

PART 4

CONFIDENTIAL FILING

ACARD

GOVERNMENT

MACHINERY

- 1. ACARD Report on Medical Equipment
- 2. Revised Report on Exploitable Areas of Service

Part 1: May 1979

Part 4: March 1986

Referred to	Date	Referred to	Date	Referred to	Date	Referred to	Date
6.3.86							
4.4.86							
14.4.86							
19.6.86							
25.6.86							
29.7.86							
18.12.86							
PT4							
GNDS							

PREM 19/1769

PART 4 ends:-

PAB to T. WOOUGT 18/12/86

PART 5 begins:-

SS/DHSS to PM 17/1/87



file *SP*

10 DOWNING STREET
LONDON SW1A 2AA

From the Private Secretary

MR. WOOLLEY
CABINET OFFICE

**GOVERNMENT RESPONSE TO ADVICE FROM THE
ADVISORY COUNCIL FOR APPLIED RESEARCH
AND DEVELOPMENT (ACARD)**

The Prime Minister has seen Sir Robert
Armstrong's minute of 12 December.

She is content with the Government response,
and has written to Sir Francis Tombs
as in the draft.

P A BEARPARK
18 December 1986

dg



10 DOWNING STREET
LONDON SW1A 2AA

THE PRIME MINISTER

18 December 1986

Dear Sir Francis,

At our meeting on 25 July we discussed ACARD's comments on the 1986 Annual Review of Government Funded R & D, and I said I shared ACARD's anxiety to improve the wealth-creating potential of Government R & D expenditure, to improve the scope for technology transfer (particularly on defence contracts) and to encourage industry to invest more in R & D.

ACARD's comments have been an important contribution to the Government's thinking on how to secure these objectives. I am sending you the formal Government response to ACARD herewith.

Kind regards,

Yours sincerely

Roger Handberg

Sir Francis Tombs

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CF
 ✓ cc. adding with
 + pps / pm
 AB ✓
 SR
 For hys
 12/12

Ref. A086/3447

PRIME MINISTER

Prime Minister

Content to sign the attached?

Government Response to Advice from the Advisory Council for
 Applied Research and Development (ACARD)

Attached for your approval is the proposed Government response to ACARD's advice on the 1986 Annual Review of Government Funded R & D.

2. When you discussed ACARD's advice with Sir Francis Tombs, Chairman of ACARD, on 25 July, you told him that you were glad to hear that John Fairclough would be co-ordinating a general Government response. Attached is a draft letter which you may like to send to Sir Francis.

3. The response has been cleared with all those Ministers with a significant involvement with R & D.

RA

ROBERT ARMSTRONG

12 December 1986

87288J

DRAFT LETTER FROM THE PRIME MINISTER TO
SIR FRANCIS TOMBS, CHAIRMAN, ADVISORY COUNCIL
FOR APPLIED RESEARCH AND DEVELOPMENT

At our meeting on 25 July we discussed ACARD's comments on the 1986 Annual Review of Government Funded R & D, and I said I shared ACARD's anxiety to improve the wealth-creating potential of Government R & D expenditure, to improve the scope for technology transfer (particularly on defence contracts) and to encourage industry to invest more in R & D.

Acard's comments have been an important contribution to the Government's thinking on how to secure these objectives. I am sending --- you the formal Government response to ACARD herewith.

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GOVERNMENT RESPONSE TO ADVICE FROM THE ADVISORY COUNCIL FOR APPLIED
RESEARCH AND DEVELOPMENT (ACARD) ON THE 1986 ANNUAL REVIEW OF
GOVERNMENT FUNDED R & D

1. The Government are grateful to ACARD for undertaking this annual exercise. There is much in the ACARD commentary with which the Government readily agree, notably the emphasis given to the importance of evaluation of R & D programmes, to the importance of technology transfer and to the need for technologies developed for defence to be applied in the civil sector.
2. In terms of the context and emphasis of the ACARD comments, however, the Government make two general observations. The first is that, while they welcome ACARD's endorsement of the need to assess the wealth-creation potential of publicly funded R & D programmes, this should not be interpreted too narrowly to refer only to the interests of industry. Apart from other forms of economic benefit, publicly funded R & D also has wider socio-economic benefits which are not dealt with in ACARD's comments. This particularly applies to medical, environmental and social research. The second observation is that the commercial exploitation of technology is first and foremost the responsibility of industrial and commercial firms. Our shared concern about levels of R & D spending in the UK, and the comparative international disadvantage that may arise, must start from the willingness and ability of firms themselves to undertake, fund and exploit R & D for their own benefit.
3. In the more specific comments which follow, the numbers in brackets indicate the appropriate paragraphs in ACARD's comments.

Issues Arising From Comments on Earlier Annual Reviews

4. ACARD are aware that their earlier advice in 1984 & 1985 contributed to the decision to establish new Ministerial and official machinery which has as its main task the development of policies which will enhance the contribution of R & D expenditure, both public and private, to improving the efficiency, competitiveness and innovative capacity of the United Kingdom economy. ACARD have been invited to assist in this work and will be kept informed as it proceeds.

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5. The Government acknowledge that there may not always have been clear lines of co-ordination between Departments with a shared interest in R & D projects (1.4). ACARD recommend that a central fund of £250,000 per annum be established for enabling and primary investigations on R & D matters of wide interest. The Government have made available to ACARD the sum of £75,000 per annum to commission research papers and to assist in preparation of reports. Some provision is likely also to be made for the new Cabinet Office Science and Technology Assessment Office. Additional central expenditure would need to be considered against a statement of what is to be achieved, by when and how this achievement is to be measured.

6. The Government are exploring ways of encouraging private sector R & D (1.5), and welcome ACARD's assistance. The Government place considerable stress on the need for greater private sector commitment to the funding and exploitation of R & D. With inflation brought down and significant improvements achieved in company profitability, liquidity and capacity utilisation, the commercial environment should now be more conducive to all forms of investment in future commercial success, including innovation and the exploitation of R & D than it has been for many years. The Government consider that the key to the contribution which civil R & D makes to the economy is not so much the level of public spending itself as the priority given by the private sector to R & D expenditure, which they hope will increase as the business climate continues to improve.

7. The Government are examining the level of public spending on civil R & D - by Government Departments, Research Councils and universities - in this year's and future public expenditure surveys (PES). Among the factors which the Government are taking into account are :

- the level of funding needed to support the most important research priorities;
- the scope for increasing the effectiveness of existing R & D budgets through better targetting and tighter management and control;
- the scope for improving commercial exploitation of R & D by closer collaboration with industry;

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-the scope for further rationalisation in the deployment of R & D resources.

These issues have begun to be addressed in relation to the Department of Education and Science (DES) funded Science Base in the PES advice from the Advisory Board for the Research Councils (ABRC) to the Secretary of State for Education and Science, and in the papers ABRC and ACARD prepared earlier in 1986 for the Ministerial Group on R & D. The ABRC, for its part, is now taking this work forward in a new strategy document which it hopes to complete in early 1987.

8. In general the Government support the ACARD view that technologies developed for defence must also be applied as fully as possible in the civil sector (1.6). The Ministry of Defence (MOD) are developing a wide range of measures designed to increase co-operation with industry, support joint programmes with the civil sector and enhance commercial spin-off. Examples include the appointment of industrialists to Research Establishment boards; the National Electronics Research Initiatives centred on the Royal Signals and Radar Research Establishment (RSRE) and funded by MOD, the Department of Trade and Industry (DTI) and industry; the setting up of Defence Technology Enterprises Ltd; and joint funding of research grants by MOD, DES and Research Councils. Most of these activities are collaborative, involving the private sector.

9. It has been agreed that ACARD will take a more detailed look at the Defence R & D programme and the Secretary of State for Defence, in welcoming ACARD's intentions to conduct such a study, set out the main elements of the MOD's approach (copy attached). ACARD are invited in particular to offer comments on action by the private sector defence industry to enhance exploitation of defence technology for civil application.

THE 1986 ANNUAL REVIEW

Distribution and Trends in Expenditure

10. The Government share ACARD's concern with the level of civil R & D expenditure in the UK, but consider that the source of funding, the way it is carried out and the extent to which the private sector's commitment is engaged

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are as important as the level of funding(2.1). In particular, public support of civil R & D for economic growth and productivity is unlikely to be effective if industry is not adequately engaged. The 1986 Annual Review indicates that UK **public** funding of civil R & D was higher as a percentage of GDP in 1983 than in the USA ,Italy and Japan, and France has since cut back on its public spending on civil R & D. It is **private** industrial funding that was lower on the same measure than in the USA, Japan and Germany.

11. The Government reviews the level and balance of its R & D expenditure each year taking account of the requirements of Departmental programmes and the cost-effectiveness with which public funds have been used. In the first half of the 1980s, DTI expenditure on innovation support increased significantly in real terms. As the Annual Review points out, the last year has seen a consolidation of DTI policies based upon their fundamental review of innovation support in 1985. The outcome has been a change of emphasis, with a greater proportion of support being made available for collaborative research, advisory services and schemes for encouraging and disseminating best practice and improving key skills. In other words, there is a shift to technology diffusion and transfer which ACARD recognise should be a major issue for Government funded R & D (3.11).

Effectiveness of Government R & D Expenditure R & D Evaluation

12. ACARD's comments on the importance of effective evaluation of Government R & D are welcomed. As is the recognition that evaluation of research programmes is complex and difficult. A considerable amount of the funding of Research Councils which relates to basic and strategic research is of a nature which cannot be subjected to evaluation with anywhere near the total rigour suggested by ACARD. But nevertheless it is agreed that greater efforts need to be made on this to ensure research is effectively targetted and executed (3.2). Evaluation need not be costly in relation to its benefits eg DTI currently devote 0.3% of their programme spend to evaluation of R & D. The Government also support ACARD's perception of evaluation results being used to inform choice between

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competing programmes. The establishment of a Science and Technology Assessment Office, reporting to the Chief Scientific Adviser, Cabinet Office, indicates the importance attached to evaluation (3.6). The Assessment Office (AO) has started work on its remit to develop evaluation methodologies, gather consistent information on, and make analyses of, the inputs and outputs from Departmental, Research Council and University Grants Committee (UGC) support for R & D and evaluate the contribution made by each to the efficiency, competitiveness and innovative capacity of the UK economy. The AO will advise Ministers, their officials, and the bodies for which they are responsible on the shape, content and conduct of their R & D programmes, with the objective of achieving a more effective contribution to the development of the UK economy. The work of the AO will improve the information base for determining relative priorities between R & D programmes.

13. Annual reassessment is carried out for Departmental R & D programmes in the normal process of research formulation. As a specific example of improvements which can be made, the Department of the Environment (DOE) are to add a specific evaluation process of the effectiveness with which research sub-programmes are targetted to meet policy objectives and, where appropriate, the extent to which they can be orientated to stimulate industrial competitiveness (3.4).

14. The AO is in the process of offering all Departments guidance on the way their R & D assessment work should be structured. Some common features can be expected to apply across all programmes; if an impartial assessment is to be obtained as efficiently as possible and greatest benefit is to be derived from the lessons of the past, an independent assessment function will be required properly linked into Department's systems for allocating R & D funds.

15. Where programmes involve cooperation between Departments, the Government agree with ACARD that mechanisms must exist to ensure that objectives are clearly agreed so that effective evaluation can be made by those contributing. Departments already cooperate on various areas of joint interest eg DTI/MOD and the Science and Engineering Research Council (SERC) for the Alvey Programme, and fuller cooperation has been agreed in other cases eg the Department of Energy (DEn) and DOE are setting up a Concordat on radioactive waste management. This Concordat covers all radioactive waste management R & D undertaken by the UK Atomic Energy Authority (UKAEA). Its aim is:

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- a. to provide a coherent national strategy for R & D into nuclear waste management
 - b. to clarify the nuclear waste management R & D needs and their financing
 - c. to establish administrative arrangements whereby agreement can be reached on a) and b) above, and to this end it requires
 - d. both Departments to publish an annual statement of R & D objectives in this field
- and e. the evaluation of projects. The AEA will prepare an annual report on the previous year's R & D.

Co-operation in environmental R & D is addressed in para 23.

Technology Transfer

16. The Government are in complete agreement with ACARD that technology transfer is of crucial importance in obtaining maximum benefit from R & D expenditure (3.7). In reflection of this importance DTI have focussed an increasing share of their R & D support on a wide range of technology transfer activities and measures to encourage best practice; MOD set up Defence Technology Enterprises Ltd; DEn seek to fund Research, Development and Demonstration (R D & D) jointly with industry such as in the Energy Efficiency Demonstration Scheme and the Offshore Supplies Office work; the Ministry of Agriculture, Fisheries and Food's (MAFF) Agricultural Development and Advisory Service (ADAS) has as its primary objective the translation and dissemination of research results into improvements in agricultural practice and efficiency; DES are encouraging universities to exploit their own research discoveries, and together with the Treasury, are reviewing Research Councils' incentives to exploit their work; the Department of Transport are looking at the same issues relation to the Transport and Road Research Laboratory: the Medical Research Council, together with the then National Enterprise Board set up Celltech, and have also set up a Centre for Collaborative Research (eventually to be self-funding) to promote the transfer of discoveries to industry and the health

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service; and the Natural Environment Research Council (NERC) are taking positive actions to interest the industrial and public service users of NERC research results in technology transfer for resource development and environmental management. Under the Energy Efficiency Demonstration Scheme, for example, savings in energy costs of about £200 million per annum have been stimulated since the scheme started in 1978 on the basis of grants to firms of up to 25% of the cost of installing novel technology which will cut energy costs.

17. As an important new initiative the Link Programme is being developed across all Departments with substantial R & D spending. The objectives of the Programme are: to accelerate the application of advances made in basic science and technology to products, processes and services of value to the economy; to bring about a real increase in industry's own expenditure on R & D; to forge more effective links between industry, institutions of higher education (HEIs) and other publicly funded research institutions; and to influence the programmes of Government Departments, HEIs and other publicly funded research institutions in the direction of greater relevance to industrial and commercial needs. The main features of the Programme will include: a number of programmes pursued normally for at least 3-5 years and funded at least 50 per cent by industry (including nationalised industry); programme proposals could arise from Departments, the Science Base or industry; the execution of projects within programmes should normally involve industry and the Science Base - projects may also involve Government Research Establishments; the Programme will include all Government Departments that spend substantial amounts of money on R & D; public expenditure on the Programme will be built up by the gradual re-shaping of planned expenditure to be consistent with Link Programme purposes and principles; and the achievement of the target level of total expenditure will be critically dependent on industry's willingness to find matching funds. The objective is that by 1991 the scheme should have stimulated up to £400 million a year of research funded jointly by industry and Government. As the Programme develops ACARD's Exploitable Areas of Science initiative should help to identify priority areas of technical and commercial promise.

18. Technology transfer is a diverse activity as the ACARD comments imply (3.8), and the Government agree with the need to encompass all the aspects noted if the topic is to be covered comprehensively. DTI, as well as various other Departments and Research Councils, are involved already in significant

activity under all the headings mentioned eg 'club' projects, support of Research Associations, involvement in the Teaching Company Scheme and assessment of technology transfer activities.

19. The Government are largely in agreement with ACARD's suggestion that both internal and external applications for R & D funding should make reference to the technology transfer potential of the work (3.9); and fully in accord with ACARD's view that Government must give emphasis to the transfer of new technologies into manufacturing industry, to improve international competitiveness.

20. In general it is not realistic for Departments to expect direct financial returns from the technology transfer activities that they support (3.10) for a variety of reasons, but chiefly because these are very wide-spread in their benefits to industry and because of the administrative difficulties of assessing and collecting repayment from a very wide range of beneficiaries, often many years after the event. The Government are considering what scope exists for providing more incentive to Research Establishments (REs) to attempt specific exploitation of their knowhow or inventions through repayment or licensing, and for reducing barriers to the commercial exploitation of REs' expertise and research results.

21. ACARD's suggestion that a senior member of each Department should have responsibility for technology transfer is fully supported by the Government and practised by Departments in terms of **general** responsibility. As well as having this central focus in each Department, technology transfer must also be the working ethos of all project directors and managers. For example, as recommended by ACARD the Director General of ADAS is at a senior level in MAFF - a role which is combined with the position of Chief Scientific Adviser, thus underlining the efforts made to ensure that research and the advisory service are fully integrated to the benefit of the UK economy.

Comments on Specific Sectors: Environment

22. The Government agree in principle with ACARD's underlying premises that adequate and robust data should be generated in advance of policy decisions; that research on topics at Departmental boundaries should not be overlooked;

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that the control of environmental hazards can be extremely expensive; and that appropriate environmental research may produce considerable financial savings (4.3 and 4.4). This acceptance in principle should not, however, obscure the fact that it will not always be practicable to meet all information needs in advance. Moreover, an increasing number of environmental policy decisions have in recent years been taken at the European Community rather than the national level and this adds a significant complicating factor.

23. ACARD consider there is a lack of inter-Departmental co-ordination on environmental R & D and considerable overlap in Departmental activity and their R & D (4.5 and 4.6). Co-ordination within a research area impinging on several interests is never easy. The Government believe ACARD may have underestimated the progress that has been made recently in reinforcing various longer-established interdepartmental links. Particular examples are the DEN/DOE Concordat on radioactive waste management; the new mechanism in place between DOE, MAFF and the Department of Agriculture and Fisheries for Scotland, involving Research Councils, for co-ordinating research activities; the NERC/Agriculture and Food Research Council agreement on co-ordinated programmes; and the new Co-ordinating Committee for Marine Science and Technology. Such efforts on co-ordination can be expected to reduce inadvertent overlap in research programmes, but a degree of overlap is inevitable and proper: for example it is imperative that Government-sponsored research on environmental pollution be seen to be independent of the Departments sponsoring the industries whose activities may cause pollution.

24. What the Government propose is a strengthening of information exchange systems between Departments and others concerned with environmental matters. DOE would seek to get those commissioning environmental research to exchange programme information - where this does not already happen - in order to produce an overview of what work is being done and where. Information would be made available at two levels; at one level for Ministers and those concerned with strategic scientific and research decisions; and at another level of detail for experts and those who must translate research needs into research activity. ACARD may wish to invite Departments to report on progress.

Construction

25. The Government agree with ACARD that the construction industry needs to be

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stimulated both to do more R & D and to apply new technology more effectively (4.11). However it is not proven that the most effective way of achieving this would be through additional expenditure by the DOE on construction R & D (4.10). A variety of possible initiatives are being considered by the Government to improve the performance of the construction industry. These possibilities include: a Construction Technology Board as recommended by NEDO primarily to improve technology transfer (4.12); an initiative to improve education and training systems; an industry technology advisory service; the development and application of robots; and more effective insistence by public sector customers on the procurement of quality assured products and the development of quality assurance systems for design and construction work (on which the Property Services Agency, PSA, is already leading the way).

26. Even though PSA is the largest single client of the UK construction industry, the Agency only accounts for around 5 per cent of the industry's output; thus public purchasing initiatives have to be carefully devised to be effective (4.13). With PSA in the lead, some other public clients are now demanding quality assured products, contractors and consultants. A growth in quality assurance schemes would lead to improved performance by the industry with a faster adoption of best practice embodying current technology as well as improved international competitiveness.

Transport

27. With a view to enhancing the contribution of its R & D programmes to wealth creation the Department of Transport (DTp) have been examining with 15 selected firms (from the industries for which they are a major customer ie construction and provision of traffic control and communication systems) the scope for closer collaboration with the Transport and Road Research Laboratory (TRRL) (4.16). Evaluation of this exercise is not complete but the main factual results show a demand for joint working and the use of TRRL staff as consultants. The scope for meeting this demand is being explored. DTp have achieved improving value for money over many years in the construction and maintenance of trunk roads and motorways, but will continue to explore options, including procurement policy, which might lead to further improvement. In executing and following up their research DTp seek to collaborate with both consultants and contractors to ensure that technical innovations and other changes in highway specifications do take account of export potential as well

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as domestic needs.

28. The Government are not aware on what evidence ACARD have based their view that R & D expenditure by British Rail and London Regional Transport is 'woefully inadequate' (4.18). Nor do they share the view that the merging of the R & D grant into the total grant will seriously affect the level of their R & D. The change was made because the Government considered that autonomy in research procurement as in other purchasing policies would improve the cost-effectiveness of that expenditure by linking it closer to the needs of their businesses. DTp have successfully encouraged British Rail to have an increasing amount of its design and development carried out by manufacturers.

29. ACARD's concern over the R & D spend of British Shipbuilders is noted (4.19), but it would be hard to justify a higher level in the present state of the industry.

30. DTp consults and advises widely both with industry and with the higher education sector on all aspects of research relating to national transport policy. But because many of the issues stand largely separate from each other, the Government does not consider that the establishment of a Transport Research Coordination Board would be a cost effective way of addressing them (4.20). Those aspects of transport research related to building and civil engineering would be covered by the proposed Construction Technology Board.

Energy

31. ACARD's opinion that the scale of expenditure on UK reactor programmes is too high compared with the levels of other civil R & D spend is noted (4.23). The current level of expenditure on thermal and fast reactor programmes is the result of collective Ministerial examination and decisions. It also takes account of commitments to international collaboration and the partial transfer to the electricity generating boards of responsibility for financing thermal reactor research. The electricity supply industry is increasing its financial contribution to fast reactor R & D. Much of the rest of the thermal reactor programme is directed towards nuclear safety. Ministers have chosen to fund a safety research programme independently of the reactor operators.

32. ACARD consider (4.24) that there should be a high potential for technology

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transfer from energy industry R & D to other civil fields. The UKAEA have gone some way down this road already, eg the non-nuclear programmes at AEA Harwell and elsewhere (to which DTI contributes about £8 million/annum support). In addition, there may be potential for further spin-off from more specialized nuclear establishments.

Defence

33. MOD and DTI are already involved in initiatives designed to transfer technology at an early stage from the defence to the civil field (eg the aircraft programmes at Farnborough and Pyestock and the programme of the National Electronics Research Initiative, and are actively seeking other joint programmes to achieve the same objective (4.26). Government is currently considering further measures to increase benefits to civil industry and the economy from defence R & D and procurement and the implications of greater international collaboration for these topics. These measures include wider industrial representation on Research Establishment (RE) management boards, sharper incentives for REs to promote industrial applications, a case study of spin-off from defence contracts, better means of encouraging industry to exploit MOD-funded R & D programmes, and a pilot scheme for back-to-back defence and civil development contracts.

34. The need to respond to customers' requirements in a competitive market is crucial to industrial performance, and provides a strong encouragement for investment, for industrial R & D and for the most efficient use of all resources. Government policy is to make the greatest possible use of competitive tendering in meeting the needs of the armed forces, with a view to securing these benefits for the UK economy and improving value for money for the taxpayer. The Government consider that in the application of this competition policy, 'off-the-shelf' procurement from overseas must remain among the options (4.27).

Improvements to the Annual Review

35. New arrangements have been agreed between the Cabinet Office and the DTI for the preparation of future Annual Reviews. These include the appointment of co-ordinators by each Department who will be responsible for all aspects of each Department's response. The co-ordinators should ensure an effective correlation between each Department's text and tables (5.2).

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There has been a significant increase in the number of people who are interested in the environment. This is a result of the growing awareness of the need to protect the environment for the future of our planet.



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10 DOWNING STREET
LONDON SW1A 2AA

From the Private Secretary

MR. FAIRCLOUGH

SECOND JOINT REPORT OF THE CHAIRMEN OF THE
ADVISORY COUNCIL FOR APPLIED RESEARCH AND
DEVELOPMENT (ACARD) AND THE ADVISORY BOARD
FOR THE RESEARCH COUNCILS (ABRC)

The Prime Minister has seen your minute
of 5 December. She is content with your
proposals for the publication of the report,
and by copy of this minute I am asking our
Parliamentary branch to make the necessary
arrangements.

(P.A. BEARPARK)

8 December 1986

dg



Prime Minister

CCSGT
(letter only)

Content with the publication of the
ACARD report by errand PQ?

W0330

5 December 1986

pgs
5/12

PRIME MINISTER

Yes no

SECOND JOINT REPORT OF THE CHAIRMEN OF THE ADVISORY COUNCIL FOR APPLIED RESEARCH AND DEVELOPMENT (ACARD) AND THE ADVISORY BOARD FOR THE RESEARCH COUNCILS (ABRC).

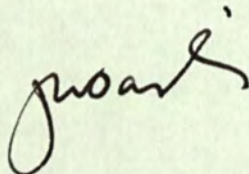
Sir Francis Tombs, the Chairman of the Advisory Council for Applied Research and Development has requested that the second joint report from the Chairmen of ACARD and ABRC which he has prepared in conjunction with Sir David Phillips, the Chairman of ABRC, be submitted to you and that your permission be sought for its publication.

2. Cmd 8591 (Government response to the first report of the House of Lords Select Committee on Science and Technology) invited the Chairmen of ACARD and ABRC to produce such a report. The first report prepared by Sir Henry Chilver and Sir Alec Merrison, the then Chairmen, was published as a Command Paper in 1983 and laid before Parliament in your name.

3. The second report discusses how the science base has and can continue to adapt to meet changed circumstances, and how it might achieve a level of collaboration with industry which ensures that the best use is made of the available resources. I suggest that permission for publication of the report be granted and that it is appropriate for the procedures followed in 1983 to be adopted. I am therefore suggesting that the report be published as a

Command paper on 12 December and laid before Parliament in your name and that, subject to your agreement, its publication announced by an arranged Parliamentary Question for written reply, taken on 11 December. A draft copy of the inspired Parliamentary Question and Answer is attached for your approval.

4. The report is a personal statement by the two chairmen and no Government response is required.

A handwritten signature in dark ink, appearing to read 'J W Fairclough', with a stylized, flowing script.

J W FAIRCLOUGH
Chief Scientific Adviser

DRAFT INSPIRED PARLIAMENTARY QUESTION TO THE PRIME MINISTER AND ANSWER
TO BE TAKEN ON THURSDAY 11 DECEMBER
[MP's name, constituency]

Question : To ask the Prime Minister when the second Joint Report from the Chairmen of the Advisory Council for Applied Research and Development (ACARD) and the Advisory Board for the Research Councils (ABRC) will be laid before the house.

Answer : The report is being published on 12 December as Cm 34 and I shall arrange for a copy to be placed in the Vote Office.

THE SCIENCE BASE AND INDUSTRY

SECOND JOINT REPORT BY THE CHAIRMEN OF

THE ADVISORY COUNCIL FOR APPLIED
RESEARCH AND DEVELOPMENT (ACARD)

AND

THE ADVISORY BOARD FOR THE
RESEARCH COUNCILS (ABRC)

SECOND JOINT REPORT BY THE CHAIRMEN OF ACARD AND ABRC

THE SCIENCE BASE, AND INDUSTRY

1. BACKGROUND

1.1 The Advisory Board for the Research Councils (ABRC) was established in 1972 to advise the Secretary of State for Education and Science on his responsibilities for civil science. Its present membership and terms of reference are given at Annex A. The Advisory Council for Applied Research and Development (ACARD) was set up in 1976 to advise the Government on the exploitation of research and technology and reports to the Prime Minister. Its present membership and terms of reference are given at Annex B.

1.2 In the Government's response (Cmnd 8591) to the report "Science and Government" from the House of Lords Select Committee on Science and Technology (House of Lords First Report, Session 1981-82), the Government agreed that the Chairmen of ACARD and ABRC should present periodic joint reports to the Government. The then Chairmen submitted their first joint report in July 1983 (Cmnd 8957). We have since succeeded them to the chairmanship of our respective bodies and believe it timely to present a second joint report.

2. INTRODUCTION

2.1 We have chosen as the theme of our report the science base and its links with industry. By the science base we mean the totality of research supported by the Department of Education and Science. This includes research supported from Science Budget funds disbursed to the Research Councils on the advice of ABRC, research supported from general university funds from the University Grants Committee (UGC) block grant and tuition fees, and research supported through the local authority higher education sector.

2.2 A strong and innovative science base is essential to the development of the new technologies and advanced skills on which industry and the nation depends. The decade immediately following the Second World War saw the emergence and growth of a range of new technology-based industries associated with the advances made in science and technology of the previous 20 years or more (eg consumer electronics, synthetic materials, petrochemicals, the motor industry). But these post-war technologies have now matured and have been widely adopted by newly industrialised countries. Industrial firms are now turning

to the science base for help in developing new areas where new fundamental knowledge is essential to their development. Examples include advanced manufacturing technology, advanced information technology (including fibre optics and satellite communication), biotechnology and molecular electronics.

2.3 The continued economic prosperity of the United Kingdom depends critically on the extent to which - in the face of intensifying international competition - it is able to achieve and maintain technological leadership. The maintenance of a strong science base is vital to this goal, but is not sufficient. Despite some successes, and despite an excellent record of achievement in basic research, its performance in exploiting research to produce new products and processes which succeed in the market place is disappointing; and all too often when a new product is successfully produced the UK does not follow-through with the continuous product development necessary to keep its initial lead. It is becoming increasingly urgent to ensure that the investment made in the science base contributes more effectively to wealth creation. To achieve this, the allocation of resources within the science base needs to take more account of economic potential, and links between the science base and industry need to be strengthened and extended.

2.4 There is a need to recognise that research undertaken within the science base and within industry is all part of a single network of national knowledge; the notion that science base research and industrially based research are things apart can act as a barrier to effective exploitation. Nevertheless different sectors of industry interact with the science base in different ways. Some sectors, for example the chemical industry, have invested substantially with their own funds in the applied research needed to produce new products. They believe it is vital for the publicly-funded science base to concentrate on basic and strategic research across a fairly broad spectrum in order to complement their efforts and pave the way for the next generation of advances. Other sectors, for example, the electronics industry, where proportionately more of the R & D investment comes from public funds, look to the science base for research which is closer to specific applications. Both types of research are needed; but it is important to recognise that a more effective contribution from the science base to wealth creation does not imply that more directly applicable research should be favoured relative to basic and strategic research. Indeed, it is noticeable that those industries which look to the science base for basic and strategic research tend to be the most internationally successful and competitive. But it does imply that when areas are selected for research - and the UK has no option but to be selective - the likely potential for wealth creation should be an important factor. It also implies that whatever research is undertaken the researchers doing the work should keep under active review its potential for economic benefit, and how that might be developed, and that the exploiters in industry should be receptive to new ideas.

2.5 Economic potential will only be realised effectively if the researchers in the science base, and the exploiters in industry, accept a joint responsibility to interact at all stages

their work. Perhaps one of the most damaging concepts that has held the UK back from exploiting its scientific expertise is the simple progressive model of scientific innovation. This, in its crudest form, holds that there is a linear sequence of basic research, strategic research, applied research, experimental development, design and eventually a marketable product, with each practitioner in the sequence devoted primarily to their own concerns. In reality successful exploitation comes from interaction between research and the market place at all levels, and in all directions. Sometimes the product comes first, and the research later. The industrial revolution was powered by the steam engine without a fundamental understanding of how it worked. Fundamental work on antibiotics followed penicillin, rather than led to it. At other times basic, strategic, and developmental work will proceed simultaneously. One of the reasons why Japan has been so successful economically is that its integrated approach to product development has made it possible to transfer research results rapidly into the design of new products and the improvement of existing ones.

2.6 Thus what is needed is to foster a community of interest between the academic world and industry. Fortunately there are encouraging signs that this is happening, and there are valuable initiatives to build on. In this report we describe some changes that are taking place and offer suggestions for others. There is also a responsibility on Government to ensure that desirable changes are not held back by too low a level of investment. A re-orientation of activities is never easy, and it is all the more difficult in a framework of reduced funding. There are, of course, many competing claims on public funds and the scientific community needs to recognise that; but if the community can demonstrate its commitment to using its funds to help increase national prosperity it will have a stronger case to make to Government.

2.7 We should emphasise that we have prepared this report in our capacities as chairmen, although we have consulted our colleagues. The views expressed should not therefore be regarded as statements by ACARD or ABRC, although we believe that our colleagues would not in general dissent from them.

3. RESOURCES

3.1 The question of what level of resources the nation should devote to the science base is, of course, an important one but the purpose of this report is not primarily to argue about the level of resources. There are other opportunities for that; ACARD has the opportunity to comment annually in confidence to the Prime Minister on any aspect of the Annual Review of Government Funded R & D that it sees fit; and ABRC can address the question in its annual advice to the Secretary of State for Education and Science on the Public Expenditure Survey which in recent years has been published and which was issued this year at the end

of July. Indeed, in this year's advice the ABRC argued strongly for an increased Science Budget.

3.2 We believe it is useful, however, for us to set out here the basic data for Government expenditure on the science base and to see how this compares with other Government expenditure on R & D. The sums involved for the main components of the science base (Research Councils and UGC) are given in the following table extracted from the 1986 edition of the Annual Review of Government Funded R & D. Also given are the sums for the other civil R & D expenditure by Government Departments, and for Ministry of Defence expenditure. The figures are given in "real" terms, that is adjusted for inflation by the Gross Domestic Product deflator. 1984/85 has been used as the base year.

Expenditure on Government Funded R & D

	----- Outturn -----				----- Plans -----	
	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89
£ millions (real terms)						
Research Councils (1)	501.3	506.9	514.0	516.3	502.0	498.6
UGC etc (2)	<u>643.7</u>	<u>629.9</u>	<u>637.9</u>	<u>632.9</u>	<u>625.4</u>	<u>617.9</u>
Total of Science Base	1145.0	1136.8	1151.9	1149.2	1127.4	1116.5
Civil Departments	947.8	949.9	937.5	905.4	838.0	785.7
Ministry of Defence	<u>2073.1</u>	<u>2176.0</u>	<u>2274.5</u>	<u>2195.5</u>	<u>2195.5</u>	<u>2195.5</u>
Overall Total	4165.9	4262.7	4363.9	4250.1	4160.8	4097.6
Science Base as % of total	27.5	26.7	26.4	27.0	27.1	27.3

1. The Research Councils' figures are less than the total Science Budget figures because they exclude the funds for postgraduate education and training, and the Science Budget grants to smaller bodies.
2. The assignment of resources to the university research effort is based on a notional attribution of universities' departments and central expenditure between research and teaching. The university sums include a component for humanities research.

3.3 It can be seen from these figures that, between 1983/84 and 1988/89:

1. MOD expenditure is planned to increase by 6%.
2. Civil Departments' expenditure, other than on the science base, is planned to decrease by 17%.
3. Science base expenditure is planned to decrease by 2.5%.
4. The science base percentage share of total expenditure drops from 27.5% to 27.3%.

3.4 However, since the 1986 Annual Review was prepared the Government has announced changes in its expenditure plans in the November 1986 Autumn statement which mean that the planning figures in the table will need revision. But it is not possible at this point to say how they will change. This is because it will take some time for Departments to determine the consequences for their R & D plans of the changes in their overall expenditure levels to which the Autumn Statement relates. The table in paragraph 3.2 therefore remains the most up to date overall picture available, although it should be viewed in the light of the reservations noted.

A HISTORICAL PERSPECTIVE

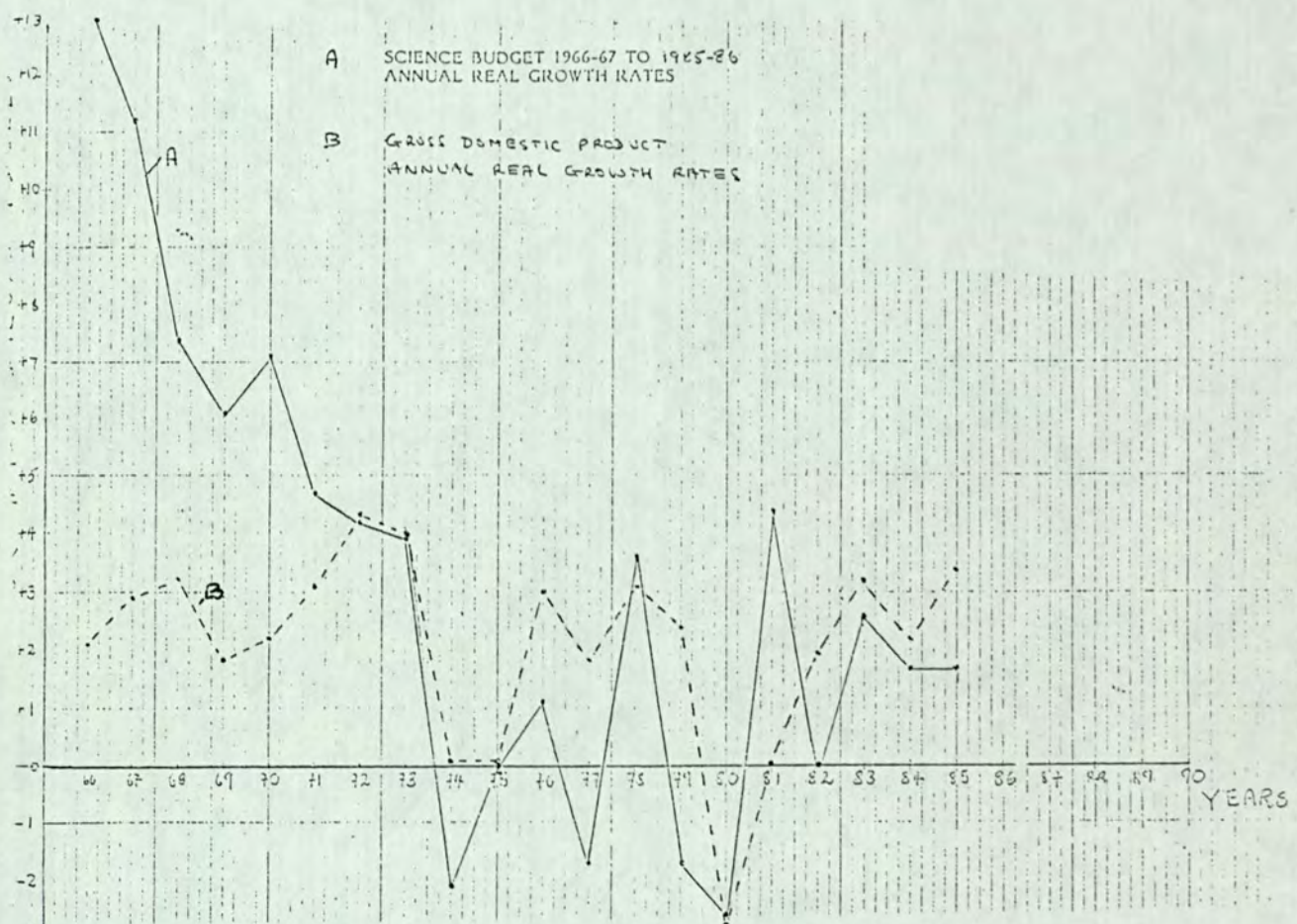
4.1 The idea that scientific research should be purposefully directed towards economic benefits is not new. The origins of Government support for the science base, which go back broadly to the first 20 years of this century, reflected just those considerations. In 1899 the National Physical Laboratory was founded with the task of bringing scientific research to bear upon everyday industrial and commercial practice. In 1909 a Development Fund was created to provide for the scientific development of forestry, agriculture and fisheries, as a result of which a number of major agricultural research institutes were established. This initiative eventually led to the formation of the Agricultural Research Council in 1931. In 1911 a fund for medical research was set up, financed from National Insurance contributions, which was administered by a body called the Medical Research Committee. This led to the formation of the Medical Research Council in 1920. In 1916 the Department of Scientific and Industrial Research was created with a wide-ranging industrial remit whose policies and priorities were rooted from the start in economic and social needs.

4.2 In parallel with the development of a research capability directed towards specific sectors there was growing recognition of the need to expand the supply of qualified scientists and technologists from the universities. The universities were, of course, the institutions where most fundamental research was done. Science had been able to demonstrate a successful contribution to national needs through two world wars, and it seemed obvious that when the universities were expanded an expansion of university research along traditional lines should accompany the expansion of student places. There was then an enlargement of the science base rooted in the university tradition, with its own internal motivations towards research for its own sake. A further push in this direction came from the demise in 1964 of the DSIR, and the creation from its component parts of the Science Research Council and the Ministry of Technology, the major role of the Science Research Council being perceived as providing a supporting capability for university research.

4.3 Over the same period an understanding of the importance of science and of employing scientific staff was beginning to spread in industry. During the first 20 years of the century, Britain was still the major supplier of most of the manufactured goods of the world and most industry was content to coast along with the momentum built up in the previous century. The historical success of industry with its reliance on native resourcefulness and imagination rather than the professional application of science and technology had led to a widespread position of independence from the universities. Although a few pioneering companies and a few individuals in industry recognised the changing situation quite early, it took the world wars and the emergence of strong overseas competition before any substantial proportion of industry began to appreciate the importance of the science base. During the last 30 years

an increasing number of industrial associations and individual representatives from industry have been working to build closer collaboration between industry and centres of research in the universities and research councils.

4.4 Nevertheless there had been a shift of emphasis over an extended period away from the science base being purposefully directed towards economic benefit. This was perhaps masked because it was accompanied by rapid growth with the resources available for science approximately doubling every 15 years. This rate of growth had to slow down or level off at some stage, and the turning point was in the early seventies. The following graph shows the annual growth rates for the Science Budget* over the period 1966-67 to 1985-86 compared to the growth in the Gross Domestic Product. Both sets of figures are in real terms, ie adjusted by the Gross Domestic Product deflator.



* The Science Budget ^{has been used} rather than the overall science base because of the greater problems in compiling figures for the latter on a comparable basis over the period.

The opportunities for research, however, have continually increased and, moreover, have grown ever more expensive. This then is the explanation for the perceived "crisis" in research funding - the growth in opportunities is outstripping the available funds. Whatever the merits of the case for some increase in Government funding for science, it seems unlikely that we will ever revert for an extended period to the growth rates of the past. There is thus a sea-change to be accommodated. We need a renewed and concerted attempt to harness the science base as a whole to try and arrest our declining competitive position; and we have to learn how to manage and make the best use of research when it is no longer possible to rely on new opportunities being financed from new money. Instead, priorities have to be determined carefully and resources redeployed from existing activities to new ones. This can be a painful process. The UK is not alone in having to face it; other nations have the same problem.

5. ADJUSTMENTS TO CHANGED FINANCIAL CIRCUMSTANCES

5.1 We can see from the table in Section 3 the actual conditions under which the Research Councils and the UGC have operated in recent years. These figures show that over the period 1983/84 to 1986/88 UGC expenditure has fallen in real terms by about 2%, while Research Council expenditure has increased by 3%. The overall effect on science base expenditure as a whole is a marginal increase - of rather less than half a percent.

5.2 At first sight these figures do not appear to provide supporting evidence for the considerable concerns expressed by the scientific community about the state of British science. However, as with many statistics, they cannot be taken at face value. The UGC figures are suspect because they are based on notional attributions of resources rather than actual - it is a notoriously difficult task to disentangle research expenditures from overall university expenditures. The Research Council figures are more firmly based on actual expenditures. But in both cases there are a number of other factors which need to be taken into account to give a true picture. In part these relate to cost increases from such factors as rates, foreign exchange, superannuation, and restructuring which mean that costs have been growing faster than the general level of inflation indicated by the GDP deflator. They also relate to the increasing costs of pursuing science at the frontiers - particularly in relation to equipment costs. There is also the frustration effect referred to earlier of the existence of many new exciting opportunities for research which, in the past, would have been funded from growth, but now have to be funded - with much more difficulty - from redeployment.

5.3 There is no doubt that the science base is under considerable pressure. This has forced a reappraisal of the organisation of the science base and has led to improvements in internal management. It has also brought a much sharper focus to the debate about the determination of scientific priorities. Within the Science Budget framework the Research Councils - with the encouragement of the ABRC - have produced Corporate Plans which integrate management planning with financial planning and scientific priorities. Considerable changes are taking place, and particularly in those Councils - the AFRC and the NERC - whose origins lay in separate research institutes but which are increasingly bringing those institutes together in a coherent framework.

5.4 In the AFRC 24 separate institutes or units are being reorganised into 8 new institutes each under a Director of Research. One of the responsibilities of the new Directors is

to examine the benefits of concentration of activities on fewer sites. At the same time, the AFRC is reshaping its scientific programme. Traditionally, the pressures have been to increase agricultural production; but with the emergence of surpluses the emphasis on research has been switched to minimising inputs so as to reduce unit costs. The Council is also building up its food research programme in response to the need - identified by ACARD among others - for more work in this economically important area. Many traditional lines of research have been cut in order to enable a response to be made to recent rapid advances in biological research which open up new opportunities of considerable potential for agriculture and food processing. The AFRC has had to absorb reductions in funding from both the Science Budget and from commissions from Government Departments, and is directing increased efforts to securing outside funding. In cash terms its budget has fallen from £96 million in 1983/84 to £93 million in 1987/88. AFRC estimate that, allowing for inflation, this will result in a drop in the volume of research of about 20% during this period. The main mechanism for achieving budget reductions has had to be through a reduction in manpower. This is planned to fall from 6280 in April 1983 to 4480 in April 1987, a reduction of almost 30%. Thus research volume will fall by rather less than the fall in manpower.

5.5 NERC has also been reorganising its management. The programmes of NERC's 13 institutes are being brought together under 3 new Directorates - earth sciences, marine sciences, and terrestrial and freshwater sciences. Its committee structure has been streamlined. In order to make room for new work, and in order to increase the level of financial support per scientist, NERC is planning to reduce permanent staff over the period 1981 to 1991 from 3350 to 2220. NERC is also seeking to broaden the base from which it receives income from Government commissions, and has been devising new marketing strategies aimed at the private sector.

5.6 Other Councils are changing the balance of their work. Since 1975 SERC has doubled the percentage of its funds spent by its Engineering Board, and initiated a range of new programmes with strong industrial links. Some examples of these are discussed later. Over the same period SERC halved the percentage spent on nuclear physics. In the last 10 years MRC has closed 23 of its units and redeployed resources into major new programmes eg in clinical molecular biology, neurobiology and diagnostic imaging. It is seeking to foster more clinical research; and it has set up a Centre for Collaborative Research which will sponsor collaborative projects with industrial, academic, and clinical interests. The ESRC has set as a major focus of its research programme the theme of "Change in Contemporary Britain" which will promote research in such areas as the changing structure of economic activity, the implications of new technology, and the social causes of drug addiction.

5.7 A particular feature of the Research Councils' reorganisation is that the institute-based Councils are taking steps to increase their interaction with the universities. The proportion of AFRC and NERC funds which supports university-based research is relatively low, and both Councils plan to increase it. This is in recognition of the flexibility to be derived from funding limited-term university grants, and of the benefits of associating institute staff with the broader-based and more fluid university community. The MRC achieves its interaction with universities both by direct support of university research, and by basing its own units within a university, although the staff continue to be employed by the Council. In many ways this unit-based approach provides the best of both worlds for research, in that an MRC Unit can organise and commit itself to its research without the distractions of other university activities, and yet still work closely with and draw on a wide range of university expertise. In a similar way, a number of AFRC's units and research stations are departments of universities or located on university campuses.

5.8 Within the UGC framework, there have also been changes. In the past the main basis for determining UGC grants to universities has been through adjustments to historically determined distributions. For the grant allocations over the period 1986/87 to 1989/90 the UGC has adopted a new approach. It is basing its allocations partly on teaching and research criteria which have been applied uniformly to all institutions, and partly on selective judgements on research. The calculation of resources for research is based on 4 components:

- i. resources for "floor" support of research through a contribution to salaries and other costs of academic and support staff. This contribution is calculated in relation to weighted student load.
- ii. an allowance of 40% of the income received from Research Councils and charitable bodies
- iii. a sum of £10 million distributed among institutions in proportion to their contract research income from industry and Government departments, in order to encourage them to increase such income
- iv. a sum distributed selectively in the light of the UGC's assessment of institutions' research strengths, taking account of research statements from each university and of advice from Research Councils, learned bodies, medical charities and individual experts.

Within individual universities, the research activities of the institution are increasingly being considered by Research Committees. Such committees operate with different remits, but typically a committee will offer advice on plans and priorities for research, on methods for resource allocation, and have some pump-priming funds of its own to stimulate new areas of work.

5.10 It is through these channels, and through other channels - for example the special funds to provide advanced research equipment for certain university groups - that the scientific community is increasing its emphasis on selectivity and concentration, and promoting better management. We applaud the measures that have been taken, and believe that the Research Councils and the universities have demonstrated a commitment to increased efficiency and change in difficult circumstances for which they deserve to be congratulated, and which the Government should be prepared to recognise as providing a sound basis for increased investment. But the process is a continuing one, and there is still some way to go. We look at some of the problems below, in the context of the dual support system, and identify some other measures (paragraph 6.7) we believe should be considered.

