Realising our potential

A Strategy for Science, Engineering and Technology

Cm 2250

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CONTENTS

CHAPTER ONE

SCIENCE AND TECHNOLOGY AND THE FUTURE OF THE UNITED KINGDOM

1.1 The understanding and application of science are fundamental to the fortunes of modern nations. Science, technology and engineering are intimately linked with progress across the whole range of human endeavour: educational, intellectual, medical, environmental, social, economic and cultural. They provide - through tools as diverse as mathematical modelling, biotechnology and earth observation from space - a vital part of humankind's armoury for solving long-standing, world-wide problems, such as poverty and disease, and for addressing new global challenges such as those facing the environment.

1.2 The history of the United Kingdom has shown the intimate connection between free trade, the application of science to tradeable products, and national prosperity. The industrial revolution which played so large a part in creating the modern world was made possible by our great engineers of the eighteenth and nineteenth centuries. In a world where ever fiercer competition prevails, history's lessons are highly pertinent.

1.3 The relationship between Government and science is subtle, complex and of critical importance. More than half of the scientific research undertaken in the United Kingdom is supported from private sources, with decisions about the allocation and use of funds quite properly taken with no Government involvement. It has long been recognised, however, that some of the benefits of scientific research will accrue to society at large and the economy generally, and not just to those carrying out or sponsoring the research.

1.4 There are educational and cultural reasons for funding research; research is needed to inform or develop policy; and Government funding of research can be important for economic reasons where support could not be justified as a straight commercial investment by an individual firm.

1.5 Science and engineering also make a most important contribution to improved public services and the quality of life. For example, recent developments in the bio-medical sciences have made possible the improved diagnosis and treatment of disease and allowed a greater emphasis on preventative medicine. The pace of development of health technologies is increasing, and the interval between scientific discovery and practical application is diminishing. This will lead to improved services and quality of life, with important consequences for the wealth-creating capacity of the nation.

1.6 Furthermore, certain areas of modern scientific inquiry - such as particle physics and space-based astronomy - require expenditure on a scale that can only be found nationally or even internationally, thereby involving science with diplomacy as well as with domestic politics.

1.7 Thus science needs Government and public funds. The decision for Government, when it funds science, as it must, is to judge where to place the balance between the freedom for researchers to follow their own instincts and curiosity, and the guidance of large sums of public money towards achieving wider benefits, above all the generation of national prosperity and the improvement of the quality of life.

1.8 Finding this balance is not a simple task, not least because much basic research will ultimately contribute to wealth creation while some applied research will fail to produce exploitable outcomes. There is no guaranteed method for the successful identification of commercial potential. Predicting exploitability is very difficult and forecasts must necessarily be imperfect. At the same time, the Government does not believe that it is good enough simply to trust to the automatic emergence of applicable results which industry then uses. Nor, on the other hand, does it believe that scientists should or could be told, from above, what to work on in order to generate relevant and industrially applicable results. Explicit decisions must be taken on how far scarce funds should be allocated according to assessment of likely uses, and how far according to judgement of the intrinsic scientific merit of the proposed research.

1.9 The importance of these decisions is demonstrated by the massive expansion in the stock of knowledge and the commensurate increase in the new avenues of inquiry which each advance opens up for researchers. No one nation can afford to sustain a significant independent presence in all of the burgeoning fields of scientific research. The Government must therefore work closely with the scientific and industrial communities to determine the appropriate mechanisms for setting priorities both in terms of the areas of research to support, and the level of funds to be committed to them.

1.10 After the General Election of 1992, the Prime Minister established new arrangements within Whitehall in order to improve the Government's handling of science and technology policy. The Chancellor of the Duchy of Lancaster, supported by a Parliamentary Secretary, was given specific Cabinet level responsibility for the area, the first time for thirty years that a Cabinet Minister had been so designated; and the Office of Science and Technology was established, bringing together elements of the former Department of Education and Science and the Cabinet Office.

1.11 It was natural that these steps, which reflected the growing importance which the Government believed should be attached to science, technology and engineering in the United Kingdom, should be followed by the first general

review of relevant policy and organisation since the early 1970's reports from Lord Rothschild and Lord Dainton[1]. This White Paper is the result of that review.

1.12 The Government has benefited from widespread consultation with the science and engineering communities, industry, the research charities, interested trades unions, and those who have responsibility for the management of research and development in the private and public sectors. Over 800 written responses followed an invitation by the Chancellor of the Duchy of Lancaster for comments on certain questions he posed; many responses went much wider. More than 250 of these have been placed in the Libraries of both Houses of Parliament and in the British Library. The Office of Science and Technology commissioned a number of specific studies which have been published already or are being published at the same time as this White Paper; and other studies and publications by, for example, both Select Committees, the Parliamentary Office of Science and Technology and the Royal Society were timely and valuable (Sections A and D of the Bibliography). The consultative process was also marked by helpful events organised by the Foundation for Science and Technology and the Parliamentary and Scientific Committee.

1.13 The responses we received focussed particularly on the following:

- the widely perceived contrast between our excellence in science and technology and our relative weakness in exploiting them to economic advantage;

- the absence of a clear statement of Government objectives, with the consequent transmission of mixed and sometimes contradictory signals to the scientific and engineering communities;

- within what most respondents recognised must be limited resources, the need to manage Government investment in science and technology to better effect;

- the need for more effective mechanisms for implementing policy, including those policies relating to international collaboration;

- problems in relation to the management of careers in science and engineering.

1 *Full details of those reports may be found in Section H of the bibliography to this White paper.*

1.14 A common theme ran through most responses: the importance of maintaining and improving the United Kingdom's scientific and engineering excellence and skills and their application to national wealth creation. The Government shares this sense of urgency. The United Kingdom's competitive position rests increasingly on our capacity to trade in goods and services incorporating or produced by the latest science and technology. This applies as much, for example, to trade in financial services as it does to manufactured goods and to both small and large enterprises. There are no captive or protected markets on which we can rely; and every year increasingly fierce competition is joined by new entrants from the Pacific rim and elsewhere.

1.15 The United Kingdom has no room for complacency if our present excellence is to be developed as well as it must be to match competitors, old and new. The Education, Industry and Employment Departments are putting in place a range of policies to address this challenge. The Office of Science and Technology will complement this work by focussing on the national effort in science and engineering.

1.16 The White Paper's themes are as follows:

- we are, as a nation, potentially very strong in science and technology. The Government shares the country's pride in the excellent natural and social science and engineering which have been and continue to be done in this country. This strength has been, and remains, an immense national asset. It should be protected. But it will not be properly utilised unless further efforts are made to break down barriers which still exist in the United Kingdom to the acceptance and recognition of the importance of science and technology to our future;

- steps should be taken which, on the basis of other countries' experience, will help to harness that strength in science and engineering to the creation of wealth in the United Kingdom by bringing it into closer and more systematic contact with those responsible for industrial and commercial decisions. Such a systematic interchange between industry, scientists, engineers and science policy makers (both in the public sector and the significant charitable sector from which the United Kingdom derives such benefit) would improve mutual understanding and allow each group to make its decisions against a better-informed background;

- the direction and management of the Government's own research and development effort in recent years have been broadly correct. However, certain modifications now need to be made to the missions, structures, and

management of the Research Councils and Government research establishments to meet better the global challenges now faced by the United Kingdom. These modifications will respect the importance of distinctive policies pursued by different Government Departments, and the need for pluralism and diversity in sustaining research vitality. They will enable the Government to present a clearer sense of strategy to the scientists and engineers it supports, and to those working in partnership with them in educational establishments, industry and the research charities.

1.17 Since this Government came to power in 1979, there has been consistent growth in real terms in the resources invested in the science and engineering base[2]. This White Paper demonstrates the Government's long-standing commitment to supporting the science and engineering base in order to maintain the excellence of our science and engineering and to produce the skilled technical people we need. The Government will continue to allocate public resources to science and engineering on the scale necessary to finance the policies in this White Paper. Detailed allocations will be settled in future public expenditure surveys in the usual way.

1.18 Our specific policies are designed to get maximum value for money from our annual public expenditure of some £6 billion on science and technology.

(1) Government's use of funds and its effort in science and technology will be made more explicit and open. Individual Departmental mission statements (see pages 9 and 10) will be widely disseminated. A Forward Look will be published each year to give the industrial and research communities a clear and up-to-date statement of the Government's strategy.

(2) Technology foresight, jointly conducted by industry and the science and engineering communities, will be used to inform Government's decisions and priorities. The process will be carefully designed to tap into the expertise of people closest to emerging scientific, technological and market developments. The aim is to achieve a key cultural change: better communication, interaction and mutual understanding between the scientific community, industry and Government Departments.

(3) The Advisory Council on Science and Technology will be developed into a new body, the Council for Science and Technology, which will draw on the findings of the Technology Foresight Programme. The new Council will help ensure that the Government benefits from outside independent and expert advice when deciding its own research spending

2 *The term 'science and engineering base' is explained more fully in the footnote to Chapter 3.*

priorities. The information generated by the Council will normally be made openly available.

(4) The Government's schemes for technology transfer will be developed to re-emphasise the importance of the interchange of ideas, skills, know-how and knowledge between the science and engineering base and industry.

(5) There will be easier access, especially for small and medium-sized firms, to the innovation support programmes run by the Department of Trade and Industry and the Scottish, Welsh and Northern Ireland Offices.

(6) The Science and Engineering Research Council will be converted into an Engineering and Physical Sciences Research Council and a Particle Physics and Astronomy Research Council. The Agricultural and Food Research Council will be modified into a Biotechnology and Biological Sciences Research Council. All the Research Councils' missions will be reformulated to make explicit their commitment to wealth creation and the quality of life. Their management structures will be modified to give each one a part-time Chairman and a full-time Chief Executive.

(7) The functions of the Advisory Board for the Research Councils will be absorbed within the Office of Science and Technology. A new post of Director-General of Research Councils will be established within that Office.

(8) The dual-funding mechanism will be maintained in recognition of the distinctive part which research plays within the overall mission of our universities. Clearer mechanisms will be developed for co-ordination between the Office of Science and Technology and the Education Departments to ensure that the two streams of university research funding are complementary.

(9) The Rothschild customer-contractor principle will be maintained and strengthened, in relation to Departmental applied research and development. Departments will continue to develop their role as intelligent customers for science and technology. The Government believes that many of the services currently provided by Government research establishments could be carried out in the private sector, and that privatisation is a realistic prospect for a number of establishments. There will be a further scrutiny of the best organisational and management structures for those laboratories which are likely to remain in the public sector.

(10) Better arrangements will be introduced for drawing together Government initiatives in science and technology, co-ordinating cross-Departmental science and technology issues, ensuring value for money from the science and technology which the Government applies in its statutory, policy-making and regulatory roles, and monitoring performance against the new Forward Look.

(11) Government negotiating positions will be better co-ordinated across the range of European and international science and technology programmes.

(12) The arrangements for the training of post-graduate scientists and engineers will be developed so that the MSc can become the normal initial post-graduate degree in science, engineering and technology, and that PhD training for those who progress beyond the Master's degree is properly underpinned. Greater attention will be given to the relevance of post-graduate training for all careers. Those post-graduates who go on to a career in academic research should be better managed.

(13) There will be a new campaign to spread the understanding of science and technology in schools and amongst the public.

These changes, together with a number of other more detailed conclusions, are described in the following Chapters.

1.19 It has been well said by the President of the Royal Society, Sir Michael Atiyah, in his 1992 Presidential Address, that

"Too much stress on organisational structures may obscure the basic fact that progress in science depends on the ideas, inspiration and dedication of individual scientists, not the machinations of councils, committees and Departments".

The purpose of the changes set out in this White Paper is to give a clearer sense of the vital national contribution made by the ideas, inspiration and dedication of our science and engineering communities, and to devise organisational structures in which the individual can flourish and national priorities and objectives can be more clearly and openly set and pursued.

1.20 The Government proposes to develop a flexible system to enable scientific and technological perceptions to be more effectively shared. This will help to provide a background against which individual researchers can choose their own lines of inquiry. Over time, it will also help Government where

necessary to reorientate the country's research. It will enable the Government to reach a more systematic judgement of the technologies which give the best fit between researchability, technical feasibility and commercial potential. Thus, the national effort will be neither over-prescribed nor under-focussed.

1.21 Government cannot, and will not attempt to, remove from industry its responsibility for investing in innovation and bringing new products to market. Nonetheless, it is the fundamental theme of this White Paper that a closer partnership and better diffusion of ideas between the science and engineering communities, industry, the financial sector and Government are needed as part of the crucial effort to improve our national competitiveness and quality of life. We have the talents; now we need fully to realise our potential.

Science and Technology Mission Statements of Government Departments

Office of Science and Technology

THE OFFICE'S ROLE IS TO ACT AS THE MECHANISM FOR DEVELOPING AND CO-ORDINATING GOVERNMENT POLICY ON SCIENCE AND TECHNOLOGY BOTH NATIONALLY AND INTERNATIONALLY; TO SUSTAIN, ENHANCE AND DEVELOP THE UNITED KINGDOM'S CAPACITY AND CAPABILITY TO HELP ADVANCE SCIENTIFIC KNOWLEDGE; TO STIMULATE THE DIFFUSION OF KNOWLEDGE, THE TRANSFER OF TECHNOLOGY AND THE MOVEMENT OF PEOPLE BETWEEN THE SCIENCE AND ENGINEERING BASE AND INDUSTRY; TO HELP ENSURE AN ADEQUATE SUPPLY OF WELL TRAINED AND SKILLED SCIENTISTS AND ENGINEERS FOR THE SCIENCE AND ENGINEERING BASE AND THE WIDER ECONOMY; AND TO ENSURE THAT GOVERNMENT EXPENDITURE ON SCIENCE AND TECHNOLOGY IS TARGETED TO MAKE THE MAXIMUM CONTRIBUTION TO OUR NATIONAL ECONOMIC PERFORMANCE AND QUALITY OF LIFE.

