpower needs required to meet these policy objectives, and allocate available resources in accordance with those priorities, and

(iii) that scientists determine the most efficient means of employing the resources allocated to meet the needs identified by the departments.

This is the operating principle of the " customer-contractor " system, and the evidence available to date suggests, so far as the Research Requirements machinery of government departments is concerned, that it is working with some success.[1]

7.10. So far as the Science Research Council is concerned, however, we are worried that a confusion of responsibilities and a failure of direction from above is inhibiting the Council in exercising its responsibilities for the support of university research and training with sufficient vigour and single mindedness. We noted above (para. 7.5) the Council's comments on their difficulties in carrying out reviews of research needs when national priorities are inadequately defined, and we have commented further on that particular instance in our recent Report on Advanced Ground Transport[2]. Similarly, when the Chairman of the SRC gave evidence to us on the subject of engineering education he emphasised the difficulties created by the fact that " it is not clear what the job is that the nation wants or indeed whether the nation knows what it wants " (Q 77). Accordingly, while the SRC are trying to do " something " about postgraduate training they are not getting guidance from Government about the overall objectives to be pursued and cannot therefore be expected to carry much weight with individual universities who may disagree with the Council's perception of national requirements.

7.11. The Richards Report has indicated that in the field of engineering research university departments " would willingly accept a more aggressive approach by SRC and other national bodies towards the formulation of policy and the promotion of the research that flows from it "[3]. In view of the scarcity of resources in terms not only of money but also of existing physical resources and manpower we are convinced that the development of a coherent set of research priorities is vital. We are aware that the SRC Engineering Board has already taken the initiative in promoting " research and study in selected areas which are not adequately covered by spontaneous research proposals " and is devoting nearly 45 per cent of its funds to this end (p 21). But, as the Richards Report suggests, " there is no overall plan to ensure that the Board has made decisions that are fitting in a national context ". Professor Richards goes on to suggest that there should be an inhouse SRC " research policy-defining activity " to enable the Engineering Board " to choose between broad options in the light of knowledge

[1] See, for instance, M Gibbons and P Gummett, *The Origins and Early Years of the Research Requirements Boards of the Department of Industry*, Science Council of Canada (January 1976)

that SRC have already gone some way to adopting it (p. 24). We are indeed somewhat surprised to discover that such a policy-defining function has not been previously undertaken by SRC. But we would not be happy if it resulted in the abdication by government departments of their overriding responsibility for identifying and promoting areas of national need. That responsibility, as the SRC's Director of Engineering recently told our General Purposes Sub-Committee, " lies somewhere else in the system . . . national objectives are quite clearly not going to be laid down by the SRC "[2].

7.12. One partial solution to ensuring that departments exercise their responsibilities is by use of the customer-contractor principle, and we have suggested (paragraph 7.8 above) that that principle might be invoked in respect of a part of the SRC's budget. Another partial solution adopted by the Government has been to expand the Advisory Board for the Research Councils, which advises on the distribution of the Science Budget between the various Research Councils, to include the Chief Scientists of the main Government Departments, and, since January 1976, the Head of the Central Policy Review Staff. This development, which goes some way towards reducing the inevitable element of horse-trading in the deliberations of the ABRC, is to be welcomed, and it is evident from the recent recommendations of the ABRC concerning the transfer of resources away from " big science " that an attempt is being made by the Board to develop a coherent forward strategy for the overall development of the Research Councils.

7.13. When the Select Committee of Session 1971-72 considered the organisation of government R & D they recommended the appointment of a Minister for Research and Development who would, amongst other responsibilities, act as Chairman of a statutory Council for Science and Technology[3]. The proposed Council for Science and Technology would have been responsible for advising the Government on the " formulation of policy and priorities for expenditure on civil and defence research and development ", and advice on the distribution of the Science Budget to the Research Councils would have been provided by a Committee for the Research Councils established by the Council[4].

7.14. In the light of the commitment by the present Government, like its predecessor, to the principle of functional departmental responsibility for R & D[5], these proposals are no longer realistic, although at the time they offered an equally coherent conceptual alternative to the present post-Rothschild system. The Government have now gone some way towards correcting the excessive emphasis on functional responsibilities by establishing an Advisory Council on Applied Research and Development, to be chaired by the Lord Privy Seal as Minister responsible for the coordination of government R & D. ACARD, as it will inevitably be known, has advisory responsibilites somewhat similar to those proposed by the Committee for the Council on Science and Technology. Amongst these responsibilities is the articulation of applied R & D " with

1 SRC, *op cit*, para 35. See also *SRC Annual Report 1975-76*, pp. 38-9

2 HC 286 (Session 1975-76), Q 97.

3 Ministers with similar responsibilities have been appointed in a number of countries, including Canada, Japan, and the Federal Republic of Germany (see *First Report from the Select Committee on Science and Technology*, Session 1975–76, HC 87, para 13).

