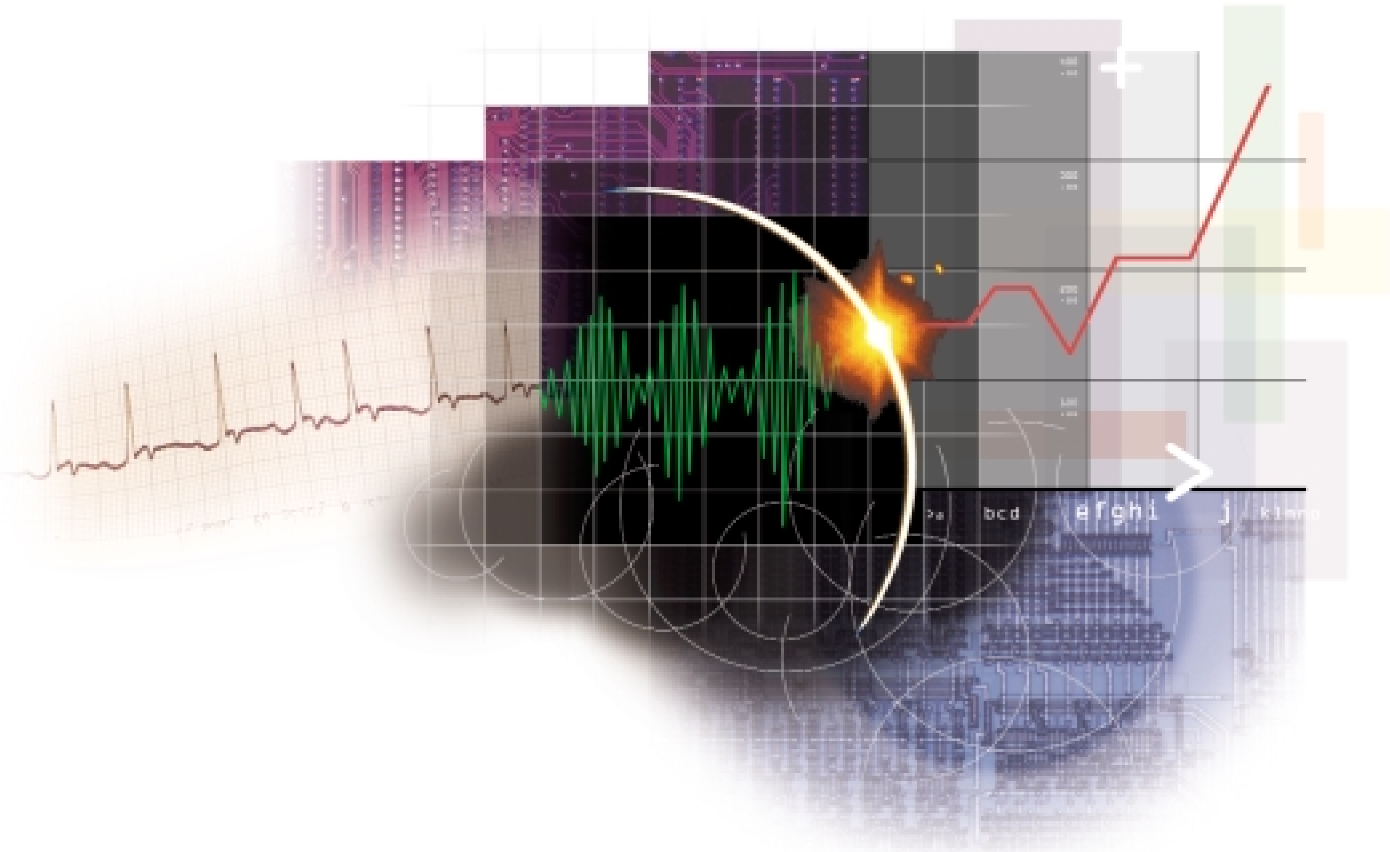
Excellence and > Opportunity

a science and innovation policy > for the 21st century



Department of Trade and Industry

Foreword from Stephen Byers, Secretary of State for Trade and Industry

Everywhere we look – at home, at work, in our schools and hospitals, on our high streets – we are surrounded by the products of science. More scientific discoveries have been made in the last ten years than in the whole of human history. Even more will be created in the next decade.

We are on the brink of exciting developments in science which will affect everyone's lives. Mapping of the human genome will unlock new cures for disease. New technology will enable us to clean up the pollution created by previous industrial revolutions. Improvements in forensic science will enable us to crack down on crime.

Such developments open exciting opportunities which can bring huge benefits for everyone. But they also carry potential risks which can cause understandable concerns for people. This White Paper provides the basis for exploiting the opportunities and meeting the challenges raised by scientific discovery.

We have a remarkable track record in this country of world class research. Many of the world's scientific discoveries have been based on the work of British research and British scientists. The UK has 1 per cent of the world's population, but we fund 4.5 per cent of the world's science, and produce 8 per cent of the world's scientific papers. In the 21st century, we must remain a world leader in science. More than any time before, science will provide the key to creating new jobs, providing better health care, ensuring a cleaner environment and tackling crime. To realise these opportunities we must build on our existing science base, to ensure excellence in science across the UK. So, this White Paper will set out our plan to invest in our schools and universities and widen opportunities, especially for women and young people, to pursue a career in science.

Scientific excellence is only the start. In the modern knowledge economy it is not enough to generate research – we also have to make the most of it. To turn ideas into products which can improve our lives. We have already introduced incentives for universities to develop commercial applications for their research. We will now build on this, to give universities a new mission to play an active role in the economy.

Stronger links between universities and business are an important element of this. Today, all companies need to innovate – to constantly develop new products and services and find new ways of doing things.

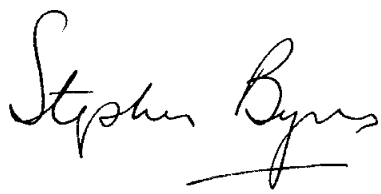
Government can help by supporting networks, at a local or regional level, which enable business to share ideas and learn from each other and from universities. We will increase the support and advice available in all parts of the country for companies, especially manufacturing firms, to innovate and adopt new technologies and practices.

We need scientific excellence and business innovation in every region, not just a few areas. We will apply the measures in this White Paper across the country, giving all our regions the opportunities to meet the challenges of the knowledge economy.

It is through innovation and scientific discovery that business can provide new products for consumers. The tougher competition policy we are pursuing helps make sure that consumer desires are the drivers of innovation. But as the debate on GM foods has shown, consumers will only buy new products which they trust. People rightly expect proper safeguards against potential public risks and full information on the implications of scientific developments. Proposals in this White Paper will introduce a framework of proper safeguards, information and accountability, providing the public trust which scientific developments must secure in order to benefit society.

Science has become an integral part of our economy and society. That creates challenges for Government as well as universities and business. Government and my Department in particular must be able to respond to the rapidly expanding interaction between science, industry and society. I will be looking at how the DTI's structure can be improved to better incorporate science and innovation into the task of making Britain a success in these important areas.

The successful economies of the future will be those which excel at generating and disseminating knowledge and exploiting it commercially. The measures set out in this White Paper provide a foundation for building a dynamic knowledge economy in the UK: investing in scientific excellence, increasing opportunities for innovation, and providing a basis for public trust in science. By putting these building blocks in place we can harness the full potential of science to improve the quality of life for everyone in Britain.



RT. HON. STEPHEN BYERS MP

A Science Policy for the 21st century

Using science to succeed

1. Science, and the innovations it gives rise to, have been driving forces of modern life for well over a century. Now, if anything, science is enabling us to make even more breakthroughs in areas like genome research, intelligent systems and sustainable technologies. To be a successful nation we must make sure our science base is strong and excellent, that we have the facility to quickly transform the fruits of scientific research and invention into products and services that people need to improve their well-being and quality of life. And we must do all this in a way that has public support and involvement. This White Paper sets out the way ahead in these areas so that we ensure science and innovation combine to generate wealth, businesses and jobs for our citizens and help us attack disease, crime and environmental degradation.

2. Our lives would be unimaginable without science. When it is guided and regulated in the right way, science brings prosperity, improves the quality of life and extends life choices for all. Much of everyday experience – even the jobs we do – is the product of scientific advances in the past. And just as important, science is helping to create the global markets and industries of the future.

3. Right now, we are on the brink of exciting developments in science with wide applications. Science has put us on the verge of creating new families of products and new industries: microrobotics, miniature robots built on an atomic scale that could unclog sclerotic arteries; machines that can translate languages and even conversations; biomimetic materials that will mimic materials found in the natural environment and, for example, help clean the earth’s environment. Existing industries and public services – education, transport, health care – will be transformed by these advances.

4. Science is already central to modern health care, generating dramatic improvements in survival rates for childhood cancer, new keyhole surgery techniques, and providing a step change in research into genetic causes of major diseases. Each time we walk into a modern hospital we benefit from decades of scientific research. Science now plays a critical role in tackling crime, as forensic science such as DNA fingerprinting helps pin-point the perpetrators of crime. In transport, the safer, more efficient and environmentally friendly transport system that we want will emerge from research into new energy efficient engines and intelligent public transport systems.

The challenge of protecting the world's endangered species and habitats will only be met if science is deployed in the battle to protect biodiversity.

5. We are doing more research, more productively than previous generations. The dramatic changes that took place at the beginning of the 20th century, such as radio, aviation and mass production, are matched by those of the 21st. What has changed is the scale, and the fact that the new technologies affect everyone, across the globe. Scientific research has been made vastly more productive by information technology which, for example, allows biotechnology researchers to scan thousands of compounds in the time it took a researcher three decades ago to survey a handful.

6. For Britain to prosper in the 21st century and to be able to play a leading role in the creation of the new global industries, we must have a first class process for pursuing scientific advance and using it successfully. We must have the ability to generate, harness and exploit the creative power of modern science.

Excellence and innovation

7. Innovation is the motor of the modern economy, turning ideas and knowledge into products and services. Innovation is a complex process, involving many ingredients, that has to be well managed to be successful. The innovation process is a cycle in which ideas, talent and design skills, money and management, come together to create products and services which consumers want.

8. The cycle of innovation must be fed by ideas and basic knowledge. That know-how can come from many sources and disciplines. In a knowledge-driven economy, science is a vital source, feeding the innovation process in a variety of ways. That is why we need to achieve both scientific excellence and the right climate and incentives for innovation to flourish.

9. The importance of excellent, curiosity-driven research cannot be emphasised too strongly. It is part of our culture but also of vital importance to industry. Major innovations flow from breakthroughs made by curiosity-driven research. It is no accident that the universities which are famous for producing spin-off companies, and for stimulating growth in their local economies, are also famous for

the fundamental research they do. An excellent science base educates young scientists and engineers in the latest techniques that they can carry into industry.

10. Since the science base is increasingly networked across the world, investment by the UK in science enables our scientists and engineers in business to access global networks and tap into global sources of knowledge. Investment in basic research is the fundamental building block for seeking greater commercial exploitation of research by businesses and universities. That is why the Government puts such a high priority on enhancing the excellence of our scientific and engineering research. That is why the Government is putting resources into the science base, reversing years of decline.

11. Investing in the generation and acquisition of new ideas goes beyond university funding. Much of the science base is in company laboratories and research centres: it is not just in universities. The Government therefore also needs to create the right climate and incentives to encourage companies to use science and technology to build up competitive advantage.

12. Investment in basic research is just one part of the cycle. Knowledge must flow out of the science base into products and services. The Government's aim, therefore, is to invest in the science base, with measures to open up channels to allow scientific know-how to flow beneficially through to society, into business and jobs, and also into health care, public services and the environment. To achieve that, we need to create bridges between the public and private sectors, often at a regional level where clusters of companies and universities can form to share ideas and exploit opportunities; and we need to make sure that we link into ideas and opportunities across the world.

13. We also need to strengthen the links in the chain of innovation in Britain. Too many good ideas still do not get fully exploited. Our public investment in basic science can deliver higher returns. We will achieve this by valuing engineers and technologists equally with scientific researchers, by making sure that people in the science base have the skills, incentives, finances and commercial partners to make it easier to turn ideas into innovations and by making sure that businesses, both large and small, understand

how to access this pool of knowledge. Researchers and managers will only innovate if they have incentives to do so and are encouraged to take risks. Our proposals aim to enhance those incentives.

14. All industries will benefit from this knowledge flow, from basic manufacturing and food processing, to the new science-based industries of the future.

15. An innovation will only succeed if it is desired and accepted by consumers and the public. That is why creating markets for innovative products is as vital as investing in basic research. The best incentive for innovators is a market open to their new products and ideas. The new, tougher competition policy we have introduced will help open up markets to new entrants and new ideas, and so spur the innovation process. Companies will invest in new products if they recognise that consumers are open to innovation and quick to adopt new services. We need competitive markets, combined with strong scientific capability, to create innovation.

16. But competition is just one side of the story for consumers. Consumers will support investment in science if it helps to deliver products they value. But, in addition, public confidence in the whole notion of science must be strong and well founded. People must feel that science is serving society and that it is properly regulated, open and accountable. The BSE crisis and the controversy over GM foods have raised questions about the value of scientific progress in society. These are questions we should ask. It is in the public interest, in the interests of scientists and in the interests of companies seeking to exploit science commercially that they are addressed. We need a more systematic and independent approach to satisfy public concerns about the risks created by scientific innovation. When science delivers innovations that improve people's lives with minimal risk that they understand, they support it wholeheartedly. Science and innovation need a stable and transparent framework of public support within which they can develop.

17. This public support is a key part of the process of innovation. Public support for science underpins the Government's investment in the science base, refuelling the cycle of innovation by allowing research to go in new directions.

18. A policy which focused on one aspect of this innovation cycle independently of the others would be a failure. A comprehensive innovation policy must embrace each stage of the cycle, from idea generation and acquisition, through transfer and dissemination to public confidence and consumer markets. That is why this Government believes that public policy has a vital role to play in the development of a knowledge-driven economy.