The Industry Departments
The Department of Trade and Industry, Scottish Office, Welsh Office and Northern Ireland Office

THE DEPARTMENTS' MAIN ROLE IS TO STIMULATE INNOVATION IN INDUSTRY SO AS TO ENHANCE COMPETITIVENESS IN HOME AND WORLD MARKETS. TO FULFIL THIS ROLE, THE DEPARTMENTS PROMOTE THE IMPORTANCE OF INNOVATION AND ITS MANAGEMENT; ENCOURAGE INDUSTRIAL RESEARCH AND DEVELOPMENT, THE SPREAD OF BEST PRACTICE AND THE TRANSFER AND DIFFUSION OF TECHNOLOGY; ENCOURAGE INTERACTION BETWEEN INDUSTRY AND ALL OTHER PROVIDERS OF SCIENCE AND TECHNOLOGY, WHETHER BASED IN THE UNITED KINGDOM OR ELSEWHERE; AND FUND RESEARCH AND DEVELOPMENT IN SUPPORT OF DEPARTMENTAL POLICY OBJECTIVES. THE DEPARTMENTS ALSO

REPRESENT THE VIEWS OF BUSINESS IN THE DEVELOPMENT AND IMPLEMENTATION OF GOVERNMENT POLICY ON SCIENCE AND TECHNOLOGY.

The Education Departments
The Department for Education, Scottish Office, Welsh Office and Northern Ireland Office

THE EDUCATION DEPARTMENTS ARE RESPONSIBLE FOR SCIENCE AND TECHNOLOGY EDUCATION AT ALL LEVELS, FROM SCHOOLS THROUGH TO HIGHER EDUCATION AND POST-GRADUATE TRAINING (THE LATTER JOINTLY WITH THE OFFICE OF SCIENCE AND TECHNOLOGY). THE DEPARTMENTS ARE THE MAIN SPONSORS OF BASIC RESEARCH IN UNIVERSITIES AND COLLEGES, PRINCIPALLY THROUGH THEIR FUNDING FOR THE HIGHER EDUCATION FUNDING COUNCILS, AND THEY SUPPORT THE INFRASTRUCTURE FOR BASIC AND STRATEGIC RESEARCH SPONSORED BY OTHERS. THE DEPARTMENTS ARE COMMITTED TO SELECTIVITY AND ACCOUNTABILITY IN THE USE OF PUBLIC FUNDS ALLOCATED BY THE FUNDING COUNCILS FOR RESEARCH, AND TO HELPING SECURE AN ADEQUATE SUPPLY OF PEOPLE QUALIFIED IN SCIENCE, MATHEMATICS, ENGINEERING AND TECHNOLOGY SUBJECTS TO MEET THE COUNTRY'S NEEDS.

Other Government Departments

OTHER GOVERNMENT DEPARTMENTS ENCOURAGE AND FUND SCIENCE AND TECHNOLOGY IN SUPPORT OF DEPARTMENTAL POLICY, STATUTORY, OPERATIONAL, REGULATORY AND PROCUREMENT RESPONSIBILITIES. WHEREVER POSSIBLE THEY INVOLVE AND CO-OPERATE WITH OTHERS IN MEETING THOSE RESPONSIBILITIES. THEY ALSO SEEK TO ALIGN THEIR OWN POLICY OBJECTIVES WITH THE GENERAL OBJECTIVE OF USING PUBLICLY-FUNDED SCIENCE AND TECHNOLOGY PROGRAMMES TO INCREASE NATIONAL PROSPERITY AND IMPROVE THE QUALITY OF LIFE.

CHAPTER TWO

SCIENCE AND TECHNOLOGY AND THEIR ROLE IN THE ECONOMY

2.1 The major challenge facing the United Kingdom today is an economic one. The nation's first priority must be to improve the performance of the economy to meet the competitive challenge of making the goods and providing the services which others, at home and abroad, choose to buy. Only in this way will the country be able to pay for the goods and services it consumes and for its investment in the future, not least in science and technology.

2.2 The country's future prosperity depends critically on the performance of the many and various organisations engaged in the provision of goods and services[3]. The Government is determined to do all it can to help industry by securing stable economic conditions and shaping its policies in ways which contribute more effectively to industry's own efforts.

2.3 Firms which are skilful at innovation - the successful exploitation of new ideas - will secure competitive advantage in rapidly-changing world markets; those which are not will be overtaken. Although just one of the large number of interdependent factors which bear upon industry's competitiveness, the capacity to put science and technology to commercial use through innovation plays a significant part in successful modern industry.

2.4 Advanced technology features increasingly in the processes used throughout manufacturing and service industries. High-technology products represent a growing share of the country's manufacturing output. Innovation is essential across the whole range of goods and services. It can be achieved through an incremental improvement or it can be a new approach to a well known process or product. In either case, knowledge of the possibilities of science and technology is a powerful ingredient in innovation.

2.5 Management of innovation is the responsibility of companies, as one element in their overall business strategy. Only they can ensure that innovation helps them win markets and serves their commercial interests. However, many firms, particularly smaller and medium-sized concerns, need some help in finding out about recent advances. Government will continue to provide access to advice and support so that best practice - in both technology and management - is widely and rapidly diffused.

2.6 To help to secure economic benefit from science and technology through increased innovation, the Government is engaged in a long-term effort to:

- promote a greater awareness of the importance of innovation throughout all sectors of the economy;

3 *The highly diverse nature of these organisations will not be overlooked in this paper when the shorthand term, industry, is used.*

- improve the effectiveness and efficiency with which firms innovate;

- facilitate access to science and technology relevant to business whatever its source;

- ensure that the needs of firms are fully taken into account in decisions on the direction, nature and content of publicly funded science and technology.

These activities form part of the Government's wider policies to improve the competitiveness of industry in the United Kingdom.

2.7 The Government review, announced in the White Paper *Scotland in the Union: A Partnership for Good* (Section C of the Bibliography), will consider the scope for transferring from the Department of Trade and Industry to The Scottish Office responsibility for a range of schemes in Scotland for encouraging industrial innovation and technology transfer. A similar review will be undertaken of the position in Wales. The object will be to bring about transfer of responsibility wherever practicable.

PROMOTING AWARENESS OF INNOVATION

2.8 All the Industry Departments, supported by the Department of Trade and Industry's Innovation Unit, are taking action to promote awareness of the importance of innovation among senior managers in the business community (including investors and financial institutions), public and private sector business support organisations, and within the education system and media. Measures include local clubs through which firms can assess how they compare with other firms on innovation, the annual United Kingdom Innovation Lecture and support for industrialists as visiting professors. The Industry Departments intend to scale up and extend the scope of these activities.

INNOVATION WITHIN FIRMS

2.9 The innovation process within firms must remain their responsibility. However, the Department of Trade and Industry and the other Industry Departments are taking steps to stimulate good practice in the design and execution of business strategies for innovation and management. Business Schools are being encouraged to develop a national modular Master's degree in the management of technology. Support is also given to provide expert business advice to companies, including advice on innovation. Measures to improve the innovation process in companies include consultancy support and the 'Managing in the '90's' programme which encourages self-help by

companies. In future, innovation will be explicitly included as an element of these programmes.

ACCESS TO SCIENCE AND TECHNOLOGY

2.10 While firms need an in-house capacity to utilise science and technology, they may acquire it from a variety of sources: their own research and development departments, other firms, the United Kingdom's science and engineering base and overseas. The Department of Trade and Industry and the other Industry Departments help in various ways to stimulate firms' own research and development, encourage technology transfer between firms in the United Kingdom, promote the use of the domestic science and engineering base and disseminate information about technology from overseas (see 6.19 below).

2.11 As well as funding research and development for policy purposes, the Department of Trade and Industry and the other Industry Departments have a range of programmes for encouraging industrial research and development through grants and other incentives. In future, the Departments will give increasing priority within these programmes to smaller firms and to partnerships with other public funding bodies in support of innovation.

2.12 The Government does not consider there to be a case for general tax incentives for spending on research and development. Its position was fully set out in response to recommendations by the House of Lords Select Committee on Science and Technology in June 1991 (Section C of the Bibliography). The Government's aim, endorsed in the 1993 spring budget, remains the avoidance of special tax subsidies which distort commercial investment decisions.

2.13 Under the present system, current spending (estimated to account for around 90 per cent of total research and development expenditure) can normally be written off for tax purposes in the year that it is incurred. Capital spending on scientific research receives a special 100 per cent allowance; other expenditure benefits from the normal capital allowance rules. The existing system of relief is therefore already substantial.

TECHNOLOGY DIFFUSION AND TRANSFER

2.14 The Department of Trade and Industry and the other Industry Departments are giving particular emphasis to the improved diffusion and transfer of existing technology between different industrial sectors in the United Kingdom, for example through the Carrier Technology Initiative.

They also intend to devote greater effort to the identification of technology from overseas and to encouraging technology transfer from overseas.

2.15 The policies set out in this White Paper are designed to encourage closer contact and exchanges between the science and engineering base and industry. The Government has promoted this transfer through its LINK and Teaching Company Schemes, discussed further in Chapters 3 and 7.

2.16 This was also the objective of proposals for 'Faraday Centres' submitted to the Government last year by the Working Group on Innovation instigated by HRH The Prince of Wales and by the Advisory Council on Science and Technology. The House of Lords Select Committee on Science and Technology has also held an inquiry (Section C of the Bibliography). The Government welcomes the principles behind the Faraday proposals: the two-way flow of industrial technology and skilled people between the science and engineering base and industry; partnerships between industrially-oriented research organisations and the science and engineering base; core research underpinning product and process development; and industrially-relevant post-graduate training. Having consulted widely, however, it agrees with the Select Committee that the objectives of the Faraday proposals can be achieved by building on and extending the more successful existing initiatives and schemes, rather than by setting up specific centres.

2.17 The Government also accepts the importance of encouraging greater innovative activity at the local level, to involve users and suppliers of science and technology and to improve the local delivery of innovation services. As recognised by the Innovation Working Group and the Advisory Council on Science and Technology, the Faraday principles and these local dimensions are substantially complementary; to be effective the transfer and diffusion of technology must include the interchange and movement of people. The principles will be taken into account when assessing applications for support under LINK, the Teaching Company Scheme and applications for technological development or transfer from industrially-oriented research organisations.

2.18 The Government will:

- further encourage industrial and academic partnerships in the provision of post-graduate research and training (a theme developed in Chapter 7);

- encourage universities as well as industrially-oriented research organisations to strengthen their links with their local business communities;

- in collaboration with the Training and Enterprise Councils, Local Enterprise Companies, Chambers of Commerce and other business support organisations, establish in England and Scotland a network of One Stop Shops to improve access and delivery of business services, particularly to smaller firms. Access to innovation-related services and to sources of science and technology, including simplified Government schemes, will feature in the portfolios of the One Stop Shops;

- consult on how best to improve access to and delivery of business services in Wales.

2.19 The Department of Trade and Industry, other Industry Departments and those Departments with a responsibility for particular industrial sectors will work more closely with firms to promote industry's future business and technology requirements. As part of its competitiveness agenda, the Department of Trade and Industry is improving the quality of its dialogue with business through its sector divisions. All the Industry Departments will act to give a co-ordinated voice for business throughout Government.

TAKING ACCOUNT OF THE NEEDS OF INDUSTRY IN PUBLICLY-FUNDED SCIENCE AND TECHNOLOGY

2.20 Basic research is, by definition, research without a specific end in view and here the market does not operate. The Government has a major role in funding basic research and this is addressed in Chapter 3. On the other hand, the Government believes that it is for firms to fund research and development undertaken to secure competitive advantage in order to make commercial gains. However, the Government recognises that circumstances can arise where market forces do not work in a satisfactory manner and investments in commercial research and development which offer a good economic return to the nation, though not necessarily to the individual firm, will not go ahead without some sort of public support. Even where market failure may prevent a worthwhile project from going ahead, Government support is only justified where the additional benefits are expected to exceed the costs of support.

2.21 Strategic research - where the work, although directed towards practical aims, has not yet advanced to the stage where eventual applications can be clearly specified - represents an important area of shared interest between industry, Government, research charities and other organisations. Because specific applications are not yet clear and the results may serve many diverse purposes, it will often be the subject of shared or collaborative funding, including public funding. The consultation exercise has confirmed that, as a broad generalisation, the scientific, industrial and Government communities do

not always get the best out of their significant strategic research effort, an issue which is addressed in paragraphs 2.23 to 2.33 below.

2.22 Most research and development undertaken by firms are in the categories of specific applied research and experimental development (the development of specific products and services for existing markets or the improvement and upgrading of existing processes). In general, such 'near-market' development (which has sometimes been interpreted incorrectly as being synonymous with applied research) is unlikely to be subject to significant market failure and the continuing presumption is that it will be funded by the private sector. Nevertheless, there will be instances where this general rule breaks down - for example, where the research is generic and points the way towards a range of new applications or where the market is characterised by small firms which can sometimes experience difficulty in raising external finance for potentially worthwhile research and development projects. Nor is it always possible in practice to distinguish clearly which innovation activities are or are not 'near-market'. This means that the 'near-market' guideline cannot be applied unthinkingly or too rigidly. An important test here will be the extent to which all the benefits of support can be captured by an individual firm or venture, which might therefore be expected to pay for the work itself, or by a wide group of firms or society generally. The approach must take careful account of the circumstances of each individual case.

TECHNOLOGY FORESIGHT: A NEW FOCUS FOR A NEW PARTNERSHIP

2.23 The United Kingdom has a strong science and engineering base and some highly innovative and technologically-strong companies. The central thesis of this White Paper is that we could and should improve our performance by making the science and engineering base even more aware of and responsive to the needs of industry and other research users, and by encouraging more firms and other organisations to be more aware of and receptive to the work being done in other laboratories, especially those of the science and engineering base. The Government believes that steps must be taken to encourage greater communication and raise the level of mutual understanding.

2.24 At the moment, many decisions are taken about the relative merits of strategic research programmes which are in competition for scarce public funds, without the benefit of any systematic, well-informed assessment of the match between potential research outputs and the likelihood that they can be appropriated by firms and organisations. Programmes which are successful in terms of the quality of research may offer no commensurate economic benefit

to the country if firms and other organisations cannot use the results. The Government believes that a co-operative effort is needed to produce a better match between publicly-funded strategic research and the needs of industry and other users of research outputs.

2.25 The immediate advantage for Government is that decisions on the balance and direction of the publicly-funded effort in science and technology can then be taken against a more adequate background knowledge of industry's priorities and concerns. For their part, firms and research teams from the science and engineering base will become better informed about each other's efforts and the research work undertaken by Government.

