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FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE

(presented by the Commission)

FIRST REPORT ON THE STATE OF SCIENCE AND TECHNOLOGY IN EUROPE

HIGHLIGHTS

1. This report is a first response to the request of the European Parliament for regular reviews by the Commission of the state of science and technology in Europe.

It draws on wide-ranging sources of information and assessment, notably: the Parliament itself, the science and technology administrations in the member states, the committees specifically established to advise the Commission on research requirements, the views of the independent evaluation panels on Community programmes, systematic monitoring of the scientific and technical press and scientific meetings, as well as ongoing work in other international organisations.

The Commission intends to update the report during 1989. Thereafter it should be published at two-yearly intervals.

2. The main aim of the report is to provide a factual basis for further reflection, both inside and outside the Community institutions, on Europe's needs in science and technology and how best they can be satisfied. It does not, however, attempt to identify at what level or in which framework at national or at transnational level action in specific fields could most beneficially be taken.

3. The tentative picture emerging from this first report can be summarised as follows:

(i) A good deal has already been done to improve the European situation by increased efforts in spending on research and development and in improving industrial performance through innovation. But the efforts are still unbalanced and fragmented. Three Member States (Germany, France and the United Kingdom) account for three-quarters of total spending on R and D in the Community; and regional variations are acute. Cooperative transnational actions (Community programmes, EUREKA, COST, ESA, CERN etc) account for only a small percentage of the total research effort;

(ii) European efforts are in case well below those of our major competitors (the USA and Japan) who are both spending more and also taking action to remedy their own weaknesses. Europe's position is also threatened by the new efforts of emerging science and technology powers (the NICs in particular);

(iii) Europe faces three main challenges:

- to increase its capacity to develop and pursue, where necessary, its own technological and economic options;
- to strengthen its international competitiveness, especially in those fields which will take on increasing importance in the future;
- to meet the social need for improved quality of life.

(iv) Europe has the resources to meet these challenges. It is rich in scientific talent and organisational ability. And in its present economic situation it can afford to invest more in R&D. The question is how to get the best out of these resources and in which areas to focus the effort.

(v) Getting the best out of European efforts entails addressing a series of issues: ensuring that science and technology are understood and accepted at all levels of European society; overcoming imbalance and fragmentation by better coordination and by ensuring an adequate basis for technological progress in the less-favoured countries and regions; encouraging the spread of technology skills throughout society; attracting more private sector finance and facilitating the diffusion of technology throughout industry; encouraging the links between industry and universities; as well as exploiting the scope for international collaboration in those areas where there are evident mutual benefits.

(vi) As far as research areas are concerned, the report highlights five areas of major relevance to the European economy:

- information technology and telecommunications - a particular research effort is needed to improve the situation of the European semiconductor industry.
- new materials and technologies for use in manufacturing industry - superconducting materials are particularly promising.
- aeronautics, where Europe faces a particular competitive challenge.
- biology and biotechnology which offer the prospect of major transformations in industry and agriculture as well as in the medical field. Specific efforts, however, are needed on basic plant biology, gene-mapping, neurobiology and biotechnology applications.
- energy, where Europe remains highly dependent on outside sources of supply - fusion is important for the longer-term and carefully targetted research on new and renewables and energy saving technologies in the shorter-term.

In terms of the quality of life there are major research needs in the fields of environment, health research and industrial , road and nuclear safety. In environment some of the research requirements have a global dimension. Europe has the capacity as well as the need to make a major contribution to the study of Global Climate change.

Underpinning these efforts in specific fields Europe must sustain and develop its capacity in basic research to provide the seedcorn for new technological openings.

4. There follow summaries of each chapter of the report.

I: SCIENCE AND TECHNOLOGY AND EUROPE'S ECONOMIC AND SOCIAL NEEDS

5. Despite substantial progress in recent years, Europe remains weak in a number of the science-based sectors which are growing rapidly world-wide. This specific weakness reflects a **technological dependence** in key areas. Electronic components is a particularly important case.

The more traditional sectors of manufacturing industry continue to account for higher shares of GDP than in the USA and Japan. Some of them have made real progress in modernising through the application of new technologies. Textiles is one example. Others, such as the paper and board processing industry, or parts of the machine-tool industry have been less successful. Even those that have radically improved their position through automation and innovation (eg. automobiles) face increasing competition. One successful company strategy in a number of industries has been to seek the capture of the top-end of the market through technology.

Major efforts continue to be needed to improve the technological position of European industry and to seize the opportunities offered by scientific and technological advance. Progress towards completion of the Internal Market will help to create the right framework conditions. But it needs to be accompanied by specific efforts in the RTD field.

6. Improvement in the **quality of life** - the environment, health, safety - are also increasingly important concerns throughout Europe. Developments in science and technology are opening up new opportunities for tackling these problems in an effective and economic manner.

7. Europe needs a **broadly-based scientific and technological capability** to respond to the twin needs of increased competitiveness and a better quality of life. This means being able to choose and to develop its own technological options where this seems appropriate. A fundamental research capability is particularly important. Fundamental research is increasingly recognised internationally as the provider of new openings and ideas and a key factor in conditioning the pattern of economic and social development longer-term.

8. The acquisition and maintenance of such a broadly-based scientific and technological capacity is, however, increasingly expensive: science is developing at an accelerating pace with ever shorter periods of time over which to depreciate investment in R&D. This underlines the importance of the most cost-effective solutions to the organisation of R&D, avoiding

fragmented efforts. It also means that the broadest possible market is needed for the commercialisation of the products of research and development.

II: EUROPEAN SCIENCE AND TECHNOLOGY IN A COMPARATIVE PERSPECTIVE

9. European efforts have to be set against the **changing international environment.** Our main competitors (the USA and Japan) have been making their own adjustments to changing needs while new players are becoming increasingly important or could be so over the coming years (the NICs, the Soviet Union, China).

10. European spending on R&D is still well below that of the USA in absolute terms and below the USA and Japan as a share of GDP. US spending in volume is 1.75 times that of the Member States of the European Community combined, and research intensity (R&D spending as a proportion of GDP) is only 1.9% in the Community compared with 2.8% in the USA and 2.6% in Japan. Germany alone has a research intensity (2.8%) comparable to Europe's competitors. Even when defence spending is excluded US expenditure remains significantly higher than the European average.

In both the USA and Japan business also invests and carries out more of the R&D than in Europe.

Both the USA and Japan have larger numbers of research scientists and engineers in their labour forces; the growth in Japan has been striking.

The United States

11. The high level of **defence R&D** in the USA, half of which is contracted out to industry, is a potent factor in mobilising resources. The precise level of spin-off to the civil sector from military R&D in general and from SDI in particular, is hard to assess. But there have been undoubted major benefits in the fields of materials, aircraft engineering, vehicle technology, computer technology and systems engineering. The shift during the 1980s of much military R&D towards development work tailored to the needs of more fundamental and applied research has, however, raised some concern in the USA about reduced industrial impact.

12. This has coincided with worries about the **competitiveness** of **US industry** and US technological dependence, notably vis-à-vis Japan. The Reagan Administration has taken initiatives to encourage American industry to cooperate in the face of this challenge and to increase the transfer of knowledge from Federal programmes to industry. These have been combined with a more restrictive approach to the wider availability of the results of research.

13. A third concern in the USA is the prospect of a **shortfall of perhaps 500,000 scientists and engineers by 2010** because of demographic trends and the pattern of university enrolment. One issue is the encouragement of foreign students (especially those from the Pacific Basin) to stay on in the USA after graduation. At the post-doctoral level there are likely to be increased pressures to "poach" skilled R&D personnel from abroad, especially from Europe.

Japan

14. The importance of **basic research** continues to be recognised in the USA: it is the only sector of Federally-funded civil R&D to have increased in recent years. In Japan, where economic success has been founded essentially on the absorption and transformation of foreign technology, efforts are now under way to build up a capacity in basic research, reflecting a perception that this will be essential in opening up new technological options for Japan in the longer-term and enabling it to stay one step ahead. Already Japan has strengths in, for example biotechnology, new materials and neuro-computing.

This interest in basic research, and the need to respond to concern about the closed nature of the Japanese science and technology system, has led to new openings in international collaboration, including the Human Frontier Science Programme.

Emerging Science and Technology Powers

15. The most dynamic NICs are planning a substantial growth in R&D spending and strategies for the development of large cadre of highly qualified personnel, as they themselves face challenges from other industrialising countries. Korea in particular is making efforts in this direction. Other emerging science and technology powers include Taiwan, India, Brazil and Israel.

China is making particular efforts to improve its science and technology capability and major research programmes have been launched.

Developments in the Soviet Union, which has the largest scientific establishment in the world and significant achievements in, for example, aspects of space technology, mathematics and theoretical physics, will depend heavily on the success of the policy of restructuring (perestroika) and its impact on the deployment of scientific resources to the civil economy.

III: MOBILISING EUROPE'S RESOURCES

R&D spending (public and private)

16. Within Europe there are major **national** differences in levels of investment in R&D; in the relative importance of the public and private sectors; and in the distribution of resources among research sectors.

Three countries (Germany, UK and France) account together for over three-quarters of total public and private spending on R&D in the European Community. Germany has by far the highest research intensity and the highest number of researchers in its labour force. Industry also plays a bigger role in both the financing and execution of R&D in Germany than elsewhere. In the less favoured Member States the public sector is by far the predominant source of R&D finance.

17. **Regional** disparities are larger still. The gap in R&D intensity is of the order of 12:1 between the Member States themselves and much greater at a sub-national level. This technology gap between the developed and the less-favoured regions is much wider than the economic gap.

Government policies and public funding

18. In the majority of Member Sates public R&D budgets have grown during the 1980s, although there has been some recent tailing off.

19. **Defence** R&D is particularly important in the United Kingdom (around 50% of the total public finance) and France (34%), and to a lesser extent Germany (12.5%). Elsewhere the shares are much smaller and in some cases negligible. The wide differences in defence R&D make coordination of national policies on dual-use technologies particularly difficult.

20. Some countries give particular emphasis to the public funding of **basic research** (Germany, France and the Netherlands in particular). In others, public expenditure constraints, the rising cost of basic research, increased emphasis on measurable cost-effectiveness and urgent need to improve competitiveness have led to a new emphasis on **industrially-oriented** research.

European Cooperation and Coordination

21. Transfrontier cooperation in Europe, involving industry as well as universities, has increased significantly in the past few years. The experience has been overwhelmingly positive. The Community's own cost-sharing programmes have been overscribed, reflecting a widely felt need for collaboration, especially at a time when pressures on national budgets have been growing. The experience of EUREKA - 213 announced projects involving 800 organisations, two-thirds of them industrial - is further evidence of this thirst for a transnational approach.

22. The share of the total European research effort that is handled through these cooperative ventures remains, however, small. The total cost of projects supported through the Community's programmes is equivalent to about 4% of total estimated EC public and private spending on civil research. Even taking into account the other major European ventures -EUREKA, ESA, CERN, EMBL etc. - the vast bulk of research continues to be financed and carried out at national level, a large share of it through national budgets.

23. The need to identify precisely where excessive **duplication** and **overlap** occur among these national efforts is pressing. Efforts are being made within CREST to improve the information base and to "confront" national policies. In the light of further progress in this forum, the Commission intends to focus particular attention on duplication and overlap in its forthcoming reports on the state of science and technology.

IV: RESEARCH ISSUES FOR THE FUTURE

24. The research needs of Europe reflect the three challenges described in Chapter I:

- to improve international competitiveness, notably in the context of the completion of the Internal Market;
- to respond to the needs of society by improving the quality of life;
- to increase the Community's capacity to develop and pursue, where appropriate, its own technological options, drawing on the opportunities offered by a solid fundamental research capability.

The following is not an exhaustive list. It concentrates on areas where particular efforts are needed to complement or to supplement ongoing or planned activities by industry and by public bodies (national and transnational).

Improving Competitiveness

25. There are significant research needs in five ares: information technology and telecommunications, industrial materials and technologies, aerospace, biological sciences and energy.

26. The European **information technology** industries are in better shape than at the beginning of the 1980s. But the negative balance of trade in IT products is large (13.4 milliard US$ in 1986), reflecting dependence in the fields of electronic components in particular.

Research is needed to give Europe the capacity to master and develop the next generation of memory chips based on circuity for feature series below 0.5 micron. A significant cross-border collaborative project (JESSI) is currently under discussion among European manufacturers.

Progress is also needed in software and advanced information processing and in peripherals (flat panel displays and optical storage technologies) where Europe's position is weak.

More basic research is required on questions such as the security and reliability of computers, computer languages and machine-learning; as well as prenormative work to prepare the integration of IT systems designed for a wide range of services (intelligent banking and financial services etc.).

27. In **telecommunications** Europe's relatively favourable position could be threatened by continuing weakness in the electronic components sector, the spiralling costs of R&D and new technological and market challenges (such as the digitalisation of networks, developments in broadband networks).

Research is needed on a wide front, including better network management systems; specific electronic and opto-eletronic components; new materials and software tools.

28. A significant research effort will also be required in the development, coordination and integration of technologies for the **application** of IT and telecommunications, including language technologies.

29. **Manufacturing industry** currently provides 30% of Community GNP and employs 75% of the industrial work force of some 41 million. A general need is to ensure the diffusion and application of available new technologies by this sector. In parallel a major research effort continues to be necessary to open up new technological possibilities for European industry and to solve particularly pressing problems. Areas of particular interest include:

- techniques for quality control (which can cost up to 25% of company turnover)
- techniques for shaping, joining and assembly
- surface treatment to prevent corrosion (which can cost up to 4% of GNP)
- powder technology, which is a particularly large and high-value market
- other high-value materials, such as metal composites (already being developed for ceramic-reinforced light alloy pistons)

A concerted research effort on superconducting materials is particularly necessary. Large financial resources are being mobilised in the USA and Japan.

- norms and standards. Prenormative work is needed in a number of areas, including lasers.

30. In **aeronautics** the European industry has had major successes, capturing (1980-1986) 23% of the civil and 27% of the military world market. But sharply increasing competition can be expected over the next 10-15 years, not only from the USA but

also from Japan and industrialising countries such as Korea and Brazil. The US remains in a particularly favourable position because of the large home market and the spin-off from military programmes.

The future commercial success of the European aeronautical industry will depend heavily on advanced technology. In order to prepare for the 1990s and beyond Europe the need is for broadly-based collaborative efforts focussed on aerodynamics and flight mechanisms, materials, acoustics, computation, airborne systems and equipment, propulsion integration and design and manufacturing technologies.

31. The future market for **biotechnology** products is difficult to quantify precisely; but worldwide the biological sciences are recognised to offer the prospect of major economic and social impacts (through environmentally "clean" transformations of agricultural and industrial productivity; progress in pharmaceuticals, chemistry and medical science; improved understanding of the brain, with its implications for computer design as well as its impact on psychology and psychiatry).

Four areas of research merit particular attention:

- **basic plant biology.** Without a better understanding of key structures and functions within plants it will not be possible to make significant advances in application technology;

- **gene-mapping** of complex organisms. For agriculture and industry the detailed mapping of the genes of important microbial plant and animal species is an essential complement to the work on basic plant biology. For medicine, a better understanding of the human genome is as necessary to the continuing process of medicine as knowledge of human anatomy is to its present state. This is laborious and expensive work. Major international efforts are underway. Europe has experience on which to build;

- **neurosciences,** where efforts are already under way to coordinate some national actions;

- **industrial and agro-industrial applications.** Particular research efforts will be needed by the pharmaceuticals industry to maintain its good competitive position, in the face of growing competition and the cost and time-scale needed for the development of new products. Research is also needed on improved food technologies and on nutrition itself.

32. The **energy** markets are currently slack, with plentiful supplies on world markets. But Europe remains heavily dependent on third countries for supplies, particularly of oil, which is still the largest single element in the Community energy balance. There is a continuing need to ensure adequately **diversified** energy supply and **efficient energy use** and to reduce as far as possible the impact of energy supply and use on the environment. Two lines of research remain of particular importance:

- **controlled nuclear fusion,** which offers the prospect in the next century of an environmentally acceptable, practically inexhaustible, geographically independent source of supply. Europe is already playing a leading role;

- research on selective **non-nuclear energy technologies** and technologies for improving energy use which offer the best prospect of exploitation on a wide scale.

Improving the Quality of Life

33. Science and technology have fundamental roles to play in devising rational and effective **environmental** policies. Continuing research efforts in Europe are needed under three interdependent headings:

- understanding the basic phenomena
- detection and interpretation of environmental changes
- prevention.

A scientific approach to understanding the complex interactions of the many complex sub-systems (the stratosphere, the atmosphere, soil, inland water, the sea) would have been unthinkable a few decades ago. But progress in basic mathematics, in analytical techniques and technologies (including remote sensing from space), together with the huge capacity to handle information through advanced computing, now makes this possible.

Some of the problems are particular to Europe in a regional sense and require European level efforts. Action is under way both through the Community programmes, COST as well as EUREKA projects. Good coordination among these projects is essential. The most complex issue of **global climate** change and the "greenhouse effect", however, is an issue with truly global dimensions. Europe has the capacity to make an important contribution to the International Geosphere-Biosphere Programme (Global Change).

34. In the field of **health**, Europe is faced with sharply rising health care costs (a world-wide phenomenon); a "greying" of its population, with the consequent increase in age-related diseases; and growing problems posed, in particular, by AIDs and cancer.

European research in the medical field suffers from particular fragmentation. This is an area where the value of concerted action across national frontiers has already been clearly demonstrated. The essential need is for more of the same in tackling the problems described above, as well as continuing research on medical technology.

35. In the field of industrial technologies and materials increasing attention will have to be given to **safety** issues. R&D has an important role to play in the development of common safety standards in particular for new technologies such as lasers.

The potential contribution of R&D to long-term **road-safety** through the development of the "intelligent" car and the infrastructure to support it, is also considerable. Cooperative efforts are already under way in Europe to address these issues (the DRIVE programme in the Community, and PROMETHEUS and other projects inside EUREKA). There is an obvious need for good coordination among all these projects to ensure optimal resource allocation.

36. Continuing attention will need to be paid also to work on the safety of **nuclear fission**. In addition to research on reactor safety, the safety of the fuel cycle, radioactive waste management and storage, the safety of dismantling nuclear plants at the end of their lives, a particular effort will be required to increase public confidence about **radiation protection**. This requires both research work itself and efforts by the scientific community to present the issues in a way which is accessible by the general public.

37. **Bioethics** are attracting growing attention world-wide. A particular effort is needed at Community level in particular because of the importance for the Internal Market of a harmonised regulatory environment. Ethical, societal and juridical considerations must accompany science and precede technological development.

Fundamental Research - the Essential Underpinning

38. Fundamental research is continuing to open up significant new opportunities through progress in mathematics, physics, chemistry and the earth sciences.

The theory of non-linear **mathematics** - pioneered in Europe - has pervasive applications, opening up prospects such as the all-optical computer, advanced modelling of climatic change or significant improvements in the functioning of the internal combustion engine.

In **physics** there are strong points in the European situation, but also some weaknesses: the efforts on laser science and technology, for example, are not on a par with those in the USA, despite some significant multinational efforts.
Europe occupies a good position both in **basic chemistry** and on the market for chemistry-based products. But there is a problem in recruiting a sufficient number of high quality students.

In **earth sciences** good European coordination is being assured by the European Science Foundation. In oceanography the USA is leading the field. Some aspects, such as the study of the coastal zone, the interface between the ocean and the atmosphere will be pursued through the Community's MAST programme and the EUREKA project EUROMAR.

Earth observation from **space** is of major potential significance for the earth sciences.

39. Within Europe there are already several multinational ventures for the common pursuit of Big Sciences (CERN, ESO, ESA, EMBL, ESF, etc.)[1]. There is growing collaboration amongst them, which must develop further. Increased collaboration with Community programmes is also desirable so as to maximise the industrial and commercial spin-offs. **Space research** is one area of particular importance.

40. There are also outstanding questions related to access to advanced middle-size research devices in Europe and the development of expensive scientific instrumentation. Given the cost of sophisticated facilities it is not feasible to imagine

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1 CERN - European Centre for Nuclear Research
ESO - European Organisation for Astronomical Research in the Southern Hemisphere
ESA - European Space Agency
EMBL - European Molecular Biology Laboratory
ESF - European Science Foundation

that they can be available in every European country. Particular attention will be needed to provide a framework for cooperation among national teams.

V: KEY ISSUES FOR SCIENCE AND TECHNOLOGY POLICY IN EUROPE

41. Alongside the research needs themselves there are some broader policy questions of particular importance:

(i) **the balance of effort between fundamental and applied research across Europe**

One theme of this report is that a sound capacity in fundamental research is essential to Europe in its pursuit of technological and economic independence. This is an area where public authorities have a particularly important role. But in the funding and execution of basic research industry too has evident self-interest. In the USA much of this research is funded by industry.

(ii) **the links between industry and the universities**

These have been growing world-wide, with industry driven increasingly to tap scientific knowledge and universities driven by financial constraints. The trend is a desirable one, with two caveats: namely, that it should not jeopardise the pursuit of fundamental research in universities and that restrictions on the dissemination of research results should be minimised.

(iii) **broadening and deepening the technology culture**

The most successful economies in recent years have been those that have sought actively to develop on a broad base the human skills required both to research, to develop, to apply and to use technology. Japan is the best example. Europe as a whole is in a weaker position. There is shortage firstly, of skilled manpower trained to use the new technologies; while the output of research scientists and engineers to develop and apply the technologies is insufficient in many countries. An added difficulty is that the brightest and the best in Europe are often attracted across the Atlantic. Particular attention will be needed to ways of increasing the supply of skills and to provide an environment in Europe that is attractive to highly qualified scientists. This means removing the barriers to mobility of research workers between European countries.

(iv) Public acceptability of science and technology

Public concern about new technologies is often based on fear of the unknown. It is important both for democracy and for the pursuit of scientific knowledge that popular understanding of the issues should be improved. This will help to ensure that informed choices are made and a sound regulatory environment established. The information effort in many European countries is still inadequate.

(v) Encouraging the private sector to invest more

Industrial investment in R&D is still too low in many European countries. The venture capital markets are insufficiently developed in many countries and they are essentially national. Action is needed at national and at transnational level to improve the access to finance for innovation.

(vi) The Diffusion of Technology

As well as opening up new frontiers through research and development, Europe needs to exploit more rapidly the technologies that are already coming on the market or are about to do so. Here Japan in particular has a head-start. Some Member States (in particular Denmark) have made considerable efforts to promote a wide diffusion of technology. Others less so. Community-level action has a helpful role to play (notably the SPRINT programme). But more could be done to spread information about available technologies and the results of research and development.

(vii) Policy Coordination and (viii) Cohesion

Particular efforts are needed to improve the coordination of science and technology policies in Europe. At the same time steps must be taken to improve the RDT fabric in the less-favoured regions so as to enable them to achieve a level of excellence comparable to that of the more developed. This cannot be done without the provision of infrastructure and trained personnel. Regional and social policy instruments could be appropriately used to this end.

(ix) Cooperation with Third Countries

Science and technology are increasingly international commodities and further internationalisation is inevitable. The issue is how best to organise cooperation in such a way that it can be a "positive-sum" game in which everybody benefits. The approaches must depend on the situation of individual countries or regions.

The European Community has a particular interest in close science and technology links with other **EFTA** countries where good relations are already established through COST, bilateral agreements as well as EUREKA.

There is scope for improved cooperation with the **USA**. It would also be appropriate to take advantage of **Japanese** openings to examine the scope for mutually beneficial cooperative ventures, especially those involving expensive, long lead-time research.

As far as **developing countries** are concerned Europe has a role to play in tackling the specific problems of medicine, agriculture, energy and the environment which they face. The wider consequences for the LDCs of scientific advances in materials and biotechnology are also of significance and will need consideration in Europe as well as at an international level.

Further reflection is needed on the potential scope for RTD cooperation with the Soviet Union and Eastern Europe, given the new developments in relations across the European continent; and also on the appropriate form for scientific cooperation with the NICs.

(x) Avoiding technological protectionism

The longer-term benefits of RTD cooperation at an international level can only be fully realised if the transfer of knowledge and technology is facilitated. But the "industrialisation" of research and the growing importance of science to trade flows has increased the pressure to restrict flows of information in order to preserve competitive edge. Policy developments in the USA in this respect will need to be carefully monitored.

FIRST REPORT ON

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MAIN REPORT

ANNEXES

1. INFORMATION TECHNOLOGY AND TELECOMMUNICATIONS
2. INDUSTRIAL TECHNOLOGIES AND MATERIALS
3. AERONAUTICS
4. BIOLOGY
5. NON-NUCLEAR ENERGY
6. CONTROLLED NUCLEAR FUSION
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14. COMPARATIVE TRENDS IN THE USA, JAPAN AND EUROPE.

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INTRODUCTION

The Background and Objectives

1. In its most recent report on the technological challenge facing Europe [1], the European Parliament invited the Commission to give an account of the European situation in the various fields of science and technology as a basis for considering future policy requirements.

2. The importance attached by the Parliament to this issue reflects a widespread recognition of the vital role which science and technology must play in the future of Europe's economy and in the construction of a prosperous and successful European Community. That recognition is enshrined in the Single European Act itself.

3. During the past few years real progress has been made in tackling the constraints on European success. European governments have launched, both inside and outside the framework of the Community, new initiatives to foster transnational cooperation among researchers in universities, industry and the public sector itself. At the Community level there has been a new emphasis on research and development oriented towards improving industrial competitiveness (ESPRIT, BRITE in particular) as well as the quality of life. The current Framework Programme 1987-1991 provides for particular efforts in these areas. Alongside the Community efforts, EUREKA has provided further evidence of the interest in and benefits from transnational cooperation in Europe.

4. Against that background the aims of this first preliminary report are:

- to draw up a **balance-sheet of progress** so far in

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1 Comparative study of the technology level of Europe, USA, Japan and the Soviet Union, Michel Poniatowski, President of the Committee on Energy, Research and Technology, European Parliament, 15 June 1987.

improving Europe's position in science and technology;

° to consider the main **research needs and opportunities** which require particular attention in the context of reducing Europe's technological dependence and improving economic competitiveness and the quality of life;

° and to identify the main **science policy** issues facing Europe over the coming years.

The report is not limited to a review of Community activities in the fields concerned or to the planning horizon of the current Framework Programme (1987-1991); nor does it make specific proposals for Community action. The aim is rather to provide the factual basis on which to consider what needs to be done in Europe, without at this stage attempting to identify what should be done at national, what is more appropriate for action in a transnational framework or what specifically might most effectively be done at Community level.

5. The report highlights the importance for the future of adequate efforts in basic research alongside and in support of the application of scientific knowledge and technical know-how to the solution of the main economic and societal questions facing Europe. It also addresses questions upstream of research (education) and downstream (innovation and technology transfer). It pays particular attention to the opportunities and needs arising from the completion of the Community's Internal Market in 1992.

6. The Commission intends to update this first and preliminary report during the course of 1989 in the light of the reactions to it from the Parliament, from national policy-makers and from the wider scientific, industrial und educational community. Thereafter it will publish similar factual analyses at two-yearly intervals.

<u>The structure</u>

7. The report has five chapters:

Chapter I recalls briefly the central role played by science and technology in economic and social development, and some of the central issues affecting the links between basic research, applied research, innovation and competitiveness.

Chapter II summarises recent policies and developments outside Europe, concentrating on the USA and Japan, but also examining briefly the situation and prospects in the Soviet Union as well as the emergence of new science and technology powers.

Chapter III surveys actions taken, nationally and transnationally, in Europe to mobilize its resources in the field of research and technological development (RTD).

Chapter IV considers the main requirements for research to improve Europe's **competitive position**, notably in the context of the completion of the Internal Market; to respond to the needs of society through improvements in the **quality of life**; and to increase Europe's capacity to pursue its own scientific and technological options where necessary, by **reducing its dependence on others**.