4 *First Report from the Select Committee on Science and Technology*, Session 1971–72 (HC 237), paras 43–49, 91.

5 See, eg, Cmnd 5711 (August 1974).

scientific research supported through the Department of Education and Science "[1]. We welcome this development and **recommend that ACARD should review the relationship between government-supported applied R & D and government-funded basic research as a matter of urgency.** In particular they should examine the operation of the customer-contractor relationship, and of the ABRC, to ensure that effective machinery exists for relating basic science policies to long-term departmental R & D strategies.

7.15. **We recommend further that the reviews carried out by ACARD should normally be published; and that the Lord Privy Seal, as Chairman of the Advisory Council, should make annual reports to Parliament on the work of the Council.**

7.16. It is not our intention to make sweeping recommendations for changes in the organisation of government R & D, which is, in any case, outside the scope of the present inquiry. Whatever misgivings the Committee may have had in 1972 the functional organisation devised by Lord Rothschild has now had an opportunity to become established and we are encouraged by the recent changes in the Cabinet Office which indicate the willingness of the Government to respond flexibly to needs which become evident as the system settles down. In 1972 our concern was to ensure that government R & D strategy was not distorted by short-term conceptions of need flowing from the exercise by departments of their proxy " customer " role, and that long-term needs, not particularly related to the needs of individual departments, were not thereby ignored. The creation of the new Committee of Chief Scientists and Permanent Secretaries, and of ACARD, indicates that the Government now recognise this danger and are strengthening the machinery for examining longer-term research and manpower requirements at an interdepartmental and extra-departmental level. We remain concerned about the need to ensure that adequate political control is exercised over R & D decisions which may have profound long-term effects on the community, but we believe that only time will demonstrate whether the new coordinating machinery is adequate for this task. We are encouraged, although not totally convinced, by the former Lord Privy Seal's assurance that the danger of " slippage " in this field " would not be of any significant size " (Q 1035).

7.17. The combination of strong research requirements machinery in the departments and stronger machinery at the centre ought to be sufficent to ensure that R & D requirements are identified and matched to meet Cabinet and departmental policy. It is then a matter of concern to ensure that these R & D requirements are communicated to the Research Councils and translated by them into policies for funding research of a more basic character, and for funding relevant postgraduate training, to meet those requirements in the longer term. The latter process is not necessarily one to be formalised into more bureaucratic machinery. Ideally, the publication by the Department of Energy, for instance, of their recent Energy R & D strategy[2], should be sufficient indication to the SRC—and to other Research Councils concerned, such as NERC—of the lines which their own policies should follow. Much therefore depends on the efficiency with which departments themselves identify and publicise their R & D strategies.

that departmental views are communicated down the line, particularly in research areas involving more than one Research Council. In particular, the Advisory Board for the Research Councils provides an existing mechanism for such communication, since it is the formal meeting place of representatives of the Research Councils and the departments. The ABRC has already established machinery specifically to deal with energy matters and with other matters such as genetic engineering and taxonomy[1]. We recommend the extension of this practice. We also recommend the establishment of lines of communication between the new Advisory Council on Applied R & D and the ABRC to ensure an efficient input from the one to the other.

The independence of the Research Councils

7.19. It is not our intention to suggest that the Research Councils should merely act as grant-awarding bodies pursuing policies dictated by government departments. There are broad areas of research and postgraduate training in the fundamental sciences where close direction from government would be damaging and unproductive. And in those areas where policy guidance is appropriate the Councils have an essential role to play in feeding up the line the views of the scientific community on research possibilities and the financial and physical requirements necessary to achieve departmental goals. We are concerned, however, that the Research Councils should not be expected to perform the role of determining R & D strategy—or even policy-formulation—which should be performed in the departments, in Cabinet and finally in Parliament. If they do slip into this role it is more likely a response to the absence of clear departmental guidance than any positive desire by the Councils to usurp responsibility not properly their own. The responsibility therefore rests firmly with government departments to provide clear and effective guidance and advice.