2.26 In this way, the Government will seek to harness the knowledge and insights of all three partners to mutual advantage by encouraging and easing the increased exchange and flow of people, knowledge and ideas. The ways in which the results of research are developed into processes and marketable products are complex and interactive. We must take account of this in designing measures to encourage a closer and more fruitful relationship between all three partners.

2.27 Having considered the experience of other advanced countries and assessed best practice in the United Kingdom, the Government has concluded that this country could and should benefit from the application of technology foresight, not only as a means of gaining early notice of emerging key technologies but also as a process which will forge a new working partnership. This partnership, and networks which develop from it, should bring together scientists and working industrialists who are best placed to assess the significance of emerging technological trends and market opportunities. This should lead to greater common understanding of the trends and uncertainties involved in future technological developments.

2.28 In adopting this approach, the Government recognises that the key to success is frequent and productive informal contacts between scientists and firms. The creation of market opportunities is not a linear process. Firms can commission research. Scientists and engineers can bring their discoveries and know-how to firms. In both cases, this is the beginning rather than the end of the complex process of bringing a product to market. A process of iteration will usually take place, where the scientist or engineer thinks more deeply about the commercial implications of the research while firms assess market opportunities in the light of the research and suggest avenues the scientists and engineers might explore. Contacts cultivated throughout a research programme are much more likely to be successful than exchanges confined to

the beginning and end of the programme. Nor does this process lend itself to formal committees or boards. Hard work and frequent interaction, in the laboratory and the office, on the telephone and face-to-face, will pay off, much more than the adoption of positions on more formal occasions.

2.29 The Government believes that technology foresight will be most valuable if it succeeds in generating informal interaction. Vice-Chancellors already meet, and will continue to meet, Chairmen and Chief Executives. But opportunities should be generated, on a much larger scale, for interaction between scientists and businessmen involved in the day-to-day business of selling in competitive markets.

2.30 The Government will now set in place the framework for such a Technology Foresight Programme, with a view to producing a first report by the end of 1994. This timetable will enable industry and the research community to be closely involved. Their participation will be crucial to the programme's success as a means of generating the sort of informal exchanges which the Government seeks.

2.31 A Steering Group to launch the Foresight Programme will be set up under the chairmanship of the Government's Chief Scientific Adviser. Its members will be drawn from the industrial, scientific and engineering communities, research charities, and from Government Departments, though most of its members will be from outside Government.

2.32 It will be for individual firms and organisations to decide for themselves what use, if any, to make of the results of this programme. Within Government, the results will be an important contribution to the deliberations of the Council for Science and Technology (see paragraph 2.39 below) as it considers its advice to Government on the strategies and corporate research plans of the Research Councils, Funding Councils and individual Government Departments.

2.33 The Government believes that engagement in the process of technology foresight will deliver considerable benefits, as it has in other countries. Scientists, engineers, economists, financiers, businessmen, industrialists, and civil servants will develop a shared appreciation of technological opportunities and industrial possibilities. The networking generated by the exercise will greatly increase interchange between the private, academic and public sectors. The contacts established will be an effective way of putting into practice the Faraday principles.

Remit of the Technology Foresight Steering Group

To draw up an agreed list of technology sectors each of which would be the subject of a foresight assessment overseen by a panel of experts, and to nominate members for these panels.

To oversee the collection of information on scientific opportunities and potential market applications from a wide cross-section of experts in academia, industry, finance, consumer research and Government.

To devise procedures for the initial and repeat consultation with researchers and

industrialists and for converting the results into working documents to enable the panels of experts to identify those technologies within their sectors which they judge of most importance to the country's economy, based on an evaluation of the fit between:

- trends in scientific research and the current or potential availability of strong research groups (science-push)

- emerging economic developments and the current or potential availability of firms or organisations with the ability to appropriate research outcomes in order to seize emerging market opportunities (demand-pull).

To develop procedures for wide and accessible dissemination of the results, including arrangements to extend the partnership arrangements down into regional, local and perhaps sectoral

NETWORKS, WHEREVER POSSIBLE BUILDING ON CURRENT NETWORKING ORGANISATIONS LIKE TRAINING AND ENTERPRISE COUNCILS, LOCAL ENTERPRISE COMPANIES AND ONE STOP SHOPS.

TO MONITOR THE EXTENT AND DEGREE OF FORMAL INTERACTION, ENCOURAGING TWO-WAY SECONDMENTS, BUSINESS AWARENESS SCHEMES AND TRAINING FOR RESEARCHERS, JOINT VENTURES BETWEEN UNIVERSITIES AND FIRMS AND SO ON.

TO SUPERVISE THE DEVELOPMENT OF THE EXERCISE INTO A ROLLING PROGRAMME.

TO LIAISE WITH THE COUNCIL FOR SCIENCE AND TECHNOLOGY IN PASSING TO GOVERNMENT CONCLUSIONS RELEVANT TO PRIORITY-SETTING AND DECISION-MAKING BY THE PUBLIC SECTOR.

A STRATEGY FOR GOVERNMENT-FUNDED SCIENCE AND TECHNOLOGY

2.34 The Government will draw upon the results of the Technology Foresight Programme in setting the future direction, balance and content of its own science and technology programmes.

2.35 Since 1983, the Government has produced an Annual Review of Government Funded Research and Development (Section B of the Bibliography). This gives a comprehensive account of publicly-funded research and development, explaining the purposes for which different Departments fund their programmes, and indicating current expenditure plans. It is therefore an account of past, present and immediate future activity.

2.36 The Government believes that this Review needs to be extended in time and scope. It therefore proposes that from 1994 it will publish each April a Government-wide Forward Look giving a longer-term assessment of:

- the portfolio of publicly-funded work best suited to the broader scientific and technological needs of the country at a time of increasing economic competition, rapid scientific advance and accelerating technological change;

- the extent to which current individual Departmental science and technology programmes are matched to that portfolio, and the prospects of bringing about a closer alignment between the two.

The important tables now produced in the Annual Review will continue to be published in the form of a statistical supplement to the new Forward Look.

2.37 The Forward Look will be prepared by the Office of Science and Technology. The Office will seek contributions from Government Departments through the official Committee on Science and Technology. It will also draw on the findings of the Technology Foresight Programme and will seek the views of the new Council for Science and Technology. The document will be considered in draft by the Ministerial Committee on Science and Technology. Once approved by Ministers, it will be published. The purpose will be to set strategic objectives over a five to ten year perspective and to consider:

- any gaps or imbalances in the education, training and research effort when set against the changing economic, social and scientific environments and when considered alongside the activity of the private sector, including the research charities;

- how our efforts compare with those of our principal competitors;

- the balance between civil and defence research, and between civil research commissioned by Departments and that undertaken by the science and engineering base;

- the balance between domestic and international research and the scope for co-operation with other countries, whether through the European Community or other international frameworks;

- opportunities for achieving synergy across programmes;

- the scope for greater concerted action and collaboration, both within the public sector (between Research Councils, universities and Government Departments) but also, as it becomes possible to draw upon the results of the Technology Foresight Programme, between the public and private sectors. The Government will look to build on the successful co-operative venture between the Wellcome Trust and the Medical Research Council whose joint infrastructural funding agreement was instrumental in the United Kingdom's success in locating the European Bioinformatics Institute in Cambridge.

2.38 The Government believes that, over time and reinforced by the results of the Technology Foresight Programme, its new Forward Look will form the basis for better-informed decisions between competing priorities, which can inform decisions taken during annual public expenditure surveys. The consideration of priorities in the survey will continue to be informed by an assessment, co-ordinated by the Chief Scientific Adviser, of science and technology proposals across all Departments. The new arrangements will make it possible better to relate specific programmes funded by individual Departments to the Government's overall strategy.

2.39 The proposed Council for Science and Technology will replace the Advisory Council on Science and Technology and bring together customers of publicly-funded research, industrialists, academics and business men and women as well as the Chief Scientists (or equivalents) of the Government Departments most directly involved. It will be an important forum of largely independent members. It will be chaired by the Chancellor of the Duchy of Lancaster on behalf of the Prime Minister, with the Chief Scientific Adviser as deputy chairman. The Office of Science and Technology will provide the Council's secretariat. It will be set up no later than January 1994.

2.40 This Council will, drawing upon the Foresight Programme, advise on science and technology issues central to the success of the United Kingdom. It will offer advice to Ministers collectively, via the Cabinet Committee on Science and Technology, on the balance and direction of Government-funded science and technology.

2.41 The Government will continue to require other external advice and guidance on science and technology issues whether of a general or specific nature. The Government is fortunate in the number of high-quality sources of expertise on which it can draw. When an independent view on scientific issues (or on the quality of scientific delivery) is needed, the Government will be ready to turn to the country's learned societies and academies, scientific and engineering institutes and councils, and professional and industrial associations. The Government welcomes the recent formation of the National Academies Policy Advisory Group and will look to it as an authoritative source of independent advice. The Government will also be ready to look for advice from individual scientists and engineers.

2.42 The Government will continue to set up expert groups with time-limited remits to produce reports and recommendations for action on specific issues. Two such groups are currently working on the issues of human genome research and the role of women in science and engineering.

2.43 In addition to the Forward Look, advice received through the channels described above will normally be published, as will any Government response.

2.44 The country will also benefit from the strengthening of Parliamentary scrutiny of science and technology. Parliament now has two Science and Technology Select Committees (several of whose reports feature in the bibliography to this White Paper). It also can draw upon the services of the Parliamentary Office of Science and Technology (whose work is also credited in the bibliography).

CHAPTER THREE

THE SCIENCE AND ENGINEERING BASE

3.1 Nearly two thirds of the Government's spending on civil research and development support the basic and strategic research carried out in the science and engineering base[4]. The Government is determined to maintain and build upon this internationally-renowned asset.

3.2 The role of the science and engineering base is to train and develop skilled and innovative people and to generate and transmit knowledge. It is primarily to the universities that we must look as the source of natural and social scientists, mathematicians and engineers with the depth and breadth of knowledge and skills to address the challenges of the next century. The Government intends to work closely with the private sector and the academic community to help to increase the effective use of highly-qualified people and hence the productive potential of the economy as a whole, and to help develop career structures and reward systems which make best use of the talents of the people working in the science and engineering base. This theme is further developed in Chapter 7.

3.3 Alongside their crucial role in teaching, the universities and other institutions of the science and engineering base are the main providers of the basic research and much of the strategic research carried out in the United Kingdom. They also increasingly collaborate with the private sector in the conduct of specific applied research.

THE IMPORTANCE OF BASIC RESEARCH

3.4 Basic research is undertaken to advance fundamental knowledge, irrespective of any foreseeable application. Such speculative research can be a major source of the revolutionary changes in our understanding of the world, producing important technological advances. Many of the dramatic improvements in recent years in our quality of life and standard of living would not have been possible without these discoveries.

3.5 The uncertainty, long time-scales, external factors and high costs, not least of obtaining and defending associated intellectual property rights (Section C of the Bibliography) are classic reasons why the private sector will only rarely invest in basic research. The Government accepts its role as the main funder of basic research. It wishes to sustain within the United Kingdom expertise across the core disciplines of biology, chemistry, mathematics and physics and to provide the climate where centres of international excellence can develop and flourish. It recognises the importance of providing a framework in which science can progress, as the President of the Royal Society said, through "the ideas, inspiration and dedication of individual scientists".

4 *The term 'science and engineering base' is used to describe the research and postgraduate training capacity based in the universities and colleges of higher education and in the Institutes, Units and Centres operated by the Research Councils, together with the central facilities (whether in the United Kingdom or abroad) supported by the Councils and available for use by UK scientists and engineers. There are also important contributions from some private institutions, in particular those funded by the charities, which in effect function as part of the science and engineering base.*

3.6 There is, however, a limit to the amount of basic research which any one country can afford: at present this country provides six per cent of the total funding for research and development in members of the Organisation for Economic Co-operation and Development. Other countries face the same constraint

> *"No matter how firm our national resolve may be to invest in the future, resources will not expand as rapidly as our intellectual capacity to pursue promising research opportunities."*
>
> (From a report prepared by the US President's Council of Advisors on Science and Technology, December 1992.)

3.7 Basic science is an international enterprise. Progress depends on the rapid sharing of ideas among scientists in different countries. It has an endless frontier, with limitless possibilities for further work. The pace of change is accelerating; in particular the time between basic research and products reaching the market is shortening.

3.8 The consequences are very important and need to be handled with care:

- public patronage of the pursuit of knowledge for its own sake is an essential activity at the heart of our culture and vitality as a nation. But when resources are short they must be devoted to research of outstanding merit;

- the universities will continue to play a vital part in sustaining basic research, at their discretion, through the resources made available to them by the Higher Education Funding Councils, as described later in this Chapter. The Research Councils will also wish to continue to support basic science which falls within their fields of responsibility, not least in response to spontaneous proposals submitted by researchers. But decisions to make Research Council funds available for such purposes must be explicit;

- we must accept that we are a small part of a large international effort. Increasingly there will be specialisation between countries. We need the capacity to maintain flexibility and an ability to understand the achievements of research leaders elsewhere. In some areas we ourselves will lead. But the United Kingdom cannot hope to stretch its intellectual or financial resources in an attempt to support work over the entire area of every research field. It is not realistic to expect that all research proposals deemed excellent in scientific terms can be supported. Nor can every individual with the potential to contribute good quality research in the field of his or her choosing be supported.

A NEW PARTNERSHIP - SCIENCE AND ENGINEERING BASE, INDUSTRY AND GOVERNMENT

3.9 The Government wishes to harness the intellectual resources of the science and engineering base to improve economic performance and the quality of life. It intends, in future, that decisions on priorities for support should be much more clearly related to meeting the country's needs and enhancing the wealth-creating capacity of the country.

3.10 There has already been considerable progress. Over the last decade many universities and polytechnics have undertaken research with and for industry and other partners, either in collaboration or on a contract basis. University income from industry has grown substantially through the 1980's, from £27 million in 1982-83 to £114 million in 1990-91. The number of university-based science parks has increased from two in 1980 to some forty in 1992.

3.11 The Research Councils have also developed closer links with industry to promote the commercial use of their research. They have established some 20 Interdisciplinary Research Centres offering opportunity for collaboration with industry and business in key technologies. They have formed, either on their own or jointly with others, companies to exploit the potential of Council research. They also participate in the cross-Departmental LINK initiative, described below, and various industrially-relevant training schemes, which are described in Chapter 7.