Chapter V outlines the main issues for science policy in Europe during the coming years.

The Inputs

8. The analysis in the report reflects a multiplicity of inputs. It draws heavily on the advice of the special groups established to advise the Commission on R&D trends, needs and priorities (CODEST, CREST, IRDAC, and the Advisory Committees on the coordination of individual research projects and programmes); the independent evaluation panels on Community programmes; systematic monitoring of scientific and technical literature and professional meetings; the views of researchers and research users in industry and universities, as well as consultants; science and technology administrations in Member States; the advice of the Commission departments concerned, both the "customers" for and the "producers" of research; as well as the European Parliament itself. It also takes fully into account the work in similar fields undertaken by other international organisations, such as the OECD.

Except where otherwise stated, the figures given are averages for the European Community. In some cases data for Spain and Portugal are not yet available; while data for Luxembourg are limited. There are often wide variations around the average (see Chapter III).

Some gaps in data available from the Member States have placed limitations on the depth of the analysis in Chapter III of national trends. These limitations should be remedied in future reports in the light of the ongoing discussions and analysis of national policies within the framework of CREST. As stated later, the Commission intends to concentrate in more detail on trends and policies in the Member States in future reports on science and technology in Europe.

I SCIENCE, TECHNOLOGY AND EUROPE'S ECONOMIC AND SOCIAL NEEDS

Science, technology and the economy

Economic Trends

1.1. In its analysis[2] of the economic benefits of completing the Community's internal market the European Commission underlined the importance to economic growth and competitiveness of economic sectors incorporating the results of advanced technologies, and drew attention to the weakness of the Community's performance in these fields.

1.2. For these "high technology" sectors (electrical and electronic goods; office and data-processing mechanisms; chemical and pharmaceutical goods) world demand has been growing at around twice the rate of that for manufactured products as a whole. Yet these sectors account (1985) for only 22.4% of the value-added of the whole of Community industry, as against nearly 29% in the USA and more than 28% in Japan. Moreover, the share has been growing more slowly in the Community than in either of its major competitors: between 1979 and 1985 it grew by 3% a year in the Community, compared with 3.7% in the USA and 17.1% in Japan. The differences between Europe and Japan are particularly striking in the case of electrical and electronic goods, where Japanese domestic demand grew by nearly 21%, and European demand by 3.5%.

Table 1.1.

Evolution of volume of domestic demand by industrial branch in the EC, the United States and Japan (1973-85, average annual rate of growth)

%

	EUR	USA	Japan
Strong demand sectors	*5,0*	*5,2*	*14,3*
Office and data-processing machines	9,0	6,5	7,2
Electrical and electronic goods	3,5	7,2	20,7
Chemical and pharmaceutical products	5,3	2,3	9,9
Moderate demand sectors	*1,2*	*2,8*	*3,1*
Rubber and plastic products	2,8	5,4	2,0
Transport equipment	1,7	2,7	5,2
Food, beverages, tobacco	1,2	0,4	0,0
Paper and printing products	1,6	2,9	2,7
Industrial and agricultural machinery	−0,1	5,6	5,6
Weak demand sectors	*−0,3*	*0,5*	*2,4*
Metal products	−0,5	−0,4	3,4
Miscellaneous manufactured products	−0,6	2,1	1,9
Ferrous and non-ferrous ores and metals	0,6	−1,8	2,0
Textiles, leather, clothing	−0,2	2,0	2,2
Non-metallic minerals (construction materials)	0,1	1,7	1,1

NB: The sectors are divided into those in which demand in OECD countries between 1979 and 1985 increased by more than 5% (strong demand), by around 3% (moderate demand), and by less than 2% (weak demand).

Source: Volimex, Commission services

2 The Economics of 1992, European Economy n°35, March 1988.

1.3. In terms of exports the Community has also been losing ground in the case of electronics and electrical equipment, in cars and other forms of transport, office machinery, and information technology. The only high growth sectors where the Community has maintained a favourable position on export markets are chemicals and pharmaceuticals. Japan in particular has continued to push ahead in the export of high-technology products. Between 1979 and 1985 Japan increased its world market share by nearly 12% for electrical and electronic equipment, by over 9% for cars and by 5.5% in information technology and office automation[3].

1.4. At the same time the Community has been increasing its **dependence** on imports of such products. Imports from outside the Community have been growing more quickly than intra-Community trade in office machinery and information technology, electrical end electronic equipment, machinery and transport equipment. Again, only the chemical and pharmaceutical industries among the high growth sectors perform well. This increase in trade dependence reflects an underlying technological dependence in certain sectors: in the case of information technology, for example, European dependence on components has been increasing despite the improvements in the performance of the IT industry as a whole.

1.5. While in the high growth industries Europe continues to be underrepresented, traditional manufacturing industry remains significant. The Community accounts for some 35% of the GDP of the EC-USA-Japan triad, but in 1986 it produced 44% of the cars, 42% of the steel and 40% of the textiles and clothing of the three combined. A number of the traditional sectors have improved their position during the past few years by large-scale investment in new technologies and major research efforts (Table 1.2.). Textiles and automobiles are two examples. Others, such as the paper and board processing industry or parts of the machine-tool industry, have been less successful. Even those that have improved their position through innovation and automation (especially automobiles where productivity has grown by over 30% 1980-87) face the prospect of increasing world competition. One successful company strategy in some industries has been to seek to capture more of the top-end of the market through the application of new technologies and their integration into the products.

1.6. Europe's interest lies in both reducing its dependence on the third countries in the high growth sectors and harnessing

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3 Market share is defined as the export of the USA, Japan or EC-IO to the rest of the world compared with exports of OECD countries as a whole to the rest of the world.

the new technologies to improving the competitiveness of its traditional industries.

The Characteristics of the Emerging Industries

1.7. The characteristics of the emerging industries and their contribution to overall economic growth and development have been the subject of considerable enquiry during the past few years [4]. Recent trends in these sectors in the European Community are analysed in detail in the forthcoming "Panorama of EC Industry: 1989" which will shortly be published by the Commission and to which reference is made in more detail in Chapter IV below.

One fundamental characteristic of the emerging industries is that they are heavily "science-based" or "science-related", with their products embodying to a significant degree the results of advanced research and development. Secondly, they reflect the emergence of new "generic" technologies with pervasive applications. Thirdly, they are calling on the expertise of an increasing range of scientific disciplines. Fourthly, some of the new fast growing sectors demand a much closer and more interactive relationship between fundamental research and commercial production than has hitherto been the norm. Biotechnological products and technologies have been described, for example, as "growing directly out of the laboratories". Fifthly, however, the pace of economic growth is linked to the diffusion, application and modification of new generic technologies by smaller innovating firms, alongside the major enterprises with their large R&D resources and the contribution of universities and research institutes.

Technology and Economic Growth

1.8. The importance of technology and the underlying scientific disciplines to growth, trade and welfare is certain to grow rather than to diminish over the coming years. The information technology revolution is far from over, as applications of IT permeate industry, households, transport and communications. On one estimate [5] the electronics industry, with an output value estimated at US$ 485 milliard in 1985 (or 4.7% of Free World GNP) is likely to reach 8% by 2000; another expects the share of telecommunications in developed countries'GNP to

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[4] For example "The contribution of Science and Technology to Economic Growth and Social Development", OECD SPT/Min(87)2, 7 October 1987.

[5] <u>Futurible</u>, Paris Dec 1986.

Table 1.2.

Extra-EC Imports and Exports by Branch, Evolution Since 1980

(Index 1980=100)	1982	1985	1987	1987 value (billion ECUs)
Processed foodstuffs				
Imports	119	155	127	12.9
Exports	136	183	159	13.2
Intra-EC trade	131	185	209	22.3
Chemicals				
Imports	126	203	185	19.7
Exports	118	187	160	32.0
Intra-EC trade	128	197	206	44.9
Plastics				
Imports	118	186	184	8.3
Exports	115	178	157	14.1
Intra-EC trade	120	186	219	29.6
Leather				
Imports	99	146	150	5.9
Exports	119	211	216	3..9
Intra-EC trade	144	210	234	5.2
Paper and board				
Imports	123	175	180	14.6
Exports	125	220	216	7.2
Intra-EC trade	125	187	234	15.1
Textiles				
Imports	113	165	165	25.8
Exports	124	204	186	19.3
Intra-EC trade	120	170	201	35.9
Footwear				
Imports	116	181	173	2.8
Exports	143	271	216	3.6
Intra-EC trade	119	151	201	5.6
Glass, ceramics				
Imports	112	162	145	2.3
Exports	122	186	164	6.5
Intra-EC trade	108	143	183	9.3
Machinery				
Imports	135	226	236	60.5
Exports	128	171	155	85.8
Intra-EC trade	119	189	232	91.1
Transport equipment				
Imports	129	202	190	19.5
Exports	139	181	159	43.8
Intra-EC trade	135	172	239	64.9
Audio/video/photo equipment				
Imports	141	215	232	18.2
Exports	139	222	207	14.6
Intra-EC trade	124	202	252	16.7

Source: Eurostat (rounded figures).

grow to 7-10% by the early 1990s (compared with 5% in the USA in 1985, and 3% in Japan and Europe)[6]. Biotechnology is likely to impact on a large number of economic sectors within the next decade and its influence could spread rapidly thereafter, affecting the chemical and pharmaceutical industries, agriculture and food and energy. New materials could induce major savings in resources and change the basis of comparative advantage between traditional raw material producers and countries that depend on imports.

1.9. In this rapidly changing world economy, growth and competitiveness will depend increasingly on successful interaction and feedbacks between the progress of scientific knowledge ("science push"), the identification of market opportunities and needs ("market pull"), the pervasive diffusion of knowledge of, access to and modification of available technologies as well as the opening up of new technological frontiers.

1.10. The Commission's analysis of the costs of non-Europe shows that progress in removing market barriers within Europe will of itself play an important role in creating the conditions for the Community to improve its competitive position. It will encourage some integration of companies, laying the basis for pooling of R&D resources to achieve the "critical mass" required to take major new steps forward in generic technologies. It will also encourage more competition and the consequent encouragement of innovation. But, the creation of the internal market in alone will not solve the problems of competitiveness. Progress in this direction must be accompanied and encouraged by adequate public policies on R&D that take account of the new realities (the ever-closer links between science, technology and the market-place) and that create the right framework conditions in which these links and interactions can best be established.

<u>Science, technology and the consequences of growth and change</u>

1.11. Improving Europe's industrial competitiveness is not in any case the only issue to which science policy can and should make a major contribution. The pressures of technological change also have important social consequences, in terms of the pattern of employment and the distribution of wealth and economic opportunity across Europe ,and consequent implications for the

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6 Borrus, M et al. "Telecommunications Development in Comparative Perspective: The New Telecommunications in Europe, Japan and the US", Berkeley Round Table on Industrial Economy, California 1985.

economic and social cohesion of the European Community. They also raise issues of an environmental and ethical nature, as well as new questions for international relations. The challenge for science policy is to help find solutions for the problems posed by scientific and technical advances as well as to help seize the opportunities which they offer.

1.12. The effect of the new technologies on employment over the longer-term is not yet well understood. A number of studies suggest that the net effect of information technologies on employment will be relatively small[7]. And advances in biotechnology and new materials could increase, rather than reduce employment. But it is obvious that there are major strucural adjustments within any economy and adverse effects for some regions and industries. Moreover, Europe has been less successful so far than the USA and Japan in translating economic growth into the growth of employment opportunities. High unemployment may itself create resistance to the diffusion of technologies that are labour-saving and, in the absence of policies to mitigate the effects, encourage a Luddite approach to new technology.

1.13. Similarly, there is a risk that technology will be seen as the cause and not the cure for environmental problems unless public policies are focussed sharply on encouraging the application of scientific knowledge and technological resources to the solution of the problems of atmospheric pollution, waste disposal and safety, and to prevention of environmental damage.

1.14. Advances in medical and biological sciences offer the prospects of major improvements in health and agriculture over the coming years. But there are important ethical issues posed by genetic engineering, and some evidence of public concern about the effects on the environment and the risks to health of certain experiments in biotechnology. A considered approach to these issues must be an integral part of European efforts to ensure an adequate S&T base.

1.15. The external aspect is also of major importance. The mastery of technology and the promotion of scientific advance in Europe have consequences not only for our competition with our major industrial trading partners but also for the trade and development of the developing countries. Biotechnology may offer us the prospect of more efficient agriculture in the longer-term, producing crops that correspond more precisely to market requirements and reducing the risks of surpluses of unwanted

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7 For example, OECD Employment Outlook, Paris 1986
Freeman & Soete: "Information Technology and Employment - An Assessment", April 1985.

products. It should also help to transform Third World agriculture and medecine. The advance of new materials, on the other hand, is likely to have consequences for those developing countries that are exporters of traditional materials.

1.16. Through the Single European Act the Governments of the Community's Member States have expressed their commitment to the protection of the environment and to a more economically and socially cohesive Europe. They have also underlined the importance of the external aspects of Community policy in the field of R&D. The final chapter of this report outlines how these commitments can be reflected in and supported by science and technology policy itself.

The Changing Scientific Environment

1.17. Science policy has also to take account of the other factors, namely: the **accelerating pace** of scientific discoveries; the **increasing cost** of research; and the trend towards a more **pluridisciplinary** approach to research, in which the traditional boundaries between sectors are breaking down and more integrated systems are developing.

Chemistry provides a vivid example. There has been an explosive growth in new compounds which are now doubling in number every 6-7 years compared with every 40 years in the 1940s. At the same time chemists are now using more and more sophisticated and costly instruments and analytical aids (lasers, spectroscopic instruments, the electron miscroscope, synchroton light, etc) and calling increasity on the help of information technology.

All this means that financial resources have to be depreciated over a shorter space of time and directed at an ever-growing number of problems. This has major implications for science policy both at national and at European level. It underlines the need for the most rational use of resources (financial, human and physical) by the avoidance of duplication and pooling, and it poses more acute problems in the definition of research priorities for public funding than in the past. It also highlights the importance for industry of having a large enough market in which to sell the products of research and thus to achieve a rapid depreciation of expenditure.

Science and Technology are vital in improving Europe's competitive position in the context of the completion of the Internal Market. They also have a major contribution to offer in meeting the societal needs of the European society for a cleaner and safer environment and better health care.

The mastery of science and technology is essential to reduce technological, and thus economic dependence and to allow Europe to be able, where it wishes to do so, to make its own technological choices.

The translation of these economic and social needs into specific requirements for research is considered, sector by sector, in Chapter IV.

But science and technology are increasingly expensive as science develops at an accelerating pace. The costs of research are placing an increasing strain on the financial capacities of individual companies or Member States. The resources devoted to science must be used to the best effect. Further pooling of these resources may offer major advantages.

II EUROPEAN SCIENCE AND TECHNOLOGY FROM A COMPARATIVE PERSPECTIVE: TRENDS IN OUR MAIN COMPETITORS

2.1. The performance of Europe vis-à-vis its major competitors can be measured in terms of resource **inputs** (financial and human) to science and technology , quantifiable scientific and technological **outputs**, and the administrative and policy framework within which science and technology develop. This chapter begins with a short analysis of the trends in inputs (how much is spent on R&D, by whom, what scientific personnel are available) and in proxy measures of output (patenting activitiy, technological trade balance, technological balance-of-payments). The comparison is between Europe[8], on the one hand, and the USA and Japan, on the other. The chapter then examines recent policy developments in the USA and Japan before concluding with a short survey of trends in some emerging science and technology powers.

2.2. The chapter draws heavily on available comparative data drawn up by the OECD, on more detailed data for Community Member States assembled by the Statistical Office of the European Communities, and on a comparative study of the Community, USA and Japan, prepared for CREST in the context of discussions on the coordination of national R&D policies in Europe[9]. This latter study forms the basis for annex 14.

In commenting on policy developments the chapter concentrates on **recent trends.** More detailed on the structure and organisation of R&D in the USA and Japan can be found in the annex.

(i) COMPARATIVE TRENDS IN SCIENCE AND TECHNOLOGY

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8 Where possible, data are given for the enlarged Community on the basis of estimates for Spain and Portugal. In most cases data for Luxembourg are not available.

9 "The European S/T "Space" in the International Context: Resources and Conditions for Community Competitiveness", Working paper prepared for COPOL 88, 29 Feb.1988.

The level of funding

2.3. Fully comparable data on total spending on R&D exist only for 1985. These show that in absolute terms total spending (civil and military) in the USA was 1.75 times that of the European Community and 2.9 times that of Japan:

Table 2.1.

Gross Domestic Expenditure on R&D
Mio ECU current (ppp)

	EC(12)	USA	Japan
1981	48,072*	76,722	25,136
1985	76,250**	134,645	48,056

* estimates for Belgium and Portugal. Excludes Luxembourg
** estimates for Belgium, Spain and Portugal. Excludes Luxembourg.

Source: Commission services estimates and Table 2 of OECD "Main Science and Technology Indicators", Paris 1988.

In terms of spending as a share of GDP the USA is also in the leading position:

Table 2.2.

Gross Domestic Expenditure on R&D as a percentage of GDP

	EC(12)	USA	Japan
1985	1.9	2.8	2.6

Only one Community country (Germany) has an R&D intensity[10] (2.8% in 1987) that is comparable to that of the USA or Japan.
The level elsewhere varies between 2.3% (UK and France), 2.1% (Netherlands) down to 1% or less for some smaller Community

10 Share of R&D spending in GDP.

countries. The US figures are, however, bolstered by the high level of spending on defence R&D. If defence expenditure is excluded, the share of US GDP devoted to R&D drops to about 1.9%, that of the Community (where military R&D accounts for some 25% of the total Government expenditure on R&D) falls to 1.4%, while that of Japan (where military R&D expenditure is prima facie negligible[11]) is almost unaffected.

2.4. In all three areas spending on R&D has grown significantly throughout the 1980s, but the growth has been more marked in the US and Japan than the Community. Between 1981 and 1985, R&D intensity rose by an average annual rate of 1.8% in the Community, by 2.6% in the USA and by 4.1% in Japan. The Japanese figure is even more striking, bearing in mind that the growth of US spending during that period and subsequently has been concentrated on defence R&D. If defence expenditure is excluded, Japanese growth in total R&D spending (public and private) is estimated to have been more than twice that of the USA and Europe (9% as against 4%)[12].

<u>Expenditure and Execution: the contribution of public and private sectors</u>

2.5. In terms of the relative financial contributions of public and private sectors to R&D, the Community lies between the USA (where the public sector share is highest) and Japan. But in most Community countries there is a significantly lower level of industrial involvement in the execution of R&D programmes than in either the USA or Japan.

Around one-half of US spending on R&D is financed from public sources, and throughout the 1980s this government spending has been growing steadily, driven by sharp increases in military R&D; private sector spending has been less buoyant. But more than 70% of R&D has continued to be carried out by industry, given that a large share of military R&D is subcontracted to the private sector.

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11 Methods of calculating military R&D expenditure are not uniform. Official figures may underestimate Japanese military R&D spending compared with those of European countries.

12 Estimate made in COPOL study - see footnote 9.

In Japan, on the other hand, industry both finances and carries out the bulk of R&D. Less than 30% of Japanese R&D is financed by the public sector, 70% being financed and executed by the private sector, especially industry; and in the natural sciences the figures are even further weighted towards industry.
In the Community around 45% of spending is financed from public sources. But only Germany and Belgium have shares of R&D carried out by industry that are on a par with Japan and the USA.

R&D personnel

2.6. The trends in the overall levels of expenditure are parallelled by those as regards R&D personnel. The proportion of research scientists and engineers in the labour force is significantly higher in the USA and Japan than in European countries, even when allowance is made for differences in data coverage. Moreover, the proportion has been growing much more rapidly in Japan. In absolute numbers the USA has a much larger R&D workforce (825,000 in 1986) than either the Community (an estimated 500,000) or Japan (now up to 400,000). But the US figure has been relatively stagnant, while that of Japan has increased steadily and sharply[13].

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13 It is worth noting that the US figure is less than half of some estimates made of Soviet R&D personnel by the US National Science Foundation (see source to table 2.3.)

Table 2.3.

Scientists and engineers in R&D as a proportion of the total labour force 1965-86

	USA	Japan	Germany	France	UK.
		-nos per 10,000 labour force.			
1965	64.7	24.6	22.7	21.0	19.6
1970	64.1	33.4	30.8	27.3	n.a.
1975	55.3	47.9	38.6	29.4	31.1
1980	60.0	53.6	n.a.	32.4	n.a.
1984	65.1	62.4	49.1	41.2	34.2
1985	67.4	63.2	n.a.	n.a.	32.8
1986	69.0	n.a.	n.a.	n.a.	n.a.

Source: National Science Foundation, International Science and Technology Update 1987.

Figures include all scientists and engineers engaged in R&D on a full-time basis except Japan, where data include persons primarily employed in R&D, and UK where data include only the Government and industry sectors.

The output from R&D

a) applied research

2.7. Three measures can be used together to provide a proxy for the "productivity" of applied R&D, namely: **patenting activity**, and especially patenting in the USA as the largest single world market; the **technological balance-of payments** (ie. receipts and expenditures related to patents, royalties and licences); and the **balance of trade in high-technology goods**.

2.8. In terms of the total numbers of patent applications and those granted domestically, Japan now ranks above the USA and Europe. In terms of those registered with foreign patent offices it ranks third after the USA and Germany, and the number of foreign registered patents has been increasing steadily. In terms of the granting of patents in the USA, the Japanese share has doubled since the mid-1970s, and Germany alone among the larger European countries has maintained its position:

Table 2.4.

US patents granted to inventors in various countries, 1975 and 1985

	1975	1985
Total	100	100
USA	64.9	53.8
Japan	8.8	18.6
Germany	8.4	9.6
France	3.3	3.3
UK	4.2	3.4
Other	10.4	11.2

Source: Derived from Appendix Table 6-11 of Science and Engineering Indicators, 1987, National Science Board, Washington DC.

The growing importance of Japan is underlined, moreover, by the number of citations of Japanese patents registered in the US, which provide an indication of the quality of applied research output[14].

2.9. The picture emerging from analysis of technological balance-of-payments data is less clear cut; but the trend has been towards a reduction in the negative Japanese balance. In 1985 Japanese sales of licences, patents etc. were equivalent to about four-fifths of her expenditure in the field[15], and more

14 This is considered further in recent work by Pavitt & Patel: **Measuring Europe's Technological Performance: Results and Prospects**, Centre for European Policy Studies, 1988.

15 Table 48 of OECD "Main Science and Technology Indicators 1981-87", Paris 1988.

recent data suggest that the gap has closed about to zero. The figures on trade in high-technology goods, as indicated in the previous chapter, underline this growing technological strength:

Table 2.5.

Export/Import ratios in selected high-technology goods, 1981 and 1986

	1981					1986				
	Japan	**USA**	**FRG**	**Fr**	**UK**	**Japan**	**USA**	**FRG**	**Fr**	**UK**
Office mach. & computers	2.75	3.23	0.93	0.73	0.68	6.63	1.11	0.92	0.7	0.79
Comm.Equip. &electronic components	6.59	0.70	1.13	1.14	0.96	8.95	0.61	1.14	1.22	0.82
Scientific Instruments	6.59	0.97	1.42	0.76	1.01	6.75	0.61	1.49	0.78	0.88
Drugs	0.28	2.27	1.77	1.99	2.61	0.30	1.42	1.71	1.90	2.21
Electrical Transmission Equipment	4.32	2.3	2.07	1.49	1.44	4.56	0.97	2.00	1.21	1.23
Aircraft & parts	0.08	3.76	0.78	1.19	1.56	0.09	2.48	0.78	1.56	1.91

Source: OECD "Main Science and Technology Indicators 1981-87", Paris 1988.

In all sectors the Japanese ratio has been growing while the US trade position has been weakening.

(b) Basic Research

2.10. Proxies for the output of basic research include, notably, Nobel Prizes (for natural sciences and economics) and numbers of publications of scientific papers. Here Europe is in a much stronger position, and that of Japan much weaker but already improving significantly.

Between 1946 and 1987 US scientists won 196 Nobel Prizes and European ones (EC-12 and EFTA) 105, while Japan had 5.

Compared with aggregate expenditure on R&D the shares of USA and W.Europe in scientific publications are somewhat larger, and that of Japan somewhat lower. The difference is even more marked in the share of total citations. But more significant is the increasing share of Japan and the declining share of the USA, while W.Europe's share of papers and citations has held relatively steady, with the decline of the UK share being compensated by the growth of those of France, Germany and other countries:

Table 2.6.

Distribution of published scientific work

	1973	1982
Japan	7.1	10.1
USA	54.4	51.1
W.Europe	38.5	38.8
TOTAL	100	100

Source: Patel & Pavitt, Research Policy n°16 (1987),Table 18

W.Europe here comprises Belgium, Denmark, France, Germany, Finland, Italy, Netherlands, Sweden, Switzerland, UK.

(ii) TRENDS IN THE USA

2.11. In 1986 the US balance-of-trade in high technology goods became negative for the first time, reinforcing a growing concern about the ability of US manufacturers to compete on world markets, the dependence of the US economy on overseas suppliers of key technologies and, specifically, the increasingly dominant role played by Japan. The apparent discrepancy between increasing expenditure on R&D and weaknesses in industrial performance has prompted questioning inside and outside Congress about the spin-off from defence expenditure, about the organisation of R&D spending, and has led to new R&D policy initiatives both domestically and internationally.

The Federal Budget - defence and civil expenditure

2.12. Between FY 1980 and FY 1988 federal spending on R&D grew by an estimated 26% in constant dollar terms[16]. But defence R&D expenditure grew by 83% in real terms while civilian R&D expenditure fell by 24%. As a result of these divergent budget trends, in FY 1988 defence accounted for about 67% of the federal R&D effort, compared with 46% in FY 1980.

2.13. Equally striking is that the fastest growing element of defence R&D has been **development**. Between 1980 and 1988 defence development doubled in real terms. During the same period Department of Defense funding of basic research spending actually fell in real terms [17].

2.14. For **non-defence** spending the picture is quite the opposite. A striking feature of the pattern of recent Federal spending is that, while spending on civil research has fallen overall, spending on basic research has actually increased by some 40%, notably in the physical sciences, mathematics and engineering:

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16 Figures are from "Research and Development FY 1989" American Association for the Advancement of Science, Report XIII,1988.

17 The attribution of particular projects to one category or another is subject to question: some "development" projects, for example, have undoubtedly had a more fundamental research element in them. The trend towards development is nevertheless striking.

Table 2.7.

US Defence and Non-defence R&D by character of work

	FY 1980 Actual	FY 1988 Estimated	Percent Change Current $	Percent Change Constant $
	(budget authority in billions)			
DEFENCE R&D	15.0	40.3	169	83
Basic Research	0.6	0.9	64	11
Applied Research	1.9	2.6	38	-7
Development	12.5	36.7	194	99
NON DEFENCE R&D	16.7	18.8	13	-24
Basic Research	4.2	8.6	107	40
Applied Research	5.0	6.5	29	-13
Development	7.5	3.7	-50	-66

Source: Table 3 of Research and Development FY 1989, AAAS Report XIII, American Association for the Advancement of Science, Washington DC 1988.

With the 1989 budget under pressure the Administration continued to press for an increase in basic research of $600 millions.

2.15. The breakdown of Federal spending by category is given in Table 2.8. This demonstrates a flattening of expenditure in the energy field, rising expenditure on health research and increasing expenditure on general science:

Table 2.8.

US Federal R&D expenditure 1972 - 1988 by area

Constant 1982 dollars

	FY 1972	FY 1986	FY 1988
Defence	22.2	33.1	34.0
Non-defence	17.6	14.6	16.1
Space	6.0	2.0	2.0
Health	4.4	5.1	6.0
Energy	1.3	2.1	1.9
General Science	1.6	1.8	1.9
All Other	4.2	4.0	4.2
TOTAL	39.8	47.7	50.1

Source: Table 1-4 of source to Table 2.7.