7.20. We have already indicated our support for the principles of the dual system for the support of research in the universities by the Research Councils, on the one hand, and the University Grants Committee on the other hand[2]. We see no reason to change that view. We have also emphasised previously the importance of maintaining a sufficiently sound "floor" of support from UGC funds to ensure that universities are free to undertake a reasonable volume of speculative research without any interference from outside agencies. Given effective guidelines from Government, we believe that the Research Councils are efficient instruments for providing selective support for research in the higher education system.

7.21. In previous Reports we have commented on complaints from some in the university world about the procedures of the Science Research Council for assessing grant applications and about the extent to which the Council's committees and boards could be regarded as representative of the academic community. We also, in our last Report, published an analysis of the distribution of SRC grants to individual research workers[3]. The Council have replied that although the latter analysis is basically sound from a mathematical point of view, "it would not be sound to draw any conclusions whatsoever about

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[1] *See Second Report of the ABRC*, 1974–75, Cmnd 6430 (1976), para 44–8.
[2] First Report from the Select Committee, Session 1975–76 (HC 87), para 15.
[3] *ibid*, Annex II.

the working of SRC policy from the analysis "[1]. If that is the case, we believe that SRC should be prepared to provide the academic community and Parliament and the public with more adequate and regular information about the distribution of their research grants and studentships, on which sounder conclusions may be based. The SRC are responsible for the distribution of substantial funds and the nature of that distribution has even greater strategic importance than the size of the funds suggest. They should be prepared to be completely open about the methods of grant distribution, and should welcome attempts to evaluate the practical effects of their publicly stated policies for research support.

7.22. We suggested in our last Report[2] that there was " room for further study of the extent to which the existence of a handful of highly-favoured university scientists may influence the formulation of SRC policy ". We continue to believe that such study should be undertaken—particularly to examine the extent to which those who receive funds participate in awarding those funds. We do not mean to imply, however, that there should be any departure from the principles of the peer-review system[3], and it is clear from overseas experience that, without the creation of a dangerously powerful bureaucracy, the peer-review system is the only effective means by which the academic community can distribute funds for basic research. We believe that the studies we suggest may demonstrate the need to widen the membership of reviewing bodies, and that that may in itself help to increase the acceptability of SRC decisions in the academic community at large. But we totally reject the more extreme proposals put to us by some disappointed applicants for grants for the abandonment of peer-review in favour of " representative " grant awarding bodies[4].

7.23. Sir Sam Edwards, the Chairman of the Science Research Council, has argued elsewhere that " Members of Parliament pay far too much attention to the Research Councils relative to their consideration of the massive expenditure of money on research going on outside the Research Councils "[5]. However, the development of fundamental knowledge and the training of highly-qualified manpower of today inevitably affects the ability of the nation to perform the applied R & D of tomorrow. Although Research Council expenditure is relatively small, its distribution is critically important for the future and in our view, therefore, it is at least as important to ensure that the Research Councils are pursuing policies which reflect national priorities and needs, as to ensure that the larger sums spent on applied R & D are spent on the right R & D.

[1] Memorandum 27.

[2] HC 87, para 21.

[3] We note the helpful description of the operation of the system in the SRC *Annual Report for 1975-76*, page 1.

[4] A very extreme proposal of this kind is put forward by Dr P S Davison in respect of the

8.1. This Report has surveyed a number of acutely difficult and complex problems facing the universities and industry in Britain, and the government departments and agencies responsible for providing support for both sectors. The Committee recognise that there are no easy solutions to these problems, and that apparently attractive schemes for remedying one problem may have unacceptable or unexpected consequences in relation to other problems. We accept that that may be the case with some of the specific recommendations in the body of this Report. But all those recommendations are at least consistent with what we believe should be one of the central aims of government policy during the next few years: namely **the creation of an environment in which the undoubted scientific and technical expertise of the people of Britain can be directed towards the recreation of a healthy and expanding industrial economy.**

Educational policy

8.2. We have come to the conclusion that in order to overcome the widely recognised malaise in the higher education of engineers and technologists a concerted effort must now be made to raise the quality, status, and appeal of scientific and technical studies in schools, in universities, and in society at large. This may be achieved partly by concentrating resources in institutions with the facilities and prestige sufficient to attract students and teachers of the highest calibre; partly by pursuing with determination the proposals of the Science Research Council for industry-related postgraduate studies; and partly by making a greater attempt to involve industry at all levels in the education process itself. But the process must begin in the schools.

8.3. We believe that measures of the kind we have suggested are vital, but we realise the fears which they may arouse in the academic community about government interference with traditional university freedom. These fears are quite proper. The independence of the universities is rightly regarded as an essential protection of intellectual liberty, and we do not wish to see the universities become agents of the State, teaching and studying only those matters regarded as important by the State. On the other hand, that liberty must not be regarded as a licence to ignore the needs of the society of which the universities are a part.