How Britain stands

19. Britain is well placed to play a full role in the global process of discovery and innovation. British science is world class. Science education in schools is better than in many other countries. Our record for scientific research and excellence is second only to the US and ahead of France, Germany and Japan[1]. We are world leaders in the life sciences: plant and animal science, agriculture, pharmacology, neurosciences, biology and biochemistry, microbiology, molecular biology and genetics, psychology and psychiatry.

20. And we are seeing rapid progress in terms of generating businesses from the science base. Many of our universities are creating strong links with industry and spinning out new companies. By 1997, 7.2 per cent of R&D in the UK higher education sector was funded by industry, compared with 5.8 per cent in the United States. A survey for the Office of Science and Technology identified 223 businesses spun out from (and wholly owned by) UK higher education institutions in 1997/98. Of course many other businesses are spun off without universities retaining a stake in them. In the past decade we have created a string of scientific companies – ARM, Autonomy, Psion, Bookham Technology – which are admired the world over. Britain is home to strong science-based industries in aerospace and pharmaceuticals, as well as being a leading centre for many design disciplines, computer games and mobile telephone software and services.

Communications White Paper

Modern communications networks and services rely heavily on science and technology. Over the past 30 years, developments in electronics have revolutionised the communications industry.

The Government will be setting out its views on the regulation of this vital sector of the economy in a White Paper. This will be broad in its scope, covering both infrastructure and content issues, and it will provide a coherent and consistent approach to the regulation of the converging communications industries.

[1] See Table 3 on page 18 Bibliometric Analysis – 1981-1998

Communications technology

Today one of the newest and most exciting research areas is optoelectronics. Key scientific breakthroughs in optoelectronics were made in the UK, both in industry and at the universities. With the help of sustained Government funding there are now a dozen or so university departments with world class reputations in this field. Within the space of a year, three of the UK's leading university photonics groups have created companies to commercialise their research – Southampton Photonics, Solstis, and ilotron.

The market for optical communications equipment, already a £30 billion business, will continue to grow rapidly, perhaps to £200 billion within a decade or so. A recent analysis of the sector put last year's UK production of optoelectronics systems and components at about £4 billion, which accounts for half of the total EU production.

DTI and EPSRC support for optical technology is now paying off in industrial terms. These programmes have helped to keep the UK's position as the prime European location for the manufacture of optoelectronic components and systems. And there are enormous opportunities, which we have yet to explore fully, in developing the content and applications which can be delivered on this rapidly evolving infrastructure.

Market value (equity–ordinary shares) UK public listed companies

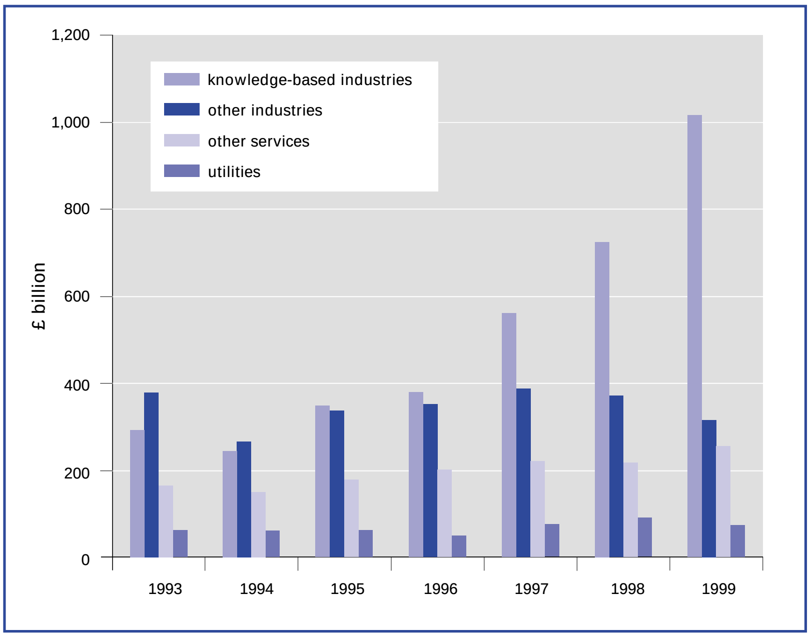


Chart 1

Source: DTI calculations based on FTSE data

21. Developments in high-tech sectors are beginning to show in our trade performance. In 1998, the UK's high-tech exports per capita were the highest of the G7 countries, and had grown by 9 per cent per annum since 1992. The power of science is increasingly recognised by financial markets: knowledge-intensive sectors such as pharmaceuticals, telecoms and information technology now account for 38 per cent of the value of the London Stock Exchange, compared with 20 per cent 10 years ago. High price earnings ratios in these sectors indicate their growth potential. And an increasing amount of venture capital is being invested in

dynamic young companies, many of them in technology sectors: between 1995 and 1999 the total invested by UK venture capitalists in start-up and early stage firms increased from £85 million per annum to nearly £350 million.

22. Our task is to build upon Britain's excellent reputation as a centre of science and innovation. But we cannot be complacent about Britain's position. We face challenges on every front. We operate in a fiercely competitive environment as other countries increase their investment in scientific research. In Europe, the French and German Governments are putting much greater emphasis on extracting higher commercial returns from their public spending on research: Germany has committed itself to a 6.7 per cent annual increase in R&D and in June 2000 announced a 50 per cent increase in post-genome research. Japan has a target of doubling its R&D budget. In some areas of science we risk falling behind the very best; we need to ensure we stay among the front runners.

23. We are in a global competition. To keep and attract the best brains in the world we need continual investment in world class facilities and must provide competitive rewards. We need to improve the quality of science teaching, so that more people, particularly more women, choose science as a career.

24. We want more companies to use science and technology to create competitive advantage. We need more sectors of the economy to work like pharmaceuticals, aerospace and defence. And we need to address some longstanding weaknesses: for example the supply of technical skills to industry so that companies can make effective use of new technology and absorb ideas emerging from scientific research.

25. And we need to make certain that all regions benefit from the development of new products and processes and new industries. The innovation strategies being developed by the RDAs will help to ensure that all areas participate in the knowledge-driven economy.

26. Science must be our servant and not our master. Public acceptance of science cannot be taken for granted. The challenge for scientists is to engage with people in debate about the benefits of what they do; Government must complement this by providing a strong and open framework of regulation, supported by scientific evidence and independent scientific advice.

Devolution

27. This White Paper is a strategy for the UK, insofar as policy and management of some aspects of science and innovation are reserved to the UK Government. Policy and management for many other aspects of science and innovation have been devolved to the new administrations in Scotland, Wales and Northern Ireland.

28. The UK Government and the devolved administrations are committed to working together to translate the fruits of scientific research and invention into products and services that improve the economic and social well-being of all the people of Britain. They also recognise the need to work together to ensure that there is a strong UK science base supported by high quality science education, and that the public is well informed about scientific issues.

Key proposals

29. Government, with others, has a clear role in the funding of basic curiosity-driven research; the value of basic research can rarely be captured by the private sector. In addition, scientific knowledge is often produced through collaboration. Society benefits from basic knowledge being shared as widely as possible. The private sector will rarely invest in research when it cannot be confident of making a return.

30. Government is the lead investor in basic scientific research and through education policy has a critical influence on the teaching of science. Government needs to ensure that our schools and universities produce creative and knowledgeable scientists, that it is an intelligent funder of basic research and that it provides our scientists with world-class facilities and equipment.

31. That is why science and its exploitation were an important theme in the Government's Spending Review 2000, which included a cross-departmental review of science and research. The review's conclusions underpin the spending plans set out in this White Paper.

32. To maintain and enhance the excellence of our science the Government will:

- invest in a new £1 billion programme in partnership with the Wellcome Trust to renew the infrastructure for science, providing world-class buildings and equipment for leading edge research;
- give a £250 million boost to research in key new areas that will shape life in the twenty-first century: genomics, e-science and basic technology such as nanotechnology, quantum computing and bioengineering;
- provide additional funding to increase over three years the basic support for post-graduate research students to £9,000 a year;
- launch in partnership with the Wolfson Foundation and the Royal Society an initial fund of £4 million a year to assist in the recruitment of up to 50 top researchers so we can compete in the world market for the best academics; and
- make 2001/2002 Science Year and run a new Science Ambassadors programme to capture children's

imagination and encourage them to take up careers in science and engineering.

33. In addition there are often market failures in the networks and links which bring the public and private, researchers and industries together. Although all parties would benefit from these linkages being stronger, it is in no one party's interest to take on the cost and responsibility for forming these networks. That is why public funding can play such a critical role. Government can facilitate such links to help turn scientific ideas into innovation. This means examining new public-private partnerships to bring businesses and universities, ideas and finance closer together, as well as initiatives to create regional clusters. Government cannot and should not attempt to manage these networks but it can play a critical role in facilitating their creation.

34. Government must also provide the best framework for scientists and businesses to make international links. To play a full part in modern science and to bring its benefits to the UK we have to co-operate internationally. Our investment in science in the UK is an entry ticket to the global collaboration that is the driving force of scientific advice. Government plays a crucial role in making this possible. A society that is closed, inward looking and defensive would not remain at the forefront of science because it could not take part in this global collaboration. Britain is stronger when it collaborates internationally. Britain must be a key player in European and global science.

35. To extend opportunities for innovation the Government will:

- establish a Higher Education Innovation Fund of £140 million over three years incorporating the Higher Education Reach Out to Business and the Community fund to build on universities' potential as drivers of growth in the knowledge economy. This will triple existing funding by the third year, to increase universities' capabilities to work with industry, particularly small firms;
- launch a new Foresight fund, initially up to £15 million, to get the best ideas from Foresight 2000 put into action fast;
- run one further round of the University Challenge Competition, to provide seed venture funding for knowledge transfer; double the number of new starts for Faraday Partnerships from four to eight a year, to link the science base to business networks; and put £15 million more into Science Enterprise Centres to bring business skills into the science curriculum;
- create new Regional Innovation Funds of £50 million a year to enable Regional Development Agencies (RDAs) to support clusters and incubators and new clubs of scientists, entrepreneurs, managers and financiers;

- support 20 Business Fellows who will lead their academic colleagues in working with business. They will spend part of their time advising companies, particularly SMEs, on their business problems, providing technical and research solutions;

- publish science and innovation strategies for government departments;

- introduce a Small Business Research Initiative to open up to small firms R&D procurement worth up to £1 billion, with a target of procuring £50 million of research from them;

- change the rules for Government funded research, so that research bodies own the Intellectual Property Rights; issue new guidelines on incentives and risk-taking for staff in public sector research establishments; and provide £10 million to commercialise research done in the public sector, including the NHS; and

- double the number of International Technology Promoters from 8 to 16 and link their work closely with British Trade International and other UK agencies overseas, to help UK universities and businesses make new partnerships across the world. And we plan to extend the network of science attachés in embassies abroad.

36. Finally, Government plays a critical role as a regulator. Britain must combine the highest possible standards for consumer safety and health with open markets to reward innovators. Only if this is done, and given the priority it deserves, will the full potential benefits of the new scientific advances be realised.

37. To restore public confidence in science the Government will as a first step:

- implement stronger guidelines from the Chief Scientific Adviser on how scientific advice should be used in drawing up Government policy; and

- publish a new code of practice for scientific advisers to Government, which will commit them to high levels of openness and transparency in their work.

38 The Government needs to be an effective investor, facilitator and regulator. But we need to be clear what this commitment to active public policy means. It does not mean going back to a situation where Government attempted to pick winners. We have learned costly and important lessons about the limitations of the state as a direct investor in companies and as a manager. But equally we have learned that the market alone will not generate the basic investment in research, the networks and the public confidence needed for innovation to prosper. Standing to one side and doing nothing will not deliver in the knowledge-driven economy.

Excellence in Science

1. Britain must enhance the excellence of its science base. The quality of the science base provides Britain with access to research around the world, which feeds into business, hospitals and schools. Facilities and equipment in the public and private sectors are important, but the real core of the science base is people – teachers, students, researchers.

2. Government has a key role in creating Britain's basic scientific capability. Government is the lead investor in basic scientific research. Through education policy, Government and the devolved administrations have a critical influence on the teaching of science. As an employer of thousands of scientists in public research laboratories Government influences the rewards available for science. Government needs to be an intelligent investor in science, determined to promote excellence and diversity and provide opportunities for everyone.

3. We must start at the base, with better education for all our children in science. And we must open up opportunities for the best research. That means top class research within universities and more R&D in industry. Public investment is vital but also making sure we get the best science possible. That means being sure we have the right university structure, that there is a proper funding framework, and that academic careers are rewarding. The approach differs in different parts of the UK but the aim is the same.

Better science in schools

4. We need better science in schools, so that every child has the opportunity to make sense of the world around us and the way it is changing; and to give the best start to those who choose to work in science, engineering or technology.

5. All children in England and Wales study science, through the National Curriculum, from the start of school until they are 16; 11 years of compulsory science. Until they are 9 or 10, most are enthusiastic about science lessons and the discoveries they make there. They achieve well, compared to children of the same age in other countries. And primary school science teaching has improved considerably in the last three years, as the results of tests for 11-year-olds demonstrate. But as they move to secondary school, too many children lose interest in science.

6. Nevertheless, the number of young people taking science and technical A levels has gone up in recent years (see Table 1 opposite), more than the overall increase in numbers staying on at school and moving on to higher education. But we need to keep a careful watch on this; in some important subjects, numbers have fallen slightly in the most recent year.

Table 1

GCE A LEVEL ACHIEVEMENTS OF 17-YEAR-OLD CANDIDATES IN SCHOOLS AND FE SECTOR COLLEGES IN ENGLAND Numbers of entries (in 000s) that resulted in a pass (ie A–E grades)						
	1994/95	1995/96	1996/97	1997/98	1998/99	%age increase 1994/95 – 1998/99
Biology	29.1	32.1	36.3	37.8	36.6	25.8
Chemistry	25.6	26.1	28.0	29.0	28.3	10.5
Physics	22.1	21.7	22.9	23.7	23.8	7.7
Other Science	3.6	3.8	4.9	5.3	5.0	38.9
Mathematics	42.5	46.4	48.6	49.5	48.7	14.6
Computer Studies	5.2	5.7	6.0	6.6	10.7	105.8
Total Maths, Science and Computer Studies	128.1	135.8	146.7	151.9	153.1	19.5
All subjects	514.5	470.9	517.5	541.5	543.6	5.7

Source: DfEE

7. The picture for first degrees is more worrying. Numbers of young people graduating in science, engineering and technology are going up, but not as fast as the total. There are some worrying trends, particularly the fall in numbers of chemistry and physics graduates, and in engineering (see Table 2).