The spin-off from military R&D

2.16. It is difficult to analyse with precision the industrial spin-off from military R&D. There have undoubtedly been important spin-offs in the fields of materials, aircraft engineering, vehicle technology, computer technology and systems engineering from defence expenditure in general and from SDI in particular. Moreover, the fact that 45% of the work funded by the Federal budget for R&D has continued to be carried out by industry has meant close industrial involvement in Federal research efforts and the continuing availability of ready markets for the products of industrial R&D. But the more defence research has been tailored to the needs of specific military defence requirements in terms of weapons systems, communications equipment and so on, the more doubts have been expressed inside the USA about the broader industrial benefits. The Administration has responded with a number of measures to increase the potential benefits to industry and competitiveness from federally-funded research, industry military R&D. These include, notably, the Federal Technology Transfer Act of 1986 and the "Competitiveness Initiative" of 27 January 1987, which provide a new framework for encouraging cooperation among Federal laboratories and between them and universities and industry.

The European situation with respect to spin-off and dual-use technologies is considered separately in Chapter III.

Industrial R&D

2.17. Table 2.9. gives an estimate of the breakdown of industrial R&D spending by area. Computers are the largest single area, followed closely by the automotive industry, then pharmaceuticals, chemicals and aerospace.

Table 2.9.

Industry Spending for R&D by Business Week Groupings, 1986 (in millions)

Industry	1986	% Change from 1985
Aerospace	$3,583.9	21%
Appliances	128.2	13%
Automotive		
cars, trucks	7,401.7	15%
parts, equipment	341.0	12%
Building Materials	223.0	8%
Chemicals	3,662.2	6%
Conglomerates	1,354.2	12%
Containers	19.4	3%
Drugs	4,721.0	17%
Electrical	1,864.0	16%
Electronics	2,586.3	5%
Food and Beverage	610.7	12%
Fuel	1,958.4	-11%
Information Processing		
computers	7,856.5	16%
office equipment	249.2	1%
peripherals	1,615.2	9%
software, services	468.0	17%
Instruments: measuring devices, controls	1,092.5	2%
Leisure Time Industries	1,467.4	10%
Machinery		
farm construction	681.7	-7%
machine tools, industrial and mining	487.2	10%
Metals and Mining	203.9	15%
Miscellaneous Manufacturing	1,692.7	11%
Oil Service and Supply	699.5	-4%
Paper	349.4	1%
Personal and Home Care Products	794.3	17%
Semiconductors	1,309.6	10%
Steel	113.0	-11%
Telecommunications	2,762.0	1%
Textiles, Apparels	68.0	-8%
Tire, Rubber	549.8	6%
Tobacco	22.5	4%
Total	$50,936.4	10%

Source: Based on "R&D Scoreboard, 1986" (Business Week, June 22, 1987).

NOTE: Based on SEC data for companies reporting 1986 sales of $35 million or more, and R&D expenses amounting to at least $1.0 million or 1.0 percent of sales.

Promoting Industrial Cooperation

2.18. The Administration has also taken new steps to encourage inter-firm cooperation. The first efforts in this direction were taken under the Carter Administration through a limited relaxation of anti-trust regulations. Then in 1984 the National Cooperative Research Act legalised the creation of cooperative associations for the purpose of precompetitive research. As a result a number of industrial R&D consortia have been established to pool resources in order to lay the foundations for regaining US competitiveness. Those most hotly-debated is SEMATECH, a Texas-based consortium in the micro-electronics field which is receiving Federal budget support (Department of Defense) in an effort to improve semi-conductor manufacturing technology, and to recapture part of the market lost in Japan.

2.19. The framework for greater efforts in R&D by industry also includes the long-standing Small Business Innovation Research Programme which is intended to encourage R&D in small high-technology business and to increase their involvement in federal R&D programmes. Under the Small Business Development Act of 1982 all federal agencies with an extra-mural R&D budget in excess of $100 million are required to assign up to 1.25% of their budget to this goal. In 1987 the total amount of research by the companies aided under this scheme is estimated at $2 milliard.

2.20. It is too early to judge the success of the various initiatives to promote cooperation within the USA. One of the results of the philosophy underlying the Competitiveness Initiative, which is the subject of major controversy, seems likely to be reduced scientific openness as a result of such measures as the granting of exclusive licences by Federal laboratories to contracting companies, and more selective admittance by third country participants, reflecting concern about the potentially negative effects of "leakage" as a result of the openness of the US research community and society more generally.

International Cooperation in R&D

2.21. Such concern also has also led to a new approach to international collaboration in science and technology. The growing costs of R&D and the severe budgetary pressures within the USA have militated in favour of international collaboration, opening up the prospect of foreign participation in "megaprojects" such as the superconducting supercollider , some elements in space research, an international approach to the sequencing of the human genome and so on. But concern about "leakage" has also led to an emphasis in the US approach to international cooperation on the principle of "symmetrical access" to programmes, facilities, results and, ultimately, markets, as well as on the need for stronger measures to protect intellectual property rights. This new emphasis is reflected in the recent agreement on cooperation in R&D between the USA and Japan.

The Prospect of Growing Skill Shortages

2.22. A further concern in the USA is about the longer-term "output" of scientists and engineers. As noted earlier, there has been no growth in the share of R&D personnel in the labour force for a number of years. This seems likely to continue. With a decreasing number of college-age students in the United States and a declining percentage of high school graduates choosing to study science and engineering one estimate[18] suggests a shortfall of more than 500,000 scientists and engineers by 2010. Meeting this potential shortfall is seen to require action to encourage more women and minorities to train in science and engineering, on the one hand; and further encouragement of foreign students to study and to stay in the United States[19], on the other. At the post-doctoral level, moreover, there will be increasing pressures to "poach" skilled R&D personnel from abroad.

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18 Changing America: The new Face of Science & Engineering, Interim Report of the Task Force on Women, Minorities and the Handicapped in Science and Technology, Washington DC 1988.

19 See, for example Picking up the Pace - the Commercial Challenge to American Innovation, Council on Competitiveness, Washington DC 1988.

(iii) DEVELOPMENTS IN JAPAN

The Organisation of Resources

2.23. In the space of 30 years (1955-1985) the Japanese share in the total R&D expenditure of the six largest industrial countries rose from an estimated 1% to 16%, placing it second only to the United States[20] ; and the number of researchers has become the second largest in the free world. As noted earlier, the bulk of this effort has been in the civil R&D field, although Japanese methods of calculating military R&D expenditure may underestimate the military effort relative to that of European countries. Certainly the Japanese have spent far from negligible amounts on R&D oriented towards naval and airforce purposes.

2.24. The private sector has accounted for by far the largest share of the increase in expenditure, notably in the field of natural sciences. Thus in 1986 the public sector accounted for only 17.6% of total R&D spending on natural sciences and for about 25% of the R&D personnel. The private sector, correspondingly, provided 82.4% of the funding and three-quarters of the staff, with industry accounting for close to 90% of the private sector effort[21] .

2.25. This private sector effort has taken place, however, within the framework of a tradition of long-term and "consensus" planning and linkages between industry, government Ministries and agencies, notably MITI, which has played a crucial role in coordinating actions between industry, universities and other government agencies and in helping to define long-term technology priorities. Strategies covering 10-20 year periods are common both in industry and government, and Japanese companies and government agencies have developed a complex network of "outlooks" on developments in R&D. Industry has also benefitted from a range of measures to encourage the allocation of resources to R&D (tax incentives, subsidies and conditional loans) and from concerted efforts to ensure the dissemination of R&D results (each of the main Japanese Ministries responsible for research appropriations - MONBUSHO, the Ministry of Education, the SCIENCE AND TECHNOLOGY AGENCY and MITI itself - has an agency of its own concerned with dissemination and application of R&D results).

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20 Estimate from the 1987 White Paper on Science and Technology, Science and Technology Agencies, Japan.

21 Estimates made by EC Delegation, Tokyo.

Applied versus basic research

2.26. Historically, the bulk of the Japanese R&D effort has been concentrated on applied research and, even more, on development, supporting an industrial policy based on the absorption and transformation of foreign technology. From the middle of the 1960s particular efforts were made (notably through the Large-Scale Project Programme) to bring together researchers from private industry and those in universities to give Japan a leading edge in applied technologies that were seen as of strategic importance (notably information technology). To a certain extent, as will be argued below, this emphasis has now changed. But technology adoption is still the main objective of Japanese science and technology policy. Still today expenditure on applied research and development dwarfs that on basic research. According to the 1987 Survey of Science and Technology Research in Japan[22] 62.3% of total R&D spending in 1986 was oriented towards development work, 24.4% to applied research and 13.3% to basic research. As might be expected the academic institutions account for the major share of this basic research and industry for the bulk of the development work. But the importance of industrial basic research has been growing: in 1986 commercial organisations funded one-third of total basic research expenditure in the natural sciences. Much of this is application oriented.

Table 2.10.

Breakdown of Research Expenditure in the Natural Sciences by Sector & Type FY 1986 %

Total		Basic Research	Applied Research	Development
Total	100	13.3	24.4	62.3
Commercial Institutes	100	6.1	21.6	72.3
National Research Institutions	100	13.8	27.4	58.8
Academic institutions	100	54.2	37.4	8.4

Source: as footnote 22.

22 The Present State of Science and Technology in Japan-Summary of the Results of the 1987 Science and Technology Research Survey, the Management and Coordination Agency, 1987.

These figures probably understate the trends. There is much more qualitative evidence of a new preoccupation in industry and government with Japan's basic research capacity as a key factor conditioning economic and social progress in the longer-term.

2.27. This preoccupation has been outlined most vividly in the 1987 and 1988 White Papers on Science and Technology from the Japanese Science and Technology Administration. These reports demonstrate the progress already made by Japan in establishing its scientific credentials through the contribution of Japanese scientists to major scientific journals, but underline also the weakness of basic research relative to industrial technology. These shortcomings derive in part from the limited experience of fundamental research on the part of most university-trained engineers and scientists since the brightest are often snapped up by industry before completing research degrees. The 1988 Paper[23] argues explicitly that Japanese research on basic science and technology, though some of it is of high quality, is insufficient compared with research on application and development. This, it is argued, reflects in part a low level of funding by public authorities. It draws attention also to the less than satisfactory level of researchers with masters or doctoral degrees; the fact that there are fewer science graduates than engineers; and there is a lack of large-scale research facilities and data-bases.

International Cooperation

2.28. A growing recognition of the importance for the longer-term of more fundamental research, of the increasing interactions between basic research, technology development and industrial competitiveness, and of the current Japanese shortcomings in this area have led to a new emphasis on international cooperation.

Measures have been taken to facilitate the participation of foreign research workers in Japanese programmes. The launching of The Human Frontier Science Programme, which is intended to be a new international framework for increased cooperation on basic research in the field of biological sciences, is part of the same drive to help remedy perceived shortcomings in scientific capacity and at the same time to respond to criticisms of the closed nature of the Japanese scientific and technological system. One important issue for the future will be to ensure that the cooperation that ensues provides benefits to all the parties concerned.

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23 Trends and Future Tasks in Industrial Technology- Developing Innovative Technologies to support the 21st Century, MITI, September 1988.

(iv) A CHANGING INTERNATIONAL ENVIRONMENT

2.29. Apart from the changing preoccupations of Europe's two main competitors (industrial competitiveness in the USA, basic research in Japan), other factors could also impact significantly on the international environment in which European science and technology develop in the longer-term. Particularly important will be the future direction of the Soviet economy, on the one hand, and the longer-term results of science and technology policies in the newly-industrializing countries (NICs) and China on the other.

2.30. In the **Soviet Union** today military R&D absorbes a dominant share of scientific talent and budgetary resources. At the same time science management has been plagued by the familiar bureaucratic ills associated with the centralised command system of organisation. President Gorbachev's efforts to reform and modernise the Soviet economy, if successful, will inevitably mean some reallocation of scientific resources to civil uses. As a consequence, over time the USSR could become an increasingly important force in terms of science and technology. The USSR has a solid tradition of theoretical mathematics; work is already under way on the Fifth Generation Computer; the Soviets already have considerable expertise in areas such as space, advanced materials and molecular biology. They have already by far the largest number in the world of scientists and engineers engaged in R&D as a proportion of their labour force - on some estimates 65% more than in the USA. Economic and administrative reforms are likely to increase the effectiveness with which these human and financial resources are deployed.

2.31. During recent years, European industry has been confronted with increased competitive pressure from the **newly industrialising countries** in Asia and Latin America. This competition concerns traditional industries (textiles, steel, shipbuilding, automative industries) as well as high tech sectors (consumer electronics, IT and microelectronics, space and aeronautics). This challenge will become even more serious as the more established NICs have to face new competition from other industrialising countries (e.g. Thailand, Indonesia, Malaysia, Philippines) with labour costs advantages on the one hand, and offensive technology development strategies in the industrialised countries on the other hand.

Therefore the most dynamic NICs are now planning a substantial growth in R&D spending and a strategy for the development of highly qualified personnel who will be very much on a par, scientifically, with their counterparts in the USA but at the same time much cheaper (because salaries will be lower).

2.32. This is particularly clear in the case of the **Republic of Korea**. Up to now **Korea's** competitive advantage in, notably, the electronics industry has been established on the basis of the successful import and adaption of existing technologies, combined with cheap labour. Its indigenous scientific and research capacity, on the other hand, is limited. But efforts are now under way to improve the available indigenous resources, notably through an expansion of graduate school education in the scientific fields, joint efforts among existing R&D institutes, universities and industry in relation to selective large-scale R&D projects and some attempts to lay the foundations for a basic research capacity. Public R&D spending is expected to grow from 2% of GNP to more than 3% by 1991; and the number of researchers will grow from 13/14 per 10,000 of the labour force in 1987 to a planned 30 in 2000. This reflects a growing perception that as technology becomes more sophisticated an increasing scientific and technical capacity is required to master, exploit and adapt it. Growing wage costs and currency appreciation have also played a role in underlining the need for improved indigenous scientific capacity.

2.33. Other industrialising countries in Asia and Latin America too have clearly recognised the importance for the longer-term of a solid indigenous scientific base and research capacity.
Since 1984, a strong industrial restructuring effort has been undertaken in **Taiwan**, aiming at giving priority to high tech sectors, notably telecommunications, integrated IT systems and biotechnology. With a US$ 663 million civil R&D budget in 1986, and more than 1% of GNP allocated to R&D, Taiwan is close to Korean standards, including a high proportion (14 per 10,000) of researchers in its population.

With the help of the World Bank, **Brazil** launched its ambitious Programme for Support in the Development of Science and Technology (PADCT) in 1982 which was further extended in 1986. R&D funds, which reach nearly 1% of the GNP, are supporting projects in areas vital to economic development: biotechnology, chemistry and chemical engineering and geosciences.

With 0.6% of GNP devoted to R&D and a considerable scientific and technological potential, **India** is emerging as a nuclear energy, space and informatics international actor.

Other developing countries which have clearly recognised the importance for the longer-term of a solid indigenous scientific base and research capacity include **Israel**, **Hongkong**, **Singapore** and **Argentina**.

2.34. In **China** the improvement of scientific and technological capacity is seen as fundamental to the achievement of ambitious longer-term goals of economic growth and development. Major research programmes have been launched, aimed at catching up in the mastery of technology in seven main fields - biotechnology, aerospace, information technology, lasers, robotics, energy and advanced materials. Other programmes are aimed at increasing the technological inputs to the export industries and the level of scientific and technical education more generally. Already China is attempting to enter the international satellite launching market.

2.35. The longer-term consequences of these trends for the advance of scientific knowledge and for the pattern of world economic growth and trade are clearly impossible to predict. But the increasing importance attached to science and technology in all these countries and the potential for the emergence of significant new science and technology powers are factors which European countries cannot ignore in their own approach to science and technology policies at a national, European and international level.

Europe as a whole is spending less on R&D than its major competitors; and European industry much less.
Moreover, the share of research scientists and engineers in the labour force is significantly higher in the USA and Japan.

Despite its own problems of industrial competitiveness the USA continues to benefit from major advantages in the field of R&D (market size, levels of military R&D expenditure) and renewed efforts are being made to maximise the industrial spin-off from Federally-funded programmes (including, notably, military R&D) as well as to improve interfirm cooperation. There is also an increasing trend towards tighter restrictions on the flow of scientific and technical knowledge out of the USA.

Japan for its part is now extending its expertise into the field of basic research to complement its strong position in applied research and technological development.
This reflects not only a wish for greater integration into the internationnal scientific community, but also the recognition that a capacity in basic research will be essential in order to influence the direction of technological development in the future.

Other industrialising countries are also beginning to develop an indigenous S/T capacity.
Europe faces major challenges from this changing international environment.

III MOBILISING EUROPE'S RESOURCES

(i) AT A NATIONAL LEVEL

3.1. A growing recognition of the challenges facing Europe has already led to some considerable rethinking of national science and technology policies during the 1980s. This has been characterised by redefinitions of public sector expenditure priorities, both as between RTD and other public policies and within RTD budgets themselves; a more important industrial orientation in most countries; a new focus on measures to improve cooperation between industry and universities; a concern about the pattern of higher education and training at one end and about the pace of innovation at the other; and the search for better value for money through improvement in the mechanisms for evaluating choices between funding priorities and the success of programmes. This process of reevaluation is still going on: in the United Kingdom a major review of science policy has been under way; in Italy and Spain there have been important reorganizations of the administrative apparatus for dealing with science policy; Germany has witnessed recent changes in the pattern of Federal spending with a greater priority now to be given to space research.

The Resources Applied to R&D

3.2. The picture varies considerably among Community Member States in the share of national resources devoted to R&D; in the relative importance of the public and private sectors; and in the sectors to which resources are applied.

3.3. In terms of the R&D effort the total volume of spending is dominated by three countries: Germany, the United Kingdom and France which together account for over three-quarters of total public and private spending on research and development in the European Community. Indeed it is characteristic of US and Japanese observers to compare the performance of their own countries with these three countries, and especially with Germany which accounts for around 30% of the total.

3.4. All three countries, together with the Netherlands, have higher than Community average shares of GDP allocated to R&D. Once again the German position stands out from the others, with some 2.8% (1987). Both France and Germany have been most successful in increasing total expenditure, with increases in the R&D intensity of their economies of 18% and 26% respectively between 1975 and 1985.

3.5. At the other end of the spectrum lie Spain, Portugal and Greece, with shares of R&D in GDP of respectively 0.7%, 0.4% and 0.35% . In all of these countries public policy has emphasized the need for increasing expenditure, but this appears so far to have achieved significant results only in Spain, where even in the mid-1980s the intensity of the R&D efforts was below 0.5%.

3.6. The remaining Community countries lie between these two extremes. Here Italy's performance is the most striking, with rapid growth in resources devoted to R&D throughout the 1980s. In real terms total (public and private) expenditure on R&D grew by well over 10% per year, pushing up the share of R&D in GNP to around 1.5% in 1986. There is a policy objective to double this figure by the early 1990s.

Table 3.1.

The Intensity of R&D Spending by Member States:

R&D as a percentage of GDP
(1987 or nearest year)

	1981	**1987**
GERMANY	2.45	2.8
FRANCE	2.0	2.35
UK	2.4	2.3*
NETHERLANDS	2.0	2.3
BELGIUM	n.a	1.5*
DENMARK	1.1	1.3*
ITALY	1.00	1.5+
IRELAND	0.7	0.8
SPAIN	0.4	0.7
PORTUGAL	0.35	0.4**
GREECE	0.2	0.35+

Sources: OECD and national data. Figures for Luxembourg not available.

* 1985
** 1984
\+ 1986

3.7. The significant differences among Member States are also evident in terms of numbers of research personnel. Table 3.2. shows that Germany and France together account for well over half of the entire Community R&D personnel, with Germany alone providing some 35%.

Table 3.2.

R&D Personnel (1985)

	Nos. (1000)	**% of Community total** (EUR=100)	**Nos. per 1000 employed**(1983)
GERMANY	398	35	4.8
FRANCE	270	24	3.9
UK	174*	15	
ITALY	118	10.5	2.7
NETHERLANDS	61.5	5.5	3.7
SPAIN	32	3	1.0
BELGIUM	32**	3	2.6
DENMARK	20	2	2.7
PORTUGAL	9***	1	0.7
GREECE	6**	0.5	0.6
IRELAND	6***	0.5	2.8 (1984)

Source: OECD and national data.

* 1986
** 1983
*** 1984

3.8. In terms of the relative importance of the public and private sectors as sources of funding for R&D and as "performers", the position also varies considerably. In all Community countries the public sector remains a crucially important source of funds. In only Germany and Belgium is public spending on R&D less than business expenditure. The increase in German expenditure on R&D, moreover, has been due more to growing business expenditure than to public expenditure, and the private sector has accounted as a result for a growing share of the total R&D funding. In Germany too a larger share of publicly-funded research than in other Community Member States is carried out by the private sector. In Italy and France, on the other hand, the improvement in R&D intensity has been the result, principally, of increased government expenditure.

Table 3.3.

Financing and Execution of R&D in the Community, 1985

	Financing Shares in %		**Execution** Shares in %		
	Business	Public Sector	Business	Public Sector	Other (univers. etc)
BELGIUM	(66)*	(34)*	(69)*	--(31)*--	
DENMARK	49	46	55	21	24
GERMANY	61	38	72	12	16
GREECE	26	74	n.a	n.a	n.a
SPAIN	49*	50*	(40)**	--(60)**--	
FRANCE	41	53	59	25	16
IRELAND	45	47	51	--49--	
ITALY	45	52	57	--43--	
NETHER LANDS	50	45	55	19	26
PORTUGAL	n.a	62	n.a	n.a	n.a
UNITED KINGDOM	46	43	63	20	17

Source: OECD and National data - Figures for Luxembourg not available.

* 1983

** Estimates for 1987

3.9. Table 3.4. illustrates in summary from the differences between Member States in their levels of R&D intensity (both total and industry-intensity) and also in levels of employment in "technology-based" industries. The outstanding position of Germany contrasts with that of the less-developed members of the Community:

Table 3.4.

Indicators of RTD
EC(12) = 100

	A R&D Intensity (total)	B Business R&D Intensity	C "High Tech" Employment	D Composite Index
GERMANY	134	138	118.5	131
FRANCE	113	111	95	108
UK	120	83	102	106
NETHER LANDS	107	102	95	103
BELGIUM	72	72	90	76
DENMARK	60	80	70	68
ITALY	59	46	80	61
IRELAND	41	49	82	53
SPAIN	23	7.5	n.a	18
PORTUGAL	18	17	n.a	n.a
GREECE	11	5	n.a	n.a

Source: derived from STRIDE report, National Board for Science and Technology, Dublin, November 1987.

R&D Intensity = Total expenditure on R&D/GDP.
Business R&D Intensity = Business expenditure on R&D/Gross Value-Added.
High-Tech employment = employment in chemicals, man-made fibres, office machinery and data-processing machinery, processing of rubber and plastics, nuclear fuels - aggregated and expressed as a ratio to total employment in all industries. The composite index at D is a weighted average of A,B and C.
Data are for 1983 and 1984, except for Portugal (1982).

Regional Differences in RTD Capacity

3.10. Such differences in R&D resources and their use are evn more striking if measured at the regional level. In 1987 the Europen Commission invited a group of external experts to analyse the situation at regional level. Their extensive report[24] (summarised at Annex 13) highlighted regional dispariries in R&D spending and in technology levels that are much greater even than those in terms of GDP per capita. Even as between the Member States themselves (Table 3.4.) there is a difference of 12:1 in levels of R&D intensity and of 28:1 in the intensity of business investment in R&D. At a sub-national level the disparities are much greater. In terms of the intensity of business expenditure on R&D, for example Oberbayern enjoys a score three times the Community average, while in a number of regions in Italy, Spain, Greece and Portugal both business expenditure on R&D and expenditure by the higher education sector are negligible. The consequences for desirable policy approaches are discussed in Chapter V.

It should be added, that the link between R&D intensity and rates of economic growth is not a simple one, as the case of Denmark illustrates. Denmark has a lower than average level of R&D intensity. But Danish policy (cf.5.20 below) has concentrated much effort on the diffusion and adoption of technologies, with R&D resources directed to areas in which Danish industry is strong. Denmark offers an interesting model of "small country" or regional strategy.

Trends in R&D Policies and Public Funding

3.11. In the majority of Community Member States there has been a real growth during the 1980s in the government appropriations for R&D. This has been most striking in the case of some of the less developed countries (notably Greece and Spain) and in France, Italy and Denmark, each of which has increased R&D resources faster than GDP (table 3.5.) Many of these countries have increased public expenditure on R&D more quickly than public expenditure overall.

Overall expenditure in the UK, on the other hand, has held broadly stable in real terms for much of the 1980s, with some redeployment of defence R&D expenditures to the civil sector. In Germany, as noted earlier, government appropriations have grown

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24 Research and Technological Development in the Less Favoured Regions of the Community (STRIDE), and STRIDE-Science and Technology for Regional Innovation and Development in Europe, 1987. Figures are from Tables 5.1. and 5.2. of the latter document.

Table 3.5

General characteristics of budget appropriations for R&D in 1986

	Government R&D appropriations in 1986 at current values and exchange rates (million ECU)		Government R&D appropriations at 1980 prices and exchange rates — Annual average rate of change (%)				Contribution of Member States to the EUR 12 total (%)		Ratio of government R&D appropriations to total budget (%)		Ratio of government R&D appropriations to gross domestic product (%)	
	total	civil	total 81-86	total 86-87(1)	civil 81-86	civil 86-87(1)	81	86	81	86	81	86
Belgium	653	642	1.3	-1.6	1.1	-1.2	2.4	2.6	1.31	1.33	0.63	0.57
Denmark	509	507	6.8	19.4	8.0	19.5	1.0	1.4	1.36	1.55	0.49	0.63
Germany	10049	8832	0.6	2.0	-0.1	1.9	30.3	28.1	4.06	4.20	1.15	1.10
Greece	99	97	4.8	12.2	5.4	12.7	0.3	0.3	0.51	0.67	0.16	0.25
Spain	802	764	6.4	21.3	6.4	17.3	.	2.3	.	1.61	0.28	0.34
France	10273	6935	3.3	-3.0	5.1	-7.3	27.9	29.3	5.62	6.34	1.31	1.44
Ireland	116	116	4.2	1.6	4.2	1.6	0.3	0.3	0.74	0.80	0.39	0.44
Italy	4409	4033	7.5	8.1	7.0	8.8	8.3	10.7	1.60	1.60	0.65	0.85
Netherlands	1705	1658	1.8	1.7	1.8	1.5	5.2	5.0	2.34	2.40	0.93	0.96
Portugal	92	92	.	35.0	.	35.0	.	0.3	.	1.04	.	0.32
United Kingdom	6787	3329	0.0	-0.4	0.5	-3.3	22.4	20.3	3.18	3.04	1.31	1.24
EUR 12	35492	27003	2.2	0.6	2.7	0.3	100.0	100.0	3.33	3.11	1.02	1.04
European Communities	661	661	.	.	.	.	.	.	.	.	.	.

(1) Comparison of provisional budgets.

Source: Government Financing of Research and Development in Community Countries, Statistical Office of the European Communities OS/12/87 only modestly compared with private sector financing.

3.12. As far as the distribution of public funds among different categories of expenditure is concerned there are again wide differences (Table 3.6.).

Even between the three largest spenders (Germany, France and the UK) there are major divergences as a consequence in the first place of **defence** expenditure, which accounts for 51% of total expenditure in the UK, for 34% in France and for 12.5% in Germany.