3.12 Full exploitation of the research carried out in the science and engineering base has sometimes been hampered by problems of communication and differences of view. Industry has not always been good at articulating its needs and identifying the scope for collaboration. For many in the universities and Research Councils, there has been a presumption, confirmed by reward and management systems, that by far the most significant criterion to be applied when judging priorities amongst research proposals is scientific excellence.

3.13 Excellence is very important; second-rate research is a poor buy. Funders of research will need to apply rigorous standards and impose strong criteria to maintain quality whilst giving much greater emphasis to relevance. There is no conflict between quality and relevance or appropriability. Indeed Research Councils already take account of multiple criteria when allocating funds. While the Research Councils should focus on the value of proposed research in terms of scientific excellence and timeliness, they should take more fully into account the extent to which outcomes could be taken up by potential

users. When setting priorities and allocating resources, Councils will take account of the needs of their particular user communities - the relevant industrial or service sectors, private and public, as well as central and local Government. The Government will similarly expect research relevant to industrial and other users to be taken into account by the Higher Education Funding Councils in their research assessment exercises.

A NEW MISSION FOR THE RESEARCH COUNCILS

3.14 The current organisation of the Research Council system into five Research Councils stems largely from the Trend Report of 1963 (Section H of the Bibliography) and the Science and Technology Act 1965.

3.15 The Government considers that in general the Research Council system has performed well in supporting high-quality research. Nonetheless, it accepts the judgement which emerged from the consultation exercise, not least from the contributions of the Advisory Council on Science and Technology, the Advisory Board for the Research Councils and the Research Councils themselves, that some reform is now needed. In particular, the Government welcomes and wishes to build on the steps taken by the Science and Engineering Research Council to develop new approaches in its funding of research and training. It agrees with the Council's submission during the consultation exercise that those developments could now best be carried forward within a new model in which each Council is given a clear focus to meet the needs of the users of research. The Government proposes:

- to ensure that all the Research Councils are better equipped to play their part in the new partnership which is central to this White Paper; and

- to make sure that there is enough capacity for the responsiveness and flexibility demanded by the rapid pace of change in science and technology.

3.16 To this end the Government has decided to:

- redraw the boundaries between the Councils, creating six Councils spanning engineering, the natural and the social sciences;

- provide each Council with a mission statement which recognises the importance of research undertaken to meet the needs of users and to support wealth creation;

- create a new framework within which the Councils will operate under the direction of the Chancellor of the Duchy of Lancaster.

3.17 The six new Councils with their missions and user communities are set out below. All five natural science Councils will, where it is appropriate to the pursuit of their specific missions, support the full range of underpinning disciplines. Individual Councils will undertake lead responsibility for the health of particular disciplines.

3.18 In considering possible structures, the Government examined various models. In particular, it considered carefully whether to adopt the recommendations of the Advisory Council on Science and Technology to set up separate funding bodies for curiosity-driven and mission-oriented research. The Government does not wish to run the risk of separating basic researchers from those who are concerned with application; rather it wishes the whole effort to be brought into closer contact with potential users. It therefore favours Research Councils which are able to identify areas for cross-fertilisation and integration along the continuum of basic, strategic and applied research.

3.19 The new Engineering and Physical Sciences Research Council will be responsible for chemistry, mathematics, physics and for all fields of engineering research. It will be expected to develop close links with the industries underpinned by the physical sciences and engineering.

3.20 The Biotechnology and Biological Sciences Research Council will, to a significant extent, combine the current work in those fields of the Science and Engineering Research Council with the current responsibilities of the Agricultural and Food Research Council. The new Council will be expected to develop close links with biologically-based industries outside the medical and health and environmental fields, which will remain within the remits of the Medical Research Council and the Natural Environment Research Council.

3.21 The new Particle Physics and Astronomy Research Council will take over from the Science and Engineering Research Council responsibility for work in those fields, including the maintenance of central facilities and subscriptions to international programmes (see paragraph 6.17 below). Of its nature, and unlike the other five Councils, it will be almost exclusively responsible for supporting basic research. Even so, the Council will not be exempt from a responsibility to consider its contribution to the creation of wealth for the United Kingdom. As its research uses the most advanced technologies, for example, in the design and construction of new telescopes, astronomical instruments and superconducting magnets, the Council has real scope for 'spin-in' and 'spin-off'. The Government expects it to seek to realise this potential.

Biotechnology and Biological Sciences Research Council

Mission:

TO PROMOTE AND SUPPORT HIGH-QUALITY BASIC, STRATEGIC AND APPLIED RESEARCH, AND RELATED POST-GRADUATE TRAINING IN BIOLOGICAL SYSTEMS WITH THE AIM OF ENHANCING THE MANAGEMENT OF BIOLOGICAL RESOURCES AND THEIR UTILISATION AND INTERACTIONS WITH THE ENVIRONMENT, PLACING SPECIAL EMPHASIS ON MEETING THE NEEDS OF USERS OF ITS RESEARCH AND TRAINING OUTPUT, THEREBY ENHANCING THE UNITED KINGDOM'S INDUSTRIAL COMPETITIVENESS AND QUALITY OF LIFE.

User Communities:

INCLUDE THE AGRICULTURAL, FOOD, BIOTECHNOLOGY, PHARMACEUTICAL, CHEMICAL AND HEALTH-CARE INDUSTRIES, TOGETHER WITH UNIVERSITIES AND COGNATE GOVERNMENT DEPARTMENTS.

Economic and Social Research Council

Mission:

TO PROMOTE AND SUPPORT HIGH-QUALITY BASIC, STRATEGIC AND APPLIED SOCIAL SCIENCE RESEARCH AND RELATED POST-GRADUATE TRAINING TO INCREASE UNDERSTANDING OF SOCIAL AND ECONOMIC CHANGE, PLACING SPECIAL EMPHASIS ON MEETING THE NEEDS OF THE USERS OF ITS RESEARCH AND TRAINING OUTPUT, THEREBY ENHANCING THE UNITED KINGDOM'S INDUSTRIAL COMPETITIVENESS AND QUALITY OF LIFE.

User Communities:

INCLUDE INDUSTRY, CHARITIES, UNIVERSITIES, LOCAL AUTHORITIES AND OTHER PUBLIC BODIES, GOVERNMENT DEPARTMENTS AND INDEPENDENT POLICY BODIES.

Engineering and Physical Sciences Research Council

Mission:

TO PROMOTE AND SUPPORT HIGH-QUALITY BASIC, STRATEGIC AND APPLIED RESEARCH AND RELATED POST-GRADUATE TRAINING IN ENGINEERING AND THE PHYSICAL SCIENCES (CHEMISTRY, PHYSICS AND MATHEMATICS), PLACING SPECIAL EMPHASIS ON MEETING THE NEEDS OF THE USERS OF ITS RESEARCH AND TRAINING OUTPUTS, THEREBY ENHANCING THE UNITED KINGDOM'S INDUSTRIAL COMPETITIVENESS AND QUALITY OF LIFE.

User Communities:

INCLUDE THE ENGINEERING, PROCESS, CONSTRUCTION, CHEMICAL, INFORMATION TECHNOLOGY, ELECTRONIC, ELECTRICAL AND COMMUNICATIONS INDUSTRIES, TOGETHER WITH UNIVERSITIES, AND COGNATE GOVERNMENT DEPARTMENTS.

Medical Research Council

Mission:

TO PROMOTE AND SUPPORT HIGH-QUALITY BASIC, STRATEGIC AND APPLIED RESEARCH AND RELATED POST-GRADUATE TRAINING IN ALL BRANCHES OF BIOMEDICAL SCIENCE WITH THE AIM OF MAINTAINING AND IMPROVING HUMAN HEALTH, PLACING SPECIAL EMPHASIS ON MEETING THE NEEDS OF USERS OF ITS RESEARCH AND TRAINING OUTPUT, THEREBY ENHANCING HEALTH, THE QUALITY OF LIFE AND THE UNITED KINGDOM'S INDUSTRIAL COMPETITIVENESS.

User Communities:

INCLUDE THE HEALTH SERVICE AND THE HEALTH-CARE, MEDICAL INSTRUMENTATION, PHARMACEUTICAL, BIOTECHNOLOGY AND FOOD INDUSTRIES, TOGETHER WITH UNIVERSITIES AND COGNATE GOVERNMENT DEPARTMENTS.

Natural Environment Research Council

Mission:

TO PROMOTE AND SUPPORT HIGH-QUALITY BASIC, STRATEGIC AND APPLIED RESEARCH, LONG-TERM ENVIRONMENTAL MONITORING AND RELATED POST-GRADUATE TRAINING IN TERRESTRIAL AND FRESHWATER BIOLOGY AND EARTH, ATMOSPHERIC, OCEAN AND POLAR SCIENCES AND EARTH OBSERVATION, PLACING SPECIAL EMPHASIS ON MEETING THE NEEDS OF THE USERS OF ITS RESEARCH AND TRAINING OUTPUT, THEREBY ENHANCING THE UNITED KINGDOM'S INDUSTRIAL COMPETITIVENESS AND QUALITY OF LIFE.

User Communities:

INCLUDE WATER, CONSTRUCTION, PROCESS, HYDROCARBONS, MINERALS, FORESTRY, AGRICULTURAL, FISHING AND REMOTE-SENSING INDUSTRIES TOGETHER WITH NATURE CONSERVATION AND OTHER REGULATORY AGENCIES, UNIVERSITIES AND COGNATE GOVERNMENT DEPARTMENTS.

Particle Physics and Astronomy Research Council

Mission:

TO PROMOTE AND SUPPORT HIGH-QUALITY BASIC RESEARCH AND RELATED POST-GRADUATE TRAINING IN ASTRONOMY, PLANETARY SCIENCE, AND PARTICLE PHYSICS, WHICH TAKES ACCOUNT OF THE POTENTIAL FOR CONTRIBUTING TO THE UNITED KINGDOM'S INDUSTRIAL COMPETITIVENESS AND QUALITY OF LIFE, BUT WHOSE MAIN OBJECTIVE IS THE IMPROVED UNDERSTANDING OF THE CONCEPTS AND PRINCIPLES UNDERLYING PHYSICAL PHENOMENA AND THEIR CONSEQUENCES.

User Communities:

INCLUDE ELECTRONIC AND COMMUNICATIONS INDUSTRIES, TOGETHER WITH UNIVERSITIES.

3.22 A study is being commissioned to consider the detailed allocation of responsibilities between the new Councils. This will report in time for its conclusions to be drawn upon when the new Councils come into being on 1 April 1994.

A NEW FRAMEWORK FOR DELIVERING THE RESEARCH COUNCILS' MISSIONS

3.23 The Government supports the Haldane principle (Section H of the Bibliography) that day-to-day decisions on the scientific merits of different strategies, programmes and projects should be taken by the Research Councils, without Government involvement. There is, however, a preceding level of broad priority-setting between general classes of activity where a range of criteria must be brought to bear. There is also a need, in a system with six separate Research Councils, for a mechanism to co-ordinate their activities and ensure that they apply common standards and user-friendly methods.

3.24 In assessing how this might be done, the Government carefully considered the model of a single national Research Council. It concluded that such an organisation risked being too large and inflexible to relate easily to its different research communities and customer bases, whether in the science and engineering base, Government or industry. But while preferring a structure with separate, smaller Councils, the Government nevertheless shares the view of the Royal Society that the work which until now has been carried out by the Advisory Board for the Research Councils should be brought inside the Office of Science and Technology. The intention will be to build on the advances made in recent years under Sir David Phillips, the Chairman of the Advisory Board for the Research Councils, to give more central co-ordination and strategic direction to the Councils' activities.

3.25 The Chancellor of the Duchy of Lancaster, as Minister of Public Service and Science, is responsible for the strategy for the science budget. He will continue to make decisions on the grant-in-aid for each of the Councils. In the light of the powers given him by the Science and Technology Act 1965 to direct the use and expenditure of that money by the Councils, he will continue to be ready to issue broad guidance to the Councils, as necessary.

3.26 The Chancellor will in future be supported in exercising these statutory functions by a new Director-General of Research Councils, located within the Office of Science and Technology, enabling the Chief Scientific Adviser to concentrate upon his responsibilities for the lateral science and technology issues across all Government Departments. The Director-General will also be

responsible for helping the Chancellor to secure the successful and high-quality operation of the Research Councils in pursuit of their new missions. In turn, the Director-General will be advised by a small standing group of independent experts selected to allow him or her to draw upon the requisite scientific, economic, industrial and management expertise in considering the baseline programmes, corporate plans, longer-term prospectuses, and performance of the Research Councils. He or she will also work, in consultation with other Government Departments, to devise suitable mechanisms for ensuring that the user communities are able to play a full and proper part in these processes.

3.27 The Director-General, supported by the Expert Group, will be responsible for considering and advising Ministers on the resources needed by the Research Councils, the Royal Society and the Royal Academy of Engineering; and on the distribution between them of funds which the Chancellor of the Duchy of Lancaster makes available for the purpose.

3.28 The Director-General will also be responsible for:

- interpreting to the Research Councils the implications for their work of the Forward Look, described in Chapter 2, and feeding back their views;

- keeping under review the boundaries between Research Councils;

- ensuring that Councils work together to achieve a common approach and take advantage of the possibilities for improved efficiency through joint working;

- encouraging the Councils to keep under review the arrangements for managing, monitoring and funding their Institutes, having regard to Government policies set out in *Competing for Quality* and *Improving Management in Government: The Next Steps* (Section H of the Bibliography);

- supporting the Minister and Accounting Officer of the Office of Public Service and Science in their responsibilities for making sure that the Councils are making effective and efficient use of the funds voted by Parliament.

3.29 On the introduction of these new arrangements no later than 1 January 1994, the Advisory Board for the Research Councils will be abolished.

GOVERNANCE OF THE NEW COUNCILS

3.30 Reflecting their new missions within the framework of the Science and Technology Act 1965, the six Councils will be established with effect from 1 April 1994 under new or amended Royal Charters which Her Majesty in Council will be invited to make.

3.31 Each Council will have a part-time Chairman and a full-time Chief Executive and Deputy Chairman. The Chairmen will be selected with a view to securing representation for the users of research and in order to bring in relevant experience from the industrial and commercial sectors most closely related to the Councils' missions.