6. THE DUAL SUPPORT SYSTEM

6.1 University research in the UK is supported through the "dual support system". The rationale of this system is that a basic level of resources is provided through the UGC to enable individuals and groups in universities to pursue and test their own innovative ideas in research to the point where it appears they are worthy of development on a larger scale; and then a case is made to the Research Councils, or other bodies such as charitable Foundations, for additional funding to pursue the ideas further. The case for additional funding is judged on its merits through committees of experts and independent referees. The additional funding is not meant to cover total additional costs; the university must continue to bear the overhead costs, and indeed is expected to make some contribution to specific costs - for example by sharing the costs of an item of equipment. The strength of the system is that it encourages creativity, particularly by young scientists who have yet to establish a reputation, by providing some resources to develop new and perhaps unfashionable ideas. But at the point where these begin to absorb substantial resources, these ideas must hold their own in a peer review.

6.2 For the system to work well universities need to be able to maintain "well-found" laboratories, which have the resources to support research in their own right, and also to act as a secure base for externally-funded research. However, the resources are no longer available to maintain well-found laboratories across the breadth of the university system,

for the Research Councils to support all the good proposals they receive. This has given rise to a number of problems affecting the efficiency of the system.

6.3 One is that grant applications to Research Councils are including requests for items of equipment or materials which in the past the university might have been expected to provide itself. In fact the dividing line between the university's responsibilities and the Research Council's responsibilities in this connection has never been easy to define, and different Councils, and even committees within Councils, operate on different assumptions. The system breaks down when a Research Council grant application is not met in full because it is felt that elements of it are more appropriate for university support, but the university is nevertheless unable to provide that support. The result is that the research is handicapped from the start.

6.4 More generally there is a tendency in Research Councils to make the funds available for university research grants stretch as far as possible by spreading them out among too many groups. It is perhaps an understandable reaction of the allocation committees when faced with a large number of high quality proposals to pare each down each to the bare minimum, and even below, but we believe this is a false economy. Often the committees will be prepared to fund the appointment of a research investigator, but not provide adequate supporting funds for the work. Councils should face this issue squarely, and be prepared to fund fewer appointments so that the support per appointment, shared as appropriate with the university, covers the real costs of the research.

6.5 A recurring problem has always been that the greater the success of the university in being awarded research grants the greater the strain on its own funds because of the associated increase in overhead costs. This problem was recognised in the recent change in UGC allocation procedures, and these now allow for an overheads element to complement the award of research grants. However, this has not entirely removed the problem at the research project level. The resources are still contained within block grant, and are subject to all the pressures to which universities are exposed in making their financial ends meet. They may not in the end, therefore, feed through to support the research grants which caused them to be given.

6.6 The changing nature of research, coupled with tighter budgets, gives cause for concern about the organisation of research undertaken in universities. Modern research is increasingly, although not exclusively, dependent on multidisciplinary teams using complex and expensive apparatus. Universities find it difficult to organise themselves to undertake this sort of work - crossing the boundaries of traditional disciplines and departments, and arranging

ed access to equipment facilities which are too costly to buy and maintain for a single institution. They are also constrained in making an efficient contribution to complex research programmes by the normal day-to-day pressures of other university work. These are the mirror of the questions posed about Research Council institutes. Those institutes were organised specifically for research, but there was a need to increase flexibility and promote wider-based contacts. Universities have the latter, but there is perhaps a need for a more clearly defined structure for research management.

6.7 The thrust of all these arguments is that the dual support system needs to undergo further adaptations if it is to instil confidence as an effective delivery system for research. It needs to be recognised that there can only be a limited number of well-found centres; those that are to fulfil this role should be identified and properly resourced. The responsibilities of the two sides of the system need to be better defined. Once a research project has been approved in the tough competitive processes now prevailing, it is important that its effectiveness is not undermined by a failure of one or other sides of the system to provide its share of the proper resources. There may be a case for adjusting the balance of resources between the two sides of the system, for example by transferring the overheads element within the UGC grant to the Research Councils. Internal research management within universities, and between universities, needs to be tightened. For the former, Research Committees could undertake a more active role; for the latter regional consortia might be formed, initially to pool expensive equipment but also to discuss complementary research programmes. Research Council units need to be even more closely associated with related university research.

6.8 In order to improve the effectiveness of the dual support system the ABRC and the UGC need to consult more closely. To assist in this a joint Working Party has been established to identify problems and consider possible solutions. We are also conscious that polytechnics have a role in research, but do not operate under a formal dual support system. Nevertheless, they receive Research Council grants on the same basis as universities, and these similarly require some support to be provided from the institution; furthermore the National Advisory Board (NAB) has recently set up a research fund, and is making research grants available to selected polytechnics in response to submissions. There is also therefore a case for ABRC to forge closer links with the NAB and joint ABRC/NAB discussions are planned.

7. LINKS WITH INDUSTRY

7.1 Alongside the changes in management, and re-orientation of scientific priorities, the Research Councils have been developing new types of collaboration with industry. The sector-orientated Councils have always had close links with their industries, and these continue to develop. We highlight below briefly and selectively (paragraphs 7.2 - 7.5) some particular features of these which are of interest; a full description can be found in Councils' Annual Reports and Corporate Plans. The position is somewhat different for SERC - the largest Council with the widest range of responsibilities. Having been split off from DSIR in 1964, it is interesting that SERC soon began to recognise the need to build up its own links with industry. It did this primarily through the formation of an Engineering Board through which to channel an increasing level of resources devoted to engineering. This shift in emphasis was formally recognised by the change of name, to include engineering in its title, in 1981. It is through new approaches developed by SERC that British industry has been developing new links with the science base, and we look at these in rather greater detail in paragraphs 7.6 - 7.12.

7.2 AFRC can point to a range of successful products arising from the commercial exploitation of its work - one of the most notable examples being the development of synthetic pyrethroids. One of its institutes - the Plant Breeding Institute at Cambridge - has been so successful commercially that it is now being considered for transfer to private ownership. Other examples of successful individual links are the commercialisation agreement with the Agriculture Genetics Company (a venture capital company) in areas of plant biotechnology which has resulted in the funding of a number of specific new projects at AFRC institutes; and the Agricultural Machinery Partnership Scheme which is jointly sponsored by DTI, MAFF, DAFS and some 20 UK manufacturers.

7.3 MRC's principal links with customers are with the Health Departments and the National Health Service who look to MRC for biomedical, clinical, and health services research. Following the agreement in 1981 that the commissioning funds transferred to the Health Departments under the Rothschild arrangements should be transferred back to the Council, a close working relationship has been built up between the MRC and the Health Departments. The Council has initiated arrangements to help promote the transfer of research discoveries with commercial prospects to British industry. An example of these is the MRC agreement with Celltech Ltd through which the company has marketed a number of products which originated as MRC discoveries. A more recent initiative is

End of 7.3 to be extended to read

The establishment of the Centre has been widely welcomed by industry and a number of joint projects have already been set up with a diverse range of major UK companies; these include work on the design and manufacture of synthetic peptide vaccines, the development and production of biosensors, and the use of novel enzymes in the design of drugs. The MRC has schemes for co-operative research grants, and co-operative student awards, comparable with those operated by SERC (see later). It also has an Industrial Liaison Group at MRC headquarters, which has a separate budget for patenting, and offers advice and assistance to MRC Units in negotiating collaborative and/or licensing agreements with commercial companies.

the establishment of the Centre for Collaborative Research at Mill Hill adjacent to the National Institute for Medical Research. The centre will act as a focus for work of commercial importance carried out by the Council's own teams wherever they are located. The establishment of the Centre has been widely welcomed by industry and a number of joint projects have already been set up with major UK companies.

7.4 NERC decided three years ago to give a deliberate impetus to its commercial and marketing activities. As part of its marketing strategy it has set up a research marketing group at NERC headquarters, created a Brussels office which has the task of keeping in touch with developments within the European Commission in order to learn about potential contracts, and has NERC agents in Washington and Manila to seek out commercial opportunities with the World Bank and Asian Development Bank respectively. It has developed a range of marketing materials in-house, including video material, targetted to specific business sectors, for example the oil industry, local authorities and water authorities. The Council is also exploring possible "framework" agreements of the kind that MRC has with Celltech and AFRC with the Agricultural Genetics Company, and is examining the possibility of forming a NERC company that would operate commercially within its sector, perhaps with city financing.

7.5 The ESRC supports a number of research centres, normally housed in universities, which specialise in particular areas and it encourages them to seek additional external funds. An example of a jointly funded activity is the Macro-economic Modelling Consortium with the Treasury, the Bank of England, and the Science Policy Research Unit at Sussex University. The Council operates an "Open Door Scheme" which provides a research consultancy for all sides of industry, and operates its own version of the Teaching Company and Cooperative Awards schemes (see later).

7.6 The new links pioneered by SERC have developed primarily from its Engineering Board's policy of promoting focused programmes in areas of identified national need. Some of these programmes have been developed through Special Directorates of which there are currently four (Application of Computers to Manufacturing Engineering; Biotechnology: Information Technology; and the Teaching Company Scheme): two former Directorates - Polymer Engineering and Marine Technology - have moved out of SERC. The former is now a constituent part of the British Plastics Federation, and the latter is a company limited by guarantee, where members are from industry, and DEn, DTI, MOD, SERC, and the Fellowship of Engineering. The objective of the Directorates is to determine and direct a programme of research, in close consultation with industry, and provide intensive support for it over a period of about 8 years. After that it is the intention that they should move outside SERC into industrially-based host organisations. As noted above, ^{two have} ~~one~~ has already made the transition.

7.7 On a smaller scale, but still representing a commitment to selected research areas, there are a number of Specially Promoted Programmes, for example covering such areas as the design of high speed machinery, chemical sensors, low dimensional structures, and protein engineering. A further scheme - the Co-operative Research Grants scheme - promotes an active partnership between academic and industrial researchers through joint SERC/industry funding of a collaborative research project. This aims to encourage research which both advances understanding, and leads to results that can be exploited by the industrial partner.

7.8 We commend all these schemes which we see as having the desirable virtues of concentrating effort on identified areas of national importance, bringing in industry at an early stage so that it can both influence the direction of the research and more easily make use of its results, and forging close links between the academic world and industry which of themselves will lead to an increase in understanding.

7.9 There are, however, two schemes which we see as being of particular importance in that they combine the elements of research and training in a way that is of considerable value to industry. These are the Teaching Company Scheme - already mentioned as one of the Directorates - and the Cooperative Awards in Science and Engineering (CASE) scheme.

7.10 The Teaching Company Scheme is jointly funded by SERC and DTI and operates through teaching company programmes. In these programmes a university or polytechnic team takes part in a company plan intended to achieve a major change in the company's techniques and procedures. The objectives are to raise industrial performance by the use of academic expertise and the introduction of advanced technology; to develop and retrain existing staff; and to encourage able graduates to train for careers in industry. The academic team consists of permanent academic staff, together with graduates recruited in consultation with the company for two-year academic appointments as Teaching Company Associates. The Associates are normally based full-time in the company and work in collaboration with company and academic staff on tasks within the programme. In addition, the university or polytechnic arranges induction and tuition in accordance with personal needs. Associate appointments may lead to higher degrees but more importantly they invariably lead to posts in industry, often with substantial responsibility and reward, either at the participating company or elsewhere.

7.11 The teaching company programmes are supported through a grant from the scheme towards the basic salaries of the Associates and academic support costs, normally complemented by an average contribution of one-third from the company. There are currently some 200 teaching company programmes in operation. These are mainly concerned with batch

manufacture in the mechanical and electrical engineering industries, but the scheme is being widened to include industries and functions other than manufacturing. We believe the Teaching Company scheme has been very successful and would strongly support a further expansion. The scheme helps companies to bring themselves up to date through close contact with the best academic expertise, and the collaborative postgraduate training given is, we believe, closely in tune with industry's needs.

7.12 The Cooperative Awards in Science and Engineering scheme is a variation of the normal SERC research studentship in which a postgraduate student is supported at an academic institution while undertaking research leading to a higher degree. In the CASE scheme the project undertaken by the student is devised and supervised jointly by representatives of the academic and industrial partners, and is of commercial significance to the company. The project may be in any area of research, design or manufacture, and SERC will normally waive any claim to industrial property rights. A student is required to spend part of the time working at the industrial partner's establishment. The company benefits from a studentship not only by obtaining an economic way of solving a problem of commercial importance, but also through the use of the scheme as a means of recruitment. In return the company contributes to the cost of the studentship, pays travelling and subsistence expenses while the student is working at the company, and is encouraged to supplement the normal level of student grant. About 900 CASE studentships are offered each year. We strongly support this route to a higher degree both because we see value in having research projects based on real problems of industrial relevance, but also because the training involves learning about how industry actually operates. We would be glad to see CASE further expanded. We attach at Annex C examples of Teaching Company and Cooperative Research Grant schemes.

7.13 Despite the value and success of the schemes described above, they do not amount in total to as large an amount of interaction with industry as we believe is needed. Thus, in the course of an enquiry into the potential for private sector funding of scientific research, undertaken at the request of the ABRC (published May 1986), a Working Party chaired by Professor Mathias reported that:

"We detected a widespread feeling that the Research Councils maintained too low a profile, and could do far more to generate awareness of the facilities and expertise which they had to offer." (paragraph 183).

"We found that, in general, companies' attitudes toward the Research Councils appeared to be that their prime functions were to carry out basic research and training, fund university research, and provide centralised facilities. It was generally accepted

that these were important on a national scale, but were not of much direct relevance to the needs of industry." (Paragraph 184).

7.14 The Working Party also investigated the attitude of companies towards university research. It found these varied considerably. At one extreme there were companies who were well satisfied with the performance of universities in carrying out basic research and providing a supply of highly qualified manpower, and had developed close working relationships with particular departments and individuals. At the other were companies who considered that academics were deficient in their lack of industrial orientation, and were hampered in developing this through their commitments to teaching and examinations, academic priorities which emphasised early publication of results, and generally the more relaxed time-horizons of the academic world.

7.15 But an important finding of the Working Party was that there was much more common ground between the Research Councils, the universities, and industry than the various parties appeared to realise. It found that in strategic research there were many possibilities for cooperative funding, with public and private funding paying complementary roles, participating in different proportions at different phases in the evolution of such research programmes. It found that where such collaborative projects existed they were greatly valued by industry, who saw them as a means of increasing mutual understanding, enabled them to make rapid contact with new areas of work without an irreversible commitment, and provided access to the skills and facilities of centres of excellence in a cost-effective way. We believe an increase in the number of such projects is highly desirable, as a means of generating the close links and shared understanding between the academic world and industry out of which successful exploitation is likely to come.

7.16 Two industrially-based initiatives are particularly worthy of note. ICI has a Joint Research Scheme through which it funds research projects in universities of interest to both the universities and the Company. Between 1974 and 1981 it has funded about 70 projects, and during 1984/85 awarded grants totalling about £0.5 million. In addition it sponsors three joint laboratories with universities: at Manchester for polymer science; at Liverpool for bio-engineering; and at Leicester for molecular biology. BP has set up a Venture Research Unit to support university fundamental research in any fields which show promise of substantial industrial relevance within a decade or so. Awards are made to the university to cover the cost of the work including salaries, capital items, consumables, travel, services, and overheads. The Unit is presently supporting 22 teams with a current budget of £1.5 million.

7.17 We would like to see other major companies develop similar joint programmes with universities and believe they would find them to be a rewarding investment. But in many respects the problem of promoting interaction is greatest with the small to medium sized companies. Large companies with their own substantial research teams have generally recognised the value of keeping in touch with university work of interest to them even if they do not fund it directly or jointly. Small to medium sized companies often do not have this capability and find it more difficult to engage in constructive interaction. In part we would hope that initiatives like the Teaching Company, Cooperative Research Grants, and CASE can help to build bridges through expanding into this sector of industry. In addition we believe that universities and Research Councils should consciously devote more management effort to improving their relationships with small to medium sized firms through a variety of different approaches. For example, these could include the preparation of registers of university and Research Council work which can be made available to interested firms, the use of university consultancy clubs which would function as a springboard for other kinds of industrial collaboration, a more aggressive effort to market science base research to potential users, and a national brokerage scheme for the Research Councils to put small companies in touch with local academic research.

7.18 We have been following with interest a recent initiative in the United States which aims to improve academic/industrial collaboration. In 1984 the Directorate for Engineering of the National Science Foundation (NSF) initiated a programme to support Engineering Research Centres at universities around the nation. The Foundation's purpose in supporting these centres was to provide cross-disciplinary engineering research opportunities for academic staff and students in close association with industry; to develop fundamental engineering knowledge in order to enhance the nation's industrial competitiveness; and to prepare engineering graduates who possessed the diversity and quality of education needed by US industry. Industrial support and collaboration was to be provided through contributions of cash or equipment, participation of key people, and membership on advisory committees.

7.19 The initiative is on a substantial scale. The first six centres were established in May 1985, and a second group of five centres in March 1986. The subjects covered by the centres include such topics as Intelligent Manufacturing Systems, Composites Manufacturing, Advanced Combustion Engineering and Compound Semiconductor microelectronics. Typically NSF support for each centre is in the region of \$1-2 million per year for five years. The response of industry has been strong; the equivalent of \$13 million had been committed by industry for the first six centres by November 1985.

7.20 The importance of this initiative is that it demonstrates how one country, which already has a better integrated industrial-academic system than the UK is preparing itself to meet what it believes to be an increasing challenge to its competitive position from other nations in the years ahead. There may well be a case for the UK to develop a small number of similar centres here. We are pleased to note for example a recent initiative of Cranfield Institute of Technology to set up a computer integrated manufacturing institute (CIM) with substantial support from industry which provides teaching, training and research in this subject; and the establishment of a new Centre for Electronic materials at UMIST which will undertake collaborative research with industry on the next generation of materials for use in electronic engineering components. What is clear is that the UK must take its own initiatives to ensure it does not fall further behind other nations in its economic exploitation of research. The competitive edge we need can come from the science base if this is properly utilised.

8 SOME NEW APPROACHES

8.1 One of the most difficult, but necessary, tasks in deciding on a selective distribution of resources to reflect economic potential is to identify which areas hold the most promise. This was the subject of a report issued by ACARD in May 1986 entitled "Exploitable Areas of Science". The report pointed out that several countries with major scientific and technological capabilities had well developed mechanisms for holding national debates between industry, science and Government about the strategic directions of their scientific programmes and the associated policy. The UK, however, had no such capability and needed one. The report recommended that the UK should establish a process for drawing together relevant knowledge; establishing communication between science, industry and Government; assessing the potential market exploitation of developments in science and technology well in advance, and changing priorities for support for research, both public and private, in line with this assessment. It was not suggested that all the budget for UK science should be treated in these terms; it was accepted that the long-term interests of the UK also required that part of the budget should enable individual scientists to pursue on their own initiative areas of research they judged to be fruitful.

8.2 The report recognised that for the process to be effective in achieving change it was essential that the resources put into R & D had to be translated into industrial products. This could only be achieved if industry were an active and committed participant in the process. ACARD have advocated that the process should therefore be separate from and funded independently of Government, and have appointed economic and management consultants to conduct technical and policy studies with the aim of advising how the process can be instituted, funded and operated to involve industry, Government and the scientific communities in an effective partnership.

8.3 To some extent a start has already been made in identifying exploitable areas, and setting up collaborative programmes to exploit them. The largest and most well-known of these is the Alvey Programme for research into information technology. The collaborative partners are industry, the academic world, SERC, and central Government. The programme is planned to extend over five years at a total cost of £350 million, £200 million from Government and the remaining £150 million from industry. A similar but smaller collaborative scheme is known as JOERS (Joint opto-electronic research scheme). Other examples of moves towards increased collaboration and co-ordination can be seen in the creation of the British National Space Centre, and the new Coordinating Committee on Marine Science and Technology. All these schemes were born of the realisation that the UK must increasingly determine its priorities, concentrate its resources, and develop a programme which will directly involve all those with a contribution to make to the enterprise, and an interest in its ultimate success. We see considerably more scope for developing similar schemes in a range of other areas.

8.4 A new approach from Government which was announced in July 1986 is to set up a Science and Technology Assessment Office located within the Cabinet Office. The function of the new office when it is fully established will be to gather and analyse information on the contributions Government support for R & D makes to the competitiveness of the UK economy. The office will work in conjunction with departments and will advise on the shape, content and conduct of their R & D programmes. It will advise Ministers collectively on the relative priorities between R & D programmes.

8.5 We believe this is an important initiative which will provide a valuable mechanism through which the Government can examine how its own R & D activities relate to its economic objectives. The Assessment Office will need to interact closely with whatever forum is set up as a consequence of the Exploitable Areas of Science report.

8.6 In an initiative taken in 1985 which could have far-reaching implications for the way universities relate to commercial exploitation, the DES announced new arrangements to give individual researchers and their universities new incentives and wider scope for exploiting their research. These arrangements were determined after a period of consultation following the decision in 1983 to end the British Technology Group's right of first refusal for the exploitation of Government funded research. Under the new arrangements, universities were invited to take upon themselves exploitation rights and asked to submit an account of the procedures they intended to adopt under a specified series of headings. Their proposals

were then examined by a Scrutiny Group. To date 33 university and university colleges have submitted satisfactory arrangements, and have been authorised to undertake their own exploitation work. They are able to retain their share of royalties and receipts without loss of general or specific grants.

8.7 We warmly welcome this initiative. We believe that benefits will flow from it both to the UK economy and to individual institutions. But more generally we see benefits arising from a changed climate of opinion within universities towards industry and exploitation. If universities are to be successful in exploiting their research they will need to develop commercial practices which will pave the way for an increased understanding and collaboration with industry generally. We hope, too, that universities will recognise that this change not only represents an opportunity for them, but also a responsibility to ensure that work with commercial potential is recognised and that its potential is realised. We also see potential in individual academic researchers becoming academic entrepreneurs and setting up their own companies to exploit their research ideas. We detect and welcome a growing sympathy with this approach in both the Research Councils and a number of universities.

9. THE WAY AHEAD

9.1 We have described in this report how the exponential growth for science funding in the past has now levelled out, and how the science base has been adapting to that situation. We have advocated a stronger emphasis on harnessing the science base for economic benefit, and have described promising initiatives which are bringing the academic world, industry, and Government closer together. In this concluding section we comment on the implications of these developments for the work of ABRC and ACARD.

9.2 We noted in section 4 that the Research Councils with the encouragement of the ABRC had developed Corporate Plans which integrated management planning with financial planning and scientific priorities. It is intended that the Councils will update these plans on a rolling basis, and that the Corporate Plans will form the main background to the ABRC's examination of Councils' activities which leads each year to the advice to the Secretary of State on the size of the Science Budget and its allocation. But just as Councils have felt the need to frame their activities in the context of a strategic plan so too has ABRC increasingly felt the need to develop a strategy of its own alongside which to consider Councils' plans.

9.3 The ABRC is currently preparing such a strategy document. It is intended that this will be wide-ranging, and cover such issues as resources, management, scientific priorities, international comparisons, national/international balance, and relationships between Research Councils and users (commissioning Government Departments and others). It will also address the dual support system and the relationship between the ABRC and the UGC and NAB.

9.4 The ABRC is also continuing to develop a programme of policy studies. One area it intends to examine is postgraduate education, and it has set up a working party under the chairmanship of Sir Alwyn Williams to review present policies and practices for the support of postgraduate taught courses. It will be commissioning further studies on international comparisons for research support to update the material prepared by the Science Policy Research Unit, for a report issued earlier this year. This later study will be undertaken in collaboration with the National Science Foundation in the USA. In view of increasing concern about the provision of advanced equipment, a study is planned to survey existing advanced equipment in university and Research Council laboratories with a view to identifying the need for and the use made of such equipment, and its costs. In an attempt to learn more about the outputs of the research process a bibliometric study is currently under way to examine the potential of publication counts and citations as a measure of the output of research centres.

9.5 ACARD will continue in its reports to identify opportunities for commercial exploitation of R & D in specific sectors of industry; it will also highlight any problems that stand in the way of exploitation and recommend solutions to both Government and industry.

9.6 A considerable volume of the R & D undertaken by industry is funded by Government in support of its procurement activities. Two recent reports by ACARD on the medical equipment and software industries have discussed how public sector procurement policies are not operating in the best interests of these industries. As it is likely that a similar state of affairs also obtains in other industrial sectors, ACARD intends to consider this problem in more detail. Well considered actions concerning the policies that govern public procurement could have a widespread and beneficial effect on the level of industrial R & D and on the innovative capacity of UK industry generally.

9.7 Many of today's large industries which employ significant numbers of staff grew from scientific developments made many decades ago. Although many start-up, 'high tech' companies have been set up in the UK to exploit today's scientific advances, there often

First sentence of 9.8 to read

9.8 In the ~~final~~ ^{final} analysis it is industry operating in the competitive environment of the market place that must recognise it has the ultimate responsibility to see the potential of research performed under the aegis of the science base and use it to enhance its own innovative capacity.

seem to be factors which militate against them growing beyond a limited size. ACARD considers that the reasons for such limitations to growth need to be fully analysed and if necessary steps taken to remove any constrictive constraints which might prevent companies from growing and thereby fully exploiting the economic benefits to be gained from the research which underpins their activities. The Council has started a study 'Barriers to Growth' to bring together information on this matter.

9.8 It is industrial concerns that operate in the competitive environment of the market place, and industry must recognise that it has the ultimate responsibility to see the potential of research performed under the aegis of the science base and use it to enhance its own innovative capacity. Firms that do not have commitment to innovation and a healthy R & D base, with staff at all levels capable of recognising the opportunities afforded by the results of their own and others' research and able to formulate what research is necessary to meet future needs, will not flourish. We would encourage industry generally to give a higher priority to R & D and to recognise the sometimes irreversible damage that low levels of R & D investment can have on their competitiveness in market places that are increasingly assailed by innovative products.

Annex A

ADVISORY BOARD FOR THE RESEARCH COUNCILS

Membership (as at 1 August 1986)

Professor Sir David Phillips, FRS (Chairman)	- Professor of Molecular Biophysics University of Oxford
Professor R L Bell	- Director-General of ADAS Ministry of Agriculture, Fisheries and Food
Sir Walter Bodmer FRS	- Director of Research Imperial Cancer Research Fund
Sir Sam Edwards FRS	- Scientific Adviser Department of Energy
Mr J Fairclough	- Chief Scientific Adviser Cabinet Office
Mr H Fish CBE	- Chairman, Natural Environment Research Council
Mr J S Flemming	- Economic Adviser to the Governor, Bank of England
Sir James Gowans CBE FRS	- Secretary, Medical Research Council
Sir Douglas Hague CBE	- Chairman, Economic and Social Research Council
Dr M W Holdgate CB	- Chief Scientist and Deputy Secretary, Department of the Environment and Chief Scientific Adviser, Department of Transport
Dr D Jack CBE	- Director of Research and Development Glaxo Holdings Ltd
Professor J L Jinks CBE FRS	- Secretary, Agricultural and Food Research Council
Sir John Mason CB FRS	- Treasurer of the Royal Society Pro-Chancellor of the University of Surrey
Professor P Mathias CBE FBA	- Chichele Professor of Economic History, University of Oxford
Professor E W J Mitchell CBE FRS	- Chairman, Science and Engineering Research Council
Mr J R S Morris CBE FEng	- Chairman, Brown and Root (UK) Ltd

Professor R O C Norman FRS

- Chief Scientific Adviser
Ministry of Defence

Professor F O'Grady CBE

- Chief Scientist
Department of Health and Social
Security

Dr D H Roberts CBE FEng FRS

- Joint Deputy Managing Director
(Technical) General Electric
Company

Mr O Roith FEng

- Chief Engineer and Scientist
Department of Trade and Industry

Sir Peter Swinnerton-Dyer FRS

- Chairman, University Grants
Committee

Sir Francis Tombs FEng

- Chairman, Rolls-Royce Ltd; and
Chairman, Advisory Council for
Applied Research and Development

Sir Alwyn Williams FRS

- Principal and Vice-Chancellor
of the University of Glasgow

Sir Martin Wood, OBE

- Deputy Chairman, Oxford Instruments
Group Ltd

Terms of Reference

The Advisory Board for the Research Councils was established by the Secretary of State for Education and Science in 1972 with the following terms of reference:

- (i) To advise the Secretary of State on his responsibilities for civil science with particular reference to the Research Council system, its articulation with the universities and departments, the support of postgraduate students and the proper balance between international and national scientific activity;
- (ii) To advise the Secretary of State on the allocation of the Science Budget amongst the Research Councils and other bodies, taking into account funds paid to them by customer departments and the purpose to which such funds are devoted;
- (iii) To promote close liaison between Councils and the users of their research.

Reports

Reports published by ABRC since the appearance of the first joint report of the chairmen of ACARD and ABRC in July 1983.

The Support given by Research Councils for In-House and University Research. The Report of Working Party of the Board (Chairman: Mr J R S Morris)	1983
A Study of Commissioned Research. Report by Sir Ronald Mason FRS	1983
Scientific Opportunities and the Science Budget 1983	1984
Scientific Opportunities and the Science Budget 1984	1984
Further Advice on the Science Budget 1984	1985
Fixed-Term Contracts for Scientists in the Research Councils: A Report to the Secretary of State for Education and Science (unbound)	1985
Science and Public Expenditure 1985	1985
High Energy Particle Physics in the United Kingdom (Chairman: Sir John Kendrew)	1985
Future Facilities for Advanced Research Computing. The report of a Joint Working Party (Advisory Board for the Research Councils, Computer Board for Universities and Research Councils, University Grants Committee)(Chairman: Professor A J Forty)	1985
The Brain Drain: Summary of Findings of an enquiry by the ABRC	1985
Science Budget: Allocations 1986-87 Planning Figures 1987-88 - 1989-90	1985
Report of the Working Party on the Private Sector Funding of Scientific Research	1986
Science and Public Expenditure 1986	1986
ABRC Science Policy Studies No 1:- Evaluation of National Performance in Basic Research (ABRC, The Royal Society, Economic and Social Research Council)	1986
ABRC Science Policy Studies No 2:- International Comparison of Government Funding of Academic and Academically Related Research (ABRC, Science Policy Research Unit, Sussex University)	1986

Annex B

ADVISORY COUNCIL FOR APPLIED RESEARCH AND DEVELOPMENT

Membership (as at 1 August 1986)

Sir Francis Tombs FEng (Chairman)	- Chairman, Rolls Royce plc
Mr A D Bain FRSE	- Group Economic Adviser, Midland Bank plc
Mr M Bullock	- Corporate Finance Director, Barclays Bank plc
Mr J F Coplin FEng	- Director of Design Rolls Royce plc
Sir Kenneth Durham	- Chairman, Unilever plc
Professor G M Edge	- Chief Executive, PA Technology
Mr A K Gill FEng	- Group Managing Director Lucas Industries plc
Mr E Hammond	- General Secretary, Electrical, Electronic, Telecommunications and Plumbing Union
Mr G Lomer CBE	- Technical Director Racal Electronics plc
Professor J S Metcalfe	- Professor of Economics Manchester University
Dr D S Oliver CBE	- Director of Research Pilkington Brothers plc
Professor Sir David Phillips FRS	- Professor of Molecular Biophysics University of Oxford: Chairman of the Advisory Board for the Research Councils
Mr C Read CBE	- Consultant
Dr C H Reece	- Director of Research and Technology, Imperial Chemical Industries plc
Sir Rex Richards FRS	- Director, Leverhulme Trust
Professor S D Smith FRS FRSE	- Professor of Physics, Heriot Watt University; Chairman, Edinburgh Instruments Ltd

In addition, the Chief Scientific Adviser, Cabinet Office, the Chief Scientific Advisers of the Departments of Energy and of Transport, the Chief Scientist and Engineer of the Department of Trade and Industry and the Chief Scientists of the Department of the Environment and the Ministry of Defence serve as Assessors to the Council.

Terms of Reference

The Advisory Council for Applied Research and Development was established in 1976. In April 1986, ACARD subsumed within its remit the Information Technology Advisory Panel (ITAP). ACARD's original terms of reference were revised and extended in 1982 and are now:

"To advise the Government and publish reports as necessary on -

- i. applied research, design and development in the United Kingdom;
- ii. the application of research and technology, developed in the United Kingdom and elsewhere, for the benefit of both the public and private sectors in accordance with national economic needs;
- iii. the co-ordination, in collaboration with the Advisory Board for Research Councils, of these activities, with research supported through the Department of Education and Science;
- iv. the role of the United Kingdom in international collaboration in the fields of applied research, design and development related to technology."

Reports

Reports by ACARD published since July 1983 are:

Improving Research Links between Higher Education and Industry (1983)
(with the Advisory Board for the Research Councils) ISBN 011 630 784 6

New Opportunities in Manufacturing: The Management of Technology (1983)
ISBN 011 630823 6

Exploitable Areas of Science (1986) ISBN 0 11 630827 3

Software - A vital key to UK competitiveness (1986) ISBN 0 11 630829 X

Medical Equipment (1986) ISBN 011 630830 3

All ACARD reports are available from Her Majesty's Stationery Office.

EXAMPLES OF TEACHING COMPANY AND COOPERATIVE RESEARCH GRANT SCHEMES

Volex plc and the University of Salford

Volex plc, formerly Ward and Goldstone, is a company whose product lines include automobile wiring harnesses, specialised cables for communications, instruments and electrical accessories. Its first Teaching Company programme with the University of Salford was authorised in 1981, and a second began in 1984.

The programmes have been associated with the design of two new products - the "Salplex" automobile electronic wiring system; and the "Saltest" computer for simultaneous assembly, monitoring, and testing of vehicle wiring harnesses.

The Salplex system is a versatile time-division multiplexing system, by which control information for a vehicle is transmitted on a single wire, and yet each transmitter/receiver unit around the vehicle is independent with no requirement for central control. The system operates much faster than previous centrally-controlled systems and without problems of radio interference. The project was awarded the Techmart Technology Transfer Trophy in 1984.

The Saltest computer unit is designed to test vehicle wiring harnesses at high speed. The computer monitors every wire connection and pin number in the loom as it is being assembled, continually and finally tests the harness, and gives a quality control print-out listing operator number, Saltest number, date and time of build, "OK to use", or a failure ticket. This last feature saves time in production, and enables repetitive faults to be pin-pointed quickly and accurately.

British Federal Limited and Birmingham Polytechnic

This Teaching Company programme is a partnership between British Federal Limited, part of the Laird Group, and Birmingham Polytechnic's Electronic and Electrical Engineering Department. The programme started in 1982 following a feasibility study into multi-axis robot control. By 1984 the programme team had developed a wide range of welding machines employing microprocessors, microcomputers, and programmable logic controllers. It had also designed a central monitoring system for robot lines and sophisticated hand

held programming controls for welding equipment, as well as being actively interested in the development of centralised control of groups of robots within a total manufacturing system.

As work progressed the original team expanded, and began to develop and implement a universal programmable logic control program which would be able to cope with the increasing high degree of sophistication and complexity demanded by the customer. This led to the Microman 8 microprocessor-based control system. This was very successful, and the Ford Motor Company placed a £2m order with British Federal for 45 robot welders and controllers for two plants. The programme is now being extended to support further development of the Microman 8 through design and manufacture of a second generation universal programmable controller which it is hoped will have world-wide sales appeal.

English Clays Ltd and Reading University

Many industrial processes involve the handling of particulate suspensions. High concentrations are preferred for the greatest handling efficiency. Unfortunately, at high concentrations, particles aggregate or flocculate with intolerable increases in viscosity and resistance to pumped flow. Reagents are added to hinder the associations and keep the material free flowing. To date, controlled amounts of reagent are added and checked by subsequent laboratory analysis, but it would be preferable to have a continuous monitoring of the efficiency of the reagent which can vary with product demand.

The Optics Group at Reading University is undertaking a cooperative research grants project, funded jointly by SERC and English Clays Ltd, on the fast characterisation of particulate suspensions through a new generation of electro-optical methods. Electro-optics is the study of the change in optical properties of a material when subjected to an electric field. The application of an electric field causes particles in suspension to rotate and align, and the transition from a random array to a full or partially aligned array can be detected by monitoring an appropriate optical property.

The Group has developed an optical monitor based on electro-optical light scattering. Although the intensity of normal light scattering is a possible indicator of particulate size, the field-induced change in intensity as individual particles begin to flocculate is a much more definite indicator. The signal is then used to regulate reagent addition. The project has already resulted in two patents and a commercial instrument.

Babcock Wire Equipment Co Ltd and Liverpool Polytechnic

Braiding is a process applied to textile yarns and metal wires to provide structure, reinforcement or electrical screening in a wide variety of products. Familiar products include hydraulic hoses and co-axial cables; a less familiar application is in the laying up of glass and carbon-fibre reinforcements for aircraft propellor blades. Improvements in speed, efficiency, and versatility of braiding machines hold the key to remaining competitive in this field on a world basis.

Liverpool Polytechnic has been working with Babcock Wire Equipment Co Ltd on a research project aimed at doubling the speed and spool capacity of their existing machines. This cooperative research grant project embraces fundamental studies on motion design and implementation, optimisation of path dynamics, spool and carrier dimensions for maximum material capacity, and control of wire tension. Life tests are currently proceeding in anticipation of prototypes of complete machines.

Netlon Ltd and the Universities of Strathclyde, Oxford, Sheffield, Nottingham and Bradford

The Netlon process is a method for integrally extruding polymeric mesh structures in one step, from the molten polymer to the finished product. It was invented in 1958 and Netlon Ltd has licensed the process in 26 countries.

The Netlon process produces biplanar structures with the sets of strands being in two distinct planes. Research begun in 1978 showed that it was possible to produce a uniplanar material in which the molecular orientation of the polymer passed through the mesh junctions, resulting in a structure in which there was no discontinuity in molecular orientation. This produced a material of high tensile strength, and high tear resistance, which was called Tensar.

Netlon Ltd identified a number of potential applications for the new product - for example the reinforcement of steep embankments, blast walls and sound barriers, the control of cracking and absorption of energy in cement-based composites, the reinforcement of bituminous materials for highway construction, and the replacement of steel strips in reinforced soil-retaining walls. There was, however, virtually no basic information available about the physical properties of molecularly orientated polyolefins, and this was needed if the potential applications were to be properly evaluated.

The company therefore entered into cooperative research grant schemes with the civil engineering departments of the Universities of Strathclyde, Oxford, Sheffield and Nottingham, under the guidance of an overall steering committee. Each university undertook research into different aspects of the problem: Strathclyde investigated testing methods for determining physical properties, and modelled the design of grid reinforced soil structures; Oxford modelled the degree of surface stabilisation of soft ground by using polymer grid reinforced fill; Sheffield investigated the behaviour of polymer grid cement-based composites; and Nottingham examined the characteristics of bituminous highway materials when reinforced with polymer grids and the response of pavement structures which included grids. At a later stage Bradford University became involved, and undertook research designed to improve the consistency of the polymer sheet before its transformation into Tensar structures, and so improve the quality of the final product. Subsequently Bradford and Strathclyde became the cooperating partners in a Teaching Company scheme based at Netlon Ltd which undertook further work on the behaviour and properties of polymer grids.

The results from the university work were very productive, and were instrumental in translating what was originally a laboratory specimen into a fully accepted, mass produced, civil engineering product. A symposium was mounted in 1984 to report on the work, and promote wide discussion of potential applications. It was attended by 400 delegates from 27 countries. A large manufacturing plant was brought on stream in this country, and a plant in Atlanta, Georgia, was also completed and brought into production. In the last five years many millions of square metres of high-strength polymer grid have been used for a wide range of applications. Netlon Ltd has received Queen's awards for Tensar technology and Tensar export achievement. The company also received the prestigious engineering MacRobert Award for the Tensar development.

Note: The first two examples have been extracted from the regular Teaching Company Newsletters produced by SERC/DTI; the second two examples come from the special edition of the SERC Bulletin produced for Industry Year 1986. The final example was the subject of the 1986 Philips Lecture at the Royal Society.

ACARD - MEETING WITH SIR FRANCIS TOMBS

(You could open by expressing satisfaction that Rolls Royce have put together a leasing package (with Goldman Sachs) for the engines of BA's proposed new Boeing 747-400s, such that Rolls Royce are able to compete for the business on the same footing as General Electric.)

Potentially, there is a lot of ground to cover in the meeting. It might be worth concentrating on two or three lines of questioning.

1. R&D Contribution to the Wealth-Creating Economy

- Are British scientists and researchers still bedevilled by intellectual snobbery manifested, for example, in the widespread view that the proper creditable product of R&D is learned papers rather than direct input to product design, production, marketing and distribution?
- The British have never lacked inventiveness; we probably have a large untapped inventory of exploitable ideas, some derived from fundamental research. Is the balance still weighted towards intellectually respectable fundamental research, rather than commercially valuable development?

2. Bureaucracy of the Allocation Process

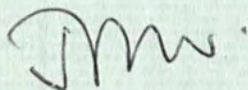
- If more emphasis is placed on commercially-driven development, is direct Government sponsorship the right vehicle?
- The bureaucratic machinery for allocating and monitoring the Government funding of R&D is a growth area, not least in the Cabinet Office (understood to be now the biggest secretariat in the CO). Instead of relying on the questionable judgement of Government officials and their advisers for the allocation of R&D funds, why not apply the same resources through tax incentives and rely on the commercial instincts of businessmen competing in the market place?
- How else can smaller businesses, unable or unwilling to grapple with the bureaucracy, get R&D support to turn creative ideas into saleable products? Doesn't the existing system favour large companies like GEC who have mastered the bureaucracy in order to tap Government funds?

3. The Shortcomings of Government

- Three years ago, in the ACARD/ABRC Report, Sir Alan Muir-Wood criticised the strongly departmental character of Whitehall. He made the point that too often

Departments are interested in their own territory - and budgets - rather than "UK Ltd"; in consequence, Government-funded R&D lacks coherence.

- That criticism still features strongly in the latest ACARD review. Is Sir Francis satisfied with the adequacy of the measures initiated or planned to overcome it?



JOHN WYBREW



30

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MINISTRY OF DEFENCE WHITEHALL LONDON SW1A 2HB

MO 26/1E

TELEPHONE 01-218 8000
DIRECT DIALING 01-218 2111/3

21st July 1986

Internals:
PS/Minister (DP) ~~PS~~ (ER)
PS/PUS Hd of ER1
PS/CDP DPP
CERN
DUS (RP)
DUS (DP)
DCER

Dear Francis,

*3358
28/7/86*

Many thanks for your letter of 23rd June. I much enjoyed our dinner and the lively discussion.

You confirm that ACARD plan to take a more detailed look at the Defence R&D programme with special emphasis on how greater civil spin-off might be secured. I would indeed welcome this, and I suggest that the Committee might find it helpful to be briefed by the MOD on our general approach to R&D in the Defence Budget and the steps we have taken or are planning to increase the contribution made by it to the wider economy. The briefings could include, if the Committee wished, a visit to one or more of the MOD Research Establishments, to see some of the activity "on the ground". If you would like to take up this invitation, please let me know and the arrangements will then be made.

As to the ground which the Committee's study might cover, I hope that you will be able to look in particular at the scope

Sir Francis Tombs
Chairman of ACARD



for private industry making a greater financial contribution to Defence R&D itself; and I feel perhaps that you could find some way in which Rolls Royce might be able to show industry the way forward. Your dual responsibilities could thereby invest the programme with great authority. An analysis of the importance attached by companies to civil exploitation of their defence R&D activities, whether funded by government or privately, and the means by which exploitation is pursued within companies, would also be very useful. I would also welcome any assessment the Committee might make of the mobility of skilled resources within industry between defence and civil activities, and the determining factors of such mobility.

Meanwhile, it may be helpful to me to set out some of the main elements of the MOD's approach, particularly as our talk over dinner did leave me with the feeling that we in MOD have not managed to put across exactly how much we already do to achieve the objectives we both discussed. The primary function of defence procurement must be - and I would hope this is common ground between us - to obtain the weapons and equipment needed for the Armed Forces at the best value for money. But having said that, defence procurement accounts for a substantial slice of government expenditure and I fully accept the onus on my Department to ensure, consistently with its primary functions, the maximum benefit for the economy at large from these funds.



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We seek to achieve this in a variety of ways. MOD's procurement strategy in recent years has placed increasing emphasis on close involvement of industry from the earliest stages of equipment planning, even before Staff Targets are framed. This reflects the Government's overall public purchasing policy which requires public sector purchasers to use the influence their purchases give us to help develop the design, technology and competitiveness of their suppliers. Staff targets themselves are now made shorter and simpler than previously, stating the military work which the equipment is required to perform without necessarily specifying the nature of the equipment itself. In this way industry is encouraged to use its initiative to develop equipment solutions which have good sales prospects overseas and draw on civil work. There is also a constant dialogue between MOD and individual firms, bringing in military operational requirements staff as well as the staff of the Procurement Executive. We are increasingly making use of cardinal point specifications which define key performance features but otherwise allow industry the maximum scope to innovate, to cut costs and enhance the export potential of the equipment. These procedures have to date been used in about 50 different contracts worth nearly £1 billion. We are now planning to include in defence contracts specific provisions to cover export possibilities.



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More generally, machinery and procedures are already in operation which should enable industrial interests and concerns to be taken into account in MOD decision-making. This includes standing consultative machinery, such as the National Defence Industries Council, periodic meetings between MOD officials and Trade Associations and regular informal meetings between Ministers, senior MOD staff and senior managers from defence industry. You emphasised the importance of links between MOD and DTI, and I agree very much with this, but those links do exist and they are closer than you seemed to imply. MOD and DTI Ministers meet regularly, and the DTI Chief Scientist and Engineer is a member of the central management board for Defence Research. In addition DTI officials are represented on MOD's Equipment Policy Committee (EPC) and there is a wide range of contacts between the industry sponsor divisions of DTI and different parts of MOD.

In international collaboration, the drive is for collaborative development and production of weapon systems, especially on a European basis throughout the Independent European Programme Group (IEPG). The member Governments of the Group have committed themselves to:

- a. greater discipline in not launching a national development programme where one already exists elsewhere, nationally or collaboratively, in Europe, and



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b. greater readiness to adopt an equipment already in production in Europe or, where otherwise acceptable, to adopt a US project for licensed production in Europe, preferably in conjunction with European allies;

c. greater pooling of effort in research and technology and the provision of research and test facilities.

Within the Ministry of Defence itself the post of Chief of Defence Equipment Collaboration has been established to develop a systematic approach to collaboration which will secure the maximum advantage for the United Kingdom.

The MOD's Research Establishments already have extensive and close links with industry and cooperate with DTI and other Government Departments in substantial joint military and civil and purely civil programmes. Of the total annual expenditure on research of some £400 million, some £150 million is placed extramurally with industry and the Universities in itself providing a continuous and often daily dialogue with scientists and engineers outside government. Current practices and recent initiatives cover a wide span, including:

a. the appointment of outside industrialists, not restricted to a defence industry background, to the management board of the MOD's Controller of Research at the



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MOD and to the boards of the Research Establishments, so as to bring an added industrial dimension to consideration of the defence research programme and to reduce overlap between industry and our own activities;

b. the development of joint military and civil research programmes based on the research establishments and including industrial participation, notably in information and space technology. This has recently been reinforced by a programme of 'National Electronics Research Initiatives', centred on the Royal Signals and Radar Establishment, with the costs shared between the MOD, DTI and the industrial participants. The aim is to establish collaborative research activities within industry to achieve an international standard of excellence in chosen areas of high technology;

c. the setting up of Defence Technology Enterprises Ltd (DTE) to identify and market technology developed in the Research Establishments for application by civil industry. I was glad to hear Mr Bullock speak up so strongly over dinner for this initiative. Defence Technology Enterprises is now well established at three major establishments, the Admiralty Research Establishment, the Royal Signals and Radar Establishment at Malvern and the Royal Aircraft Establishment, Farnborough. It has been building up its



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portfolio of potentially exploitable material - there are already 400 items on its database - and recruiting firms as associate members - more than 100 firms have already joined. DTE let its first major licence at the beginning of the year for a software package developed at RSRE Malvern. Both DTE and the Research Establishments themselves will have displays at this year's TECHMART exhibition. The MOD is considering the establishment of Science Parks adjacent to the Research Establishments, again to facilitate the flow of technology into industry, both defence and civil;

d. MOD support for the national science base at the Universities has recently been enhanced by our participation with the Department of Education and Science and the Research Councils in funding joint research grants; we are also seeking to widen the scope of joint programmes with Universities and Research Councils and to promote common use of facilities and staff exchanges with the Universities.