In the **civil** sector, the most important categories of expenditure are, generally, research financed from general university funds and non-oriented research. The Netherlands and Belgium concentrate much of their R&D support in the universities, and Germany and Denmark also give above-average shares of total public funding for research to higher educational institutions. In the United Kingdom, on the other hand, the percentage of funds going to the universities for research purposes is well below average and that to finance non-oriented research significantly below and declining; while in France the picture is mixed, with university-funding below average but support for non-oriented research high.

Outside these categories Germany and the Netherlands spend higher-than-average shares of public funds on **environmental** research; Italy has focussed in the past a particular resource effort on **energy** (notably nuclear energy) research; Greece, Denmark, Ireland and Portugal on R&D to improve **agricultural productivity**. But generally the most important growth sector during the 1980s has been R&D **on industrial technologies**, where there have been major investments by Germany, France, Italy, Spain, Ireland and Denmark in particular.

3.13. This latter feature of R&D budgets is associated with the greater general **industrial orientation** in public R&D policy than hitherto. This has been characterized by:

- measures to encourage higher levels of spending on research and development by industry itself. Practically all Member States now provide some form of tax relief for industry on R&D investment. Many offer, in addition, financial incentives in the form of grants or loans. As noted above, the Netherlands and Germany, in particular, have witnessed a steady and significant growth in industrial R&D spending;

- the targetting of financial support on specific "high" technologies with major industrial applications.

Breakdown of provisional R&D budgets by objectives in 1986 and 1987 (%)

NABS Objectives	EC/CE 1986	EC/CE 1987	EUR 12 1986	EUR 12 1987	BL 1986	BL 1987	DK 1986	DK 1987	DE 1986	DE 1987	GR 1986	GR 1987	ES 1986	ES 1987	FR 1986	FR 1987
1. Exploration and exploitation of the earth	0,6	0,7	1,6	1,8	2,5	3,1	1,3	1,5	2,1	1,9	5,5	7,1	5,3	7,7	1,5	1,4
2. Infrastructures and general land-use planning	0,8	0,6	2,2	2,2	0,6	0,7	2,4	2,3	1,9	1,9	0,4	0,3	3,4	0,2	3,2	3,2
3. Control of environmental pollution	5,8	5,3	1,6	1,7	2,4	2,2	1,5	1,3	3,3	3,3	3,4	2,1	0,4	2,0	0,5	0,4
4. Protection and improvement of human health	4,1	2,8	3,5	3,6	2,1	3,0	3,3	4,8	3,0	3,2	9,3	7,4	4,0	8,6	3,8	3,6
5. Production, distribution and rational utilization of energy	56,8	51,6	8,7	7,1	10,1	9,5	6,7	4,4	10,5	8,7	2,6	3,6	12,3	3,1	7,1	6,7
6. Agricultural productivity and technology	1,9	1,5	3,6	3,6	7,2	7,6	7,0	8,5	2,0	2,0	24,9	26,0	4,9	6,7	3,6	3,6
7. Industrial productivity and technology	26,7	33,2	12,8	13,7	16,2	12,8	20,6	16,2	14,3	15,3	8,7	11,2	17,1	21,5	12,1	10,6
8. Social structures and relationships	0,8	1,1	2,2	2,1	0,7	0,5	4,3	3,6	2,3	2,3	6,4	7,3	0,9	0,9	2,9	2,7
9. Exploration and exploitation of space	1,1	1,5	4,6	5,4	7,3	9,8	3,1	2,6	4,5	4,9	0,6	0,4	4,8	8,8	5,8	5,9
10. Research financed from general university funds	-	-	22,1	23,0	22,8	22,3	29,5	32,1	31,8	31,5	26,9	25,3	18,3	19,8	11,8	12,0
11. Non-oriented research	1,4	1,8	11,3	10,7	20,5	23,6	19,7	22,3	11,8	12,3	6,1	6,7	20,6	8,5	15,1	14,7
12. Other research	-	-	0,8	1,1	6,3	3,8	-	-	0,1	0,1	2,2	0,2	2,2	3,4	1,2	1,0
Total financing of civil R&D	100,0	100,0	75,1	76,1	98,5	98,9	99,5	99,6	87,6	87,5	97,1	97,7	94,2	91,1	69,0	65,9
13. Defence	-	-	24,9	23,9	1,5	1,1	0,5	0,4	12,4	12,5	2,9	2,3	5,8	8,9	31,0	34,1
Total financing	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0

Table 3.6. continued

Breakdown of provisional R&D budgets by objectives in 1986 and 1987 (%)

NABS objectives	IR 1986	IR 1987	IT 1986	IT 1987	NL 1986	NL 1987	PO 1986	PO 1987	UK 1986	UK 1987
1. Exploration and exploitation of the earth	0,7	0,6	1,1	1,4	0,6	0,6	10,2	9,0	1,7	1,7
2. Infrastructures and general land-use planning	3,9	4,2	0,9	0,8	4,2	4,6	8,9	10,5	1,4	1,6
3. Control of environmental pollution	0,8	1,0	1,0	0,9	3,0	3,1	3,0	3,4	0,7	1,5
4. Protection and improvement of human health	4,9	3,9	4,4	4,5	2,2	2,5	0,2	0,2	3,7	3,3
5. Production, distribution and rational utilization of energy	1,2	1,1	17,4	11,1	4,6	4,0	5,0	4,7	4,6	3,6
6. Agricultural productivity and technology	27,3	24,2	3,7	3,5	4,4	4,3	14,4	14,2	4,6	4,3
7. Industrial productivity and technology	26,1	27,2	19,1	19,1	14,8	17,6	7,3	6,2	6,7	9,9
8. Social structures and relationships	8,0	10,0	1,1	1,2	3,5	2,4	0,2	1,3	1,3	1,2
9. Exploration and exploitation of space	1,1	2,3	6,9	9,3	2,9	2,8	-	-	1,8	2,6
10. Research financed from general university funds	23,9	23,0	28,6	31,9	43,1	40,7	35,5	30,5	14,9	15,3
11. Non-oriented research	2,2	2,4	7,0	6,6	9,8	10,3	1,8	0,5	6,8	3,3
12. Other research	-	-	0,2	1,9	4,3	4,4	13,5	19,5	0,3	0,3
Total financing of civil R&D	100,0	100,0	91,6	92,2	97,4	97,2	100,0	100,0	48,4	48,8
13. Defence	-	-	8,4	7,8	2,6	2,8	-	-	51,6	51,2
Total financing	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0

Source: Government Financing of Research and Development in Community Countries, Statistical Office of the European Communities OS/12/87.

Information technology has been the focus of particular attention in most countries (early examples of national policy initiatives in the 1980s included the Plan d'Action de Filière Electronique in France, the Information Stimulation Plan in the Netherlands, the Alvey Programme in the UK. These are now being phased out , to a large extent superseded by transnational actions (see 3.49 below);

- measures to promote better technology transfer - the dissemination of research findings to industry. Generally this has been concentrated on the results of civilian research efforts. But in the UK earlier this year a scheme was launched (the Civilian Industrial Access Scheme) to increase the spin-off to industry from defence R&D by encouraging industry to make greater use of the technical expertise and facilities of defence research establishments;

- a new emphasis on cooperation between government research bodies, higher education institutions and industry. In the United Kingdom, for example, the LINK initiative was launched in December 1986 to encourage collaborative programmes between the three parties in pre-competitive but industrially-relevant research.

3.14. A sharper focus on industry-oriented R&D has meant also a greater emphasis in public support on more "down-stream" R&D, with more immediate commercial application. The picture varies a good deal across the Member States, but in many the balance **between support for basic research and applied research has shifted in favour of the latter.** Public expenditure constraints, the rising cost of much basic research, and increasing emphasis on measurable cost-effectiveness have all contributed to this trend in a process that has been dubbed "the shift from science to technology policy"[25]. In some countries (France, Germany, Netherlands), non-oriented research continues to be given a high level of priority, alongside support for pre-competitive industry-oriented R&D. In the United Kingdom, on the other hand, the public funding of basic research has been downgraded relative to the financing of pre-competitive applied R&D, this reflecting a particular UK concern about the perceived difficulty of translating British invention into innovation.

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25 See STRIDE report.

Duplication and Overlap

3.15. Outlines of the situation in each of the Member States are given in the short synopses that follow. More detail is to be found in Annex 12, which reflects the ongoing work within CREST to compare national policies and identify potential areas for cooperation. This process, which is discussed further below under **Policy Coordination**, is not yet complete. It is already clear, however, that there are areas where duplication of effort and overlap do exist. One aim of subsequent reports on the state of science and technology will be to highlight these areas.

Dual Use Technologies

3.16. One difficult question in this context is the difference among Member States in the organisation of R&D on so-called "dual-use" technologies. The common features in the technological requirements of the defence and civil sectors affect several key areas: sensor and signal/image processing, complex system design and information processing, man-machine interfaces, vehicle technology, advanced design and manufacturing technology, electronics/ microelectronics/ optoelectronics/ bioelectronics, communications, advanced materials, medical technology, electrical and mechanical engineering, and energy conversion.

The development of these dual-use technologies is funded in Europe through defence and/or civil R&D programmes, depending on the country and the degree of resources devoted to military R&D.

The need to improve coherence between civil and defense programmes, where they overlap, in order to optimise the use of resources (manpower and financial) has been recognised at national level (cf. 3.13 above) and mechanisms are implemented in the principal countries to avoid unnecessary duplication and promote technology transfer from civil to defense and vice versa. These efforts to promote the optimal use of resources at national level are reasonably successful in some areas but more remains to be done in other areas where duplications or barriers to technology transfer remain significant.

3.17. However, the most significant duplication arises not in national programmes but between European countries. To the extent that civil applications are taking the lead in driving the development of several dual-use technologies, civil programmes to promote European technological cooperation, in particular Community programmes and EUREKA contribute to a more efficient use of resources (see below) Their impact is however, inevitably limited, given their size and scope.
In those technological fields which are more driven by defence applications, much remains to be done to establish effective cooperation between countries.

Another trend which is important in discussing the harmonisation of defence and civil research efforts to establish a broad competitive technology base is the escalation of the cost of developing and producing military equipment. This has led defence departments in Europe to reduce their support for some dual-use technologies and to concentrate their resources on military-specific developments (a trend observed in the USA - cf. Chapter II).

While this trend reduces the risk of duplications between civil and defence programmes, it also implies that an additional effort by industry or through civil programmes is needed to maintain a broad competitive technology base in Europe.

BELGIUM

GROSS DOMESTIC PRODUCT (GDP) : 104.5 Billion ECU (at current prices and exchange rates) (1985)

GROSS domestic EXPENDITURE for R&D (GERD) : 1,542.6 Mio ECU (est.) (1985)

GERD/GDP : 1.48 % (est.) (1985)

NATIONAL BUDGET : 49,112 Mio ECU (1986)

R&D BUDGET : 652.6 Mio ECU (1986)

R&D BUDGET/NATIONAL BUDGET : 1.33 % (1986)

NUMBER of RESEARCHERS PER 1000 LABOUR FORCE : N.A.

PERCENTAGE OF GERD financed by industry : N.A.

DEFENCE R & D AS A % OF TOTAL GOVERNEMENT APPROPRIATIONS : 1.6 % (1986)

RESPONSIBLE MINISTRY FOR S&T : Deputy Prime Minister, Responsible for the Budget and the Science Policy.

STRUCTURE of S&T POLICY : The coordination of the whole structure is the responsibility of the Science Policy Office ("Services de Programmation de la Politique Scientifique") belonging to the Prime Minister's Services. However, a significant portion of the "Science policy budget" is the direct responsibility of the different ministries.

NATIONAL PRIORITIES :

1. More concentration of funds on selected research topics :
   - informatics (Artificial intelligence, software and microelectronics);
   - biotechnology and biosciences;
   - aerospace;
   - new materials;
   - telecommunications;
   - oceanography.
2. Increased support for fundamental research and more cooperation between university and industry;
3. More incentives to industry in order to increase its share (already one of the highest in Europe : about 62 % in 1985) in the overall funding of R & D;
4. Maximum encouragement of participation in Community and international programmes.

TRENDS : The responsible government officials state that the ratio GERD/GDP should rise from about 1.5 % to the same level as Netherlands (about 2.3 %) but after a budget increase in 1985 the overall funding shows only marginal increases.

COMMENTS : The new federal structures of the Belgian State, may lead to a different share of the coordination of research among linguistic communities, regions and national authorities. However, at international level the national authority should be totally responsible for coordination.

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DENMARK

GROSS DOMESTIC PRODUCT (GDP) : 76.4 Billion ECU (at current prices and exchange rates) (1985)

GROSS domestic EXPENDITURE for R&D (GERD) : 959.3 Mio ECU (1985)

GERD/GDP : 1.26 % (1985)

NATIONAL BUDGET : 32,738 Mio ECU (1986)

R&D BUDGET : 508.7 Mio ECU (1986)

R&D BUDGET/NATIONAL BUDGET : 1.55 % (1986)

PERCENTAGE OF GERD financed by industry : 48.9 % (1985)

DEFENCE R & D AS A % OF TOTAL GOVERNMENT APPROPRIATIONS : 0.4 % (1986)

NUMBER of RESEARCHERS PER 1000 LABOUR FORCE : 3.1 (1985)

RESPONSIBLE MINISTRY FOR S&T : The Ministry of Education and Research and the Ministry of Industry.

STRUCTURE of S&T POLICY : Each Ministry has responsibility for supporting research related to its function. The Government's internal co-ordination of S&T policy is guided by its National Research Committee under the chairmanship of the Minister of Education and Research and by its Industrial Policy Committee chaired by the Ministry of Industry. Both ministries have advisory councils (the council for Research Policy and Planning and the Council of Technology). The largest shares of the national R & D are funded by the Ministry of Education and Research (more than 50 %), the Ministry of Industry (about 25 %).

NATIONAL PRIORITIES : S & T is a top priority policy area in the mid-1980's in Denmark. Three topics have been declared :
- Information Technology;
- Material research;
- Basic Biotechnical R & D.

Most Danish companies are SMEs and special Government effort is necessary to aid the dissemination of information on new technology and its adoption.

TRENDS : Denmark ranks amongst the EC Member States which spend between 1 % and 2 % of the GDP for R & D. Since 1980 an increase of about 8 % per year has been registered. The Government's plans provide for a GERD of about 2.3 % of GDP for the year 2000.

COMMENTS : Danish research and technology rely on wide international cooperation. About 5 % of the national R & D resources are attributed to participation in international cooperation, including the EC R & D programmes. Participation in Nordic research cooperation is of importance to Denmark.

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FEDERAL REPUBLIC OF GERMANY

GROSS DOMESTIC PRODUCT (GDP) : 826.4 Billion ECU (at current prices and exchange rates) (1985)

GROSS domestic EXPENDITURE for R&D (GERD) : 22,009.4 Mio ECU (1985)

GERD/GDP : 2.66 % (1985)

NATIONAL BUDGET : 238,935 Mio ECU (1986)

R&D BUDGET : 10,049 Mio ECU (1986)

R&D BUDGET/NATIONAL BUDGET : 4.20 % (1986)

PERCENTAGE OF GERD financed by industry : 60.9 % (1985)

DEFENCE R & D AS A % OF TOTAL GOVERNMENT APPROPRIATIONS : 12.4 % (1986)

NUMBER of RESEARCHERS PER 1000 LABOUR FORCE : 4.8 (1983)

RESPONSIBLE MINISTRY FOR S&T :
The Federal Ministry for Research and Technology (BMFT) and the Ministries of the Länder Governments.

STRUCTURE of S&T POLICY :
The Federal and the Länder Governments attach importance to the freedom of research and the principles of "subsidiary funding". The Länder have mainly the responsibility for R & D in the universities (about 13 % of 1987 total R & D); the Federal Government is responsible for non-university R & D (about 24 % of 1987 total). The funding of the supporting bodies (DFG, MPG, FhG) and the national research centres is shared between the Federal and the Länder Governments. The Government believes that in a free-market economy the primary responsibility for R&D is that of industry (61 % of the 1987 total R & D). Further strengthening of performance and private initiative will be assisted by tax incentives which will be provided within the 1990 tax reform.

NATIONAL PRIORITIES :
- Increased promotion of basic research, strengthening of research with long term prospects, and expansion of preventive research (ecology, health, climate);
- Promotion of industrial research in the area of market oriented technologies;
- Improvement of the basic conditions for innovation in SMEs.

More specifically : the completion of the Airbus family; information technology; materials research; biotechnology; selected physical technologies (laser, thin-film); regenerative energy technologies.

TRENDS :
National R & D expenditure increased between 1973 and 1987 from 2.1 % to 2.7 % of GDP. The business sector's contribution to global R & D expenditure increased from 56 % in 1981 to 61 % in 1987 and is far the highest among the EC Member States.

COMMENTS :
International cooperation has a high priority in the S&T policy of the FR Germany. About 8.2 % of the Federal Government R&D expenditure was committed to international organisations in 1987.

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GREECE

GROSS DOMESTIC PRODUCT (GDP) : 42.8 Billion ECU (at current prices and exchange rates) (1985)

GROSS domestic EXPENDITURE for R&D (GERD) : 148.9 Mio ECU (1985)

GERD/GDP : 0.35 % (1985)

NATIONAL BUDGET : 14,763 Mio ECU (1986)

R&D BUDGET : 99.5 Mio ECU (1986)

R&D BUDGET/NATIONAL BUDGET : 0.67 % (1986)

PERCENTAGE OF GERD financed by industry : 26.3 % (1985)

DEFENCE R & D AS A % OF TOTAL GOVERNMENT APPROPRIATIONS : 2.7 % (1986)

NUMBER of RESEARCHERS PER 1000 LABOUR FORCE : 0.8 (1983)

RESPONSIBLE MINISTRY FOR S&T :
General Secretariat of Research and Technology, an autonomous body within the Ministry of Industry, Energy and Technology.

STRUCTURE of S&T POLICY :
Each ministry is responsible for its own research. The Ministry of Industry, Energy and Technology finances 43 % of the total R & D Public Expenditure and, the Ministry of Education 29.2 %. The G.S.R.T. coordinates the R & D efforts between the various ministries, Research Institutes, sectoral companies, Universities and International Organizations.

NATIONAL PRIORITIES :
- improvement of the role of the country in the international division of labour;
- establishment of institutional infrastructure for scientific and technological development;
- production of scientific and technological results of quality;
- exploitation of research results and assimilation of technology transfer ;
- activation of applied and technological research for assimilation of imported technology;
- making public opinion more aware importance of research for economic and social development.

In the new 1988-1992 National Plan, high priority is given to social and human sciences, information technology, biotechnology, and development of industrial research.

TRENDS :
GERD as a percentage of GDP has increased steadily from 0.21 in 1981 to 0.35 in 1985. The aim is to reach 0.65 in 1992.

COMMENTS :
Greek participation in the EEC programmes has increased substantially over the last years.

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FRANCE

GROSS DOMESTIC PRODUCT (GDP) : 674.0 Billion ECU (at current prices and exchange rates) (1985)

GROSS domestic EXPENDITURE for R&D (GERD) : 15,587.4 Mio ECU (1985)

GERD/GDP : 2.31 % (1985)

NATIONAL BUDGET : 162,565 Mio ECU (1986)

R&D BUDGET : 10,273.1 Mio ECU (1986)

R&D BUDGET/NATIONAL BUDGET : 6.34 % (1986)

PERCENTAGE OF GERD financed by industry : 41.4 % (1985)

DEFENCE R&D AS A % OF TOTAL GOVERNMENT APPROPRIATIONS : 32.5 % (1986)

NUMBER of RESEARCHERS PER 1000 LABOUR FORCE : 4.1 (1984)

RESPONSIBLE MINISTRY FOR S&T : Under the new Government, there is a Ministry of Research and Technology (ministère délégué) who is responsible for S&T policy in France. Space policy is under the Ministry of Post, Telecommunications and Space.

STRUCTURE of S&T POLICY : In parallel or in cooperation with the Ministry of Research and Technology, other ministerial departments have also an important role in directing scientific and technical activities : the Ministry of National Education, of Industry, of Defence, of Economy and of PTT. Despite some considerable efforts to regionalise research, the French S&T system is centralized.

NATIONAL PRIORITIES : The first priority is the further promotion and development of industrial research. Priority will also be given to the employment of young researchers in order to solve the problem in the age structure of the French scientific body, and to training through research. The priorities in fields of research are :

- Technological Development programmes : nuclear energy, space, aeronautics, telecommunications, electronuclear equipments.
- National Programmes : Biotechnology, food industry, medical research, human and social sciences, production technology, electronics, natural resources, new materials, new chemistry, research for development, research on general planning of land-use and transport.

TRENDS : During recent years, there has been an increase in R&D financing as percentage of GDP from 2.01 % in 1981 to 2.31 % in 1985. Research has been designated as a national priority for France.

COMMENTS : In order to encourage the private enterprises to start their own research, the government has given several incentives (direct and indirect aids) for the creation of research infrastructure within enterprises and hiring of researchers by industry.

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SPAIN

GROSS DOMESTIC PRODUCT (GDP) : 216.2 Billion ECU (at current prices and exchange rates) (1985)

GROSS domestic EXPENDITURE for R&D (GERD) : 1,144.4 Mio ECU (1985)

GERD/GDP : 0.53 % (1985)

NATIONAL BUDGET : 49.848 Mio ECU (1986)

R&D BUDGET : 801.7 Mio ECU (1986)

R&D BUDGET/NATIONAL BUDGET : 1.46 % (1986)

PERCENTAGE OF GERD financed by industry : 49.1 % (1983)

DEFENCE R&D AS A % OF TOTAL GOVERNMENT APPROPRIATIONS : 4.8 % (1986)

NUMBER of RESEARCHERS PER 1000 LABOUR FORCE : 1.0 (1983)

RESPONSIBLE MINISTRY FOR S&T : The interministerial Committee for Science and Technology composed of representatives from 9 ministries involved in research, is the official organism for the planning, coordination and follow up of national S&T policy.

STRUCTURE of S&T POLICY : The National Plan defines the framework for the S&T activities of the nine ministries involved in research, whose work is coordinated by the interministerial committee. The Spanish Autonomies are quite independent in deciding and implementing their own S&T policy. Efforts have been made to coordinate those efforts at national level.

NATIONAL PRIORITIES : Priority sectors are :
- Information and production technologies.
- National resources and agro-industrial technology.
- Quality of life.

The priorities set by the national Plan are, among others, the following :
- improvement of knowledge and progress in innovation and technological development;
- conservation, upgrading and optimal exploitation of natural resources;
- development and strengthening of the competitive capacity of industry, trade, agriculture and fisheries;
- strengthening of national defence;
- adaptation of Spanish society to the changes brought about by scientific development and the new objectives;
- improvement in quality of education;
- encouragement of creativity, the development and dissemination of culture in all forms;
- improvement of health, social security and the quality of life.

TRENDS : In Spain GERD as a percentage of GDP has increased from 0.4 in 1981 to 0.53 in 1985. The Spanish Government is determined to increase even further the national R & D efforts to levels comparable with the other advanced European countries.

COMMENTS : In 1987, GERD is estimated to be 0.75 % of GDP.

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IRELAND

GROSS DOMESTIC PRODUCT (GDP) : 24.1 Billion ECU (at current prices and exchange rates) (1985)

GROSS domestic EXPENDITURE for R&D (GERD) : 192.4 Mio ECU (1985)

GERD/GDP : 0.80 % (1985)

NATIONAL BUDGET : 14,411 Mio ECU (1986)

R&D BUDGET : 115.7 Mio ECU (1986)

R&D BUDGET/NATIONAL BUDGET : 0.80 % (1986)

PERCENTAGE OF GERD financed by industry : 45.4 % (1985)

DEFENCE R & D AS A % OF TOTAL GOVERNMENT APPROPRIATIONS : 0.0 % (1986)

NUMBER of RESEARCHERS PER 1000 LABOUR FORCE : 2.8 (1984)

RESPONSIBLE MINISTRY FOR S&T :
Ministry for Science and Technology operating within Department of Industry and Commerce.

STRUCTURE of S&T POLICY :
In 1987 Irish S&T was considerably reorganised. Minister of State for Science and Technology was appointed and a general programme of rationalisation of S&T agencies undertaken. NBST and IIRS were merged to form EOLAS

NATIONAL PRIORITIES :
Strategic Research Programme emphasises application - oriented research and has identified Biotechnology, Engineering, Advanced Materials and Information Technology as priorities.
Policy aims to concentrate national S&T effort on indigenous firms. The South East Region - one of weaker R&D regions - has been declared a pilot region for S&T related economic development.

TRENDS :
S&T has had small budget increase in 1987 despite widespread cuts in most other spending departments. Government expenditure on S&T increased in real terms by 1.4 % per annum average from 1981-1987. All Irish S&T expenditure is civilian R&D.
S&T expenditure has declined in Agriculture and Energy and increased in S&T for Manufacturing Sector.

COMMENTS :
Major S&T interests are strengthening indigenous industry S&T participation and S/T infrastructure with the help of EC structural instruments.

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ITALY

GROSS DOMESTIC PRODUCT (GDP) : 473.0 Billion ECU (at current prices and exchange rates) (1985)

GROSS domestic EXPENDITURE for R&D (GERD) : 6,307.3 Mio ECU (1985)

GERD/GDP : 1.33 % (1985)

NATIONAL BUDGET : 275,537 Mio ECU (1986)

R&D BUDGET : 4,408.5 Mio ECU (1986)

R&D BUDGET/NATIONAL BUDGET : 1.60 % (1986)

PERCENTAGE OF GERD financed by industry : 44.6 % (1985)

DEFENCE R & D AS A % OF TOTAL GOVERNMENT APPROPRIATIONS : 8.5 % (1986)

NUMBER of RESEARCHERS PER 1000 LABOUR FORCE : 2.7 (1986)

RESPONSIBLE MINISTRY FOR S&T : Ministry for S&T Research

STRUCTURE of S&T POLICY : The Ministry for S&T Research will become "Ministry for the University and S&T Research", responsible for all Government funded research.

NATIONAL PRIORITIES :

1) Increase in overall funding of Government and private enterprises since 1980.
2) Emphasis and increased funds for research on new technologies such as :
   - biotechnologies and fine chemicals;
   - information technologies;
   - new materials;
   - nuclear fusion;
   - telecommunications;
   - optics and lasers;
   - advanced transport;
   - satellites and space crafts;
   - biomedical instruments.
3) Decrease in funds for nuclear R & D for the production of electricity.

TRENDS :

- The new Ministry for University and S&T research should lead to streamlining the whole Government R & D structure and simplify the administration of Government research establishments.
- Incentives (mainly fiscal) for private funded R & D.
- The ratio GERD/GDP was 0.74 % in 1980; by 1987 it was about 1.40 %.
- Increased European and international cooperation.

COMMENTS : Italian authorities wish to bring the ratio of GERD/GDP to same level of Italy's largest European partners (France and UK) in a 4 or 5 years.

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LUXEMBOURG

GROSS DOMESTIC PRODUCT (GDP) : 4.7 Billion ECU (at current prices and exchange rates) (1985)

GROSS domestic EXPENDITURE for R&D (GERD) : N.A.

GERD/GDP : N.A.

NATIONAL BUDGET : 2,005 Mio ECU (1987)

R&D BUDGET : N.A.

R&D BUDGET/NATIONAL BUDGET : N.A.

PERCENTAGE OF GERD financed by industry : N.A.

DEFENCE R & D AS A % OF TOTAL GOVERNMENT APPROPRIATIONS : N.A.

NUMBER of RESEARCHERS PER 1000 LABOUR FORCE : N.A.

RESPONSIBLE MINISTRY FOR S&T :

Ministry for national education and youth.

STRUCTURE of S&T POLICY :

Interministerial Committee for coordination of Research and Technological Development.