3.32 Council membership will be streamlined, to ensure that Councils are small enough to discharge their Chartered functions while having a sufficient coverage and balance of experience and expertise to reflect and express authoritatively the perspective and views of the research and user communities throughout the United Kingdom, including industry and Government. Councils will also begin to recruit more of their senior staff from industry, and in accordance with targets to be agreed with the Director-General, to increase the level of exchanges, secondments and other interactions at all levels between the Councils, industry and Government.

3.33 These new arrangements are expressly designed to strengthen the links between industry and all of the Research Councils. In future, Councils' strategic decisions on their research portfolios will be taken against the background of the results from the Technology Foresight Programme and the Government's own Forward Look. Councils will also be better able to take direct account of the more extensive and deeper links which, in line with their new missions, they will now develop with industry and other users of their research and training output.

3.34 The Government will, of course, monitor the extent to which the Research Councils are successful in delivering this and indeed all aspects of their missions and consider their organisation and level of funding accordingly. To this end, each Research Council's corporate plan will be updated and agreed annually with the Director-General, taking account of the developing needs of industry and other user communities, and the extent to which targets have been met.

3.35 The LINK scheme, and the collaborative training schemes described in Chapter 7, will continue to be important vehicles for the Research Councils' collaboration with industry.

The LINK Scheme

- LINK IS A CROSS-GOVERNMENT INITIATIVE WHICH AIMS TO BRIDGE THE GAP BETWEEN THE SCIENCE AND ENGINEERING BASE AND INDUSTRY FOR THE BENEFIT OF THE UNITED KINGDOM ECONOMY.

- THERE ARE 32 LINK PROGRAMMES. EACH PROGRAMME SUPPORTS A SERIES OF PROJECTS, AND EVERY PROJECT INVOLVES A MINIMUM OF ONE SCIENCE AND ENGINEERING BASE PARTNER AND ONE INDUSTRIAL PARTNER. GOVERNMENT GRANT IS 50 PER CENT OF TOTAL PROJECT COSTS, INDUSTRY PROVIDING THE OTHER HALF.

- LINK HAS SO FAR COMMITTED £200 MILLION OF GOVERNMENT MONEY TO PROGRAMMES. THE RESEARCH COUNCILS HAVE COMMITTED SOME £70 MILLION OF THAT TOTAL, AND ARE INVOLVED IN 30 PROGRAMMES.

3.36 The Office of Science and Technology will now take lead responsibility for LINK, in line with the Office's mission, as set out in Chapter 1, in particular its cross-Governmental perspective and its role in stimulating interaction and movement of people between the science and engineering base and industry.

3.37 Accordingly, responsibility for the LINK Steering Group and its secretariat will be transferred to the Office of Science and Technology. It will report jointly to the Chancellor of the Duchy of Lancaster and the President of the Board of Trade to reflect the Department of Trade and Industry's considerable sponsorship of the scheme.

3.38 The Chancellor of the Duchy of Lancaster will look to the Chairman of the LINK Steering Group and the Chairman of the Teaching Management Committee to work closely with the Technology Foresight Steering Group, to broaden the applicability of the two schemes, and to provide all Government Ministers which support the schemes with a supplementary source of advice on the Research Councils' effectiveness in delivering 'exploitation'.

3.39 As well as working within the overall framework of the Government's Forward Look for publicly-funded science and technology, individual Councils will also have close working links with cognate Government Departments. For example, the Medical Research Council will maintain its close links with the Health Departments. The new Biotechnology and Biological Sciences Research Council will want to build on the close relations which the Agricultural and Food Research Council has with the agriculture Departments.

3.40 The Medical Research Council and the Health Departments have pioneered the concept of a Concordat which articulates their expectations and obligations and provides a framework for the systematic development, review and evaluation of their respective needs, priorities, activities and progress (Section D of the Bibliography). Other Councils and other Departments are working up the concept. The Government wants to build on this sensible good practice so that Departments and Councils are fully informed of each other's current programmes and future plans, and in order to make transparent the relationship between universities, Research Council institutes and establishments and Government research establishments. It proposes that each of the new Research Councils should work with the Government Departments with which they have a significant policy connection to draw up and publish Concordats.

SUPPORT FOR RESEARCH IN THE UNIVERSITIES: THE DUAL SUPPORT SYSTEM

3.41 The Government issued a major policy statement on higher education in its May 1991 White Paper (Section G of the Bibliography). This reaffirmed the production of a trained workforce as the central mission of higher education and announced a series of major reforms including the abolition of the binary line; the establishment of new unitary Higher Education Funding Councils in England, Scotland and Wales; new advisory arrangements in Northern Ireland, and new quality assurance and assessment arrangements.

3.42 The May 1991 White Paper reaffirmed the Government's commitment to a dual support system for university research, under which the universities have access to two streams of public funding for research - general funds provided by the Higher Education Funding Councils and available for use at the institutions' discretion, and specific funds, provided by the Research Councils and tied to specific projects. It set out the criteria - plurality, competition, selectivity and accountability - to be applied to the future funding

of university research. It also confirmed changes in the boundary between the two funding streams, designed to minimise confusion and improve accountability.

3.43 The May 1991 White Paper considered two alternative models for distributing the general research funds within the dual support model:

- funding teaching and research separately, with the general research funding routed either through the existing Research Councils, or through a new research funding agency building on the existing Advisory Board for the Research Councils' arrangements;

- the continuation of a single channel - on the lines of the Universities Funding Council - for the general funding of research alongside teaching.

It noted that both these routes had attractions; and that the first could be a logical step in the development of research funding which the Government did not rule out for some future time. It concluded, however, that for the purpose of introducing the wider higher education reforms the second model was to be preferred; and that the general research funds should flow, alongside funds for teaching, through the Education Departments and the new Higher Education Funding Councils.

3.44 The Government has reviewed this policy in the light of the consultation exercise conducted for the current White Paper - in particular, of the Advisory Council on Science and Technology's recommendation that general research funds should continue to flow through the Funding Councils but should originate from the Office of Public Service and Science rather than the four Education Departments. It has concluded that there should be no change in the mechanisms for general research funds which will therefore continue to flow through the Education Departments and the Higher Education Funding Councils.

3.45 However, the Government accepts that this places a premium on the need, acknowledged in the 1991 White Paper, for good working links in order to ensure:

- an effective, mutually-reinforcing partnership between the two sides of the dual support system at all levels - within Government, between Funding and Research Councils, and between Research Councils and universities;

- that all recipients of public funds for research have a clear understanding of the Government's strategy as expressed in the Forward Look described in Chapter 2 and that the arrangements for allocating funds operated by the Research Councils and by the Funding Councils provide recipients with the incentives to contribute to the achievement of that strategy;

- that those mechanisms also provide the accountability and transparency appropriate to funding provided from the public purse;

- that excellence and relevance are sustained through competition and selectivity which ensure that funds are available to seed new ideas and new people, as well as for those with proven records.

3.46 The Government will look to the Funding and Research Councils to consider and further develop institutional and personal incentives to motivate staff to work towards the achievement of these changes and the related objectives and targets.

3.47 Effective links are vital in a field where the universities and Research Councils are joined by many other funding groups with an interest - industrial and other employers, the British Academy, medical and other research charities, and Government Departments. The Government welcomes the example already set by the recent formation of the broadly-based Working Group on Post-graduate Support, set up to review the division of responsibilities for funding the training of post-graduate research students.

3.48 The Government will increase cross-membership between the Research and Higher Education Funding Councils. New arrangements for co-ordination will be needed to reflect the interests of the four Education Departments now responsible for funding research in the United Kingdom, as well as the interests of the Office of Science and Technology for the science and engineering base throughout the Kingdom. There will be a new co-ordinating committee for the science and engineering base chaired by the Chief Scientific Adviser, and involving, as necessary, participation by other funding groups, such as the research charities. The co-ordinating committee will, as necessary, refer issues needing resolution to the Ministerial and official Committees on Science and Technology.

CHAPTER FOUR

SCIENCE AND TECHNOLOGY AND THE MINISTRY OF DEFENCE

4.1 As the Gulf conflict illustrated, technology can provide the decisive edge in military operations; a substantial investment in defence research and development is therefore vital for our forces. The primary purpose of such investment is to ensure that the nation continues to have the military capabilities necessary for the successful implementation of the Government's defence and security policies.

4.2 In *Civil Research and Development* published in 1987 (Section H of the Bibliography) the Government envisaged a gradual reduction in the real level of defence research and development over a decade. The latest published plans for defence (*Cm 2219* Table 4.14) indicate that a significant reduction is taking place: plans for 1995-96 are one fifth lower in real terms than expenditure in 1987-88.

4.3 In 1993-94 the Ministry of Defence expects to spend some £2.6 billion on research and development to meet the needs of the Services. Of this around three quarters are accounted for by development programmes for specific equipment normally undertaken by industry, the balance being spent on research.

4.4 By the turn of the century the reduction in Government defence-related research and development is expected to be about one third. Within this, spending on research is planned to reduce by some 15 per cent over the next five years, while, at the same time, rationalisation of the Defence Research Agency will bring substantial efficiency improvements. The reduction in development expenditure will be proportionally greater than in research.

4.5 Research is sponsored on a customer-supplier basis, and is mainly provided through the Defence Research Agency. Over the next few years industry is expected to play a greater part in meeting defence research needs as a result of the decision to expose to competition a greater proportion of the funds spent with or by the Agency. This proportion is expected to rise from about one quarter in 1992-93 to about two thirds by 1997-98.

4.6 The Ministry buys commercial technology wherever it offers best value for money, as it is increasingly likely to do. This produces opportunities for 'spin-in' from the civil to the defence sector. Micro-electronics and information technology are areas in which this has happened. Fresh possibilities are identified in the continuing programme of technology audits, and - to reflect the fact that some significant activity is outside the technology audit programme - foresight exercises are conducted to identify important

technologies which will underpin future defence applications. Companies have every opportunity to offer their technology for defence purposes in bidding for defence equipment projects.

4.7 The Ministry is making increased efforts to:

- ensure that the technologies its research generates are more widely available for civil use. 'Spin-off' to the civil sector includes a wide range of technologies, from speech recognition and water pollution control to avionics and advanced aircraft materials;

- exploit the commercial potential of its research;

- encourage collaboration with the civil sector wherever possible so as to enhance the contribution of its research programmes to the economy as a whole. Collaboration encourages 'spin-off' to the civil sector and the use of dual technologies in defence applications.

4.8 The Defence Research Agency is playing a central part in these efforts, and the work previously pursued by Defence Technology Enterprises Ltd has now been superseded by new Agency initiatives.

4.9 The Agency is establishing a strategy for its relationship with industry which will encourage the transfer of technologies. The transfer of the Agency to Trading Fund status on 1 April 1993, together with the Agency's rationalisation programmes, will enable the Agency to become progressively more commercially competitive. It is developing the non-Governmental use of Agency facilities to undertake profitable ventures and will vigorously pursue the commercial exploitation of technology generated within the Agency to maximise its royalty income.

4.10 The Agency's annual report will in future monitor progress in transferring its expertise and technology to industry and on the Agency's generation of income from sources outside Government.

4.11 The Agency at present contracts with industry and the universities to procure some £200 million a year of defence-related research and associated products and services. There is a continuing programme of joint funding with industry of technology demonstrator programmes. The proportion of Agency research carried out in-house is expected to decline, as more work is exposed to competition. Progress will be tracked in the Agency's annual report.

4.12 Central to the development of the Agency's relationship with industry is the Pathfinder programme, launched in 1992. Industry is being given access to the Agency's forward plans and invited to contribute projects which align with companies' own plans. The first round prompted an enthusiastic response, with some 600 proposals received. This indicates the reception Government can expect for the wider Technology Foresight Programme proposed in Chapter 2 - the Steering Group for the latter exercise will work closely with the Ministry of Defence to share experience and lessons. Amongst the expected benefits of the Pathfinder programme is the opportunity for industry, through early involvement, to identify those ideas likely to have wider applications, thereby meriting investment for development for civil as well as military purposes. The programme will also allow industry to influence the nature of the Agency's work to facilitate wider future applications.

4.13 At the same time, the Agency is developing a network of contacts with the civil research sector. Research clubs with private firms pursue research of common interest such as remote-sensing and robotics, and the Ministry collaborates with Research Councils each year in Joint Grants for work of defence relevance in the academic sector. Joint defence/civil programmes are mounted with the Department of Trade and Industry on some aspects of aerospace technology. Use is made of LINK, where joint programmes include work on helicopter technology and semi-conductor materials.

CHAPTER FIVE

SCIENCE AND TECHNOLOGY AND THE CIVIL DEPARTMENTS

5.1 So pervasive are science and technology nowadays that most Government Departments use them - to a greater or lesser extent - when exercising their policy, regulatory, statutory and procurement responsibilities. Each Department will have its own particular way of expressing the generic mission set out in the box in Chapter 1. Increasingly, Departments are producing their own science and technology strategies. For example, the recent White Papers *The Health of the Nation*, *This Common Inheritance*, *Scotland in the Union: A Partnership for Good*, and *Innovation 2000* (Sections C and E of the Bibliography) demonstrate the extent to which policy is infused and informed by science and technology. This important and positive trend can be traced through the Annual Review of Government Funded Research and Development (Section B of the Bibliography).

5.2 As with research and development undertaken for national security, programmes undertaken or supported by civil Departments in pursuit of their policy objectives can also provide results which industry could use. There is an opportunity for industry itself to be involved in the formulation of such work, thereby maximising the probability of 'spin-off' for the trading economy while preserving the integrity of Departmental policies. Equally, there are possibilities for commissioning work of dual use - for policy and commercial purposes - which represents a more cost-effective solution for the nation than tackling the two objectives separately. Some policy Departments will increasingly make use of joint funding with the Department of Trade and Industry and with firms for these purposes.

5.3 Departments obtain scientific advice and services, act as customers for applied research, and commission basic and strategic research to underpin and further their wider policy objectives. The customer-contractor relationship was established by the Rothschild Report of 1971 (Section H of the Bibliography). As part of the preparations for this White Paper, a special study was carried out under the auspices of the Office of Public Service and Science into the allocation, management and use of Government expenditure on science and technology. The report of this study is being published at the same time as this White Paper (Section E of the Bibliography). The Government has concluded that the 'Rothschild principle' remains as valid today as twenty years ago. It believes that the utility and quality of research needed by civil Government Departments are best guaranteed by leaving them free to determine their own needs and commission the work from suppliers who compete to meet their specifications.