Some examples of the actual and potential cooperation
/ between the Research Establishments and industry are enclosed.

I look forward to hearing from you in the near future.

Yours sincerely,
George Younger
George Younger

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EXPLOITATION SUCCESSES AND PROSPECTSLINKS BETWEEN MOD RESEARCH ESTABLISHMENTS AND INDUSTRYRoyal Signals and Radar Establishment (RSRE)(a) Awards

- A recent Queen's Award for Technological Achievement (to the Electronic Materials Division at RSRE) was for the research and development of high resolution X-ray detector crystals for application in body and brain scanners. The award was shared with Hilger Analytical Ltd (HAL) who now manufacture the crystals and export the whole production.
- An early Queen's Award was for Liquid Crystal materials for displays. These were invented at Hull University in cooperation with RSRE and are covered by MOD patents. More recently, coloured dyes were invented jointly by RSRE and BDH Chemicals and also jointly by RSRE and ICI to give coloured displays.
- Queen's Awards for Technological Achievements for Advanced Semiconductor Crystal Growth Equipment, for a System of Sensors for Intruder Detection and for Semiconductor Detectors for Infra-red Imaging.
- Rank Price Fund Awards for Semiconductor Materials for Infra-red Detection, Liquid Crystal Materials, Integrated Semiconductor Infra-red Detector and Pyroelectric Infra-red Vidicon.
- McRobert Award for Photon Counting System for application of Lasers to the Measurement of Fluid Flow.

(b) Direct current electroluminescent displays were originally developed at Thames Polytechnic in cooperation with RSRE. Work has continued at Phosphor Products of Poole (a firm formed originally by the staff at Thames Polytechnic) and high hopes are held for eventual exploitation.

(c) The CORAL 66 programming language was designed and developed at RSRE. It was the first attempt to create a high-level structured language for real-time control applications. Industry has developed compilers and related tools and applications include a traffic control system which was developed as a product in its own right.

(d) RSRE designed and implemented the world's first ALGOL 68 Compiler which now forms the basis of current commercial implementations with continuing sales.

(e) SDS is a software package which provides a way of managing the large amount of design data generated during the development

of large software products. Written at RSRE, it is now a product of Software Sciences Ltd and is to be developed further as part of an Alvey project.

(f) ELLA is a hardware description language. Used as a logic simulator, it can validate designs produced using traditional techniques, enabling early detection of errors. Used at the highest level, architectural specifications can be evaluated and optimised quickly, before effort is invested in detailed design work. ELLA is in the final stages of being licensed for commercial exploitation.

(g) ESPRIT. RSRE is leading the ESPRIT project to produce a super-computer for high speed processing. The aim is to achieve a marketable product with support in more than one European country.

(h) Industrial Consortia. RSRE has also led several industrial consortia for the exploitation of electronic technology, for example the Gallium Arsenide Consortium, the Surface Acoustic Wave Consortium, the Liquid Crystal Consortium and the High Performance Silicon Systems Consortium.

(i) Links with DTI. RSRE participates in a number of DTI committees/policy bodies including:

- (1) The Electronic Devices and Materials Committee
- (2) Alvey
- (3) Joint Opto Electronic Research Scheme (JOERS)
- (4) JOERS Displays Advisory Committee (JDAC)
- (5) Computer Requirements Board
- (6) British National Space Centre

(j) Statistics

- (1) the number of industrial visitors to RSRE to discuss technology - 7000 per annum
- (2) the number of confidentiality agreements signed with UK companies - 25 since 1984
- (3) the number of companies which have seconded staff to work within RSRE - 35 since 1983
- (4) the MOD Patents Branch have negotiated 48 licences with industry for the use and transfer of RSRE IPR.

Royal Aircraft Establishment (RAE)

- (a) Flow Field Calculations. RAE has made major contributions to the development of computer-based techniques for the calculation of airflow around aircraft. Methods developed by the Establishment have been used extensively by BAe in the design of the wings for the A310 and A320 airbus aircraft. The contribution of this work to the success of the former has been acknowledged by US industry when lobbying Congress.
- (b) Helicopter Rotor Systems. Part of RAE's research programme on helicopters in recent years has been aimed at improving the aerodynamic design of the rotor blades, leading to new blade sections and tip shapes that give an increase in rotor lifting capability of about 30 per cent compared with that achieved in service today. Fabrication of the more complex blade shapes that result at an economic cost has been made possible by advances in composite material technology which also had their origins in RAE. The benefit of this work was confirmed by a technology demonstrator programme which has recently been brought to a successful conclusion in close collaboration between Westlands and the Establishment. The results are being applied by Westlands to the design of the main rotor of the Anglo/Italian EH101, which has both civil and military applications and to developments of the W30 helicopter.
- (c) Aluminium-Lithium Alloys. Early work on lithium-containing aluminium alloys in the USA and USSR led to the widespread belief that production of lower density aluminium alloys with acceptable properties for aeronautical application would have to await the development of suitable power metallurgy techniques, and would therefore result in an expensive product. However alloy research at RAE over the past 6 years has shown that this is not so and that Al-Li alloys can be produced by a conventional and inexpensive ingot metallurgy route to meet desirable target levels for density and mechanical properties. RAE worked closely with British Alcan during the development programme with the latter concentrating on establishing a viable commercial production process. Particular problems of handling lithium and of metallurgical control of the melt have been overcome and material in a variety of forms produced from 1000 Kg ingots has been evaluated by a range of potential customers in the UK and overseas. An agreement has been signed granting Alcan the necessary licences on the relevant RAE patents to produce, use and sell aluminium-based alloy products containing lithium in as-cast or semi-fabricated forms for defence and aerospace applications.
- (d) Cover Glasses for Satellite Solar Cells. Solar cells constitute the primary source of power on artificial satellites. Cover glasses to protect these, although individual small components, make in total a significant contribution to the weight of the satellite. A joint programme by RAE and Pilkington has led to a significantly lighter product with a longer service

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life. As a result the firm now has some 70% of the world market (excluding the Soviet Union). A joint Queen's Award for Technology was recently granted to the firm and the Establishment for this achievement.

(d) RAE developed carbon fibre composite materials and structure for multi-purpose aircraft application. The materials are now finding widespread use in general engineering.

Royal Armament Research and Development Establishment (RARDE)

(a) Road Transportable Bailey and Medium Girder Bridges. These bridges, developed for military use, have been widely used in a number of third world countries.

(b) Remote Control Tracked Vehicle. This was developed for use in Northern Ireland for investigations of suspicious articles etc. It has been adopted by a number of police forces throughout the world.

(c) High Current Transistors. These were originally developed by DCVD, for use on tanks. A firm now markets them, and one known application is in large medical equipment.

(d) Hydrogas Suspension. Developed for the Challenger tank, this is now being taken up by several companies.

(e) Mechanical Handling Devices. In military contexts remote control 'arms' have to do a wide variety of tasks, and hence require much flexibility. A patent application has been made in respect of a recent development, namely a 'Draw String Gripper', which has considerable licensing possibilities.

Admiralty Research Establishment (ARE)(Portsmouth)

SPATE (Stress Pattern Analysis by Thermal Emission). This new method is now incorporated into an instrument for measuring stresses in structural components under dynamic load.

Directorate of Components, Valves and Devices (DCVD)

Semicustom Approach to Microcircuit Design. The concept of the Uncommitted Logic Array (ULA) was largely created and demonstrated through a MOD/VCD sponsored development project. Subsequently it has been evolved and extended in circuit complexity to form the basis of a major commercial business, eg in Sinclair and Nixdorf computers.





10 DOWNING STREET
LONDON SW1A 2AA

From the Private Secretary

MR. FAIRCLOUGH

RF || We have arranged a meeting between the Prime Minister and Sir Francis Tombs, which will take place on 25 July. The meeting is at Sir Francis' request.

/ I should be grateful for a note from you on the points you think Sir Francis is likely to raise, and for a short background brief to cover them.

(Mark Addison)

25 June 1986

ls

M. R.

PRIME MINISTER

Kathy Cunningham
7140.

Sir Francis Tombs has asked to see you
for half an hour or so in his capacity
as Chairman of ACARD. As you know, he
took over not long ago from Sir Henry
Chilver.

I am sure you will wish to see him, perhaps
some time during July.

Agree?

Yes

Mango

Duty Clerk.

ME

19 June 1986

Confirmed for
July 25th

OK
25/6.

~~Carolee.~~

would you fix up a $\frac{3}{4}$ meeting

pl in July for Sir Francis T. We shall
need to commission briefing from John
Fridgell. — C. O. Chay (will be
advised).
Met 25/6



10 DOWNING STREET

From the Private Secretary

3 June 1986

Dee Tony

The Prime Minister has received a report from the Advisory Council for Applied Research and Development (ACARD) on the medical equipment industry, together with a covering letter from the Chairman of ACARD. A copy of the report is attached.

The Prime Minister has agreed that the report should be published.

As is customary, a written response will be provided by Government and the Prime Minister has asked that the Secretary of State for Health and Social Security should take the lead in co-ordinating the Government response.

I am copying this letter and the report to the Private Secretaries of other Cabinet Ministers and to Sir Robert Armstrong and the Chief Scientific Adviser, Cabinet Office.

L e

Mark Addison

Mark Addison

Tony Laurance Esq
Department of Health and Social Security



10 DOWNING STREET

THE PRIME MINISTER

3 June 1986

Dear Sir Francis,

Thank you for your letter of 22 May and the Council's report on medical equipment. The medical equipment industry is an important one for this country, and the Council's recommendations will need to be considered carefully.

I agree to publication of the report. I have asked for arrangements to be made for the Government's written response and this will be communicated to ACARD in due course.

Yours sincerely

Margaret Thatcher

Sir Francis Tombs

PRIME MINISTER

ACARD REPORT ON MEDICAL EQUIPMENT

Sir Francis Tombs has submitted to you a report on medical equipment drawn up by a working group, and endorsed by the Council.

The report and his covering letter are at Flag A. A summary of the report's recommendations is at Flag B.

The report grew out of a concern that the UK medical equipment industry was showing signs of failing to keep up with its international competitors. It concludes among other things that the industry does need to adopt a more international perspective, that Government support for R & D needs to be increased, and that NHS decision makers need strong support to encourage them to support the UK industry wherever possible.

Sir Francis seeks your agreement to publication, which you normally give for the ACARD reports of this kind. John Fairclough agrees that you should give it in this case. DHSS are content.

DHSS would then need to coordinate a draft response. John Fairclough notes that the Government will need to consider particularly carefully the recommendations dealing with public expenditure (eg an increase on capital equipment budgets for Health Authorities), providing additional manpower to the DHSS Procurement Directorate, expanding the evaluation programme for new medical equipment and increasing Government support for R & D in the industry. But he thinks the general tenor of the report is reasonable and consistent with the general direction of Government policy.

Agree to publication? Agree that DHSS should be asked to
coordinate a Government response? *Yes*

A letter of acknowledgement for your signature to Sir Francis
Tombs is attached at Flag C.

MEA

MARK ADDISON

30 May 1986

CJ2AAX

✓CBG

Peter Casey
to be published PITH.



W039

MR ADDISON - No. 10

27 May 1986

ACARD REPORT ON MEDICAL EQUIPMENT

The Advisory Council for Applied Research and Development (ACARD) has recently considered a report on the medical equipment industry prepared by a Working Group set up by the Council. ACARD approved the report and invited Sir Francis Tombs to submit it to Government. He will shortly be sending a copy to the Prime Minister. For your information a copy is attached. A summary of recommendations follows the foreword. I attach a draft reply for the Prime Minister to send to the ACARD Chairman.

ACARD would like the report to be published and have invited Sir Francis Tombs to seek the approval of the Prime Minister. It has been customary for such approval to be given, and I see no reason why approval should not be given in this case. Although the Government will wish to consider the recommendations carefully, particularly those which involve public expenditure (paras 68, 100, 144 and 154), the general tenor of the report is reasonable and consistent with the broad directions of Government policy.

The Council will expect the Government to provide a written response. The subject is of interest to several Departments and two Research Councils, but the natural lead Department is DHSS and I recommend that they be invited to co-ordinate the Government response. It would be helpful if the Prime Minister could draw the attention of her colleagues to the report and indicate to them how the report will be handled by means of a Private Secretary's letter. A draft is attached. We shall supply you with the required number of copies.

JOHN W FAIRCLOUGH
Chief Scientific Adviser

DRAFT LETTER FOR THE PRIME MINISTER'S PRIVATE SECRETARY TO SEND TO PS/SECRETARY
OF STATE FOR HEALTH AND SOCIAL SECURITY

ACARD REPORT ON MEDICAL EQUIPMENT

The Prime Minister has received a report from the Advisory Council for Applied Research and Development (ACARD) on the medical equipment industry, together with a covering letter from the Chairman of ACARD. A copy of the report is attached.

The Prime Minister has agreed that the report should be published.

As is customary, a written response will be provided by Government and the Prime Minister has asked that the Secretary of State for Health and Social Security should take the lead in co-ordinating the Government response.

I am copying this letter and the report to the Private Secretaries of other Cabinet Ministers and to Sir Robert Armstrong and the Chief Scientific Adviser, Cabinet Office.

DRAFT LETTER FOR THE PRIME MINISTER TO SEND TO SIR FRANCIS TOMBS

Thank you for your letter of [22 May] and the Council's report on medical equipment. The medical equipment industry is an important one for this country, and the Council's recommendations will need to be considered carefully.

I agree to publication of the report. I have asked for arrangements to be made for the Government's written response and this will be communicated to ACARD in due course.



ADVISORY COUNCIL FOR APPLIED RESEARCH AND DEVELOPMENT

70 Whitehall, London SW1A 2AS Telephone: 01-233

The Rt. Hon. Margaret Thatcher, MP.,
The Prime Minister,
10 Downing Street,
London, SW1.

spk DHHS

22 May 1986

Dear Prime Minister,

ACARD REPORT ON MEDICAL EQUIPMENT

The Advisory Council for Applied Research and Development (ACARD) has recently completed a study of the medical equipment industry. I have pleasure in enclosing a copy of the report on the study. The report, and its recommendations, have been endorsed by the Council who have invited me to submit it to the Government, and seek your approval for publication.

The UK medical equipment industry has a turnover of around £1 billion a year. The industry world-wide has seen substantial growth in recent years, and is expected to continue to grow for the foreseeable future. It is a high technology industry in which Britain has been very successful, but where there are signs that our industry is beginning to fall behind in important areas of the business. It is also an industry which is strongly influenced by the public sector which, in addition to its normal activities towards industry, is, through the NHS, its dominant home customer.

In the view of the report, the long term health of the industry will depend on an adequate level of research and development, with strong links with academic research and clinical practice. It will also depend on being able to attack overseas markets successfully, which will require better marketing and design, and the removal of the unnecessary regulatory barriers which exist, particularly in Europe. It will also require a home market which not only provides a base of demand for products which can be sold profitably overseas, but also allows growth opportunities for the many small companies in this business. Many of the difficulties which the industry faces are by no means unique to medical equipment, but we have tried to concentrate on those which are, or which at least apply to this industry with particular force.

The report makes a considerable number of recommendations, which are summarised at the end of the report. They cover a wide area, including the encouragement of R&D links between firms and health service staff, Government R&D support, and the regulatory and information activities of DHSS. The most important group of recommendations, however, is aimed at the character of the home market, which is determined by the actions of NHS buyers. We believe that this market needs to be a free one, but also well-informed and responsible, which implies considerable improvements in NHS systems, attitudes and practices. ACARD believes that if its recommendations are accepted, they will provide an environment in which this important and growing industry has every chance to prosper, provided that those within it take the opportunities offered to them.

Yours sincerely,

Francis Tombs

Sir Francis Tombs

Enclosure

ADVISORY COUNCIL FOR APPLIED RESEARCH AND DEVELOPMENT

REPORT ON MEDICAL EQUIPMENT

Cabinet Office
May 1986

FOREWORD

The UK medical equipment industry has a turnover of around £1 billion a year, and has in the past been one of Britain's successes. It is a business much of which can expect to see major technical changes over the next few years, and which is becoming increasingly international. Indeed, with the UK representing only a very small proportion of the world market, it is essential for the industry to take an international view if it is to be able to afford the commitment to R&D which will be necessary to keep up with the competition in many areas of the business. Although many indicators of its performance remain strong, there are worrying signs that the industry may be failing to keep up, both technically and commercially.

The industry is also strongly influenced by the actions of the public sector. In addition to the usual background of Government economic policy and industrial sponsorship, it operates both nationally and internationally in a complex regulatory environment. Above all, its home market, which is important for any industry, is dominated by the actions of buyers within the National Health Service.

Against this background, ACARD set up a Working Group in December 1985, with the following terms of reference:

- i. to examine the UK medical equipment industry, with particular reference to its technological capability, its international opportunities, and its prospects in the face of international competition;
- ii. to review the effects of the activities of Government and other public bodies on the ability of the industry to compete world-wide, including where relevant their effects on the character of the domestic market;
- iii. to make recommendations.

The members of the Working Group were:

*Sir Rex Richards FRS Director, Leverhulme Trust
(Chairman)

*Mr M Bullock Corporate Finance Director, Barclays Bank plc

Mr P F Burden Director of Manufacturing Operations,
Rolls-Royce Ltd.

Mr. R.F.O. Burlinson Managing Director, Orbec Ltd.

Mr. J. Hutton Senior Research Fellow, Centre for Health
Economics, University of York

Mr B D Muddell Director, Business Planning, Smiths Industries
Medical Systems

Professor D K Peters Professor of Medicine, Royal Postgraduate
Medical School

Mr C J Spry District General Manager, Newcastle Health
Authority

Mr P R D Styles MBE Director-General, British Health Care Trade
and Industry Council

*ACARD member

The Group also had assessors from the Department of Health and Social Security, the Department of Industry, and the Science and Engineering Research Council, who made valuable contributions to its work.

The report of the Working Group was considered by ACARD in May 1986, and has been submitted to the Government for their consideration. It is now published to draw attention to the Group's recommendations, and as a stimulus to discussion.

The Council is grateful to the members of the Working Group for their contribution to ACARD's work, and to the many companies, organisations and individuals who helped in their work, including the ACARD Secretariat in the Cabinet Office.

SUMMARY OF RECOMMENDATIONS

A. Our central recommendation is in para 73, in which we emphasise that NHS decision makers should be kept constantly aware that NHS purchasing is by far the dominant domestic influence on the shape of the UK medical equipment industry, and that the NHS benefits both directly and indirectly from a healthy UK industry. We recommend that the Health Departments should issue guidance emphasising the need for a full option appraisal, including full consideration of British equipment and making use of the available expert advice, for all major NHS purchases whether or not they are financed from public funds. (para 73)

B. NHS decision makers need stronger support in terms of systems, information, and expertise. The new NHS Director of Procurement and Distribution should continue the process of improving NHS information, financial, and purchasing systems as rapidly as possible. DHSS should take steps to provide for increased research and information on the health economics of new techniques and equipment. Health Authorities should be encouraged to invest in new equipment where this can be shown to offer increased efficiency, and the economic appraisal expertise available to Health Authorities should be strengthened. The DHSS/SHHD evaluation programme should be continued and expanded, and the modest expenditure devoted to it should be materially increased. The pump-priming funds available to the DHSS should be used primarily to introduce new medical technologies of British manufacture to the NHS and to promote their rapid assessment. (paras 64, 66, 67, 77 and 144)

C. The capital equipment provision in both Regional and District Health Authority budgets should be increased, and steps should be taken to ensure that this provision is used for the purpose for which it was allocated. (para 68)

D. The market for equipment in the primary health care sector is growing rapidly outside this country. In considering policy on the funding of primary health care services, the Government should take into account the interest of the medical equipment industry in a GP market parallel to that existing elsewhere. Trial practices should be established in which GP's would be

encouraged to provide a greater range of services, and UK industry should be linked with this experiment and encouraged to use these practices as a test ground for new products aimed at the GP market. (paras 92 and 93)

E. Government support for R & D on medical equipment should be substantially increased. A mechanism should be set up to coordinate the programmes of DHSS, DTI and SERC in the medical equipment field. This mechanism should involve participation by MRC and industry. (paras 154 and 155)

F. The industry needs to address international markets, and there are several steps the Government could take to help it to do so. The regulatory environment is particularly important. Additional manpower should be provided to STB for the operation and expansion of the Manufacturer Registration Scheme. The Government should take a stronger political initiative within the European Community to create a freer internal market in medical equipment by eliminating the barriers currently created by differing national standards and regulatory regimes. (paras 100 and 102) The Government should recognise the value to UK industry of overseas students studying medicine and its supporting disciplines here, and in particular should give positive encouragement to postgraduate study in the UK in these areas. (para 75) DTI should give wider publicity to market reports from British Posts overseas and to the other help to exporters which Posts can provide. (para 54)

G. A single Branch within DTI should be given coordinating responsibility for all those sponsorship and support activities towards the medical equipment industry that fall to DTI, including responsibility for liaison with DHSS and SERC on matters relating to the industry. (para 126)

H. We found perceived barriers to the essential close collaboration between the industry and members of the health care professions, and make recommendations to overcome them. The Health Departments should issue new guidance to Health Authorities which, whilst reiterating the need to prevent corruption in purchasing activities, gives positive encouragement to the creation of R & D links with UK-based firms. They should also issue guidance on the terms of relationships with firms, and should encourage Health Authorities

to employ staff on contracts which permit them, if they wish, to spend part of their time in industry. (paras 117, 118 and 119) The Health Departments, the main trade associations and those professional associations which are active in this field should take steps to improve understanding between people in industry and those in the health service. (para 120)

I. The industry could also derive greater benefit from the education and training system. SERC should give high priority to medical engineering in their support of postgraduate training. Medical engineering, industrial design, and management engineering should be priority areas for future university appointments. (paras 158 and 159)

J. There are problems in obtaining good and relevant statistical and market data on the industry. A joint group from industry, Customs and Excise and DTI should be set up to produce a more helpful classification scheme for the Government statistics relating to the industry. (para 163) The NHS should begin now to plan how its equipment purchasing data could be made available to industry. (para 164)

INTRODUCTION

1. The medical equipment industry is a major one, with a turnover in the UK of around £1 billion a year. It has seen substantial growth world-wide in recent years, growth which is expected to continue in the foreseeable future, and which in some areas has been quite spectacular. It is an industry in which Britain has been very successful, and which contains important high technology sectors. It is also an industry strongly influenced by the actions of the public sector which, in addition to its normal activities towards industry, is in this case, through the NHS, its dominant home customer. But there are signs that the UK is falling behind the game in important areas of the business. It was these circumstances which led ACARD to set up this Working Group.

2. There is no universally accepted definition of what the medical equipment industry is, and almost every writer on the subject adopts a slightly different view. For our study, we have taken a pragmatic view based on industrial considerations as well as what is actually produced and traded. We have concentrated on those sectors which produce hardware specifically designed for medical use. Following DHSS practice, we have included in this definition both capital and consumable items. The wide range of this definition can be seen by listing just a few of the items which come within it: artificial hip joints, autoclaves, catheters, electrocardiographs, forceps, hospital beds, massage apparatus, MRI scanners, spectacles, syringes, wheelchairs. However, whilst directing our attention primarily to this area, we have also looked at a penumbra of other activities surrounding it, which some would include in the definition of medical equipment. Various kinds of laboratory equipment, diagnostic kits, and surgical dressings come within this latter area, as do some major components of medical equipment (eg magnets for MRI). As suggested above, our reasons for regarding a given area as within, or not within, our "core" are in some cases partly industrial. Thus, for example, surgical dressings are produced mainly by the pharmaceutical industry, which is very different in character from the medical equipment industry as we have defined it. In addition, we have tried to take note of developments in other areas where these seem likely to impinge on the business of our "core" industry. An example is the development of intravenous anaesthetics, which will affect the market for the traditional inhalation equipment.

3. We have found in the United Kingdom an industry which seems to us to be at

the crossroads. It has many strengths, but also a number of weaknesses. It is being exposed to fiercer competition than ever before, both at home and abroad, in a rapidly changing technological environment. The potential for success is there, but so is the potential for a failure which would leave our successors wondering how another major British industry was lost.

4. In what follows, we have inevitably concentrated more on the weaknesses than on the strengths, because it is in these areas that we see the greatest scope for action. We have also produced many more recommendations addressed to the public sector than to industry. This partly reflects the position of ACARD as an advisory body to Government. It also partly reflects our preference for recommendations to specific recipients to take specific actions over more general recommendations aimed at "the industry". It does not, as we hope the text makes clear, reflect a belief that all fault, or all merit, lies with Government rather than industry. Indeed it is, and must remain, those in industry who will carry the main burden of responsibility for success or failure.

THE WORLD MARKET AND THE UK'S PLACE IN IT

5. There are no reliable and up to date figures for the world market in medical equipment. This stems partly from the familiar delays in producing international statistics, but much more from the fact that, as we have already indicated, "medical equipment" is not an area in which statistics have been collected on a well-defined and accepted basis. We have had to use such figures as we could find, from a variety of sources. One set of industry analysts, applying a rather wide definition of medical equipment, estimates the world market in 1985 as \$30 billion, broken down as follows:

Table 1

Product Group	Sales (\$ billion)			
	US	Europe	Rest of World	Total
Laboratory diagnostics	2.50	1.25	1.25	5.00
Imaging	2.75	1.25	1.00	5.00
Other electromedical	2.75	1.25	1.00	5.00
Single-use	6.50	3.00	2.50	12.00
Specialties	1.50	0.75	0.75	3.00
Total	16.00	7.50	6.50	30.00

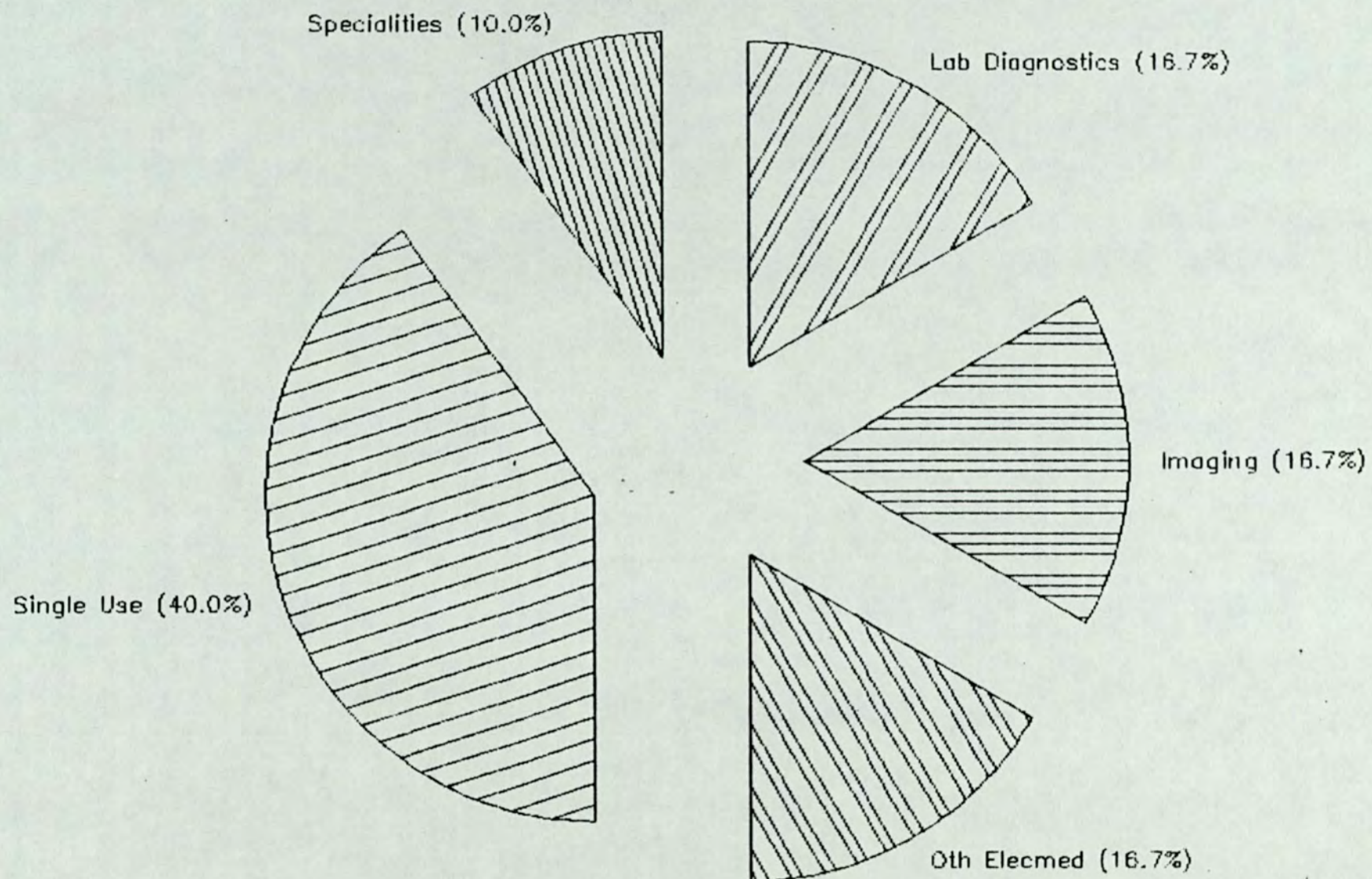
(Source: E.B. Savory Milln & Co.)

6. A more detailed breakdown by equipment type is given in Appendix 1. Those of us with knowledge of the market regard these figures as plausible, but we must emphasise that we have not been able to check them, and their authority is simply that of their source. It will be seen immediately that the market is dominated by the USA, which on all estimates amounts to about half the world market (strictly, the free world market). The UK market is generally reckoned to amount to around 4% of the total. This is consistent with the picture derived from DHSS statistics and estimates, which show a UK market, on their definition (wider in some respects and narrower in others) of around £1 billion a year.

7. We have not found it possible to obtain figures for market growth which are both consistent and credible. The DHSS figures appear to show UK market growth of around a third (in cash terms) between 1982 and 1984, equivalent to

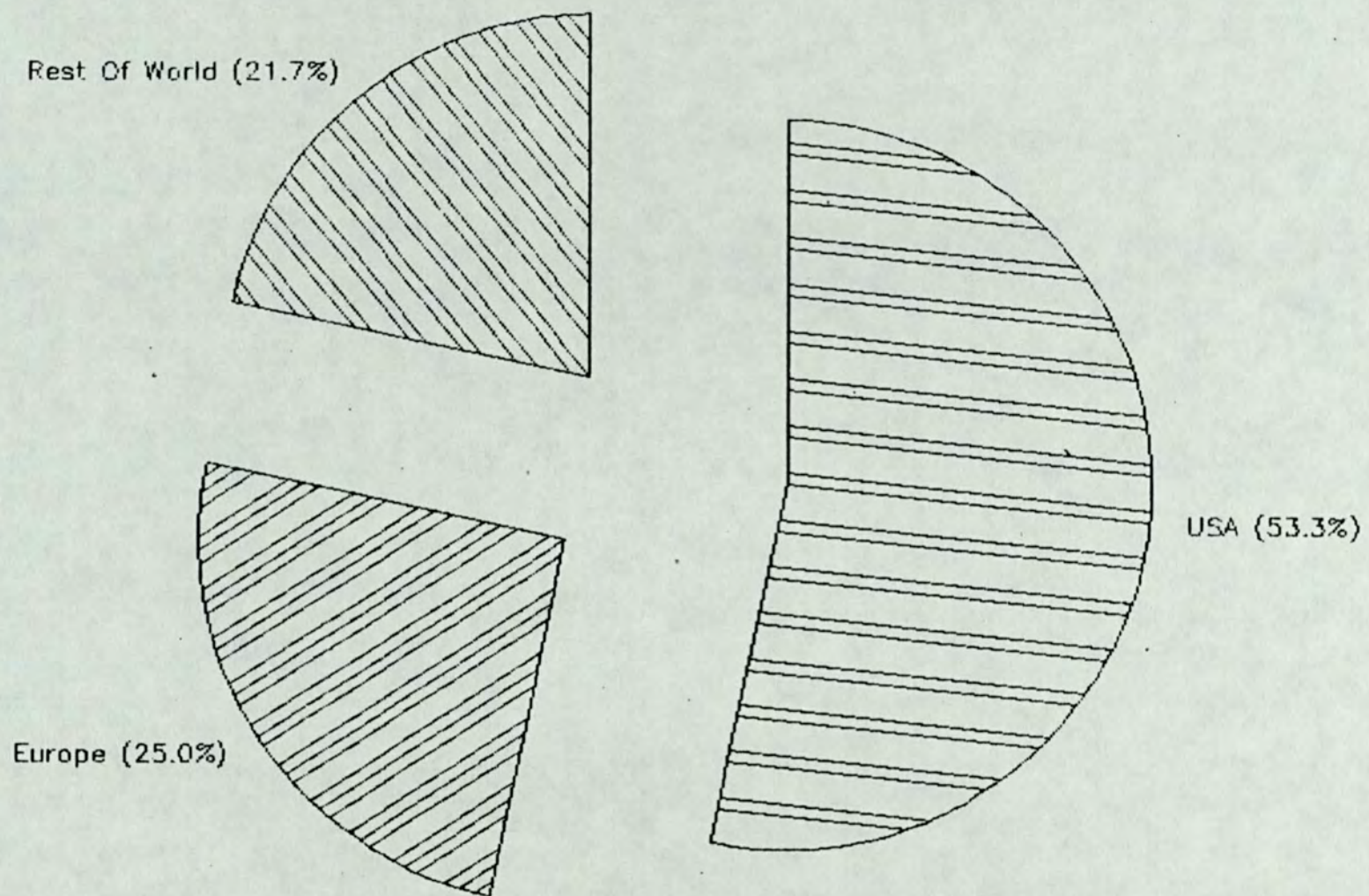
Estimated World Market by Product

1985



Estimated World Market by Area

1985



growth in real terms of some 9% a year, but it must be said that this does not accord with the perception of many in the industry about their principal market. The most reliable figures available are for US production which, according to the US Department of Commerce, grew by 6.9% a year in real terms between 1977 and 1983, and is forecast to grow at 4.9% a year from 1986 to 1990. These figures, however, mask a very wide variation between different types of equipment, some of which industry analysts forecast to show annual increases of 25% or more. These are mainly to be found amongst the areas of new technological opportunity, which we discuss later in this report (para 105 et seq.)

8. International trade in identifiable medical equipment in 1983 amounted to somewhat over \$3bn, on the OECD's rather restrictive definition. The principal exporter was, not surprisingly, the US, followed by Germany, Japan and the UK. Some way behind came Ireland, France, Switzerland, Italy, Sweden and Yugoslavia.

9. The UK has for many years maintained a positive trade balance in medical equipment. But between 1980 and 1984 the position deteriorated quite markedly (Table 2). Imports grew faster than exports in every year from 1981 onwards, so that although the trade balance did not change greatly in cash terms, it came to represent a much smaller proportion of the total volume of trade (imports plus exports). 1985 showed a reversal of this general trend, with a sharp increase in the trade balance. Exports retained the growth levels they had shown in the previous few years, whilst the growth of imports slowed very markedly. This may reflect a slowdown of home demand resulting from the shortage of money perceived within the health service.

Table 2

UK TRADE IN MEDICAL EQUIPMENT 1980-1985

	Exports		Imports		Trade balance £m	Trade balance Total trade %
	Value £m	% change over previous	Value £m	% change over previous		
1980	266.0	11.7	196.0	10.0	70.0	15.2
1981	287.9	8.2	244.7	24.9	43.2	8.1
1982	348.3	21.0	306.2	25.1	42.1	6.4
1983	411.5	18.1	371.3	21.2	40.2	5.1
1984	476.6	15.8	433.9	16.7	42.7	4.7
1985	560.5	17.6	470.4	8.4	90.1	8.7

Source: DHSS analysis of Customs and Excise statistics

10. Table 3 shows the UK's performance in particular markets. The figures demonstrate that the UK industry is showing encouraging growth in the US, albeit from a low base, and with much lower growth in 1985. But our trading performance in Europe has been very disappointing, given that this market is on our doorstep, and that the main parts of it are fellow members with us of the European Community. Our performance vis-a-vis the rest of the world is more satisfactory in trade balance terms, though we see a rapid growth in import penetration, from a low base. Our principal export markets in this category are Japan, the Middle East and the countries of the former Empire. We may therefore be seeing the effects of erosion of our position in former colonies, coupled with the recent decline in the position of the OPEC countries. Increasing import penetration probably reflects mainly the rise of Japan in this business, but there are also imports of relatively low technology items from emerging countries like Malaysia.

Table 3

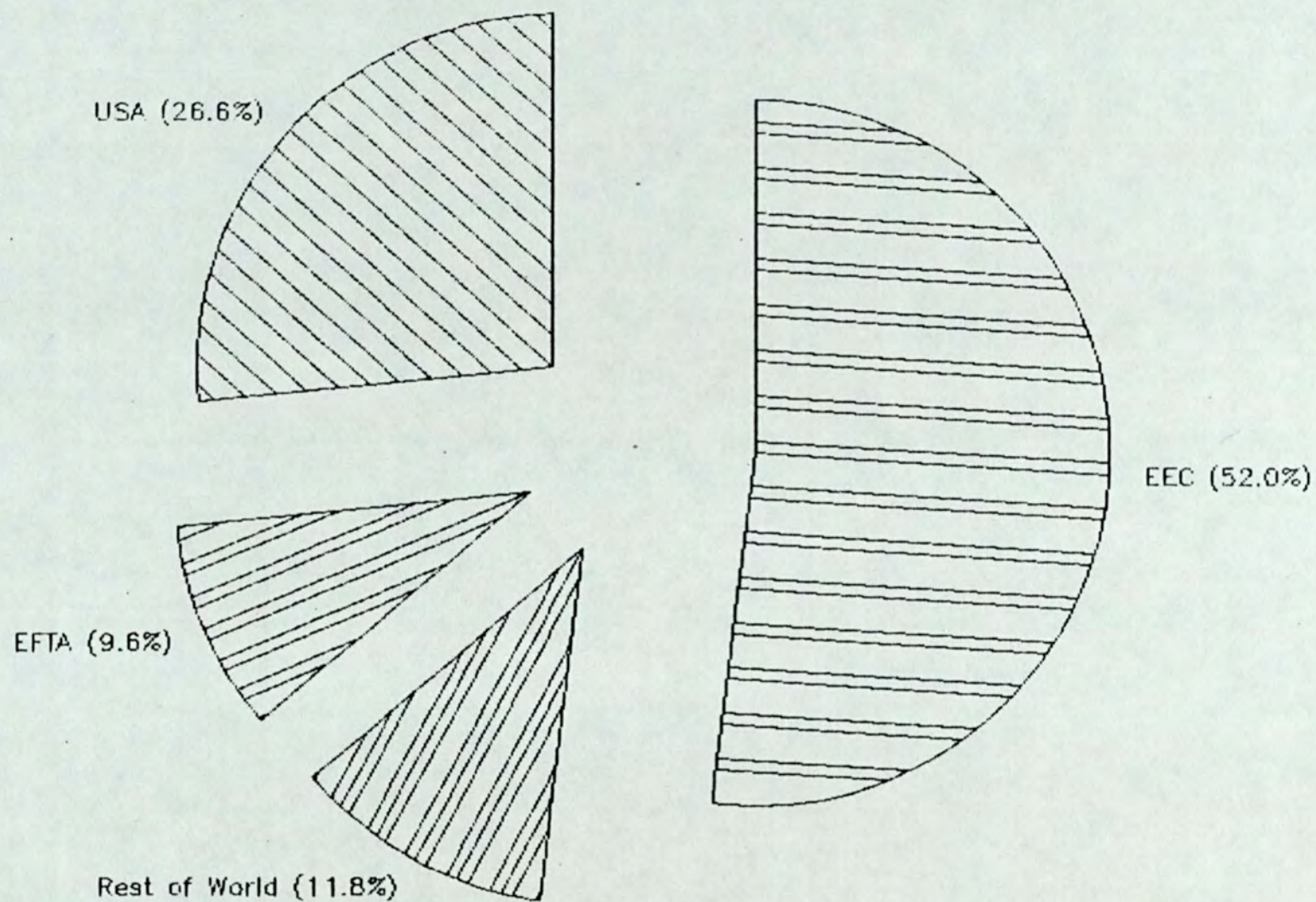
UK TRADE IN MEDICAL EQUIPMENT 1980-1985 BY AREA

	Exports		Imports		Trade balance £m
	Value £m	% change over previous	Value £m	% change over previous	
USA					
1980	25.9	n/a	40.4	n/a	- 14.5
1981	30.9	19.6	66.2	63.9	- 35.3
1982	41.8	35.0	93.5	41.2	- 51.7
1983	71.6	71.5	121.3	29.7	- 49.7
1984	92.2	28.8	131.8	8.6	- 39.6
1985	98.8	7.2	125.2	-5.0	- 26.4
EEC					
1980	101.5	n/a	116.7	n/a	- 15.2
1981	97.0	- 4.4	129.7	11.1	- 32.7
1982	113.3	16.8	156.9	21.0	- 43.6
1983	139.7	23.4	176.5	12.5	- 36.8
1984	163.9	17.3	214.8	21.7	- 50.9
1985	196.5	19.9	244.5	13.8	- 48.1
EFTA					
1980	23.5	n/a	17.3	n/a	+ 6.2
1981	23.3	- 0.8	21.8	25.8	+ 1.5
1982	27.2	16.9	25.8	18.1	+ 1.4
1983	29.2	7.3	34.3	32.9	- 5.1
1984	34.0	16.4	40.9	19.4	- 6.9
1985	41.9	23.1	45.0	10.1	- 3.2
REST OF WORLD					
1980	115.1	n/a	21.6	n/a	93.5
1981	136.7	18.8	27.0	25.2	109.7
1982	166.1	21.5	30.0	11.2	136.1
1983	170.9	2.9	39.2	30.7	131.7
1984	186.5	9.1	46.4	18.4	140.1
1985	223.3	19.7	55.6	19.9	167.6

Source: DHSS analysis of Customs and Excise statistics

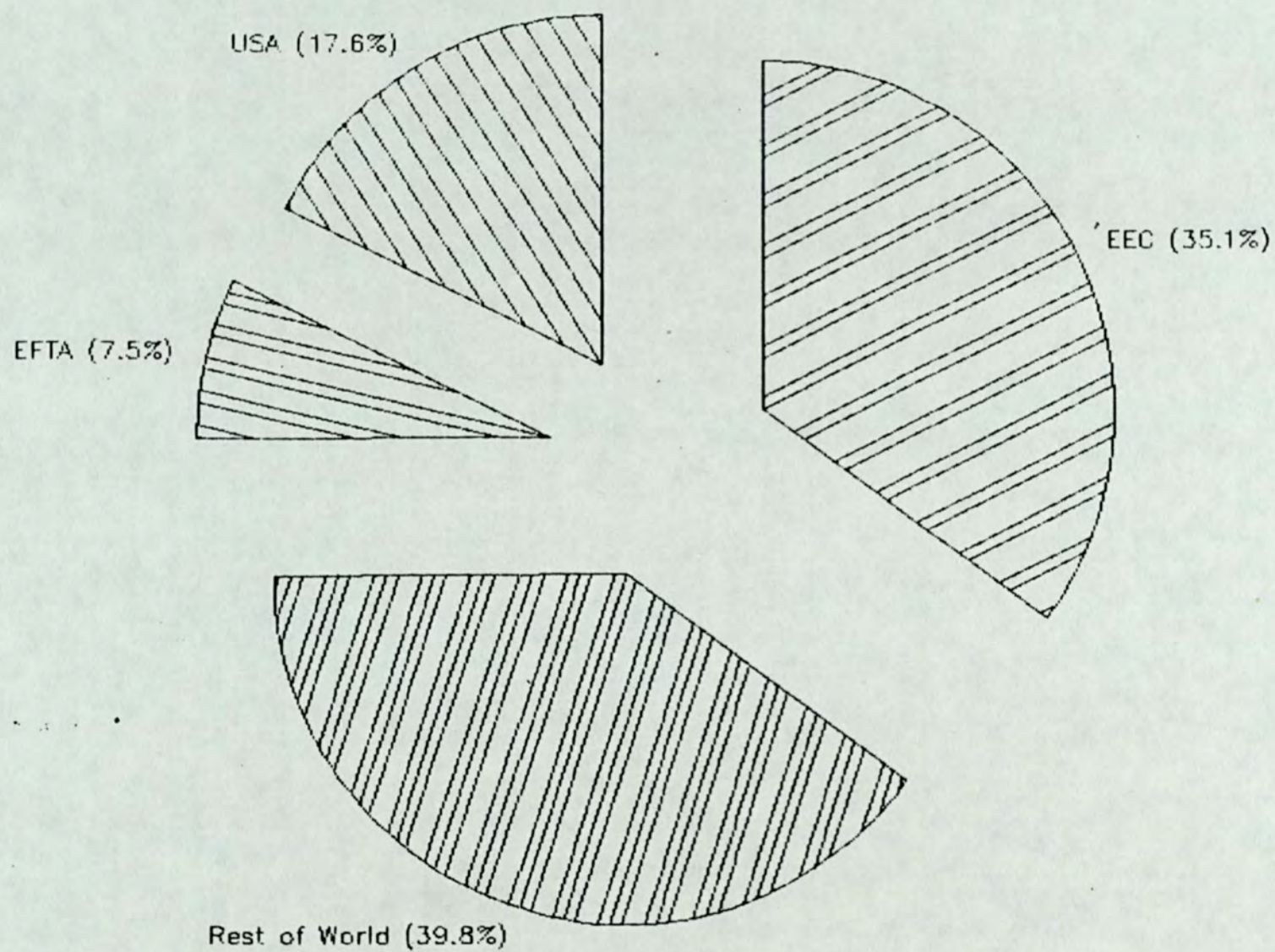
UK Imports of Medical Equipment

1985



UK Exports of Medical Equipment

1985



11. At the level of individual countries, the UK's top ten export markets in 1985 were (in order), the USA, Germany, France, Saudi Arabia, Ireland, Italy, Japan, the Netherlands, Australia and Denmark. This list has changed very little over the previous few years. Thus our principal competitors are also among our principal overseas markets. One implication of this is that any obviously protectionist strategy towards the industry could be highly counterproductive, and most industrialists to whom we have spoken would oppose any such strategy.

12. Appendix 2 shows the UK's trade performance for particular sectors of the business. This information is, however, difficult to interpret, mainly because some of the categories themselves are not very usefully defined. This reflects fundamental limitations in the original data gathering.

13. The statistics do not, we must admit, present a clear picture. They can be interpreted in support of the hypothesis that the UK is falling behind internationally, but they can equally well be interpreted as showing a highly successful performance interrupted by a brief dip in the early years of this decade. The picture we have gained from our industrial, medical, and NHS contacts is, however, much clearer. It tells of an industry which is falling behind in the areas of high technology, and surrendering the leading edge of clinical practice increasingly to foreign competition. At the same time, it is under threat in lower technology, commodity, areas from low-cost competitors in the developing countries. We do not believe that this evidence, anecdotal though it is, can be set aside. On the contrary, we think it likely that it is giving warning of major problems before these are reflected in the statistics. The picture is not, however, one of unrelieved gloom. There are British firms in many areas who are performing successfully in demanding areas of the international market. Britain also has a strong position in medical science, which, as we shall see, should be a considerable industrial asset. But the situation overall nevertheless gives us considerable concern.

THE BRITISH INDUSTRY

14. Data on the UK medical equipment industry are very incomplete. Indeed, in some ways it is misleading to refer to a medical equipment industry at all. For many firms medical equipment is only a part of their overall business. More important, the term embraces, as we have seen, a wide variety of products, within which individual enterprises are often very specialised. For any given product, there are likely to be only four or five real competitors in the market place, and the market can therefore be regarded as broken into a large number of subsectors. Nevertheless, the term is not meaningless. There clearly exist firms a substantial part of whose business consists in selling goods, other than pharmaceuticals, which are specifically designed for medical use. And these firms operate in an environment which is distinctive and which has a large number of common features between the various subsectors. We look first at the statistical data on the sector, and in particular at its financial performance.