NATIONAL PRIORITIES :

- Setting up Government structures and public research centres to carry out R & D activities with Government funds.
- Transfer of results of research, gathered in public research establishments, to industrial innovation.

TRENDS :

A new law (March 1987) will initiate the establishment of a certain number, (up to 6 or 7) of Public Research Centres; two centres are already operational in 1988.

COMMENTS :

Luxembourg does not collect at present data on R & D expenditure but will do so probably in 1989. R & D activities have been carried out until recently exclusively in private industrial concerns, this should change with the establishment of the government-funded public research centres mentioned above.

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PORTUGAL

GROSS DOMESTIC PRODUCT (GDP) : 27.3 Billion ECU (at current prices and exchange rates) (1985)

GROSS domestic EXPENDITURE for R&D (GERD) : 111.7 Mio ECU (1985)

GERD/GDP : 0.41 % (1985)

NATIONAL BUDGET : 8,801 Mio ECU (1986)

R&D BUDGET : 91.5 Mio ECU (1986)

R&D BUDGET/NATIONAL BUDGET : 1.04 % (1986)

PERCENTAGE OF GERD financed by industry : 30.8 % (1984)

DEFENCE R & D AS A % OF TOTAL GOVERNMENT APPROPRIATIONS : N.A.

NUMBER of RESEARCHERS PER 1000 LABOUR FORCE : 0.8 (1984)

RESPONSIBLE MINISTRY FOR S&T :
Ministry for Planning and Territorial Administration. JNICT is the major planning, policy and overall coordination body with responsibility for preparation of R & D Budget.

STRUCTURE of S&T POLICY :

Since 1986 and the establishment of the Superior Council for Science and Technology there has been major changes and much new investment in S&T.

NATIONAL PRIORITIES :

Priorities of the Government programme (April 1987) for R & D are applied research related to users, strengthening basic research in universities, promoting mobility in science, and developing joint mobilization programmes between research and industry, as well as strengthening public sector S&T infrastructural capability. Major Sectoral Research Action programmes are biotechnology, robotics/microelectronics, material sciences and, marine sciences.

TRENDS :

R&D expenditure in 1986/87 doubled 1985's allocation with plans to steadily increase it to reach 1 % of GDP by 1990. JNICT's budget was multiplied by 4.5. in the last four years.

COMMENTS :

Low level of International R&D Participation but set to increase steadily with EEC membership and priority given by Government. A major priority is to strengthen S&T infrastructure as well as education and learning of S/T researchers.

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THE NETHERLANDS

GROSS DOMESTIC PRODUCT (GDP) : 165.3 Billion ECU (at current prices and exchange rates) (1985)

GROSS domestic EXPENDITURE FOR R&D (GERD) : 3,492.6 Mio ECU (1985)

GERD/GDP : 2.11 % in 1985

NATIONAL BUDGET : 70,599 Mio ECU (1986)

R&D BUDGET : 1,704.9 Mio ECU (1986)

R&D BUDGET/NATIONAL BUDGET : 2.40 % (1986)

PERCENTAGE OF GERD financed by industry : 50.2 % (1985)

DEFENCE R & D AS A % OF TOTAL GOVERNMENT APPROPRIATIONS : 2.8 % (1986)

NUMBER of RESEARCHERS/PER 1000 LABOUR FORCE : 3.7 (1983)

RESPONSIBLE MINISTRY FOR S&T : The Ministry of Education and Science and the Ministry of Economic Affairs.

STRUCTURE of S&T POLICY : Decision making is based on a broadly structured network of advisory bodies. S & T Policy is prepared by the Council for Science and Technology Policy (RWT), chaired by the Prime Minister within which the Minister of Education and Science acts as coordinating minister for science policy and the Minister of Economic Affairs as coordinating minister for technology. The policy is market-oriented, aiming to improve competitive strength of the Dutch industry via the broadening of the technology base of the industry, improving the quality, the use, and the diffusion of technology.

NATIONAL PRIORITIES : The dissemination of knowledge via innovation centres and major incentive schemes :

- The Innovation Stimulation Scheme (INSTIR) provides grants for R & D labour costs whether in-house or contracted R & D.
- The Technological Development Credit Scheme (TDC) offers support for R&D on new products, processes, and services on condition that they are technologically new and risky.
- The SME Business Research Programme (OMK) stimulates SMEs to carry out advanced R & D projects.

The Innovation-Oriented Programmes (IOPs) include among others : Biotechnology, Membrane Technology, Technical Ceramics, and IC Technology.

TRENDS : National R & D expenditure increased between 1980 and 1988 from 2.03 % to 2.40 % of GDP. The business sector increased its contribution to global R & D expenditure from 50.2 % in 1985 to 55.3 % in 1988.

COMMENTS : The "Internationalisation of Education and Research" is a major issue in the Dutch S&T policy.

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UNITED KINGDOM

GROSS DOMESTIC PRODUCT (GDP) : 595.0 Billion ECU (at current prices and exchange rates) (1985)

GROSS domestic EXPENDITURE for R&D (GERD) : 13,837.6 Mio ECU (1985)

GERD/GDP : 2.33 % (1985)

NATIONAL BUDGET : 223,312 Mio ECU

R&D BUDGET : 6,786.8 Mio ECU (1986)

R&D BUDGET/NATIONAL BUDGET : 3.04 % (1986)

PERCENTAGE OF GERD financed by industry : 46.1 % (1985)

DEFENCE R & D AS A % OF TOTAL GOVERNMENT APPROPRIATIONS : 50.9 % (1986)

NUMBER of RESEARCHERS PER 1000 LABOUR FORCE : N.A.

RESPONSIBLE MINISTRY FOR S&T : Cabinet Office has overall responsibility reporting to Prime Minister but ministerial departments have responsibility for own R & D.

STRUCTURE of S&T POLICY : S&T structure has been strengthened into central structure under Prime Minister, with the Advisory Council on Science and Technology (ACOST) as expanded advisory body. The S&T Assessments office assists Departments, Research Councils and University in R & D expenditure proposals.

NATIONAL PRIORITIES : Three main priorities have to be considered at the national level :
1. maintain and enhance quality in S&T;
2. increase social and economic return from S&T;
3. improve management, ensure greater concentration and selectivity of S&T activities.

As regards sectoral research, action programmes are developed by individual ministries.
Government is conducting "searching review" of R & D priorities across Government with emphasis on contribution of Government funded R & D to efficiency, competitiveness and innovative capacity.

Criteria revised in 1987 for distribution of Science Budget.
1. Internal Funds - Timeliness and Pervasiveness.
2. External - Exploitability. Applicability and Significance for Education.
3. Financial - Benefits and Costs/Affordability.

TRENDS : Overall level funding for 1987-89 committed with cuts in defence research and small increases for Research Council and University Grants Committee. UK Government is determined to secure greater Industry funding of R & D, and also to ensure that Industry takes more responsibility for R & D. Emphasis has shifted from project support to collaborative research.

COMMENTS : Main concern is to ensure value for money in all research and development, international as well as national, to which UK Government contributes.

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(ii) EUROPEAN COOPERATION

3.18. Examples of collaborative research ventures in Europe can be traced back over many years. CERN (the European Organisation for Nuclear Research) was established in 1953; ESRO (the European Space Research Organisation) and ELDO (the European Launcher Development Organisation), which were later merged to the European Space Agency (ESA) were set up in 1962, the same year as the signature of the Anglo-French Concorde project; 1970 saw the establishment of Airbus Industrie.

3.19. At the level of the European Community the first collaboration in coal and steel research began in 1955, this to be followed by cooperation on nuclear research under the Euratom Treaty in 1958. In the aftermath of the doubling of oil and energy prices in 1973/74 the Community's research efforts were extended in 1974 into the non-nuclear energy fields, the environment and raw materials. In 1971 the first cooperation within the COST framework was begun, involving the Community and other European countries; COST remains an important framework for cooperation on specific projects.

3.20. But the 1980s have witnessed a qualitative and quantitative development in Community activity, characterised by the introduction of more industry-oriented "second-generation" R&D programmes, medium-term resource planning for Community research, and Community level actions both upstream of research (in the field of education and training) and downstream support for innovation.

Underpinning this cooperation now is the political commitment of the Community, enshrined in the Single European Act:

to strengthen the scientific and technological basis of European industry and to encourage it to become competitive at the international level;

to encourage and support cooperative efforts between industry and research centres and universities;

and to adopt a Framework Programme as a medium-term planning tool.

By laying down the objectives , priorities and expected financial requirements for the Community's activities in the fields of RTD and breaking it into lines of action, the Framework Programme forms a guide for specific programme decisions. Another of its aims is to familiarise scientific institutions and companies with the research opportunities offered by the Community in the medium term.

3.21. The main elements in the programme for 1987-1991 are given in the following table, which illustrates the emphasis given to information technologies, telecommunications, the modernisation of Community industry, biotechnology, marine Science & Technology, alongside the long-standing collaboration in nuclear fusion and fission and the environment.

3.22. The largest single programme is now ESPRIT, which was launched in 1984 with the aims of providing the European information technology industry over the subsequent 10 years with the basic technologies required to meet the competition of the 1990s; encouraging industrial and university cooperation in information technology, and contributing to the development of internationally accepted standards. For its first five years the ESPRIT programme had a total budget of 1500 MECU, half of it funded by the Community, and half by the research partners themselves. In its second phase ESPRIT has a budget of 3.200 MECU, again shared equally between the Community and the research partners. The first phase of the programme concentrated on pre-competitive research in micro-electronics, information processing systems, and application technologies such as computer aided manufacturing systems. The new phase includes, alongside the application-orientation, some emphasis on more basic research targetted on issues such as artificial intelligence.

3.23. The second largest group of industry-oriented activities aims at the modernisation of European industry through the use of advanced technology and the development of new materials. Here the BRITE programme is the largest single element. BRITE was launched in 1985 as a four-year programme funded jointly by the Community (185 MECU) and research partners in universities or industry. Building on its experience with the BRITE programme and the related EURAM programme on advanced materials (under which together some 300 projects are being financed) the Commission has recently submitted proposals for a new combined programme for 1989-92, which is designed to attract SMEs in particular and which, it is estimated, could generate projects costing 1.000 million ECU. Most of the Community funding of 440 MECU will be on applied research, but up to 7% of the budget will be made available for more fundamental work in areas where industrial progress is hindered by weakness in basic sciences.

3.24. A third element in the Framework Programme which has a specifically applied industrial orientation is RACE which is designed to ensure that the different telecommunication systems and services now being developed in Europe remain consistent. The specific aim of the RACE programme is to enable the Community to move towards integrated broadband communications based on integrated digital networks in a system able to handle a wide

Table 3.7.

FRAMEWORK PROGRAMME OF COMMUNITY ACTIVITIES IN THE FIELD OF RESEARCH AND TECHNOLOGICAL DEVELOPMENT (1987–91)

Breakdown of the amount deemed necessary between the various activities envisaged

			million ECU
1.	**Quality of life**		375
1.1.	Health	80	
1.2.	Radiation protection	34	
1.3.	Environment	261	
2.	**Towards a large market and an information and communications society**		2 275
2.1.	Information technologies	1 600	
2.2.	Telecommunications	550	
2.3.	New services of common interest (including transport)	125	
3.	**Modernization of industrial sectors**		845
3.1.	Science and technology for manufacturing industry	400	
3.2.	Science and technology of advanced materials	220	
3.3.	Raw materials and recycling	45	
3.4.	Technical standards, measurement methods and reference materials	180	
4.	**Exploitation and optimum use of biological resources**		280
4.1.	Biotechnology	120	
4.2.	Agro-industrial technologies	105	
4.3.	Competitiveness of agriculture and management of agricultural resources	55	
5.	**Energy**		1 173
5.1.	Fission: nuclear safety	440	
5.2.	Controlled thermonuclear fusion	611	
5.3.	Non-nuclear energies and rational use of energy	122	
6.	**Science and technology for development**	80	80
7.	**Exploitation of the sea bed and use of marine resources**		80
7.1.	Marine science and technology	50	
7.2.	Fisheries	30	
8.	**Improvement of European S/T cooperation**		288
8.1.	Stimulation, enhancement and use of human resources	180	
8.2.	Use of major installations	30	
8.3.	Forecasting and assessment and other back-up measures (including statistics)	23	
8.4.	Dissemination and utilization of S/T research results	55	
		Total	5 396

range of new and conventional telecommunication services from telephones to videophones, cable TV, data transmission and electronic mail. The RTD component will make an important contribution to the Community's development strategy for the telecommunications sector as a whole, which will be of great importance to the functioning of the internal market.

3.25. Other sectors too now have a significant applications-oriented component. The Community's biotechnology programme (BAP - Biotechnology Action Programme), notably covers a number of research fields relevant to the needs of industry and agriculture and is complemented by a programme of projects specifically for the application of biotechnology to agro-industry.

3.26. Alongside the part-funding of contract research in these and other areas of the Framework Programme and the work of the Community's own Joint Research Centre (which is itself now to have a more industry-oriented vocation) the Community is

- promoting **cooperation and exchanges of research scientists** among the Member States through the SCIENCE programme (formerly called the STIMULATION programme)

- encouraging **student mobility** and cooperation between **higher education institutes** in Europe through its ERASMUS programme

- promoting strong and long-lasting **partnerships between enterprises and universities in training, notably** in respect of high technology (COMETT)

- promoting the effective **dissemination of the results from its research activities** and contributing to their application through the VALUE programme;

- working towards the **lowering of language barriers** to the circulation of information through the EUROTRA programme;

- encouraging **innovation** through the SPRINT programme which aims to create more favourable conditions for innovation and technology transfer in general, as well as other sectoral programmes such as STAR (telecommunications) and VALOREN (energy technologies) which are specifically oriented towards the needs of the less-developed regions of Europe;

- promoting the **application of new information and communication technologies** in order to develop the information services market, through the IMPACT programme and through sectoral programmes (AIM, DRIVE, DELTA).

3.27. The experience of the Framework Programme activities both under the current Programme and under the first programme (1984-87) has been overwhelmingly positive, demonstrating a real thirst for cross-border cooperation. The enthusiasm generated by the Community programmes in the industrial and higher educational worlds is indisputable. The ESPRIT and BRITE programmes, in particular, have been massively oversubscribed, with the Commission and its Advisory Committees having to turn down for support a large number of potentially good projects. The same is true of programmes such as ERASMUS, which has been oversubscribed by a factor of at least three and COMETT (which in 1987 received applications for 120 MECU compared with available finance of 16 MECU). The clear evidence is that the provision of a framework encouraging cooperation and collaboration in Europe in the scientific and technological fields responds to a widely-felt need, particularly at a time when pressures on national funding have been growing.

3.28. The experience of the EUREKA initiative also confirms the growing interest in European collaboration as a means of improving Europe's technological base and making the most of the opportunities offered by the Internal Market.

3.29. Since EUREKA was launched in 1985, 213 cooperative cross-border projects have been announced in the fields of information technology, robotics, biotechnology, communications equipment and other high technology fields. These include, most notably, the High Definition Television Project, a major set of projects in the area of flexible automated assembly (FAMOS), as well as projects in the transport and environmental research field. The total EUREKA project portfolio has currently an estimated value of some 3.8 milliard ECU, which is equivalent to around 1 milliard ECU per year (about half the level expected to be generated by the Community programmes); and already some 800 organisations - two-thirds of them industrial - are involved. While some of these collaborative industrial projects, which are intended to be more "downstream" than Community projects, might well have gone ahead even in the absence of the EUREKA framework itself, the number of projects coming forward confirms the growing industrial and university interest in collaboration and cooperation. In the case of EUREKA, cooperation has the added dimension of facilitating cooperation between companies and institutes in Community Member States, on the one hand, and those in the EFTA countries in particular, on the other - around half the EUREKA projects involve participants from each grouping[26].

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[26] More detailed information on the trends in EUREKA and in the links between EUREKA and Community programmes can be found in the Commission's Communication

3.30. EUREKA is an important complement to the Community's own activities in support of the objective of improving the mastery of new technologies. The Commission plays a full role inside EUREKA on behalf of the Community in an effort to maximise the synergy between the two groups of research activity. It has recently outlined ways in which cooperation between the Community and EUREKA can be reinforced without prejudicing the operation of the Community's own R&D programmes themselves [27].

(iii) POLICY COORDINATION

3.31. The Community programmes (currently about 1.000 million ECU a year) are small compared with the R&D budgets of Member States (over 35.000 MECU in 1986); and the total cost of projects supported through the programmes is only equivalent to about 4% of total estimated public and private spending on civil research (about 50 milliard ECU per year). Even if all the other European collaborative actions are taken into account - EUREKA, COST, ESA, CERN, EMBL etc. - **the bulk of research continues to be financed and carried out at national level,** a large share of it through the national budgets discussed earlier. Given the pressures on resources and the risks of fragmentation and duplication of effort it has been recognised by European governments that better coordination of national policies is now required. That recognition is reflected in Article 130H of the Single European Act which promises better coordination.

3.32. There are a number of factors which have constrained coordination to date. These include: the different R&D capacities among Member States; the different balance between civil and military R&D; different patterns of involvement by the public and private sectors; different traditions in higher education; different sectoral priorities reflecting in part specific economic and social concerns (eg. energy in Italy, the environment in Germany).

Broad policy coordination is at present limited to the exchange of better mutual information about programmes and policies under way and exchanges of views among scientific advisors and experts in the Advisory Committees of Community programmes; while specific coordination efforts are reflected in the concerted actions in the fields of medical research and the environment

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COM(88)291 final of 24 June 1988, and in its report to the Parliament of 18 July 1988.

27 COM(88)291 final.

and, together with other European countries, within the framework of COST.

3.33. The pressures of the Internal Market will militate in favour of further policy coordination among Community Member States through the need to develop common standards, the opening up of public procurement, the requirements of competition policy. The framework for intergovernmental cooperation provided by EUREKA will also push in the same direction: intergovernmental coordinating committees already exist for some of the larger projects and aim to provide a framework for dealing with the problems of concerted Government actions which will be a necessary corollary to research cooperation. But the degree of coordination is likely to remain patchy unless the commitment reflected in Article 130H of the Single European Act is vigorously pursued.

The Commission attaches particular importance to the ongoing work within CREST designed to facilitate an in-depth exchange of information on national policies and thus to help identify duplications and overlaps. As noted earlier, it intends to focus particular attention on this question in forthcoming reports on the state of science and technology in Europe.

A great deal has already been done, both at a national and a transnational level, to tackle Europe's problems. The success of the Community's RTD programmes, the rapid development of EUREKA, other bilateral and multilateral ventures inside Europe, have demonstrated that there is a thirst for cooperation across national frontiers and that it can be mounted successfully, despite the barriers of cultural and linguistic differences.

But policy coordination among the Member States of the Community is still weak and particular efforts are needed to reduce the potential for duplication and overlap in national efforts. Dual-use technologies pose particular problems in this respect.

IV RESEARCH ISSUES FOR THE FUTURE

4.1. Three main challenges face the Community:

- to improve its international competitiveness, notably in the context of the completion of the Internal Market;

- to respond to the needs of society by improving the quality of life; and

- to increase its capacity to pursue its own scientific and technological options where necessary, by reducing its dependence on others.

These three goals are interlinked. By improving competitiveness the Community will create the wealth which makes it easier to tackle issues of social concern. Technological independence, on the other hand, is linked to longer-term competitiveness, with fundamental research offering opportunities to increase the scope for determining, rather than simply responding to economic change in an international context.

4.2. The organisation of this chapter reflects these three concerns by dealing, **firstly**, with the research requirements to improve competitiveness; **secondly**, with the areas where research has a particularly important contribution to make in meeting Europe's social needs; and **thirdly**, with the scientific and technological base of fundamental research, which provides the essential underpinning and the seedcorn for the longer-term.

There are, inevitably, overlaps between and among these categories. The most obvious is in the case of the biological sciences which will make significant economic and social contributions (through their impact on industry and agriculture, on the one hand, and in the fields of health and environment, on the other), and where progress on specific questions of fundamental research is essential if major break-throughs are to be achieved. The categories chosen, however, reflect the areas where the most significant contributions can be expected from individual areas of research.

4.3. Under each heading the chapter considers the market situation, the research needs and action underway in Europe (in industry, at Member State level and, where appropriate, within the framework of the European Community). More details on each area of research are given in the annexes, while the industrial and services markets are analysed separately in depth in the **"Panorama of EC Industry"** which is shortly to be published by the Commission.

4.4. This is a first analysis of the main research needs, which the Commission intends to refine during the coming months. But it already reflects a wealth of inputs and advice from inside and outside the Community institutions; the main contributions have already been indicated in the Introduction to the report. It was not possible in such a short report to be exhaustive . The report concentrates on the areas where the needs are most clear.

I IMPROVING COMPETITIVENESS

4.5. There is a broad consensus internationally on the areas of technology which are expected to be important for industry and the services over the period to the end of the century:

Table 4.1.

Emerging Technologies

Japan	**USA**	**EC**
Electronics	Electronics	Information Technology
Software Engineering	Automation	New Materials
New Materials	Computing	Biotechnology
Biotechnology	Advanced Materials	Energy
Biomaterials	Medical Technology	
	Thin Layer Technology	

Sources: The Status of Emerging Technologies: An Economic/Technological Assessment to the year 2000. US Department of Commerce, June 1987
Trends and Themes in industrial technologies, MITI,1988
Panorama of EC Industry 1989 (forthcoming publication by the EC Commission).

4.6. As underlined in Chapter I, the new groups of technologies are not independent of each other. Lasers, for example, which are developed from opto-electronics, are used for cutting and milling metals and plastics, composites and ceramics. On the other hand silicon and, for the future, superconductors are materials on which improvement in electronic components

depend, while superconductors may modify significantly the way energy is transported and stored. Some of interrelationships are identified by the concentric circles in Table 4.2.
Specific research needs in Europe can, however, be identified in five fields:

1. Information Technology and Telecommunications, where Europe has made substantial progress, but where rapid developments are occurring world-wide;

2. Industrial Materials Technologies, which are vital to the success of manufacturing industry;

3. Aeronautics, where Europe faces a particularly important competitive challenge;

4. Biological sciences, which are the focus of attention world-wide and which offer the prospect of radical improvements in agricultural and industrial production and major commercial opportunities, in addition to their impact on medicine and the environment;

5. Energy, where adequate and secure supply at reasonable cost and in an environmentally acceptable form is an essential prerequisite to the functioning of the European economy.

1. INFORMATION TECHNOLOGY AND TELECOMMUNICATIONS (Annex 1)

The Market Situation

4.7. Europe's weaknesses in this area, especially in the **information technology** industry, attracted great concern at the beginning of the 1980s. The European industry was characterised by a flagging IT market, low market shares, low R&D and low capital investments. Moreover, the balance of trade in IT products was negative, amounting to a deficit of 10.6 milliard US dollars in 1984.

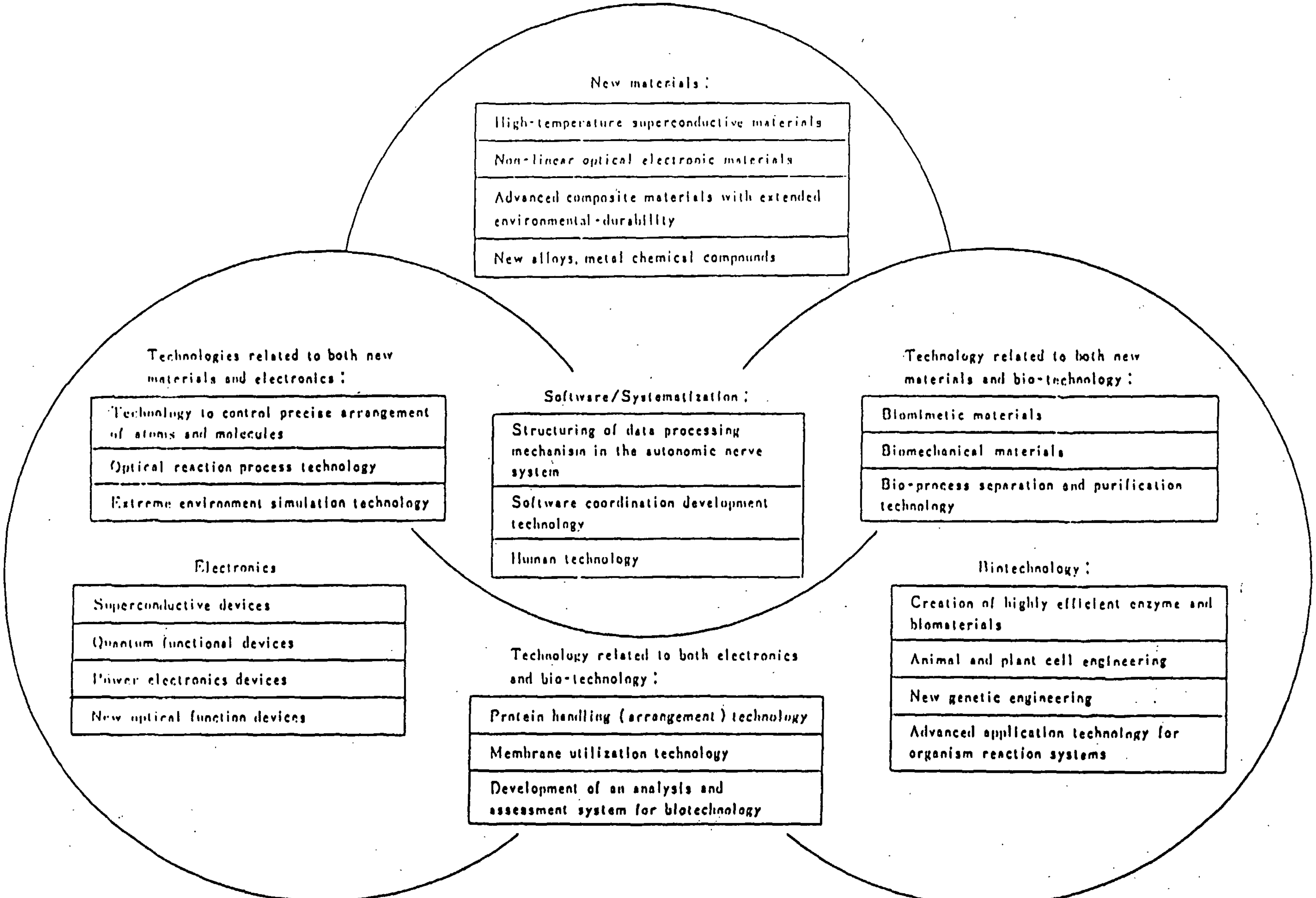
Concerted action was taken from 1984 onwards by the European companies to rectify the position. These actions encouraged a new dynamism in the European industry and helped mobilise human, financial and technological resources which were supported by collaborative programmes such as ESPRIT. The fruits of these combined efforts are just starting to appear:

- In a world-wide market growing at more than 15% yearly, the six main European companies have been growing at a 25% p.a.

- In the European market, the largest European companies have

Table 4.2.

Emerging technologies with wide penetration effect



SOURCE: Japanese White Paper on S&T. 1988. MITI.

significantly increased their market share, bringing it close to 50% from 33% in 1983.

- In software and services market, the European companies are holding a favourable position, taking advantage of the strong growth of the market demand.

- European IT companies are now investing in R&D a proportion of their sales that is very close to that of US companies. Nevertheless the needs for R&D in the IT field are accelerating.

4.8. Although the European Information Processing industry seems on the way to overcome some of its traditional weaknesses, major problems still remain. These include:

- The penetration of European Information Systems companies on overseas markets is still minimal (15 to 25% of sales).

- The balance of trade in IT products has not improved. On the contrary in 1986 the trade deficit increased to 13.4 billion US dollars.

- The Electronic Components industry has not progressed in Europe at the same rate, making the Information Systems industry and other user industries even more dependent on foreign suppliers of critical and strategic components (Table 4.3.).