5.4 Within this framework, however, the Office of Science and Technology will take an active role in drawing together Government initiatives; promoting opportunities for collaboration between Departments; identifying areas of overlap or duplication; encouraging Departments to develop relevant output measures and performance indicators and to evaluate the success of programmes they commission. The Technology Foresight Programme described in Chapter 2 and the Forward Look endorsed by the Cabinet Committee on Science and Technology will set a broad framework for these activities.

5.5 The Office of Science and Technology will attach particular importance to ensuring that issues and developments which cross Departmental boundaries are effectively handled. Additional machinery may from time to time need to be put in place to address these, building on the experience gained from the British National Space Centre, and the Inter-Agency Committees on Global Environmental Change and Marine Science and Technology. Departments will, where appropriate, embody their working relationships with Research Councils in Concordats, as described in Chapter 3.

5.6 The official Cabinet Committee on Science and Technology will be responsible for keeping under review Departments' performance in relation to the Forward Look for Government-funded science and technology. Departments will be expected to demonstrate:

- adequate systems for consulting those with an interest in the outputs of their research and development programmes, especially industry, and for reflecting the results in their contributions to the Forward Look;

- success in achieving research objectives in conformity with the Forward Look, for example in improving the quality of life, increasing the extent of collaboration with industry and securing the commercial exploitation of research results.

ALLOCATION, MANAGEMENT AND USE OF GOVERNMENT EXPENDITURE ON SCIENCE AND TECHNOLOGY

5.7 Since 1989, the Government has taken a number of measures to strengthen the customer-contractor relationship. Responsibility for commissioning research and development has generally been placed with the relevant policy divisions of Departments tapping into the intelligence built up by the Chief Scientists' groups and equivalent arrangements within Departments. These divisions hold a budget, which they use to implement

their decisions on the research and development they need to meet their policy objectives. They draw up specifications and enter into contracts with the suppliers whom they judge can best deliver to specification. The divisions are expected to mount competitive tenders wherever practicable, and to seek value for money. In addition, Chief Scientists take a strategic overview of the contribution of science and technology to policy development over both the long and short term.

5.8 In parallel, almost all of the Government research establishments have become Next Steps Agencies. In common with other Agencies, they operate at arm's length from their parent Departments within an agreed management framework. Each is headed by an accountable Chief Executive who is set annual performance and financial targets by the responsible Departmental Minister. The Agencies listed in the box on page 45 are expected to be financially self-sufficient and cover their costs from charges which they make to their customers. They are encouraged to compete for business from other public sector customers.

5.9 In these ways, responsibility for determining research priorities has been placed clearly on the customer, and market forces have been brought to bear on the research and development undertaken by Government Departments. However, the study conducted in preparation for this White Paper recommended that more could be done to extend and accelerate the operation of market forces in relation to the science and technology which Government Departments commission in support of their policy, statutory, regulatory and procurement responsibilities.

5.10 The Government believes that the study has identified a number of steps which could usefully be taken to strengthen the customer capability of Departments. All Departments must have effective procedures for reviewing their requirements for scientific advice and services, and their delivery. Competitive tendering procedures, which avoid favouring one supplier over another, must become the normal mechanism for placing work unless there are significant cost or wider value for money considerations that justify alternative action. The Government will publish annual information on the extent of competitive tendering and, more generally, will review progress in carrying forward the study's recommendations on Departments as customers for research and development.

5.11 The Government also accepts the study's findings that a fully open market for research and development, accessible to all competent suppliers, will enable Departmental customers to obtain an efficient and effective service from

Science and Technology Agencies

	Department	*Launch*
Central Science Laboratory	Ministry of Agriculture, Fisheries and Food (MAFF)	April 1992
Central Veterinary Laboratory	MAFF	April 1990
Agricultural Development and Advisory Service	MAFF/Welsh Office	April 1992
Scottish Agricultural Science Agency	Scottish Office	April 1992
Transport Research Laboratory	Department of Transport	April 1992
Defence Research Agency	Ministry of Defence (MOD)	April 1991
Chemical and Biological Defence Establishment	MOD	April 1991
Meteorological Office	MOD	April 1990
Building Research Establishment	Department of the Environment	April 1990
Forensic Science Service	Home Office	April 1991
Natural Resources Institute	Overseas Development Administration	April 1990
National Engineering Laboratory	Department of Trade and Industry (DTI)	October 1990
National Physical Laboratory	DTI	July 1990
Laboratory of the Government Chemist	DTI	October 1989
Warren Spring Laboratory	DTI	April 1989

a broad supply base embracing both public and private sector suppliers. This will facilitate exchanges and contacts between the public and private sectors as customer Departments continue to diversify their supplier base.

5.12 The Government believes that many of the services currently provided by its research establishments could be carried out in the private sector, and that privatisation is a realistic prospect for a number of establishments. However, there are other establishments for which privatisation is not currently a realistic option. Where establishments are to remain, for the time being, in the public sector, the Government will ensure that customers are provided with a high-quality service in a way that represents best value for money. Careful consideration will need to be given to holding the level of any such capacity to the minimum necessary to meet Government's statutory responsibilities and other essential requirements.

5.13 The Government therefore intends to undertake a scrutiny of the public sector research establishments to review, sector by sector, the future status of establishments, looking in depth at privatisation, rationalisation and different options for ownership. It will build upon reviews in progress, or which have recently been completed, as part of the regular appraisal and review process undergone by all Next Steps Agencies. It will also take account of special reviews already under way, such as those announced recently by the President of the Board of Trade.

5.14 The Government recognises that science and technology are integral to the missions of many Departments, and that changes should strengthen the effective provision of scientific expertise and advice.

CHAPTER SIX

SCIENCE AND TECHNOLOGY AND INTERNATIONAL CO-OPERATION

6.1 Science and technology do not respect political or national boundaries. In recent years, especially, they have become truly global in their nature for several reasons. Key issues, such as the environment, human population and AIDS, plainly have a global dimension. The academic traditions of international co-operation and partnership mean that the results of basic scientific research are rapidly disseminated to an ever-growing international community; improvements in global communications have accelerated this process. Today scientists are probably more aware than ever before of the importance of contacting colleagues working elsewhere on subjects related to their own area of study. The mutual interest goes beyond subject specialisms to a more general awareness of the benefits that can accrue from knowing more about the conditions and ways in which fellow researchers are working elsewhere.

6.2 Similarly the number of technologically-advanced countries has increased. Recently-industrialised countries have been able to exploit the international knowledge and science base by developing a domestic capacity sufficient to enable them to understand, develop and exploit research findings, irrespective of their countries of origin. The same is true of individual companies. They too are operating internationally, reflecting not only the importance of larger markets but also the flexibility of much modern technology and the potential for pursuing technological opportunities in many different locations.

6.3 The Government attaches great importance to having an outward-looking, global perspective in its science and technology policy. Last year, a special programme was launched to help scientists in the former Soviet Union. This year, the Government is setting up a new advisory group to develop future scientific and technological relations with Japan and other countries in the Far East.

6.4 The Government played an active part in the 1992 United Nations Conference on Environment and Development when the Prime Minister announced both the Technology Partnership Initiative, building, together with developing countries, on the United Kingdom's track record in transferring environmentally-sound technologies, and the Darwin Initiative, which placed the United Kingdom's scientific, managerial and commercial strengths in biodiversity at the service of the global efforts aimed at the conservation and sustainable use of biological resources. The Overseas Development Administration has a key role to play in promoting sustainable development in countries supported by the British Aid Programme; and the British Council is facilitating human resource development and the transfer of technology.

6.5 The United Kingdom must continue to play an active part in international scientific and technological activity at all levels, whether this involves individual scientists, companies or Government. As the newly-emergent nations begin to contribute to extending and expanding the knowledge base on which the technologies of the future will depend, this country's world share of total scientific research will inevitably be reduced.

6.6 The Government recognises that it is vital to use our own scarce resources to best effect by co-operating in a sensible international division of labour, facilitating foreign access to the patented findings of research undertaken in the United Kingdom while at the same time improving our take-up of the far greater proportion of research carried out overseas. This will be the foundation of the Government's international policy for science and technology. The Chancellor of the Duchy of Lancaster, as Minister of Public Service and Science, will play an active part in helping to co-ordinate the United Kingdom's position across the whole range of international science and technology collaborations and agreements.

EXCHANGES AND CO-OPERATION AT THE INDIVIDUAL LEVEL

6.7 The Government recognises the important contribution of the individual links between scientists and laboratories, often organised along subject lines. The International Council of Scientific Unions, and the Royal Society, as the United Kingdom member of that Council, have played a particularly important role in promoting unfettered international scientific contact. The Government helps to promote exchanges and links through its support of the British Council and through the aid programme. It is right that scientists and engineers should themselves take the lead in developing these contacts and exchanges. Funding bodies should nevertheless seek and receive reports evaluating the use of their funds in developing such links.

EXCHANGES AND CO-OPERATION WITHIN THE EUROPEAN COMMUNITY

6.8 Naturally, and in line with the general principle of subsidiarity, some science and technology programmes are best considered and conducted at the national level. But the Government believes that an important benefit of Community membership is the access which it provides to European-wide research collaborations. A much wider and more varied group of partners is involved than could ever be possible through a purely domestic research programme. In its participation in the Community's Research and Development Framework Programmes which have been running since 1984, the Government has worked with its partners to build up a research portfolio

which will help underpin the competitiveness of European industry in world markets. This has placed the focus on pre-competitive research, in particular on research leading to the development of standards and codes of practice, as well as on underpinning infrastructural research programmes addressing European environmental, medical, agricultural and training issues.

6.9 Between 1987 and 1991 British academics and industrialists secured just under 20 per cent of all the contracts by value awarded under the Community Research and Development Framework Programmes. The consultation exercise was helpful in drawing out the perceptions of these participants and the Government proposes to draw upon their observations in developing its future negotiating and management approaches to the Framework Programmes. The Government will:

- use technology foresight and the Forward Look for Government-funded science and technology, described in Chapter 2, to draw industry and the science and engineering base more effectively into its policy-thinking on the purpose, size, direction, shape and content of future programmes;

- work with industry and the science and engineering base to generate a more influential exchange of information and opinions with the Commission;

- maintain its efforts to improve the management of Framework Programme lines, not least to bring about a more rigorous evaluation of Community-funded research and the more systematic dissemination of research findings;

- help to develop effective links between the Community's Relay Centres. This may be facilitated through special access points such as One Stop Shops, with a view to broadening and deepening the participation of industry in the Framework Programme. Dissemination of Community research and development results will also be promoted through other channels suited to particular sectors.

6.10 The costs of Community research - as for domestic, publicly-funded research - must be met by the taxpayers of the United Kingdom. Like other Member States, the United Kingdom must strike a balance between the funds it devotes to Community and domestic programmes. The system of attributing the cost of Community expenditure to Departments (on the basis of lead policy responsibility for the content of specific programmes) has given Departments a clear incentive to seek value for money from Community programmes.

6.11 The Government has noted the concerns expressed in the consultation exercise that the handling of the public expenditure implications of Community Programmes can inhibit the country's negotiating position. Before negotiations on new Framework Programmes, the Government will take a strategic judgement on the best practicable balance between domestic and Community programmes. This balance will be reviewed in the course of the annual public expenditure survey.

CO-OPERATION AND COLLABORATION IN EUROPE AND BEYOND

6.12 Although the Community provides a major focus for the United Kingdom's international endeavours in the field of science and technology, the country benefits from the many other forms which international collaboration takes, some in Europe and others stretching to and across the other continents.

6.13 The United Kingdom participates, alongside many other European countries, in the European High Technology Programme (EUREKA) initiative which aims at facilitating industry-led and market-driven collaborative projects between firms and research institutes in a wide range of advanced technologies.

6.14 Inter-governmental and inter-agency agreements give United Kingdom scientists access to collaborative ventures and facilities all over the world, and foreign researchers access to facilities in the United Kingdom. We shall continue to build up the international use of facilities here, taking the opportunity of co-operative ventures to site facilities in this country, along the lines of the initiative taken by the Wellcome Trust and the Medical Research Council to locate the European Bioinformatics Institute in Cambridge. Our astronomers make use of telescopes sited in Australia, Hawaii and the Canary Islands. Japanese researchers work with British researchers on ISIS at the Science and Engineering Research Council's Rutherford Appleton Laboratory. Through the Natural Environment Research Council our earth scientists and oceanographers participate in the Ocean Drilling Programme and in Antarctic science collaboration.

6.15 Many of these collaborations centre around those areas of science - astronomy, particle physics and fusion for example - where, if advanced research is to be undertaken at all, major and expensive long-term capital investments are needed and where the prospects of commercial exploitation and 'spin-off' are severely limited. As the equipment required to conduct experiments and take observations has become more sophisticated and expensive, so too have major facilities tended to be conceived as, or developed

into, collaborative ventures so that costs can be shared and research issues of common interest to humanity addressed. At the same time, there has been a steady increase in large co-ordinated programmes (for example the World Climate Research Programme and the Human Genome Project) where shared human problems are addressed by the pooling of effort in the pursuit of common research objectives.

6.16 A recurrent theme raised during the consultation exercise was how to secure the right balance between participation in these large international programmes and sustaining lively and creative research communities in small science programmes. In recent years, there has been a deliberate reduction in the share of the country's basic science budget devoted to large science. The Government believes that this balance is a matter of policy which needs to be explicitly addressed.

6.17 This is a major reason why it has decided to establish a Particle Physics and Astronomy Research Council which, unlike the other five Research Councils, will focus primarily on the basic end of the research spectrum. In the consultation exercise, some argued that the funding of international subscriptions should be taken outside the science budget of the Office of Public Service and Science. In the Government's view it is important for such subscriptions to be seen as part of our scientific endeavour rather than our foreign policy. Decisions on relative priorities must be taken in the context of the science budget. It will be for the new Particle Physics and Astronomy Council to match its scientific plans with the resources which the Government decides that the country can afford to make available for its basic science mission. The Director-General of Research Councils will be asked to bring forward proposals for handling this within the science budget as a whole, so that the Council does not have to cope entirely within its own grant-in-aid with short-term variations in international subscriptions which arise for reasons beyond its control. These can build on the improvements made in recent years in the handling of such fluctuations in the United Kingdom's subscription to CERN (the European organisation for nuclear research).