Table 2

FIRST DEGREE GRADUATES FROM UK HE INSTITUTIONS BY SPECIFIED SUBJECTS: 1994/95 AND 1998/99									
	1994/95			1998/99			Percentage change		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Mathematics	2,212	1,223	3,435	2,275	1,363	3,638	2.8	11.4	5.9
Computer Science	6,469	1,805	8,274	8,167	2,213	10,380	26.2	22.6	25.5
Physics	2,004	476	2,480	1,844	476	2,320	–8.0	0.0	–6.5
Chemistry	2,607	1,503	4,110	2,143	1,481	3,624	–17.8	–1.5	–11.8
Biology	1,537	2,175	3,712	1,630	2,405	4,035	6.1	10.6	8.7
Electrical and Electronic Engineering	4,433	356	4,789	4,560	475	5,035	2.9	33.4	5.1
Chemical Engineering	939	278	1,217	818	305	1,123	–12.9	9.7	–7.7
All other Engineering	12,117	1,680	13,797	12,089	1,705	13,794	–0.2	1.5	0.0
Technology	1,400	880	2,280	1,291	769	2,060	–7.8	–12.6	–9.6
Total Engineering and Technology	18,889	3,194	22,083	18,758	3,254	22,012	–0.7	1.9	–0.3
Total – Science, Engineering and Technology	33,718	10,376	44,094	34,817	11,192	46,009	3.3	7.9	4.3
Total first degree qualifiers – all subjects	117,544	120,253	237,797	121,676	141,995	263,671	3.5	18.1	10.9

Source: DfEE

8. Our aim is to make science more exciting for all our children. We have therefore announced that:

- 2001/02 will be Science Year, raising the profile of science and technology in schools and with teachers and parents. The year aims to increase pupils' interest and to promote science as fun, exciting and relevant to everyday life.

9. And we are improving the science curriculum; we need to give teenagers opportunities to ask questions, challenge accepted facts and think creatively about science. From September 2000, the curriculum will have greater emphasis on practical science (investigation and experimentation). The Qualifications and Curriculum Authority is doing a full review of the science curriculum to make it more relevant to the 21st century.

- As part of Science Year, the Government will establish a new Science Ambassadors' programme. Top science students will form links with their old school or college, inform pupils about their own experiences and provide coaching and mentoring. The programme will reach out in particular to those schools from which few pupils go to university to study science and engineering. It will inspire young people to aim high and help them in deciding on study and career choices. It will help to widen access to university and will provide personal development opportunities for the science students themselves.

10. We are encouraging links in schools between science, technology and design through Young Foresight.

Young Foresight

Teachers from over 2,000 schools in England and Wales have registered interest in Young Foresight, designed for use at Key Stage 3. Mirroring the work of the Foresight Panels, it challenges children to identify and solve problems associated with the development of innovative new products for the world of 2020. The project is receiving support from the Institution of Electrical Engineers, AEA Technology, Ford, Jaguar, Marconi, Rolls-Royce plc and Thames Water, who are putting local business mentors in classrooms to help teachers and children. Pilots are now running in 12 schools, using specially produced films and materials designed to meet the new standards set by the Design and Technology curriculum. The aim is to bring design and technology alive in the classroom by introducing local industry to its future workforce as they learn to design for the future. Young Foresight will be extended to about 100 schools during the next academic year, when there will be a national competition ending in a live event on BBC Television's Tomorrow's World.

11. Excellent teachers are the key to exciting science in schools. But too many teachers do not have degrees in the science subjects they teach, and their age profile is worrying in England, Scotland and Wales. We are now offering £10,000 training and recruitment packages for teachers in shortage subjects, including science and technology; we shall watch carefully to see whether this is sufficient to meet the need.

12. Teachers need to keep in touch with developments in their subject, and this is particularly important in science and technology, where the pace of change is constantly accelerating. As part of our national strategy to support the teaching profession we will:

- from spring 2001, pilot in 17 Local Education Authorities in England and Wales a package for development and training of science teachers at Key Stage 3;

- continue to work across Government on how to connect the professional development of teachers and teaching, and the curriculum in schools, with innovation in research and the application of science taking place in the private sector and in Higher Education Institutions; and

- working with the Council for Science and Technology and science teachers, consider further steps to support the professional development of science teachers, including those recommended in the Council's report on science teaching[2].

13. Science teachers and their pupils deserve the best materials. There is no shortage here; rather, there is too much on offer. And significant numbers of teachers, particularly in primary schools, are not aware of the resources available. Many only occasionally use materials from certain providers, others never do so[2]. Teachers need support to help them decide what will best meet their needs in the classroom. We want to offer that support and to encourage more co-ordination between the providers. So we are working with the providers of science materials to:

- provide a single point of support for science teachers, through education–business consortia within each Learning and Skills Council area in England. These issues are being considered in Scotland, Wales and Northern Ireland.

14. Modern science works best in modern buildings and with modern equipment. That is why we have provided £60 million to upgrade science laboratories in schools, so that teachers and pupils have the right environment for their work.

World-class infrastructure

15. In our universities and research institutes we need world-class facilities to enable our scientists and engineers to do world-class research. We inherited the legacy of nearly 20 years of neglect; many people are struggling with outdated buildings and equipment. The Government tackled this as one of our first priorities and we have already provided £750 million over three years, with the Wellcome Trust, through the Joint Infrastructure Fund (JIF), a ground-breaking

[2] Source: *Science Teachers: A report on supporting and developing the profession of science teaching in primary and secondary schools*, Council for Science and Technology, February 2000

public/private partnership in support of much needed research infrastructure in UK universities. This is a good start. We are now doing more:

- in partnership with the Wellcome Trust we are providing a further £1 billion of investment in science infrastructure for the two years 2002–3 and 2003–4 comprising £775 million from Government and £225 million from the Wellcome Trust. Government funding for capital expenditure will be allocated to universities, so that for the first time in many years, universities will be able to plan strategically to meet their future needs for buildings and equipment.

16. Information and communications are an increasingly important part of the research infrastructure. There is an ever-increasing need for exchange of complex data, requiring high bandwidth, such as annotated gene sequences, climate models and data from particle accelerators. To ensure that the UK remains at the leading edge of network access provision, we will improve the academic high-speed network, which links thousands of computers in 200 higher education and 600 further education institutions, and provides international connectivity. This matches developments in Europe on increasing the speed of transnational connections and linking European Centres of Excellence, envisaged in plans for a European Research Area.

The new Science Research Investment Fund will have four streams:

- £675 million for universities from the Science Budget and the Higher Education Funding Council for England. Allocations will be linked to research excellence and the volume of research undertaken. Universities will decide their own priorities and will be expected to provide 25 per cent of the investment they undertake. This will be an incentive for universities to deepen their relationships with third parties, including business, through sponsorship, joint developments or generation of research income;
- £150 million fund provided by the Wellcome Trust for investment in buildings for sciences within the Trust's remit, drawn from the top-rated but unmet bids submitted to the JIF;
- a separate £75 million of Wellcome Trust funding for biomedical science project-related equipment and refurbishment spend; and
- the Office of Science and Technology will retain £100 million to modernise Research Council institutes and to contribute to large national projects.

CERN – a showcase of international collaboration

CERN, European Laboratory for Particle Physics, has been at the centre of European particle physics for nearly 50 years. Founded in 1954 with 12 member nations, including the UK, it has grown to 20 members and a total budget of about £400 million per year. Particle accelerators and detectors, needed to answer the most fundamental questions about the nature of the universe, are extremely expensive and typically too costly for a nation to build and operate on its own.

The Large Electron-Positron (LEP) Collider will be finally switched off in 2000 after 11 successful years of operation. When first constructed, it was the largest and most powerful accelerator of its kind in the world, with particles accelerated to almost the speed of light in opposite directions around a 27-kilometre ring, then collided together to recreate the energies available in the first moments after the Big Bang.

The LEP has produced some amazing discoveries, but is being dismantled to make way for the new Large Hadron Collider (LHC), which will be much more powerful and – it is hoped – will lead to even more fundamental discoveries such as the origin of mass. The LHC is in fact not just a European but a world machine – the US has cancelled a similar project and committed funds to the LHC, and other contributions have come from Japan, India, Canada and countries all over the globe.

CERN was also the place where the World Wide Web was created (by a British scientist), and is currently at the centre of key developments in the next generation of the Web, known as the Grid, which will have a similarly huge effect on communications across the planet.

The UK has been a leading player in CERN from the start. With UK physicists, computer scientists and engineers involved in CERN at all levels, we have benefited enormously over the years. Our membership continues to be an essential part of our commitment to fundamental science.

17. Some elements of research infrastructure, such as research vessels and the largest telescopes, need to be planned and managed at national and, increasingly, international level. The Government is developing a rolling 10-year plan for future large infrastructure projects, taking account of developments elsewhere in Europe. Our aim is to ensure that researchers based in Britain have access to the best facilities in the world. Sometimes, it will make sense to go outside Europe to do that. Sharing with European partners we have the opportunity to build a new European infrastructure with leading edge facilities and equipment, much better than anything we could support with national funding alone.

18. As part of the more strategic approach to infrastructure planning, the Government is reviewing the Council for the Central Laboratory of the Research Councils (CCLRC) which operates major national research facilities for Research Councils and universities. While other elements of the structure of Research Councils put in place by the last White Paper 'Realising our Potential'[3], are working well, the CCLRC was not given a clear mission or proper funding arrangements; we should now do so.

Funding excellent research

19. British science is among the best and most cost-effective in the world. With only 1 per cent of the world's population, we are responsible for 4·5 per cent of the world's spend on science, produce 8 per cent of the world's scientific papers and receive 9 per cent of citations. UK scientists claimed around 10 per cent of internationally recognised prizes steadily throughout the last century. We are second in output and quality only to the United States, ahead of countries such as France, Germany and Japan, which are larger than the UK, and spend more on public science. In value for money, we are second to none.

20. We are faced, however, with increasingly fierce competition across the world to produce the best research. We need to maintain our world lead in the fields where we are strongest, and develop a lead in new areas, while maintaining the capacity to do science which is recognisably world class, across the board. Only in this way can we gain full access, through the international exchange of new knowledge and ideas, to all

Table 3

Bibliometric analysis – 1981–1998

Country	Share of world papers %	Share of world citations %
United States	34.2	47.9
United Kingdom	8.2	9.2
Japan	7.8	5.8
Germany	7.4	6.2
France	5.5	4.7
Canada	4.5	4.6
Italy	3.0	2.3

Source: OST

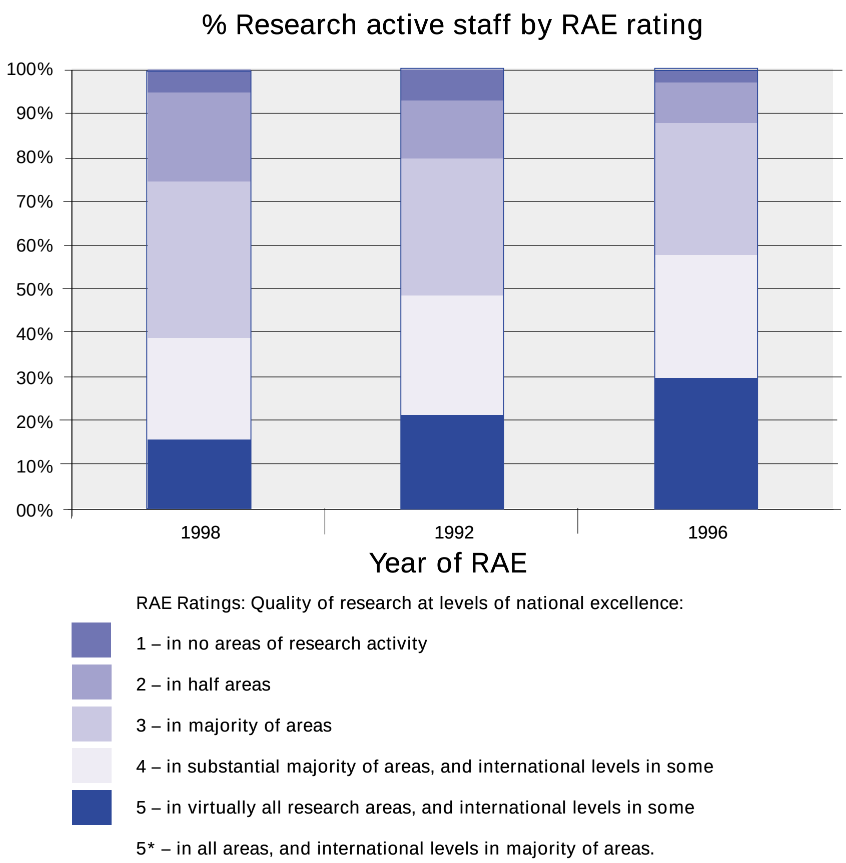
[3] *Realising our Potential: A Strategy for Science, Engineering and Technology,* Cm2250, May 1993.

the science which is done outside this country.

21. The dual support system, with infrastructure money for research provided through the Higher Education Funding Councils, and project grants awarded by Research Councils, is improving the quality of the research base, encouraging excellence through competition, with more money going to the best research, and a strong focus on quality outputs. It has concentrated most research funding in the main centres of excellence, facilitating cross fertilisation of ideas between the best people in different disciplines working in the same place, while maintaining pockets of particular excellence elsewhere, so supporting diversity and dynamism. But there is scope for refinement, increasing the focus on excellence and sharpening the competition, as standards improve here and throughout the world. The Funding Councils are conducting their own review and will invite views in the autumn.

22. The funding system has its critics. Some argue that the Funding Councils' Research Assessment Exercise (RAE) favours single subject research at the expense of interdisciplinary collaborations, and that good ideas for interdisciplinary research can also fall into gaps at the

Chart 2



Source: HEFCE

interface between Research Councils. In fact, 55 per cent of UK papers involve collaborations between different institutions; 20 per cent involve international collaboration[4]; academics who do interdisciplinary research are as likely to have high RAE scores as those who focus on single subjects[5]. But we need to do more to support these links, especially on collaboration between disciplines.