- The situation is similarly critical in certain types of computer peripherals. These represent an ever-increasing share of the value of Information Systems.

- A major weakness in Europe is the lack of trained personnel.

Table 4.3.

Electronic components - Main Trends
1980 - 1987

Million ECU EUR-12

	1980	1985	1986	1987
Apparent Consumption	6,083	13,125	13,117	n.a.
Net Export Earnings	+ 1,246	+ 104	+ 498	n.a.
Total Production	7,329	13,229	13,615	14,060

Source: **Panorama of EC Industry 1989**
Note: By comparison, the USA has a components market worth more than 29 milliard ECU in 1986, and Japan 23 milliard.

4.9. The relative success in some areas of European IT serves to highlight the remaining problems. Continued action is also required to consolidate the newly acquired competitive positions. This means:

- ensuring the economic climate and boundary conditions which allow full exploitation of the potential demand.

- strengthening European technological capabilities in key areas.

4.10. **In the telecommunications sector** the relatively favourable situation of Europe, in industrial, technological and commercial terms could be threatened by:

- the continuing weaknesses in the field of electronic components;
- new technological and market challenges (digitalisation of networks, ISDN and broadband networks);

- the spiralling costs of R&D in telecommunications;

- the effects of rapid changes in the regulatory environment world-wide.

Substantial efforts are therefore needed to secure and to reinforce the present position of European industry and telecommunications operators.

<u>Research needs: Information Technology</u>

4.11. Further advances in the field of **electronic components** will lead, for example, to an increase of the capacity of memory chips beyond the present state of the art (1Mbit). Progress towards the objective of 64 Mbit chips make it necessary to design circuitry for feature sizes below the level of 0.5 micron. This requires highly sophisticated design and production techniques. The new technological approach, combined with the currently stronger industrial and technological position of the European semiconductor companies, should provide opportunities for Europe to come back into the race. A significant cross-border collaborative effort in Europe is proposed under the Joint European Submicron Silicon project (JESSI), which aims to develop the design and manufacturing techniques needed for Europe to change its competitive position vis-à-vis the USA and Japan . This project will need appropriate support from companies and public authorities.

4.12. At the same time progress needs to be made in **software and advanced information** processing, given the growing demand for increased capabilities for computing, for knowledge - (rather than data-) processing,and for enhanced user friendliness.

Key issues in this context are: operating systems; management systems for data base; parallel architectures which can provide powerful computing capabilities (Europe has very good capabilities in this field); RISC architectures, especially for microprocessors.

The traditionally good technical position of Europe in the software area is being reinforced by the advances made through some major cooperative projects developed in ESPRIT. Further efforts are nevertheless required if Europe wants to stay in the race: USA and Japan (especially through ambitious long term projects such as TRON, SIGMA, 5th Generation...) are making major efforts in this field.

4.13. **Peripherals** will become increasingly important with the development towards integrated systems. Research work on flat panel displays and optical storage technologies is progressing fast; but Europe's situation is rather weak and requires early attention.

4.14. At the same time as this applied research effort, however, the fast-developing IT industry is demonstrating a need for more **fundamental research** in computer services (to solve problems of reliability, safety and security); in programming languages appropriate to the expanding hardware facilities; in machine-learning; in areas such as the design of autonomous mobile robots, cognitive engineering, and specifically the analysis and better design of human-computer-work interactions.

4.15. Finally, there are major needs in the field of **prenormative research**, because of the increasing importance of standards (and of their early definition of standards) in the context of evolution towards the integration of complex systems designed for a wide range of new applications (intelligent banking and financial services; advanced robotics; multimedia systems; bioinformatics; intelligent car and transportation systems; home automation...).

Research Needs: Telecommunication Technologies

4.16. The key issues in telecommunications are essentially related to the establishment of broadband networks, equipment and services, which are expected to happen from the mid-1990s onwards (the present narrow-band ISDN network, which will use technologies already available, requires basically standardisation work).

Most technological developments are therefore generated by demand pull, linked to each major component of the broadband communication systems:

a) **broadband infrastructures** will carry information flows 1000 times more important than today.

This will require enhanced systems of network management using the resources of advanced information processing and of data base management systems. The USA are presently ahead in these areas.

b) **broadband equipment** will develop according to three technological stages allowing each time considerable gains of speed, of volume transmitted and received and of cost effectiveness. These three stages will use:

- VLSI electronic components for switching; coding/decoding; network management.

  The design and use of these components require strong advances to be made in the field of software. Here Europe is still behind US and Japan;

- optoelectronic components which will allow better and quicker interfaces with fibreoptics transmission;

- optical communication (operational after 2000) which implies: new materials for components; new component manufacturing technologies; new software tools in order to control and manage considerable flows of information transmitted at very high speed *(coherent multichannel* techniques allowing multiplexing of optical channels on one fibre by frequency allocation).

c) **broadband services.**

Their implementation requires substantial activity in:

- service engineering techniques, (covering issues of standardisation, software, expert systems, data libraries, image processing), in order to establish operational services able to combine data, images and voice through merging of data processing and telecommunications. The 3 main regions of the world seem to be at the same stage in this field;

- appropriate exploitation of technologies through increased activity test beds, language customisation of hardware and software, permanent feedback with the users of new services, in order to provide advanced/intelligent terminals for specialised business use and for domestic use (by combination of PCs, TVs, hifi....).

Research Needs: Application Technologies

4.17. The convergence and maturing of information technologies, telecommunications and audio-visual services has created conditions favourable to the intensive exploitation of the basic technologies, adapting them to the specific needs and constraints of different categories of users (the business world, public administration, social services, individuals) in order to meet social and economic needs.

4.18. The fields of potential application are very numerous: health, transport, agriculture, public administration, education and training. And the spread of technologies to be used and integrated in this respect is broad: personal computers, optical discs, microprocessor cards, new medical and educational imaging techniques, computer languages close to ordinary human language, expert systems, mobile telephones, integrated digital services, broad band networks, high definition television, direct satellite transmission, etc....

The problem is to combine and integrate as far as possible the broad range of technologies already available or under development; and to optimise their overall performance in technological, economic and social terms, while avoiding the risks caused by the present proliferation of independent systems which are conceived from particular, and often exclusively national perspectives. Avoidance of such risks requires cooperative and concerted actions at a European level among all the actors concerned.

4.19. In Europe there is a particular need to make use of the opportunities offered by information technology to facilitate the flow of information across linguistic boundaries. This is particularly important to the Community's service and distribution industries, which currently represent 59% of GDP and 60% of employment in Europe. It will be of increasing relevance in the context of the completion of the Internal Market. The current EUROTRA programme at Community level, which began in 1982, has already produced a sound basis for the creation of a European language industry. But new efforts are needed to:

(a) encourage industrial participation in the development work and knowledge transfer between universities and industry;

(b) exploit the results of research on artificial intelligence, voice and pattern recognition and expert systems developed under programmes such as ESPRIT. The transformation of ongoing pre-competitive research into industrial applications will lead to increased outlets and demand for normally "monolingual" natural language processing technology such as text processors, hyphenation, grammar and spelling checkers, optical readers and the like, thus providing further impetus for the growth of the information technology industry.

European Action in IT and Telecommunications

4.20. Assuring the necessary and most effective efforts on R&D in these fields will require further encouragement and coordination at European level. Action is already under way in some areas. The second phase of ESPRIT is now in operation. And in the field of sub-micron technology, as noted above, discussions are in progress between European manufacturers to establish an appropriate framework for research (the JESSI project); the Community will have a role to play as catalyst.

Within EUREKA, information technology projects represent a major share of the project portfolio. It will be important to capitalise on the successful experience of European collaboration in the information technology field and to ensure the best possible coordination between projects and programmes.

4.21. As far as more basic research on IT is concerned, Europe is in a different position from its competitors. In the US and particularly Japan, such research is largely the preserve of industry; while in Europe industry has been more short- or medium-term oriented. This is an area where action at a European level can be of immense value in encouraging the necessary work to be carried out in a cooperative framework and in helping to commit industrial finance to the projects.

2. INDUSTRIAL MATERIALS AND TECHNOLOGIES (Annex 2)

The Market Situation

4.22. Industrial technologies support the design, engineering, manufacture and operation of products and processes. They are inseparable from the materials which must be developed, processed and finished to meet the designer's intentions.

4.23. The primary customer for industrial technologies and materials is manufacturing industry, which currently provides about 30% of GNP in the European Community, and 75% of the industrial work force of some 41 million people. The Community balance of external trade in manufactured goods - +15% in 1987- is positive.

Table 4.4.

EC Trade Balance in Manufactured Goods
Milliard ECUs

	Imports	Exports	Balance
1981 (EC 10)	171	236	+ 65
1987 (EC 12)	252	289	+ 37

Source: EUROSTAT

Moreover, some of the traditional sectors of manufacturing have invested heavily in new technology in the past few years: the textile industry is the most telling example, with great confidence in the industry that the move towards computer-integrated manufacturing is likely to reinforce its position on world markets (the EC accounts for 55% of world production). Despite the improving position in many areas, however, Western Europe suffers from structural weaknesses, namely an inadequate capacity to respond to growing demand in some of the more developed markets -particularly those where the economies of scale are largest, such as transport equipment, machinery, instrument manufacturing, paper and printing.

4.24. Successful manufacturers are seeking increasingly to capture the top end of the market by new and improved products, usually with a higher technology content in the product itself or in its means of manufacture. The potential for increased productivity and flexibility is particularly great in the "mature" industries (such as textiles, clothing, motor vehicles and food as well as textiles). Improving the situation depends heavily on the further diffusion and application of available technologies by these industries. It also depends, however, on advances in the technologies themselves and in exploiting the possibilities that they offer. Progress in R&D is therefore fundamental to long-term success. Here Europe is hampered by the low level of industrial R&D compared with that of the US and Japan (a point underlined in Chapter II and III).

Research Needs

4.25. Particular areas that require renewed research efforts are:

- the development of technologies to improve product and process quality and reliability. Ensuring quality and reliability can typically cost 5-25% of company turnover, and for one Member State has been estimated to cost the equivalent of 10% of GNP. Significant improvements are possible through successful R&D on optical engineering, sensors, power control engineering and through the use of modelling in areas such as the filling of complex injection moulds, particle formation in atomisers, positioning of sensors for monitoring, or the design of composite materials;

- techniques for shaping, joining and assembly, and for surface treatment. The prevention of corrosion, which is estimated to cost 4% of GNP in industrialised countries, makes progress in surface treatment potentially of real economic significance;

- catalysts and membranes. Progress in the understanding of catalysis could lead, in particular, to cleaner production through higher specificity; while the world market for membranes (currently estimated at 400MECU/year) is likely to grow significantly as new applications are identified;

- powder technology. This is a large and high-value market (about 2 milliard ECU/year in USA, half as big in Europe and Japan). While steel, semi-finished powder and metallurgical components can be valued at between 20-50 ECU/kilo, ceramic powder parts can cost 2.000 ECU/kilo. International competition is particularly strong, driven in part by the requirements and spin-offs, such as vacuum technology, from the space programmes;

- other high-value materials, such as metal matrix composites (already being developed for ceramic -reinforced light alloy pistons) and anisotropic materials using various strengthening techniques such as particles or fibre reinforcement;

- superconducting materials.

In information and communication technology the further development of superconducting materials could lead to qualitative breakthroughs (by minimising heating), as well as progress in technologies based on magnetism (eg. fast switching devices, nuclear magnetic resonance for medical diagnosis, controlled nuclear fusion). And if economic devices carrying high current densities could be built, long distance electricity distribution networks and magnetic superfast trains would acquire a more practical dimension.

Some very fundamental aspects of superconductivity, however, are not yet understood and the prospects for development of high current density devices are still uncertain. In Japan around one-third of the research effort is devoted to work on these issues.

In Europe, where some of the seminal discoveries were first made, reactions to the explosion of interest in the field was rapid (the EC Commission convened the first group of interested experts in June 1987). But in terms of resources made available the European response was much weaker than in the USA and Japan.

In order to match the financial, technological and human resources made available by competitors, systematic joint European action is needed.

4.26. In addition to research on technologies and materials themselves there is a growing need, in the context of the 1992 market, to ensure that there is an adequate research base for the development of common <u>norms and standards</u> in the field of industrial technologies and materials, including notably in respect of lasers, membranes, new materials in general, fracture mechanics, construction materials and production technologies. This is in addition to the preparatory work on IT and telecommunications standards referred to earlier.

<u>European Action</u>

4.27. It is important that industry itself should be encouraged to invest more in the R&D that is required in the areas outlined above. National authorities clearly have an important role to play in providing the right framework conditions. Community cost-sharing programmes are also of significance. The very high rate of subscription to the Community programmes (on average there are 5 times more good proposals than can be funded under the present conditions) indicates that European industrialists increasingly recognise the need for R&D and are ready to participate and contribute with company funds to at least half the cost of Community-managed pre-competitive R&D on industrial technologies and materials. A new programme of Community support for industrial technologies and materials has recently been proposed to the Council, which aims to provide a European dimension and to act as a catalyst to the research discussed above. As noted above, a specific effort within Europe is needed on superconducting materials.

4.28. Providing and stimulating financial commitment by industry is not, however, of itself sufficient to maximise the benefits of R&D. Two other things are also required, which would benefit from a European dimension:

- action needs to be taken to improve the availability of skilled research managers in industry. It could be useful to examine further what action in the field of training might be appropriate at a European level, whether inside or outside the Community framework;

- top management of industry as well as research managers, must be more directly involved in R&D projects, which ought to be closely integrated in corporate strategies. The independent panel which recently evaluated the BRITE programme has made such a recommendation in respect of projects financed under the Community's own programmes. The positive results of such involvement have already been witnessed in the case of the ESPRIT programme and in the preparation of the Commission's proposal in the aeronautics field.

3. AERONAUTICS (Annex 3)

The Market Situation

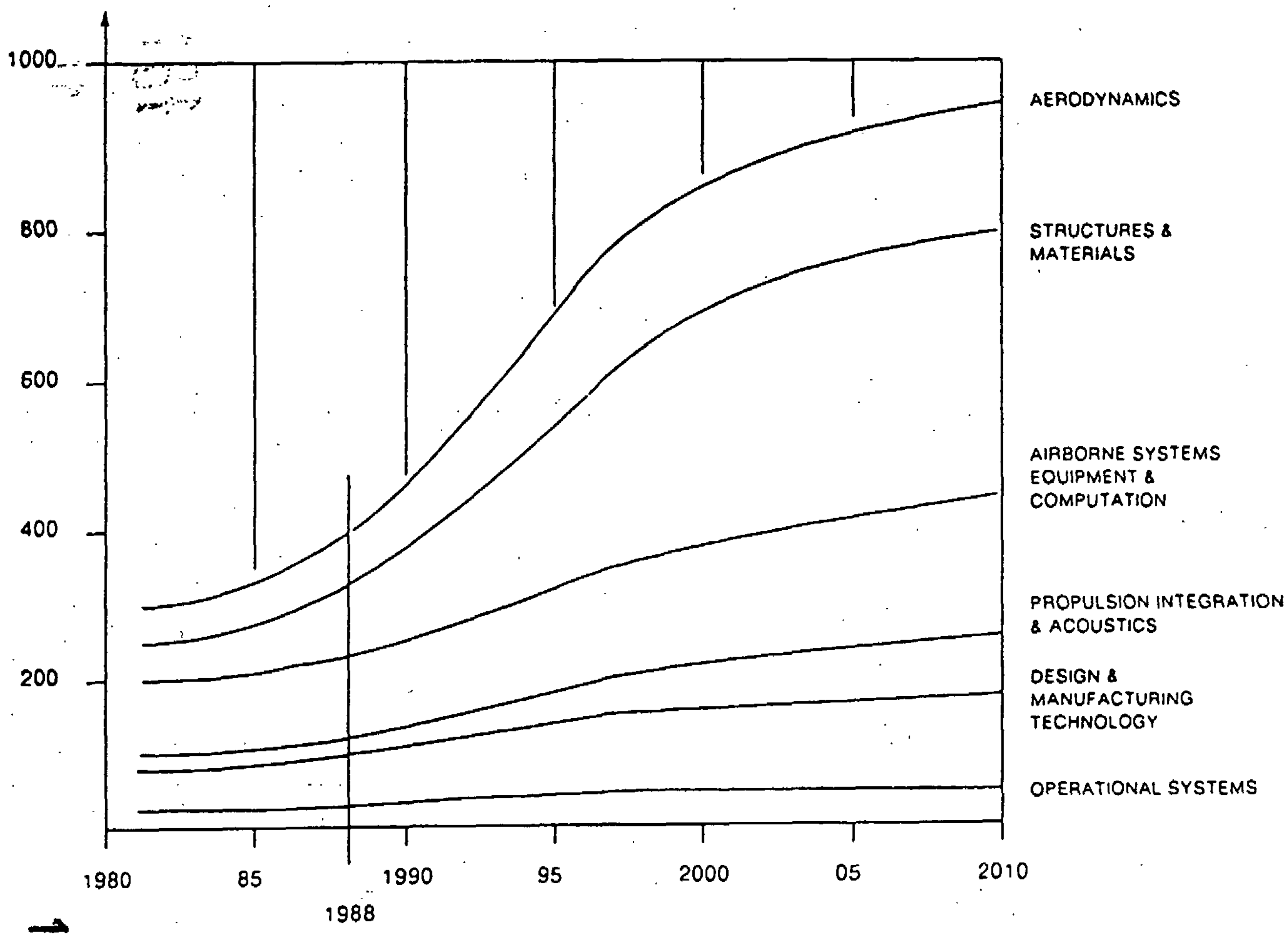
4.29. During the period 1980-86 the European aeronautics industry captured 23% of the civil and 27% of the military world market. The world market is expected to expand substantially up to the end of the century and increasing competition to capture it must be expected, not only from the USA but also from Japan and industrialising countries such as Korea and Brazil. The US industry remains in a particularly favourable position, however, because it enjoys a large home market and it benefits from the spin-off from military R&D programmes.

The Challenge for Research

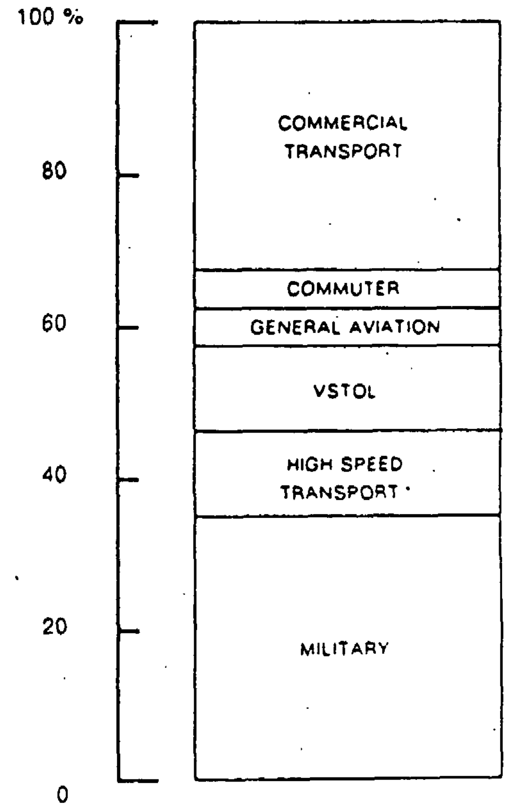
4.30. The aeronautical industry depends heavily on advanced technology to ensure competitiveness, incorporating progress in aeronautics, the design of complex structure and advanced materials, electronics, etc as well as the design and implementation of new manufacturing methods. The development of these technologies requires a long-term strategic approach, while their application necessitates a broad industrial base.

Table 4.5.

SCENARIO OF FUTURE EUROPEAN AIRCRAFT
RESEARCH & TECHNOLOGY NEEDS



AIRCRAFT CATEGORY
BREAKDOWN IN YEAR
2010



* ASSUME 50 % OF SST, 25 % OF HST

(Source : EUROMART Study)

European Action

4.31. If Europe is to be able to meet the challenge in an increasingly competitive environment a broadly-based transnational collaborative effort in R&D is now required (Table 4.5.). The Commission has recently proposed a pilot programme at European level. This would provide a firm foundation for cooperation between the European aeronautical industries, and between them, universities, national research centres and SMEs. It would also enable specific urgent research projects to be tackled right away. The scope of the programme is discussed further in the annex. The main technology areas identified for the pilot phase are: aerodynamics and flight mechanics, materials, acoustics, computation, airborne systems and equipment, propulsion integration and design and manufacturing technologies (Table 4.5.). Special attention will be paid to safety and environmental aspects, as well as common norms and standards.

4. LIFE SCIENCES AND TECHNOLOGIES (Annex 4)

4.32. Developments in the life-sciences open up possibilities that straddle the concerns of economic success and social need; ranging from improvements in agricultural and industrial productivity that are environmentally "clean"; to progress in pharmaceuticals, chemistry and medical science; to improved understanding of the brain, with implications not just for medical science but for the design of computers; to new knowledge about the mechanism of evolution itself. Their major economic contribution could be to shorten production processes and increase efficiency in the pharmaceuticals industry; to speed up the development of new strains of plants (it took 50 years from 1930-1980 to increase the yield of corn by 70% through a long process of genetic selection; the same improvement could now be obtained in a few years or less); and to develop and produce products in new ways (computers built with biological components may be able to deliver vastly higher performances than current technology allows).

For convenience, the issues for research discussed below are treated predominantly in the context of Europe's economic needs, with medical research alone dealt with separately in the context of the needs of European society. But it should be remembered, for example, that genome analysis, which is discussed below, will be of major significance in the context of medical diagnosis and therapy as well as in bio-industries and agriculture; while certain aspects of medical research (medical instrumentation) are of relevance in the context of competitiveness and technological independence.

The Market Prospects

4.33. In both the USA and Japan biology and its applications have been identified as fields of major potential significance to industry over the period to the end of the century; and there is a widespread expectation of a rapid growth world-wide of application technologies (cf Chapter I), although determination of future market size and timing is particularly difficult. A cooperative analysis of 11 market forecasts to 2000 undertaken in 1984 showed a range of between 9 milliard dollars for the least optimistic and over 100 milliard dollars for the most optimistic[28]. The uncertainties have not changed in the meantime, although there is a broad consensus that pharmaceuticals, agriculture and food-processing offer the greatest market opportunities. One reason for the difficulty is the pervasive nature of the potential application of biological research; another is the speed of change in this field, which has been made possible by the development of instrumentation based on advanced physics, chemistry, informatics and mathematics.

Research Needs

4.34. Europe has pioneered many of the most important developments in the life sciences, from the discovery of the "double helix" to monoclonal antibodies and receptor-targetted pharmacology; from biological application of physical spectroscopy to the crystallographic study of the three dimensional structure of nucleic acids and proteins including, quite recently, those associated with membranes; from the regulation of gene expression to genome structure and predictive medicine.

In spite of its many achievements, however, Europe is inferior to America in breadth and depth of coverage and in the capacity to expand rapidly in new fields and to exploit the results in industry.

4.35. In several areas of biology, Europeans have found it useful to complement existing collaboration with the rest of the world (and especially with the USA) by improved collaboration among themselves. The European Molecular Biology Organisation and the European Molecular Biology Laboratory, as well as the Basel Institute of Immunology are particularly significant examples.

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28 **High Technology Industries, Profit and Outlook: Biotechnology**, US Department of Commerce, International Trade Administration, Washington DC 1984.

4.36. Taking into account the ongoing and planned activities of these organisations and suggestions made by the authorities of some Member States and by university and industry researchers, 4 areas of research merit particular attention in Europe:

- **basic plant biology**
- **the molecular investigation of the genomes of complex organisms**
- **neuroscience,** and
- **biotechnology based agro-industrial research and technology development.**

Basic plant biology

4.37. The new tools associated with progress in modern genetics and biotechnology now make possible a diversity of potential applications for the improvement of crop sciences, for environmentally safe land use and disease control methods. But it has become apparent world-wide that the bottleneck to progress lies less in the absence of adequate application technologies, and more in large gaps in our basic understanding of key structures and functions within plants. European biotechnology has now reached a stage where the ability to manipulate plant genes, largely established by pioneering laboratories in several Member States, has outstripped the knowledge of many underlying biological functions and metabolic properties.

4.38. In order to make significant advances in biotechnology, it is therefore essential to go back to the investigation of plant physiology, using all the new tools developed for molecular investigation. If major efforts are made, it may be possible within 5-10 years to identify, for example, the "quality" molecules of many plants - those associated with innocuity, flavour, nutritional value, and texture. If they can be identified, their synthesis controlled, the "quality" molecules would make a real difference to agricultural production, providing the basis for a better balance between high quality and low quality crops. At the same time it will be easier to establish a better balance between "bio-natural" and chemical practices in agriculture, enabling increased production to be based on biological supply of chemical fertilizers and pestides. Finally, better understanding of basic biology would enable closer monitoring of the interactions of crop plants with other species, which would permit better ecological monitoring of land use.

This work is of particular importance in a global context. In order to feed a world population, which could be as high as 10.000 million in 50-60 years time, without at the same time increasing the greenhouse effect, new methods of food production will be needed. Efforts must be stepped up now to provide a solution to the problems that will face Europe and the rest of the world in the longer-term future.

4.39. A major effort in this field would be at the crossroads between molecular biology, physiology and genetics. Such a multidisciplinary approach requires elaborate integration of work programmes which could be achieved at the desired level of excellence only through coordinated transnational action.

Genome Analysis

4.40. Each of the 10 trillion cells in the human body contains about 100.000 individual genes. The sum total of these genes corresponds to what is known as the human genome. Knowledge of the human genome is as necessary to the continuing process of medicine as knowledge of human anatomy has been for the present state of medicine. The major diseases which affect human beings all have genetic components; and many diseases result directly from one or more defective genes. Understanding the entire genome sequence would allow a more rapid identification of these disorders and an accurate detection of hereditary predispositions. In the field of agriculture and industry the molecular investigation of important microbial plant and animal species is an essential complement to the work needed on basic plant biology discussed above.

4.41. The necessary research work is complex. It consists of several phases, involving respectively the detailed and physical mapping of genomes, the development of automated techniques for large-scale cloning and sequencing, and finally, the sequencing itself.

4.42. The importance of this field has been recognised outside the Community. In Japan a major effort is being made on the automation of mapping and sequencing techniques; while the USA are setting aside $3.5bn for work on the human genome during the next 10 years.

4.43. Europe has many of the skills and resources to make a major contribution to the international efforts on complex genome analysis. Already some actions are under way at a national level (France, UK, Germany, Italy). However, even the largest European country cannot work on its own in this costly endeavour. The Community as such already has experience in the field of genome analysis (the Community BAP programme has involved some 24 laboratories in the sequencing of one yeast chromosome). Other discrete steps have been taken using existing programmes or new proposals under the Framework Programme, to organise transnational research on small-scale sequencing projects; and new efforts will be made under the Predictive Medicine initiative. Given the cost and complexity of genome analysis, further work in Europe requires transnational effort.

Neurosciences

4.44. The past few decades have seen an explosion in knowledge of the nervous system. In the past many disciplines such as medical science, physics, chemistry, and molecular biology studied the nervous system in isolation from each other. But neuroscience today is an alliance of disciplines applied to this most complex branch of the life sciences.

4.45. Even with the considerable amount of information already accumulated on what the brain is made of, what it looks like and how its elements behave, the really big questions about, for example, how man remembers, feels and carries out voluntary movements, remain unanswered.

4.46. The applications of knowledge in this field go beyond pharmacology, psychology, psychiatry and medicine. The neurosciences are increasingly interesting also in terms of information theory and technology. The brain has capacities for information storage and processing, including plasticity, adaptivity, learning and creative association which cannot be matched by the best computers available at present. Mathematicians, physicists and biologists hope to build computer models that go much further than today in mimicking some of the skills of real brains.