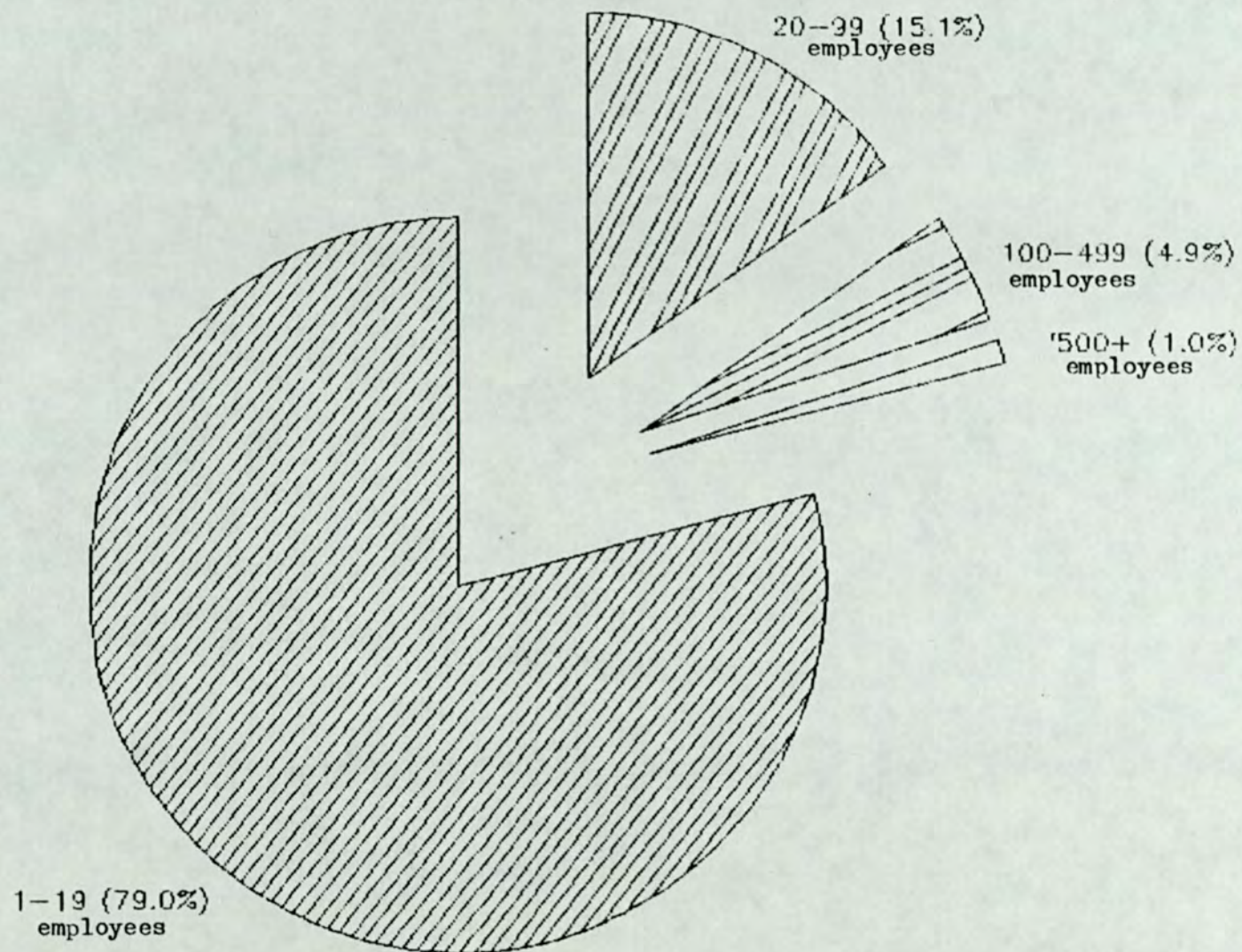
15. DTI performed a special analysis for us of the 1980 and 1983 Census of Production data covering a large majority of firms in the industry. This provides us with a statistical picture of the sector. It is based on "establishments" (typically single manufacturing sites) rather than companies. The evidence suggests that the total number of companies involved will be about 10% less than the number of establishments.

16. This analysis shows us a sector which is relatively small, comprising approximately 0.5% of the manufacturing sector. Average sales of the largest establishments are only some £22m. On the other hand the average sales of the smaller companies are quite high at a little over £200K and there are a number of attractive aspects to the sector's performance: output growth is faster than the rest of manufacturing, gross value added as a proportion of sales is reasonably high and, with improving labour productivity, net margin on sales is also improving. In the light of this, it is noteworthy that the population of the sector has not increased; in fact we find a broadly stable population of just over 1,000 establishments, the great majority of which are very small (78%) employing below 20 employees.

17. The 230 establishments comprising the small (20-99 employees) to large (over 500 employees) segment compares broadly with the 300 core medical equipment companies identified by commercial analysts, with a further 100

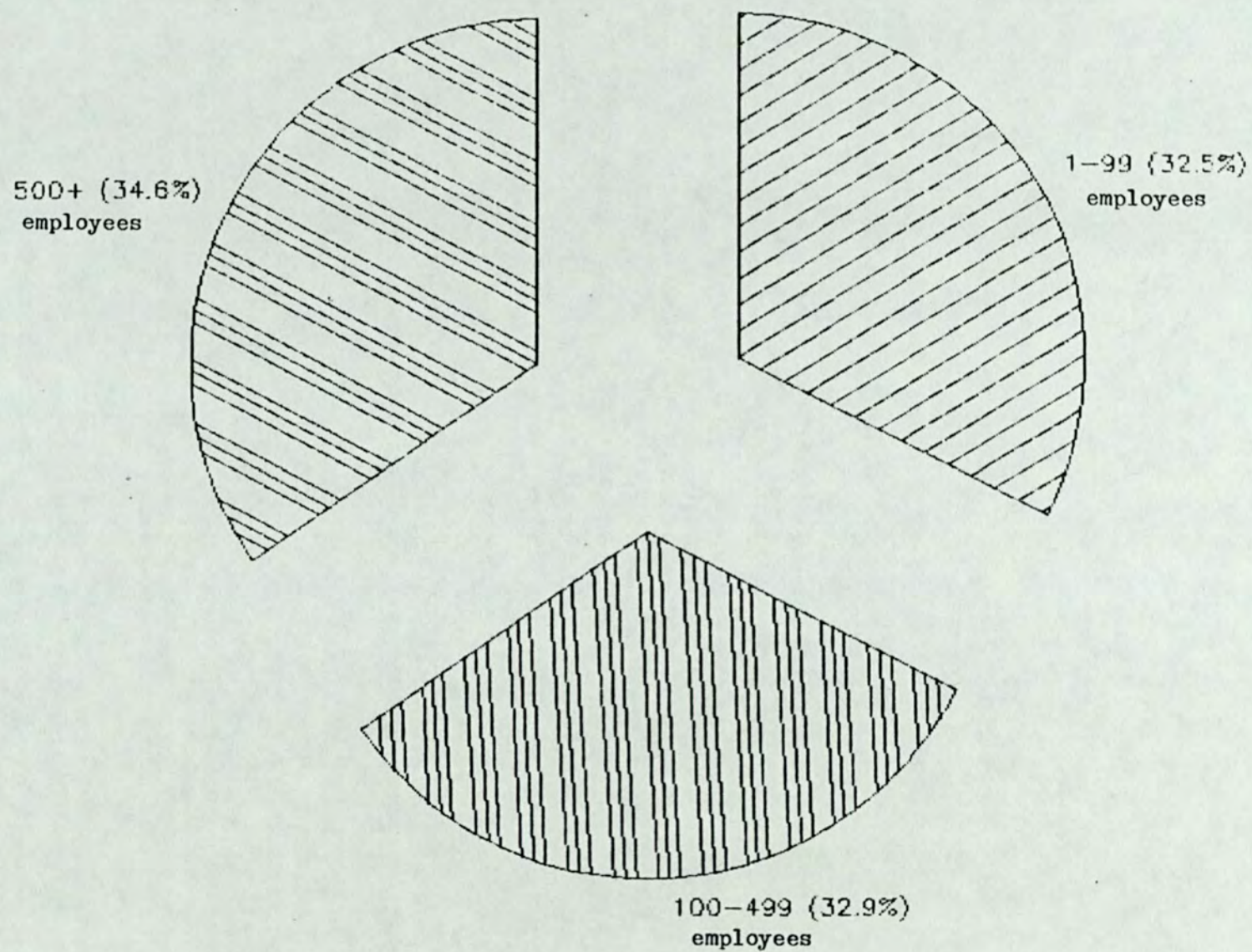
Medical Equipment Industry

Number of Establishments
by number of employees



Medical Equipment Industry

Gross Output by size of establishment



engaged peripherally in the sector alongside other light engineering or electronics activities.

18. Total output is shared roughly equally between the large, medium and small segments, but output per establishment naturally varies with size:

<u>Establishment size</u>	Average Turnover <u>£K</u>
Very small/small	200
Medium	4,500
Large	22,300

(Source: 1983 Census of Production)

19. In 1983 gross output of the sample was £731m, nearly 50% higher in cash terms than in 1980, suggesting a lively compound growth rate of approximately 15%. This compares with manufacturing output as a whole which fell by 6% over the same period. £116m of this gross output was accounted for by factored goods. These thus constitute a significant part of the business even for manufacturing companies.

20. Total employment in 1983 was 29,000, a fall of 10% from 1980 despite the increase in output. This fall was concentrated in the operatives section of the workforce; the number of technical and administrative staff in fact rose slightly over the period. There does not appear to be any correlation with capital expenditure trends, which appeared to be weaker proportionally to sales in 1983 than 1980 (3.4% of sales as against 4.1%).

21. Compared to manufacturing as a whole, the industry appears to have lower wage and salary costs for both operatives and technical and administrative staff, and lower capital intensity; however the gap narrowed somewhat between 1980 and 1983. The lower capital intensity is not surprising given the assembly nature of most companies' operations, and the low pay levels may be explained by a large population in unskilled or semi-skilled operatives in the disposables sector in particular.

22. The sector has a reasonably high ratio of gross value added to gross output of approximately 47%, and an improving margin on sales with which to

Medical Equipment Industry

Compared with All Manufacturing



1. Gross output per head
2. Gross value added per head
3. Gross value added/gross output
4. Wages and salaries per operative
5. Wages and salaries per admin, tech and clerical employee
6. Net capital expenditure per head

service depreciation and capital - 12.7% to 15.8%. This reflects the higher labour productivity. The ratio of gross value added to gross output is noticeably higher than manufacturing as a whole (47% as against 35%).

23. There are some signs of rationalisation within the sector in the three years spanned by the censuses, with the number of medium sized establishments falling by 6% and their share of gross output also falling. Sales by the larger establishments rose considerably faster than the rest of the sector (by 99% as against 50%). However, the large establishments' gross value added as a proportion of sales appears to have fared worse than the overall sector performance with their margin falling from 49.2% to 40.7% as compared with 48.5% falling to 46.9%. The share of output taken by smaller companies also increased, as did their gross value added margin.

24. A published analysis of medical equipment manufacturers' accounts by Inter- Company Comparisons covers 60 medium and large companies, based on 1983/84 data. Not all principal UK manufacturers are included, and because of the usual differences in definitions, data cannot be compared directly with those from the Census of Production.

25. The ownership of the 60 companies is divided between:

Foreign Groups	12
UK Industrial Group Companies	15
UK Independents	33
	—
	60
	—

26. The picture that emerges is again of a fairly attractive financial performance and position: reasonably rapid growth, high profitability and good liquidity. These features are also well spread between the different types of companies and there are signs that the UK owned companies are performing more strongly, on the face of it, than the foreign owned businesses. This may, however, reflect the impact of intra-group charges or pricing by the foreign groups. Even so, both the portfolio of medical equipment companies being assembled by the UK industrial groups and the UK independent segment show good

signs of financial health.

27. US owned companies comprised four out of the top five companies in the industry (Travenol, Abbott, Sherwood and Dentsply), but thereafter the UK industrial group members occupied a strong position, with the independents comprising the bulk of the rest of the market. The UK industrial groups appear to have assembled portfolios of companies by acquisition of mid-sized companies, rather than to have developed their interests "organically". There is little evidence of venture capital affecting the industry strongly to date.

28. The largest turnovers (for their UK operations in each case) amounted to £64.1m for Travenol, £46.9m for Abbott and £28.2m for Picker. Thereafter there were only a further eight companies with turnover above £10m. Although there are large individual variations, sales had grown more slowly over the previous three years among the foreign companies and particularly rapidly for the UK independents - 4.6% per annum v 24.8%, with UK industrial companies growing at 6.5% per annum. Export sales data are patchy, but for these companies exports appear to average 37% of turnover, higher amongst the top ten, but broadly similar between the different types of company. Given that total turnover will include some imports, this figure is broadly consistent with Government statistics.

29. The ratio of profit before tax to sales averaged 7% across all the companies. Apart from a sharp jump in 1981/2 in profitability after a previous gradual decline, there are no particular trends discernable. The average return on capital employed over the past three years for companies included in this sample was 17.8%. This is noticeably higher than many other manufacturing sectors during this period and is higher than several related sectors.

30. We now turn to the small company segment. For this segment, fewer statistical data are available, and we have had to rely to a greater extent on our own experience. Within the industry, small companies broadly play three roles: first they act as distributors for other people's products, either produced by other small UK manufacturers or imported from abroad. Second, there are the small component or sub-assembly manufacturers who either supply other larger companies on a subcontractor basis, or who attempt to supply end users, usually relying on distributors to market their products. Finally, there are those small companies that manufacture or assemble their own discrete, stand-alone products. Again, many rely on distributors or possibly

larger companies acting on an OEM basis to sell their products to the end user. Some, however, do employ their own direct sales forces.

31. There are several factors which appear to contribute to making the medical equipment sector a difficult one for small companies to enter and in which to grow rapidly.

32. Most product development in the industry has to be undertaken on a speculative basis, in the hopes that a market for the product can be found at the end of the development process. Although the NHS is a large buyer relative to its sector, the NHS does not procure any large amount of equipment R & D on its own account. The course of the development process is frequently dependent on a close personal relationship between medical staff in a hospital and the technical staff of a small company. The products are frequently very highly customised to meet a particular hospital's requirements and may not be produced with an eye to the larger market opportunities.

33. Small companies naturally enough tend to cover very narrow parts of the market, both in terms of products and geographic areas. It seems that companies are constrained by the costs of broader market penetration rather than by lack of technological resources or lack of initial profitability. Typically new companies will sell a narrow range of products into a limited number of Regional Health Authorities, relying on a gradually developed contact within the Authority or an important local hospital to produce highly customised, high margin, products to suit particular local markets. They find it difficult to extend their marketing to other Authorities or other countries. These companies are thus frequently high value but low volume producers with little chance to develop a sustained and efficient level of production. For these reasons there appears to be a reasonably high birth and death rate in this lower segment of the industry: entrepreneurs are attracted initially by the charm of an apparently secure high margin sale, but thereafter are unable to develop a sustainable scale of operations.

34. Similarly, the inhibiting cost of large scale marketing also appears to block a development path noticeable in many other technological markets whereby companies start generating cash flow from distribution and then use their cash flow to lever themselves into the development of their own discrete products - an attractive market pull model of development.

35. A further important hindrance to the stronger development of this segment of the industry, and indeed of medium sized companies too, is the erratic and highly seasonal nature of the procurement process by Health Authorities. This ties up higher than usual amounts of working capital and is an important contributory factor to erratic profitability and eventually company failure in the small company end of the industry. We discuss this further below (para 68).

36. To some extent these problems of high market entry and penetration costs and uncertain sales levels can be overcome by startup companies being created with sufficient capital mass. Attracted by the overall healthy returns of the sector, a number of new companies have been started, financed by a combination of venture capital and institutional funds. While this is an encouraging trend, two factors appear to be holding back a higher flow of such capital. First, a number of the companies formed decided to tackle the emerging large systems end of the electromedical market. Although the returns in the early stages were attractive, they have increasingly had to compete directly against the larger electronics majors that have entered the market and the smaller companies' returns have progressively suffered. Those companies, such as the Oxford Instruments Group, which chose to enter intermediate or component markets, have done noticeably better. Second, it seems that the high costs of marketing can be "fought through" but not leapfrogged with greater capital. Hence, despite the strong performance of the established companies, new companies in the medical equipment sector have difficulty in offering the rapid initial growth which venture capitalists seek.

37. In summary, the sector's overall financial health appears to be reasonably good. Sales growth, productivity growth, profitability and liquidity are well above average; although there are some signs of "thinning" in the middle of the industry, this may have been due to the demise of weaker companies, and there are indications of fresh domestic capital coming into the industry at the top end. The bottom end also continues to be active and there are some smaller companies based on strong technological positions that have managed to grow into well found medium sized operations with strong international sales.

38. On the other hand, there are some features of the present position which are not as healthy as they should be. First, the diseconomies of marketing and budgeting described earlier are inhibiting the full development of what is, in most areas, a technologically effervescent small company sector. It appears

difficult for well managed small companies to grow rapidly. At the upper end there is still strong evidence that, despite the involvement of larger capital from the UK industrial groups, British companies are losing market share in domestic and overseas markets where technologically and even financially there appear to be no barriers to their competing effectively.

39. These disquieting features are reinforced for us both by the evidence we have heard from practising clinicians, which is virtually unanimous in telling us that the UK industry is missing out both in larger equipment and at the leading edge of technology, and also by some sample data on NHS purchasing which we have been able to obtain.

40. We have been supplied with an analysis of the annual issues of 1310 stock lines held in a medical and surgical store serving Hammersmith Special Health Authority and Paddington DHA. This shows the following picture:

	% by number	% by value
Produced by British firms	64	53
Produced in the UK by foreign firms	31	29
Supplied from abroad by foreign firms	5	18

41. It is supported by an analysis of the inventory of electromedical equipment held at the Hammersmith Hospital. Only 4.5% of the British-made items have a replacement cost above £10,000, as opposed to 20% of the foreign-made. This differential is still greater if only items bought in the last 5 years are considered, the corresponding figures being 3% for British-made and 25% for foreign-made items. These figures clearly suggest that the UK industry is tending to lose out at the upper end of the market in price terms, though any sample of this kind is naturally dominated by X-ray and pathology laboratory equipment.

42. This picture is borne out by a sample of purchases by Newcastle DHA over the period 1980-1985. This sample, covering items in selected categories, accounted for 19% of the DHA's total inventory value, and was skewed in favour of large, expensive items, the average value being £65K. 32% of this sample, by value, was made in Britain, again supporting the impression that high-cost

equipment is predominantly of overseas origin.

43. It is more difficult to get objective data on technology levels, but as we have said, the evidence from clinicians (borne out by a tour which some members of the Group made of a major "leading edge" hospital) is unanimous that the UK's position is being eroded. There are undoubtedly British firms that are amongst the world leaders in their particular sectors, but they are spread thinly; in those leading edge areas where the UK is represented at all, it tends to be represented by a single firm. This makes the industry very vulnerable to any failure by that firm, or sometimes to deliberate predation by competitors seeking to eliminate a rival.

44. One factor contributing to the health of the industry will be the ability of companies to choose appropriate manufacturing strategies. The manufacturing strategy of a firm will be strongly influenced by the market which it is serving. In the commodity end of the business companies need to offer goods from stock which implies a stock holding of finished goods and possibly also holding stock at lower levels of added value, such as raw material, forgings or castings. At the other end of the medical equipment sector, capital goods, often of high technology, it is usually essential to provide a very rapid service support organisation which in its turn requires the company to hold stocks of replacement parts. It is likely that the problem of inventory management will be common throughout the medical equipment industry. Holding inventories can impose a significant financial burden on the enterprise, and a clear management manufacturing strategy is necessary to minimise inventories.

45. All companies, with the exception of those simply factoring other people's goods, will need an assembly and product assurance organisation, in many cases involving sterilisation, and will need to conform with the DHSS registration scheme. Whether to make the individual piece parts which comprise the saleable product is a discretionary decision. The parts which should be selected for domestic manufacture should be those which have the greatest effect on the performance of the saleable item, are preferably unique to that business, and command a high margin. These parts should be made with the highest level of manufacturing technology and automation consistent with the volumes involved. Other parts should be purchased from organisations who have built up an expertise in serving other industries.

46. In the high technology capital goods areas of the medical equipment

industry, this strategy appears to be followed in that most detailed parts are purchased from specialist suppliers and, as seen above, the companies are doing quite well with an adequate return on capital employed. These companies appear, rightly, to be concentrating their managerial and financial resources on the technology of the product rather than on manufacturing. At the commodity end of the business there are some well planned manufacturing operations with a strong emphasis on production engineering. However, there is also a number of companies, a possibly dwindling number, who attempt to make a large proportion of what they sell using traditional semi-craft methods. These companies are very vulnerable to low cost imports, and our observations of several of these companies indicate declining market share and retrenchment into highly differentiated specialised sectors of the market to enable them to survive. Our view is that only by making changes to their manufacturing practices will they succeed, probably by further retrenchment into a range of products in which they can become significant in world terms, and hence achieve sufficient throughput to justify a high level of automation.

ADDRESSING THE WORLD MARKET

47. As we have seen (para 6 above) the UK market constitutes a relatively small percentage of the world total, which is dominated by the USA, and as a result, exporting is essential for those firms whose activities are capital intensive or whose products involve high R&D costs. Only thus can they hope to attain sales levels comparable with their foreign, and particularly American, rivals and hence to sustain the investment and/or R&D required to remain competitive. The experience of the Swedish industry suggests that the task of competing successfully in the world market from a relatively small home base is not a hopeless one.

48. The emerging interest of major UK industrial groups such as GEC, BTR, BOC, Unilever, and Smiths Industries opens up the possibility of a British multinational sector. In this regard, the example of Picker International is instructive. In this case GEC created a multinational by acquisition, and this led to its UK products having a better presence in the USA and elsewhere, which in turn has led to an expansion of manufacturing in the UK.

49. The creation of true multinational companies is likely to remain a rare circumstance, though a very important one when it occurs. For most companies, world markets will be addressed by exporting. However, the need to export is not one which has always been recognised throughout the industry; there is evidence that many firms who had previously depended almost wholly on the home market were driven to export only when hit by limitations on NHS growth. There is also evidence that firms remained for too long dependent on traditional markets and were reluctant to enter the US and European markets.

50. The world market is fiercely competitive. Besides high performance standards in the product, firms have to satisfy a variety of technical standards and regulatory regimes. We discuss the regulatory picture in more detail below (para 94 et seq.). In most countries, products are chosen (as in the UK) by individual doctors and hospitals, so it is vital that exporters have marketing organisations which can reach down to this level. If they are selling capital equipment, they must often maintain a servicing capability to respond within hours to a failure in any one of the hospitals supplied. They may also have to defend themselves against potentially expensive challenges by their rivals, for example to their patent rights.

51. In general, it is only major companies that can enter a new market by setting up their own marketing organisations there from scratch. Most companies have to find local distributors, and finding the right distributor is of critical importance. The exporter obviously wants a distributor with good market access and servicing coverage, but he also wants a firm small enough for his product to be a significant part of his business. Once he has found a distributor, he will need to maintain good contact with him, train his staff as appropriate, and respond to his signals about what the local market requires. All this requires a positive commitment to, and involvement with, the market. Sometimes a small company may "piggy-back" on the marketing organisation of a larger one. This can be very successful if there is a good match between product ranges, but in this situation the smaller company's worries about the priority given to its products, and the fear of being bought out, tend to be still greater.

52. There have been attempts, notably by the British Health-care Export Council, to organise co-operative distribution and/or servicing arrangements in specific overseas markets. This appears a sensible approach, but none of these attempts has succeeded in practice. Companies have been doubtful whether their products would receive their fair share of the co-operative company's attention and unwilling to commit the necessary up-front costs to an unproven scheme.

53. The support which Government provides to exporters is particularly important for an industry of this character. We welcome the moves by the British Overseas Trade Board to direct its support for overseas missions towards tightly focussed missions aimed at specific countries and specific product areas. But we regret the cut-backs in fairs and exhibition support, which is now insufficient to support all the activities which are considered worthwhile. This form of support is very necessary for small exporters, and fairs and exhibitions are an acknowledged way of making contact with potential distributors.

54. A further form of support to exporters is provided by the commercial staff in British Posts (Embassies, Consulates, etc.) overseas. These can be of particular value in helping companies to establish contact with potential distributors. The comments on the quality of this service which we have received from industry range from glowing to highly critical. We ourselves have received some very useful information from Posts, and it is our impression that the quality of commercial staff has improved markedly in recent years. It is

clear that first class help can be given both by staff who have in some way specialised in commercial work and also by non-specialists who are able to bring their full ability and commitment to bear on a commercial post. We hope that the Foreign and Commonwealth Office will continue its efforts to upgrade the status of commercial work and the quality of those performing it, and to eliminate any remaining vestiges of the attitude which saw commercial posts as second class and a distraction from the mainstream of diplomacy. We are also concerned that the availability of market reports produced by our overseas Posts is not sufficiently well-known; we recommend that DTI should give wider publicity to them and to the other help to exporters which Posts can provide.

55. We stress once again that exporting can no longer be a discretionary activity for an industry which has no protected home market. The UK market is in many cases too small to provide the turnover which companies need if they are to match the R & D capabilities at the high technology end, or the manufacturing capabilities at the low cost end, of major international competitors. Our industry cannot avoid this competition, even in its home market, and it must therefore meet it head-on by becoming international itself.

NHS PURCHASING

56. The NHS is by far the dominant buyer of medical equipment in the UK, and its practices determine the character of the national market. It does not operate for profit, and this is an important difference from the health services of many other developed countries. The vast bulk of medical equipment currently is used in hospitals, and this section therefore concentrates on the NHS hospital service. We deal subsequently with the general practitioner (GP) market. Where procedures are described, they are those relevant to equipment purchase for existing hospitals. The fitting out of new hospitals follows slightly different rules, but the same underlying principles.

57. The NHS does not function as a single entity. In England, the service is organised into 14 Regional Health Authorities (RHAs), which are in turn divided into a total of some 200 District Health Authorities (DHAs). Both RHAs and DHAs enjoy very considerable autonomy, and in particular RHAs have virtually total purchasing autonomy. In other parts of the UK, different organisational structures apply. For example, in Scotland the 15 Area Health Boards have some aspects of medical equipment advice, evaluation and supply undertaken by the Common Services Agency. In England, although there may be similarities in organisational structures, management styles and detailed working practices of both RHAs and DHAs can vary very considerably from one to another. Nevertheless, for equipment procurement there are typical patterns which do not vary greatly in substance.

58. The second important feature which must be noted is that the management and purchasing practices of the NHS are at present in a state of very considerable flux. Changes are being introduced which, in general, we welcome, but at present their application is very incomplete and very patchy. Thus we cannot describe a settled and uniform situation. We have therefore chosen to describe the practices which prevailed in England before the recent changes, and which still largely prevail in many places, and to indicate the important ways in which they are changing.

59. Decisions to purchase capital equipment are made by committees subject to budgetary constraints. The process is initiated by a user, normally a doctor but sometimes a scientist, putting forward a bid. After discussion with colleagues within his own department, the bid will be put forward to the DHA. The DHA usually has a capital committee which decides the relative priorities

of the different bids, and ranks them in a number of categories according to cost. For items below some level, the DHA will have authority to purchase. For larger items, the DHA will submit a list of ranked bids to the RHA, which will in turn combine these into a regional ranking. Purchasing takes place from the head of each list until the available budget is exhausted.

60. As a result, equipment choices in the past were primarily determined by users, whose main motivation was, naturally enough, to obtain what they saw as the best possible equipment for their patients and staff. Users did not have capital budgets of their own, and their financial interest was therefore primarily in whether the running costs were sustainable within the departmental budget. The eventual outcome was determined by bargaining between medical and scientific colleagues both within and outside the committee structure. A study by York University researchers found that: "For individual equipment bids the comparison of alternative models is done by the bidder, and the information on which he makes his choice is not generally available to the final decision-making committee. In only 15% of cases did divisional colleagues challenge users' bids and in only 7% of cases did they suggest alternative suppliers or equipment. Regional Scientific Officers frequently question bids on the grounds that the equipment is not the most appropriate for the purpose. This is done on the basis of past experience and knowledge of the market rather than detailed appraisal of the alternatives." There was little joint purchasing of capital equipment by departments in the same hospital, and still less between Health Authorities.

61. Regional Supplies Officers in practice tended to come into the process after the decision to purchase had been made, and their job was then to buy the selected equipment as efficiently as possible. They were frequently constrained to use single tender action, often in circumstances where the manufacturer knew that his equipment had been selected and accepted by the relevant committee. He therefore had little incentive to reduce the price previously quoted. Even where the tendering process was nominally competitive, users frequently wrote specifications such that only one manufacturer could meet them.

62. In the view of the York researchers, the fact that equipment choices were made by a large number of users, and that cost was a minor factor in choice, encouraged firms to differentiate their products in order to establish brand loyalty in the form of clinical preference. This prevented their achieving long production runs, but allowed them to charge prices high enough to remain

viable. Other reasons, including the past performance record of the company and its equipment, and a desire for local standardisation, can also be adduced to explain the considerable brand loyalty which exists in this field. But the York analysis is certainly consistent with the pattern we have discerned of a large number of small "national niche producers" unable, and perhaps to some extent unwilling, to break out of their niches and achieve growth and an international presence.

63. As we have noted above, there are developments in NHS management which are changing the practices of the past. They include:

- (a) the increasing authority of Regional Scientific Officers, which has led to more frequent challenge to users' recommendations at Regional level;
- (b) the introduction of option appraisal for larger capital purchases;
- (c) an increasing concern with value for money in the field of medical equipment maintenance;
- (d) the designation of Departmental Equipment Officers in clinical departments with responsibility for a range of aspects of equipment use and budgetting;
- (e) the introduction of management budgetting, which brings the consultant face to face with the financial consequences of his clinical activities;
- (f) the development of more disciplined and questioning approaches to the allocation of funds for medical equipment purchase;
- (g) the introduction of general managers to whom consultants are accountable for their use of resources;
- (h) the gradual emergence of centres of expertise, arising from the designation of Regions as centres of contracting responsibility for particular classes of equipment.

64. All these developments are tending inexorably to constrain the freedom of

doctors and scientists to determine equipment selection free from the critical scrutiny of others, and without responsibility for the financial consequences of their actions. As such, they tend in the direction of the free, but responsible and informed, market that we should like to see in the UK. But, as we have said, their impact so far is patchy. There are many reasons for this, but two important ones are the low level of awareness among NHS purchasing staff of the appraisal techniques which they will now be expected to use, and the generally poor state of information on equipment holdings and recurrent costs, which means that the data base for proper whole-life costing is largely absent. There is much action to improve NHS information systems, but clearly the lack of information now constrains the speed at which the purchasing environment can change. We urge the new NHS Director of Procurement and Distribution to continue the process of improving NHS information, financial, and purchasing systems along the lines set out above, as rapidly as possible.

65. Where the new information systems have been introduced, they have revealed budgets for capital equipment which appear wholly inadequate in the light of replacement needs for existing equipment, let alone the new opportunities now being offered. Global figures are not available, but one DHA which has responsibility for equipment to the value of some £25 million has an annual budget for its replacement of £825,000. This must be compared with assessed replacement needs averaging around £2 million a year, and a backlog of equipment already being used past its optimum replacement date worth £6.2 million. An RHA in another area with direct responsibility for a £70 million inventory has an annual budget for its replacement of £3.5 million. Although the actual numbers quoted will vary considerably from one Authority to another (depending partly on how responsibility is split in different Regions), we have no reason to believe that the ratios these figures imply are at all atypical. They suggest that something like a doubling in equipment replacement budgets would be necessary to achieve reasonable equipment lifetimes.

66. In fact, there is some evidence that the NHS should, on a pure efficiency basis, be doing more than simply replace existing equipment as it becomes worn out. We believe that there are areas in which capital can and should replace labour, with a saving in the cost of health care. Routine analyses of body fluids are amongst the more obvious examples. We are also aware that manufacturers' claims of savings often need to be treated with considerable scepticism. There is therefore a need for evaluation of the economics of new

techniques and new equipment. Often this will need to be based on practical trials, which it would obviously be inefficient for every Health Authority to conduct independently. This might be done by DHSS itself, but there are alternative possibilities, for example MRC through its new Health Service Research Committee or an independent institute for health economics. We believe that the availability of such information is particularly important within a system like the NHS, where cash-limited funding may in some circumstances prove a disincentive to efficiency, in contrast to profit-oriented systems elsewhere. (See para 78 below.) We therefore recommend that DHSS take steps to provide for increased research and information on the economics of introducing new techniques and equipment, and that Health Authorities should be encouraged to invest in new equipment, where this can be shown to offer increased efficiency. This too is likely to require an increase in capital equipment budgets.

67. National assessments of efficiency will always need to be interpreted locally, and supplemented by local assessments for smaller-scale innovations. As we have already suggested we are not convinced that Health Authorities generally have the necessary expertise to do this. We recommend that the economic appraisal expertise available to Health Authorities should be strengthened.

68. If the recommendation in para 66 is accepted, it will immediately come up against the difficulty, in a system geared to cash accounting, of finding the funds for the initial equipment purchases. Closely related to this is the problem of annuality. There is certainly a large bunching of orders at the end of the financial year, which imposes on manufacturers serious problems of production planning and cash flow, and which almost certainly produces inefficient purchasing decisions. We are not convinced that this is an inevitable consequence of the present system of annual budgets. The flexibility which Health Authorities now have, both within and between financial years, should be sufficient in a well-managed system to avoid this bunching. The real problem seems to be that many Health Authorities use their capital budget as a financial regulator, and in particular delay commitments until after NHS pay has been settled, typically half-way through the financial year. Pay accounts for a large fraction of total NHS expenditure, and settlements sometimes exceed the provision made for them. Typically a 1% variance on pay above the provision in the cash limit will equate to around 50% of an Authority's annual target for cost improvements. To maintain the service development targets which those

improvements were intended to finance, the Authority may well sacrifice part of its equipment budget. Thus even a fairly small variance in the costs of pay awards can translate into a quite large change in the much smaller capital equipment budget. Since we are not in a position to recommend reforms of the NHS pay system, we can see no practical way of avoiding this situation without restricting the freedom of Health Authorities to use their capital budgets in this way. We are aware that this runs counter to the desirable aim of giving greater responsibility to Health Authorities, but given the present financial pressures in the health service, we see no alternative if the necessary levels of capital expenditure are to be achieved. We recommend that the capital equipment provision in both Regional and District Health Authority budgets should be increased and that steps should be taken to ensure that this provision is used for the purpose for which it was allocated. We recognise that this involves substantial sums of money, but the situation exemplified by the figures above has convinced us that it is necessary.

69. For smaller equipment and disposables, the procurement picture is very different. These are sold at the level of the DHA or the individual hospital. Doctors, nurses and sometimes service departments (eg sterile supplies departments) may all play important roles, but the greatest single influence is that of Supplies Officers. Price is the dominant influence on choice. The main difference between these two types of sales is that once an enabling contract for disposables has been let, a steady level of business is more or less assured until a new tendering round, whereas small equipment is subject to a less severe version of the "regulator" effect referred to above. Here too, recent initiatives are leading to a more disciplined model, including a rather greater degree of centralisation, with more binding commitments to national, inter-Regional and Regional contracts.

70. Our concerns in this area are rather different from those in the area of capital equipment, though one which is common to both is the level of cost accounting expertise in the NHS. This is particularly relevant to sterile items, where Health Authorities have to choose between single use and re-sterilisation. Closely related is our concern that choices between competing products may be based too strongly on initial costs, with too little attention given to overall value for money. This is particularly relevant to items with a limited lifetime (eg surgical instruments), where durability needs to be a factor in the evaluation.

71. In some cases, particularly at the commodity end of the market, there is a

conflict between quality and price in circumstances in which it may not be clear to the purchaser what is being foregone by opting for the cheaper item. For example inadequate control of sterilisation by a manufacturer may become apparent only from a large statistical sample of his products. Even in cases where the trade-off will eventually become apparent to the user, this may happen only after long-term contracts have been let, to the detriment of better quality manufacturers, and with a distorting effect on the price structure of the market. The problems identified in this paragraph are ones of lack of information, rather than competence and practice in evaluating available information. In our view, they need to be addressed in the context of attempts to create a better informed market, and particularly the DHSS Manufacturer Registration Scheme, which we discuss below (para 99 et seq).

72. We have considered whether we should recommend an extension of bulk purchasing, particularly at the Regional level, both for capital and for non-capital equipment. The arguments for doing so are the savings which would accrue to the NHS and, from the industrial point of view, a reduction in the very fragmented market, allowing opportunities for companies to achieve faster growth. It would also allow the available expertise within the NHS to be deployed on a smaller number of key decisions. The disadvantages are that large-scale co-ordination can move too slowly to respond adequately to changes in clinical demands and in the products on offer, the risks of monopoly, and the vulnerability of firms to decisions on individual large contracts. There have been considerable moves in the direction of co-ordinated purchasing and of the creation of centres of expertise within the NHS, and the dynamic continues to be in this direction. We welcome these moves, in particular those towards greater co-ordination (aided by the increased influence of Regional Scientific Officers) and the use of nationally-agreed specifications. We do not feel it necessary to recommend any new initiatives in addition to those already under way.

73. We consider that it should be kept constantly before NHS decision makers that NHS purchasing is by far the dominant domestic influence on the shape of the UK medical equipment industry, and that the NHS benefits from a healthy UK industry both directly, in having a competent source of supply close at hand, and in the important indirect sense that the funding available for the NHS is a direct function of the health of the economy. We welcome the group set up under the chairmanship of a DHSS Minister, Mr Whitney, to study what further action the NHS might take to improve the competitiveness of its supplying

industry more widely. In the medical equipment field, as we have already indicated, we have no wish to see protectionist measures introduced to sustain uncompetitive firms, but we do believe it important that NHS purchasers should ensure that British options are fully considered, drawing on the centres of expertise existing within the NHS and academe and the advice available from DHSS Procurement Directorate. Where a proper option appraisal is carried out, we should expect this to be done as a matter of course. But we are concerned that major purchases are still sometimes made without a full option appraisal, particularly where they are funded from charitable sources. We recommend that DHSS and the other UK Health Departments should issue guidance emphasising the need for a full option appraisal, including full consideration of British equipment and making use of the available expert advice, for all major NHS purchases whether or not they are financed from public funds.

THE RELATIONSHIP BETWEEN HOME AND OVERSEAS MARKETS

74. Given the importance of export markets, it is legitimate to ask how important is the relatively small domestic market to the prosperity of the industry. We believe that it is very important. Some of the reasons why this should be so are common to many industries; they include the intrinsic value of domestic sales, which still provide a very large part of the industry's demand and are the base from which a small company will normally hope to grow. They also include the confidence given to overseas buyers by home sales, and the availability of demonstration installations. In the case of medical equipment, the "demonstration" function assumes particular importance within the medical education system.

75. We have become very aware of the importance of the medical education system in influencing buyers' choice of equipment. It appears quite common for a doctor to buy a particular make of equipment simply on the basis that it is what he has used during training, or that he has encountered it at an important centre he has visited. It is still more common for training to have a more subtle, but still very important, influence in establishing brand names in the trainee's mind, accustoming him to particular conventions (eg in the layout of controls), or establishing clinical practices (eg nursing premature infants in enclosed incubators rather than open cribs). For all these reasons, it is important to industry that overseas medical students should continue to seek training here rather than in the countries of our industrial competitors. It is still more important at the postgraduate stage, because those who study at this level are likely to be the opinion leaders, and important influences on purchasing, in their own countries. We recommend that the Government should recognise the value to UK industry of overseas students studying medicine and its supporting disciplines here, and in particular should give positive encouragement to postgraduate study in the UK in these areas.

76. The home market also offers the possibility of close interactions with users. This is not only a means of obtaining market feedback, important though that is; users are important in the innovation process as a source of new ideas, and even when the idea originates in industry, they have an important role in evaluating its usefulness and shaping its application to clinical practice. The UK's strength in advanced medical practice and research should be of great value to our industry, but there is evidence of considerable scope for improvement in the interactions between industry and health service

professionals. We discuss this below (para 110 et seq.).

77. The relationship between home and overseas markets will clearly depend in part on how far their requirements, in terms of hardware, are similar. From our investigations, we believe that in general there is great similarity between the underlying requirements of countries in the developed world, though there will from time to time be national "fashions" for or against particular new techniques. However, the NHS is inherently conservative in respect of genuinely new medical technologies, expecting their efficacy to be clearly demonstrated before it will buy equipment in significant quantities. This can hardly be faulted on medical grounds, but it does stand in contrast to the US, which is, if anything, over-receptive to innovation. Recent changes in charging systems in the US resulting from Government pressure to reduce the cost of the Medicare programme (the so-called Diagnosis Related Groups) have led to a greater concern for value for money, but it is likely that the US will remain a more receptive climate for innovation than the UK. It will need a deliberate effort to create market openings in the NHS for new technologies. We recommend that the pump-priming funds available to the DHSS (para 145 below) should be used primarily to introduce new medical technologies of British manufacture to the NHS and to promote their rapid assessment.

78. Although underlying requirements may be similar, the way in which equipment is sold may differ substantially between markets. In most of the important developed-country markets, profitability is the driving motivation, and a major consideration in purchasing decisions. Cost-based systems such as the NHS require a different sales approach, and show different priorities in their purchasing. In the NHS, net annual expenditure tends to be the driving financial motivation, rather than profit, overall economic impact, or even efficiency. For example, an instrument which allowed a hospital to increase its throughput for some diagnostic test at the same total annual cost might in the US be welcomed as offering the possibility of generating more income, and hence profits. In the UK, the impact could be that more patients, having been diagnosed, would have to be treated, thus increasing net annual expenditure. Of course, by no means all cases will be of this type, and we believe that the divergence between the two purchasing approaches is in fact greater than it needs to be, because the factors that contribute to efficiency in a cost-based system are very similar (though not identical) to those which contribute to profitability. We have already (paras 66 and 67 above) made recommendations to improve the efficiency orientation of the NHS in its equipment buying. We

believe that this will have the incidental effect of aligning the UK market more closely with export markets, and that the information provided by efficiency assessments will prove valuable when selling to profit-based systems.

79. One particular manifestation of different health-care funding systems, which leads to a clearly visible difference in equipment markets, concerns general practitioner services. In the US, and to a lesser extent in Europe, there is a significant market, which many commentators expect to grow rapidly, for relatively small equipment aimed at GPs. In the UK this market is very weak, for reasons which we discuss below (para 83 et seq.).

80. So far, our discussion has been of developed country markets. Markets in the underdeveloped countries are in principle different. It has been suggested to us that there is a potentially large market for "appropriate technology" equipment - simple, cheap, and rugged. Certainly many observers believe that such a market ought to exist, and that equipment of this kind would meet a real need. But to say that a market ought to exist is not to say that it does. Developing countries often perceive their own needs differently from Western observers, and it appears that many doctors and hospitals in such countries are reluctant to buy what they see as second class equipment. The World Health Organisation has certainly had very limited success in trying to achieve agreement on specifications for "appropriate technology" hardware. In addition, the countries involved are, by definition, relatively poor, and much of what they can afford to spend on health care must be devoted to providing the most basic services. We have already seen that the equipment market outside the US and Europe is estimated to account for less than a quarter of the total, and this includes a number of fully developed countries (eg Japan, Australia, Canada). We remain to be convinced that "appropriate technology" equipment specifically designed for developing countries is at present, in hard commercial reality, a major ungrasped opportunity for British industry. This is not to say, however, that there will not be market opportunities for less sophisticated versions of some currently expensive items, directed both at cost-conscious institutions in the developed world and at underdeveloped countries. It is also very possible that an "appropriate technology" market will emerge in the future, and this area will merit re-evaluation from time to time.

81. Although inherent needs are similar over much of the world, there are

major non-tariff barriers to trade imposed by differing standards and regulatory regimes. These force firms to create and maintain variants of their basic products for specific markets, and to submit them to several essentially similar national tests. They can impose very considerable costs and delays in penetrating new markets. This is a major issue which we consider below (para 94 et seq.).

82. This section has considered the relationship between home and overseas markets. It has argued that the home market can and should provide an important springboard for the penetration of world markets. In identifying ways in which the link between home and overseas markets could be improved, to the benefit of industry, it has identified three areas which merit substantial coverage in their own right. These are the GP market, regulatory regimes, and interactions with users. We discuss the first two of these in the succeeding sections, and the third as part of our discussion of research and development.

THE GENERAL PRACTITIONER MARKET

83. In most developed countries there are signs that more and more treatment and diagnostic tests will be given by GPs, thereby generating a rapidly increasing market for medical equipment designed specifically for the GP, but for reasons to be discussed below this trend is making little progress in the UK.

84. The GP market world-wide is growing rapidly, and this trend is expected to increase in the future, largely due to developments in technology.

Biotechnology and other improvements in analytical techniques are making it possible for routine analyses (eg blood glucose) to be carried out cheaply and quickly without specialist staff. Developments in electronics make it possible to reduce the cost of other diagnostic instruments (eg electrocardiographs) to the point where they can reasonably be considered for use in surgeries.

Information technology now offers the prospect not only of automating "office" functions, but also of allowing data (eg diagnostic images) to be transmitted between hospitals and surgeries.

85. At the same time, the high costs of the "hotel" services in hospitals are leading to pressure for as many patients as possible to be treated in the community, and for hospital stays to be minimised where they cannot be avoided altogether. This will increase the equipment market outside the hospital service (though in the UK one would expect local authorities and community health services to be involved as well as GPs). The implications for testing are less clear, partly because the out-patient clinic is a very valid option, and will probably vary between different types of test. A hospital referral for a test can confidently be expected to involve more administration and more medical time than the same test conducted in the GP's surgery, but the overall economics will depend on the efficiencies to be gained from high throughput, and the extent to which wider availability of facilities results in unnecessary testing. We are not aware that the comparative economics of delivering particular types of health care through the hospital system or through GPs have been well studied for the UK. We believe there is a case for such study, preferably by the practical route of establishing trial practices in which GPs would be encouraged to provide care and testing of types normally performed in hospitals.

86. In the UK, the way in which GPs are funded militates strongly against

their taking on additional responsibilities which require them to acquire equipment. Hence it denies UK manufacturers a home market sector corresponding to that which exists, and which will become increasingly important, overseas.

87. British GPs are formally independent contractors to the NHS. They are contracted to provide "general medical services", but these are nowhere precisely defined. Nor are there accepted professional norms defining at all closely what should be done by GPs rather than in the hospital service. Some norms clearly exist, but the boundary area is wide and very fuzzy.

88. The structure of GPs' fees and allowances is complex, but two features stand out: direct reimbursement of expenses applies to only a few types of expense (albeit important ones), none of them related to equipment; and only in a very few cases is a doctor paid a fee for services of a particular kind. Cervical cytology testing provides an example of such a case. The levels of fees and charges are set annually such that the average GP should earn, after expenses, a sum determined by the Review Body. For those expenses not reimbursed direct, including the purchase of equipment, historic data are used to calculate what the average GP can be expected to spend.

89. There is a financial incentive for a doctor to provide a better service only in so far as by doing so he can obtain additional fees for the services provided or can attract more patients. The scope for either is limited. There are few fees for providing particular services. Nor is it easy to attract patients - patients are remarkably loyal and in rural areas there may be no other practice nearby. There is no financial incentive for him to raise the level of care offered, nor to take on himself something for which he could reasonably refer the patient to hospital. Spending on equipment effectively comes directly out of his own pocket, and can only be recovered if it enables him to support more patients, or to provide one of the specific services for which a special fee is payable.

90. This system encourages GPs to run their practices economically, but it also tends to push any sophisticated health care towards the hospitals, whether or not this is the most cost-effective way to provide it. It is difficult for funds to flow between these two parts of the health care system should a shift in responsibilities be regarded, now or in the future, as offering greater efficiency.

91. There are other possible ways of funding GPs which would create an equipment market more akin to that in other developed countries. However, some of these, such as direct reimbursement for spending on equipment, or a greatly extended system of fees for services provided, might go to the other extreme by encouraging GPs to take on unnecessary work. This is not our intention. We consider that what is needed is a system of financing which links GP and hospital spending, and encourages the most cost-effective distribution of the total resource, without the artificial constraints of the present system. The Health Maintenance Organisations which exist in the US provide one model of such a system, but we have not studied this model in detail. We note that at least one RHA is also considering ways of making a financial link between hospital and primary health care; we are encouraged that they see valid arguments for such a link on health care grounds alone.

92. We do not claim that a major change in health service financing can be considered on the basis of the industrial interest alone. It is possible that this interest might be consistent with the more efficient delivery of health care, but it would have taken us well beyond our remit to consider this area in detail. However Ministers are considering policy on the funding of primary health care services, including GPs, and believe that the points we have made should be taken into account in that consideration. We recommend that, in considering policy on the funding of primary health care services, the Government should take into account the interest of the medical equipment industry in a GP market parallel to that existing elsewhere.