23. There are also concerns that the RAE is too focused on published papers, giving too little credit to applied work. Some believe that it deters the best academics from entering collaborations with industry and from doing research relevant to industry's needs. It is essential that the main funding streams do not create such perverse incentives. So we welcome the emphasis in guidance for the next RAE, in 2001, that basic and strategic research done in confidence for business, as well as patents, should be given equal weight alongside papers published in peer review journals; it is the excellence of the science that should count. We shall monitor closely to see that the guidance is followed, and whether it proves sufficient to ensure a proper balance.

24. We do not consider that the RAE should be used to divert research funds to support universities' applied work with business, instead of its present focus on excellent fundamental research. Work with industry is an important part of the mission of all universities, and an

Initiatives in multi-disciplinary research

Bioinformatics – bringing together advances in IT to handle the vast quantity of data emanating from genome and related research. In addition to the established BBSRC and EPSRC joint Bioinformatics Initiative and MRC investment, all the natural and physical science Research Councils are collaborating to establish new research groups.

Tissue Engineering – involving disciplines such as molecular biology, developmental biology, cell biology, biochemistry, physiology, anatomy, material science, imaging, modelling, chemistry and engineering, along with medical/clinical expertise: BBSRC, EPSRC and MRC are taking forward a joint, multi-million pound investment in a new Interdisciplinary Research Centre.

Climate Change – NERC, EPSRC and ESRC are providing up to £10 million over five years for environmental scientists, engineers and economists to work together on climate change in an initiative launched in July 1999.

Urban Regeneration and the Environment – the URGENT programme, involving NERC and EPSRC, began in late 1996. URGENT aims to stimulate the regeneration of the urban environment through understanding and managing the interaction of natural and man-made processes. Forty-one projects are underway, with annual funding of about £3 million.

[4] HEFCE Review of Research Policy Funding – to be published.

[5] Evaluation Associates Ltd report to the UK Higher Education Funding Bodies, April 1999 (RAE1/99).

alternative to blue skies research for many. The right way to support that mission, to the extent that it does not pay for itself, is through a dedicated funding stream. We set out our plans for a Higher Education Innovation Fund in the next chapter.

Funding priorities

25. We are giving a £250 million boost to key areas of scientific research. This will enable us to:

- maintain strength across the board while focusing on important areas of growth for UK science, such as opportunities to capitalise on our strength in genomics and to work with European partners at the same time as building national strengths in e-science and informatics. And we shall also give priority to key areas of basic technology such as nanotechnology, quantum computing and bioengineering underpinning future advances in science.

26. A first version of the decoded human genome is now available. Now that we know the code, the next step is to understand what the genes do and how they work. Competitor countries are increasing their expenditure in genomics to accelerate identification of genome function – a key step in understanding the genetic basis of susceptibility to illnesses, including cancer and heart disease, which should then lead to improvements in diagnosis of disease, its prevention and treatment. By knowing the genetic make-up of each individual person, we will have greater ability to target therapies on individuals; at present nearly one-third of drugs do not have the desired effect on the patients who are prescribed them. Exploiting the genome is a unique opportunity and the UK has the right mix of strong companies, scientific expertise and available risk capital to capitalise on that mix. This will depend crucially on accelerating momentum in the science base.

27. The second key area is informatics and e-science, underpinning the next generation of e-commerce. It will be a key enabler to assist multi-disciplinary and multi-location research. For genomics, and for other scientific areas such as environmental sciences, particle physics and astronomy, there is a need for radically new hardware and software solutions to process, communicate, store, analyse and visualise the huge expansion of data now being produced by global teams of scientists. This new generation of e-science infrastructure will underpin the next generation of e-business technology world-wide later this decade.

28. Basic science advances our understanding of how the world works; basic technology advances our ability to make things work for us. Developments in science and technology often march hand in hand; advances in science can

Basic Technology

New basic technology is about creating new capabilities. Research on new basic technologies rarely yields something immediately ready for the marketplace – the original programmable computer was invented by Charles Babbage in the 19th century – but it is the fertile basis for further R&D and private sector investment which eventually leads to marketable products.

For example, research into superconductivity, started some 30 years ago in UK universities and at the Rutherford Appleton Laboratory (RAL), has been exploited through the formation of Oxford Instruments which leads the market for high field magnets for Magnetic Imaging in hospitals, with annual turnover in this and other areas of £160 million. The expertise has also been used in large detectors at the CERN particle physics laboratory, one of which was designed by RAL. Researchers in 'Big Science' areas are often working at the frontiers of technology and engineering to advance their research, but the initial requirements of particle physicists and astronomers have also led on to the development of the internet and camcorders.

There is a wealth of opportunities in basic technology arising from the science and engineering base – for example detectors and imaging, laser systems, intelligent systems, nanotechnology and tissue engineering. These and other areas are important for maintaining the attractiveness of the UK to technology-based firms, both multi-nationals and high-tech small- and medium-sized enterprises (SMEs).

Nanotechnology involves working at the smallest of possible scales, manipulating individual atoms and molecules, opening up the possibility of incredibly small electrical devices and sensors (including biosensors) as well as medical applications, for example for re-constructive surgery. The basic technology brings together research in materials, physics, chemistry, molecular science, micro-fabrication and engineering.

provide the basis for advances in technology, advances in technology provide platforms enabling new science to develop, and are often an essential first step in innovation.

29. Science and technology are of equal value, but in the past we have not put enough emphasis on basic technology. Changes to the RAE will help to address this. In addition, the Government is asking the Research Councils for a new initiative on basic technology, such as nanotechnology and quantum computing.

30. Alongside national expenditure on these priorities, we want to ensure that the opportunities for European collaboration are fully exploited. European Framework Programmes are worth about £9.5 billion over four years; 5 per cent of total public expenditure on research across the EU. Returns to the UK have been substantial. Under the 4th Framework Programme, the UK led all other EU countries in numbers of collaborative links; 73,000 links (each involving many people) and 33 per cent of all research fellows funded under the programme came to the UK. Indications from the first calls of the 5th Framework Programme are that the UK has again put in a strong performance. Our priority areas are already important features of the 5th Framework Programme; we aim to reinforce them in negotiating the 6th Framework Programme, which will start in 2003.

Academic rewards

31. We want the best people in the world to do science in Britain. That means encouraging the ablest people to come here who would otherwise work abroad, and encouraging the best of those who are here to stay.

32. At present, over 11,000 UK resident students take a Master's degree in science, engineering or technology and over 5,000 a PhD[6]. In general, numbers are holding up, but not increasing as fast as we need for the knowledge economy. There are shortages in some key areas, and concerns about quality. Universities say it is often impossible to get the best people in the world to take top jobs here.

33. The action we are taking to improve the infrastructure and provide funding for exciting new areas of science will make universities and research institutes better places to do science. As teaching improves, a new generation of pupils will leave school more enthusiastic about science. But people who want to do science also need to be able to afford to do it. Universities need to compete in the world market for the best academics. It is important that they set pay levels in the light of the need to recruit and retain such staff. We shall:

- provide additional funding to improve the basic support for post-graduate research students, over three years, from £6,620 outside London to £9,000 a year. Our aim is not to compete with starting salaries in business – that would not be realistic – but to provide a better basis for students to pursue their studies with a rising income over the next three years; and
- working in partnership with the Wolfson Foundation and the Royal Society, we will launch a fund, initially worth £4 million a year, to assist in the recruitment of up to 50 leading researchers in key areas of science, so that we can compete in the world market for the best academics. And we shall be looking for new ways to attract scientific entrepreneurs back to the UK.

34. 30,000 or more researchers are on fixed-term contracts. Young people need to be able to see that jobs in university research lead somewhere – whether within academia or to careers outside. We are concerned about career development prospects for young people starting out and so we are encouraging the university employers and the Funding and Research Councils to develop:

- targets for, and better monitoring of, institutional performance in managing contract staff;
- recognition and reward schemes for the development of researchers;
- promotion of relevant evaluation and best practice models; and

[6] This includes medicine and dentistry, subjects allied to medicine, biological sciences, veterinary science, agriculture and related sciences, physical sciences, mathematical sciences, computer science, engineering and technology.
Source: Higher Education Statistics Agency via OST.

- better provision and co-ordination of career guidance and staff development resources.

35. We are also improving opportunities for women. More girls now study science to a higher level than ever before and more girls are achieving good A levels in science and mathematics. And they are doing well at degree level; the rate of increase in science graduates is faster for women than for men. But few women are reaching top academic positions; fewer than 10 per cent of biological sciences professors are women, even though women are now over 60 per cent of graduates in the biosciences.

36. We need to do more to help women to progress in scientific careers:

- the ATHENA project identifies the barriers which are hindering women's progression and retention in higher education careers, and tackles them by encouraging mentoring, setting up regional networks for academic women and improving equal opportunity practices.

37. We also need to help those who leave scientific careers, perhaps to have a family:

- as a first step, we are finding out how many women with relevant qualifications and experience have left careers in science, engineering and technology. We will identify the barriers to their return, and evaluate existing and new ways of overcoming them. In 2001, we shall act on the results of that study.

38. Women have an important contribution to make to science policy and scientific advice. We have met the target set in 1994 for women to be 25 per cent of the membership of SET-related bodies. This is not enough; our next target is 40 per cent by 2005.

Attracting scientists and engineers to the UK

39. We want more overseas scientists and engineers to come to the UK. That is why the Prime Minister launched an initiative last year to increase numbers of overseas students studying here. We also need more of those who have the skills and knowledge that the UK needs to stay on to pursue opportunities here. At present, about a quarter of overseas science PhDs and about a third of overseas engineers studying in the UK remain here to take up work. In the past, some foreign nationals studying in the UK faced difficulty in obtaining permission to work here after their studies, even when they had been offered a job.

Immigration and work permit rules acted as a barrier to their choice. To address this – and ensure that skills are not lost to the UK by default – the Government:

- is changing the rules so that students who qualify for a work permit can get one without leaving the UK. A clearer system with new guidance for students and employers will be in place this summer;
- is removing the requirement for separate permits for supplementary work, so that foreign academics can work more easily in the private sector, for example as consultants, or entrepreneurs; and
- as part of the joint effort to create a European Area of Research is starting to tackle barriers to free movement within the EU for scientists who come from countries outside it, reinforcing the support provided by existing mobility programmes. This should be a particularly important feature of the 6th Framework Programme. Knowledge moves with people; people – not institutions or programmes – are the real science base.

Opportunities for Innovation

1. At the same time that we enhance the excellence of our science and engineering research we must encourage science to flow throughout our society. We need scientific knowledge to flow into entrepreneurial start-ups, into manufacturing industry, into medicine and health, and into improving the quality of life. This means opening new channels for science to flow through society and focusing on new links, national and regional, public and private, which will enable this.

2. The UK needs to strengthen the links in its innovation cycle, bring universities and business closer together, provide researchers with skills and incentives to take their ideas to market. Only if science flows out of the science base into society will it open opportunities for all. We have to create a new culture, where people think ahead, see opportunities and can take risks.

Foresight

3. The Foresight Programme is a central driver – bringing people together, to share knowledge, create visions of the future and act on them. Priorities identified in the first Foresight reports in 1995 have led to new research in areas ranging from automotives to mobile telephones to applied genomics. As part of the agenda for action set out in the 1998 Competitiveness White Paper[7], the Government doubled financial support for Foresight panels, launching a new round of the programme looking ahead to 2020 and helping to shape agendas for

Foresight helping healthcare

Cerebrovascular diseases are the third most common cause of death in the UK. Each year, the UK's accident and emergency departments treat more than 500,000 patients wiith head injuries. Disabled survivors can mean stress for family carers and a high cost to the community at large.

Now, in response to specific recommendations from the former Foresight Health and Life Sciences Panel, a new £16 million centre in Cambrdge brings together skills and facilities from around the country to offer more effective treatment for patients. The Cambridge Cerebrovascular Centre (CCC), a Foresight Challenge winner, uses innovative imaging techniques to investigate cerebral injuries and advance prevention and treatment procedures. Research into the genetic basis for high blood pressure should also lead to better targeted treatment to prevent strokes – at present, all patients receive the same treatment even if their risk of suffering a stroke is low.

Establishing the Wolfson Brain Imaging Centre, the only unit in the country specifically designed for patients with acute brain injuries, is among the Centre's biggest achievements to date. The unit brings together a wide range of medical disciplines plus high technology in the form of two state-of-the-art scanners. Research carried out into the patterns of low blood flow and metabolic stress that follow strokes and head injuries has already had an enormous impact on the safe and effective management of brain swelling.

Now in its third year of funding, the CCC is looking to the future. Plans include research into whether genes determine the risk of stroke in patients with high blood pressure, and whether vascular imaging techniques can be used to assess the risk of stroke. The Centre will also be looking at how vascular imaging techniques can be used to predict the future risk of stroke.

[7] *Our Competitive Future: Building the Knowledge Driven Economy*, Cm 4176 December 1998. Available at www.dti.gov.uk/comp/competitive

business, Government and science, throughout the economy. Foresight panels will report in November 2000, with new ideas for action. And we are working with trade associations, banks and others to help more and more businesses to use Foresight for themselves. The Foresight website provides access to Foresight for everyone.

- Government will launch a new Foresight fund, initially up to £15 million, to get the best ideas from Foresight 2000 put into action fast.

Universities in the knowledge-driven economy

4. The universities will be at the heart of this effort to build the knowledge economy. Universities can play a central role as dynamos of growth. But they will only fulfil that mission if they match excellence in research and teaching with innovation and imagination in commercialising research. To do that they will need the skills and the infrastructure to translate science into products, services and marketable commodities.

Enterprising university initiatives

The *White Rose Consortium* – the Universities of Leeds, Sheffield and York – have pioneered regional co-operation between universities and was one of the first to receive an award under the Biotechnology Exploitation Platform (BEP) Challenge in early 1997. Within 18 months, it achieved 8 spin-outs and over £2 million in income from licence deals etc.