8.4. We believe that our proposals are not inconsistent with the maintenance of university independence, so long as the universities themselves recognise and respond to the legitimate pressures now coming from the rest of the community. Accordingly we hope that much of what we and others are proposing will be taken up without the need for government direction. We hope that the universities and the agencies which act as buffers between them and the State, namely the Research Councils and the University Grants Committee, will take the initiative. But we believe that the Government and Parliament have a responsibility to the community at large to provide the political lead and encouragement to enable the universities to adjust to the demands which are now being made of them.

Industry

8.5. We have made a number of proposals designed to facilitate the transfer of knowledge from universities to productive industry, to improve the deployment of qualified personnel in industry, and to increase the attraction of industrial employment for high calibre scientists and engineers. There are some measures which clearly can—and should—be taken by the Government, including measures to improve the pay of qualified industrial personnel and institutional changes such as those proposed in relation to the National Research Development Corporation. But individual companies, like individual universities, must recognise that the solution of many of the problems is in their own hands.

8.6. It is abundantly clear, however, that the process of innovation in industry is dependent on the availability of private capital. Whatever steps are taken by Government to improve relations between universities and industry, the need to provide incentives for industrial innovation will remain.

LIST OF WITNESSES*

Wednesday 26 *November* 1975 (HC 23—i)

Standing Advisory Committee on Relationships between Higher Education and Industry

Professor M J Frazer, Professor C Eaborn, FRS, Dr A K Barbour, Dr J W Barrett, CBE and Dr M D Robinson, ARIC

QQ 1–41

Wednesday 3 *December* 1975 (HC 23—ii)

Science Research Council

Professor Sir Sam Edwards, Mr J M Ferguson, Professor G Allen, Mr A G Senior and Mr A J Egginton

QQ 42–103

Thursday 4 *December* 1975 (HC 23—iii)

National Research Development Corporation

Mr W Makinson, MSc, FRAeS, CEng, MIEE and Dr J C Cain, ARIC, FIBiol

QQ 104–171

Tuesday 9 *December* 1975 (HC 23–iv)

Science Departments, University of Cambridge

Professor Sir Brian Pippard, FRS, Professor G V R Born, FRS, Professor J F Davidson, FRS, Professor R W K Honeycombe and Professor W A Mair

QQ 172–217

Wednesday 10 *December* 1975 (HC 23—v)

Cambridge Science Park

Dr J R G Bradfield, Mr P Woodsford, Mr P J Gilgallon, Mr S Goodfellow, Mr Unwin, Mr C R Buxton and Professor O R Frisch

QQ 218–256

Monday 19 *January* 1976 (HC 23—vi)

Director of Patscentre International, Cambridge

Mr Gordon Edge

QQ 257–312

Thursday 22 *January* 1976 (HC 23—vii)

Chairman of Diebold Group Inc

Mr John Diebold

QQ 313–331

Wednesday 28 *January* 1976 (HC 23—viii)

Hewlett-Packard Ltd

Mr Dennis P Taylor and Mr Robert Coackley

QQ 332–398

The Cambridge Instrument Co Ltd

Dr E D Barlow

QQ 399–420

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* The Evidence taken before the Science Sub-Committee, together with the Memoranda submitted by witnesses, have been published in parts as House of Commons Paper No. 23—i–xx, Session 1975–76.

Wednesday 11 *February* 1976 (HC 23—ix)

The Oxford Instrument Company Ltd

Mr M F Wood, Mr G B Marson and Dr J B McKinnon

QQ 421–461

Wednesday 18 *February* 1976 (HC 23—x)

Dr Frank Jones, FRS

QQ 462–499

Wednesday 25 *February* 1976 (HC 23—xi)

EMI Ltd

Mr John Read, Dr John Powell, Mr William Ingham and Mr Jon Chaplin

QQ 500–554

Wednesday 3 *March* 1976 (HC 23—xii)

British Steel Corporation

Mr C E H Morris, Dr R S Barnes and Mr John Baker

QQ 555–588

Monday 8 *March* 1976 (HC 23—xiii)

Plessey Company Ltd

Mr W R Thomas and Mr D H Roberts

QQ 589–639

Wednesday 10 *March* 1976 (HC 23—xiv)

Swan Hunter Shipbuilders Ltd

Dr P A Milne and Dr F Taylor

QQ 640–701

Wednesday 17 *March* 1976 (HC 23—xv)