93. If there were to be a rapid emergence of a GP market in the UK, there is a serious risk that British industry would be unprepared and that much of the benefit would go overseas. However, if trial practices of the kind referred to in para 85 were established, this would allow industry to prepare itself for larger scale change. More positively, it could, and in our view should, be linked with active encouragement to British industry to develop and test in practice products aimed at a future UK GP market. We recommend that trial practices be established in which GP's would be encouraged to provide a greater range of services, and that UK industry should be linked with this experiment and encouraged to use these practices as a test ground for new products aimed at the GP market.

REGULATORY REGIMES

94. As we have noted above, differing national regulatory and standards regimes fragment the world market, and can impose substantial delays and costs on exporters. (Typical figures for the certification of a piece of clinical analysis equipment might be 2-4 months, and £10,000-25,000, for a single European market.) They thus constitute major barriers to trade. This is true whether or not they are discriminatory in intent or in the way they are applied. The UK has a reputation as one of the most free and open markets for medical equipment, and industry is not seeking any form of protectionism. Rather, it is seeking equally free access to other markets.

95. The most obvious means of regulation of the market is by means of standards, and in the UK the NHS is advised to require conformity with relevant British Standards where these exist. Most important markets have their own national standards. The differences between them sometimes, of course, reflect real underlying differences (for example in mains voltages). In a few cases, they seem to be deliberate attempts to protect a domestic industry. The majority, however, are simply the result of individual countries creating their own standards independently, before any international standards exist. Once this has happened, the process of reconciling these standards can be very slow. Even when international standards have been set by the international standards organisations, their translation into national standards may be equally slow. Britain has a good record in this respect. The US has one of the worst, because it lacks any strong national standards body. As a result, individual states and cities tend to create their own standards or rely on those of the Underwriters' Laboratories, which as the name suggests is a private testing organisation created by the insurance industry. There are domestic pressures for greater harmonisation, but so far they have made relatively little progress.

96. There is little that can be done directly to improve the position in the US. Harmonisation of European standards would, however, be very beneficial in itself, and might well increase the pressures towards harmonisation in the US. This is an obvious area for action within the European Community, but so far the Commission has produced only one Directive in this area, on the harmonisation of safety requirements for medical electrical equipment. Despite having been over 10 years in gestation, this is limited in its effect, and some Governments (notably Germany) have in the interim established national legislation which conflicts with it. We believe that there is scope for much

greater action by the Community in this area.

97. In the UK, the main force for action on standards for medical equipment is the Scientific and Technical Branch (STB) of DHSS's Procurement Directorate, operating through the machinery of the British Standards Institute as appropriate. STB are fully aware of the need for greater harmonisation of standards, and are heavily involved in the relevant international bodies. Their work is well regarded by the industry. But we are not convinced that the problem is sufficiently appreciated, or given sufficient priority at the political level. We consider that if progress is to be made at anything like the speed which is desirable a strong political impetus is necessary. The obvious vehicle for this is the European Community, where it would fit well with the UK's general emphasis on removing the remaining obstacles to free internal trade.

98. Product standards do not, by themselves, constitute an adequate system of regulation. They can cover some important areas, such as electrical safety, but in a rapidly-moving field with a wide diversity of products it is not possible to have comprehensive standards for each. Nor can product standards adequately cover manufacturing practice, which is important when (for example) poor sterility control or an occasional defective item can have potentially disastrous effects for the individual patient. There are two broad approaches to this problem. One is product approval, in which every new product has to be approved, normally after testing, by the national authority. The "homologation" scheme operated by France is of this type. There are three objections to this approach: it requires a great deal of effort to operate; it does not address the question of manufacturing standards; and it may act as an undesirable brake on innovation. The UK has therefore favoured the alternative approach of manufacturer registration.

99. The Manufacturer Registration Scheme was set up by DHSS in 1982 and is gradually being expanded until eventually it will include all medical equipment. The aims of the scheme are to:

control manufacturing quality by monitoring companies' manufacturing standards and practices;

provide information for the NHS which will be of assistance in purchasing;

give the NHS confidence in manufacturers' claims of compliance with

product standards.

100. Manufacturers are inspected by DHSS, and are required to satisfy it that their manufacturing facilities and processes comply with Guides to Good Manufacturing Practice issued by DHSS and based on British Standards. Once approved, the company is included in a register which is issued to the NHS and updated regularly. The NHS is recommended to buy products covered by the Guides only from registered manufacturers. The scheme is open to overseas manufacturers, whose premises DHSS also inspects. We consider that this is a good system, but we are concerned that STB, who are responsible for the Scheme, do not have the resources to operate it in the way we should wish to see. First, the scheme is not being expanded as fast as we should wish. Second, there is some feeling in industry that the Scheme is in fact operating to the disadvantage of British manufacturers, because the limited resources available do not allow overseas manufacturers to be inspected as frequently and as thoroughly as British ones. We recommend that additional manpower be provided to STB for the operation and expansion of the Manufacturer Registration Scheme.

101. DHSS are negotiating with the US FDA an agreement whereby each would accept the other's inspections, but no other nation yet has in full operation a scheme similar enough to permit further such agreements. There is however currently considerable activity in various countries to set up new manufacturer registration or type approval schemes, but there is no generally accepted form for such schemes. This is causing some alarm among manufacturers (not only UK ones) because of the differing requirements they will have to meet and inspections to which they will have to submit. Here as in the case of standards, the EC has failed to set a European pattern which would prevent a proliferation of incompatible national schemes among its members, some of which (eg the French scheme) operate in a highly protectionist way. Here, too, only a political initiative has any chance of giving a real impetus to harmonisation.

102. We recommend that the Government should take a stronger political initiative within the European Community to create a freer internal market in medical equipment by eliminating the barriers currently created by differing national standards and regulatory regimes.

RESEARCH AND DEVELOPMENT

103. There is no good quantitative information on the sector's expenditure on R & D. Research at the beginning of the decade by a York University group found R & D expenditures in the region of 7-8% of turnover amongst a sample of medical capital equipment manufacturers. This is a high figure by the standards of manufacturing industry generally. But the sample was drawn from the medical electronics sector, and may have been biased towards larger firms, both factors which one might expect to lead to higher R & D expenditures than for the medical equipment industry as a whole.

104. Outside the medical electronics sector, we believe that R & D levels are much lower. Even amongst successful companies in the disposables sector, for example, figures of around 2% would be more typical. The anecdotal evidence suggests that some companies have very low levels of R & D, and that this is primarily devoted to fairly small product improvements rather than to preparing the company's technology base for major changes. We are very concerned at this picture, which suggests R & D levels wholly inadequate to maintain and develop the UK's position in a rapidly moving industry.

105. We have identified a number of areas in which major technological developments are going on or can be foreseen in the near future. These technological developments are likely to change appreciably the performance and/or cost of medical products in these areas and thus represent commercial opportunities also. They can be expected to provide high growth areas for the business over the medium term.

106. There is overlap between some of the categories chosen for this list so that the same technological development may appear under more than one heading. We nevertheless felt that this grouping provided the clearest presentation of the main areas of opportunity.

1. Materials

New and improved materials, particularly non-metallic, for use in replacing body tissues, fluids and structural components, particularly blood vessels; entry ports to the body.

2. Implantable devices

Orthopaedic replacements; replacement organs eg heart valves, intra-ocular lenses; active devices - cardiac pacemakers and other stimulators for organ control, pain relief, muscle activation. Devices (which may not be entirely implanted) for controlled release or infusion of drugs or other therapies. Monitoring devices, particularly biochemical sensors.

3. Laboratory Diagnostics

Equipment and reagents for use in the laboratory; biosensors. Automation of more processes - microbiology, bacteriology, microscopy.

4. Diagnostic kits

Simple kits which allow diagnostic testing of body fluids to be done away from the laboratory; biosensors.

5. Medical Imaging

Magnetic resonance imaging (possibly associated with spectroscopy); ultrasonic imaging; other forms of tomography. Function studies using radioisotopes. Digital radiology - detectors; image storage and transmission; display units, associated software.

6. Other diagnostic methods

Magnetic resonance spectroscopy; magneto-encephalography; magneto cardiography; endoscopy; expert systems.

7. Patient monitoring

Improved sensors; computerised signal analysis; displays and warnings.

8. Surgery

Surgical endoscopy; laser surgery; variable-wavelength lasers; improved transmission fibres. Micro-surgery.

9. Anaesthetics

Respiratory gas analysers; blood gas sensors; injectable non-local anaesthetics.

10. Therapeutic devices

Infusion pumps (which may be associated with sensors in closed-loop systems); other forms of controlled drug release; laser-stimulated drug breakdown. Stimulators for muscle control, pain relief, restoration of function.

11. Wound healing

Materials for covering and filling wounds; artificial skin; replacement body fluids.

12. Support for the Elderly/disabled

Prosthetic and orthotic devices with improved function; appearance and control. Improved actuators for use by handicapped people. Incontinence control and management devices.

13. Screening

Simple, cheap, accurate (possibly home-use) devices/techniques for screening for major diseases: e.g. cancer, heart, stroke.

107. We have not attempted to give an exhaustive list, nor to provide detailed accounts of any of these developments, nor to rank them in any order of importance. They are given as examples of potentially important developments in a rapidly expanding area. Our main concern has been to demonstrate that this is a business much of which will see major technical changes over the next few years. Those companies that hope to remain in the parts of the business that will be affected will need to make a large commitment to research and development.

108. We do not believe that Britain can afford to ignore these areas. They cover a large part of the sector, and a substantial part of the remainder is vulnerable to low-cost competition from the less developed countries. These areas of technological change represent opportunities for a nation with a

strong technological base and a leading position in medical research, provided that the links can be made between that research and the development of saleable products.

109. Some of the areas we have identified, for example in imaging, involve levels of cost which are likely to make them the prerogative of at least moderately large companies. But for many of the others this is not so and we see nothing in the technology which is inherently inconsistent with a flourishing small and medium sized company sector. But these "leading edge" areas will in general be characterised by high R & D costs in relation to market size. This implies that a successful operator in one of these areas will need to capture a significant proportion of the world market for his product.

RELATIONS BETWEEN INDUSTRY AND USERS IN R & D

110. Academic studies of the medical equipment industry have demonstrated the importance of strong interaction with users if innovation is to be successful. Indeed, ideas for new products often come from users themselves. Successful innovatory firms therefore need convenient access to prospective users, and develop close relationships with such groups, most frequently (but by no means exclusively) in the teaching hospitals. Besides the access which they give to the leading edge of medicine, and the practical user experience which they bring to bear on development, such links also connect the firm and its product to influential points on the medical grapevine which, as we discuss elsewhere, is an important influence on marketing. A successful firm of even moderate size will seek such links internationally, but a small firm is likely to depend strongly on domestic links, often with a more or less local hospital. For any firm, its domestic links are likely to be of particular importance, because it is obviously easier to sustain a close relationship with someone close at hand.

111. For UK industry, such links assume particular importance. First, the UK is, as we have already mentioned, amongst the leaders in medical science. This offers the industry the opportunity to get close to the leading edge of medicine, and access to the ideas emanating from its practitioners. Second, the NHS has, by the standards of other health services, a very high level of scientific support. This forms a huge resource which could be a great asset to an industry whose own stock of qualified people is relatively small.

112. The evidence we have received on this topic has been conflicting. There have been some conspicuously successful examples of co-operation between industry and the health service. But we have also been told by both doctors and industrialists that such links are more difficult to forge in the UK than in the countries of our major competitors. The reasons given for this have varied widely. Our own view is of a very patchy situation in which some firms and some health service staff, find no difficulty in linking together whilst others either see no need for such links or have an exaggerated perception of difficulties. We have no doubt, however, that there is room for improvement.

113. Part of this improvement needs to come from industry. There are too many UK firms who pay insufficient attention to R & D, or who do not devote the necessary effort, particularly high-quality technical staff, to creating and maintaining relations with the medical community. There is also sometimes a

failure to understand the imperatives and constraints motivating doctors, researchers, and scientific staff. As a result, those who are able and willing to collaborate often find it easier to form relationships with foreign companies.

114. But we also have no doubt that there is room for improvement within the health-care system, and particularly the NHS. Hospitals rightly see their primary role as treating patients, and some researchers are fiercely jealous of their academic freedom and hence will not accept any constraints of commercial confidentiality. But there are many examples world-wide, and in other fields within the UK, of successful relationships between academic researchers and industry in which both sides accept that their legitimate interests have been met. And there is no reason why hospitals cannot accept collaboration with industry as an important subsidiary objective, which can bring them positive benefits.

115. There are some hospitals in which collaboration with industry is indeed viewed as an entirely normal practice for many staff. In others however, the prevailing culture seems to regard any collaboration as exceptionally difficult. In particular, a close link between a doctor and a particular firm tends to be viewed with suspicion as liable to give rise to conflict of interest, if not outright corruption. As a result, some of those who do wish to co-operate with industry feel obliged to maintain relations with several competing companies; this in turn makes those companies reticent about discussing commercial secrets which they fear may leak to their competitors. One influence adduced here is the Prevention of Corruption Acts, and the guidance on them issued by the Health Departments. This guidance has been interpreted by some as strongly discouraging the development of any close contacts with firms. This has led many senior managers and consultants in the NHS to be profoundly cautious about entering into relationships with industry.

116. As we have already seen, this caution is largely unnecessary; other institutions have demonstrated that such relationships pose no insuperable problems, are entirely consistent with a high standard of probity in public purchasing, and can be accepted as a normal and desirable way of working. Nevertheless, we consider it important to remove this perceived barrier where it exists.

117. We recommend that the Health Departments should issue new guidance to

Health Authorities which, whilst reiterating the need to prevent corruption in purchasing activities, gives positive encouragement to the creation of R & D links with UK-based firms.

118. In our view, collaborative arrangements between health service staff and firms should normally involve some tangible benefit to the individual and/or his department. Where hospital facilities are used, it is also right that the hospital should benefit, and the terms should take full account of any associated costs. Many health service professionals have little knowledge of how to structure their relationships with firms, and how to deal with such matters as intellectual property rights. We believe that it would be right for the Health Departments to issue guidance in these areas. Once the guidance is issued, doctors and scientists should generally be allowed to negotiate their own arrangements, subject to their declaring these to their Health Authority administration, and to some mechanism based on peer review to prevent gross violations of the norms.

119. A further positive step would be arrangements under which people could work part-time for the health service and part-time for industry, including forming their own companies. Such arrangements are rare in the UK, but much more common overseas. In the US, for example, it is common for small medical companies to have practising clinicians and hospital scientists on their boards of directors and thus both involved in and benefitting directly from the exploitation of their research. We recommend that the Health Departments should encourage Health Authorities to employ staff on contracts which permit them, if they wish, to spend part of their time in industry.

120. Underlying many of the problems, perceived and real, which we have identified is a large measure of mutual incomprehension between industry and the health service. There are many on both sides who need to be more aware of the concerns and priorities of the other, and the ways in which they can interact. Therefore, in addition to the more specific measures above, we recommend that the Health Departments, the main trade associations and those professional associations which are active in this field should take steps to improve understanding between people in industry and those in the health service.

GOVERNMENT INDUSTRIAL SPONSORSHIP AND SUPPORT

121. Sponsorship and support responsibility for the medical equipment sector is divided between DHSS and DTI. MRC and SERC also have relevant research and development activities. BTG is involved in its normal role of commercialising inventions.

122. DTI makes available its normal means of financial support to industry, including support for investment (eg regional assistance, or assistance for inward investment). So far as R & D support is concerned, responsibility is split, the historical basis of division being that equipment used with the patient present fell to DHSS and equipment used with the patient absent to DTI. This division is no longer regarded as well-founded, and is not observed in practice. The growing use of electronics in instrumentation has drawn DTI into direct involvement with "patient present" products. This has been facilitated by the support mechanisms available to DTI such as the former Microprocessor Applications Project and Support for Innovation (including the support administered by the Biotechnology Support Unit). It has also been influenced by the shortage of funds in DHSS to support major projects in industry, so that it is increasingly DHSS practice to pass expensive industrial support projects on to DTI for consideration. DTI however maintains its own close contacts with firms in the electromedical and biotechnology sectors, many of whom seek support direct from DTI.

123. In early 1986, DTI had outstanding R&D support for medical equipment projects totalling £8.2 million, which might be expected to lead to annual expenditure of around £2.5 million. This figure for grants outstanding had declined sharply over the previous two years, mainly as a result of the moratorium introduced by DTI in 1984 and the subsequent changes in the Support for Innovation scheme announced in April 1985. The largest proportion of the outstanding grants was towards the instrumentation/electronics sector (46%) followed by biotechnology (43%). In addition, there were extant pre-production orders in the electronics sector totalling £3.2million. Following the review already referred to, this form of support is currently available only under very limited circumstances.

124. The instrumentation branch of DTI's Electronics Applications Division, which is responsible for the instrumentation/electronics part of the industry, has a technical committee on which sit representatives of DHSS and the MRC Clinical Research Centre, and hold 6 monthly meetings with DHSS at Under

Secretary level. When a medical project comes to the Division, whether for R & D support or other selective assistance, advice is sought from STB, who contribute to the technical appraisal. Other parts of DTI draw on DHSS advice as required, on a less formal basis.

125. Of the industrial opinions of DTI that we have received, the majority are favourable; its officials (including those involved with export promotion) are characterised as helpful, and understanding business. But it has been suggested that the industry suffers from not having a sponsorship section within DTI able to represent its views on matters of general industrial policy. We suspect also that large parts of the industry, outside the electronics and biotechnology areas, may not have regarded DTI as having any great relevance to their business.

126. We believe the fragmentation of sponsorship responsibility within DTI is a weakness. It deprives the industry of a clear voice within DTI, and it creates problems for those other organisations (such as SERC) who want to co-ordinate their activities with those of DTI. It may also lead to a lack of awareness of the industry amongst those in DTI for whom responsibility for some part of it is a small part of a more diverse workload. We recommend that a single Branch within DTI should be given coordinating responsibility for all those sponsorship and support activities towards the medical equipment industry that fall to DTI, including responsibility for liaison with DHSS and SERC on matters relating to the industry. This would not preclude some DTI support being given through special units, such as the Biotechnology Unit, provided there was liaison with the designated Branch.

127. Within DHSS, the primary responsibility for sponsorship falls to the Procurement Directorate and in particular the Scientific and Technical Branch. This has a number of relevant responsibilities, of which the most important are described below.

128. One section of STB is responsible for the normal non-financial sponsorship of the industry, including such things as links with trade associations, competition policy, commercial intelligence, representation of the industry's interests within Whitehall etc. This section also administers the Manufacturer Registration Scheme.

129. There are various specialist groups within STB which are responsible for

liaising with BSI and others on national and international standards for their products. In practice, they are the leading UK participants in standards-making in this area. This area has been dealt with above (para 94 et seq.).

130. The DHSS programme of support for equipment research and development and evaluation has been in existence for about 20 years. The funds reached their highest level in 1980/81. Since that date, they had declined in real terms by about 30% until 1985/86, when a special additional allocation of £0.5 million was made to help cope with an increasing number of requests for support of nuclear magnetic resonance applications. The total allocation for 1985/86 was £5.2 million. This can be split into three broad areas. About £2 million is spent on the evaluation of new medical products (para 140 et seq.). £1.2 million is spent in support of the Bioengineering Centre at Roehampton. This Centre is operated by University College, London, with whom DHSS have a long-term contract for the development of new methods of manufacturing and fitting artificial limbs. The remaining £2 million is spent in support and development across the board.

131. The distribution of this £2 million can be analysed in several ways. One is in terms of where it is spent:

universities	- 40%
hospitals	- 34%
industry	- 26%

132. The numbers of projects (total of 68) are distributed in almost the same proportion. This is rather unusual. The typical pattern in the past has been for there to be a smaller number of more costly projects with industry, and the change may reflect the increasing practice of passing on major industrial support projects to DTI for consideration.

133. One can also analyse the areas in which this £2M R & D money is spent:

aids for disabled (including incontinence)	- 25%
path lab equipment and reagents	- 24%
medical imaging	- 18%
surgical implants	- 6%
dental materials	- 5%

sterilisation methods and monitoring	- 5%
medical optics (incl lasers)	- 4%
others	- 13%

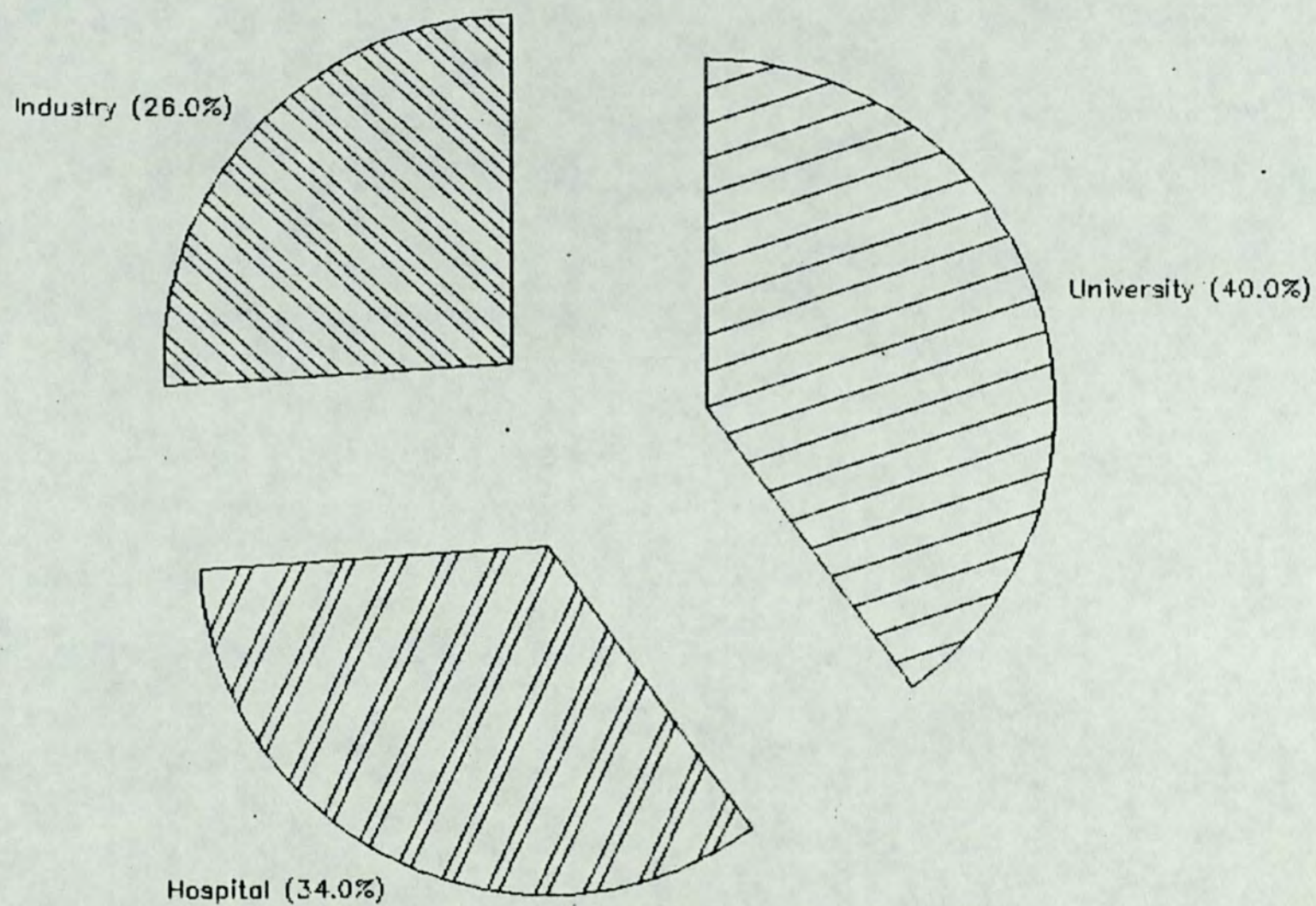
134. This distribution reflects the special priority which DHSS gives to equipment for the elderly and the disabled as well as the two dominant technology areas of imaging and pathology. This special priority in turn reflects partly the Department's direct responsibility for services for the disabled and partly the lack of strong market pull for innovation in these areas.

135. Apart from the Bioengineering Centre, DHSS support only two centres on a long-term basis, both in the area of aids for the disabled. All other support is given to individual projects. Few of these are actually invited by the Department, but STB staff are very active in stimulating outside bodies to make proposals, and in reshaping proposals received. The programme is under the control of a Research Liaison Group which, besides the research management from the Procurement Directorate, includes members from the Customer Divisions in DHSS and 5 external advisers appointed by the Chief Scientist. This Group is involved particularly in the strategic balance of the programme, identification of new areas of interest, and decisions on high-spend or long-running projects. Individual projects may be authorised by the Director of STB if they receive medical and customer support as well as the approval of at least two external referees. A number of small advisory groups exist to help in the oversight of particularly important areas (eg magnetic resonance imaging).

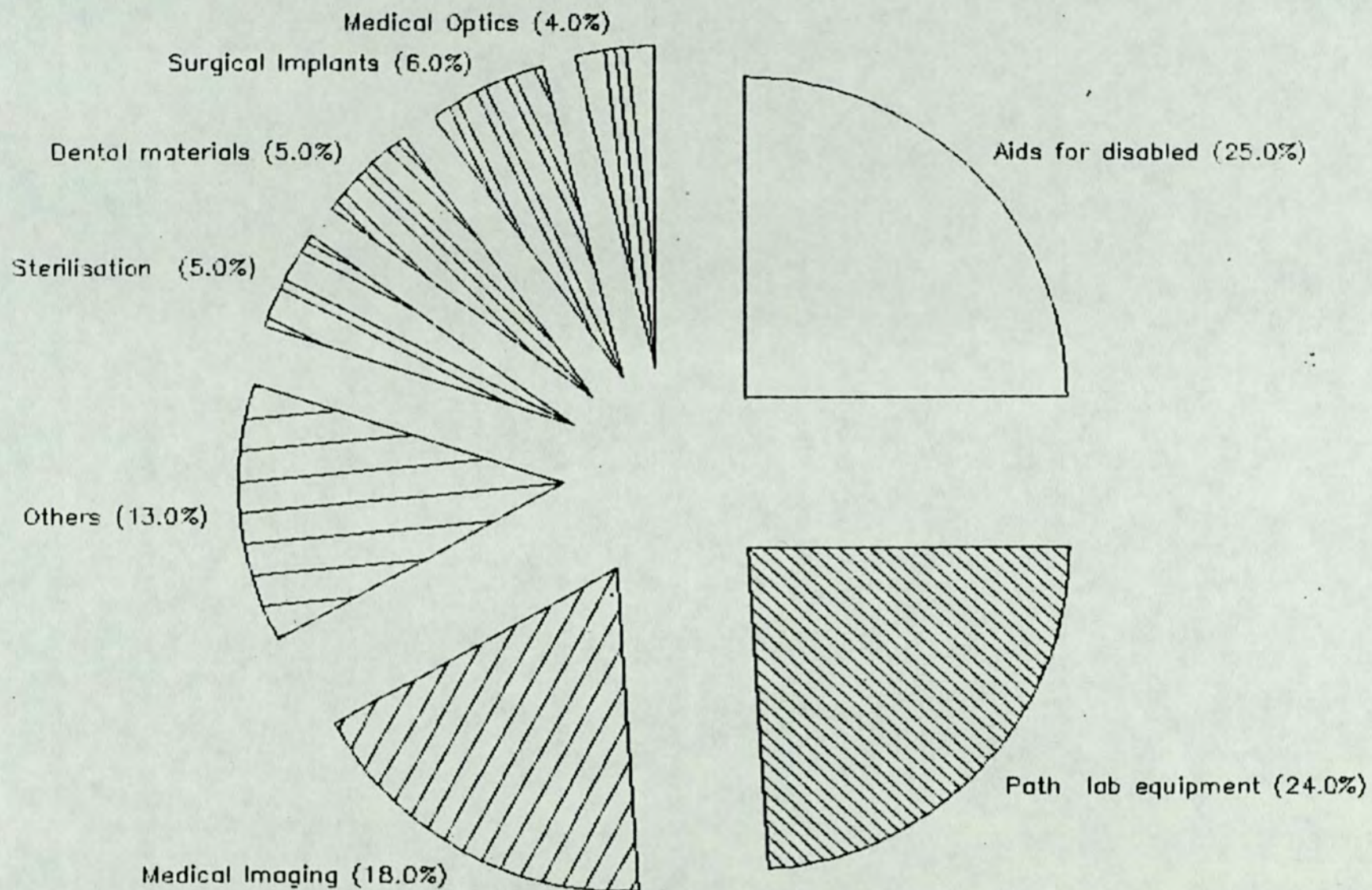
136. DHSS normally receive between 40 and 60 R & D proposals each year of which about three-quarters are accepted. However, a good deal of informal filtering goes on before proposals are submitted. There is also a good deal of re-direction - particularly to DTI - and liaison with SERC and BTG, though DHSS acknowledge that liaison arrangements still require some improvement. With the exception of one very costly project, we are not aware of good proposals being turned down for lack of money. But the number of submissions is small, and to a large extent controlled by DHSS itself with knowledge of the money available. In addition, we have already seen that major industrial proposals tend to be redirected to DTI.

137. The outcome of projects is monitored by the Research Liaison Group. DHSS have assessed the outcome of the 50 projects which have come to completion

DHSS Supported R&D by Sector



DHSS Supported R&D by Area



during the last two years as follows:

- 3 produced patents
- 9 produced new assay or test methods
- 5 produced new products now in manufacture
- 5 produced prototype requiring further testing
- 10 produced reports for publication which appeared to represent the end of the project
- 8 produced reports indicating further work is needed
- 6 were unsuccessful

138. The first three categories represent a fairly reasonable assurance of success while the next three are somewhat uncertain.

139. When developments are funded in industry, DHSS seeks a levy payment on sales, the levy being set "at a level which would not affect sales". Receipts are low. In the case of developments in universities and research establishments, the industrial property is transferred to BTG for exploitation.

140. Evaluations of new medical equipment are recommended by DHSS technical officers. Equipment is bought by DHSS and handed over to the evaluating body, normally a Health Authority which can expect to retain it once the evaluation is complete. (In the special case of X-ray equipment, it is sold to an authority at 50% of its cost price.) For some types of equipment, DHSS has designated evaluation centres to embark on a continuous programme of comparative evaluation, and at some of these DHSS has funded staff. In other cases, it arranges ad hoc evaluations of batches of equipment. The Scottish Home and Health Department (SHHD) also arranges comparative evaluations. The main emphasis has been on electromedical equipment, in view of the implications for safety, accuracy of diagnosis and reliability of operation. The programme is still limited in its scope, and has tended to concentrate on more expensive and sophisticated types of equipment.

141. In most cases, each item of equipment is subjected to:

- i. a technical assessment against current safety and performance standards;
- ii. a subjective assessment of the quality of construction, the serviceability and the likely reliability;

- iii. a period of "user" experience, to establish its clinical acceptability in operational and ergonomic terms.

142. Findings and results are discussed with the manufacturer or supplier, who is given an opportunity to comment in writing. Reports on all the models in a batch are then published, complete with manufacturers' comments, in special "Evaluation Issues" of "Health Equipment Information". Each issue is intended to be a "buyer's guide", covering all models which have been evaluated and which are still on the market in the UK, as well as carrying full reports on any recent models. Any which stand out as particularly good or bad value are highlighted. Although there is no firm quantitative evidence there is reckoned to be a good correlation between DHSS evaluation reports and the subsequent sales of the equipment in question.

143. Several European countries have broadly similar evaluation programmes and there is a European "club" which acts as an information exchange, and tries to harmonise the form of reports. Other countries' reports are said to be generally no less objective than DHSS's own, but are not sufficiently similar in form and coverage to be published in the UK as they stand. Rather, they are used as pointers for DHSS's own evaluations. This largely reflects the fragmentation of the market by standards and regulation, so that the models on sale in one country are unlikely to be precisely similar, and tested against precisely the same standards, as those in another. We should like to see more harmonisation of report formats, but recognise the obstacles so long as this regulatory picture persists.

144. Although it is aimed at the NHS, the DHSS/SHHD evaluation procedure is welcomed by industry, as providing a basis for informed decision taking, without imposing choice. It is contrasted favourably with more dirigiste regimes which have been followed elsewhere, and which, by delay in responding to technical developments, have tended to fossilise the market. We ourselves strongly support the concept, as aiding the creation of the open but informed and responsible market which we wish to see. We have also been impressed by the form and content of the evaluation reports which we have seen. We recommend that the evaluation programme be continued and expanded, and that the modest expenditure devoted to it should be materially increased. We have in mind an increase of the order of 50% in real terms.

145. STB also has pump priming funds, about £0.5 million a year, to support the purchase of new equipment normally at the early production stage. As in the case of evaluation studies, the purchase is made by DHSS and the equipment becomes the property of a Health Authority which is expected to produce a short assessment report. For pump priming, however, the initiative comes formally from the manufacturer, normally after discussion with DHSS technical officers. Cases are assessed within STB, in consultation with DHSS medical staff and the relevant Regional Scientific Officer (for all but very small projects), and decisions are made by the Branch Director. DTI are not normally involved.

146. The criteria include encouraging British industry by initiating a market, providing a shop window, providing a base for the development of exports, encouraging technological and medical advance, etc. During 1984/85 contracts to the value of £412K were placed in respect of 17 product types, which were distributed to 53 locations. The programme is well-regarded by industry. It is close in character to the evaluation programme, and can be seen in some ways as a variant of it.

147. In general, those parts of the industry that have regular contact with STB have a high opinion of its technical competence and its work in standards, quality assurance, and evaluation. They are concerned that staff reductions have now left the Branch overstretched. Its R&D programme is much less well known in industry, and does not seem to be regarded as an important source of industrial benefit. We believe that it should be more widely publicised, though we recognise that at the present low level of funding this might well lead to demands well in excess of resources.

148. The Chief Scientist of DHSS spends relatively small sums of money on evaluating the economics, in health service terms, of new equipment developments. We have recommended above (para 67) an increased activity in this area, without commitment as to the route.

149. Local Health Authorities also spend some money on R & D; it is not known how much of this is on equipment, but the figure is believed to be small.

150. SERC has a "specially promoted programme" in medical engineering. This was initiated in 1977 as a programme in biomaterials, but in 1981 its remit was broadened to cover all aspects of medical engineering. Between 1978 and the end of 1985 156 grants were awarded to a total value of approximately £5 million.

Grants outstanding currently amount to £2.4 million, which can be expected to give rise to an annual expenditure of some £1 million with an industrial contribution of some £160,000. In addition, there are 38 current training awards, giving rise to an annual expenditure of a little over £200,000. Research activities under this programme include the development and evaluation of new materials for implantation, the design of new prostheses, the characterisation of diseased tissue that has to be replaced, the production of external aids for the disabled, investigation into new methods for the care of the incontinent and developments in advanced imaging techniques. Not surprisingly, in view of the origins of the programme, there remains a strong emphasis on biocompatible materials and applications for materials in medicine, this topic accounting for 30-40% of current support. Diagnostic aids are also important, at 20-30% of support. DHSS are represented on the committee which is responsible for the programme, and their advice is influential.

151. The SERC programme is, in keeping with the role of SERC, in the area of basic/strategic research, and SERC funding is restricted to academic institutions and hospitals, though co-operative programmes with industry are encouraged. In fact, 71% of grants under the programme have active industrial collaboration, and about a third of projects completed to date have led to patents. There are two main limitations on the programme. One is finance, which at present allows SERC to support only 25% by value of the proposals received, which is a lower figure than SERC would regard as normal. The committee responsible for this area is very aware of budgetary limitations and hence tends to discourage high value applications and to reduce significantly the value of those approved. Interest in medical engineering is increasing rapidly, and is leading to increased demands on finance. The second limitation is the lack of mobility within the university system, which inhibits the formation of the interdisciplinary teams which are necessary in much of this work.

152. There is some relevant SERC support outside the specially promoted programme. In particular, the Biotechnology Directorate is spending about £0.5 million a year on biosensors, and the Chemistry Committee a similar sum on molecular sensors. In neither case, however, is the programme exclusively, or even dominantly, medical in its aims.

153. MRC does not have a programme in medical engineering or medical equipment per se, though new ideas of potential commercial value frequently emerge from

the work which it supports. MRC is keen to improve the translation of such ideas into commercial products and has recently set up a large centre for collaboration with industry at the National Institute for Medical Research. MRC is also strongly involved in the support of research groups, either in its own units, in hospitals, or in universities who may be the first users of new equipment, and actively promotes studies of the usefulness of new techniques (such as MRI) in order to establish their clinical value. The MRC also supports from time to time research into novel medical techniques and equipment as part of its role in the advancement of basic medical science and medical practice, though it would not regard this as a major part of its activities. Thus, although there is close liaison between officials of the MRC and those of the DHSS and SERC, research and development on medical equipment forms a relatively minor part of the discussions.

154. In summary, the total Government support for R&D on medical equipment, excluding the Bioengineering Centre, SERC training awards and DTI pre-production orders, is of the order of £6 million a year, or rather less than 1% of the industry's turnover. This figure is low by the standards of many other high technology industries, especially those benefitting from defence R & D expenditure, and very low by the standards of agriculture, fisheries and food (for which the figure is around 3%). It is more surprising given the direct benefit which the public sector, in the shape of the NHS, might hope to derive from the results of R & D. It also needs to be seen against the background of the widespread belief that over much of the industry private investment in R&D is too low to remain competitive in the long term (para 104 above). We recommend that Government support should be substantially increased. We believe that a rough doubling in real expenditure over a 4-year period would be both realistic and attainable.

155. Even at this increased level (around 1.5% of the industry's turnover), Government support will not be large. It must therefore be well-spent, and in this connection we are concerned at the fragmentation of responsibility for programmes. We have already made proposals to unify responsibility in DTI, and we understand that SERC have established internal coordination arrangements. But we believe there is still a need to improve coordination between Departments. These links should involve MRC, as a body which should be well-attuned to the future prospects for medical science and practice. We recommend that a mechanism should be set up to coordinate the programmes of DHSS, DTI and SERC in the medical equipment field. This mechanism should

involve participation by MRC and industry.

156. Although in general we believe that funds will be best spent by responding to specific proposals, we consider that the Departments involved should take deliberate steps to ensure that support is available in those areas in which the UK has a fledgling high technology medical industry with reasonable prospects of success. They should also ensure that support is available for key underlying technologies, and for leading-edge medical technologies which have not yet reached the stage of industrial development. It is possible to encourage proposals in these areas, whilst retaining a basically responsive system, as all three Departments have demonstrated in this field or elsewhere. One particular priority for the new coordination arrangements will be to encourage joint proposals linking industry with health service staff and academics.

THE INDUSTRY AND THE EDUCATION SYSTEM

157. As we have seen, the medical equipment industry will be highly dependent on technology for its future, and hence on attracting the right R&D manpower, in terms of both quality and skills. It is dependent on marketing to a large population of prospective users, most of them of high technical competence themselves, and it suffers from weakness in its industrial design. We are concerned that in all three of these areas the industry is not managing to recruit the people it needs.

158. So far as R&D is concerned, the growing electronic content of medical equipment means that the industry requires electronic engineers and software engineers. Both these skills are acknowledged to be in short supply, and to be a problem in the economy more generally. We support the efforts being made to increase the supply of these skills, recognising that an important part of doing so will be to increase the numbers in schools taking mathematics and physics at A level. Some parts of the industry also perceive a shortage of molecular biologists and medical engineers. These are skills whose shortage is felt less generally in the economy, and which are also more specific than is appropriate as the subject of an undergraduate course (though some coverage of these areas at the undergraduate level is entirely right and appropriate). Specialists in these areas must be produced very largely by postgraduate training. Ideally, industry would itself play a large part in developing, or sponsoring the development of, the people it needs. But this is much easier for large firms than for small ones, and in an industry with few large firms, this route cannot be relied upon. We recommend that SERC should give high priority to medical engineering* in their support of postgraduate training. We include in this taught courses, research training, and mid-career updating schemes. We note, and support, the priority already given by MRC to molecular biology. In medical engineering (which is of course an interdisciplinary subject), we are aware that the rate at which training can be expanded may well be limited by the number of academic staff available to teach. For this reason, and also in the interests of research, we recommend that the development of medical engineering groups be a priority area for future university appointments.

*Medical engineering is the term we have chosen to use here to mean the application of all forms of physical science and engineering to the design, development, and production of equipment for use in the diagnosis of illness or

the treatment or care of patients. It includes the fields of biomaterials and biosensors, and the application of engineering methodology to the investigation and treatment of patients. It embraces the activities which others have called biomedical engineering, bioengineering, or clinical engineering.

159. We have heard, and in some cases seen for ourselves, that too much British medical equipment is badly designed. This is not primarily a matter of aesthetics, though these too may influence user choices. From the user's point of view it is primarily concerned with reliability and ease of use. From the manufacturer's point of view design for manufacture is of great importance to the efficiency and cost of production. Enlightened manufacturers involve a good industrial designer at a very early stage in the development of a new product. But there are too few such manufacturers and, probably as a result, few industrial designers specialising in this area. We support the efforts of SERC, DTI and others to increase the industry's awareness of the importance of design and the supply of skills in this area and the related one of management engineering. We recommend that these areas too should be given priority for future university appointments.

160. We are also concerned at the quality of the marketing staff deployed by the industry. We have heard too many times that representatives of overseas companies are both more professional in their marketing technique, and also better able to discuss their products as technical equals with prospective buyers. To a large extent the fault here must be laid at the door of an industry which sets too small store by the quality of its representatives in the field, and hence does not recruit (and pay for) the standard of representation it needs. But we believe it also has something to do with a national attitude to selling which holds it in low esteem, and with a general low level of business education nationally. Although we do not offer any formal recommendations in this area, we nevertheless believe it essential for the industry to ensure that its sales and marketing staff are adequately trained, particularly in respect of their ability to discuss the technical aspects of products with prospective users.

STATISTICS

161. This report has commented at various points on the inadequacy of the statistics, both national and international, relating to medical equipment. People in Government, trade associations and industry have said that they are hampered in their work by lack of knowledge of UK production, domestic market, and overseas trade broken down on a basis which is consistent between different sources, and which is sensible medically and industrially. Whilst the problem of international statistics is only to a limited extent within the power of the UK to solve, improvements could and should be made to the availability of UK data.

162. The two most relevant sources of Government statistics are the overseas trade statistics collected by Customs and Excise, and the quarterly and annual Census of Production data collected by the Business Statistics Office, which is part of DTI. The types of information collected for these two statistical series are in principle capable of giving a good picture of the industry. But there are problems with the way the information is classified:-

- a) The structure of the trade statistics at the most basic level (the tariff heading, identified by an 8-digit code number) is unhelpful. Many items of interest cannot be identified, and too high a proportion of the trade flows fall into ill-assorted residual categories.
- b) This structure cannot be aligned closely with that of the quarterly production statistics.
- c) In the Annual Census of Production, the industry as we have identified it is scattered through a number of Activity Headings. This problem was largely solved for us by a special analysis performed by the Business Statistics Office, but this is not a facility which industry can generally use.

163. If these problems could be solved, we think the UK statistics would provide as much as could reasonably be expected of them. We know that there are problems in changing Government statistical classifications. In particular, there are various international requirements to be met. But the information we

have seen from other countries operating under the same constraints leads us to believe that the problems of collecting and presenting the statistics more helpfully are not insuperable given the will to do so. To achieve this improvement will, however, require a great deal of detailed work. We therefore recommend that a joint group from industry, Customs and Excise and DTI should be set up to produce a more helpful classification scheme for the Government statistics relating to the industry.

164. Industry also needs more detailed information on such matters as sales of particular equipment types, and market shares of firms. This kind of information is appropriately obtained from commercial, rather than Government, sources, but the supply of such information in the UK is slender. In the US, it is more freely available, largely from commercial firms who buy and analyse basic purchasing information from hospitals. Similar information from the NHS would be valuable to industry (and also to researchers and administrators) and if sold to commercial analysts could provide a modest financial benefit to the health service. In the past, NHS information systems on equipment have not been sufficiently good for this to be a realistic possibility. Although some authorities are still moving much too slowly the position is now improving sufficiently for it to be considered. We recommend that the NHS begin now to plan how its equipment purchasing data could be made available to industry.

CONCLUSION

165. The main responsibility for the future of the medical equipment industry will rightly rest with those in that industry. But because of the many points at which Government interacts with the industry, there is much that Government can do to help. Our hope is to see a financially healthy industry with a strong presence at the leading edges of technology, where the UK should be able to hold its own in the longer term. This presence will require an adequate level of R & D, and strong links with both academic research and clinical practice. In our view, the long-term financial health of the industry will depend on its being able to attack overseas markets successfully. In addition to technical competence, this will require good marketing and design and the removal of the unnecessary regulatory barriers which fragment the European market in particular. It will also require a home market which not only provides a base of demand for products of a kind which can be sold profitably overseas, but which also allows companies to grow from being highly specialised and local niche producers to medium-sized companies with coherent, well-designed and well-marketed product ranges.

166. The character of the home market is determined by the behaviour of the NHS, which must recognise the impact which its practices, and especially its procurement, have on the UK industry, and must accept some responsibility for the health of that industry. This implies not only changes in the attitudes of individual buyers, but also changes in systems and in the availability of information. Buyers need better information, and they need to take more account of efficiency in their buying decisions. The home market needs to be rather less fragmented, particularly in using nationally agreed specifications and procedures but not to the extent of massive centralisation of purchasing. Our aim is a free, but well-informed and responsible market, which we believe is the main need of the industry.

THE WORLD MARKET FOR LABORATORY DIAGNOSTICS DEVICES - 1985

Product type	Sales value (\$ million)
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Clinical Chemistry	2,000
Immunology	1,750
Microbiology	750
Other	500
Total	5,000

THE WORLD MARKET FOR IMAGING DEVICES - 1985

Product type	Sales value (\$ million)
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X-ray	3,000
CT X-ray	800
MRI	300
Ultrasound	600
Nuclear medicine	300
Other	negligible
Total	5,000

THE WORLD MARKET FOR OTHER ELECTROMEDICAL DEVICES - 1985

Product type	Sales value (\$ million)
--------------	-----------------------------

Patient monitoring	1,100
Anaesthetics	750
Dialysis and Heart-lung	450
Laser surgery	200
Infusion pumps	500
Endoscopes	250
Pacemakers	900

Other	850
Total	5,000

THE WORLD MARKET FOR SINGLE-USE DEVICES - 1985

Product type	Sales value (\$ million)
Dressings, bandages	1,500
Infusion supplies	1,100
Needles, syringes	750
Sutures, needles and ligatures	700
Drapes, clothing	700
Catheters, tubes	500
Gloves	450
Dialysis supplies	400
Anaesthesia and respiratory supplies	300
Ostomy products	300
Nursing care products	250
Electrodes and gels	250
Incontinence products	250
Staplers	200
Oxygenation supplies	100
Medical gases	300
X-ray films and supplies	3,000
Other	950
Total	12,000

(Source: E.B. Savory Milln & Co.)