The *University of Oxford* established Isis Innovation in 1988 as its technology transfer company, to which it assigns its intellectual property rights and which then assesses, protects, develops, and takes the inventions to market. In 1997 the University significantly increased its investment in Isis and in the last two years Isis has filed 100 patents and managed the spin-out of 10 new companies. Oxford's spin-outs Oxford Asymmetry, Oxford Biomedica, Oxford Glycoscience, Oxford Molecular, and Powderject Pharmaceuticals have a market capitalisation of well over £1 billion, and have directly created about 3,000 jobs.

Cardiff University operates a well-established Innovation Network providing an effective bridge to facilitate technology transfer between academics, Welsh companies and business intermediaries. Since its launch in March 1996, the Network has developed a wide range of activities, including a regular newsletter distributed to over 2,000 businesses; a 'Needs and Opportunities' service to promote and stimulate technology transfer activities, and an Annual Dinner and Awards competition. To date, the Network has been responsible for attracting over 500 companies to the University for the first time.

In Scotland the *Universities of Dundee, Edinburgh, Glasgow and Heriot-Watt and Strathclyde* have developed an extensive range of practical courses in entrepreneurial awareness, technology management, business planning and commercialisation. They are now collaborating to develop the Institute of Enterprise for Scotland, to build on existing initiatives from each of the partner universities.

Satellite success in Surrey – a university spin-off company aims high

Surrey Satellite Technology Ltd (SSTL) is an excellent example of the benefits to both sides when industry and academia work in collaboration. SSTL is wholly owned by the University of Surrey, working out of modern buildings in the heart of the campus. Established in 1985, SSTL has built up an enviable reputation as world leader in the field of small satellites. It has designed, built and launched 15 microsatellites and last year launched its first minisat – UoSat12 – funding its development entirely from its own internal resources. In 1998 SSTL won the Queen's Award for Technological Achievement.

SSTL built its reputation on a simple satellite design which it could adapt to meet the needs of countries new to space but who wanted to establish their own space programmes. Engineers from the customer come to Surrey and work with SSTL on the construction of the satellite, creating the necessary element of technology transfer. But this is not all. SSTL has also been successful in selling to major established space nations, with recent sales to NASA (US) and CNES (France). They have also created a joint venture company in China with Tsinghau University.

SSTL employs more than 100 full-time staff who work alongside 8 academic staff, 70 graduates and usually about 20 customer staff. The students and academic staff benefit from being able to pursue their studies in a real commercial space environment while the company benefits from the strong intellectual input which comes from working with the University.

December 1999 saw the introduction of the Government's MOSAIC programme, designed to enhance the UK's small satellite capability and further assist in its transfer from the academic environment into scientific and commercial markets.

5. Our universities are not just creators of knowledge, trainers of minds and transmitters of culture, but can also be major agents of economic growth, responding to the influences of globalisation and new technologies, and the need to interact with businesses. The challenge for them is to stimulate and facilitate the increased transfer of knowledge to business and society, across all sectors of the economy, while improving the quality of teaching and research.

6. We want to see a diversity of excellence in universities, with universities adopting a variety of missions, building on their strengths. All universities must focus on producing excellent teaching, though the nature of teaching may vary. In addition, some universities will want to focus on excellent research, some on excellent knowledge transfer and some on a combination of these, so that there is diversity of excellence.

7. The Government has already done a great deal to support universities in forging their new role: University Challenge, the Science Enterprise Challenge, and the Higher Education Reach Out to Business and the Community fund. European money has helped too, particularly in regions which get assistance from the structural funds. Universities are developing strategic partnerships with business – local, national and international – setting up science parks and incubators, and spinning out new companies, to use the knowledge they have generated.

8. But much more needs to be done to support this change in culture, creating a climate for enterprise in all our universities; a balanced set of incentives which encourage researchers to exploit the results of their work and in which they receive proper recognition and reward for doing so. Substantial incentives are needed for world-class knowledge transfer.

9. We shall now:

- establish a new Higher Education Innovation Fund worth £140 million over three years to build on universities' potential as drivers of growth in the knowledge economy, incorporating the existing Higher Education Reach Out to Business and the Community (HEROBAC) fund and tripling existing funding by the third year. This will be a permanent third stream of funding for universities. While many activities involved in commercialising research will become self-sustaining in the longer term, many universities need help now to build their capacity to engage in knowledge transfer, and continuing help in their efforts to improve the productivity and competitiveness of small firms.

10. And we shall do more to connect universities and business, building on the initiatives we have already taken. We shall:

- run one further round of the University Challenge Competition, with a further £15 million providing seedcorn funding for the development of new commercial initiatives, and bringing them to the point where the venture capital market will take them up. Fifteen professionally managed seedcorn funds, involving 37 universities, have already been set up under University Challenge;
- double the number of new starts for Faraday Partnerships from 4 to 8 each year so that by 2002 we will have a network of 24 Partnerships across the UK. These link universities and independent research organisations with businesses and finance, to develop new products and processes, drawing on ideas from Foresight and making use of Government schemes such as LINK and the Teaching Company Scheme (TCS). Independent Research and Technology Organisations (RTOs) play a very important role in them; and
- to benchmark our performance we will introduce a new survey to measure the UK's performance in university–business interaction.

11. As universities develop a more active approach to the exploitation of their knowledge they also need support. Good guidance is available at the technical level, with a joint handbook published by the

Faraday Partnerships

Following the successful launch of the first four Faraday Partnerships in 1997, a second round was announced in June 2000. These are:

Faraday Partnership in Aerospace and Automotive Materials led by Oxford, Oxford Brookes and Cranfield Universities, the Motor Industries Research Association (MIRA), The Oxford Trust and the Heart of England Business Link.
Themes: developing the capabilities of the cluster of materials manufacturing firms in the Thames Valley/South Midlands to use the research expertise of leading universities and MIRA for aerospace and automotive applications.

Faraday Plastics led by Rapra Technology Ltd, and Warwick Manufacturing Group.
Themes: carrying out research to help UK suppliers of plastics and end-user firms to develop cleaner, lower cost, faster and more flexible processes by improving the design, durability and disposal characteristics of plastics.

The Smith Institute Faraday Partnership led by The Smith Institute and various universities.
Themes: improving industrial use of high quality mathematics and computer science for developing industrial strategy and planning industrial products and processes.

The TechniTex Faraday Partnership led by Heriot-Watt, UMIST and Leeds Universities and the British Textiles Technology Group (BTTG).
Themes: developing UK capability to produce new technical textiles and engage user businesses in their applications (for example in medicine, construction and defence).

Patent Office and the Association for University Research and Industry Links (AURIL). This is now available on the Web at www.auril.org.uk. But more needs to be done to get the attention of top management in higher education and spread best practice:

- so we will work jointly with the Committee of Vice Chancellors and Principals and AURIL to define the framework for managing IP in universities, to promote guidance for the sector and new ways of sharing best practice.

Stimulating demand from business

12. As well as universities reaching out and transferring their knowledge to business, we need more companies to use science and technology to create competitive advantage. Our record on this is still very weak. Too many of our companies still lack awareness of the need for change, or the ability to do so. In many industries we invest less in research and development than our competitors, and our companies are less ready to change and innovate than others. This is particularly true of large firms.

Knowledge Transfer Programmes in Scotland, Wales and Northern Ireland

The Welsh Assembly has made available £14 million over 2000/01 and 2001/02 to launch a Knowledge Exploitation Fund for encouraging enterprise in the FE and HE sectors in Wales, to help institutions exploit their knowledge base, contributing to wealth creation and community development. The Assembly has also recently introduced a 'Know How Wales' initiative to strengthen collaboration between industry and academia and significantly enhance the prospects of commercialising the outputs of industrially relevant academic research. Additional stimulus to knowledge transfer in Wales will come from the Wales Spin-out Programme, recently launched by the Welsh Development Agency. This aims to create more than 90 new spin-out businesses from Welsh FE and HE institutions over the next three years.

The Scottish Executive has made £11 million available over three years to Scottish Enterprise to manage a Proof of Concept Fund which will fill a gap in the funding of research with commercial potential. The scheme provides 100 per cent grant support and is open to bids from universities, research institutes and NHS Trusts. The funding allows academic innovative thinking at a pre-development, conceptual stage to be developed for the market place and used as a basis for growing businesses. In its first year, 83 applications from the biotechnology, semiconductors and microelectronics, and food and drink clusters were received under its first call for proposals. From these applications, nine projects were awarded grant support totalling £1.5 million. This year, a total of £4 million has been awarded from the fund. Applications from three more clusters (Oil and Gas, Creative Industries and Optoelectronics) will be accepted under future calls and it is estimated that approximately £6 million will be awarded in 2001.

The Centre for Knowledge Based Systems for Industrial and Medical Applications was established in 1995 as a collaborative venture between NIKEL and NIBEC in the University of Ulster, and ICL. By taking advantage of and fusing the partners' specialisms in knowledge engineering, bioengineering and information technology, KBSIMA specialises in research themes with commercial application and exploitable technology development. Two successful spin-out companies have already been formed by KBSIMA - MINEit and the Synergy Centre in Belfast. Two new start-up activities are under development – a spin-in activity to exploit healthcare delivery and a new joint venture telemedicine company. Future developments within KBSIMA will concentrate on Medical Informatics and Electronic Commerce applications, involving both research and technology transfer. Research will be both contract and collaborative. The Centre will host the prestigious Marie Curie Training Site 'Personalising E-Commerce Using Web Mining', and will work with the Northern Ireland Centre for Business. A new 'Ulster Institute of Telemedicine' will be created and the Centre will be developing web-based wireless technologies for e-health applications and formalising contacts to provide a comprehensive network of international collaboration.

Table 4

Business Enterprise Research and Development (BERD[8]) – 1998	
Country	Spend as a % of GDP
Japan*	2.10
USA	2.08
Germany	1.57
France	1.37
UK	1.19
Canada	1.03
Italy	0.56

Source: OECD Online–Main Science and Technology Indicators. 3/8/99
*1997 data for Japan. 1998 not yet available.

Table 5

Share of turnover in manufacturing devoted to technological development[9] activities		
Firm size	UK % of turnover	EC average % of turnover
Small	3.3	2.3
Medium	2.9	2.3
Large	3.2	4.4

Source: Analysis from *Community Innovation Survey II* – based on data from 1994–96

13. Change must come from within business, as it is coming in universities. Government can facilitate, catalyse and challenge. And, with its responsibility for the fiscal framework, for the education system and for the regulation of competition, Government creates the environment for business, and so affects demand.

14. The Government is introducing a series of measures to stimulate investment in enterprise and innovation, and encourage risk taking, against the essential background of macro-economic stability. Capital Gains Tax relief, enterprise management incentives, the tax credit scheme for small firms' research and development and the all employee share scheme are all designed to change the climate for investment across the economy, changing the risk/cost ratio for investment in research and development.

Pharmaceuticals is now the most important innovative high-tech industry in the UK: accounting for nearly 25 per cent of high tech R&D investment, compared to OECD average of 8 per cent.

The Government aims to retain and strengthen the competitiveness of the business environment for pharmaceuticals. That is why we have established the Pharmaceuticals Industry Competitiveness Task Force, to bring together the expertise and experience of industry leaders in the UK with Government policy. The Task Force will report to the Prime Minister in April 2001.

15. The Government also has an important role in the supply of people in the labour market: science and technology graduates, and people with technical skills to work in the new jobs created in the knowledge economy.

16. The mix of skills is important. We need to foster creativity and make sure that the skills and insights developed in science, social science and arts disciplines reinforce one another and provide a source of

[8] Definition follows the OECD's Frascati Manual. It excludes R&D funded by businesses that is performed overseas or in other sectors of the UK economy (such as: higher education; government departments, agencies and non-departmental public bodies; local authorities; and private non-profit organisations).

[9] Includes intra-mural and extra-mural R&D, purchase of external technology, investment in connection with innovation and industrial design.

skills, problem-solving and innovation for the good of the economy and the community.

17. There are some important mismatches between supply and demand; particularly shortages of electronic engineers, computer scientists and of people with the technical skills to do the new jobs created by the knowledge economy. And there are concerns about the quality of students entering higher education IT courses. These concerns are not limited to IT: employers say that many science and engineering graduates do not have the full range of skills they need for jobs which require flexibility and awareness of the world of work.

18. For engineers, the Engineering Council is working to raise standards for engineering qualifications. The Government is also encouraging the Engineering Council to update its role so that it can add greater value to the wider ‘engineering community’ by improving the effectiveness of existing activities. The basis of the review is the pressing need to move away from a narrow view of engineering to a broader definition which takes account of the impact of engineering across all sectors of the economy including finance, medicine and even the arts.

19. For more companies to make the most of science and technology, we need more people who combine strong technical skills with ability as managers and entrepreneurs:

- we will put a further £15 million into Science Enterprise Centres on top of the £29 million already committed, to teach science, engineering and technology graduates business and entrepreneurial skills;
- and we are introducing Graduate Apprenticeships from September 2000. New graduates will be able to combine honours degree or higher level study with learning underpinned by a National Vocational Qualification and Key Skills Units. £5 million is available over two years for small- and medium-sized firms wanting to participate.

20. The new Cambridge MIT institute (CMI) will play a key role in the new network of Science Enterprise Centres, adapting MIT’s expertise in entrepreneurship, competitiveness and productivity to the UK environment. CMI will carry out interdisciplinary research in areas likely to be of benefit to future technology. UK students will be exposed to MIT’s methods of teaching, and researchers will work with the MIT facility, and the benefits will be disseminated to other universities through the network. Other universities are making similar global connections.

University of Nottingham Business School

The new Jubilee Campus at the University of Nottingham was opened by the Queen in December 1999. Its striking design incorporates features that make it one of the most energy efficient 'green' campuses ever constructed. At present the new campus is host to the three schools of Education, Computer Science and Business. As if to underline the Campus' statement of modern technology and design, the new Institute for Enterprise and Innovation is being established in the Business School, following success in the first round of Science Enterprise Challenge. The Institute is responsible for the encouragement of entrepreneurial skills development, commercialisation and technology transfer through innovation. The Nottingham model focuses upon realising the potential for entrepreneurial skills by applying students' creativity, research and learning to the development of contemporary live projects with the potential for successful commercialisation. This 'concept bank' approach raises the possibility of skills development and the progression of new ideas simultaneously.