4.47. To that end, and to ensure a timely and original first European contribution to this rapidly developing field, the Commission launched the BRAIN initiative on adaptive intelligence and neuro computing.

This latter initiative needs to be followed by other action at a European level to pool resources and complementary skills.

Industrial and agro-industrial applications

4.48. The European pharmaceutical industry has enjoyed rapid growth in the 1980s, with production almost doubling between 1980 and 1987 and imports low. But it now faces a number of problems.

These include the high cost (around 100 million ECU) of developing and bringing to the market a new product or chemical entity (NCE); the short period of exclusiveness granted under existing patent protection legislation (it takes usually over 10 years from the time of patent application until a marketing authorisation is obtained) ; and increasing competition from the US and Japanese industries. European research is still highly effective but the results achieved in Japan in particular (19 NCEs out of 56 introduced in 1987) demonstrate that a redoubling of effort is required and more investment is essential.

4.49. There is also a need for further efforts in the agro-industrial field, where the Commission has already made proposals for action at Community level. These are described more fully in the annex.

The funds estimated necessary for the programme proposed on agro-industrial research (ECLAIR) are limited (80 MECU for 5 years). They allow a reasonable start, but - if successful - they are likely to need expansion in the coming years to meet the expected needs. Industry has suggested, moreover, that the currently proposed programme on improved food technology (FLAIR - 25 MECU over 5 years) should be complemented by an action at European level to stimulate research on **nutrition.** A new look at nutrition is desirable given the importance of the nutritional aspects of health and the possibilities offered by new technologies for food production. This "new nutrition" is being pursued in the USA and Japan in particular. In Europe the implications for transfrontier trade in food products, for the CAP, and the need for common standards would need to be considered.

5. ENERGY (Annexes 5+6)

The Market Requirements

4.50. An adequate supply of energy at reasonable cost in the right place at the right time is fundamental to the proper functioning of industry, commerce and transport and to the satisfaction of human needs for heating, cooking and travel. Technologies that supply energy, as well as those that ensure its most efficient use are truly "enabling" technologies, without which our economies and societies would rapidly break down.

4.51. The future energy needs of the European Community up to the end of the century and alternative ways to satisfy them have been extensively analysed by the services of the Commission with the help of national experts and the modelling tools developed under the Community's non-nuclear energy R&D programme. The range of scenarios they present are a good starting point to identify research needs.

Table 4.6.

Scenarios for Community energy needs in 2000 a.d.

	Mtoe	**EUR-10**
	2000 a.d.	**1985**
Primary energy demand	1036 - 1218	942
Solid Fuels	229 - 309	218
Oil	430 - 539	413
Gas	196 - 256	182
Nuclear	150 - 235	116
Hydro, Geothermal, Solar, etc.	21 - 22	12

Source: Energy 2000, CEC 1986.

The range of figures reflects uncertainties about future economic growth, the future price of oil, emission controls, the size of nuclear power programmes in individual Member States and progress in development and use of new and renewable energies.

All the scenarios point to a growing demand for electricity, which could rise to as much as 20% of the energy used by the final consumer in 2000, compared with around 15% today. Beyond 2000 too the demand for electricity is expected to grow more quickly than other fuels.

4.52. The broad conclusions from this analysis - supported by national studies and those of major energy companies, and reflected in the Community's agreed energy objectives to 1995- are in favour of **diversification** of European supply and **increased efficiency of energy use** as means to ensure energy and economic security.

The close relationship between energy production and use and the **environment** add a further and compelling argument in favour of diversification. In order to minimise the negative environmental effects of each energy source it is important to have access to several solutions.

Research Needs

4.53. Many of the technologies are available now; some will only be available in the longer-term as a result of major research efforts. Those efforts, which in some cases will not bear fruits for 10-20 years or even longer, must not be weakened or abandoned simply because the price of oil in the short-term has dropped to less than half its value in the early 1980s.

In the past few years there has been some reduction in of expenditure on energy as a whole inside and outside Europe. This applies particularly to research on new and renewable energies and on fast breeder reactors as well as fossil-fuel based technologies. Expenditure on nuclear fission research continues to be the largest element in public expenditure on R&D as a whole (Table 4.7.).

4.54. The reduction in support for energy R&D reflects progress accomplished since major programmes were launched in the aftermath of the 1973-74 "oil crisis"; problems encountered in bringing some projects to successful technological or commercial development; and shifts of priority in publicly-financed research away from energy and towards information and industrial technologies. There remain areas where a significant level of effort needs to be maintained because of their longer-term potential for providing environmentally benign and independent sources of energy supply and use in Europe. This is particularly the case of **controlled nuclear fusion** and for carefully targetted actions in the field of **non-nuclear energies**. As far as nuclear fission energy is concerned the main needs lie more in the field of public acceptability rather than in production technology itself. The issue of acceptability and safety is discussed separately in part 2 of this chapter.

Controlled nuclear fusion

4.55. Nuclear fusion should provide ultimately an environmentally acceptable, practically inexhaustible, geographically independent source of energy. The economic aspects are impossible to define precisely at the present stage, but will need to be periodically monitored as the fusion and long-term energy scenarios become better known. The environmental aspects will also deserve continuous study as fusion programmes approach the technological stage.

4.56. Fusion research is already a major European collaborative venture under Community auspices. This long-term project, embracing all the work carried out in the Member States, is designed to lead in due course to the joint construction of prototype reactors with a view to their industrial production and

TABLE 4.7.

MARKET REQUIREMENTS FOR ENERGY TECHNOLOGIES IN DIFFERENT TIME SCALES

	Up to 2000	Between 2000 and 2020	After 2020
Rational Use of energy	Energy conservation and energy use technologies (buildings, industry, transport) combustion technologies **	**	*
Electricity	Storage Conversion and transportation **	**	***
Oil	Exploration-Exploitat. ***	assisted extraction ***	**
Gas	Exploration **	conversion into liquid fuel e.g. alcohols et al ***	**
Coal	improved -exploitation and uses -fluidised bed combust. **	- Coal gasification - Combined cycles - electricity generation **	MHD gasification/liquefaction ***
Nuclear	Safety waste disposal decommissioning **	2nd generation nuclear reactors with improved safety features **	Breeder and Fusion reactors ***
Renew. Energies	Cost reduction: Solar Wind Biomass Hydraulic Geothermal *	Cost reduction : Photovoltaic solar *	Cost reduction **
Energy-Environment	Emission Reduction, radioactive waste and emission control SO2, NOx, (CO2) CO2 abatement ***	CO2 ***	CO2 ***

Potential market in primary energy requirements : *** > 30 % - ** 10 to 30 % - * < 10 %.

marketing. Two third countries (Sweden and Switzerland) have joined the programme. A multi-annual programme for the period (1.1.1988-31.3.1992) has recently been approved. A new Programme Decision should be taken in January 1991, which will need to be prepared by in depth analysis not only of the outlook for fusion itself, but of the role it could play in the energy and environmental scenarios for the next century, both within the EC and world-wide. In particular, the global climate change study (discussed later) should indicate the acceptable limits to fossil fuel combustion. Analysis will also be needed of the prospects for nuclear fission waste disposal. Both results will help to define the long-term role to be played by fusion.

4.57. Scientific wisdom, technological skill and managerial efficiency have made of the EC fusion programme a recognised success. Scientific and technical achievements place Europe in the forefront of world-wide magnetic fusion research:

- JET, the flagship of the Community fusion programme, is the world's largest experiment, which has made a large step towards the demonstration of the scientific feasibility of fusion;
- the European medium-size devices in operation contribute also to the progress of fusion, and the construction and commissioning of new devices are proceeding according to schedule;
- European industry is building all these devices and has already been entrusted with some long-term advanced development.

This leading position of the Community fusion programme makes Europe an appealing partner for international collaboration both in bilateral frameworks (Canada, Japan, USA) and within multinational organisations (OECD, IAEA). In particular, under IAEA auspices, an agreement on participation by EURATOM- together with the USA, the USSR and Japan - in the conceptual design activities for an International Thermonuclear Experimental Reactor (ITER) has recently been signed.

4.58. The EC decision to concentrate on magnetic rather than inertial confinement has so far proved judicious: on a world-wide basis, the inertial approach should, however, not be neglected (Table 4.8.). Two-thirds of efforts, in the USA for example, are devoted to magnetic confinement and one-third to inertial confinement (which has a direct connection with military technology).

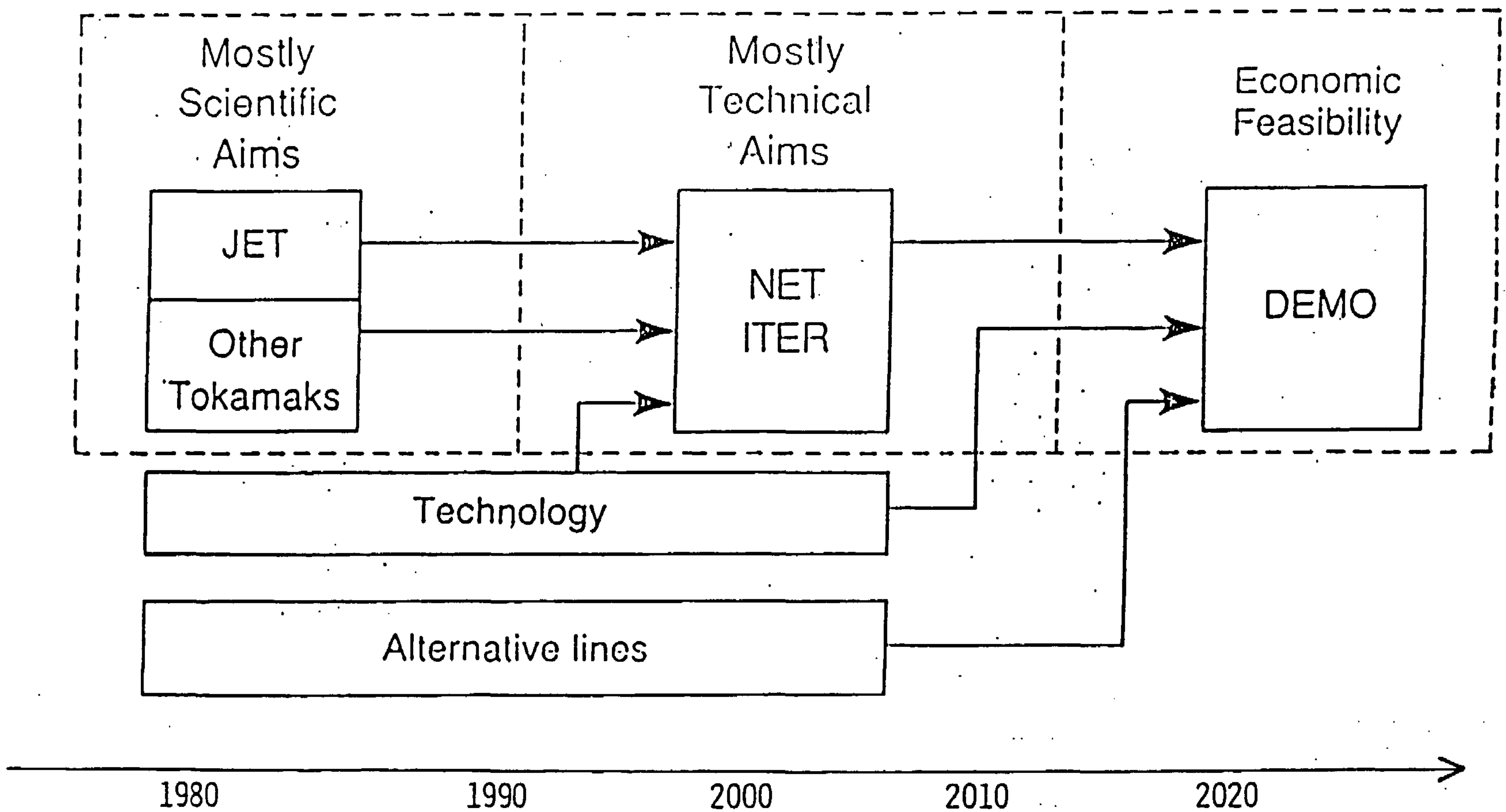
Suggestions to develop the inertial confinement approach, either by lasers or by heavy particles, have been made in Italy. Development of this approach would be at least as expensive as the present magnetic confinement programme.

Comparison between public R & DD expenditures in 1987 ($ 1987)

(% of the total)

	EC	JAPAN	US	COMM R&D	COMM. R&DD (incl. JRC)
	%	%	%	%	%
Energy conservation	9	4	8	3,3	8
Hydrocarbons	3	5	2,5	1,4	7
Coal	9	11	10,5	2,3	12
Nuclear Fission	39	44	33	7,8	20
Renewable energies	9	5	7	9,7	11
Advances nuclear + Fusion	21	28	18	73,0	41
Others	10	3	21	2,5	1
TOTAL	100	100	100	100	100

European Fusion Programme Strategy



THE THREE ABOVE-MENTIONED STEPS TOWARDS FUSION REACTORS (DEMONSTRATION OF SCIENTIFIC, TECHNOLOGICAL AND ECONOMIC FEASIBILITIES) ARE INTERDEPENDENT AND OVERLAP EACH OTHER.
AT THE TIME OF THE NEXT PROGRAMME REVISION (1-1-1991), THE PHYSICS AND TECHNOLOGY DATA BASE WILL PROBABLY BE SUFFICIENT TO ALLOW TO DECIDE ON THE STARTING DATE OF THE DETAILED DESIGN OF THE NEXT STEP.

Table 4.8.

Table 4.8. continued

VARIOUS APPROACHES TO CONTROLLED FUSION RESEARCH

APPROACH	CONFIGURATION	LINE
MAGNETIC CONFINEMENT	TOROIDAL	TOKAMAK
		ALTERNATIVE LINES: i) Stellarator ii) Reversed Field Pinch iii) Others
	OPEN	MIRROR
		OTHERS
INERTIAL CONFINEMENT	LASERS	
	LIGHT ION BEAMS	
	HEAVY ION BEAMS	
OTHER APPROACHES	Muon-catalyzed fusion and fusion with exotic fuels, are sometimes also considered as a remote possibility.	

- At present, the Community funding for fusion R&D amounts to about 200 MioECU per year, corresponding to an overall yearly expenditure of about 450 MioECU. An increase of the order of 100 MioECU/year will be necessary during the detailed design of the Next Step (1992-1994). A further increase will be required during the construction phase; its amounts will depend upon the frame in which the construction will take place.

- Europe is concentrating on magnetic fusion (only 2% expenditure devoted to inertial fusion, because of military implications), and within that approach: 80% expenditure are devoted to tokamaks and 20% to alternative lines (no research on open configurations).

- For comparison: the US fusion programme follows both the magnetic confinement approach (two thirds of expenditure) and the inertial confinement approach (one third). Within the magnetic approach, open configurations have recently been abandoned (a large mirror device has been moth-balled) and US magnetic research is - like in Europe - putting emphasis on tokamaks.

Non-nuclear energies and energy-saving technologies

4.59. Progress on non-nuclear energies has significantly evolved since research activities throughout the Community were stepped up from the early 1970s. The three successive Community programmes on energy R&D, together with the Community's demonstration programmes, have made an important contribution to this development in Europe and throughout the world.
The present state of research can be considered under four main headings:

(i) renewables

Solar power plants using photovoltaic cells have good long-term prospects provided the costs for the cells and the associated array structures can be reduced to about 1 ECU/Watt. Another important area is the development of passive solar technology to reduce conventional energy requirements for heating and cooling in buildings.

Wind energy research aimed essentially at cost reductions and reliability of larger wind generators. Long-term contributions of up to 10% of total electricity demand in some regions are conceivable.

Biomass research aimed also at reducing overall costs of collection and conversion of biomass through pyrolysis, gasification and liquefaction.

Geothermal R&D focussed on "Hot dry rock" technology development could provide heat and power almost anywhere in Europe where the geological conditions are favourable once economic feasibility is achieved.

(ii) Rational energy use

Development work is concentrating on heat pumps, advanced batteries and fuel cells. Heat pumps have the potential to reduce energy use in domestic and industrial heating by 30-50%. Advanced solid batteries are being developed for electrical vehicles. Fuel cells are being given particular attention in the field of energy production and storage.

Energy savings research in industry is focussing on component development and unit operations. In combustion research for stationary applications and in transport the main interest lies in the twin concerns of energy saving and pollution abatement.

(iii) Fossil fuels

One important field is the use and conversion of solid fuels, i.e. coal, peat, lignite, including the possible reduction of environmental pollution involved in the coal conversion processes. Research on liquefaction, combined cycle electricity generation with fluidised beds and coal gasification is being carried out in some of the Member States and at Community level. The use of coal/liquid mixtures is also being researched.

The bulk of hydrocarbons research is being carried out by the oil and gas companies themselves . At Community level the focus of activity is to increase the economic exploitable reserves accessible to the European oil industry. Drilling techniques are progressing as far as speed and reliability are concerned, especially in the deep and off shore drilling sectors. The same holds for production techniques including assisted recovery.

(iv) Energy Modelling

A fourth important research area embraces the analytical tools essential to understanding energy systems and their interface with the economy and the environment. This is an area where the value of coordinated activities among different research institutes and universities in a Community framework has already proved its worth (cf. Energy 2000 study cited earlier).

Future Options

4.60. Some of the technology options which were pursued in the aftermath of the first "oil crisis" have now come to an end from the point of view of research, because they have reached their goals and led to practical exploitation (one example is passive solar water heating which is now relatively widely developed in Europe, notably in Southern Europe).

Others have come to an end either because of specific technological problems encountered or because, for economic reasons, they do not offer the prospect of broad application. One example of the former is solar tower power stations.

On the other hand, new perspectives have emerged in the light of the trends described earlier. These are analysed more fully in the Annex on non-nuclear energies and summarised in table 4.9. The new targets are reflected at Community level in the Commission's recent proposal (the JOULE programme).

Table 4.9.

Priorities for non-nuclear energy R&D

Rational Energy Use (RuE)

- energy saving in buildings (energy management and control, heat pumps, solar energy applications)
- combustion technology (computer simulation of combustion, experimental verification with advanced non-intrusive diagnostics)
- industrial processes (heat recovery including development of heat exchangers and heat pumps, unit operations, energy and process system models)
- fuel cells (solide oxide, molten carbonate) high Tc superconductors, energy storage.

Renewables

- wind energy (large-scale wind installations, wind measurements and modelling)
- photovoltaic solar energy (crystalline and amorphous silicon technology)
- hydraulic energy (small hydro, study of potential of tidal and wave energy)
- biomass (production and storage of energy crops, biological and thermal conversion, pilot projects)
- geothermal energy (hot dry rocks, brine handling and corrosion and scaling of resources, study of deep geology)

Energy derived from fossil sources

- oil exploration and recovery techniques
- conversion of gas into liquid fuels
- combined cycle electricity generation with fluidised beds and coal gasification
- coal liquefaction and in situ coal gasification
- new solid fuel burners
- Magneto-hydrodynamics

Modelling energy and environment

- energy resources, energy supply and demand systems
- energy/environment interactions
- assessing impact of the Single European market on energy/economy

II IMPROVING THE QUALITY OF LIFE FOR EUROPE'S CITIZENS

4.61. European science and technology have a major contribution to make in three main areas:

- in producing a better **environment**
- in improving **health**; and
- in enhancing **safety**.

In addition there are important social responsibilities which must be addressed in the field of **bioethics**, which are considered separately below.

1. THE ENVIRONMENT (Annex 7)

4.62. There is increasing public awareness about the threat to the environment. Political leaders have responded to such concern and have proposed specific national, regional and international actions. The relevance of the European dimension has been formally recognised by the Single European Act, which identifies the protection and the improvement of the environment as a main objective of Community action.

4.63. Environmental problems are complex, in continuous evolution and incompletely known. Research provides therefore a vital basis on which policy responses can be evolved.

Though many problems are common to industrialised countries, and others are "global" in the literal sense of the word (namely they concern the whole globe and require world-wide collaboration), many problems are of a regional nature. Moreover, the European Community has regulatory responsibilities which must rest on sound scientific knowledge and reliable technical know-how. Joint research at Community level is therefore needed to provide this knowledge and know-how efficiently and economically (through complementarity and task sharing), and also to provide it in a form acceptable to all concerned.

<u>Research Needs</u>

4.64. An overview of the main issues for research is given in Annex 7. The research problems to which need or would greatly benefit from research at a transnational level in Europe are summarised in Table 4.10. They form three interdependent sets:

- **understanding the basic phenomena**
- **detection and interpretation of environmental changes**
- **prevention.**

Understanding the basic phenomena

4.65. Since the environment results from the complex interaction of many complex sub-systems, these must each be analysed (the stratosphere, the atmosphere, soil, inland water, the sea), and their mutual interaction studied by a systems approach (large ecosystems, climate in its regional as well as global aspects). In addition further efforts are needed to understand the environment within buildings, an area on which the Community's JRC is carrying out pioneering work.

A scientific approach to a system of this complexity would have been unthinkable a few decades ago. However, progress in basic mathematics, analytical techniques (including remote sensing from space), together with the huge capacity to store and analyse information by advanced computing now make this approach possible.

Detection and interpretation of environmental changes

4.66. A second set concerns the continuous detection and interpretation of environmental changes and the assessment of their consequences on human, animal and vegetable life as well as on geological resources and the sea. This is needed to provide public assurance that undesirable trends will be detected and also to provide data for the analysis outlined in 4.65. above.

Environmental epidemiology is included in this activity. The advantages of a European dimension in terms of statistical significance are obvious. Environmental toxicology and the development of suitable systems to identify and measure noxious agents is also important.

Prevention

4.67. The third set concerns prevention, including the development of clean technologies, the abatement of existing noxae and the elimination of toxic wastes. Research on the safety of industrial practice and compatibility of agricultural practice with the environment also belongs to this group. Since 'able 4.10.

Key Research Issues in the Environmental Field

A. Understanding the basic phenomena

- mechanisms of climate;
- atmospheric (troposphere and stratosphere) chemistry ("ozone hole");
- physiology of organisms under environmental stress (pollutants, drought, etc);
- functioning, stability and vulnerability of ecosystems, including stress ecology, natural population dynamics;
- metabolism and effects of xenobiotic substances in man, animals and plants;
- interactions between atmosphere, soil and water bodies;
- chemistry and biology of soil under the influence of pollution and other stresses (eg. agricultural practise), vulnerability to erosion;
- basic mechanisms of seismic and volcanic events;
- study of the effects of pollutants on materials;
- research into the prevention of accidents from hazardous industrial activities.

B. Detection and Interpretation of Environmental Changes

- improvement of methods for the analysis of the components of environmental matrices;
- earth observation by remote sensing techniques;
- elaboration of methods for storage and treatment of data on the environment, also in support of modelling;
- collection, compilation and assessment of data on environmental quality;
- description and evaluation of damage symptoms on organisms;
- epidemiological studies in human populations exposed to environmental pollution;
- studies on soil deterioration and erosion;
- recording of indicators for climatic changes.

C. Prevention of Environmental Damages

- development of sound technologies for pollution abatement and waste recycling and disposal;
- development of alternative, less polluting technologies and products ("clean technologies");
- methods for the ecologically sound management of ecosystems and renewable resources;
- rehabilitations of disturbed or degraded ecosystems;
- development of safer technologies (chemical plants);
- investigation of the possibilities to predict, and to mitigate the consequences of, disasters of man-made and natural origin;
- design of methods and materials for the protection and restoration of the cultural heritage.

these activities are continuously evolving, so must the research itself. Studies on the prevention and mitigation of man-made and natural hazards also belong under this heading.

Global Climate Change

4.68. The greatest source of concern and the most difficult to analyse is the so-called "greenhouse-effect".

Continued burning of coal and oil since the beginning of the industrial era has resulted in increasing quantities of carbon dioxide being added to the natural composition of the planet's atmosphere. Although the oceans act as a large sink through complex phenomena involving phytoplankton photosynthesis, large quantities of carbon dioxide remain in the atmosphere, which is now enriched in this gas by 15-20% with respect to pre-industrial values. Natural recycling of CO_2 by green terrestrial plants is also seriously impaired by deforestation.

Carbon dioxide is not transparent to the infrared light radiated back by the earth's surface as a result of incoming solar radiation, which means that heat is trapped in the lower layers of the atmosphere. The planet is thus being heated in a similar way to that of a greenhouse.

Scientific consensus is that such heating will produce an increase in the global mean surface temperature of 1.5 to 4.5°C over the next 50 years. The atmospheric accumulation of other greenhouse gases, such as methane, nitrous oxide and the chlorofluorocarbons also plays a role.

The climate change resulting from such heating would have serious consequences for agriculture, and a significant rise in the level of the seas is expected from the thermal expansion of the oceans alone, apart from the melting of the ice caps.

4.69. The issue has global dimensions and is made enormously complex by the uncertainties still affecting the measurement of global heating, the regional and seasonal features of the anticipated climatic changes (precipitation patterns, frequency of droughts and other extreme events, etc.), and the uncertainties about future energy patterns. It involves an assessment of the rates of carbon dioxide production, of the role of the oceans and biosphere as sinks and sources, of the rate of deforestation, the possible shifts of bioclimatic zones, the modelling of all the interactive components of the climate systems (atmosphere, oceans, cryosphere, biosphere), and an appreciation of the consequences of energy policy options.

4.70. Intensified research is needed to reduce as much as possible, and as soon as possible, the remaining uncertainties, especially as regards the timing, the magnitude and the regional distribution of climate change; the impacts which the change would have mainly on agriculture and water resources, on the sea level and its consequences for the coasts and coastal-based economic activities, on socio-economic structures in general; and on environmentally benign energy options capable of leading to reduced carbon dioxide emissions. At the same time research is needed to ensure preparedness in respect of changes which cannot be prevented in time, so at least alleviate their consequences.

4.71. Such research requires European and world-wide cooperation, not only because of the multi-disciplinary character of the issue, but also in view of the need for a coordinated approach to choices that might have to be made on future energy, agriculture and industry policies and on measures able to counteract or alleviate the affects of the climate change.

European Action

4.72. At a European level the Community will need to mobilise various modes of action to satisfy research needs for the understanding, monitoring, protection and improvement of the environment, starting from its own "in house" research carried out in the JRC (a guarantee of independent high level S/T know-how for the whole Community), to a shared-cost action and international collaboration.

In the latter context a major contribution at the Community level to the implementation of the International Geosphere-Biosphere Programme (Global Change) deserves careful attention.

At the same time an adequate liaison needs to be assured with other transnational environmental R&D actions in Europe, and notably within EUREKA and with the space agencies (in particular with ESA) to ensure a proper balance between the space instruments themselves and the requirements of the scientific community (see also point 4.106. on Earth sciences).

2. HEALTH RESEARCH (Annex 8)

Research Needs

4.73. Three main issues in the field of health provide the starting point for consideration of research requirements:

(i) **the rising cost of health care and delivery systems.** Health costs in the Community amount to more than 200 milliard ECU per year, the equivalent of about 8% of GNP. They are rising both because of the increasing sophistication of medical equipment and opportunities for treatment, and because of the growing incidence of certain diseases. This is related in part to:

(ii) **the "greying" of Europe's population.** Europe faces the prospect of an ageing population over the period to the end of the century as a result of lower reproduction rates in the 1970s and 1980s, on the one hand, and higher life-expectancy, on the other. This will mean a quantitative increase over the coming years in age-typical illnesses, with consequences for the demand on medical services;

(iii) the need for major progress in the fight against diseases such as **cancer and AIDs**, as well as those related to the environment and life-style.

4.74. Public health research in the Community, which is about half that of the USA, amounts to less than 2% of total health costs. If properly aimed, it can make a major contribution to meeting all three of the needs described above. Research on prevention, care-delivery systems and organisation is essential to ensure the best value-for money in health delivery (i); while the need for targetting research efforts on the specific problems posed under (ii) and (iii) is widely recognised.