Mechano - Therapy Appliances, Massage Apparatus etc	1980	17.0	9.1	+ 7.9
	1981	24.7	10.9	+ 13.8
	1982	24.9	14.9	+ 10.1
	1983	27.5	17.3	+ 10.2
	1984	28.9	20.8	+ 8.1
	1985	32.2	20.8	+ 11.4
Hygiene Articles of Rubber	1980	10.3	3.0	+ 7.3
	1981	10.8	2.4	+ 8.4
	1982	8.5	3.0	+ 5.6
	1983	8.6	3.9	+ 4.6
	1984	5.2	2.4	+ 2.8
	1985	10.8	5.4	+ 5.4
Medical Sterlising Apparatus	1980	3.6	0.8	+ 2.8
	1981	2.7	0.9	+ 1.8
	1982	4.7	1.3	+ 3.4
	1983	2.7	1.3	+ 1.3
	1984	2.6	1.9	+ 0.7
	1985	4.5	2.3	+ 2.2
Invalid Carriages	1980	4.8	0.5	+ 4.3
	1981	4.1	0.7	+ 3.4
	1982	4.7	0.6	+ 3.1
	1983	4.5	2.1	+ 2.4
	1984	5.4	1.8	+ 3.6
	1985	6.4	1.4	+ 5.0

UK TRADE IN MEDICAL EQUIPMENT BY SECTOR
£m

	Year	Exports	Imports	Balance
Spectacle Glass, Frames - Parts	1980	20.6	29.0	- 8.3
	1981	21.8	26.6	- 4.8
	1982	30.8	36.6	- 5.9
	1983	34.5	37.8	- 3.4
	1984	41.8	47.4	- 5.7
	1985	45.2	61.1	- 15.8
Instrumental - Ophthalmic, Medical, Surgical, Dental, Veterinary and Dissecting, also Medical Appliances including Dental	1980	115.8	68.9	+ 46.9
	1981	129.5	87.3	+ 42.2
	1982	154.0	107.7	+ 46.2
	1983	185.2	136.8	+ 48.4
	1984	216.6	171.6	+ 45.1
	1985	262.6	188.8	+ 73.8
Orthopaedic Appliances including Limbs, Eyes, Teeth, Deaf Aids and Parts	1980	18.2	18.2	+ 0.1
	1981	20.1	22.3	- 2.2
	1982	21.1	30.9	- 9.8
	1983	26.1	42.5	- 16.4
	1984	42.7	52.3	- 9.6
	1985	47.7	55.4	- 7.6
Electro-Medical Apparatus excluding X-Rays	1980	20.3	17.3	+ 3.0
	1981	25.5	18.8	+ 6.7
	1982	31.7	20.5	+ 11.2
	1983	37.9	29.4	+ 10.5
	1984	50.8	34.8	+ 15.9
	1985	70.2	35.1	+ 35.2
Apparatus based on use of X-Rays or Radiations from Radio-Active Substances	1980	26.7	27.2	- 0.5
	1981	31.6	46.1	- 14.5
	1982	48.0	62.4	- 14.3
	1983	62.1	67.4	- 4.3
	1984	55.6	65.4	- 9.8
	1985	48.3	63.2	- 14.9
X-Ray Films (including Dental Film)	1980	17.1	18.7	- 1.7
	1981	7.1	24.1	- 17.0
	1982	6.5	22.7	- 16.3
	1983	10.6	27.1	- 16.6
	1984	11.7	28.9	- 17.2
	1985	14.4	29.9	- 15.5
Furniture - Medical, Dental, Surgical and Veterinary	1980	11.6	3.3	+ 8.2
	1981	10.0	4.6	+ 5.4
	1982	13.4	5.6	+ 8.8
	1983	11.9	5.6	+ 6.2
	1984	15.3	6.6	+ 8.7
	1985	18.1	7.2	+ 10.9

GLOSSARY OF ABBREVIATIONS

ACARD	Advisory Council for Applied Research and Development
BSI	British Standards Institution
BTG	British Technology Group
CT	Computer tomography
DHA	District Health Authority
DHSS	Department of Health and Social Security
DTI	Department of Trade and Industry
FDA	Food and Drugs Administration
GP	General Practitioner
MRC	Medical Research Council
MRI	Magnetic resonance imaging
NHS	National Health Service
OECD	Organisation for Economic Cooperation and Development
OPEC	Organisation of Petroleum Exporting Countries
RHA	Regional Health Authority
SERC	Science and Engineering Research Council
SHHD	Scottish Home and Health Department
STB	Scientific and Technical Branch (a part of DHSS)



10 DOWNING STREET

From the Private Secretary

MR STARK
CABINET OFFICE

I attach for information a copy of a letter from Sir Francis Tombs to the Prime Minister, in response to hers of 4 April, about ACARD.

Mark Addison
14 April 1986

JB



CFPS

Prime Minister (4)

ADVISORY COUNCIL FOR APPLIED RESEARCH AND DEVELOPMENT

70 Whitehall, London SW1A 2AS Telephone: 01-233

The Rt. Hon. Margaret Thatcher, MP.,
The Prime Minister,
10, Downing Street,
London, SW1.

CF
Cord / see the file
please. 11/00 14/6

9th April, 1986

Dear Prime Minister,

RB

ms

100/4

Thank you for your generous letter of
4th April from which I am pleased to learn of your
satisfaction with the work of the Advisory Council for
Applied Research and Development over the last four years.

I have passed on your comments to my predecessor
as Chairman, Sir Henry Chilver, and will bring them to
the notice of the current members of ACARD who, I am
sure, will be very gratified by them.

Yours sincerely,

Francis Tombs

Sir Francis Tombs

GOVT. MACH : Accord; Part 4



10 DOWNING STREET

From the Private Secretary

MR. STARK
CABINET OFFICE

The Prime Minister has now seen Sir Robert Armstrong's minute of 2 April about the Advisory Council for Applied Research and Development. She has agreed with Sir Robert Armstrong's recommendation that ACARD should continue as proposed in the minute. She has accordingly written to Sir Francis Tombs.

(Timothy Flesher)
4 April 1986

Edw



10 DOWNING STREET

THE PRIME MINISTER

4 April 1986

Dear Sir Francis.

I am writing to say how pleased I am with the work which the Advisory Council for Applied Research and Development has undertaken during the last four years. The comments which ACARD have provided on the Annual Review of Government R and D have been particularly helpful and have caused some rigorous reviewing of Departments' programmes so as to secure from these maximum benefit in terms of the wider development of the United Kingdom economy. We will continue to look to ACARD for advice as we continue with this work.

I welcome ACARD's intention to give priority to encouraging greater private sector investment in R and D, to gaining greater effectiveness in international collaboration and to increasing the contribution of basic science to the creation of national wealth.

Please convey my thanks to the members of ACARD.

Yours sincerely
Margaret Thatcher

Sir Francis Tombs

SM
ACO m 6186
8/4

910
Ref. A086/1010

PRIME MINISTER

Advisory Council for Applied Research and Development (ACARD) *IV 2/4*

ACARD was last reviewed in 1981 when you agreed that it should continue in being. At that time you thought it unnecessary to conduct a further review after two years, and no review was undertaken in 1983.

2. A further review of ACARD was, however, undertaken in 1985-86, in line with the Government policy for keeping the work of non-departmental Public Bodies under review.

3. This review has been completed and a report is attached. All the Departments concerned with the work of ACARD (Trade and Industry, Education and Science, Defence, Energy, Environment, Health, Agriculture and Food, as well as Treasury and the Foreign and Commonwealth Office) endorse the view that a body such as ACARD is needed. Although some Departments are critical of some of the advice given by ACARD (which has sometimes, of course, been critical of Departments' programmes), all recognise the impact that advice has had, for example, in leading to the MISC 119 assessment of priorities for Government R and D.

4. We are making no recommendations to change the composition, method of work or terms of reference of ACARD. Neither do we recommend amalgamation with ABRC. We are, however, recommending that the Information Technology Advisory Panel (ITAP) be subsumed within ACARD and I am submitting a separate report to you about this.

5. We are recommending that over the next two years, ACARD should give priority to:



i. considering how private sector investment in R and D could be increased and finance for innovation improved;

ii. considering how international collaboration in the fields of applied research and development might be more effectively pursued;

iii. consider (together with ABRC) how basic science can be more effectively harnessed to the creation of national wealth.

6. I therefore recommend that ACARD should continue but that ACARD should also continue to be reviewed on the same basis as other NDPBs, every three years. I also recommend that you recognise the value of ACARD's advice to the Government and endorse the priority activities listed above. A draft letter to the Chairman of ACARD is attached.

ReA

ROBERT ARMSTRONG

2 April 1986

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REVIEW OF THE ADVISORY COUNCIL FOR APPLIED RESEARCH AND DEVELOPMENT (ACARD) REPORT FOR THE PERIOD 1982-1986

GENERAL BACKGROUND

1. ACARD was established in 1976 and met for the first time in January 1977. It was last reviewed in 1981. That Review recommended that ACARD should continue, with a further review in two years time. However, the Prime Minister expressed herself as fully satisfied with the review and said that it was unnecessary to carry out a further review in two years.
2. In July 1982, in Cmnd 8591, the Government published its response to the Report by the Select Committee of the House of Lords on Science and Technology entitled "Science and Government". This Report reviewed the arrangements for scientific advice to Government. In its response the Government set out extended terms of reference for ACARD (Annex I) to enable it to cover the fields of applied research, design and development and the application of research and technology, together with the co-ordination of these activities with basic research. This co-ordination was to be achieved by working with the Advisory Board for the Research Councils. The Chairmen of ACARD and ABRC were asked to present joint periodic reports to the Government which would review scientific opportunities and their implications, on a selective basis. The reports would not necessarily be confined to activity in the public sector. The Government also decided to introduce a system of Annual Reviews of Research presenting information on Departments research programmes and budgets which would be reviewed interdepartmentally, with independent advice from ACARD.
3. There are sixteen members of ACARD, including the Chairman. Members are appointed for 3 year terms and there is a turnover of 5 members each year. (The current membership is at Annex II). The present chairman, Sir Francis Tombs, took office in succession to Sir Henry Chilver on 1 November 1985. The Chairman of ABRC, Sir David Phillips, is an ex-officio member. Although a balance of membership across industrial sectors, and including academics and a Trade Unionist, is maintained members are there not in a representative capacity but as individuals of some distinction in their own field able to give independent advice. Meetings are attended by the Chief Scientific Adviser, Cabinet Office, and by Chief Scientists from the Departments of Energy, of Environment and Transport, of Defence, and of Trade and Industry. The Council's Secretariat is

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provided by members of the Science and Technology Secretariat, Cabinet Office, and there is a joint secretariat arrangement with the ABRC.

4. The Council has increased the number of full meetings a year from 4 in 1982 to 7 and would expect to maintain this level given the volume of work. The increase has been largely due to the development of the Annual Review of Research and Development and the requirement on ACARD to provide informed comment and advice on what is revealed by the Annual Review of the Government programmes. (More is said of this in a later section). Much of the more detailed work of ACARD is carried out by small working groups set up to report on particular issues. Typically a working group will meet monthly for 6 to 18 months depending on the complexity and the state of knowledge of the subject under study. Both written and oral evidence is taken and visits are often made to companies, laboratories etc. The resulting ACARD reports are submitted to the Prime Minister with a request for permission to publish. This has never been refused. On occasions a report will not be the outcome but advice will still go forward to the Prime Minister in the form of a letter from the Chairman of ACARD. Publication of a report is not seen as the end product of a study. By convention it is usual for Government to provide a written response and work will usually continue either through the working group, the Chairman or the Chief Scientific Adviser and Secretariat, to disseminate the findings to targetted groups and to begin to implement some of the recommendations. Not all recommendations will require Government action, many are directed at industry and therefore their implementation may require considerable promotional work with industrialists. The high regard in which ACARD members are held is of considerable assistance in this process.

COSTS

5. The costs of ACARD are met from the Cabinet Office vote and are set out in detail in Annex III. ACARD members and members of working groups are unpaid but their expenses are reimbursed when claimed. It is important to note, first, that the figures given take no account of the substantial contribution from members. Many are senior industrialists who not only, for example, do not claim travel and subsistence costs but also devote a lot of their time outside formal ACARD meetings to working groups and often provide hospitality for meetings and other facilities at their companies' expense. Secondly, in its earlier years ACARD was able to draw substantially on inputs from the Central Policy Review Staff. With the disbandment of the Central Policy Review Staff (CPRS) and the further development of ACARD work the configuration of staff support has altered and the use of outside consultants increased.

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6. The activities of ACARD have been reviewed in line with the guidance given by the Machinery of Government Division for the Review Programme of Cabinet Office Advisory Bodies. There has been consultation with those Departments principally concerned with ACARD's work, namely Energy, Education and Science, Environment and Transport, Agriculture and Food, Treasury, Foreign and Commonwealth Office, Defence, Health and Social Security. The conclusions form the basis of the following paragraphs:-

Is there a continuing need for outside advice in the field covered by ACARD?

7. The need for outside and independent advice on applied research and development is, if anything, greater now than it was when ACARD was last reviewed. Immediately following that Review the House of Lords Report "Science and Government" was published and in its response Government accepted the main thrust of the Report; "that the Government has a responsibility to secure an adequate scientific and technological input to policy making". The response went on to say that "excellence in the development and exploitation of science and its applications is essential if the economic prosperity of the country is to be advanced in the coming decades, and if companies based on science and technology are to play their part in providing new employment opportunities". The response went on to extend the terms of reference of ACARD and establish the Annual Review in the way set out in para 2 above. Since then three Annual Reviews have been published and Central Government expenditure on R & D has risen from £3506.4m in 1981/82 to an anticipated £4530.1m in 1985/86. At the same time the ability to compete in world markets and, indeed, in the home market has become increasingly dependent on the ability to maintain a leading edge on scientific development and to apply the scientific and technological knowledge produced more effectively. The question of how better to do this in order to improve the competitive position of the UK is central to all the work undertaken by ACARD.

It is cost-effective to maintain a special and formal body for the purpose, or could the need be met equally well by informal, ad hoc methods?

8. Whilst recognising the need, and establishing the machinery for, central co-ordination of science and technology the Government has not accepted the case for a co-ordinating Minister. Where issues arise which straddle the responsibility of several Ministers the Prime Minister plays a co-ordinating

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role on broad scientific and technological issues involving several Departments. ACARD forms one part of the support to the Prime Minister in her co-ordinating role. The increasing importance of science and technology to the economic health of this country, the increasing pace of technological change and scientific development throughout the world lead to the conclusion that ad hoc arrangements would be wholly insufficient and that the cumulative process of formulating advice, to which ACARD contributes an independent voice, is necessary. However, as noted earlier, ACARD's advice is not only made available at the centre of Government. It also has a catalytic effect across Departments and between Government and industry. Its advice is not merely interpretive but is directed at the implementation and better management of change. To be credible in this role ACARD has had to establish its reputation for sound, independent advice and this could not be done under any ad hoc arrangements. ACARD's use of working groups with a finite life limited to the task to be done provides for informal, flexible methods of working whilst maintaining with ACARD's formal structure the sustained effort necessary to provide the quality and level of advice required.

Is ACARD doing a good job, judged by its terms of reference and the practical usefulness of its advice?

9. In contrast to the last period reported on from 1977-81 ACARD's main output has been less one of special reports and more its commentary on the Annual Review. Comments by Departments, which are summarised in Annex IV, stress the development of this part of ACARD's role although not all Departments are uncritical of this aspect of its work. It has to be said that ACARD's comments on the Annual Review have led to a very critical examination by Ministers of some Departmental programmes, and some reallocation of resources.

10. The first Annual Review, produced in 1983, although only partial in coverage, was welcomed by ACARD in its advice as an important advance in Government's ability to take a broad informed view of its R & D efforts. A similar reception was given by the press and the scientific community. The 1984 Annual Review provided the first comprehensive and coherent database of all

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Government R & D expenditure, together with summary totals, commentary, and statements by each Department (and Research Council) of its objectives in R & D. It was well received by the press and informed opinion as an improved vehicle for the consideration of R & D across Government. The Council set up a special Sub-Group of its members, including the Chairman of the Advisory Board for the Research Councils and the Chief Scientific Adviser, as well as independent members drawn from a wider circle, to help prepare its detailed confidential advice to Government. In its comments ACARD drew attention, in particular, to the high proportion of the total Government R & D effort devoted to defence in comparison to most of the UK's competitor nations and the apparent mismatch between R & D resources devoted on the one hand to agriculture and on the other to manufacturing industry in relation to the economic significance of the two sectors. On both these points, Government responded by the institution of official groups to examine the issues in greater depth. In the case of defence R & D the issue is still under review by Ministers in the broader context initiated by the 1985 Annual Review.

11. The 1985 Review continued the format introduced in 1984 but broadened the coverage and detail, including, for example, more detailed international comparisons, data on the nationalised industries, and a consideration of strategic research. ACARD's commentary on the 1985 Review (again prepared with the help of a Sub-Group) reinforced its earlier advice, but centred on its firmly held view that, in comparison with competitor nations, the totality of national support for civil R & D, both public and private, as a percentage of GDP, was no longer sufficient. It urged Government to review critically its R & D expenditure, against a set of criteria based on the contribution which R & D could make to wealth creation. Government has considered these views at Cabinet level. It has caused further work to be undertaken within the Cabinet Office and can be expected to implement important changes in the distribution and use of R & D funding across Departments in order to enhance the contribution of research and development, undertaken for whatever primary purpose, to improving the efficiency, competitiveness and innovative capacity of the UK economy. Without the preparation and publication of the Annual Review ACARD could not have supported its comments with detailed analysis. Equally, without ACARD's informed and independent commentary the impact of the Annual Review exercise would have been lessened.

12. Since 1981 ACARD has published four Special Reports. These are listed in

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Annex V and the response to these reports is summarised. In addition to the four published Reports ACARD currently has under preparation Reports on "Exploitable Areas of Science", "Software Engineering" and the "Medical Equipment Industry". The first has been seen and publication approved by the Prime Minister. This report makes recommendations for better identification of scientific developments together with market opportunities for their exploitation. If the recommendations are successfully implemented the UK will be in a better position to enter new markets early rather than being in the forefront of scientific discovery but late in its application. The other two reports will be completed before the end of May this year. Working Groups, for whose reports publication was not sought, were on "Financial Aspects of Innovation" and "Control and Instrumentation Technology". On the former a letter of advice was sent by Sir Henry Chilver to the Prime Minister and on the latter a decision has still to be made about the best use of the advice generated. ACARD are currently considering new studies of areas which include "Opto-electronics", "Space" and "Digital Cellular Radio". They are also considering how best to return to the subject of private sector R & D, the availability of investment for innovation and the interplay between the various Government support schemes and private industry.

13. As part of the work in follow-up to its Reports and the advice it gives on the Annual Review ACARD has held a number of meetings with Ministers, these are listed in Annex VI.

14. ACARD has not yet given any special attention to international collaboration (Item 4 of its terms of reference). It has, however, commented on this aspect of the Annual Review and in view of its increasing importance, will give priority to the subject during 1986. A detailed paper is to be considered at the April meeting.

Should changes be made to the composition and operation of ACARD which would streamline its work or reduce costs?

15. ACARD's method of work has not altered substantially since it was last reviewed but the volume of work it undertakes has increased (numbers of meetings are shown in Annex VI). It now meets 7 times a year, usually for only half a day, in full session. Meetings with Ministers are usually informal and with only a small group of members. The detailed work of preparing commentary on the Annual Review is carried out by a special Sub-Group which involves some non-ACARD members with special expertise. Similarly the working groups which

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prepare the special reports draw on a wide range of experts. This combination of a distinguished group of 16 core members, with a third replaced each year, and the use of small working groups, with a wider membership set up for short periods to undertake specific tasks, works well and no changes are recommended.

Is there scope for amalgamating the body with another one?

16. It has recently been suggested by the House of Commons Education Science and Arts Committee that a Council on Science and Technology be established (in line with the House of Lords Select Committee on Science and Technology recommendation in 1981) which would be based on ABRC and would subsume both ACARD and ABRC and the functions of both bodies. Government has yet to give a formal response to this report. However, it is hard to see how such amalgamation could take place since the two bodies have different, albeit complementary, roles. The DTI's comment on ACARD's work put this succinctly:

- "- ABRC advises a single Department and controls a budget;
- ACARD advises Government (with a truly independent voice) and controls no budget."

The DTI comment goes on to say "few would doubt the value of Council's commentary, but that role could be jeopardised by a possible constraint in independence brought about by closer links with ABRC."

17. ACARD and ABRC do seek to work together on issues of common interest as, for example, on the report "Improving Research Links between Higher Education and Industry". The first joint report by the Chairmen was published in July 1983 and the second will be published during 1986. However, neither the Cabinet Office, nor DES have been satisfied with the co-ordination achieved and steps have been taken at both Secretariat and Chairman level to improve this.

18. Consideration is presently being given to subsuming the role of the Information Technology Advisory Panel (ITAP) within that of ACARD. This is the subject of a separate report.

Conclusion

19. The work of ACARD, particularly in commenting on the Annual Review, has

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stimulated discussion of Government priorities for R & D at Ministerial level and has led to an agreement that such discussions should form a permanent part of the consideration given by Government to R & D. ACARD's comments have focussed on the need to ensure the effective contribution of all Government R & D to improving the competitive position of the UK economy as well as satisfying other Departmental requirements such as procurement and regulation. If these discussions are to lead to improvements the informed, independent voice of ACARD will continue to have value.

20. In summary it is agreed that:

- i. the aims of ACARD, as set out in its terms of reference, are still valid
- ii. the work of ACARD in the four years under review has contributed substantially to an increased awareness by Government, industry and the higher education sector of the strategic importance of R & D for the economic health of the country
- iii. although the number of meetings and costs of ACARD's work have risen this has been justified by its increased input to inform debate and decision making on R & D.
- iv. its composition and method of working are appropriate to its task
- v. it would not be appropriate to amalgamate ACARD with ABRC but consideration is being given to incorporating ITAP into ACARD.

21. It is further agreed that ACARD should give priority over the next two years to:

- i. considering how private sector investment in R & D could be increased and finance for innovation improved
- ii. considering how international collaboration in the fields of applied research, design and development might be more effectively pursued
- iii. considering (together with ABRC) how basic science can be more effectively harnessed to the creation of national wealth.

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List of Annexes

- Annex I ACARD Terms of Reference
- Annex II ACARD Current membership and members who have served since January 1982
- Annex III ACARD costs
- Annex IV Departments comments on ACARD
- Annex V Government response to ACARD reports
- Annex VI ACARD Meetings

CONFIDENTIAL

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Annex I

ACARD Terms of Reference

"To advise the Government and publish reports as necessary on -

- i. applied research, design and development in the United Kingdom;
- ii. the application of research and technology, developed in the United Kingdom and elsewhere, for the benefit of both the public and private sectors in accordance with national economic needs;
- iii. the co-ordination, in collaboration with the Advisory Board for Research Councils, of these activities, with research supported through the Department of Education and Science;
- iv. the role of the United Kingdom in international collaboration in the fields of applied research, design and development related to technology".

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Annex II

ACARD: Current Membership

Sir Francis Tombs F Eng (Chairman)	Chairman, Rolls Royce Ltd
Mr M Bullock	Corporate Finance Director, Barclays Bank plc
Mr J F Coplin F Eng	Director of Design, Rolls Royce Ltd
Sir Kenneth Durham	Chairman, Unilever plc
Mr J W Fairclough	Director of Manufacturing & Development, IBM (UK Ltd, Chairman IBM (UK) Laboratories
Mr A K Gill	Group Managing Director, Lucas Industries plc
Mr E Hammond	General Secretary, Electrical, Electronic, Telecommunications, and Plumbing Union
Dr B C Lindley CBE	Director of Technology, BICC Ltd
Mr G J Lomer CBE	Technical Director, Racal Electronics plc
Mr R Malpas CBE F Eng	Managing Director, British Petroleum Company plc
Professor J S Metcalfe	Professor of Economics, Manchester University
Professor Sir David Phillips FRS	Professor of Molecular Biophysics University of Oxford: Chairman of the Advisory Board for the Research Councils
Dr C H Reece	Director of Research and Technology, Imperial Chemical Industries plc
Sir Rex Richards FRS	Director, Leverhulme Trust
Professor S D Smith FRS FRSE	Professor of Physics, Heriot Watt University; Chairman, Edinburgh Instruments Ltd

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Annex II (Contd)

FORMER MEMBERS OF ACARD (SINCE JANUARY 1982)

Sir Henry Chilver F Eng FRS (Chairman)	Vice-Chairman, Cranfield Institute of Technology
Dr D V Atterton CBE F Eng	Chairman, Foseco Minsep Ltd
Viscount Caldecote F Eng	Chairman, Delta Group plc
Sir Kenneth Corfield F Eng	Chairman and Chief Executive, Standard Telephones and Cables Ltd
Dr D L Georgala	Head of Laboratory, Unilever Research
Professor W B Heginbotham	Director-General, Production Engineering Research Association
Mr C S King CBE	Deputy Chairman, BL Technology Ltd
Sir Alec Merrison FRS	Vice-Chancellor, University of Bristol, Chairman of the Advisory Board for the Research Councils
Sir Alan Muir Wood F Eng	Senior Partner, Sir William Halcrow and Partners
Mr D H Roberts F Eng FRS	Director of Research, The General Electric Company plc
Mr J L van der Post F Eng	Chief Executive, Water Research Centre
Professor Sir Hans Kornberg	Professor of Biochemistry, University of Cambridge
Mr P C Michael	Chairman and Managing Director, Micro Consultant Ltd
Lord Scanlon	Formally Chairman, Engineering Industries Training Board
Professor J M Thomas FRS	Professor of Physical Chemistry, University of Cambridge

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Annex III

ACARD COSTS (Current Prices)

	1982/83		1983/84		1984/85	
	Time	£	Time	£	Time	£
Chief Scientific Adviser	1/5	10,810	1/5	11,264	1/5	12,307
Grade 5	1/4	10,556	1/4	10,984	vacant	-
Grade 6						
Adviser	1/3	13,900	1/3	14,566		
Grade 7	1.5	43,709	1.5	46,047	2	65,152
Misc (inc T & S)	---	9,002	---	4,750	---	7,337
Consultants	---	1,500	---	17,821	---	19,358
Totals (out turn)		89,477		105,435		104,154

	1985/86		1986/87	
	Time	£	Time	£
Chief Scientific Adviser	1/10 9mths	5,600	1/10x12mths	7,467
Grade 5	1/5 6mths	4,426	1/5x12mths	8,852
Grade 6	1/10 7mths	2,313	1/10x12mths	3,965
Grade 7	2x12mths	61,032	2x12mths	64,604
Statistician (Grade 7)	3x4mths	3,597	1/3x12mths	10,791
HEO	1/2x3mths	2,805	1/5x12mths	11,220
Misc (incl T & S)	1x12mths	14,900	1x12mths	18,325
Consultants		40,000		65,000
TOTALS (Estimated)		134,673		200,224

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ANNEX IV

ACARD REVIEW DEPARTMENTAL COMMENTS: SUMMARY

Department	General	Annual Review	Reports
DTI	ACARD probably stimulated more discussion in DTI than any other Department - underlines need for good communication between both. Against amalgamation of ACARD & ABRC because: ABRC advises a Department & controls a budget; ACARD advises Government (with a truly independent voice) & controls no budget. Not fulfilled remit regarding international collaboration. Staffing of Secretariat may not be correct balance - need for more administrative staff.	Role as independent adviser to Government has grown particularly regarding commentary on Annual Review.	Recent reports seem to have had less impact perhaps because more in-depth longer studies.
DEn		Has been most significant in commentary on Annual Review.	ACARD reports little direct impact on Department but contribute to general debate which impinges on energy. ACARD should produce more frequent & snappier reports (shorter & more closely targetted).
DES	Disappointed that ACARD & ABRC have not succeeded in working effectively together - particularly on Exploitable Areas On balance should continue but needs greater competence, more visible independence, greater accountability & closer collaboration with ABRC.	ACARD's comments on the Annual Review a significant development since 1982 but room for improvement in quality of its evaluation and comments should be published.	

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MOD	Terms of reference still very relevant to issues of generating the right kind of direction and investment levels in R&D to increase wealth generation.	Comments on Annual Review appear to misunderstand the wide range of MOD activities within definition of R&D & its conclusions therefore based on false premises.	ACARD reports usually peripheral to MOD interests but expect software engineering to be very relevant.
MAFF	ACARD has a distinguished membership & has done some valuable work. Question whether it is appropriate to attempt an across the board approach to applied R&D on whether ACARD has the support to do this.		
DOE	Most ACARD work of marginal interest to DOE - partly because ACARD concentrates on issues related to industrial success, partly because DOE has not been sufficiently industry-oriented in its R&D.		Reports valuable but often not very exciting or innovative. Should get into wider economic fields and challenge fundamental national policies more deeply.
DHSS	ACARD built up a high reputation, a useful & effective body. Would welcome closer attention from ACARD on service related fields with which Department concerned.	Understand value of their independent advice and would not wish to encourage any change which reduced the profile of R&D in Central Government.	Particularly interested in reports on Facing International Competition and Improving Research Links between Higher Education & Industry.
HMT	Moderately useful, especially in highlighting particular areas.	Comments on the Annual Review have focussed attention on important issues, eg need for better objective setting and evaluation of level and balance between different Departments' programmes.	Analysis underlying specific recommendations not always sufficiently rigorous. Would be better to concentrate on focused recommendation on specific areas, perhaps in response to commissions from Ministers.

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ANNEX V

ACARD REPORTS

Title	Publication date	Comments
1. Facing International Competition - The Impact on Product Design of Standards, Regulations, Certification & Approvals	July '82	(October 1983) Shortly after publication of the ACARD report the Government published a White Paper "Standards, Quality & International Competitiveness" (Cmd 8621). The report & White Paper have resulted in a number of positive actions by Government eg Quality Assurance Advisory Scheme, DTI's National Quality Campaign, the National Accreditation Council for Certification Bodies, NEDC 'Task Force' on Standards and Quality Assurance, Financial Assistance for the Development of Certification Schemes.
2. The Food Industry and Technology	Sept '82	(July 1984) Government accepted most of the recommendations in the report and developed an action plan to implement them. Actions so far are an increased food mission in and change of title of the Agricultural Research Council to include Food, establishment of a Priorities Board in Food & Agriculture R&D by MAFF, increasing "real" expenditure on food R&D. Other actions are continuing.
3. Improving Research Links between Education & Industry	June '83	(Formal response awaited). This study carried out in collaboration with the Advisory Board for the Research Councils (ABRC) was set up by invitation of the Prime Minister. Although some of the minor recommendations have been implemented the Government has found difficulty in responding to the two main recommendations because of problems over funding. The two recommendations related to (a) an 'industrial seedcorn fund' equal to 25 % of the money earned by higher education institutes (HEIs) from contracts, consultancy and services (b) pump-priming suggest for HEI infrastructure for academic-industrial cooperation. The report has been influential in Government thinking & the Council will continue to press for a response.

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ACARD REPORTS (Continued)

Title	Publication date	Comments
4. New Opportunities in Manufacturing - The Management of Technology	Oct '83	(September 1984) The Council considered that the Government action following this report was disappointing in view of the importance which ACARD, and the Government in their response, said they attached to the use of advance manufacturing technologies. ACARD express concern that the main recommendation on technology transfer has not been adequately addressed by Government. However, it should be noted that technology transfer will be dealt with in some detail in the 1986 Annual Review of R&D.

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Annex VI

MEETINGS OF MAIN ACARD COUNCIL AND SUB-COMMITTEES - 1JAN82 TO 31 MAR86

(Financial years)	82/83	83/84	84/85	85/86
Main ACARD Council	5	6	7	7
Annual Review	-	-	8	7
Facing International Competition	2	-	-	-
Control systems and Instrumentation	-	3	7	-
Software Engineering	-	-	4	7
University-Industry Links	2	4	-	-
Promising areas of Science	-	6	7	3
Food technology	5	-	-	-
Advanced Manufacturing Technology	7	6	2	-
Medical Equipment	-	-	-	6

Meetings with Ministers

The Council has held meetings with the following Ministers

- i. 11 December 1981 - Minister of State for Industry and Information Technology, Mr Kenneth Baker MP.
- ii. 20 June 1984 - Secretary of State for Trade and Industry, the Rt Hon Norman Tebbit MP.
- iii. 2 October 1984 - Secretary of State for Education and Science, the Rt Hon Sir Keith Joseph Bt MP.
- iv. 9 May 1985 - Minister of State for Industry and Information Technology, Mr Geoffrey Pattie MP.
- v. 14 June 1985 - Chief Secretary to the Treasury, the Rt Hon Peter Rees QC MP.
- vi. 12 March 1986 - Minister of State for Industry and Information Technology, Mr Geoffrey Pattie MP.

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Review of the Advisory Council on Applied Research and Development (ACARD)

Summary Report

1. ACARD was established in 1976 and met for the first time in January 1977. It was last reviewed in 1981. That review recommended that ACARD should continue, with a further review in two years' time. However, the Prime Minister expressed herself as fully satisfied with the review and said that it was unnecessary to carry out a further review in two years.
2. In July 1982, in Cmnd 8591, Government set out extended terms of reference for ACARD to enable it to cover the fields of applied research, design and development and the application of research and technology, together with the co-ordination of these activities with basic research. Government also introduced a system of Annual Reviews of Research to review Departments research programmes and budgets interdepartmentally, with independent advice from ACARD.
3. Largely because of this requirement to comment and advise on the Annual Review the volume of work of ACARD has increased. The Annual Review has been published in 1983, '84 and '85. ACARD's comments have led to a very critical examination of Departments' programmes and some reallocation of resources. They have, most recently, prompted the establishment of permanent Ministerial machinery to review Government priorities for R & D with a view to improving the contribution of Departmental programmes to the efficiency, innovation and competitiveness of the UK economy.
4. ACARD has also published four reports on
 - Facing International Competition
 - The Food Industry and Technology
 - Improving Research Links between Higher Education and Industry (jointly with ABRC)
 - New Opportunities in Manufacturing.

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It will shortly published a fifth on

- Exploitable Areas of Science

and two others are nearing completion on

- Software Engineering

- The Medical Equipment Industry

5. The main thrust of all of these reports centres on the recognition that the ability of the UK to compete in world markets and in the home market has become increasingly dependent on the ability to maintain a leading edge on scientific development and to apply the scientific and technological knowledge produced effectively. The question of how better to do this in order to improve the competitive position of the UK is central to all the work undertaken by ACARD.

6. Members of ACARD are drawn from a wide range of industries, from the universities and Trades Unions but they are not there as representatives of their organisations. They are there as individuals of some distinction in their own field to provide wholly independent advice to Government. At the same time they are able to act as a catalyst across Departments and between Government and industry. They are assisted in their work by a wide range of similar individuals and members recruited to serve on working groups. These groups have a finite life and advise on specific issues. The Chief Scientific Adviser, Cabinet Office, through whom they relate to the Committee of Departmental Chief Scientists, also assists the work of ACARD.

7. The cumulative experience allowed for by the formal ACARD structure with the ad hoc working group arrangements works well and no change is recommended.

8. In order to co-ordinate its activities with basic research the Chairman of ACARD and the Advisory Board for the Research Councils (ABRC) are ex-officio members of the other body and there is a joint secretariat. The first joint report to Government of the two Chairmen was published in July 1983 and the second will be published in 1986.

9. The roles of ACARD and ABRC differ. ACARD has the responsibility of providing independent advice to central Government across all Departments,

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whilst ABRC is advisory to the Department of Education and Science on the allocation of the Science Budget. It is therefore not recommended that they be amalgamated.

10. Consideration is being given to the incorporation of the Information Technology Advisory Group into ACARD. (This is the subject of a separate report).

11. In summary it is agreed that:

- i. the aims of ACARD, as set out in its terms of reference, are still valid
- ii. the work of ACARD in the four years under review has contributed substantially to an increased awareness by Government, industry and the higher education sector of the strategic importance of R & D for the economic health of the country
- iii. although the number of meetings and costs of ACARD's work have risen this has been justified by its increased input to inform debate and decision making on R & D.
- iv. its composition and method of working are appropriate to its task
- v. it would not be appropriate to amalgamate ACARD with ABRC but consideration is being given to incorporating ITAP into ACARD.

12. It is further agreed that ACARD should give priority over the next two years to:

- i. considering how private sector investment in R & D could be increased and finance for innovation improved
- ii. considering how international collaboration in the fields of applied research, design and development might be more effectively pursued.
- iii. considering (together with ABRC) how basic science can be more effectively harnessed to the creation of national wealth.

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DRAFT LETTER FROM THE PRIME MINISTER TO SIR FRANCIS TOMBS

I am writing to say how pleased I am with the work which the Advisory Council for Applied Research and Development has undertaken during the last four years. The comments which ACARD have provided on the Annual Review of Government R and D have been particularly helpful and have caused some rigorous reviewing of Departments' programmes so as to secure from these maximum benefit in terms of the wider development of the United Kingdom economy. We will continue to look to ACARD for advice as we continue with this work.

I welcome ACARD's intention to give priority to encouraging greater private sector investment in R and D, to gaining greater effectiveness in international collaboration and to increasing the contribution of basic science to the creation of national wealth.

Please convey my thanks to the members of ACARD.



10 DOWNING STREET

From the Private Secretary

MR. TOLAN
Cabinet Office

ACARD - EXPLOITABLE AREAS OF SCIENCE

Thank you for your minute of 5 March. On the basis that you are content that the inclusion of Part II raises no fresh issues, I see no reason why you should not proceed with publication.

I am copying this minute to Sir Robin Nicholson and Mrs. Cunningham.

MARK ADDISON

6 March 1986

h



MR ADDISON - No 10

cc Sir Robin Nicholson
Mrs Cunningham

OK

ACARD REPORT - EXPLOITABLE AREAS OF SCIENCE

You may recall that Sir Henry Chilver (then Chairman of the Advisory Council for Applied Research and Development - Sir Francis Tombs became Chairman on 1 November 1985) wrote to the Prime Minister on 9 September 1985 seeking approval for publication of the Council's report on "Exploitable Areas of Science". Sir Robin Nicholson minuted you on 3 October with advice on the further handling of the report. The Prime Minister replied to Sir Henry on 7 October agreeing to publication of the report. In my minute to you of 31 October, I sought permission, on behalf of the Council, for inclusion of a slightly modified version of the Prime Minister's letter in the report. You replied on 5 November that agreement had been given to this request.

2. In December of last year (just before the report was about to be printed), Sir Robin Nicholson received firm representations to include material from Part II (annexed in his minute to you of 3 October) in order to exemplify the proposals in Part I. There were sufficiently good reasons to support the representations that he felt unable to resist the request. A second part to the report has therefore been drafted. This has inevitably led to delay in its publication.

*Report in Folder A1 Back
attached 16/9/14*

3. Attached is the revised full report; Part I (the original version for publication) is the same apart from brief reference to Part II, and a second part describing a case study is included. This fuller version provides a more rounded report and will assist the reader in understanding the recommendation in Part I.

4. We do not believe that inclusion of Part II raises any new issues. The Council would still like the Prime Minister's letter to be printed in the front of the report.



5. I would be grateful for your advice.

A handwritten signature in dark ink, appearing to read 'A. Tolan', located to the right of the typed text.

A TOLAN

Cabinet Office

5 March 1986

GOVT. MACH: Accord: Pt 3.



Advisory Council for Applied Research and Development

Exploitable Areas of Science

March 1986
~~December 1985~~

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CONTENTS

	Page
FOREWORD	i - ii
Executive summary	iii
Summary of the report	iv - vi
PART I. ALLOCATING RESOURCES TO SCIENCE - THE NATURE OF THE PROBLEM	
1. Introduction	1 - 5
2. Science, technology and economic performance in the UK	6 - 18
3. Approaches to foresight activity in exploitable science	19 - 26
4. A process for exploitable science	27 - 32
PART II. A CASE STUDY	
5. Technology: the bridge between markets and exploitable science	33 - 37
6. Markets, Technology and Science in Communications and Information	37 - 61
Acknowledgements	62 - 64

Foreword

On 25 October 1983, ACARD announced the establishment of a study of Promising Areas of Science. The objective of the study which was linked to the Council's role in advising Government on its Annual Review of Research (this review of the Government's total expenditure on R&D was announced in a White Paper, Cmnd 8591, in 1982), was to survey current scientific developments and advise the Council on work which showed commercial and economic promise in the medium to long term. A Study Group was set up with terms of reference outlined in the Introduction to this report.

The members of the Study Group were:

Dr C H Reece (Chairman)	Director of Research and Technology Imperial Chemical Industries plc
Mr A Best	Anthony Best Dynamics Ltd
Professor Sir Hermann Bondi FRS	Master of Churchill College, Cambridge
Mr R Cutting	Sinclair Research Ltd
Professor C Hilsum FRS	Chief Scientist, GEC Research Laboratories
Mr C S King CBE	Deputy Chairman, BL Technology Ltd
Professor J S Metcalfe	Department of Economics, Manchester University, and Director of PREST
Professor D K Peters	Department of Medicine, Royal Post-graduate Medical School
Professor Sir David Phillips FRS	Laboratory of Molecular Biophysics, University of Oxford
Professor G G Roberts FRS	Department of Applied Physics, University of Durham
Professor J M Thomas FRS	Department of Physical Chemistry, University of Cambridge

The Study Group held ten meetings over the course of the study and arranged a series of meetings with companies and organisations with major responsibilities for R&D. This report is based on the discussions of the Group and the views of those consulted during the exercise.

Executive summary

1. There is a thesis, widely accepted in the United Kingdom, that research cannot be organised to deliver economic return. The thesis is not generally accepted in other countries. They believe that science is now so important to a country's future that some attempt must be made to structure support, and achieve more effective exploitation of science.
2. This exercise is an overview gathered by the Study Group after consulting an incomplete but generally representative series of groups in the United Kingdom. It is therefore limited in depth and completeness. It is set against a backcloth study of the predictions of scientific futures in USA, Japan, France and Germany.
3. The report analyses the prospect for increasing the longer term economic return to the United Kingdom from its expenditure on basic, strategic and industrial scientific research, and uniting their thrust so that it has an effective total impact.
4. We believe that the value of this report lies in its conclusion that a process is needed to prioritise and guide a substantial proportion of that part of the national scientific resource be it Research Councils, Ministry of Defence or, Department of Trade and Industry, and to stimulate its effective exploitation to the benefit of the United Kingdom. The remaining and significant proportion of publicly funded scientific research should be determined by peer judgement of scientific excellence etc in the established way.
5. The study recognises that past levels of support of UK science have been the desirable result of prosperity and that their fruits have tended to give benefits worldwide rather than to the United Kingdom. However, in the future, national economic success will be built on the foundations of scientific knowledge and capability. From this comes the challenge which we must meet — to use our considerable national investment in scientific ability for the national benefit, and at the same time significantly increase our exploitation of research and development done outside the UK.
6. We do not have a forum in the United Kingdom where we can manage the process referred to above. It is, we believe, a matter of national priority that such a forum be established.

Summary of the report

1. Countries with a major technological capability have developed mechanisms for holding debates about directions in science and technology and the associated policy. In this country, we do not have a forum in which to carry out this activity. In fact, we do not even have the information which allow would this to be managed effectively, and our presently dispersed data are essentially non-interactive.

2. The study we have carried out has led us to a view of the means by which the process could be pursued, given some trust and commitment by industry and the established scientific organisations. Such an activity cannot be done occasionally, but must be continuous, with sufficient resources committed, both in quantity and time, to ensure that there is consistency of judgement.

3. We conclude that it is both feasible and desirable to create a framework for an agreed process for generating strategic exploitable science priorities.

Outline of the Report

4. The study considered the economic and social activities in society and related them to their influence on technology in order to determine the science areas required to underpin that technology. The first chapter outlines the origins of the exercise and sets out the terms of reference for the study which were:

a. to report on those areas of science and specific scientific developments likely to have significant economic consequences within ten years and within twenty years;

b. to comment, as far as possible, on the adequacy of the above areas of science in the UK in terms of the technology perceived to be required in the future.

There is a clear relationship between the study, the Annual Review of Government-funded R&D, and the Government's view on the Annual Review expressed in Cmnd 8591 that, 'skilful value judgements as to

allocation of financial and manpower resources are, however, needed. This will involve distinguishing between vital and dormant areas, identifying gaps, disparities and duplications, and considering the opportunity cost of relinquishing certain areas of research.'

5. We consider in Chapter 2 the main issues which arise in the process of assigning promise to areas of science. We define an exploitable area of science as 'one in which the body of scientific understanding supports a generic (or enabling) area of technological knowledge; a body of knowledge out of which many specific products and processes may emerge in the future'. Thus the exercise is not perceived to be one of picking winners but of strategic policy aimed at creating a reservoir of knowledge out of which the, as yet unidentified, winning products and processes will emerge. An 'aide-memoire' for identifying promise in science is presented and some rules of thumb given for minimising the inherent risk in resource allocation that opportunities might be missed and promise extinguished.

6. The issues raised by such considerations are summarised in the form of a sequence of questions, each one focussing upon a particular aspect of exploitable science—

- i. Which areas of generic technology are supported by a particular area of strategic science?
- ii. Has the UK the scientific resources to advance a particular area of strategic research? If not, how quickly can resources be acquired eg by changing the emphasis of undergraduate and graduate programmes?
- iii. Within a generic technology what classes of new products and processes will become possible within a ten or twenty year horizon?
- iv. What indicators are there of the likely costs of translating knowledge from the generic pool into marketable products and processes?
- v. In which areas of existing industrial and commercial activity will the new products and processes find initial application? What advantages will they offer and how might markets respond to these advantages?
- vi. How quickly might the perceived markets develop and what might be the ultimate niches of the new products and processes?
- vii. What evidence is there for a foreign industrial presence in the relevant areas and what implications does this have for UK market share?

7. The approach taken in the study is described in Chapter 3. Ways in which technological forecasting and scientific assessments have been made

in the past both in the privately and publicly funded R&D domains are discussed. A brief outline is given of an exercise commissioned by the Study Group with the Science Policy Research Unit (SPRU) of Sussex University on how other countries undertake assessments of the potential of R&D.

8. In Chapter 4 we collect together our conclusions and recommendations. As indicated earlier we consider the exercise as only the start of a process requiring much more detailed analysis leading to implementation and resource allocating decisions. Our principal recommendation therefore is that *'a process should be established for identifying exploitable areas of science, which has some certainty of continuity, for the long-term economic health of the country'*.

11. In arriving at this conclusion we carried out a review of the current state of areas of science in the UK and their relationship with market need and technological opportunities. As our remit required, we looked at science from a traditional disciplinary focus and also across conventional boundaries. The preliminary findings from this examination are not published in the report but have had considerable influence on the conclusions we reached.

PART 1. ALLOCATING RESOURCES TO SCIENCE -

THE NATURE OF THE PROBLEM

1. Introduction — allocating resources to science — the nature of the problem

1.1. *Background and Remit*

1.1.1. Central to the ACARD terms of reference is a charge 'to advise the Government and publish reports as necessary' on 'the application of research and technology, developed in the United Kingdom and elsewhere, for the benefit of both the public and private sectors in accordance with national economic needs'. The Council has published several reports on subjects relevant to this remit, for example, robotics, computer-aided techniques, advanced manufacturing methods. The object of those reports was to focus attention on new technologies in order to encourage their exploitation by industry.

1.1.2. A number of steps back from the point of exploitation of technology is a stage of scientific experimentation which increasingly forms the base from which new technologies and innovation flow; however, not all basic scientific research is exploited or exploitable. Historically, a prime motive of the scientific process has been the advancement of knowledge, but rarely does scientific progress occur without a point or points of reference; cross-fertilisation of ideas has been a rich source of scientific innovation in the past. Major scientific discovery is usually made in fields which have already been identified as having significant potential. In the fullness of time, many such discoveries lead on to new technologies. Such notions prompted the Council to consider the feasibility of identifying the fields of science on which future technology and innovation might be based. If such a process were feasible there would clearly be implications for technological development, industrial competitiveness and for resulting economic considerations. ACARD decided, therefore, with the endorsement of the Advisory Board for the Research Councils, to examine the feasibility of identifying areas of science which had significant economic potential for the future. At the same time, it was thought desirable to examine the adequacy of the national scientific research effort in relation to such scientific fields which were identified.

1.1.3. We were invited by ACARD, therefore, to form a Study Group with the following terms of reference—

- a. to report on those areas of science and specific scientific developments likely to have significant economic consequences within ten years and within twenty years;
- b. to comment, as far as possible, on the adequacy of the above areas of science in the UK in terms of the technology perceived to be required in the future.

1.2. *Scope of the Study*

1.2.1. In the spectrum of basic and applied science, there will be areas that informed observers will select as more likely than others to have economic potential on a ten or twenty year timescale. The exploitation of these areas may result in changes in industrial practice, the service sector, national infrastructure, health care, social conditions, the environment, lifestyles, educational techniques, etc. Perceptions of the areas which have economic potential will be formed from two fundamental considerations:

- a. judgements on fields of scientific research which are likely to lead to new industrial and commercial opportunities;
- b. judgements on the changes in society and the marketplace which are likely to require the application of new technology.

1.2.2. Science comes in an infinite variety of shapes and sizes. The private sector often has a clear idea of where it thinks the research which it undertakes is leading in terms of the marketplace. However, some private sector research and much public sector research is of a more speculative or curiosity-driven nature. The initial reasons for such research may be for advancement of knowledge but ultimately important technologies may arise. Development and commercial exploitation of such technologies will depend on a complex of factors but finally a market must have developed. Predictions about the potential of curiosity-driven activities implies some arbitrariness, but informed judgement at the time may in many cases have yielded a reasonable assessment of the likely potential of such research. *We considered the feasibility of such a process to be central to our remit.*

1.2.3. The scope of the study was confined therefore to those areas of science which we considered likely to be economically significant in the future, and included all the major fields, such as health, communications, energy, space, manufacture, defence, etc in which such areas might be located.