Nottingham's innovative approach to the environmental impact of a university campus will be accompanied by an equally innovative concern with the curriculum delivered there and the realisation of the commercial potential of discoveries made in the university as a whole.

21. And Government is committed to work with business to address shortages in intermediate skills. We are taking the following initiatives in England and Wales:

- we are consulting on proposals for two-year Foundation Degrees, which will provide higher education with a strong vocational element, giving graduates the flexibility which higher education brings, together with the strong practical grounding which business is looking for. Development of Foundation Degrees will start in autumn 2000 with the first pilots starting in 2001. The Government looks to business to become fully involved with the development of Foundation Degrees, to ensure that they deliver the right skills;
- at the same time, we are consulting on ways to strengthen arrangements for Modern Apprenticeships and we have launched the Engineering Technicians Initiative to bring together clusters of small firms to improve the technical and managerial skills of technicians in the manufacturing sector.

22. In addition in England:

- as part of our new skills strategy we are forming a new partnership between government, business, education and national training organisations to deliver a real improvement in ITEC skills, by improving the image of careers in IT and promoting dialogue between employers and providers on what the needs are;

- we are encouraging women returners to take up skilled jobs in the IT and communications sector where 30,000 new jobs are created each year and demand outstrips supply; and
- we are tackling the career stereotyping which prevents girls from taking these opportunities: the Government's 'taster day' programme, introduced in April, will give girls aged 15 or 16 a chance to try out non-traditional areas of work, including engineering, science and IT. Women's groups in science and engineering are training women who can act as role models to talk in schools. We welcome this initiative.

23. Government shares the risks of research with business by supporting the development of underpinning knowledge for standards, and through sharing the costs of collaborative research. The LINK scheme brings large and small companies together with universities and other research organisations, to deliver Foresight priorities.

24. We shall make it easier for UK business to do collaborative research by streamlining LINK, developing a model agreement for collaborations and common procedures for use by sponsors by October 2000. We shall

LINK – Applied Genomics

The largest ever LINK Programme, in Applied Genomics for healthcare has just been launched (July 2000), with £15 million of public funds (£5 million each from DTI, BBSRC, and MRC) matched by £15 million from industry. It will support projects to develop platform technologies in areas such as control of gene expression, analysis of gene products and DNA-based diagnostics.

Targeted particularly at the small genomics companies supplying products and technology to large pharmaceutical and diagnostic companies, the programme will help UK companies to exploit advances in genomics and data arising from the Human Genome project. It will support individual collaborative projects in pre-competitive research between the science base and one or more companies.

As well as research output, the programme will provide an opportunity for the transfer of technology and know-how between the science base and industry, and between the larger healthcare companies and those to which they outsource the development of new genomics-based therapies and diagnostics. It will also take forward the DTI's Genome Valley Report[10] by enhancing the attractiveness of the UK as an investment location in biotechnology.

[10] *Genome Valley: The Economic Potential and Strategic Importance of Biotechnology in the UK.* Department of Trade and Industry. December 1999.

also work with European partners to streamline arrangements for Framework Programmes. And by bringing people together and supporting work in Europe and international organisations, we shall continue to work with business to facilitate the development of technical standards which work for the new technologies as well as for established industry.

25. New designs are often the trigger for new technical innovation, and vice versa. The Design Council, supported by Government, plays an important part. The Design Council's Millennium Products initiative demonstrates the wealth of talent within the UK to design innovative products and services. It has selected over 1,000 products as representing the best of British innovation and design over the last five years, to inspire the creative entrepreneurs of the future. Two of the products selected are: IP+, the world's first commercially-available intelligent artificial limb; and Marin-Ark, an innovative life raft system.

The National Endowment for Science, Technology and the Arts (NESTA) established under the National Lottery Act 1998 supports innovation and brings on creative talent. NESTA has an endowment of £200 million which generates an income of £10–12 million each year to fund:

- an Invention and Innovation Programme, designed to support each year some 50–100 innovative and commercially viable ideas;
- a Fellowship Programme, which involves the identification and development annually of around 25–50 exceptionally creative and talented individuals in science, technology and the arts; and
- an Education Programme, which aims to support up to 15 innovative and inventive projects each year designed to develop fresh and engaging ways to teach and learn in these fields and to widen public understanding of science.

NESTA's first awards, announced in May 2000, included funding for innovations ranging from keyhole surgery to amphibious vehicles and for individuals working on interactive technology, astrophysics and science centres. Further awards will be made this autumn and three times a year from then on.

Millennium Products – design and innovation

IP+ the world's first commercial intelligent limb: Chas A Blatchford & Sons Ltd

Conventional artificial limbs do not adjust naturally to changes in speed, so that the gait can often become uncomfortable and awkward. Blatchford solved this problem by developing the world's first commercially-available intelligent artificial limb.

The Intelligent Prosthesis Plus (IP+) contains a computer chip which automatically modifies the swing of the knee to create a natural gait that matches the user's original walking pattern. This means that amputees can walk at different speeds in comfort and with minimum effort; they can walk further and move faster.

Andy Sykes, Blatchford's design engineer, says "IP+ is specifically designed for above-the-knee and through-the-hip amputees. What we do is work out the amputee's entire range of walking speeds and then programme the IP+ with those characteristics. This development was a massive improvement on conventional artificial limbs, which were usually set at only one speed. With IP+ some amputees do take a much greater part in outdoor activities, games and sports, because they can change speed without thinking about it. It's like an automatic gear box."

Blatchford is working on further generations of products controlled by microprocessors to provide even more advanced control than the IP+. "In the future, limbs will automatically adjust for stairs, slopes, standing and stumbling, thus maximising the amputee's ability to control the limb," explains Andy. "The end result being that they'll be able to walk easily, naturally and safely."

Marin-Ark: an innovative life raft system: RFD Limited

In the wake of such tragedies as the Estonia disaster in which many people died in freezing Baltic waters clinging to capsized life rafts, RFD, based in Northern Ireland, developed the Marin-Ark life raft system. Evacuees climb into a cylindrical telescopic chute, which adjusts automatically for the lift and fall of the waves, and slide straight into a 100-person inflatable life raft that cannot be turned upside down because it is internally symmetrical.

Four Marin-Ark evacuation stations on a ship are capable of safely accommodating 1,600 people in less than 18 minutes. Even though Marin-Ark life rafts may be pushed under by the capsize, they will automatically blast free of both the ship and their escape chutes before popping up to the surface, fully inflated and the right way up.

Peter Rea, RFD marketing manager: "This has been an incredibly successful product for us. You'll now find Marin-Ark on around 20 vessels, from Norway to the South Pacific. The new 2,000-passenger P&O cruise ship, Aurora, is fitted with them. Sea France's cross-Channel ferries, Renoir and Manet, also have Marin-Ark, as does the Commodore Clipper, which runs between the UK and the Channel Islands."

Regional clusters and innovation

26. While some elements of the framework for innovation can only be determined through national action, there are significant differences in innovation between regions, calling for different approaches. Manufacturing companies in the Eastern region invest around ten times as much in R&D as companies in Yorkshire and the Humber. While all regions must participate in the economic success of the country through innovation, priorities for action within the regions differ.

27. Development agencies in Scotland, Wales and Northern Ireland have been actively pursuing this agenda for some time. For England, the RDAs have an important role to play in stimulating economic activity and promoting productive relationships between all the regional players. They are charged with developing regional innovation strategies as part of their overarching regional economic strategies.

28. Part of RDAs' role is to support the development of clusters, geographical concentrations of companies, specialised suppliers and associated institutions such as universities, co-located for mutual competitive advantage. Clusters can encourage innovation by providing:

- scope for collaboration to define and assess new customer needs and new technological and delivery possibilities;
- fast access to sources of new components, services and machinery;
- strong competitive and peer pressure; and
- access to a pool of mobile skilled people within the cluster, helping to spread best practice and technical expertise.

29. The Minister for Science is leading a high level Clusters Policy Steering Group, with other Ministers, the RDAs, local government, the SBS, the private sector, academia, the TUC and the CBI, to identify barriers to the growth and development of clusters and to recommend policy initiatives to remove these barriers. The Group is drawing up a map of existing clusters across the UK, to be completed by October. As a result of this work, changes have already been made to Planning Guidance[11] to make it more cluster friendly and DETR and DTI will be issuing best practice guidance for businesses and the planning authorities in relation to clusters.

30. RDAs' innovation strategies contain ideas for helping clusters to thrive and grow, including encouraging the setting up of science parks and business incubators. In the last Budget, the Chancellor announced a £50 million innovative clusters fund to provide capital for bringing elements of RDAs' strategies into effect. This is just a starting point.

[11] Planning Policy Guidance note 11 on Regional Planning, to be published summer 2000; Planning Policy Guidance note 12 on Development Plans, published January 2000.

- We will create new Regional Innovation Funds totalling £50 million a year to enable RDAs to run programmes, building on the £50 million capital fund already announced. Alongside stimulation of increased private sector involvement, this could include a tailored package of support for incubation, and support for local or regional clubs of scientists, entrepreneurs, managers, advisers and financiers: the aim is to pump prime a new generation of personal networks for the new economy.
- We are consulting RDAs about regional extension programmes for manufacturing excellence and productivity. These would both provide a counselling service to help manufacturers to exploit the full benefits of new technology and also encourage networking between manufacturing companies and regional and national sources of expertise.
- We will support 20 Business Fellows, with more to follow, to lead their colleagues in working with business. They will spend part of their time advising companies, particularly SMEs, on their business problems, providing technical and research solutions. Criteria for selection of Business Fellowships will take account of RDAs' regional priorities and will focus on strengthening links with business.

Medilink

Medilink (Yorkshire & Humberside) is a professional association that brings together medical technology companies, hospitals and universities to generate new opportunities and advance the interests of the medical technology sector. The association has 120 full member companies and provides services for over 400 Yorkshire and Humberside companies.

Medilink provides a range of services but is particularly active in the area of product research and development, where its product innovation centre provides support in taking ideas from concept through to commercial exploitation. With its strong links to the science base and a detailed knowledge of the medical equipment market, Medilink is in a prime position to facilitate a two-way flow of information between the knowledge base and its member companies. Five spin-out companies have been established and, during the last three years, Medilink has looked at over 300 product ideas, resulting in more than 100 new products currently under development.

Success is not achieved overnight in the medical equipment sector. Medilink's current achievements follow a sustained effort over the past three years, but it will be a further two years before the majority of the R&D leads to commercially successful products.

Departmental science strategies – the Department for International Development supports pest control in India

India produces 2.5 million tons of cotton each year, sustaining livelihoods of over 17 million people, mostly poor farmers for whom the cotton crop is often the only source of income. Unfortunately, the increasing cost of pest control – often more than 40 per cent of production costs – has reduced the viability of growing cotton. Overuse of insecticides and poor spraying techniques have made the cotton bollworm resistant to most of the available insecticides, forcing farmers to buy more toxic (and expensive) chemicals and pushing them into steep spirals of debt.

As part of the science strategy of the Department for International Development, the Government has funded research aimed at minimising the impact of significant pests of cotton production systems. Building on this research, a group of UK and Indian scientists, working with the farmers themselves, has developed and tested an integrated pest management package of methods which reduces the need for insecticides. The results of trials by 637 farmers in three states have been dramatic, with a 44 to 95 per cent reduction in pesticide use, a 77 to 92 per cent reduction in health hazard and a 17 to 70 per cent increase in yield, massively increasing the farmers' income.

Recognising the potential of these methods, the Indian Government is funding their promotion throughout the country's 20 major cotton districts. Widespread adoption of these methods therefore now seems assured and will have a major and sustainable impact on improving the livelihoods of small farmers, on human welfare and on the environment.

Scottish Science Strategy

Scottish Ministers plan to publish and implement a science strategy. They are consulting widely on the shape and content of that strategy under six broad headings covering how to:

- ensure that the Scottish economy takes maximum advantage of science to promote the well being of the people of Scotland;
- ensure that Government takes full and effective account of scientific evidence in making policy decisions, and has the capacity to deal with scientific issues;
- secure the best possible scientific education for Scottish learners;
- secure a strong base of science research; and
- work across the UK, the EU, and internationally, to secure the above objectives.

Strategies for Government departments

31. All Government departments have a role to play in encouraging innovation, through the way they pursue their objectives, whether framing regulation, purchasing and delivering services, managing and controlling risks. Collectively, Government departments spend £4.4 billion a year on science and technology in support of their objectives. We are therefore asking departments to:

- publish science and innovation strategies, drawing on Foresight, and focusing on how they can maximise the potential of science and technology activities and how they can drive innovation.

32. The strategies will cover arrangements for improving connections with relevant science and technology overseas, as well as arrangements for commercial exploitation of research, following recommendations from the Council for Science and Technology. And they will say how departments are encouraging innovation, through their approach to regulation, to procurement, and to the services they offer. The Ministerial Science Group, involving representatives of the devolved assemblies and supported by the Chief Scientific Adviser, will oversee the strategies.

Defence Diversification and Regional Development

1999 was the Defence Diversification Agency's (DDA) first full year of operation and one in which it began to deliver on its mission of providing a world class technology innovation brokerage service benefiting small and medium sized firms. As well as offering these businesses an easy route into DERA's technology, the DDA is providing greater awareness of, and access to, technology being developed by SMEs that has potential for application in defence.

The DDA has a remit to ensure that all areas of the UK have equal access to its services – irrespective of how far the client is from a DERA site. A regional network of Technology Diversification Managers (TDMs) work in partnership with existing business support networks and with RDAs and other agencies.

DDA successes include:

- assisting the design and development of a high powered marine vessel with a focus on: efficient hull designs; material strength; small arms weapon protection; and stealth;
- using DERA's world class expertise in the field of Voice Recognition systems to revolutionise car security systems;
- assisting small firms in luxury yacht markets, including the development of forward looking sonar for wreck detection, weather simulation testing for exposed instrumentation, and the design of commercial underwater vehicles;
- assisting the technology transfer of a remarkable new puncture sealant system into MoD's Defence Procurement Agency, and as a consequence into the UK Armed Forces; and
- working jointly with an SME to produce a Power Transistor capable of 50 per cent more power and 25 per cent more bandwidth than the best equivalent currently on the market.