Y-ARD Ltd

Mr F D Penny and Mr J Neumann

QQ 702–760

Wednesday 24 *March* 1976 (HC 23—xvi)

Lucas Industries Ltd

Mr J J Righton and Mr Ewen M'Ewen

QQ 761–826

Wednesday 7 *April* 1976 (HC 23—xvii)

Principal of the University of Manchester Institute of Science and Technology

The Lord Bowden

QQ 827–857

Thursday 1 *July* 1976 (HC 23—xviii)

Secretary of State for Education and Science and Officials

Rt Hon Frederick Mulley, MP

Secretary of State for Industry and Officials

Rt Hon Eric Varley, MP
Sir Ieuan Maddock and Mr Martin Lam

QQ 899–968

Tuesday 6 *July* 1976 (HC 23—xx)

The Lord Privy Seal and Officials

Rt Hon Lord Shepherd
Sir Kenneth Berrill and Dr Robert Press

QQ 969–1036

APPENDIX II

LIST OF MEMORANDA*

HC 136—i

1. Memorandum by Dr Ron Johnston, Department of Liberal Studies in Science, University of Manchester
2. Memorandum by the Standing Conference of Professors of Physics
3. Memorandum by Computer Technology Ltd

HC 136—ii

4. Memorandum by the Social Science Research Council
5. Memorandum by the University Grants Committee
6. Memorandum by the Principal and Vice-Chancellor, Heriot-Watt University
7. Memorandum by the Vice-Chancellor of Lancaster University
8. Memorandum by the Director of the Wolfson Foundation
9. Memorandum by Professor D E Hughes, University College, Cardiff
10. Memorandum by the Wellcome Trust
11. Memorandum by the Scientific Instrument Manufacturers' Association
12. Memorandum by the Shipbuilders and Repairers National Association
13. Memorandum by the British Ship Research Association
14. Memorandum by the Electrical Research Association
15. Memorandum by the Machine Tool Industry Research Association
16. Letter to the Clerk of the Sub-Committee from the Managing Director of Sira Institute Ltd
17. Letter to the Chairman of the Sub-Committee from the Managing Director of Cambridge Consultants Ltd
18. Memorandum by Professor Donald Michie, Machine Intelligence Research Unit, University of Edinburgh
19. Letter to the Clerk of the Sub-Committee from Professor J Loxham, Cranfield Unit for Precision Engineering
20. Letters to the Clerk of the Sub-Committee from Professor R M S Smellie, Cathcart Professor of Biochemistry, University of Glasgow
21. Memorandum by the Institution of Professional Civil Servants
22. Memorandum by Mr Ronald Amann, Centre for Russian and East European Studies, University of Birmingham

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23. Memorandum by the Department of Industry
24. Memorandum by the Department of Education and Science
25. Memorandum by the Lord Privy Seal

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26. Further memorandum by the University Grants Committee
27. Memorandum by the Science Research Council
28. Further memorandum by the Science Research Council
29. Memorandum by the Confederation of British Industry

* *Note:* The Memoranda listed here are published in House of Commons Paper No 136—iiv (Session 1975–76) and are additional to those submitted by witnesses before the Science Sub-

31. Memorandum by the Trades Union Congress

32. Memorandum by the Association of University Teachers

33. Memorandum by the Committes Vice-Chancellors and Principals of the Universities of the United Kingdom

34. Memorandum by Members of the UDIL Group

35. Letter to the Clerk of the Science Sub-Committee by Dr E J Duff, University of Manchester Research Consultancy Service

36. Letter to the Clerk of the Science Sub-Committee from Dr A R Lansdown, Director, Swansea Tribology Centre, University College of Swansea

37. Letter to the Clerk of the Science Sub-Committee from the Principal of the University of Strathclyde

38. Memorandum by the Heads of Polytechnic Chemistry Departments

39. Memorandum by Dr P S Davison, Research Director, Scientific Documentation Centre, Dunfermline

40. Memorandum by the British Library

41. Memorandum by the Cranfield Institute of Technology

42. Memorandum by Mr Graeme Norris, Centre for Computer Studies, University of Leeds

43. Exchange of letters between the Clerk of the Science Sub-Committee and the National Research Development Corporation

44. Memorandum by Professor A W J Chisholm, University of Salford

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45. Memorandum by the Institution of Mechanical Engineers

46. Exchange of letters between the clerk of the Science Sub-Committee and the Chief Scientist, Department of Industry (extract)

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