6.18 The Government recognises that competition is a great spur to scientific breakthroughs. However, like the science itself, the cost nowadays can be astronomical. The largest scientific projects require the investment of resources at a level which demands justification in world rather than national or European terms. This has been recognised in the field of fusion where new developments are being carried forward on an inter-continental, co-operative basis. The challenge is to extend this approach to other fields.

6.19 The Organisation for Economic Co-operation and Development has established a Mega Science Forum whose task is to identify areas where scientific communities, and their Governments, might agree to pool resources, divide specialised labour and develop joint programmes. The United Kingdom is playing an active part in this new body and the Government will monitor its performance with care. It remains ready to pursue all avenues which offer worthwhile opportunities for making best use of the finite resources available worldwide to advance the frontiers of fundamental knowledge.

6.20 It is also important to ensure that the United Kingdom exploits to the full opportunities to capitalise on overseas research and development and to promote British science and technology abroad. At any one time, between three quarters and four fifths of the 13,000 overseas students in the United Kingdom with Government-assisted awards are studying science and technology. The activities and responsibilities of science and technology sections in our overseas Embassies will be reviewed. Funding for the Overseas Science and Technology Expert Missions scheme has recently been extended, and industry will be consulted on more comprehensive activities designed to identify opportunities for transferring technology from abroad.

CHAPTER SEVEN

MEETING THE COUNTRY'S NEEDS FOR SCIENTISTS AND ENGINEERS

7.1 As knowledge has increasingly become the main component in adding value to goods and services, the wealth of nations has come to depend more and more on the knowledge and skills of their people. High-quality education and training are critically important. As a country we have suffered in the past from a culture which placed too low a value on education and training in general, and which gave insufficient recognition to the importance of knowledge and understanding of scientific and technological issues. As the Advisory Council on Science and Technology said in its contribution to the consultation exercise (Section A of the Bibliography):

> *"It is difficult to overstate the importance of science and technology for economic growth and improving the quality of life. There is an overwhelming argument for increased scientific education for all and greater attention to the development of the next generation of highly qualified science and technology personnel."*

7.2 The Government shares this view and has embarked on a radical agenda of changes in the education and training system, including:

- changes to the school curriculum. These will ensure for the first time that all pupils, girls as well as boys, will study a broad and balanced programme of science and technology right through to the age of 16. In Scotland the curriculum is designed to give a clear place to science and technology for the whole of compulsory schooling;

- better guidance and information. Pupils can now expect impartial and accurate careers guidance and access to work experience. They, their parents and employers have a right to more information about the subjects and qualifications available and how well schools and colleges are performing. This will help them make sensible choices at key points, as well as raising standards and encouraging the education system to be more responsive to the needs of society, the local community and the individual;

- new, attractive vocational qualifications at all levels, fostering parity of esteem with academic courses. The General National Vocational Qualifications (GNVQs) and National Vocational Qualifications (NVQs) in England and Wales and the General Scottish Vocational Qualifications (GSVQs) and Scottish Vocational Qualifications (SVQs) in Scotland provide new full and part-time options alongside qualifications at General Certificate of Secondary Education (GCSE), Advanced (A) and Advanced Supplementary (AS) levels and Standard and Higher Grades in Scotland. These will help secure the Government's aims of increased participation and higher attainment in further and higher education, and hence an improved skills base;

- commitment to the National Targets for Education and Training as a means of increasing demand for, and achieving improved levels of attainment in, high-quality education and training. The Targets have a key role to play in building a world-class work force. The Government's expenditure plans for further education will enable a large step to be taken towards the achievement of the Targets. The National Advisory Council for Education and Training Targets, and the Scottish Advisory Council for Education and Training Targets, have been established to monitor and to report on progress towards the Targets.

7.3 These reforms have been the subject of several recent Government White Papers (Section G of the Bibliography). The Secretary of State for Scotland is currently considering responses to the proposals contained in the report prepared by the committee chaired by Professor Howie which examined proposals for the reform of the Scottish Upper Secondary Awards System. In general, reforms in education have very long lead-times. Understandably, the debate stimulated by the consultation exercise preceding this White Paper revealed some impatience for quicker results. Progress depends, however, upon a committed and sustained effort over many years. As described above, the Government is making such an effort and will continue to do so.

7.4 Seven issues were major subjects of concern in the consultation exercise:

- meeting the needs of the economy for highly-qualified scientists, mathematicians and engineers - those qualified to at least first-degree level;

- ensuring adequate provision of people with craft and technician skills;

- encouraging the Business Schools to include regular modules dealing with the management of innovation and the understanding of science and technology for general managers;

- increasing the participation of women in science and engineering;

- ensuring that more of the very highly-qualified (those trained to post-graduate level) have skills which are better matched to the needs of potential employers, including those outside the academic world;

- providing a satisfactory career structure for those continuing to undertake research in universities;

- raising the general level of public awareness and understanding of scientific and technical issues.

MEETING THE FUTURE NEED FOR SCIENTISTS AND ENGINEERS

7.5 In 1990 over one million people were employed in science and engineering occupations in the United Kingdom. The numbers employed in these occupations have grown sharply in the last 20 years, with an increase of 400,000 (over 50 per cent) recorded between 1971 and 1990. This growth is projected to continue, although at a slower rate, for the rest of the decade.

7.6 Recent trends in the supply of specialist scientists and engineers show a healthy growth. An increasing proportion of young people is now continuing into higher education. The proportion of young people entering higher education in Great Britain has increased from one in seven in 1987 to over one in four in 1992. The number studying science and engineering has grown roughly in line with the overall growth in participation. The annual output of graduates in natural science and engineering in Great Britain is projected to reach 67,000 in 1995/96, compared with 40,000 in 1986/87. Just over a quarter of all degrees and equivalent qualifications awarded in 1990/91 were in the natural sciences, mathematics and engineering - slightly above the average for countries in the Organisation for Economic Co-operation and Development.

7.7 Nevertheless there is room for improvement. The proportion of engineering and technology graduates is currently forecast to fall between the late 1980s and the mid 1990s and the proportion graduating in engineering is below the average of countries in the Organisation for Economic Co-operation and Development. In general, too few students, including too few of the most able, are attracted into engineering careers. The ratio of applicants to places and the average level of entry qualification is lower for biological and physical science and engineering courses than for courses in humanities, languages and social sciences. The Higher Education Funding Council for England expressed concern in its contribution to the consultation exercise (Section A of the Bibliography):

> *"many institutions report a shortage of good quality applicants to read for first degrees in science and technology subjects, despite efforts by universities to recruit them."*

If this is to change, more young people must perceive science and engineering in industry as an attractive and worthwhile career. They must also see the value of developing the entrepreneurial skills which will help businesses exploit more effectively the results of research, science and technological development.

7.8 In the longer-term, the Government's reforms in schools and further education should lead more young people to have the grounding in

mathematics, science and technology needed to pursue these subjects in higher education. On the supply side, the Government has, with the help of the Engineering Council, provided additional places in engineering in higher education through specific initiatives, such as the Engineering Technology Programme and the Manufacturing Systems Engineering Initiative. To provide an incentive to universities and colleges to recruit more students in science and engineering, it has announced an increase in the differential between the fee rate for classroom and laboratory/workshop-based courses. It has asked the Higher Education Funding Councils to provide incentives for institutions to offer more two year, full-time, vocational diploma courses, and to encourage engineering and technology at all levels through its funding.

7.9 Many employers said in the consultation exercise that they wished to recruit and retain high-calibre people with appropriate technical qualifications. A major responsibility rests with them to meet this objective by offering financial rewards and career structures which fully reflect the value of scientists and engineers to their organisations; to make full use of the skills of these highly-qualified people across the organisation rather than in specialised roles; and to cultivate links with schools and colleges to inform potential future recruits of industry's needs.

7.10 Professional bodies can also make a significant impression. The Government recognises the efforts of the Engineering Council, the Engineering Institutions, and the Royal Academy of Engineering to improve the general perception of engineering and to raise the status of engineering as a career. The Technology Foresight Programme will also contribute in due course to improved understanding of the long-term requirements of the economy for technically educated and trained people.

7.11 Past attempts at detailed planning to meet future needs for skills have generally failed. The Government's intention is to ensure a flexible system in which universities and colleges can respond to the demands of students and employers to meet their needs. It will assist communication between the different interests by monitoring and publishing information on trends in supply and demand for scientists and engineers. A report commissioned by the Office of Science and Technology from the Institute of Manpower Studies (Section G of the Bibliography) suggests that monitoring could be achieved using existing sources of information. Beginning next year, the Government will compile, publish and disseminate data on the stocks and flows of scientists and engineers and on indicators of labour-market demand and supply.

7.12 New modules on innovation, new product development, and the management of science and technology will be developed by the Economic and Social Research Council in conjunction with the Business Schools both for inclusion in Master of Business Administration (MBA) degrees and shorter training packages.

7.13 Another theme of the consultation exercise was well expressed by a submission which noted the:

> *"widespread waste of talent and training, throughout industry and academia, due to the absence of women."*

Women are the country's biggest single most under-valued and therefore under-used human resource. The Government believes that there is massive scope to attract more women into science and engineering. It has set up a working party to address this important issue and looks forward to receiving its report later this year.

POST-GRADUATE EDUCATION AND TRAINING

7.14 Post-graduate work originally developed as a training for future teachers and researchers in higher education, with most students undertaking research for a doctoral degree. Over the last two decades higher education institutions have recognised a need for advanced specialist knowledge for a much wider range of employment, and have responded by expanding their provision of post-graduate courses.

7.15 The largest expansion has been in taught courses. The number of new entrants in Great Britain to full-time post-graduate taught courses in universities increased by over 80 per cent between 1980 and 1990. There was also a significant expansion in the equivalent numbers undertaking a qualification by research - up by 40 per cent over the same period.

7.16 The Government welcomes the growth in post-graduate courses. It is concerned, however, that the traditional PhD does not always match up to the needs of a career outside research in academia or an industrial research laboratory. A minority of those studying for a PhD in science, mathematics and engineering can realistically expect a long-term career in university research, even allowing for the increase in vacancies expected over the next decade because of the current age profile of university staff. The majority will move into other fields. A period spent in PhD training represents a substantial investment of public funds and it is important to ensure that it represents good value for money for the taxpayer, as well as for the individual concerned.

7.17 Concern about the nature of PhD training is not new. As long ago as 1968 a Working Group of the Committee on Manpower Resources for Science and Technology (Section G of the Bibliography) recommended that:

> *"The universities should examine the nature and purpose of the PhD from first principles and consider drastic action to bring within its scope other forms of post-graduate training more closely related to the needs of industry."*

7.18 In recent years there have been some promising developments as universities and Research Councils have turned their attention to this issue. In particular the two Councils which spend most on post-graduate training - the Economic and Social Research Council (ESRC) and the Science and Engineering Research Council (SERC) - have launched a number of significant initiatives.

Economic and Social Research Council

HAS ISSUED **POST-GRADUATE TRAINING GUIDELINES** SETTING OUT THE SKILLS TRAINING WHICH INSTITUTIONS MUST PROVIDE FOR STUDENTS IF THEY ARE TO QUALIFY FOR ESRC SUPPORT.

HAS REQUIRED AWARDING INSTITUTIONS TO DEMONSTRATE THAT THEY CAN OFFER SUITABLE LEVELS OF TRAINING AND AN ACCEPTABLE RESEARCH ENVIRONMENT.

HAS DECIDED TO PROVIDE SUPPORT FOR PART-TIME RESEARCHERS, SO ALLOWING ABLE STUDENTS WHO WISH TO REMAIN IN EMPLOYMENT TO COMPLETE RESEARCH DEGREES RELEVANT TO THEIR PROFESSIONAL INTERESTS.

HAS DECIDED TO TARGET STUDENTSHIPS IN AREAS SUCH AS MANAGEMENT AND BUSINESS STUDIES AND TO FAVOUR PROPOSALS WHICH INVOLVE LINKS WITH RESEARCH PROJECTS WITH BUSINESS OR POLICY OBJECTIVES.

Science and Engineering Research Council

HAS INTRODUCED A NUMBER OF SCHEMES TO BRING THE POST-GRADUATE TRAINING IT SUPPORTS MORE CLOSELY INTO LINE WITH THE NEEDS OF INDUSTRY.

MORE THAN 1800 **COLLABORATIVE AWARDS IN SCIENCE AND ENGINEERING (CASE) RESEARCH STUDENTS** ARE JOINTLY SUPERVISED BY ACADEMICS AND EMPLOYEES DRAWN FROM THE COLLABORATING UNIVERSITIES AND FIRMS. THE UNIVERSITY DEPARTMENT AND THE FIRM AGREE ON THE PROJECT AND THE STUDENTS ARE REQUIRED TO SPEND A MINIMUM OF THREE MONTHS ON THE PREMISES OF THE FIRM. OTHER RESEARCH COUNCILS HAVE SIMILAR SCHEMES.

TOTAL TECHNOLOGY RESEARCH STUDENTS ALSO BENEFIT FROM THIS SORT OF ACADEMIC AND INDUSTRIAL CO-OPERATION AND RECEIVE TUITION IN APPROPRIATE MANAGEMENT, FINANCIAL AND SOCIAL SUBJECTS.

INDUSTRIAL STUDENTSHIPS ARE GIVEN TO CANDIDATES IN FULL-TIME EMPLOYMENT.

STUDENTS ON THE **INTEGRATED GRADUATE DEVELOPMENT SCHEME** ARE RELEASED BY PARTICIPATING FIRMS FOR SHORT PERIODS OF INTENSIVE INSTRUCTION (TYPICALLY 14 TO 16 ONE-WEEK PERIODS OVER TWO YEARS). THE STUDENTS CARRY OUT SUPERVISED PROGRAMMES RELATED TO THEIR INDIVIDUAL NEEDS AND INTEGRATED INTO THEIR NORMAL WORK.

THE TEACHING COMPANY SCHEME PROVIDES INDUSTRY-BASED TRAINING FOR HIGH-CALIBRE GRADUATES RECRUITED, IN CONSULTATION WITH THE COMPANY, FOR TWO-YEAR ACADEMIC APPOINTMENTS AS TEACHING COMPANY ASSOCIATES. THE ASSOCIATES THEN WORK IN COLLABORATION WITH COMPANY AND ACADEMIC STAFF ON PROJECTS WITHIN THE COMPANY. INDUCTION AND GENERAL BUSINESS TRAINING ARE PROVIDED CENTRALLY AS PART OF THE SCHEME. BY MARCH 1992 ONE THOUSAND TEACHING COMPANY SCHEME PROGRAMMES HAD BEEN LAUNCHED.