33. As part of this new approach:

- we are introducing a new programme, the new Small Business Research Initiative (SBRI), to encourage more high-tech small firms to start up, or to develop new research capacity, so stimulating innovation throughout the economy. This is inspired by the US Small Business Innovation Research Fund. Under SBRI, departments and Research Councils are opening up to small firms, R&D procurement programmes worth up to £1 billion, with the target of procuring £50 million of research under these programmes from small firms. Each participating department will aim to procure at least 2.5 per cent of their relevant requirements from small firms. Research Councils will move to meet the target over time, drawing on new money.

Intellectual property: changing the rules

34. Intellectual property (IP) is one of the distinctive features of a knowledge-based economy. Defined broadly, IP includes not just patents but also copyright, and rights over designs, trademarks, databases and confidential information. The publicly-funded science and engineering base is already a major source of IP and its importance is likely to increase.

35. Organisations doing research – such as the universities and the Government's public sector research establishments (PSREs) – need to consider the interface between managing IP and achieving the other goals of their research. The primary aims of research vary, but include advancing knowledge and underpinning public policy. IP policy must not undermine these aims and issues like whether to disclose any results before patenting require careful consideration. Openness is paramount for research that supports public policy.

36. The Government believes that effective IP management should be a fundamental goal of universities and research bodies in the public sector, because:

- identifying and managing IP is essential for effective knowledge transfer out of the research base, to benefit the wider economy; and
- IP can itself be a valuable asset deserving protection.

37. Research organisations need to follow some basic principles if we are to achieve this goal. First, the management and exploitation of IP needs to be recognised as important by the top management in research organisations – by vice-chancellors and principals of universities, and their top management teams, and by the chief executives of PSREs. It is not enough to leave this task to the experts.

Partnership in managing IP

A network of NHS Trusts and universities has come together in the North West to exploit the IP arising from publicly-funded research. The aim is to improve healthcare, create jobs and improve the performance of industry.

The network originated around Manchester, where three NHS Trusts (Central Manchester, Salford Royal and South Manchester) are working in partnership with four universities (Manchester, UMIST, Salford and Manchester Metropolitan). Their MANIP partnership (Manchester Intellectual Property) receives funding from the DTI Biotechnology Exploitation Platform. IP is identified, evaluated and an exploitation route agreed. Much of the IP arises from joint work between the NHS Trusts and the universities, and often the route to exploitation is managed by the partner university technology transfer unit including the Manchester Bioscience Incubator.

A second partnership between thirteen NHS Trusts and two universities has developed around Liverpool. This was instrumental in obtaining some of the funding to set up MerseyBIO, the bioscience incubator in Merseyside. Again the partnership is managing the innovation process between healthcare and industry, concentrated among new businesses.

38. Second, there need to be experts, and enough of them. Managing IP and supporting its commercialisation are specialised tasks. Universities and other research bodies need to employ people with the right skills mix and to resource the function adequately. In time the activity should become self-financing, but the lead times are long and some net expenditure will be needed in early years.

39. Third, universities and PSREs should learn from each other. There needs to be more sharing of best practice and understanding of the choices available on issues like the sharing of returns from exploitation between staff and institution. IP management is also a function that can often be shared between different organisations.

40. The need to manage IP better was at the heart of the Baker Report[12] on PSREs published by the Government last year. The full response to the Baker Report is published alongside this White Paper. We are now announcing a new drive to support the links between research and innovation at PSREs and improve the handling of IP. The key measures are:

- we are consulting on new guidelines on IP ownership and management for Government. We need a change in culture, away from the practice of avoiding risk by holding on to IP from research at the centre of government. The guidelines propose a general rule that research providers – like PSREs – should own the IP;
- we are changing the Civil Service Management Code so that scientists in the Civil Service will be able to benefit from helping to exploit their work commercially, for example through equity in spin-out companies;
- we are publishing new guidance on incentives for staff at PSREs[13]; and
- to help bridge the gap in finance for seed investments, the Government will commit £10 million to a new fund for commercialising IP, aimed at PSREs including Research Council institutes and the NHS, as the cornerstone of an interdepartmental action plan which sets out a range of measures to support PSREs in their mission to exploit the results of their work. The action plan is set out in full in the Government's response to the Baker Report. It also includes a new role for Partnerships UK, the new body established to help develop successful PPPs. PUK will offer advice to PSREs and others trying to commercialise IP.

41. As universities and public sector research establishments become

[12] *Creating Knowledge – Creating Wealth: Realising the Economic Potential of Public Sector Research Establishments*. Published 1999. Available at www.hm-treasury.gov.uk/docs/1999

[13] *Good Practice Guidance for PSREs and Staff Incentive Schemes* (July 2000)

more effective in exploiting the results of their work, some will generate significant income streams. But not all will do so. The Government's purpose is to generate benefits to the economy at large, not to create a substitute for proper arrangements for public funding for essential research infrastructure.

42. There is ample scope for using the Internet to manage IP better. An innovative project will be launched this autumn by the Association for University Research and Industry Links (AURIL), with a clearing-house offering technology available for licensing across the university sector. The Government welcomes this, and will itself be introducing a new IP portal in autumn 2000, designed to provide visitors with clear basic information on the full range of intellectual property rights and the part these play in protecting creativity and inventiveness. It will signpost to other sites with more detailed information for those who need it.

Intellectual Property Portal

The Intellectual Property Portal website, due for launch in autumn 2000, is being developed by the UK Patent Office as a direct result of a report from the Intellectual Property Group of the Government's Creative Industries Taskforce.

The Taskforce recommended creation of 'a single website containing basic information about intellectual property which should signpost users and creators appropriately, so that they can obtain licences for particular use and information to enable them to protect their rights. It should be signposted from other sites where those seeking information might be looking.'

The Portal is aimed at both those who already have an understanding of IP and those who do not. This will be done by:

- providing access to sites with information that can answer specific detailed queries;
- providing answers to frequently asked questions both on general and topical issues and then offering users fast, direct access to existing sites containing more detailed information; and
- providing links to the latest news relating to IP issues.

The Portal will be designed to evolve and be responsive to users by allowing them to nominate relevant sites they have found useful – making the knowledge base ever-expanding.

Global links

43. Action to encourage innovation at national level is not enough. We must leverage our resources by co-operating globally. As companies respond to the new challenges of the knowledge-driven economy by shifting the focus of their innovation from central R&D laboratories to global R&D networks, it is essential for UK companies to have access to world-wide sources of technical knowledge.

44. Government must provide the best framework for scientists and businesses to make international links. To play a full part in modern science and to bring its benefits to the UK we have to co-operate

internationally. Our investment in science in the UK is an entry ticket to the global collaboration that is the driving force of scientific advance. Government plays a critical role in making this possible. We want to attract the best scientific companies to the UK. We want the UK to be regarded as an intellectual hub of the new global economy. A society that is closed, inward-looking and defensive would not remain at the forefront of science because it could not take part in this global collaboration. The UK is stronger when it collaborates internationally. The UK must be a key player in European and global science.

45. The UK is Europe's premier location for mobile foreign direct investment, attracting a 22 per cent share of all investment in the EU[14] from companies based outside, and 40 per cent of Japanese and US investment in the EU[15]. This investment will yield broad benefits to the UK over a period of years. We want more companies to locate their R&D in this country. The measures contained in this White Paper to improve the climate for business innovation, knowledge transfer and networking will improve our attractiveness as a location for mobile investment. The Government is refocusing Regional Selective Assistance to generate more skilled jobs in high technology knowledge-driven projects in assisted areas. We will also encourage RDAs, universities and associated bodies to propose integrated packages of services and support for potential inward investors in R&D and in high technology.

46. We will also help by:

- fostering links between science and technology providers and users in the UK and overseas: we are doubling the number of International Technology Promoters, to identify opportunities and create new partnerships across national boundaries, and we plan to expand the network of science attachés in embassies abroad;
- supporting research collaborations through fostering international contacts between scientists, focusing in particular on removing any obstacles to the normal free flow of information; and
- raising awareness across the world of UK strengths in science and technology, challenging the image of Britain as a centre only of heritage, tradition and the arts.

47. The Foreign and Commonwealth Office is working closely with the Chief Scientific Adviser and with British Trade International, the British Council, the Royal Society and the Department of Trade and Industry, to ensure that synergies between their different programmes are exploited to deliver these objectives.

[14] Source: United Nations Conference on Trade and Development (UNCTAD) *World Investment Report*, 1999

[15] Source: US Department of Commerce, 1998 (stock figures: over 40%) and Japanese Ministry of Finance, June 2000 (cumulative flows: over 45%)

The work of the International Technology Service (ITS)

ITS helps UK firms to establish global links through sponsored overseas missions and international secondments. Through its network of international technology promoters it facilitates technology partnerships with foreign firms and research centres.

International Technology Promoters offer individual help to firms in various forms, including advice and consultation, contact-making and support during the first stages of technology transfer. They work closely with business intermediaries in the UK and overseas. In the past year, more than 500 companies have received direct assistance. ITS's North American ITP helped to link UK company LumiTech with an American university – Texas A&M University – which has the technology relevant to LumiTech's specific innovative application: bioluminescent technology to produce highly sensitive reagents capable of measuring molecules central to the life and death of cells.

LumiTech's diagnostic kits are used to study changes in cell viability, important in diseases such as cancer, diabetes and Alzheimer's disease. Such cell tests are increasingly vital to most areas of modern biomedicine. Laboratories are under increasing pressure to reduce their reliance on radioactive compounds or other hazardous chemicals and to increase the speed and automation of screening procedures. LumiTech's kits address all these problems, providing a safe, easily automated and rapid alternative for high throughput screening applications. In conjunction with Nottingham Trent University, a Teaching Company Associate is now working with LumiTech to develop the technology. The plan is for LumiTech to enter into a licensing agreement with the Texas A&M University once the production process is ready to go live. Thanks to the ITP programme, LumiTech is well on its way to transferring the technology that will facilitate its growth plans. And the company is convinced that without the ITP's contacts and support, the project would have taken much longer – or might not have been feasible at all.

48. European Union proposals to create a European Research Area offer new opportunities to strengthen our ability to compete, as a union, in global markets. The UK is committed to creating the key elements of the Research Area:

- closer contacts and stronger links between research organisations across Europe;
- better information on how European countries compare with each other, and the rest of the world, with a map of centres of scientific excellence;
- a high speed electronic network for scientific communications throughout the Union, linking to the rest of the world;
- a common community patent, to be agreed by the end of 2001; and
- action to remove obstacles across the EU to the mobility of researchers from outside the EU.

Confident Consumers

1. Consumers play a vital role in the cycle of innovation. Consumers do not stand at the end of the scientific pipeline passively waiting to consume new products. They are agents in the process of innovation. Innovations only succeed when they are taken up by consumers, who in the process of using a new product often discover or even create uses for it that the original inventors never deemed possible.

2. A good example is the telephone. One of the first uses of the telephone was for people to listen in to live performances of plays. But usage of the telephone only really took off when consumers started using it to communicate with one another. The full potential of the innovation was only realised by consumers creating new ways to use it. Much the same is happening with the Internet. Used in its early stages as a way for academics to share research, the Internet's true potential has only begun to be realised when the technology has been made available to consumers to use freely. Active, intelligent and even creative consumers are a vital part of the cycle of innovation.

3. So government policy to encourage the cycle of innovation needs to address consumers, alongside researchers and innovators who turn ideas into products. The consumer's role in fuelling innovation has to be as effective as the other components of the process.

4. Consumers will take up innovations when they are affordable, easy to use and when they generate clear benefits, for example by allowing people more choice, saving time or extending life. Consumers compare the benefits from a new product with the costs of acquiring and installing it. But they also compare benefits with risks. When a new product seems to offer only minimal improvements to the quality of life or the range of choices available, at an unacceptably high level of risk, then consumers are

STATEMENT	**FIVE POINT SCALE (%)**				
	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
I am amazed by the achievements of science	19	56	16	5	>1
Scientists and engineers make a valuable contribution to society	21	63	10	3	>1
Science and technology are making our lives healthier, easier and more comfortable	14	54	17	9	>1
The benefits of science are greater than the harmful effects	7	36	31	15	>2

Base: 1839. Fieldwork took place between 6 and 21 January 2000.
Source: OST/Wellcome Trust survey into public attitudes to science (to be published shortly).

unlikely to adopt it. Most people in Britain are positive about science – over two-thirds agree that science and technology are making our lives healthier, easier and more comfortable.

5. The Government's role is to work on both sides of this equation of benefit and risk that consumers make. That means adopting policies that promote and spread benefits as widely and quickly as possible, while also assuring consumers that the highest possible standards of safety are being adhered to. That is why the 1999 Consumer White Paper[16] placed consumers at the heart of policy making.

Benefits to consumers

6. The best way to bring consumers the benefits of new products, at affordable prices, is to pursue an active competition policy. Companies will only develop new products and services if they see consumer markets that are open to new entrants. A company will only invest in research, development and innovation if it can see the possibility of recouping its investment in consumer markets.

7. Indeed there is growing evidence that in a global market, the most innovative companies are drawn to the most innovative and open environments. Innovative companies want to learn from innovative consumers who are early adopters of new technologies. That is one reason why mobile telephone companies have prospered in Scandinavia: they have learned from local consumers quick to adopt new products.

8. But as well as markets being open, their size matters too. The heavy investment needed to develop really innovative products will be recouped more easily in larger markets, with more consumers. In the past, European companies have often been at a disadvantage against their US competitors because European companies have served smaller national markets. The large domestic market in the US has served, especially in the case of computing and software, as a better pad from which to launch innovative products into global markets.

9. That is why Britain's commitment to completing the Single European Market is an essential component of innovation policy. Access to a market of 250 million consumers will put European companies on the same footing as those in the US.

10. Government has already taken action to promote innovation by spurring competition. We have introduced much tougher legislation covering competition, through the Competition Act 1998. We will keep a close watch on the working of this Act and stand ready to take further action, if necessary, to make sure that markets are open to new entrants who spur innovation.