1.2.4. It is neither likely nor desirable that the *entire* budget for UK science should be treated in strategic terms. Many fundamental areas of research

will remain, where the long-term interests of the UK are best served by leaving first-rate scientists to judge fruitful areas of research quite independently from external pressures. There are motivations for practising science other than the purely economic ones, eg for intellectual curiosity and for education and training. However, economic reasons cannot be ignored in the formulation of British science policy. It is a question of balance, and it is our judgement that economic and social factors have been given less weight in the formulation of science policy than is justified by Britain's economic circumstances.

1.3. Annual Review of Government-funded R&D

1.3.1. In June 1982, the House of Lords Select Committee on Science and Technology in its First Report made a number of recommendations about the organisation of Government advice on science. A major feature of the reply (Cmnd 8591) by Government to the report was the decision to introduce a system of Annual Reviews of Research. ACARD was invited by Government to comment on the issues raised in the Annual Review in order that independent advice could be obtained on the allocation of public expenditure resources to R&D.

1.3.2. The first review carried out in 1983 concentrated on assembling a database of Government R&D expenditures, and on establishing procedures for the collection of such information regularly in the future. It was not intended in the 1983 Review to set Government-funded R&D in any national or international framework. This was a major aim of the subsequent review. The 1984 Review emphasised that decisions on levels of R&D funding must be a matter of informed judgement based on knowledge of the prospective subject of study, taking into account other expenditure priorities. ACARD has provided its advice to Government on both reviews as an input to the process of such informed decision-making. The 1984 Review also commented that the analysis was a broad-brush exercise which could not fulfil all the objectives set out in Cmnd 8591 for the Review. It could only indicate areas where expenditures appeared to be out of line, whether with international figures or by comparison with their expected economic significance: further studies would be required. We see the study which we were invited to undertake very much in this context.

1.3.3. Cmnd 8591, in commenting on the Annual Review, concluded that 'the analysis required will not be a facile choice of areas where more money should be spent. In the Government's view, overall UK expenditure on research and development as a percentage of GDP is sufficient. Skilful value judgements as to allocation of financial and manpower resources are,

however, needed. This will involve distinguishing between vital and dormant areas, identifying gaps, disparities and duplications, and considering the opportunity cost of relinquishing certain areas of research. The emphasis will be on review of long-term plans'. Clearly the study which we were asked to undertake by ACARD is highly relevant to the objectives outlined in Cmnd 8591. As indicated above, the Annual Review is well-established in terms of the basic information which it provides on allocations of Government R&D funding, and attention should now be focussed on scientific aspects of priorities for Government R&D funding.

1.4. National Scientific Priorities

1.4.1. The UK carries out roughly 5% of total world R&D, and cannot, therefore, be involved in all the areas of research which are covered by other countries. In the current range of national R&D activities a process of selection has taken place, however carried out, which has determined which areas were supported to the exclusion of others. It is the process of selection and the results of that process which is relevant to the second part of our terms of reference.

1.4.2. Concern has been expressed in recent years by those with interests in science policy that the processes by which national scientific priorities were determined were not clearly visible. There was no mechanism by which to assess the national competence in any particular technology or branch of science or to judge whether the process of selection paid sufficient regard to national needs in relation to factors other than those concerned mainly with excellence in scientific research.

1.4.3. At a national level, a need for clearer identification of priorities relevant to fundamental, strategic, and applied research has been expressed. It was concluded at a seminar in 1982 organised jointly by the Leverhulme Trust and the Society for Research into Higher Education that 'a national research policy is required to guide the allocation of public money to fundamental and strategic research'. The report of the seminar went on to suggest that priorities could not be left entirely to Government, and that 'there is a need in this country to find a mechanism which will allow the greater involvement in the determination of research priorities of higher education institutions, the UGC, the Research Councils, the scientific community and likely users of research — industry and Government'.

1.5. International Aspects

1.5.1. The nature of international competition and the cost of research are such that the development of new technology cannot realistically be treated

in the context of a closed economy. Trade, foreign investment and licensing are alternative ways in which the returns to research may be garnered. Science in a historical context has rarely been hindered by international boundaries, and the scientific process has been benefitted from the close interaction of scientists in the world community.

1.5.2. To maintain its position within the world economy the UK will be required to draw deeply on its own resources of inventiveness and innovation. A thrusting higher educational research system is needed responsive to the demands to which it will be subjected. Countries which appear to have enjoyed success in scientific research and its application in recent years have made conscious efforts to formulate national research priorities for the basic sciences. The Japanese with their long-term plans and French with their national symposia on science have developed processes for identifying the scientific priorities, for influencing Government to make funds available for such priorities, and for obtaining a commitment to implementation of the priorities.

1.6. Further Structure of the Report

1.6.1. We noted at the outset of this exercise, as mentioned above, that those countries which had enjoyed most success in recent years in their exploitation of science had moved towards an approach or process for guiding national scientific and technological activities which was closely related to the ways in which their economies and societies were developing. In this report we discuss the relationship between such activities and support in strategic science and generic technology and industrial and commercial markets. This discussion is contained in Chapter 2. Ways in which different countries go about the process of relating scientific priorities to economic and societal factors were investigated by commissioning a study with consultants. The results of this study and the approach which we subsequently decided to adopt are outlined in Chapter 3. In Chapter 4 we conclude by giving our considerations and recommendations on a process for relating national priorities in strategic science to the needs of the economy and society.

2. Science, technology and economic performance in the UK

2.1.1. Our terms of reference in this exploratory study were to identify exploitable areas of scientific research, namely, areas where a basis for profitable commercialisation can be anticipated within a period of ten to twenty years. In this context, commercialisation means the transformation of scientific understanding into profitable new products and processes by UK firms. This chapter provides a brief overview of the issues which arise in the process of assigning promise to areas of science. We do not attempt to hide the complexity of the questions we discuss. Nor do we pretend to forecast future states of the world in more than the broadest terms.

2.1.2. In 1969, the Department of Education and Science published a report by the then Council for Scientific Policy (CSP) entitled 'An Attempt to Quantify the Economic Benefits of Scientific Research'. That report pointed to the close association between applied research and its economic justification, and noted that although fundamental scientific research was carried out for its cultural value and intellectual challenge, it had often given rise also to unexpected technological progress. Suggestions were made on how the economic benefits of science might be assessed, and the need to make an appraisal of underlying scientific discoveries in relation to their economic significance for the industries on which they had been based. The aim of such assessments was to make possible the prediction of long-term economic changes resulting from support of particular scientific areas.

2.1.3. At the time, the report was particularly forward-looking. Thus, although the CSP Report proposed a series of *ex post* studies of science-based industries which were to be confined somewhat narrowly to the underlying science, the report also recognised that it might be necessary eventually to consider the interrelations between all science-based industries and all associated scientific discoveries. It was realised that such a task would not be straightforward, even with the assistance of techniques such as systems analysis and critical path analysis. Furthermore the report also acknowledged, more in passing, that in such *ex post* rationalisations, it might be difficult to distinguish features of society resulting from previous scientific activity from changes due to other organisational/market forces

in society, or to determine the extent to which such changes were related to previous technical/scientific advances. Nevertheless, it was considered, in full recognition of the magnitude of the problem, that it would be worthwhile to explore these ideas further, and the CSP set up a Working Party to consider possible methods of quantifying the economic benefits of scientific research. Before the Working Party had reported, however, the CSP became defunct in 1972.

2.1.4. Since that time interest in such studies, and assessments have been pursued in other forums both nationally and internationally. Both academia and industry have sought to develop and analyse information on scientific and technological activities and relate these to technical innovation and development in order to improve the basis for policy and theory. In such analyses there is a clear difference in approach to the science carried out in the private sector to that carried out in the public sector. Although scientific assessments in both sectors rely to some extent on extrapolations of past trends, the assessment by industry of the technological potential of applied research relies on a more structured approach, incorporating economic, technological, socio-political and other parameters, than does assessment of public sector science. Assessment of public sector research tends to be inherently more difficult than that of private sector research because the objectives are less clearly defined in the economic sense and it is less process- or product-orientated.

2.2. Scientific Support and UK Economic Performance

2.2.1. The Government believes that the resources available for scientific research should depend primarily upon the level of gross domestic product, so that any substantial increase in resources for science in the United Kingdom is most likely in the longer-run to be funded by economic growth. The economic performance of the UK economy since 1945 has been so weak compared to that of other countries in the OECD to raise doubts about the capacity of the UK to support the scientific community at previous levels. For example, the support per scientist in the UK has, in the past, been greater than in most European countries and fell little behind that in the USA. But it is likely to become lower compared with both in the future, which will be of importance because of the competitive nature of science. The relatively poor performance of the UK economy is reflected not only in the statistics of *per capita* income growth but also in the statistics of foreign trade, with the UK share of world exports of manufactures falling from 20% in 1954 to less than 9% in 1984. In world terms the UK is a small economy with its standard of living heavily dependent upon foreign trade. The trade pattern is no longer one of exporting manufactures to less developed and Commonwealth countries in exchange for imports of food

and raw materials. Rather it is dominated by trade in manufactures and semi-manufactures with the advanced industrial countries of Western Europe, North America and Japan. In 1984, over 75% of UK imports and 66% of UK exports involved trade in highly competitive markets for manufactured and semi-manufactured goods compared with figures of 53% and 79% in 1955. So far as services such as banking, insurance, consultancies, etc are concerned, the export ratio was 23.5% in 1983 compared with 27% in 1962 and the import ratio 18.5% as against 23% in 1962.

2.2.2. The exploitation of North Sea oil resources has had a profound effect on the UK economic structure. The higher real exchange rate which has resulted is an important factor in 'crowding out' UK manufactured exports and generating in 1983 a negative trade balance on manufactured goods for the first time since records began. Yet North Sea oil will be exhausted some time, be it in 20, 50, or 100 years, and the consequent reduction in income will require the development of new export opportunities if UK standards of living are to be maintained, let alone grow at average European rates.

2.2.3. It is here that a policy for strategic science becomes particularly significant. The export opportunities which maintain standards of living are those which offer high value added per unit of employment; products with a knowledge base in advanced technology which can be sold on world markets at favourable terms of trade. The products of relatively mature technologies are increasingly the preserve of low-wage newly industrializing countries with which the UK has little realistic prospect of competing without a drastic fall in living standards.

2.2.4. Japan, for example, has experienced very rapid import penetration from less developed countries in a number of mature technological areas, and has yet maintained the most impressive growth rate in the industrial world. The reason lies in the close link between structural changes and economic progress as new dynamic industries expand and displace existing activities. In the general process of growth the agricultural sector declines relative to manufacturing, which in turn is eclipsed by the growth of the service sector, while within the manufacturing and service sectors new activities continually emerge to compete with and displace established activities. No single technology offers unlimited scope for improvement so the process of growth has to be sustained by new economic impulses based upon innovation, that is, upon an entrepreneurial injection of new technological activities into the economy.

2.2.5. The role of strategic science policy over the next twenty years of UK economic growth then becomes clear. On the one hand, it should contribute

to existing activities keeping close to world best practice. On the other hand, it should respond to the important export and growth opportunities which lie in newly emerging technologies where the knowledge base is changing rapidly enough to prevent low-wage countries establishing a technological presence. To grasp opportunities at the cutting edge of international competition will require new patterns of resource allocation, and the allocation of resources to strategic science should be seen as an integral part of this market driven process. Structural change is, of course, painful in the short-term as particular skills are no longer needed and regional concentrations of industry decline. But, over the longer-term, a failure to develop new economic activities has even more painful consequences for the nation as a whole. *Of itself, strategic support of science is a small but necessary part of this picture of growth and transformation.*

2.3. The Nature of Exploitable Science

2.3.1. An exploitable area of science is one in which the body of scientific understanding supports a generic (or enabling) area of technological knowledge: a body of knowledge from which many specific products and processes may emerge in the future. It is this connection with future technological development which gives the exploitable area strategic importance. Thus exploitable areas of science exist 'where the basic principles are known but the final products have yet to be identified' (Improving Research Links between Higher Education and Industry, ACARD/ABRC, 1983, p.11). It is intrinsic to this definition that exploitability depends upon three sets of considerations:

- i. the potential for development within the area of science;
- ii. the generic technologies which will be advanced by a greater understanding of the particular fundamental scientific principles; and
- iii. the potential areas of application which products and processes flowing from the generic technology will have.

2.3.2. According to Frascati definitions of R&D, basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application in view. So far as the Annual Review of Government-funded R&D is concerned, it was recognised that basic research was often considered by the funding agency to have a strategic dimension, and that the division between basic and strategic aspects of such research was difficult to identify. For applied R&D, it was possible for the customer to distinguish and quantify the precise practical aims and objectives of the programmes. Applied research with strategic aims was, therefore, research directed primarily towards practical aims or

objectives, but it was too early in the evolutionary cycle of the subject under investigation for the eventual applications to have been clearly specified. The actual duration of the strategic phase of the evolution of a field of study would vary widely from field to field.

2.3.3. The identification of promise will require a blend of judgements involving questions both internal to and external to the pursuit of fundamental science. The matching of extrinsic and intrinsic criteria in the pursuit of national objectives will, in turn, require an institutional and decision-making structure which does not locate strategic science and industry in different, mutually exclusive categories. Rather it will require a framework which draws together the relevant knowledge inputs, establishes communication between science and industry, mobilizes resources in pursuit of the strategic objectives, and changes the balance of support as the potentials of market exploitation, scientific advance and technological development evolve. Flexibility in response to changing priorities will be a central element in any policy of strategic support for science. Government programmes with emphasis on pre-competitive research involving collaboration between university departments and industry are one measure which may find wider application in a policy of strategic support.

2.3.4. It will be clear that technological knowledge bridges the gap between strategic science and the market place. The likely success of a programme of strategic scientific support will depend not on treating the development of the scientific and technological knowledge as independent, sequential stages but rather in treating them as interdependent processes, advancing in step in the development of a generic pool of technological knowledge. To seek to organise science in such a way that it leads naturally to exploited technology is the objective. Strategic science is a national investment to be justified in terms of the national return it promises to generate. The organisation of strategic science should, therefore, reflect this need for results to be followed by exploitation in the national interest. Effective interaction between industry and the scientific community is vital if strategic research is to succeed.

2.3.5. It would be foolhardy in the extreme to pretend that the identification of exploitable areas and their commercialization is straightforward. Picking precise winners is not a feasible policy option. The process by which new industrial activity is generated and absorbed into the prevailing economic structure is one of immense complexity. Nevertheless, it is clear that technological innovation has been and will continue to be the mainspring of economic growth and, moreover, that future technological development will depend closely upon advances in scientific understanding.

2.3.6. To forecast exploitable areas in any precise way is no less difficult, the links in the chain are many, the uncertainties at each stage considerable, while the possibilities of success or failure also depend upon decisions made in the many countries which compete with the UK in world markets. Nonetheless, we believe it is possible to identify broad areas of activity where a change in scientific knowledge or of market trends will make it profitable for industry to develop new products and processes.

2.3.7. Rather than pick winners in this narrow sense, strategic policy is concerned to create a reservoir of knowledge out of which the, as yet unidentified, winning products and processes will emerge.

2.3.8. The case for public support of strategic science lies in its having long-term implications without as yet offering a return to immediate exploitation in the market place. Thus strategic science falls in the gap between fundamental science and applied science, being neither the primary concern of the university sector nor of private industry. The time horizons, attitudes to risk, and objectives which motivate scientific research in the two sectors are sufficiently different to provide little incentive for strategic research to be performed by either. Much of the work supported by the Research Councils is, however, strategic. Like basic research, strategic research is concerned with advancing fundamental knowledge, and like applied research it is concerned with developing new technological possibilities. It is at this interface when different attitudes to risk and different objectives meet, that the problems of identifying and funding strategic research arise.

2.4. Selectivity and Strategic Support

2.4.1. The resources available for scientific research are always limited relative to the claims which can be made on them. Science policy cannot avoid questions of choice, the setting of priorities, the sacrificing of some areas of science in favour of others. Naturally this entails risks but this is true for any realistic situation in which limited resources have to be allocated.

2.4.2. In this context a policy for selecting exploitable areas of science explicitly must introduce criteria for choice which are external to science. Within the Research Council system both external criteria and criteria of intrinsic scientific worth are taken into account, particularly in those Research Councils—AFRC, MRC and NERC—whose remits are essentially focussed on practical problems. However, while external criteria are clearly taken into account within the Research Council system, neither the individual Councils nor the ABRC have comprehensive information about

externalities—scientific, technological, economic and social developments; nor do they have mechanisms for systematically presenting and evaluating this information. Neither is there a system to determine the relevance of commissioned research which is wholly aimed to produce benefits as perceived by Government departments

2.4.3. In allocating funds for strategic reasons internal scientific judgements remain indispensable but are no longer sufficient, and have to be supplemented by judgements of commercial and technological relevance, that is, by judgements of the external worth of the particular scientific area. In general terms these external judgements relate to two situations:

- i. where the products and processes which ultimately stem from the strategic science will be valued in the marketplace;
- ii. where a need is apparent but the commercial criteria are not applicable, either because relevant markets are non-existent, or give distorted signals to decision-makers. The science and technology related to environmental protection, health and defence are important examples within this category.

2.4.4. The definition of the margin between strategic and non-strategic work will be an important element in a policy to support exploitable areas of science. Considerations of strategic research cannot avoid comparison with fundamental research as well, since the use of external criteria implies judging the competing demands of strategic and fundamental research for the same resource.

2.5. Investment Decisions and Exploiting Science

2.5.1. The support of exploitable areas of science can properly be viewed as an investment decision, in which current outlays are incurred in anticipation of future returns. The objective would be to create a portfolio of areas of science on which UK industry would draw over an extended period, to ensure its future competitiveness in international markets as outlined in the 1983 joint ACARD/ABRC report 'Improving Research Links between Higher Education and Industry', referred to earlier.

2.5.2. The elements of a strategy are criteria for choice, the identification and collection of relevant information, and an institutional mechanism which ensures that UK industry does indeed draw successfully on the strategic sciences and related enabling technologies. A policy which succeeds in generating good, commercially relevant knowledge will have

failed if UK firms do not exploit the related technological opportunities. It will have failed *a fortiori* if that knowledge base is exploited by overseas competitors. The matching of knowledge and exploitation in the UK is the key objective in any policy of strategic science. A successful strategy will require that a process is established with clear elements of continuity to achieve this objective.

2.5.3. The choices to be made in allocating funds to strategic research fall into two related categories: the areas of science to be given strategic status; and, the levels at which those selected are to be funded. If one area is selected as exploitable, the level of support should reflect the date in the future at which profitable commercialisation of the related technologies is expected. The funding policy should provide the resources to ensure that all relevant knowledge is acquired by the expected date of commercialisation. That the timing element is important in exploitable research is not surprising. Modern industrial history is replete with examples of misplaced technological endeavour in which either the UK was too late — allowing competitors to build a commanding commercial advantage — or too early — investing in a technology before market opportunities had emerged. The greatest increase in national wealth is obtained not simply by developing new technologies but by developing them at the right time. The ability of UK firms to exploit promising science is not independent of the strategy of foreign competitors or their effectiveness in development and exploitation. Of course, the fact that any area of science is not of strategic importance at the present moment in no way rules out its becoming strategic at a future date. Successful policy will have to accommodate shifts in priorities over time and be flexible enough to effect these changes.

2.5.4. The usefulness of any investment framework lies in the insights which arise from its systematic application. By providing a framework for informed choice, it identifies the information which is required, even if in practice that information can be based on no more than intelligent guesswork.

2.5.5. Broadly speaking, the framework identifies costs and benefits associated with the support of strategic research. The relevant costs relate to the programme of research funding over a period of years, while the benefits relate to the commercial and other consequences of exploitation *net* of the costs of translating the generic pool of knowledge into specific products and processes. Whereas the support of exploitable areas of research will be met by public funding, the costs of developing specific products and processes will fall to a greater degree upon UK industry. The balance of funding between public and private support will require careful

consideration to ensure that promise in science is translated into exploitation in the market place.

2.6. *The Costs of Strategic Research*

2.6.1. The costs of strategic research depend on the capital intensity of the research process, the quality of the research teams, and the level of fundamental understanding which exists in the research area. Since the outcome of a research programme is surrounded by uncertainty, some judgement has to be made as to the bounds of possibility, and the 'real costs' adjusted accordingly. Also, it is more difficult in some areas than in others to change course in response to new opportunities because of long lead times in equipment and skills, and this is often an important factor in making choices.

2.6.2. All other considerations being equal, the case for giving an area strategic support becomes stronger the lower is the anticipated cost of acquiring the relevant knowledge.

2.6.3. The nature of international competition and the cost of research are such that the development of new technology cannot realistically be treated in the context of a closed economy. Trade, foreign investment and licensing are alternative ways in which the returns to research may be garnered. Science in a historical context has rarely been hindered by international boundaries, and the scientific process has benefitted from the close interaction of scientists in the world community. Indeed, the fact that the results of scientific research are disseminated internationally implies that the UK can supplement its own strategic programmes by drawing upon the results of foreign research. It is frequently observed that foreign technological programmes successfully exploit the results of UK research and there is no *a priori* reason why the converse should not hold.

2.6.4. It is unlikely, however, that this will be possible unless the UK maintains at least a gatekeeper presence in a given area, with a sufficient investment in manpower and facilities to replicate and improve on foreign advances as and when they occur. Below this threshold, which will vary across sub-disciplines of science, the UK could not hope to gain direct access to the best practice strategic science developed overseas.

2.6.5. International collaboration may also be possible in some circumstances, provided that the countries concerned can agree on strategic objectives. The degree to which UK strategic science can be based upon international collaboration will depend on the extent to which exploitable

areas have been identified world-wide, and the extent to which UK policy seeks to develop areas independently from major competitors. Pre-competitive joint ventures between UK companies and between UK and foreign companies may also offer advantages in the development of specific products and processes arising from the generic pool of knowledge. This may be particularly relevant where UK companies are small relative to Japanese, American and European competitors. The recently announced EUREKA programme within Europe provides one example of possible collaborative arrangements.

2.6.6. To maintain its position within the world economy the UK will be required to draw deeply on its own resources of inventiveness and innovation. A thrusting and more entrepreneurial higher educational research system is needed responsive to the demands to which it will be subjected. Countries which appear to have enjoyed success in scientific research and its application in recent years have made conscious efforts to formulate national research priorities for the basic sciences. The Japanese with their long-term plans and French with national symposia on science have developed processes for identifying the scientific priorities, and for obtaining a commitment to implementation of the priorities.

2.7. *Benefits from Exploitable Science*

2.7.1. The benefits flowing from a programme of exploitable science depend ultimately upon the products and processes which UK industry develops and exploits in world markets. *Elements of entrepreneurship are an indispensable component of a successful strategic policy.* The benefits will in each case depend on the improvement in performance that the new products and processes offer to their users, either in terms of cost reduction or enhanced capabilities. The greater the advantages which the new technologies provide, the greater will be their ultimate application, and the more quickly they will be absorbed into the economic structure. The pace of absorption is of considerable importance in determining the economic return to innovation. The application of new technology always involves the displacement of existing productive activities and there are natural barriers to this substitution process, partly economic, partly social, and partly relating to the inherent uncertainty surrounding the characteristics of new technology. The more quickly markets absorb the new technology, the greater the wealth generated, and the greater the justification for supporting the underpinning areas of strategic science. One need only to note the power of compound interest to see the importance of timing. At a rate of interest of 10% (a modest one for risk-laden ventures) a sum of £1,000 today would have an equivalent present value of £390 in ten years time and only £150 in

twenty years time. All other things being equal, the case for strategic support is greater the greater the range of application of the new technology and the quicker the economic application is likely to occur.

2.8. *Niche Concept*

2.8.1. An ecological analogy is sometimes helpful. When treating the question of competition between different species, ecologists employ the concept of a niche to reflect the interaction between environment and the rival species. Exploitable areas will give rise to new technological species introduced into a commercial habitat, populated with existing industrial activities, and the problem is to identify the niche and the costs of filling it with profitable UK-based activity.

2.8.2. Consider, for example, developments in opto-electronics. The technology flowing from this could affect a wide variety of information-disseminating activities. The opto-electronics niche could be identified with regard to:

- a. a range of existing information-disseminating activities which could be directly affected. Telephone, telex, newspaper, and library activities come immediately to mind, as do cable television and possible niches in medical electronics and control engineering;
- b. alternative technologies which compete for a niche, eg cable versus satellite-based communications.

2.8.3. The extent to which the potential market benefits may be captured by overseas competitors must also be part of the assessment procedure. From a narrow viewpoint the UK, *qua consumer*, can always obtain the benefits of new technology by importing the relevant products. However, in so doing, it forfeits the incomes which could be earned in their production and thus limits the general capacity to consume and benefit from the new technology. Considerations of international competition impinge upon the selection of exploitable areas in a number of ways. The ability of UK firms to exploit overseas markets enhances the return to UK from strategic science. Evidence of foreign scientific activity provides a case for accelerating UK efforts, in order to prevent competitors developing a lead time which renders UK production unprofitable. Conversely, in areas where UK industry does not have an anticipated competitive edge, the case for a strategic research underpinning of these technologies is correspondingly reduced.

2.9. *Net Benefits*

2.9.1. In assessing the benefits expected from a programme of strategic science, account must be taken of the very high development costs likely to

be incurred in translating the pool of generic knowledge into specific products and processes. Such costs must be subtracted from the identified commercial returns to arrive at a net benefit figure. These downstream activities have rightly been identified as major overhead costs — incurred in development, design, construction of pilot plant, and other activities to capitalize on generic knowledge. To spread these overheads requires a large market, and for the UK this can often be achieved only in international terms, by entering markets within the advanced OECD countries of Europe and North America.

2.9.2. To minimise the costs of exploiting the generic pool of knowledge it will be necessary to establish continuous close collaboration between industry and the scientific community: to ensure that research objectives and resource commitments illuminate the problems found in particular areas of technological development. The Alvey programme may provide a good guide in this respect.

2.10. *Identifying Exploitability: Aide-Memoire*

2.10.1. The issues raised so far may be summarised in terms of a sequence of questions, each one focussing upon a particular aspect of exploitable science.

- i. Which areas of generic technology are supported by a particular area of strategic science?
- ii. Has the UK the scientific resources to advance a particular area of strategic research? If not, how quickly can resources be acquired, eg by changing the emphasis of undergraduate and graduate programmes?
- iii. Within a generic technology what classes of new products and processes will become possible within a 20 year horizon?
- iv. What indicators are there of the likely costs of translating knowledge into marketable products and processes?
- v. In which areas of existing industrial and commercial activity will the new products and processes find initial application? What advantages will they offer and how might markets respond to these advantages?
- vi. How quickly might the perceived markets develop and what might be the ultimate market niches of the new products and processes?
- vii. What evidence is there of a foreign industrial presence in the relevant areas and what implications does this have for UK market share?

2.10.2. It is inevitable that hindsight will indicate opportunities missed and promise extinguished but such risks are inherent in any process of resource

allocation in which relevant information is scarce. They should, however, be minimized by adopting rules of thumb of the following simple kind:

- i. Support a portfolio of strategic areas with individual prospects for exploitation which are positively correlated or at worst independent;
- ii. Select strategic areas where the generic technologies suggest a wide field of industrial and commercial application;
- iii. Continuously monitor science and technology programmes in major international competitors;
- iv. Establish close liaison between the scientific, industrial and financial communities in the UK to facilitate the free flow of information on exploitable science and the establishment of a shared vision;
- v. Terminate programmes where the case for them is no longer supported by criteria of strategic promise.

2.10.3. Precise answers to these questions will never be available for today's decision-makers, they will only be revealed as the new products and processes are absorbed into the economic structure. However, intelligent guesses can be made and these should provide an initial guide to areas of promising science. Strategic decisions should not be seen as irrevocable. A policy for exploitable science is a process, in which decisions are made in the light of the best available information and reviewed as and when new information becomes available.

3. Approaches to foresight activity in strategic science

3.1.1. We discuss briefly in this chapter some approaches to assessing the potential for emerging areas of science in both the public and private sectors. Also described is a survey which we commissioned with the Science Policy Research Unit, Sussex University, to investigate how some other major industrialised countries went about the process of generating a view on scientific priorities. Finally we outline our approach to developing an overview of exploitable science.

3.2. *Technological Foresight in Industry*

3.2.1. Technological forecasting is an aspect of long-term market forecasting, which became of widespread interest to many major companies in the mid-1970s. Various techniques were developed each somewhat similar to the other, with the basic objective of assisting in the decision-making process on R&D and innovation. A typical approach was to assemble a high level corporate team or engage a firm of consultants to examine future technological trends and the related market potentials, the reasons for such trends, the way in which they might impact on company business, and how the company should respond to the opportunities presented. For many companies the results of such types of forecasting proved to be disappointing, perhaps because many forecasts were merely extrapolations at a time of high economic growth and they identified little that was not already known, whereas the economic changes in the last decade have produced many discontinuities which had not been foreseen. The lessons from such exercises indicated that forecasting was more successful when

- a. the innovation process was clearly understood ie technology 'push' and market 'pull' were both essential in company research and innovation;
- b. close collaboration was required between those undertaking the forecast whether inside or outside the company and research workers and management within the company;
- c. a receptive attitude to the forecast was required at senior management level in the company.

Forecasts also tended to be more satisfactory in relation to a narrow range of technology than when consideration of a broad range of technologies was required.

3.2.2. In reaction to the relative lack of success, the credibility in the techniques used has been reduced; nevertheless, organisations require a view of the future in order to develop strategies which enable them to adopt rapidly in a period of fast-moving economic and scientific changes. Such a view can only be obtained by using the most reliable source of data and developing insights in a systematic and structured fashion. The technologist involved in innovative development often underestimates the effort required to complete development of the innovation, and often has inadequate perception of changes in market or technological conditions which might affect exploitation of the innovation. The success of innovation is dependent on the relationship between technological potential, and future market need. Completely accurate forecasting is not possible, but such precision is not essential anyway for many long-term planning purposes. The error in forecasting should not be a major determinant of the success or failure of an innovation. But forecasting can be a valuable tool to assist in decisions to identify innovations likely to be a major success and to avoid major failures. Perhaps the greatest value in such forecasting activities is the development of comprehensive databases and the increase in confidence which their use gives in planning future directions. Such decisions are concerned essentially with human behaviour and as we discuss later in relation to technological assessment in Japan, forecasting is closely related to the behavioural aspects of decision-taking.

3.3. *Scientific Foresight in Publicly Funded R&D*

3.3.1. Technological forecasting holds greater potential, in spite of the aforementioned difficulties, for strategic or applied research than for basic or curiosity-orientated research. But the increasing complexity of organisation and management of publicly funded R&D, against a background of rapid economic and scientific change, has highlighted the need to develop procedures not only for recognising the important areas of curiosity-orientated science *per se* but also for identifying the areas of such research with significant strategic potential, in order to establish priorities for support of these areas.

3.3.2. The apparent absence of an underlying rationale for support of basic science was noted some 20 years ago. Two sets of criteria were suggested for determining the relative assessment of support for different scientific activities. The first related to internal criteria relevant to the advancement of scientific knowledge and the second, to external criteria, related the wider effects which science might have on other scientific fields and to society, for example, in the form of new ideas and techniques for industrial exploitation. In general, internal regulation has been the primary

mechanism by which basic science has been organised and the distribution of resources within fields and specialities controlled. The system used for such regulation has generally been termed peer-review. Up to the mid-1970s when support for scientific research was increasing rapidly, such a system worked reasonably efficiently in ensuring that most science of merit was supported. However, the slow-down in growth of science budgets has placed pressures on the system, and attention has been drawn by Irvine and Martin to three problems which such pressures have produced

- a. the resources which big sciences consume are disproportionate to the total scientific activity which big sciences generate;
- b. the concentration of research activity within fewer institutions which has tended to reduce their accessibility to the wider scientific community;
- c. the peer-review system had become less appropriate as a mechanism for restructuring scientific activity.

Another problem relates to the unsatisfactory nature of peer-evaluation in identifying declining science areas and groups, because of the deep-rooted institutional and social factors which would require to be addressed.

3.3.3. Although external criteria have played a part in determining the overall levels of support for science and to some extent its distribution, such criteria have tended to reflect the needs of the scientific community along the lines described above. However, recent resource constraints have increased the pressure on the scientific community to have greater regard to external criteria in order that basic research results in more tangible and practical benefits for society. Of particular concern is the need to establish procedures for determining priorities between fields. The present distribution possibly reflects more post-war scientific planning decisions than a conscious effort in subsequent years to establish priorities on a systematic basis defined by present or future national needs. The availability of improved statistics through, for example, the Annual Review of Government-funded R&D, and work of bodies such as the Advisory Board for the Research Councils, University Grants Committee, National Advisory Board, etc will assist in providing a clearer picture of R&D support and facilitate a more directed approach to the organisation and management of publicly-funded R&D.

3.4. *Other Foresight Activities*

3.4.1. *Science and Engineering Research Council*

The SERC's main concern has traditionally been to sustain the universities' research capability across the range of academic scientific disciplines where

the allocation of funds has been based primarily on criteria of intrinsic scientific worth. However, over the last 10 years SERC has built up its engineering programmes under the direction of its Engineering Board—on which industry is strongly represented and where questions of industrial relevance are taken into account in the allocation of funds. With DTI, SERC has also developed collaborative programmes with industry in both engineering and science. Prospective industrial applications are increasingly taken into account by SERC's Science Board.

In September 1984, the Science and Engineering Research Council (SERC), published a report entitled 'A Strategy for the Support of Core Science' which represented the SERC Science Board strategy for defining and developing the research themes crucial in underpinning the science-base sectors of the national economy and for which a strong core science capability was required. In developing their strategy, the Board emphasised the importance of multidisciplinary activities and proposed that SERC central facilities could perform an important function in promoting multidisciplinary studies. Difficulties imposed by the compartmentalised funding of research were recognised.

3.4.2. We applaud this initiative by the Council particularly the recognition that a continually evolving strategy is required incorporating not only considerations of scientific merit, but which also has some regard to the needs of the science base of industry, and urge that universities will take due action in formulating their academic plans for the next 10 years.

3.4.3. *Royal Society Study of the Health of the Science Base*

At the invitation of the Advisory Board for the Research Councils, the Royal Society embarked on a study in 1984 of the health of basic science in Britain. The exercise will concentrate on two broad areas of basic research of far-reaching scientific, and, ultimately economic importance. By looking at trends over the last 20 years, an attempt will be made in the study to assess the health of basic science in the two areas in absolute terms and by comparison with the performance of other countries. Resources made available for basic research (inputs) and the products of basic research (outputs) will be examined.

3.4.4. *Study by the Science Policy Research Unit*

Before embarking on the task set in our remit by ACARD we considered it necessary to make some enquiries initially on how organisations in other countries went about the business of identifying emerging areas of science which at the time showed potential for significant economic development in the future. We therefore invited the Science Policy Research

Unit (SPRU) of Sussex University to undertake a study to review previous appraisals of scientific developments that showed long-term (10 years or more) promise of commercial exploitation. The principal objective of the study was to report on:

- i. assessments, which had been carried out in the last 20 years, of scientific developments that showed promise at the time of the assessment of leading to technological developments of economic significance;
- ii. the role which the assessments might or might not have played in such developments;
- iii. retrospective studies of significant technological developments to trace the science on which they were founded and determine whether any predictions could have been made of the economic significance of the basic science;
- iv. the techniques that might be employed in a study of exploitable areas of science undertaken under the auspices of ACARD.

3.4.5. The study covered four major industrialised nations, namely, the United States, Japan, France and West Germany. We have not included the full report of the SPRU survey. The findings were reported in a book published in November 1984.

3.4.6. The main conclusion was that 'the United Kingdom should attempt to bring the level of its long-term scientific and technological foresight activities up to that found in Japan'. The 'desirability of integrating, as the Japanese have done, the forecasting efforts of Government funding agencies, and industry, something which can only be achieved by drawing in wide sections of the research community' was also emphasised.

3.5. *Our Approach to the Identification of Exploitable Science*

3.5.1. The SPRU study indicated, that of the four countries studied, Japan had a more committed approach to forecasting than had the other countries and detailed scientific assessments had become accepted as an essential component of national and industrial R&D strategy. Also, Japan tended to make longer term projections than did other countries. The approach proposed in the SPRU study contained many features to which we were attracted but we felt that it was not completely appropriate for the circumstances which existed in the United Kingdom. We considered that the inherent differences between the two countries in R&D organisation and management were sufficiently great as to require some modifications to the proposals made by SPRU for the purpose of this study. For example, the

proportion of research carried out by the private sector is much higher in Japan than in the UK, and the recent recessionary trends had less impact on Japanese industry. The research base in the UK is spread across a wider range of organisations each with varying objectives. Perhaps our clearest impression from the SPRU findings in Japan is that the Japanese showed almost a total dedication to the forecasting process, irrespective of the quality of the outcome and by such commitment made them almost self-fulfilling.

3.5.2. We believe, therefore, that it is possible to develop an assessment of scientific areas with potential in the UK using the approach outlined below but in order to obtain a commitment on the Japanese scale, changes in attitudes are required which largely depend on three factors:

- i. a longer term view of scientific innovation;
- ii. co-operation and communication of information between competing commercial interests, higher education institutes and Government;
- iii. acceptance of the consequences of major structural change.

3.5.3. Our views on the reason for Japanese success in technological forecasting are confirmed by a 1983 report on 'A Case Study of Technology Forecasting in Japan' by Professor Dore of the Technical Change Centre. The report describes the highly effective process by which priorities were set in the choice of scientific projects in relation to the balance between technological potentiality and market prospects, but the success in achievement was based on a complete commitment by a 'a consensus society' to the choices made.

3.5.4. We were attracted by the suggestion of circulating a questionnaire to the R&D community but were not persuaded to pursue this approach since it was uncertain whether the replies would contain the information necessary for a comprehensive assessment to be made. The approach which we decided to adopt therefore was to seek a range of opinions on areas of science with economic potential from scientific workers at the laboratory bench to leaders in the scientific community and corporate planners in industry. Information was also sought on social change, market and resource trends, overseas developments in science and technology, political, economic and trade considerations.

3.5.5. In order to obtain a broad spectrum of scientific and other views links were established with a wide range of knowledgeable people within the scientific and technological communities. Major forward-looking UK manufacturing companies and other organisations were approached in

order to gain an insight into their thinking on the science which would present future opportunities and markets. Another perspective on the potential of science was also obtained through approaches to major science and technology institutions like the Royal Society, Fellowship of Engineering, and Research Councils. (A list of the organisations visited is included at the end of the report). Each organisation approached was invited to form a small group consisting of, for example, an outstanding laboratory scientist, design engineer, research team leader, technical director, forward planner, economic forecaster, etc. In the case of the science and technology institutions the groups consisted of outstanding young scientists/engineers and scientists/engineers eminent in their particular field of interest. Arrangements were made for a pair of members of the Study Group to visit each organisation to hold a free-ranging and uninhibited discussion on scientific areas likely to have significant economic consequences. Such discussions took place over half a day or, occasionally, a full day. At the outset of each meeting it was stressed that information given would be treated confidentially. A report on each meeting was produced and forwarded to the organisation for their comment/amendment or further elaboration. This process of consultation has involved a considerable body of people and allowed collection of information at a level of detail which might not have been possible by circulation of a questionnaire.

3.5.6. We would not wish to give the impression that the consultation meetings were completely unstructured. Careful consideration was given to the approach to take in the discussions and a framework of questions was drawn up to ensure that the major interests of the study were covered, and that themes were broadly similar from meeting to meeting so that comparisons could be made. The major theme questions were as follows:

- a. What do you consider to be the most important areas of science likely to realise future economic returns within a 10 year and a 20 year time-scale?
- b. In the case of industrial companies,
 - i. Can the main technologies likely to be used in your industry in the next decade and possibly the following decade be identified?
 - ii. What are the newly emerging technologies in your sector?
 - iii. What technical progress do you consider necessary in supporting sectors and is the rate of progress adequate?
- c. Does the nation allocate its resources for scientific research properly, and can you identify unimportant areas of science receiving too much support and important areas receiving too little support?

- d. How do you consider changes in markets and society will affect the directions of science undertaken by the country?
- e. What are the methods employed for corporate planning of future research and development activities, and how and where do you get the data or information on the technical factors, markets, etc which you take into account when formulating long-term strategy?
- f. Would a UK strategic overview of science be of help and made use of by your organisation in planning for the future and if so would you be willing to share that commitment with competing UK organisations against foreign competition?

A supplementary list of questions was also available for use in following up lines of enquiry. Not all questions were relevant to some organisations and in practice a flexible approach was taken in using the framework of questions during discussions.

3.5.7. In order to obtain information an area of science with potential being developed in other parts of the world, approaches were made to the Scientific Counsellors in major industrialised countries seeking their assistance in providing information on the scientific technical-commercial scene world-wide so as to identify exploitable new scientifically-based developments which offered potential market applications in the various industrial sectors. The sources for such information included overseas companies, national statistics, universities, scientific conferences, symposia, technical literature, data on market sizes/growth rates, competitive situation, etc.

3.5.8. We also collected a wide range of published material on contemporary science in the research literature, Government statistics and data on R&D, research plans of organisations, and relevant consultants studies.

3.5.9. Our views on the process of identifying exploitable science have been greatly shaped by the consultative approach described above.

4. A process of exploitable science

4.1.1. We assembled a considerable body of information on science areas during the course of the study which has been used to draw together in this final chapter our conclusions and recommendations on the process by which exploitable areas of science might be identified and commercialised to the benefit of the UK. The overriding conclusion which we draw from our deliberations is that a process be established with the twin objective of (1) gathering information and identifying exploitable areas of science and (2) creating a commitment to translate exploitable science into technology in order to realise commercial processes and products. Although the picture we have obtained is incomplete because of limitations on the resources and time available to us, the impressions are sufficiently clear and revealing to indicate that action must continue in order that the scientific community can strengthen and increase its contribution to the national technological effort. We see greater commercialisation of the results of scientific research as being of the first importance both to increasing the international competitive strength of UK industry, and to increasing the long-term resources available to support science in the UK.

4.1.2. We have not considered the study to be one of picking winners. Rather, we consider that the primary concern at this stage is the need to establish a framework for science decision-making, from which winners are more likely to emerge via market-driven processes.

4.2.1. The report prepared for us by SPRU argued that a major contributory factor in the markedly better performance of Japan over recent years in technology-based industrial sectors related to the difference in level of scientific foresight activities between Japan and other industrialised nations. Although SPRU pointed out that the Japanese approach took insufficient account, for example, of other dimensions relating to technological and industrial development and we have suggested that basic cultural differences and differences in R&D organisations obviate against the wholesale adoption of Japanese methods, we are firmly convinced that the fundamental principle is sound. With growing

competition in the world industrialised markets and increasing technological sophistication of the products in those markets, most industrialised countries require a strong science-based economy, decision-making procedures on national science policy must balance judgements on scientific and technical potentials against social and economic developments. The French are developing for their own needs a system similar to that of the Japanese by setting up an international network based on the Centre de Prospective et d' Evaluation (CPE), reporting directly to the Minister of Industry and Research, to assemble relevant databases to assist in the process of long-term scientific and technological forecasting.

4.2.2. During the preparation of this report we heard a number of opinions and views on the way that science policy is developed in the UK, and it is clear that present arrangements are not entirely satisfactory to many of those consulted, particularly in the private sector, who depend on the underpinning science and output of scientific manpower from the public sector. We referred earlier in Chapter 2 to the part which internally and externally motivated criteria should play in considerations of nationally important areas of strategic science. Internally motivated criteria are those traditionally associated with the peer review system which is driven by a process geared to the pursuit of knowledge, and intellectual challenge, in which the recognition of successful achievement is largely in scientific publication and academic peer esteem. Left to itself, such a system does produce externally exploitable work, but often the effects are random and exploitation is a by-product arising fortuitously rather than by judgement. Moreover, the peer review system is particularly weak at exploring the interfaces between different, established branches of science and it is at the boundaries that significant commercial prospects often lie. If science policy is to *increase* the chances of producing advances in understanding which are of industrial and social significance, while at the same time generating substantial intellectual challenge, then that policy must be based upon information and criteria internal to and external to science. Strategic science policy will be facilitated by identifying the range of opinions relevant to the allocation of resources, by science judgements which seek to match scientific opportunity with social and commercial needs over a variety of time-scales.

4.2.3. In every country, science policy is selective insofar as science must compete with other claims on the public purse. Wealthy countries, in particular the USA, can afford to treat the commercial exploitation of science as a random process. An internally directed approach to science policy-making is often wasteful of resources. The objective of strategic policy should be to develop the science and technology to the point at which

it can be rapidly and effectively assessed and exploited when market opportunities present themselves. We are convinced that it is feasible to identify the relevant range of opinion through a process of wide consultation and assembly of relevant data. The identification of opinion should involve a continuing dialogue with researchers (new and established), research allocation organisations (Research Council committees) and the industrial research community which iterates between areas of science with promise and those priorities identified by the providers and users of research funds. Above all, though, the process should be continuous. *We recommend therefore, that a process should be established for identifying exploitable areas of science, which has some certainty of continuity, for the long-term economic health of the country.*

4.3. *The Structures and Resources in Support of Science Policy*

4.3.1. In order to achieve the objective outlined above, we consider that four key elements in the process are:

- a. the gathering of information on a continuing and permanent basis and its communication to the relevant parties and bodies;
- b. the evaluation of relevant opinions and information, and the identification of exploitable scientific areas;
- c. the allocation of resources to the priority areas in science;
- d. the commitment to exploit the results of science to UK benefit.

Such information gathering and distribution would be a two-way process allowing continuous comment and refinement by the scientific and industrial communities. Broadly based decisions would carry conviction and practitioners as well as potential users would become part of the process. We believe that this would enhance their commitment and confidence in the process. We also believe that this offers the greatest possibility of success in the UK context.

4.3.2. We have concluded that the information necessary to identify exploitable areas of science is acquired at present in a fragmented fashion in the UK. A number of bodies such as ACARD, the ABRC, Royal Society and UGC, together with industry all play a role but rarely do they interact as a combined force to shape policy and direction. Both ACARD and the ABRC tend to operate in a reactive mode. A structure is required which can gather, analyse, prioritise, and direct relevant information into the decision-making machinery. The decision-making process must recognise the three spheres of activity, scientific, technological, and commercial. The structure should link with other bodies, such as the Requirement Board of

DTI and the appropriate scientific bodies of other Government Departments and organisations.

4.3.3. We do not propose that new arrangements are necessary for the mechanisms of funding science. In order to generate a process for identifying exploitable science, resources will be needed to develop the database and to provide judgements on the quality of information. We envisage a small management group to steer the process of identifying exploitable scientific areas independent of the bodies, both public and private, directly concerned with the management of science budgets together with a small group to advise on overall strategy.

4.3.4. If such a process is to be effective in achieving change, it is essential that resources put into R&D must be translated into industrial products, entrepreneurs in science must be brought together with entrepreneurs in industry. That process should be intimately concerned with identifying areas of science with potential, marshalling resources, and executing programmes. The first report of the House of Lords Select Committee on Science and Technology expressed concern that there was too rigid a distinction between basic and applied research and this was noted by Government in their response to the report; the response also suggested that ACARD and ABRC should review the links between basic and applied research and whether these are useful distinctions in the context of the process we have described. We concur with that view and would wish to see a more pluralistic approach to science funding, flexibility should be built into funding mechanisms to allow research programmes to be built up and ended as appropriate. Whether the distinction between basic and applied research is useful in this context should be kept under review.

4.3.5. We discussed briefly in Chapter 1 the relationship of our exercise to the Annual Review of Government-funded R&D, and referred to comments in the Government response (Cmnd 8591) to the first report of the House of Lords Select Committee that the Annual Review analysis should 'not be a facile choice of areas where more money should be spent'.... skilful value judgements as to allocation of financial and manpower resources are, however, needed. This will involve distinguishing between vital and dormant areas, identifying gaps, disparities and duplications, and considering the opportunity cost of relinquishing certain areas of research. The emphasis will be on review of long-term plans'. The Annual Review process is now established and we believe that it should now consider long-term R&D plans of Government Departments. The identification of exploitable areas of science should not be independent of the Annual Review.