7.19 Last year, the Science and Engineering Research Council launched two pilot schemes. The post-graduate training partnerships, sponsored jointly with the Department of Trade and Industry, allow research students to work in an industrial setting under co-operative guidance and supervision from the participating Industrial Research Organisations and universities, informed by the views of industrial customers. A new four-year engineering doctorate also had its first intake in October 1992. The students will be required to address a major engineering problem (or set of problems) with a clear industrial focus. A quarter of the students' time will be spent on accessible taught course work both in technical and broadening subjects. In both pilot schemes, and indeed in all of the schemes illustrated in the box above, students receive an enhanced stipend. The intention is to persuade more very able young people to see the intellectual challenge of research and training conducted in an industrial setting and for industrial purposes.

7.20 While welcome, these changes have been piecemeal. The Government considers that faster and more systematic change is now needed. In its contribution to the consultation exercise, the Advisory Board for the Research Councils recommended a new pattern of post-graduate training:

"A year spent in formal Master's education should be the normal first step for students likely to benefit from additional training. This step should not be a token hurdle. The resultant qualification should be substantive, of value in itself, and contribute to the judgement, not least by the student, of whether such training is desirable and, if so, what the nature of that training should be."

7.21 The British Academy is already planning such a pattern in the humanities. In future, this should also become the normal pattern for students seeking support for research training from the Research Councils. The new pattern will be achieved within planned resource levels. Some students will already have undertaken work on their undergraduate course which fits them for direct registration for a PhD. But for most students who have undertaken a first degree, the Master's qualification will provide an opportunity to acquire extra knowledge and skills, either in preparation for a period of research training leading to a PhD or for employment. The Government sees the following advantages in this arrangement:

- it will allow more students to be supported to the Master's level, through which they can acquire skills of value for a range of careers within industry or elsewhere;

- students will have an opportunity during this year to consider whether they have the wish and aptitude to proceed to research leading to a PhD degree;

- applicants for PhD training can be selected on a more informed basis by reference to their personal motivation, ability to benefit from PhD training and suitability for either an academic or non-academic career.

7.22 The Government would also like to see steps taken to ensure that the research training itself is more closely related to the needs of potential employers. This is primarily for institutions, but the Research Councils will be expected to provide a lead (as the Economic and Social Research Council has done through its post-graduate training guidelines). It wishes to see more research students undertaking work in industrial and commercial settings, with exposure to the environment in which research and development operates. The training should prepare the student for the budgetary, time-limited, interdisciplinary and team-based manner in which research and development is conducted and constrained within firms. The Government fully endorses the Royal Society's view in its report on the Future of the Science Base (Section D of the Bibliography) that:

"some degree of flexibility and versatility should be incorporated into PhD training..... This should include elements of non science-specific training and at the very least should include communication skills and, where appropriate, the management of human, material and financial resources."

7.23 The Government will invite the Research Councils to work with the Higher Education Funding Councils and the universities to develop plans for the phased implementation of this policy, within the framework for the co-ordination of the science and engineering base set out in Chapter 3. Institutions will need time to adapt and develop their course provision to allow for the new structure and to generate the requisite involvement of non-academic employers. Research Councils will need to change the balance of support, providing more post-graduate awards for Master's level training and fewer awards for the more highly-selected group who will go on to undertake a further period of research training, normally for three years.

7.24 The consultation exercise confirmed the concern in the scientific community about the levels of financial support available from the Research Councils for students undertaking research training. Some argued that they were insufficient to secure a future supply of high-quality students. Against this, there is no evidence of a shortage of good applicants. There is very high demand for most Research Council studentships. The Research Councils can and do offer awards at higher levels where they consider them to be justified in particular fields.

7.25 Within their new missions, Research Councils will be responsible for ensuring the supply of very highly-qualified scientists and engineers within their areas, with particular attention to the needs of industry and the wider economy. It will be for the Research Councils to develop policies on the supply of very highly-qualified scientists and engineers in their areas, having particular regard to the balance between quantity and quality, in consultation with universities, Government, and employers. They will need to decide the numbers of students they should support in each field, and the appropriate level of support, taking account of demand, and in particular the extent to which employers are willing to supplement stipends, as in current schemes such as the Collaborative Awards in Science and Engineering.

RESEARCH CAREERS IN UNIVERSITIES

7.26 During the 1980s there was a rapid increase in the volume of research carried out in the universities. Much of the research is undertaken by research staff specially recruited for particular projects and employed on short-term contracts. As a consequence, the number of such staff has grown rapidly in the 'old' universities in the United Kingdom, from 8,000 in 1980 to 16,500 in 1990; and in science and engineering subjects in 1990 these institutions employed six research assistants for every ten members of permanent academic staff.

7.27 This movement towards staff on fixed-term contracts is not unique to the universities. Many employers have found that there are advantages in this arrangement. It provides employer and employee with greater flexibility and encourages more mobility between employers and between sectors. All this can be productive. Post-doctoral experience within universities can be invaluable to those intending to undertake a long-term career in research.

7.28 Nevertheless the current pattern of contract staff in universities is a matter for concern, and was raised by many during the consultation exercise. For the universities and the purchasers of research, the quality of work may suffer if too much effort is expended in recruiting and training new staff. The evidence suggests that many contract staff have ambitions for a long-term career within universities, something which is realistic only for a small proportion. Such individuals may diminish their employment prospects in other fields by taking a succession of short-term contracts. While individuals must remain free to exercise choice in such matters, they ought to do so with the benefit of professional career advice and counselling.

7.29 The responsibility for considering the employment arrangements for such staff rests primarily with universities as their employers, and the Committee of Vice-Chancellors and Principals last year issued guidance to universities on these issues (Section G of the Bibliography). However, the Government recognises that the universities' flexibility is limited by the terms of the grants and contracts on which staff are employed. The Government warmly endorses the Wellcome Trust's initiative to analyse the research staff which it funds with a view to giving a higher proportion of them better career prospects.

7.30 The Research Councils are major funders of research workers in universities through their project and programme grants. The Government believes that universities and Councils must co-operate to ensure that these workers receive appropriate counselling and advice.

7.31 The Government looks to the Research Councils to adapt their grant-making arrangements to help universities to improve the career opportunities of research staff. Councils should:

- when awarding grants, ensure they hold up-to-date information on the receiving institutions' personnel policies and their arrangements for the initial counselling, training and subsequent career development of research assistants;

- keep these arrangements under review and evaluate their success in helping research assistants to plan their future careers (academic or otherwise) and institutions to identify and nurture those who show special promise as research leaders;

- adopt arrangements for grant support within the dual support system which would help universities to increase career openings - through longer-term grants, or by allowing a margin within grants which could be used by universities to build up contingency funds to meet the additional costs of employing a cadre of semi-permanent research support staff who would be retained between contracts;

- ensure that the principal investigator intends to commit sufficient time to a project to provide adequate leadership and guidance to those undertaking the project, and in suitable circumstances encourage the investigator to undertake more of the research him or herself with grant paid for substitute teachers rather than substitute researchers;

- look at the scope to put more of their funding into supporting promising researchers, through expansion of their fellowship schemes or otherwise, rather than through support for specific projects. The Government intends to invite the Director-General of Research Councils to work with the Royal Society and the Councils accordingly. It endorses the Royal Society's view that there should be a shift away from the support of research assistants on specific projects towards more individual fellowships, such as those provided by the Society's highly-regarded University Research Fellowship scheme which allows for the longer-term support of individual 'high fliers' and enables promising young researchers to acquire research experience in preparation for a permanent academic post.

RAISING PUBLIC AWARENESS OF THE CONTRIBUTION OF SCIENCE, TECHNOLOGY AND ENGINEERING

7.32 The economy needs an adequate supply of specialist scientists and engineers. There is also a broader social and economic need to raise the general public's level of understanding and awareness of scientific and technological issues and of the role of science, technology and engineering in the economy. Many decisions, whether taken by firms, Government, other organisations or individuals, would benefit from such a greater appreciation. As the Royal Institution said in its contribution to the consultation exercise preceding this White Paper:

"Any national policy for science and technology must contain, as a necessary foundation, the diffusion among the public at large of an appreciation of what science is."

7.33 Over the long-term, the Government expects that its reforms of the education and training systems will lead to an improvement in the general level of understanding of scientific and technological issues across the population, and give a corresponding boost to the supply of scientifically literate manpower to industry. But inevitably these changes will take some years to have a significant effect. The first pupils to follow a full 11 years of the new National Curriculum in science in England and Wales will not reach the age of 16 until the year 2000. The pattern in Scotland with its curriculum guidelines is similar. It will be several decades before this change has an impact on the population as a whole.

7.34 There are other ways of getting across information and knowledge about science and technology - for example through the media, through public libraries, leisure or work-related adult education, public exhibitions, displays and educational activity throughout the national and local network of museums and galleries, and through school and college activities involving parents and local businesses as well as children. There is already a wide range of valuable activity and the Government applauds these efforts, for example:

- the British Association's annual Festival of Science and the Edinburgh International Science Festival;

- the Royal Institution's Annual Christmas Lectures;

- the Science Book Prize sponsored by Rhône Poulenc and organised by the Committee on the Public Understanding of Science and the Science Museum;

- the Continuum and Technology Enhancement Programmes administered by the Royal Academy of Engineering and the Engineering Council on behalf of the Gatsby Charitable Foundation;

- a database of speakers on science, engineering and technology subjects (the 'Talking Science Database'), sponsored by the Department of Trade and Industry and being compiled by the Committee on the Public Understanding of Science;

- laboratory 'open days', lectures and visits for schools, and other activities supported by the Research Councils;

- the extra-mural activities of universities in schools and their commitment to adult continuing and professional education;

- the work of public libraries in making available books and other materials about science and technology;

- the 'launch-pads' and 'hands-on' initiatives of the country's science and industrial museums and exploratories;

- the activities of many firms and companies at the local and national level through, for example, the United Kingdom Mathematics Foundation, the Science and Technology Regional Organisations, Neighbourhood Engineers Scheme, Women into Science and Engineering, and the Wealth from Science and Engineering Programme for secondary schools and colleges.

7.35 There is therefore a wide variety of organisations contributing, with a range of target audiences and objectives in mind, to improving the public understanding of science in its widest sense. In this context the important role of Government Departments - whether in contributing to the activities described above, or in developing their own initiatives to underpin their particular mission - should not be overlooked. All these contributions, whether from within or from outside Government, are important elements in the overall effort. It would not be sensible to attempt any central direction of this diverse activity.

7.36 The Government was nevertheless grateful for, and impressed by, the many imaginative proposals made during the consultation exercise, and has held discussions with leading practitioners to explore how best to act on the recommendation of the Royal Academy of Engineering to:

> *"take steps to improve the public understanding and the complementary roles of science, technology and engineering and their vital importance to the country's economic future ..... a campaign should be targeted at the City, media, company chairman and chief executives at all levels and in all regions and the educational fraternity at school and university level."*

7.37 The Government has accordingly agreed with key players in the field, including the Gatsby Charitable Foundation and the Wellcome Trust, that they will work together to promote such a campaign throughout the country, having due regard to the many schemes already in place and the specific objectives of the organisations involved. The Government intends that particular initiatives should include:

- Government co-sponsorship with appropriate partners of a high-profile mobile exhibition, or series of exhibitions, built around the theme of science for the 21st Century, and comprising various (and evolving) activities and exhibits, to culminate in a national exhibition of science, technology and engineering innovation at the Science Museum around the 150th Anniversary of the Great Exhibition in 2001;

- Government support, with other partners as appropriate, for the successful Creativity in Science and Technology (CREST) Award scheme for task-orientated project work in schools, in order to build on its relevance to curriculum requirements, and to increase both the profile of the scheme and the extent of its coverage of the schools of the United Kingdom;

- working with the Gatsby Foundation, the British Association for the Advancement of Science, and other players to bring greater focus and coherence to the schemes in all regions of Britain which have the aim of encouraging young people to consider careers in engineering-related industry; and to consider the introduction, on a pilot basis in the first instance, of a networking service for education institutions and others in regions where a need exists for improved dissemination of wide-ranging information about scientific activities and opportunities, both locally and at the national level;

- working with the Research Councils and other bodies to improve scientists' understanding of communicating with the public in particular, as part of the emphasis on communication skills in research training described earlier in this Chapter.

7.38 Successful promotion of the public understanding of science and technology is most likely to be achieved by organisations and individual scientists and engineers passing on their knowledge and enthusiasms within their local communities. Nevertheless, as this White Paper has shown, all Government Departments, in addition to industry, would gain from a more scientifically- and technologically-informed population. The Government therefore has a leading part to play in pump-priming selected new activities and encouraging networking amongst the many players. The Chancellor of the Duchy of Lancaster, as Minister of Public Service and Science, will set up a special fund, from which small grants will be given to cover part of the costs of activities designed to increase public understanding and appreciation of science and technology.

CHAPTER EIGHT

CONCLUSION

8.1 This White Paper has set out the reforms (summarised in paragraph 18 of Chapter 1) which the Government believes are necessary to build on the country's existing strengths in science, engineering and technology.

8.2 The Government's strategy is to improve the nation's competitiveness and quality of life by maintaining the excellence of science, engineering and technology in the United Kingdom. It will do so by:

- developing stronger partnerships with and between the science and engineering communities, industry and the research charities;

- supporting the science and engineering base to advance knowledge, increase understanding and produce highly-educated and trained people;

- contributing, according to the United Kingdom's strengths and interests, to the international, and particularly European, research effort;

- continuing to promote the public understanding of science and engineering;

- ensuring the efficiency and effectiveness of Government-funded research.

The science and technology programmes undertaken in support of Departments' policy, statutory, operational, regulatory and procurement responsibilities will contribute to this overall strategy.

8.3 The Government will monitor the overall success of its strategy, and the health of the United Kingdom's science and technology more generally, through the *Forward Look*, described in Chapter 2. Having benefited from the consultation exercise which preceded this White Paper, the Government would like to draw increasingly on the well-informed contributions of industry and the scientific and engineering communities, the research charities and other interested bodies. Science, engineering and technology are critical to our future well-being; we must all work together to make sure that they contribute fully to realising the country's potential.

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