[16] *Modern Markets: Confident Consumers*,. Cm 4410, July 1999.
Available at www.dti.gov.uk/consumer/whitepaper

11. Britain has led the way in the creation of the Single European Market. Measures pushed by Britain at the Lisbon summit of the EU in May will take this process further, more quickly, by encouraging member states to learn from one another's best practice.

12. We must deregulate European markets as we draw them together. This particularly affects areas such as pharmaceuticals, where there can be a gap of 1–4 years between the launch of a new medicine in one national market in the EU and its launch throughout the EU. This delay means that it is harder for pharmaceutical companies to reap the rewards of innovation in the EU than it is in the US. That is why the Government has pressed for measures to speed product and patent approval in the EU.

13. The Government will continue to press the EU to learn from best practice where competition has led to innovation. The outstanding example is in telecommunications, where deregulation in the EU has led to lower costs, higher usage among consumers, more operators entering the market and as a result more investment in science and innovation to give companies a competitive edge. The EU has played a central role by helping to set EU-wide standards for mobile telephones, a measure which has helped to create a single unified market, and combining that with deregulation.

14. To support innovation, we must encourage competition in consumer markets. For Britain that means playing a leading role within the EU to push it towards a more open and innovation-driven approach to economic policy.

An independent and transparent framework

15. Consumers are concerned that new products may have harmful effects, especially those which directly touch on food or health. Scientific advance can create new risks to our health and our environment as well as posing social and ethical challenges. As scientific knowledge advances, we understand more about the risks from old technologies, as well as from new ones. Advances over the last 30 years in our understanding of the risks from X-rays are just one example of this.

16. When consumers feel the risks and benefits are clear and properly assessed it is up to them to make their own judgements about whether to buy and how to use a product. Government cannot eliminate risk. But where Government does have a role is in assuring consumers that risks have been properly assessed and controlled, and in communicating those risks clearly and simply, and at the right time.

17. If Britain is to share the benefits from scientific advances, here and throughout the world, we need a strong and stable framework for identifying and managing all these issues. Our aim is to make sure that risks are properly assessed and continuously monitored by a transparent process and that these risks are clearly communicated.
Of course, Government alone cannot achieve this. The media also have a vital role to play. The public framework for assessing risks must be open to public scrutiny at every stage. As a society we can no longer, if we ever could, expect people to trust blindly in Government and scientists to get it right. Consumers will feel confident only if risks from new technologies are questioned and challenged in an open and informed way.

18. There is perhaps no more critical example of this than the development of new products and medicines from the sequencing of the human genome. We must press ahead with that work, but do so in a way that delivers clear benefits to people and which gives priority to people's health and safety, through:

- support for the basic research: this is one of our key priorities for the next three years, as set out in Chapter 2;
- strong regulatory control, through the Medicines Control Agency, the Medical Devices Agency and the Gene Therapy Advisory Committee, and others;
- careful attention to the views of all the stakeholders, through the Human Genetics Commission;
- constructive partnership with industry. That means a commitment to wide dissemination of basic data, as shown through the successful international collaboration on the Human Genome Project, while providing the conditions for industry to invest and innovate; and
- action to harness the potentially enormous impact and benefits of gene science on future healthcare by developing a strategy for service provision in the NHS. This will tackle questions like genetic testing, counselling and the best use of emerging therapies.

19. Public trust is vital to innovation. That trust is easily lost and hard to win back. People in Britain generally support science and innovation. However, the recent controversies over BSE and genetically modified foods show that the public are also concerned about risks, particularly when they involve food and health. We must not dismiss these worries, nor get them out of hand. Were a climate of distrust to build up around science, it could drive scientists away from the UK and in the long run impoverish us.

20. Just as science plays a critical role throughout society, so it plays an increasingly important role in Government policy making. Science plays a key role not just in assessing the risks from new products such as mobile telephones but also in understanding the BSE crisis. Science plays a critical role in environment policy and indeed in trade policy, where many of the most intractable disputes, for example about hormones used in meat production, can only be settled with the help of scientific advice.

21. The Government is committed to incorporating scientific advice into policy making across all fields, in a more open way. Government's responsibility is to:

- take a long-term and wide view of possible risks as well as benefits;
- ensure that the views of the best experts internationally as well as nationally, are brought to bear, particularly on the most difficult issues. When there is a high level of uncertainty about the science, there is a greater need to get help from the best scientists in the world;
- be open about the facts and assumptions which underlie scientific advice and decisions on it; and
- listen to all groups who have an interest, including consumers as well as scientific experts.

The Expert Panel on Air Quality Standards

The Panel was established in 1991 to advise the Government on air quality standards from a health perspective. It has a Chairman and 11 members – independent experts appointed for their scientific and medical expertise in the fields of atmospheric science, occupational medicine, epidemiology, statistics, respiratory medicine and clinical immunopharmacology. Observers and assessors from the Devolved Administrations, the Health and Safety Executive and the MRC Institute for Environment and Health also attend the meetings.

The Panel meets about four times a year. It considers peer-reviewed scientific and medical literature on pollutants, drawing on the work of the Department of Health's Committee on the Medical Effects of Air Pollutants. It invites other experts on the subject to present their views. It has commissioned its own epidemiological research to help it with the standard setting process. The Panel publishes its recommendations for public comment before reaching its final conclusions and publishing the final report.

The Panel has made recommendations for nine different air pollutants (benzene, 1,3-butadiene, carbon monoxide, ozone, sulphur dioxide, particles, nitrogen dioxide, lead and polycyclic aromatic hydrocarbons). For each pollutant it has recommended a standard for a level of the pollutant in the air that will have no, or minimal, effects on health. The recommendations have formed the basis of the Government's national air quality objectives in its Air Quality Strategy.

Information on the Panel is available on its website at www.environment.detr.gov.uk/airq/aqs

22. The principles are covered in the Chief Scientific Adviser's guidelines on scientific advice and policy making, first published in 1997. Fuller and stronger guidelines revised in the light of experience over the last three years are being published alongside this White Paper[17].

[17] *Guidelines 2000: Scientific Advice and Policy Making*, July 2000.

23. Scientific advisory committees are central to that system, and it is essential that they work to the highest standards. Scientific advisory committees help government collect scientific information and make judgements about it – on a very wide range of issues spanning everything from the food we eat and grow to the quality of our environment, the safety of our roads and transport, and the buildings we live and work in. They review, and sometimes commission, scientific research, and they offer independent, expert judgement, including where facts are missing or uncertain. Increasingly they have to take account of social and ethical issues and the concerns of consumers; and the way they work is evolving, with increasing dialogue and transparency. They are basic building blocks of using scientific advice in policy making.

24. We have therefore decided to underpin the guidelines with a Code of Practice, which all Scientific Advisory Committees will follow. The Chief Scientific Adviser will take the lead in developing the Code, consulting widely. A first consultation document is published today alongside the White Paper[18].

25. Before finalising the Code, and considering what other arrangements are needed to ensure a strong and transparent framework for scientific advice and decisions, the Government will want to consider the report of Lord Phillips Inquiry into the handling of risks from BSE in cattle before 1996. There could be important lessons to learn from that experience.

Scope of the Code of Practice

The Code for Committees should focus on the following needs:

- to maintain high levels of transparency during routine business and the publication of papers explaining committees' activities;
- for committees to communicate effectively with the media and the wider public;
- for an inclusive approach. That means public consultation as a committee is newly formed or its remit reviewed, and as it formulates views on major issues;
- to be clear why a committee is required and whether its scope should be narrow and technical or consider broader issues, for example ethics;
- to give members a clear idea of their rights, duties and responsibilities, and what is expected of them;
- to ensure that membership of a committee reflects both its remit and the degree of public concern in the area. This includes the need to draw on the best available expertise covering all the relevant disciplines and at least the main viewpoints where the issue is contentious. Where committees are to consider wider issues there is a need to consider the background of lay members, and how they will be involved;
- for transparent mechanisms for identifying, assessing and managing the impact of potential conflicts of interest, meeting the requirements of existing Cabinet Office guidance;
- for high standards in working practices, including best practice in handling, assessing and synthesising the particular type of scientific evidence and the uncertainties which surround it; and
- to ensure that resources for implementing the Code are proportionate to the importance of the issues.

[18] Consultation on a Code of Practice for Scientific Advisory Committees. July 2000.

Public dialogue

26. Expert scientific advisory committees are absolutely essential to our society. Without the knowledge and wisdom of the people who give up their time to serve on them, we would not be able to identify or manage the risks from science, or gain the benefits of scientific advances. We all owe them a debt of gratitude.

27. But members of scientific advisory committees would agree that science is too important to be left only to scientists. Their knowledge, and their assessment of risks, is only one dimension of the challenge for society. When science raises profound ethical and social issues, the whole of society needs to take part in the debate.

28. The Government is establishing new strategic bodies to help facilitate dialogue. The Food Standards Agency has this as an important part of its role, integrated with its regulatory responsibilities. Two new biotechnology commissions, the Human Genetics Commission and the Agriculture and Environment Biotechnology Commission established alongside the Food Standards Agency, have representatives from all interested groups, and a remit to facilitate public debate. They report to Ministers in the devolved administrations as well as UK Ministers.

29. These Commissions face a challenging task, bringing together widely different views on very difficult issues and working under public view. If they are successful, they will provide models for the future. The Government will watch their work closely to see what lessons can be translated into other areas.

30. The main focus of the Commissions' activity will, at least initially, be on the issues in the UK. But many of the issues raised by science go beyond national boundaries. And decisions are often made by supra-national regulatory bodies, for example, the institutions of the European Union, informed by scientific advice commissioned, collated and analysed by groups of scientists from many nations. The Government is working to ensure the principles behind good scientific decision making are followed in such international bodies.

Medical Research Council Consumer Liaison Group

The MRC has recently set up a Consumer Liaison Group as a Subcommittee of the Council to advise on ways of promoting effective consumer engagement in MRC activities and to ensure that the MRC is aware of and able to respond to consumer interests and concerns about research. All the members, a majority of whom are not experts, were recruited through a process of public advertisement. The Group is free to determine its own agenda. Topics for discussion at its first meeting, held in May 2000, included guidelines on tissue collections, the UK Population Biomedical Collection and animals in research.

Techniquest

Techniquest, now an integral part of the exciting Cardiff Bay and barrage development, has become one of the leading UK science centres with a strong educational role for people of all ages. It has already attracted over one million visitors and, in addition, works closely with industry, schools, local universities and the Research Councils in pursuit of its public appreciation of science mission.

New channels for communication

31. If people are to have a confident relationship with science, it is important that there are plenty of opportunities for them to learn about recent scientific developments and to debate their value. This point was recently emphasised by the House of Lords Science and Technology Committee in their report 'Science and Society', which has made a valuable contribution to this debate.

32. OST is conducting a review of science communication, working closely with the Wellcome Trust, aiming to improve understanding of the best ways to communicate science and to conduct effective dialogue. And scientists need skills to participate in the debate: we will build on existing Research Council initiatives to help scientists understand how to communicate their work.

33. As a society we are celebrating science more today than ever before. Millennium Commission funding will lead to a substantial increase in the number and size of UK Science Centres. The Millennium Commission is investing over £250 million in the creation of 14 new science and technology centres, including Millennium Point, Birmingham; @Bristol; the National Space Science Centre, Leicester; The Odyssey, Belfast; and Our Dynamic Earth, Edinburgh.

34. There have also been significant developments in presentation within science and technology centres. For example, the new Wellcome Wing at the London Science Museum examines contemporary science, with visitors being encouraged to engage in debate on the regulation and application of modern science. The Government is working with the Royal Society, the Royal Institution, the British Association for the Advancement of Science, the Research Councils and the centres and museums themselves, to ensure that they operate as centres of dialogue and debate, as well as of information, providing opportunities for adults and children who want to find out more about science and the contribution it makes to our lives.

The National Space Centre

In Spring 2001 the National Space Science Centre, Britain's first attraction dedicated to space, will open its doors to the public in Leicester. The £46.5 million Space Centre is backed by £23.25 million from the Millennium Commission and was co-funded by the University of Leicester and Leicester City Council.

The Space Centre will provide families with a journey of discovery through interactive challenges, stunning images and sounds and real space hardware. It will use stories, personalities and technology of the past and present to explain our current understanding of space and how it will affect our future. It will give visitors the latest theories answering those big questions: Where do we come from? How will it all end? Could an asteroid ever destroy the Earth? as well as: How do you eat or breathe in space?

A visit to the Space Centre will include a show in its multi-media Space Theatre, housing this country's newest hi-tech planetarium. The shows are being produced in-house by some of the world's leading planetarium experts and will be unique to the Space Centre.

The Space Centre's Challenger Learning Centre, which opened in 1999, is the first such centre outside North America. The project's flagship educational programme, it involves groups taking part in realistic simulations of space missions by becoming astronauts, engineers and researchers exposed to the science and technology of space missions. Each mission requires a crew to work together in teams, making decisions and solving problems to ensure they complete their mission successfully.

Conclusion

35. Science played a significant role in shaping the 20th century. It will have an even bigger impact on our lives in this century. Science will provide the key to improvements in areas as diverse as health care, the environment and crime prevention.

36. In the global knowledge economy in which we now live, jobs and prosperity depend on the application of new ideas and skills. This is a challenge for us all. British universities must build on their world-class expertise and embrace a new entrepreneurial role, bringing forward the businesses of the future. Business needs to exploit developments in technology to the full and to develop stronger links with universities, to turn our scientific and engineering excellence into world-beating products and services.

37. Government has a key role to play. This White Paper sets out what we need to do. We are committed to introduce an open and accountable system of regulation to ensure that science works for the benefit of us all and does not expose the public to undue risks. We will invest in our science infrastructure and in cutting edge research and provide opportunities for making the most of the talent of all our people. And we will introduce new incentives for the commercial application of research. The Government is backing the proposals in the White Paper with increased investment in science and innovation in all parts of the country. This is investment in the future: providing a sound foundation for building a healthier, safer society, a cleaner environment and a dynamic knowledge economy for the 21st century.

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