4.4. The Nature and content of Research and Development

4.4.1. The process outlined above should in time lead to a more rational allocation of resources to those science areas of prime national interest. This could require changes in emphasis in the scientific efforts of higher education institutions and Research Councils. Mechanisms may be needed for attracting students to scientific areas of economic promise with intrinsic growth potential. Consideration may be needed of the wider balance of disciplines in the universities. As frontiers expand in new areas, old subjects may be overtaken, for example, and university structures need to keep pace with the rapid advance of knowledge.

4.4.2. We recognise that some areas of science are of potential importance not because of their relevance in terms of direct market applications, but because of other factors such as Government policy, legal constraints, public pressure, etc. Such areas relate particularly to health care, the environment and consumer safety. There are also areas of science and technology which have important social implications, for example, the increasing desire by women for both careers and families and the technology which might assist in the fulfilment of those needs. Society itself creates pressures requiring a scientific or technological response and may also have a direct effect on the process of innovation itself. Thus the current pressures towards alternatives to animal experimentation will have a direct bearing on the science of health care. There is also little doubt that public concern about environmental issues will increase in the next 10–20 years in the UK, rather than diminish. The scientific issues are complex, but such concerns require a reasoned scientific response to avoid the possibility of serious economic consequences and misguided solutions. Careful consideration will be needed of which scientific areas in the environmental field are essential to the UK and which can be left to the international scientific community; for example, geological science may be relevant to waste disposal in the UK but the 'Greenhouse effect' is of international interest. The area of product liability has attracted considerable investments in R&D by the private sector in recent years. It is our view that careful and selective attention should be given to non-market forces which will have significant impact on acceptance by society of change and science/technology.

4.5. Industrial R&D Priorities

4.5.1. The major manufacturing companies in the UK have quite sophisticated techniques for developing a foresight of science which will be

of relevance to their future and are also able to obtain further insights by commissioning work. We have the impression, however, that wide-ranging foresight activities are required throughout the R&D system. The SPRU study suggested that Government should stimulate science and technology forecasting by the provision of incentives (financial or otherwise). We agree that such forecasts are necessary but do not see a role for Government and propose that industry itself should set up the mechanisms for undertaking long-term research forecasting on a permanent and routine basis.

4.5.2. Attention was drawn by SPRU to the need for comprehensive data on the inputs to research, and output data in order to develop sophisticated forecasting techniques. Regular and detailed statistics on R&D in firms, universities and the Research Council institutions are required. The Annual Review of Government-funded R&D is beginning to provide comprehensive statistics on public sector funding of R&D. Some information on industrial R&D support is available but is far from comprehensive both in terms of coverage and detail. Nor does the UK possess the large indigenous data-banks on science and technology, patents, etc, available in Japan and the United States. The UK does not possess the large number of 'think tanks' capable of undertaking assessments of science and technology which the USA and Japan possess. UK databases on science and technology tend to be too academic in nature and appear to be geared primarily to the needs of the specialist researcher than to the broader requirements of industrial research, development and exploitation.

4.6. *Conclusion*

In summary, it is clear that profitable innovation requires the matching of two sets of perceptions:

- i. what is possible in scientific and technological terms, and
- ii. what is commercially desirable.

The process of identifying exploitable areas of science must draw together these two perceptions, creating a shared vision of the directions in which to develop this dimension of science policy, visions shared by industry, science, and Government which are based upon continual dialogue and discussion. Moreover, most important of all, to support science in terms of its investment potential requires a commitment by all those involved to achieve the promised return to the benefit of a strategic science policy.

PART II. A CASE STUDY

5. TECHNOLOGY: THE BRIDGE BETWEEN MARKETS AND EXPLOITABLE SCIENCE

5.1.1. In Part II we provide a case study to illustrate some of the principles described in Part I of the report. We have chosen information and communication technology to illustrate the approach.

5.1.2. Our central theme is that of science and the production of goods and services which are valued in the marketplace. Technology enables the promise of science to be exploited in ways which create employment and raise standards of living in general. Of course, we recognise that the links between science and its commercial exploitation are complex and not unidirectional. New technologies are rarely if ever fully developed when they are first introduced commercially. A typical history of a new technology or industrial activity involves a sequence of advances in products and processes, advances which are stimulated by market pressures and by opportunities opened up by new scientific developments. Furthermore, the extent of commercial application of any one technology depends on the technologies with which it is in competition, and it is often held back by a lack of development in complementary technologies.

5.1.3. Our use of the word trend needs to be clarified. The primary trends are those developments in science, economic and social environments which alter the balance of relative commercial returns to the development of different techniques. Thus, changes in the population, age, structure and advances in fundamental knowledge are examples of primary trends which will greatly influence the commercial development of medical technology. Environmental attitudes on waste disposal will greatly influence the application of nuclear technology. Similarly, the persistent tendency of real wages to rise, and changes in the relative availability of different materials and sources of energy continually generates new opportunities for technological development.

5.1.4. These and other primary trends induce secondary trends or patterns of technological development, for example, more fuel efficient aero-engine

technology, more efficient measuring techniques, the displacement of paper-based communications technology with electronics-based communications, but they are consequential trends arising from the pressures and opportunities created by economic, social and scientific change. In what follows, we shall be concerned almost exclusively with primary trends.

5.1.5. We have side-stepped many complex issues by focussing on such broadly defined primary trends. A more detailed identification of strategic promise in science would have to look in much greater detail at developments in particular markets, in the profitability of different technological solutions, and the contributions which different sciences would make to those solutions.

5.1.6. In Part I we suggested that the following elements are required to identify an area of exploitable science:

- a. Economic and social pressures affecting the returns from developing different technologies;

- b. The technological solutions which are likely to arise in response to the pressures;

- and c. The areas of science likely to underpin the required advances in technology.

5.1.7. We do not believe that actual developments in science, technology, and markets follow a simple linear trend and the schematic representation shown at the end of Chapter 6 is used to illustrate the complexity of relationships between markets, technology and science. The one shown relates to communications but similar models could be drawn up for other areas, for example, energy, environment, transportation, health, etc. At the centre of the model are the economic activities which are currently discernable or possible, surrounded by technological applications broadly relevant to such activities which are linked on the outside to the scientific activities from which new technologies will arise. For some activities there is little associated science,

although links with technology might be greater.

General Trends

5.1.8. Various trends in society are so broad that they influence many areas of social and economic activity. The following such trends are the more obvious ones -

- i. Demography - total population, age structure, distribution, household composition, birth-rate, marital status, etc;
- ii. Employment rates - workforce size, activity rate, unemployment, labour mobility and factors affecting, age of workforce, sectoral demands, skills availability, etc;
- iii. Attitudes to work - motivation, work values and rewards, incentives, work quality and ethic, entrepreneurship, training, lifestyles, etc;
- iv. Work forms - full-time/part-time work, job-sharing, self-employment, formal work/informal work, centralisation, mobility;
- v. Reaction to change - acceptance of new technology, attitudes to industry, need for apparent stability, environmental concerns, security, etc.

5.1.9. Other broad trends are also clearly discernable, for example, the increasing desire of people for autonomy, to act independently, and to have greater control over their own lives. Such trends will continue to affect the development of communications and transportation technologies in particular. The impact of single-issue pressure groups whether institution-based or not may have unforeseen results on societal and technological developments. Groups in the legal, trade, industrial, business, scientific, or medical professions are all able to exert pressures which affect the direction and rate of technological development. Government itself is also a major influence.

5.1.10. A major preoccupation or trend in recent years relates to aspects of security, ranging from the safeguard of individuals and their rights or property to the protection of a scientific advance or intellectual concept and various aspects of civil, national and international security. The increasing penetration of electronic technology in the activities of business, industry and society generally will require technological responses and present opportunities. Similarly an ageing population may demand an increase in security consciousness.

5.1.11. General trends in the broad allocation of consumer expenditure are relevant. In 1983, consumers expenditure accounted for about 60% of Gross Domestic Product (GDP). The proportion of consumers' expenditure in various categories was as follows:

	% of total consumer expenditure at current prices		Consumers expenditure indexed at constant 1980 prices	
	1972	1983	1972	1983
Food	18.3	15.0	96	101
Alcoholic drink	7.2	7.3	79	98
Tobacco	4.5	3.4	104	85
Clothing & Footwear	8.3	6.6	82	110
Housing	12.9	15.0	85	104
Fuel & Power	4.4	5.2	94	98
Household goods & Services	8.0	6.8	99	109
Transport & Communication	14.4	17.1	92	110
Recreation, Entertainment and Education	9.0	9.1	75	107
Other goods, services and adjustments	13.2	14.5	90	100

The most significant trends in the last ten years has been the large increase in consumers' expenditure on transport and telecommunications, whilst that spent on tobacco and non-electronic media has decreased.

The proportion of consumer expenditure on food fell whilst that spent on housing rose.

6. MARKETS, TECHNOLOGY AND SCIENCE IN COMMUNICATIONS AND INFORMATION

- 6.1.1. An increasingly complex society is becoming more and more dependent on its knowledge. The planning of a business enterprise depends on the data it gathers on markets and competition. The treatment of a malfunctioning body depends on diagnosis. The science of data handling has progressed greatly in the last ten years largely due to an improved capability for processing information in electronic systems. The improvement in processing has justified improvements in acquiring this data, for the two should go hand in hand - there is little point in gathering data which cannot be used.

Market Trends

- 6.1.2. The two most significant trends which have stimulated developments in new technologies in communications and information in recent years are:

- a. rising real incomes and demand for entertainment, both home-based entertainment and greater variety in entertainment.
- b. information activities are historically labour-intensive but rising real wages has lead to continuous cost-cutting pressure to reduce employment.

- 6.1.3. So far as markets for information are concerned, it is possible to distinguish different types of trends:

- i. Information as decision-making input to business;
- ii. Information which is the final commodity:
 - a. scientific and technological information
 - b. entertainment;
- iii. Information as a public good;

- iv. Difficulty of maintaining property rights on information, and information is expensive to produce but cheap to copy.

6.1.4. The increasing complexity of modern society raises the amount of information required for it to work efficiently which is now taking place on an international scale. This increases the amount and type of information required for decision-taking. The information society depends on:

- a. Acquisition of information
- b. Storage and processing of information
- c. Communications.

The development of computers has provided greater processing and storage power and has lead to the pressures behind the development of digital communications systems. However, these technologies acquire significance only in so far as they displace existing activities. Different types of displacement are:

- a. a trend away from paper-based storage and communications, this has implications for paper-based industries;
- b. displacement of analogue communications systems by digital systems eg digitally-based networks.

6.1.5. Mechanical processing of numbers was first carried out in the last century and electro-mechanical devices made towards the end of the century. Although the first electronic calculating machine was built in 1946, it was in the mid-1950s that the processing of information became an identifiable predominant activity of working people. It has been suggested that it was at that time, certainly in the USA, that the industrial society gave way to a post-industrial society or society based on the production and distribution of information. Much of the so-called service sector, which has grown at the expense of manufacturing, is concerned with information activities, and much of manufacturing industry is itself involved in communication of information.

- 6.1.6. The availability of communication technologies and their widespread use, will permeate practically all human endeavours. Identifying characteristics of information processing techniques and devices will find applications not only for management, gadgetry and games but will have a profound influence on the pattern of life, through, for example, basic changes to the production and processing methods of industry, employment and leisure, economic and social development, and even the interaction between nations. The the key feature of the information society is the controlled acquisition and accumulation of knowledge in communication systems and amplification of the processing techniques with which to use that acquired knowledge. The support of knowledge systems themselves thus becomes a major driving force of economic activity.
- 6.1.7. The proliferation of communication and transfer mechanisms will radically transform transactions between individuals and groups in society relevant not only to private services sectors of the economy but also to education, public sector services, private communication, performance of functions and many others. One aspect of such development concerns the problem of public access to information, such as protection of privacy, for example, by the consent of individuals to the use of stored information and protection of data from external penetration of or internal leakage from communication systems.
- 6.1.8. Better communications will increase the possibility of working from the home, which might have some effect on travel and commuting. The ability to work, with the help of communications, from home will also permit growing numbers of women to continue working after starting their families. This trend, already strong in the field of software, may well spread to other economic fields.
- 6.1.9. One major effect of the growth in world communications technology will be the increasing internationalisation of business opportunities. Thus the satellite will allow information to be instantaneously distributed and shared around the world, with the

possibility, however, for destabilisation to occur over the world's commercial markets rather than being confined to one particular market. Transactions and trading in goods and services round the world will result from an increasingly electronically based world business and commercial community. In money markets the UK financial community might well be fortunate in being in a favourable geographical position to conduct business with the USA and Far East in the same day.

- 6.1.10. Video recording and transmission is in its infancy and business opportunities for future video applications in education, counselling, advisory service, selling, etc are clearly possible. However, technological innovation in communications is unlikely to proceed linearly and advances are likely to occur in fits and starts. For example, experiments have been started in electronic shopping and marketing but it is highly unlikely that people will wish to do all their shopping electronically although for some sections of the populations and for some transactions it will be advantageous to do so. Similarly teleconferencing will not totally replace the face-to-face business meeting, since it will probably be found to be inappropriate or inadequate in many circumstances.
- 6.1.11. Cable television also offers many options for development. Apart from delivering locally produced programmes such systems can produce a diversity of television communication ranging from business, religious, news services to health, childrens, scientific, art or other networks. Already in the USA cable networks are drawing audiences in the prime viewing times from the national television companies and it has been forecast that in the next decade such companies may well have only 50% of the total television audience.
- 6.1.12. The rate of change in communications technology has begun to impact at a local level on paper-based systems and will expand to dominate more widely distributed systems. As well as increasing the speed of flow through information channels and of transactions, the new technology is renewable and self-generating. However, because of such technology, information is being generated at rates unsurpassed in

the past, and uncontrolled, unorganised information could impede the exploitation of the developing knowledge base. Developments in modern information technology will therefore have a vital role to play in the selection of information. On-line database technology will be essential to the wide availability of required useful information and dissemination of knowledge. Wider access to such databases will require development of much better software.

6.1.13. Global communications with a variety of objectives will be of increasing importance, and the satellite will have a key role to play. Satellite technology is advancing rapidly and now incorporates the functions of ground stations. As demonstrated recently the development of space shuttles for the retrieval and servicing of satellites will have relevance for the information economy as well as for space exploration.

6.1.14. Growth in communications may see greater internationalisation of national languages. It is unlikely that a world language will arise although English may be used increasingly as an international business and legal language. As the global economy becomes

increasingly interdependent, national cultural and linguistic traditions may well be reinforced, as they have been in Europe since the formation of the European Community, but communications technology may provide, for example, the simultaneous automatic machine translation of national languages, for broadcasting worldwide, and ease communication between national communities.

6.1.15. In summary, market directions will lead to the continuing need for technological innovation in:

Electronic Information Services - videotex, viewdata, Prestel,
Teletext, cabletext, interactive video, video-cassettes

Home computing - hardware, interfaces, telecomputing, software

Enhanced communications - cellular radio, electronic mail,

teleconferencing

Electronic banking and financial services - automated money tellers
(AMT's), robot banking, smart cards, EFTPOS

Communications Technology in Retailing - information service,
teleshopping

Electronic entertainment - Cable TV, video, satellites (including
and education ground-based infrastructure)

The two important aspects of satellite technology relate to direct communication of both voice and video and the ability of satellites to take in data which has implications in the area of remote sensing. The foregoing developments may be attributed to the tendency of society to increasing intensiveness in information requirements whilst developments in science have reduced substantially the cost of transmitting and processing information; these are the two most fertile trends in stimulating new communications technologies.

THE ACQUISITION AND HANDLING OF INFORMATION

- 6.2.1. In the context in which we analyse the topic, we consider "information" as made up of both data and knowledge and a series of rules for combining them. It is obvious that humans exploit all three in deciding on a course of action. Computers are not yet as good as humans in coming to judgements because programming is still at an early stage of development. The handling of information may be broken down into five parts, each a subject in its own right. These are:

1. Acquisition
2. Organisation
3. Processing
4. Transmission
5. Exploitation

- 6.2.2. The **acquisition** of data depends on sensors, which are now becoming extremely sophisticated, often involving an overlap between two or

more sciences, chemistry, physics, biology and electronics. Not only is progress being made to measure directly parameters which were previously the target of difficult laboratory experiments, but also in detecting traces of elements or molecules - sometimes as few as five atoms. Moreover, we can do this, with exceptional rapidity, often in real time.

- 6.2.3. The **organisation** of the information is an important step in understanding its importance. It can be classified and compared with information already held in the system memory. The size and management of the knowledge base now becomes critical. Cognitive Science and Artificial Intelligence will play key roles in the improvement of information handling.
- 6.2.4. Data **processing** is generally recognised as the feature by which electronic computers have made their major impact. But present computers process information step-by-step, or sequentially, by the so-called Von Neumann process. Future progress may well depend on the ability to master parallel processing techniques, with processing units distributed around the computer, or by optical processing.
- 6.2.5. **Transmission** of information locally, nationally, or internationally is fundamental to data handling. There have been two hardware developments which have completely changed the nature of data transmission, and will determine the shape of the next ten years. The first is optical fibre transmission, and the second satellite communications. The ability to observe the world as a whole gives us not just a system of communications but also an ability to sense remotely, to gather data which was previously not available.
- 6.2.6. The final stage of **exploitation** can be divided into two classes. Sometimes data are exploited in a machine, such as a robot, without human intervention. The growing fields of robotics and computer aided (or integrated) manufacturing are examples. The other class is direct exploitation, where a human is expected to interact with the system. The conclusions emerging from the electronics are presented to the eye or ear of the operator. This interaction can be

cyclic, particularly with voice command to the electronic system acting as the input.

- 6.2.7. It must not be forgotten that much of the progress expected in data handling will depend on the development of new materials. These are the subject of a separate sub-section.

6.3. Data Acquisition

a. Sensors

- 6.3.1. The present standard of sensors and instrumentation in most of UK industry is weak and rudimentary except in the growing area of biotechnology. Therefore, it is hardly surprising that the majority of organisations which we have visited have highlighted the need for improved understanding and development of sensors. In order to produce a reliable device it is important to consider the overall system. That is, the transducer and the associated instrumentation cannot be divorced from the sensor at the front end. Moreover, advances in microprocessor instrumentation now permit more sophisticated control of the sensor, thereby conferring greater reliability and specificity.
- 6.3.2. Several Research Council sub-committees have expressed the requirement for programmes of fundamental research directed towards the applications of specific sensors: for example, medical scientists are concerned about the development of biosensors which could lead to completely new clinical procedures; chemical engineers are developing an interest in the use of sensors for process control; and biotechnologists require improved sensors for detecting minute quantities of organic molecules. There is no doubt that research will need to be multidisciplinary. It will impinge on the activities of solid state physicists, electronic engineers, biologists and enzyme, polymer; and electro- and software chemists. In some areas such as speech input and recognition, it will require signal processing skills of the micro-electronics engineer to integrate the sensor and the detector on the same microchip. The development of sensory

techniques will also have an impact on the production of robots in manufacturing technology.

- 6.3.3. An indication of the wide range of basic scientific research required for the development of improved sensors can be gained by studying requirements in the medical field. Here, priorities vary from cheap and reliable *in vitro* sensors for use in the home or hospital ward, to more sophisticated ones for *in vivo* investigations, eg blood monitoring. Chemically sensitive semiconductor devices utilizing antibody-antigen reactions and novel organic materials which react highly specifically and reversibly (such as receptor proteins) are required. In order to produce biological sensors it will be necessary to develop surfaces compatible with proteins and other biological molecules, to investigate means of immobilizing ionophores in thin films and control the deposition of the active-species onto specific sections of a micro-device. Research will also be required into the physical properties of novel transducers to be used in conjunction with the sensor to provide reliable, on-line, real-time instruments, eg ion sensitive field effect transistors, optical fibre sensors and piezo-electric devices.

b. New Analytical Techniques

- 6.3.4. Advances in instrumentation and in analytical techniques applicable in many disciplines continually emerge as a result of the discovery of new physical effects and principles. We only describe briefly a few examples here and the reader is advised to consult the published literature for more information. For example, the resolution of electronic microscopes is being greatly extended, novel X-ray techniques are emerging based on synchrotron storage rings, nuclear magnetic resonance is now being used successfully in tomography, and surface analytical techniques such as photoemission are currently being refined for the study of thin films and catalysts.
- 6.3.5. Contemporary micro-electronics is already making powerful demands on existing methods for characterising materials and devices. Molecular electronics will demand molecular scales of resolution in chemical

analysis; new techniques are required to study ultra-thin film on substrates, solid-liquid interfaces, surface phase transitions, low dimensional structures, nanomole quantities of molecules etc. UK physicists have an excellent reputation in this type of research which ultimately leads to a profitable export industry in high quality instruments. The UK has been and remains a world leader in the production and export of mass spectrometer and photoelectron spectroscopic equipment.

6.4. Organisation

a Memory

- 6.4.1. Data storage for computers represents the largest single area of activity in current semiconductor research, the objective being to produce larger and faster memories, with corresponding reductions in the "cost per bit" of information stored. There is worldwide recognition of the need for this improvement in memory technology and a large number of major companies are carrying out research in the area. One result of this wide recognition is that memory products have become a commodity on a worldwide scale with cyclic episodes of shortage and glut.
- 6.4.2. Memories however form an essential element in all computers and availability is of fundamental importance. The current emphasis on support for this work given by the Alvey committee acknowledges the key strategic importance of UK sources of this commodity to reduce vulnerability to fluctuations in supply from Japanese and American sources.
- 6.4.3. In addition to semiconductor based memories the exceptionally large capacity available in optical memories (laser/disc systems) is beginning to be the subject of significant research work. There is the prospect that for some applications large optical memories could displace semiconductors.

b. Memory Organisation

6.4.4. With the growing availability of ever larger memories there is increasing interest in the optimal organisation of these memories to make better use of the power available. The human brain is one evident example of the efficient organisation of a massive memory base in which information is retrieved by reference to the nature of the information rather than by making use of the memory 'address' in which the information is stored.

6.4.5. As a pointer to methods of organisation of large memories, therefore, much attention and current research is being directed in the area of cognitive science to begin to understand how the human brain and memory is used to achieve such functions as learning language, recognising speech, recalling experience, etc.

c. Knowledge Base Organisation

6.4.6. At a less anthropomorphic level, experience is rapidly increasing in the construction and manipulation of large accumulations of data and knowledge in existing computer databases. These provide plenty of raw material to enable experiments on the most efficient ways of gaining access to these data. Research on database management is of substantial commercial interest and will undoubtedly result in new products of significant commercial potential.

6.4.7. More recently, the value of accumulations of knowledge has begun to be recognised - or rules from experience of the form 'if A and B then C'. Work with knowledge sets of this sort is the basis of current research in the development and application of Expert Systems. This is widely recognised as an area with huge commercial potential enabling the provision of automated expert advice and guidance in areas such as medical, legal and military applications. With the assistance of such a system a comparative non-expert could provide the effective skill of a highly trained and experienced specialist.

6.4.8. Further development of this approach leads to the area of Artificial Intelligence where advice, decisions and subsequent actions may be made by the computer without the intervention of the human operator.

Again it is widely acknowledged that the commercial potential of such systems is very large indeed.

6.5. Processing

a. Computers

6.5.1. Traditional computers have been organised with one 'central processing unit'(CPU) which carries out one instruction after another (generally operations on data which has been recalled from and is subsequently put back to memory). The sequence of instructions executed by the CPU is exactly determined by a precisely written program which is predetermined by the computer programmer. This consequential instruction approach is generally known by the name of its inventor - von Neumann.

6.5.2. Current developmental activity in achieving greater processing power has largely concentrated on increasing the speed of operation of the CPU, enabling it to carry out more instructions per second, and also by increasing the scope and variety of the operations which it is able to execute. Although substantial increases in computer power have been achieved by this route there are clearly upper limits on achievable electronic speeds and on a sensible level of complexity for the processor.

b. Distributed Processing

6.5.3. With the availability of reasonably cheap semiconductor processors there has been a natural move towards the incorporation of more than one CPU in a single computer. The implication of this is that a number of commands or instructions can be executed in parallel, clearly giving rise to the prospect of greatly increased effective speeds for carrying out computing tasks.

6.5.4. However, the majority of computer scientists have been trained along von Neumann lines and so have considerable difficulty embarking on the design and organisation of a machine which has no single CPU.

There is no corresponding standard approach to the electronics organisation of such a computer and considerable amounts of research will be required to develop effective use of multiple distributed processors. In general terms, there is an assumption that in lieu of one very large memory and one powerful CPU, future computers will contain a large number of processing units each associated with a comparatively smaller segment of memory. Research work in this area has just begun and success in this area will be key in the successful design of the next generation of computers.

c. Software

6.5.5. Implicit in the move to distributed processing approaches is the need for a corresponding new generation of software. What is the optimum way to organise a set of commands to a whole series of processors so as to achieve the optimum execution of a computing task? Again, faced with liberation from the classic serial von Neumann approach there is no standard approach to adopt and at the present time the ability to define effective techniques. It is almost as though software writers had been taken back to the late 1940s and begun the task of organising a computer all over again.

6.5.6. As a result the whole area of software strategy, languages and operating systems for effective data processing is at a highly embryonic stage but is clearly the key to successful exploitation of fifth generation computers.

d. Other Processing Approaches

6.5.7. For some particular applications specialised approaches to processing are possible. For example, it is currently feasible to take an optical image and manipulate it in the optical domain in order to extract fine detail information only. This need involve no digital data processing of any kind. Another application example is the identification of small changes between pairs of images which is a technique currently exploited in component stress analysis and in security applications.

6.5.8. Since optical records contain very large amounts of information when expressed in electronic bit terms, and there are vast amounts of image information which require processing (eg remote sensing satellites looking for weather or resources) then this technique extends the prospect of much more speedy information processing than would be possible in a digital computer. For this reason, this and similar specialised techniques are the subject of much current research.

6.6. Transmission

6.6.1. The last twenty years has seen the habits of the community changing dramatically, with a move away from hard copy to electronic pictures, from books, and to some extent, newspapers to TV. This ability to bring information directly and cheaply into the home has by no means reached a plateau, consumer spending on TV and related hardware having doubled in the last ten years, and still increasing at 7% per annum in real terms. In spite of this growth, the consumer still spends more on letters and telephones than on TV, though expenditure on communications is increasing quite slowly. The improvements in the telephone system in the past ten years have been largely due to the substitution of modern hardware into the existing system, electronic exchanges, transistorised repeaters, microwave links. The first results of revolutionary changes, with progress in optical fibre systems and satellite communications, are beginning to be realised. These will lead to cheaper communications, particularly over long distances.

a. Optical Fibre Communications

6.6.2 It is now possible to impress a light signal into an optical fibre, and detect it 100 kms away, without any amplification en route. Moreover, the system gives many times more bandwidth than conventional cable, so that the same fibre will hold many conversations. The cost of communications, plus electronic techniques for compression of data, will make videophones practical for the

consumer.

- 6.6.3 Improvements in fibres should allow repeaterless transmission under the Atlantic within 10 years, giving considerable competition to satellite systems. The ability of optical fibres to pass information along many close-packed channels without mutual interference can be exploited in many ways, one being in phased-array radar systems. Remote control, either by free-space borne infra-red, or local miniature microwave systems, will become commonplace.

b. Satellite Communications

- 6.6.4 The increasing number and use of satellites in data transmission makes them an important feature for us to consider. A well-publicised use - as telephone repeaters - will come under increased competition from optical fibres. TV distribution in countries with a dispersed population will expand. A development with a pronounced effect on the Third World will be direct transmission from source to set. The low noise amplifiers that are necessary have recently become available, but their cost is still too high for widespread use in poor countries, who need them most. This will change.

- 6.6.5 However, satellites, and communication via them, can take on a more novel and extremely important role, for the satellite can be used on an observation platform for monitoring the atmosphere, the sea, and the land.

c. Remote Sensing

- 6.6.6. The development of sensors and even more of better processing equipment has made remote sensing a subject with great potential. There will, no doubt, be continued interest in remote sensing by aeroplane and further development of sensors which will make this a useful method for ad hoc service inspection. But the main interest centres on remote sensing by satellite because of the long term continuous surveillance of virtually all parts of the earth's surface that is thereby possible. With electromagnetic sensors, information

is yielded by every pass but with operational and infrared sensors a clear sky is required.

6.6.7. Remote sensing has been very useful in the geographical search for mineral and similar sources, although apart from perhaps changes in the time of day, and therefore illumination, an unchanging situation is viewed and, a very few satellite passes are sufficient. Further opportunities for such uses of remote sensors will depend on the development of new sensors. It is different when the object being viewed is changing. Meteorological satellites are well developed, but satellite study of the oceans for surveys, current and surface temperature is at an early stage; instrumentation, also, is not yet sufficiently advanced. The monitoring of the state and condition of crops such as sugar beet, coffee, sugar, wheat, giving greater understanding of the progress of plantations and agriculture will shortly arise with enormous implications for commodity markets. No doubt there will be political and legal problems, but it is expected that these will, in due course, be resolved.

6.6.8 The development of satellite borne sensors is an important field to which the UK has, so far, only made a relatively modest contribution outside specific areas of great scientific importance, such as, in particular, the upper atmosphere and some aspects of sea surface screening. There may well be scope for a broadening of the UK's effort in the sensor field.

6.6.9. Though it is easy to be distracted into believing that the satellite and its instruments are the most interesting parts of the enterprise, the downstream element is likely to pre-dominate. Computerised processing is required not only for the flood of data generated by a satellite, but particularly for embedding this new information in information only attainable by other sensors and methods. Ultimately this union will require a body of skilled interpreters. The development of interpretation techniques and methods, and producing sufficient numbers of people able to participate in these economically very important activities is a major challenge, as is the link with new customers and increasing their awareness of the

value which can be added to their business by information obtained from satellites.

d. Navigation

- 6.6.10. The position of an object on earth can be determined extremely accurately by a satellite. Ship navigation can clearly benefit from a suitable system, but there are also possibilities for vehicle course control in areas where a local transmission system for navigation is impracticable.

6.7. Exploitation

a. Exploitation and Interpretation

- 6.7.1. It is only by the practical applications of information acquisition and handling that users will see worthwhile benefits. The scope for useful applications grows as technical capability for information handling grows. Early computers had limited (but speedy) number manipulation and storage capability and were therefore applied to critical calculation tasks, where the principle ability of the computer was directly exploited.
- 6.7.2. As mass storage of information became technically feasible, user applications were able to expand from high speed arithmetic to the holding and modifying of very large collections of information. Clearing banks' customer account records and airlines' reservation systems are examples of user operations, once performed manually, and now exclusively handled by computers.
- 6.7.3. Today, we have available even more abundant storage and processing capacity enabling applications to be designed which go beyond large but intrinsically simple tasks, towards functions previously only carried out by the human brain, involving, for example, interpretation and judgement. As yet such applications are in early stages of development but their common characteristic is that they are used in an interactive mode with the human operator. Interim results are

made available to the user, who then has an opportunity to confirm, challenge or modify those results before further work is carried out. A working dialogue between computer and user then allows a combination of the intrinsic abilities of each.

- 6.7.4. At present we are learning how best to store and handle information to support this dialogue. Considerable work is required to develop efficient ways to extract human knowledge in a form suitable for machine storage; to identify the rules used in forming judgements such that they can be automated; and to facilitate a ready dialogue between computer and user employing the ear, eye and voice.
- 6.7.5. A small number of such systems operating in limited environments exist at present but, for example, a full scope medical diagnosis ability equivalent to a GP will require at least a decade of development work.
- 6.7.6. Development will be required therefore in: knowledge elicitation; analysis of decision and judgement rules; high resolution visual displays which are capable of accepting user input via touch; voice synthesis techniques for audio output; speech recognition techniques to allow direct voice input and command; and natural language working to allow the dialogue to take place in common usage English.
- 6.7.7. The information filtered and assessed by the electronic systems emerges and is available for use. The direct use, in an automatic engine or robot, is already becoming normal practice in manufacture. The indirect use, via a human being, is also of critical importance. Two systems of output presentation are available, and both will make great strides in the next few years. We describe these before enlarging on direct exploitation in manufacture.

b. Visual displays

- 6.7.8. Optical presentation, the electronic display, has for many years relied on the cathode ray tube (CRT). The television monitor is a refined instrument, but its performance is now outstripped by the

capabilities of the camera and the transmission and processing electronics. There is a demand for flatter systems, with a resolution of 1200 lines, and an area of 1 metre square. It is unlikely that a variant of the shadow-mask tube will meet this specification, but it would be surprising if some satisfactory system were not evolved in the next 20 years.

- 6.7.9. On a less ambitious scale, we can see flat panel displays dominating the market for word processors and vehicle instrument panels, and it is likely they will replace cathode ray tubes in most computers. They will take a fraction of the portable TV market, but their extra convenience will not generally outweigh the poorer picture they give.
- 6.7.10. Both types of display, CRT and flat panel, will become completely interactive, with the operator communicating by touch with the electronic system, and, possibly, to some home base. Home voting on important - or trivial - topics will be simple and cheap. This is likely to become an important technique for market surveys, home shopping and advertisement monitoring.

c. Aural Presentation

- 6.7.11. Research on speech output is now in an advanced stage, and the next five years should see the production of quite sophisticated systems, with a language capability not inferior to a person of average intelligence. The production of words is already solved, in that present machines can read books to the blind. It is more difficult for the machine to decide which pattern of words will carry the intended meaning. Most articles on this topic stress the importance of output to blind operators, but there are a range of uses in real-time situations, where an operator can assimilate speech without being distracted from the scene being viewed.
- 6.7.12. Speech recognition, direct interaction between the voice of the operator and the electronic system is more difficult. Progress here would have great impact on telephone systems, but this, as with most examples, does involve the recognition of any voice. The gains from a

successful development are large, not least would be in security systems. Speech input is three times as fast as professional typing and can be performed non-locally ie while the operator is moving or is remote. The subject is so important that it is certain rapid progress will be made.

MANUFACTURING TECHNOLOGY

6.8.1. In industrialised countries throughout the world today, there is a pronounced trend of increasing efforts in development and implementation of advanced manufacturing technology. This technology includes such developments as new types of machining processes, for example laser machining, new types of materials such as composites, and new ways of organising manufacturing such as cellular manufacturing. However, by far the most significant and important type of advanced manufacturing technology being developed and implemented today is computer integrated design and manufacture. The objective of such advanced manufacturing technology are:

- a. higher quality products straight from the "drawing board;"
- b. reduced development time;
- c. reduced testing time;
- d. reduced machine tool non-productive time;

Computer Integrated Manufacturing CIM)

6.8.2. Manufacturing engineering in the United Kingdom will increasingly be required to consider the totality of the process from raw material to product in much the same way as chemical engineering does at the present time. The traditional compartmentalisation between design and it's methodology, production technology, quality control, and the man-machine interface will be broken down and transformed into an integrated system. Such integrations will be made possible by co-ordination of all aspects of the manufacturing system by extensive use of computerised databases shared across many functions(see

diagram). A flexibly automated factory will use computers in virtually all aspects of manufacturing, integrating production functions with planning and control functions. The application of a flexible automation system may well extend beyond the site of production to co-ordinate with sales and even the retail point. The designer will generate the data base which will define the component. This database can be used with finite element analysis software to determine the stresses, strains and deformations. Solid modelling techniques will be used to examine clearances and the stylistic design. The design of press tools can be automatically generated from the database. The programs for control of machine tools in the manufacturing process will also be automatically generated. From this design database and the market requirements we shall generate inventory control and shop floor scheduling. The manufacturing processes in turn will be automated by robotic tool changing on machines, automated controlled storage and retrieval systems for components, and automated inspection of the finished product by robot.

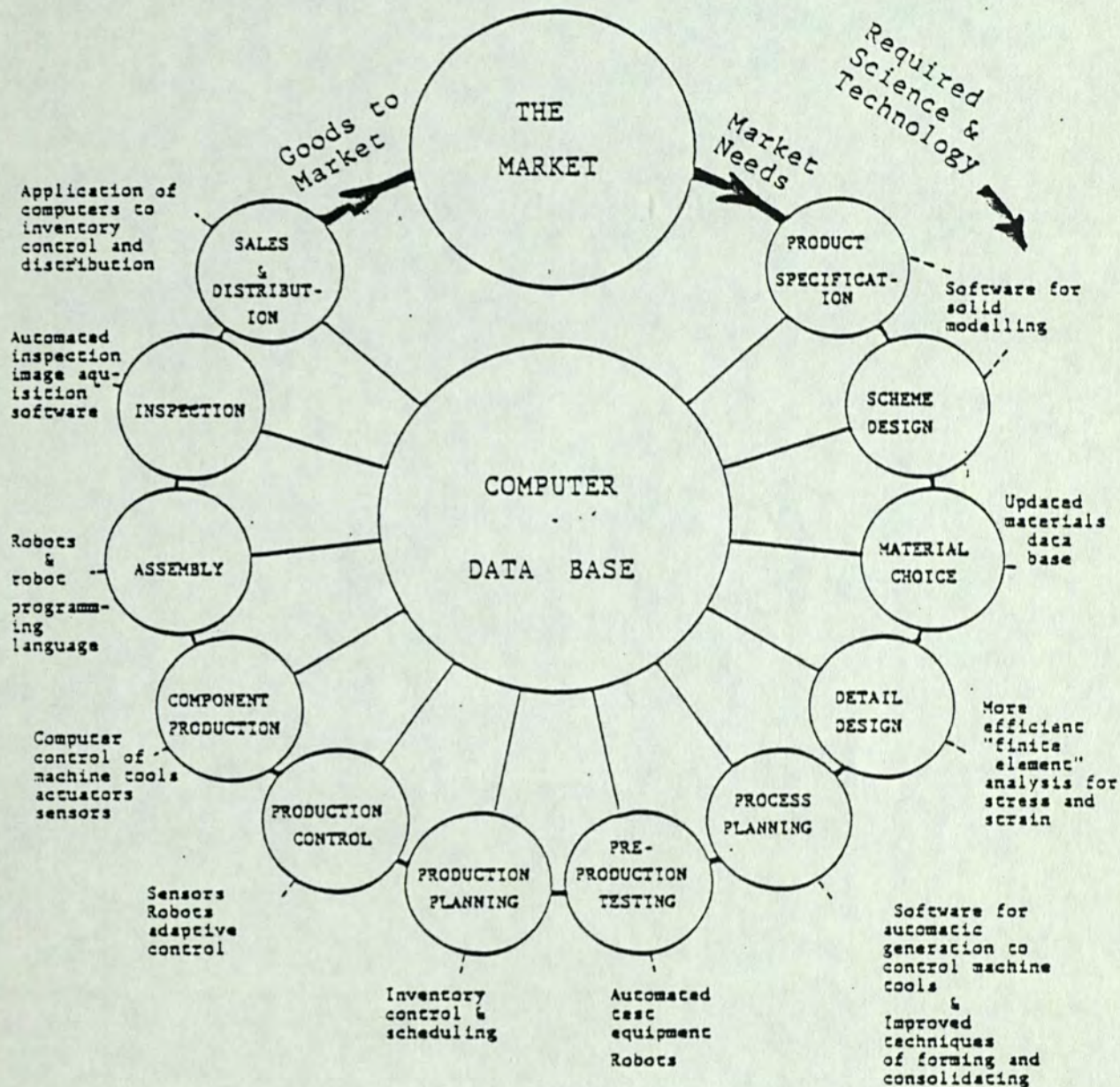
Automatic Processing

- 6.8.3. The rapid increase in computing power cannot be exploited effectively if it is not matched by a corresponding improvement in the quality of the input data, especially in the field of automatic process monitoring control. There is an apparent lack of information on sensor technology and an inter-disciplinary approach is needed. A major area requiring attention in sensor research is concerned with the development of materials to make them cheaper, more robust and more capable of working in hostile environments for long periods without servicing. Much of the basic science exists, it is the translation into hardware and useable technology which is mainly required.

Areas of science and technology which are of importance to the development of integrated design and manufacturing systems are -

1. Software for solid modelling
2. Object recognition and image acquisition
3. Management of large data bases

INTEGRATED DESIGN AND MANUFACTURING



4. Actuators
5. Sensors

MOLECULAR AND SUPERMOLECULAR ELECTRONICS

6.9.1. Electronic and optical devices used in the microelectronics and communications industries rely largely on inorganic materials for their operation. However, the richness of the variety of molecular materials, especially of the organic solid state, offers a range of possibilities for development which contrasts markedly with the relative paucity of possibilities achievable with the elemental crystalline inorganic structures of present day electronics. Molecular materials vary in complexity from simple molecules through molecular crystals and polymers to complex macromolecules such as the proteins and nucleic acids. The consensus forming in the scientific community is that the wide range of structure and complexity of molecular materials coupled with the ability to enlist the techniques of synthetic organic chemistry will make it possible to develop materials with specific properties tailored to specific needs. This will pave the way for the exploitation of new and exciting phenomena.

6.9.2. Research on molecular electronics (defined as the systematic exploitation of organic molecular materials in the field of electronics) is of very wide scope and is inevitably interdisciplinary. It has three main but related aspects; the design and preparation of new molecular materials, the study and optimization of applicable properties, and the development of practical devices. Materials and properties of particular interest include: **Liquid** crystals, both for their now familiar use in displays and for their potential use in switching and memory elements;

Langmuir-Blodgett films with the natural molecular orientation within each monolayer, the control over molecular architecture, and the precise definition of thickness, whose potential is being explored in applied areas such as ferroelectricity, electro-optics, lithography, etc.; **Polymeric photoconductors and semiconductors** which can be doped to increase their response, yielding photocopying systems and novel storage battery materials which need contain no metal; **Organic metals**

and superconductors, of potential value in connecting active materials and conventional semiconducting substrates; **Resist materials** which react in electron beams and permit microlithography with features approaching molecular dimensions; **Photochromic and electrochromic** materials which change colour rapidly to produce stable high-density information storage systems; **Pyroelectric and piezoelectric** materials useful in detectors and transducers such as the electret microphone; **Biological molecules** which can be used as sensors when immobilized on a semiconductor substrate; **Electro-optic nonlinear** materials which combine high response and stability useful in integrated optics and opto-electronics.

- 6.9.3. It is now recognised that modern day computers based on silicon are reaching the frontiers of technology and suffer from disadvantages in many respects. These include the limits imposed by heat dissipation, sequentiality, effective programmability, efficiency and sensitivity. It may be possible to overcome these limitations by building a computer out of molecular components. For example enzymatic reactions in biological systems dissipate very little energy and can perform, reversibly a tactile pattern recognition task that would involve many steps for a digital computer. The prospect of a supermolecular information processor brings the whole range of scientific questions usually considered in the field of molecular electronics into sharper focus, viz molecular structure, switching, interactions, transport and input/output by optical or electronic means. It seems likely that the facility of biological molecules to self assemble into complex useful structures is a worthy target for possible utilization in future technologies. This ultimate expression of molecular electronics is a long way into the future. However, it is clear that the study progression from current technologies to molecular electronics and subsequently to supermolecular electronic systems will draw on a very broad science base involving biology, chemistry, computer science, electronic engineering, materials science and physics.

MATHEMATICS WHICH UNDERPINS DEVELOPING AREAS IN THE ACQUISITION AND HANDLING OF INFORMATION

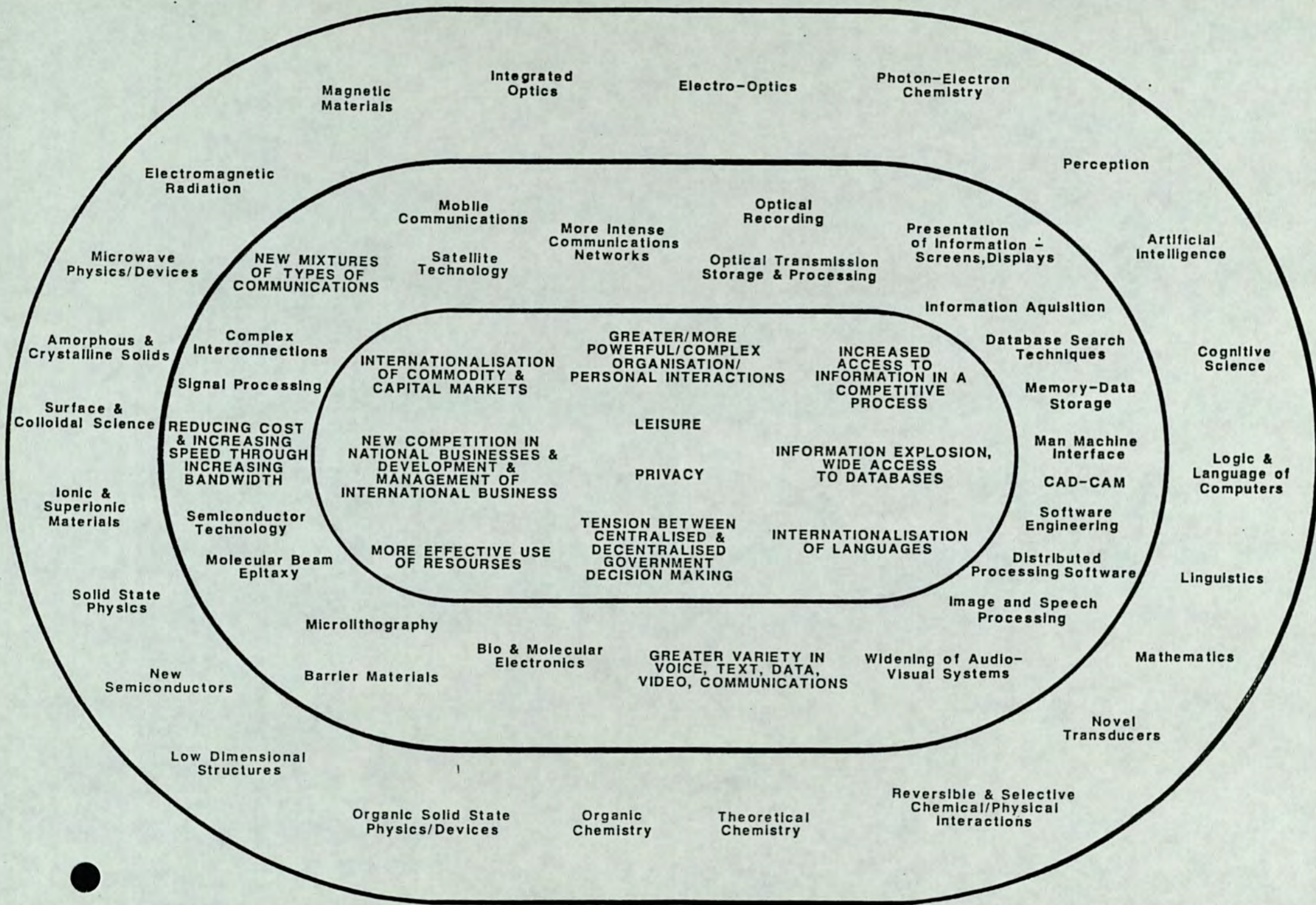
6.10.1. The earlier sections highlight those areas of core science which are likely to lead to developments in the acquisition and handling of information. By a similar token, progress will be required in key areas of mathematics so as to underpin the relevant science. Three important areas are summarised below:

Logic Theory This area used to be the purest of all subjects but, with the advent of high speed computing, this situation has altered dramatically. Indeed, the boundary between "mathematical logic" and the "theory of computation" is very indistinct.

Coding and Optimisation Theories Such theories are important for the construction of efficient algorithms in data processing and to overcome problems of computational complexity in the communications industry.

Artificial Intelligence Human intelligence is believed to be as much dependent on pattern recognition (a parallel processing activity) as a logical activity (a sequential process). Major developments are taking place in the sciences of artificial intelligence, a major thrust at present being in expert systems, computer programmes encapsulating human expertise in a form that can be interrogated. Such systems will have a role to play in capturing and transferring scientific knowledge (place to place or person to person) and in enhancing scientific creativity. Substantial progress in artificial intelligence may have to await the successful introduction of fifth generation computers.

6.10.2. In summary, there will be a continuing demand for mathematicians to develop theories which will ultimately enhance scientific creativity and improve technology. In many areas such as artificial intelligence and whole organism response, progress will only be achieved by close collaborative ventures between mathematicians and physical, computer and biological scientists.



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Unilever plc

The Royal Society
The Fellowship of Engineering
The Conservation Society
Materials Forum

National Coal Board

Science and Engineering Research Council
Medical Research Council
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PART 3 ends:-

PM to Sir H Chilver 7.10.85

PART 4 begins:-

A. Tolan to MGA 5.3.86.