European Action

4.75. Research is proceeding on all these fronts in the Member States, but often in a fragmented manner. Most national research programmes in the field of medicine and health consist of a large number of relatively small projects carried out by scattered and relatively small research teams often working independently at universities, hospitals etc. This is an area where the value of more coordinated action across national frontiers has already been recognised and concerted action within the Community framework has proved its worth. The principal characteristic of this concerted action is that Member States themselves select the projects for coordination at Community level and execute the work themselves; while the Commission coordinates the national research contributions.

4.76. The future action lines in health research recommended by the Advisory Committee for the Community's Health Research Programme are summarised in table 4.11. It will be seen that they correspond very clearly to the needs described earlier. They also include one other important aspect of R&D on health research - the development of medical technology - which has an economic as well as social dimension.

3. SAFETY (Annex 9)

4.77. The safety of the environment in the home, at work and in travel is a fundamental social need, linked also to the control of costs in health. The contribution of R&D to safety is pervasive - from the use of new materials to the development of robotics, from the improvement in vehicle and aircraft technology to the development of monitoring and sensing techniques to identify potential dangers in the environment and in machinery and equipment long before they occur.

Industrial and Road Safety

4.78. In the field of **industrial technologies and materials** increasing attention will have to be given to the safety aspects of design of consumer goods and also to the safety of the working environment itself, as foreshadowed in the Single European Act itself. An important issue, where R&D has a role to play, is the development of common safety standards in respect of the new technologies themselves. Lasers for industrial use are a significant example.

4.79. The potential contribution of R&D to **road safety** in the longer-term is particularly great, and major efforts are being undertaken in Europe to develop both the "intelligent car" and the road infrastructure that it will require. This is an area where collaborative transnational efforts are important both because of the scale of the research requirements and the need for a harmonised approach. The Community itself has launched a significant programme (DRIVE - Dedicated Road Infrastructure for Vehicle Safety in Europe) which is designed to help coordinate efforts on the infrastructure; while within EUREKA the PROMETHEUS project and other related transport R&D projects are focussed on

FUTURE ACTION-LINES PLANNED IN HEALTH RESEARCH

CANCER

Cancer research training scheme
Clinical treatment research
Epidemiological research
Early detection and diagnosis
Drug development
Experimental (fundamental) research

A I D S

Disease control and prevention
Viro-immunological research
Clinical research

AGE-RELATED HEALTH PROBLEMS

Reproduction
Ageing and diseases
Disabilities

ENVIRONMENT AND LIFE-STYLE RELATED HEALTH PROBLEMS

Breakdown in human adaptation
Nutrition
Consumption of illicit drugs
Infections

MEDICAL TECHNOLOGY DEVELOPMENT

Diagnostic methods and monitoring
Treatment and rehabilitation
Technical and clinical evaluation

HEALTH SERVICES RESEARCH

Research on prevention
Research on care delivery systems
Research on health care organization
Health technology assessment

the in-car research requirements. Coordination of effort is a major preoccupation.

Nuclear fission safety

4.80. A third area where continuing safety research is of the utmost importance is **nuclear fission**. The dependence on nuclear power for energy supplies varies significantly as between Member States. But as the Chernobyl accident demonstrated forcefully, the safety of nuclear power is a matter that concerns each and every Member State.

4.81. The needs and outlook for research on nuclear safety both outside and inside Europe are presented in annex 9. The USA used to be in the forefront of research but the Americans have now reduced their efforts. Japan is continuing to make a significant effort. The results of Soviet work in the field are not fully available, although some opening has occurred after Chernobyl. Europe has moved into the forefront, with some countries playing a leading role (France, Germany and the United Kingdom).

4.82. In the field of **radiation protection** (where Community research programmes have either directly supported or coordinated 80% of the effort inside the Community) continuing research is needed on:

- Human exposure to radiation and radioactivity (measurement and interpretation of radiation dose; transfer and behaviour of radionuclides in the environment, making full use of the information coming from Chernobyl).

- Effects on the human body of exposure to radiation; assessment, prevention and treatment.

- Management of risk of exposure to radiation.

4.83. A major information effort is also required. In the aftermath of Chernobyl, political and social considerations overrode scientific and technological arguments about radiation levels and their effects. Scientists and technologists are partly responsible for this. Before the event they underestimated the importance of systematic information and education of the public; while after the event they confused the public by non-homogeneous technical jargon and disagreements about details. This has had negative consequences in some countries on public confidence in the nuclear community. This confidence can and must be restored by greater openness and willingness to communicate, not only in terms understood by fellow scientists, but also in terms accessible to a much wider public progress. Particular efforts must be made in this direction over the coming months and years.

4.84. Continuing research work is also needed on <u>reactor safety</u> (notably the phenomenology of low probability severe accidents; mitigation of the consequences of severe accidents; structural behaviour of reactor components; fuel behaviour; improved passive safety mechanisms); the <u>safety of the fuel cycle;</u> <u>radioactive waste management</u> and <u>storage</u>; <u>decontamination and dismantling techniques</u> for nuclear plants; and control of fissile materials.

4. BIOETHICS

4.85. The progress in biology described earlier is so rapid and the resulting applications so pervasive and substantial that the utmost attention must be given to their impact on individuals and society. Ever since biotechnology began to open up major new possibilities, notably in the field of genetic engineering, biologists themselves have been conscious of this need . More than a decade ago they proposed and implemented a moratorium on genetic engineering research until the conditions for safety were identified. Since then, public opinion as well as public authorities has become progressively aware of the problem and bio-ethics has become a subject of constant attention and action, not only at the national but also at the international level (for example the yearly Bioethics Conferences of the Summit of industrialised countries). In Europe itself, the Council of Europe has created a standing Committee for bioethics.

4.86. The Community's obligations in the field of health and safety, as well as the need (for competition reasons) to avoid the emergence of widely divergent legislation in the Member States on biotechnological applications and products are compelling reasons for a Community approach to this issue. Such an approach would contribute to public confidence in science in the Community, without which the European Technology Community cannot be soundly built.

In the first half of 1988 the German Presidency of the EC Council, in complete agreement with the EC Commission, called for the pursuit of bioethics at Community level. Some progress has been made. The momentum should be maintained and increased. It is essential that ethical, societal and juridical considerations accompany science and precede technological developments.

III FUNDAMENTAL RESEARCH - THE ESSENTIAL UNDERPINNING

4.87. A solid capacity in fundamental research, both free and targetted, provides the essential underpinning to the research in specific fields described above. As the provider of new ideas and knowledge it offers opportunities for quantitative change and new openings of both economic and social significance, widening and deepening the scope of technology options. It is therefore of vital importance to Europe's quest for independence and autonomy.

4.88. In the USA, while Federal support for non-military applied research and development has decreased, that for fundamental research has increased over the last 5 years (cf. chapter 2). Japan is now fully aware of the need to strengthen its basic research at home, and in an international framework has, for example, launched the Human Frontier Science Programme for joint development of fundamental research in neuro- and cell biology by the Industrialised Summit Countries. In the USA scientific research proceeds on a very broad front, and gives opportunity to "free", individual choices, whereas in Japan targetted basic research prevails. The implications of this new international emphasis on basic research are discussed further in chapter 5.1. below.

4.89. European excellence in fundamental research is demonstrated by the attribution of Nobel Prizes and by the other indicators of performance discussed in Chapter II. However, most European researchers would think that US occupies the first place in their own field[29] . During the last decade, industry and universities have become increasingly aware of each other. The questions posed by the further evolution of this trend in Europe are also discussed in chapter 5.

The Organisation of Basic Research

4.90. One permanent problem for basic research policy is the distribution of resources between a small number of large and expensive projects (so-called "Big Sciences") and more diffuse and less expensive activities of small groups and individuals.

The question has been partially solved in Western Europe by several multinational ventures for the common pursuit of Big Sciences (eg. CERN for high energy physics, ESO for astronomy,

29 This emerges clearly from **The Community of Science in Europe**, Mark N.Franklin, a study made on behalf of the CEC in collaboration with the European Science Foundation (contract STI 042, November 1986) and subsequently published by Gower (ISBN 0566056321).

ESA for space, EMBL for biology, ILL for neutron sources, ESS for synchroton radiation[30]). Moreover, some very large national facilities, such as the German centre in Hamburg are open to bilateral collaboration. These activities have been successful and there is growing collaboration among them, which is a welcome trend. In the future, international collaboration in Big Sciences may have to extended world-wide. Controlled nuclear fusion is a case in point, as discussed earlier.

Simultaneously, several networking initiatives have been taken so as to assure the benefits of complementarity and task sharing among individual scientists and small groups. The European Science Foundation (ESF), the European Molecular Biology Organisation (EMBO) and the European Community's Stimulation programme (now called the SCIENCE Programme), together with the Community's sectoral R&D programmes, play important roles in this context.

There remains, however, the question of access to advanced middle-size research devices and the development of expensive scientific instrumentation. Given the cost and sophistication of many of the facilities in question it is not feasible to imagine that they could all be available in every European country, let alone very major laboratory. Particular efforts are therefore needed to provide a framework for cooperation among national teams and to reduce the risk of fragmented research efforts. In 1989, in recognition of this problem, the Community will initiate a pilot programme to support mutual access to large national installations. Suggestions have also been made within CREST to launch a feasibility study on joint European development of scientific instrumentation.

Developments in specific scientific disciplines

4.91. Within the broad area of fundamental research, some developments in mathematics, physics, chemistry and the earth sciences should be highlighted. Fundamental biology, together with basic biotechnology and its applications was dealt with earlier in section I.

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30 CERN - European Centre for Nuclear Research
EMBL - European Molecular Biology Laboratory
ESO - European Organisation for Astronomical Research in the Southern Hemisphere
ESA - European Space Agency
ESF - European Science Foundation.

Mathematics

4.92. In modern mathematics, the theory of non-linear phenomena and related geometrical ideas deserve attention because they are revolutionising the theory and application of dynamic systems, with far-reaching implications for physics, chemistry, biology, meteorology, ecology, technology and, probably, sociology and the science of economics. Most real world problems are complex and non-linear; therefore they fall outside the scope of traditional closed-form analysis. The subtle and versatile techniques of dynamic systems theory now make it possible to model and to explore the evolution over time of both natural and man-made systems.

4.93. The combination of theoretical advance and significant computing power now makes it possible to distinguish those systems which evolve towards a stable solution; those that evolve to a situation of stable oscillation; those that reach alternative final states depending on small differences in the initial conditions; and those that develop into a state of steady but perpetual chaos. The search for an underlying order in the ensemble of all chaotic trajectories in a chaotic system remains a major challenge to modern mathematics.

4.94. Specific examples of the impact which the theory of non-linear, complex phenomena has on other branches of science and technology can be found in Annex 10. These include the development of the first optical version of a transistor, and demonstration of the feasibility of an all-optical computer; advanced modelling of climatic change (of relevance to the Global Change initiative discussed earlier); improvements in the functioning of the internal combustion engine.

4.95. The theory of non-linear phenomena was pioneered in Europe. And Europe continues to play a significant role . Research projects in fields such as those mentioned in 4.94. above are amongst those accepted, after stiff competition, under the EC Stimulation programme, reflecting the continuing interest of European researchers in pushing out the frontiers.

Physics

4.96. In addition to encouraging further collaboration among existing multinational ventures in high energy physics etc., greater attention needs to be given to the exploitation of technology spin-offs. This must be done without side-tracking the main projects. The scope for closer links with EC technological research programmes and to the industrial firms participating in them could be usefully explored.

4.97. As far as fundamental physics are concerned, particular attention needs to be given to the study of condensed matter, because of both its implications for materials technology and its need for large and medium scale investigation facilities (such as synchrotron radiation and neutron sources, high power lasers, irradiation devices). The USA and Japan are well provided with such devices. In Europe, however, they are often unique and, (as suggested above), could be open to increased transnational use.

A suggestion along these lines was made in 1985 by the UK Sciences and Engineering Research Council and could be pursued through the EC programme of Access to Large Installations.

4.98. Among the scientific developments of particular interest in terms of the expected technological impact, is **high temperature superconductivity** (the ability of electrical currents to flow without resistance), which was discussed in section 1 above in the context of industrial materials.

4.99. Other areas of the physics of matter should also be mentioned, because of their electromagnetic, optical or mechanical properties, such as "low-dimensional" (i.e. very thin) materials, artificially structured materials, material obtained and performing under extreme conditions, liquid crystals, quasi crystals. Progress on these subjects has a high priority in the USA.

4.100. Developments in optics and lasers are also interesting: in advanced optics, Western Europe is in a good position and has pioneered some recent developments (for instance, the Joint European Optical Bistability Project within the EC Stimulation Programme).

In lasers, however, in spite of some important national and multinational developments inside BRITE and EUREKA, European efforts are not on a par with those in the USA, where there has been a significant spin-off from military R&D, and notably SDI. The need for strengthened joint European action in this field merits careful consideration.

Chemistry

4.101. Chemistry is also developing rapidly, "pushed" by progress in computing, mathematics and physics instrumentation and "pulled" by biology and by a pervasive market demand.

Here as in other technological areas, quality is becoming more important than quantity. From the scientific standpoint, computer modelling and prediction as well as progress in analytical tools[31] are changing the way in which chemicals are isolated, identified, designed by computer and synthesized. Progress in the theory of chemical reaction is leading to a whole spectrum of new catalysts (synthetic enzymes, catalytic surfaces, cluster catalysis, homogeneous catalysis) and photochemically primed events. At the same time a number of techniques, including "intelligent" selection membranes are improving separation and purification.

4.102. Europe occupies a very good position both on the market for chemistry-based products (see chapter I) and in basic science. There are, however, some problems of public acceptance because of the issue of toxic waste. Possibly related to the latter, there is also some difficulty in recruiting a sufficient number of high quality students (cf. chapter 5).

Earth Sciences

4.103. The importance of progress in the earth sciences for the prediction of natural phenomena with major economic and social impacts (eg. earthquakes), as well as for the rational exploitation of land resources goes without saying.

4.104. The oil companies, in particular, are themselves engaged in significant basic and applied research. Deep drilling has been pioneered by the Soviet Union; and there are major efforts in the USA. Good European coordination is assured by the European Science Foundation (cf. the Geotraverse Project supported by the EC). At a national level, the German government recently decided to initiate a very ambitious programme to drill a very deep (10 km) hole through the crust of the earth. This is important because other deep drills (notably those carried out in the Soviet Union)have suggested that conventional methods in exploration of the earth crust may be affected by artifacts.

4.105. Oceanography, as part of the earth sciences, is being actively pursued throughout the world. The US is leading the field, with a high level of participation of Japan and some European countries. Some aspects such as the study of the coastal zone, the interface between the ocean and the atmosphere (important for understanding global climate change) will be

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31 Mass and optical spectroscopy
NMR: Nuclear Magnetic Resonance
ESCA: Electron Spectroscopy for Chemical Analysis
XAFS: Xray Absorption Fine Structure
XANES: Xray Absorption Near Edge Structure
Neutron activation, neutron scattering, chromatography.

5.4. This is a matter for all European governments to reflect upon. In many areas basic research is very expensive. This is obvious for fields like high energy physics or oceanography or space. But many smaller-scale basic research investigations now also require high-cost sophisticated equipment. Costly basic research cries out for a joint or coordinated approach whether through the sharing of expensive facilities or the formulation of coordinated work programmes. Resource-pooling is already happening to some extent in Europe, notably through CERN, EMBL, ESO, the basic research programme of ESA and ESF[33]. The SCIENCE programme of the Community is also helping to demonstrate the usefulness of joint approaches to speculative basic research. And in ESPRIT II and under the new BRITE-EURAM programme currently before the Council provision has been made for joint projects on more targetted basic research topics than hitherto.

5.5. The Commission believes that this trend should be reinforced during the coming years. It considers basic research to be an essential aspect of Community efforts, underpinning research aimed at improving competitiveness and research on the societal problems facing Europe. Basic research supports industrial development longer-term alongside - but distinct from - shorter-term product development. Basic research also performs the vital function of "training" researchers in the paradigms, methods and norms of research . To neglect this human capital would seriously compromise Europe's long-term prospect. As suggested in Chapter IV, biology is one field where new fundamental research efforts are now needed to lay the foundations for more applied research later, notably in the fields of health and agriculture.

Private industry should also be encouraged to invest more in basic research for the longer-term. Historically, important advances in fundamental research have been made by scientists working within private sector companies (one example is the work on beta-blockers which recently led to the award of a Nobel Prize to Sir James Black).

(ii) <u>The links between industry and the universities</u>

5.6. The Japanese technological success is partly attributable to close relationships between universities, industry and government, including the establishment of a series of

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33 CERN - European Centre for Nuclear Research
EMBL - European Molecular Biology Laboratory
ESO - European Organisation for Astronomical Research in the Southern Hemisphere
ESA - European Space Agency
ESF - European Science Foundation.

specifically cooperative ventures involving firms, universities and MITI laboratories[34]. In the USA industry-university cooperation dates back over many years, but in the 1980s it has witnessed a qualitatively new development in the form of major multimillion dollar contracts between companies and universities enabling companies to be the first to have access to the work carried out on campus in a broad scientific domain and for a period of years[35]. In Europe the traditions of industry-university links vary considerably but the general trend has been towards a reinforcement, with industry driven increasingly by the need to tap scientific knowledge and universities by financial constraints. One associated phenomenon has been the growth of "science parks" on both sides of the Atlantic (eg. Durham in the USA, Cambridge in the UK). Community cost-sharing programmes such as ESPRIT and BRITE have aimed to encourage the links by deliberately providing a framework in which industry research workers and those in universities can team up in specific R&D projects.

5.7. The trend towards close industry-university links in Europe should be further encouraged. It is one more potential means of maximising the use of scarce R&D resources. But there are two caveats. The first is linked to the balance between basic and applied research (point (i) above). There is a risk that increasing university dependence on industry may encourage more and more university resources to be devoted to short-term problem-solving to the neglect of longer-term and more fundamental research. Secondly, there is a risk that exclusive relationships between companies and universities or university departments may lead to restrictions on the availability of research results. This is already an important issue in the USA, and it is likely to grow in importance in Europe. Already the OECD, in a recent report has expressed concern about the implications for the longer-term[36].

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34 notably the JISEDAI (Basic Technologies for Future Industries) and ERATO (Exploratory Research for Advanced Technology) programmes. This is not to say, of course, that the Japanese experience can be directly translated to Europe.

35 Well-known examples are the ten-year-agreement between HOECHST and the Massachusetts General Hospital for the creation of a department of molecular biology; and a five-year-agreement between MONSANTO and Washington University in St.Louis for research on proteins and peptides.

36 Science and Technology Outlook, 1988 OECD, Paris 1988.

The Commission has shown the way to avoid the risks in Community programmes through the nature of the contractual arrangements made with participants, which provide a basis for both assuring the dissemination of research results to interested parties while safeguarding the interests of the specific research groups involved. But this is an issue which will need to be considered further in all research funding programmes of a national as well as a transnational nature.

5.8. Two other more specific developments at a European level also deserve attention in the context of links between universities and industry. The first is the creation by a number of multinational companies of a European Institute of Technology aimed specifically at creating links between industrial R&D efforts and pre-competitive university research. The second is the growing industrial interest in participation in the multidisciplinary collaborative research associations in Europe known as European Laboratories without Walls (ELWWs). This latter issue is currently under discussion by the Community's Management and Coordination Advisory Committee on Biotechnology and by the Industrial Research and Development Advisory Committee (IRDAC).

Basic research must be given adequate support and attention, if solid foundations for the future are to be constructed.

Industry-university links should be further encouraged, but attention must be paid to the consequences for the nature of university research work and the availability of research results.

EDUCATION AND INFORMATION

(iii) Broadening and deepening the technology culture

5.9. The conduct and management of research and the application of the technologies that result from it all depend on the skills of individuals. The most successful societies in the post-war period have been those that have sought actively to develop those skills, to create a general climate of technical literacy and to encourage the emergence of large numbers of highly trained scientists and engineers. In the future these skills will be ever more in demand.

5.10. Japan has witnessed the most significant growth in general technical literacy and in the numbers of research scientists and engineers. In the USA the numbers are high but stagnant, and increasingly worries are expressed about the future availability of the manpower needed to carry through the new technological revolution. In Europe the traditions of some countries are stronger (Chapter II) than others. But there are widespread mismatches between the output of traditional education and the demand for skilled manpower. There are particular shortages of highly qualified scientific personnel in the smaller and less developed countries of the Community (see (viii) below). But even in some of the larger countries the shortages of science-based skills are already a source of some concern and there are new worries about a "brain-drain" as US universities and companies seek to entice the brightest and the best to meet their own future needs for highly qualified scientists and engineers. The US drive will not be directed only at Europe: a key issue in the USA now is whether and how to encourage the large number of Asian students at US universities to stay on in the USA. But Europe will continue to be a major potential source of supply of highly trained research scientists to the USA.

5.11. The question of science education, training and skill acquisition is one principally for national governments. Industry also has an important role to play and many industries have already increased their own training efforts as a partial solution. But the value of complementary action at Community level has already been demonstrated by the success of the COMETT and ERASMUS programmes. Alongside, the Community must now move forward in improving the attractions of the wider European framework to the most able national research workers by more rapid progress in creating a genuine **Researchers' Europe**. As the scope of research needs widens and deepens it is less and less possible for individual countries, however large, to offer centres of excellence in every field. It becomes in consequence increasingly important for researchers to be able to take advantage of the possibilities offered by the whole European Community. At present the mobility of researchers is hampered not only by language problems, but also by practical problems such as different social security systems, pension arrangements and so on. Progress in this area will be greatly facilitated by the removal of barriers to the free movement of labour within the Community in the framework of progress towards the Community's Internal Market.

(iv) The public acceptability of science and technology

5.12. A related issue is that of public acceptability of science and technology. Public concern has two facets. On the one hand, people worry about the dangers and risks associated with new technology, and particularly the possibility of involuntary accidents (a repeat of the Chernobyl accident, the escape of dangerous biological cultures, the possibility of major chemical spillages etc.). On the other, there is ethical concern about the possibilities offered by scientific developments, for example in the field of genetic engineering, which may be voluntarily exploited.

5.13. Concern about new scientific developments is often based on fears of the unknown. This is particularly true at present in the case of biotechnology. Public opinion surveys in the USA and in some European countries have revealed considerable confusion about its benefits and risks. They have also demonstrated that the degree of acceptability of new technologies such as biotechnology depends heavily on the level of general education and on the depths of understanding of the issues surrounding a particular scientific development or technology[37].

It is important for the proper functioning of our democracies and for the advance of European society that popular understanding of the issues should be improved. Only in that way will sensible choices be made; a sound regulatory environment established to minimise the risks; and an informed basis created for examination of the ethical issues. The role which information can play in this respect is visibly illustrated in the case of the Netherlands where tough regulations on safety matters combined with a high quality, extensive and systematic provision of public information in schools and through the mass media has helped to reduce concern about recombinant DNA techniques.

5.14. The Commission has a role to play on behalf of the whole Community in improving public understanding about these important issues by help in the design and development of consistent and objective information material. The prospect of a large expansion of satellite broadcasting could offer new opportunities for Community-backed programmes on science and technology issues.

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37 See Science and Engineering Indicators, 1987,NSF Washington; "Public Opinion on Biotechnology: (un)known, (un)loved?" in Biotechnology in Holland, 1985/5; Democracy and Biotechnology, Mark Cantley, in Swiss Biotech, 5(1987).

More attention must be paid in Europe to the development of human resources, both to pursue scientific knowledge and to apply its results. A particular effort must be made to provide an attractive environment inside Europe for research workers in which the brightest and the best have easy access to the centres of excellence which are available in different countries.

At the same time a particular effort must be directed to improve public understanding of science and technology issues.

INDUSTRY AND THE PRIVATE SECTOR

(v) Encouraging the private sector to invest more in R&D

5.15. A major challenge for Europe is to increase the share of its economic resources that are devoted to investment in R&D, which for the bulk of European nations is well below that of the USA and Japan (Chapters II and III). Much of the efforts must be made by industry itself, which has been the leading source of the growth of funds in non-military R&D expenditure in the USA and Japan. It is in industry's own interests to invest more in R&D as the source of longer-term improvements in competitiveness and profitability. But the growth in industry-funding of R&D is not uniform across Europe. Industry-funding of R&D must be focussed not only "downstream" on projects of short-term commercial benefit. Japanese and US industry is spending more and more money on targetted basic research to create the conditions for longer-term advance. European industry must do the same.

5.16. Factors of importance in encouraging investment in R&D and innovation include the general economic climate, tax regimes, and (for innovative investments) the existence of developed venture capital markets (the latter being of particular importance to nascent or small companies). In Europe overall rates of industrial investment vary widely; each country has its own system of tax or other incentives to support industrial R&D; while venture capital markets (which are developed in the United Kingdom, and to a lesser extent in the Netherlands and Belgium) are essentially national markets.

5.17. The Community's R&D programmes on industrial technologies (ESPRIT, BRITE in particular) have already played a role in helping to commit industry-funding of R&D through cost-sharing mechanisms. A number of initiatives at European level have also been taken to encourage investment by small and medium-size enterprises. **The European Venture Capital Association** (ECVA) was created in 1983 with the support of the Commission. In collaboration with ECVA the Venture Consort project aimed at promoting transnational financing of innovation in SMEs was launched in 1985. The Commission has also recently approved the launching of an initiative for financial support for the establishment of "seed capital" funds and for a European network of such funds.

The barriers to transnational industrial and technological cooperation have already been analysed separately in a separate Communication by the Commission, which contains an action plan[38].

The Commission is also exploring with the financial Community whether it would be appropriate to establish one or several investment companies specialised in this kind of project. It is also exploring with the insurance companies the most appropriate way to insure the risks involved and thus to remove one of the main obstacles to investment in innovative projects. These two initiatives (**Eurotech Capital and Innovation Insurance Facility**[39]) aim to ensure the industrial and commercial application of the results of European R&D programmes.

In addition, the European Investment Bank has made available loan finance to SMEs, with priority for innovative investment, using its own resources and those of the New Community Instrument (NCI). Between 1985 and 1987 its loans for investment in high technology amounted to 1,094 million ECU. The proposed NCI V includes investments in high technology as one of the two priority areas.

The Commission is also working towards improvements in the flow of information between potential financiers and the promoters of projects who are seeking external finance, by establishing a project data-base.

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38 COM(88)114 final, du 28.3.88

39 formerly EUROTECH INSUR

5.18. Alongside action to improve the flow of private funds to industry the Commission has operated competition policy in such a way as to balance the need to increase the overall level of investment in industry in R&D against that of avoiding distortions to competition. A specific framework has been established for the handling of joint agreements between enterprises in R&D and for state aid regimes for R&D projects. As the Community moves further towards the completion of the Internal Market, with a consequent increase in competition, on the one hand, and concentration, on the other, the application of competition policy to R&D and particularly to transfrontier R&D arrangements will become an increasingly important issue.

(vi) The diffusion of technology

5.19. R&D itself lies at the centre of a complex feedback process involving education (upstream) and innovation and diffusion or technology transfer (downstream). As well as investing more in R&D, industry also has to know and understand the new technologies coming on the market and to invest directly in them. An expert group of the OECD has recently noted that "the economic advantages of new technologies derive from their diffusion rather than from their refinement..... New technology in itself has hardly any economic advantages as long as it is not effectively used and widely applied...."[40]. The sluggish growth in European demand for electronic goods (chapter 1.2) is one important example of the slow rate of adoption of new technologies. It should also be said that the benefits of research to develop those technologies are also enhanced the more widely they are disseminated, even though this may not always be in the immediate commercial interest of an industrial firm or research consortium.

5.20. Technology transfer is another area where the Japan is in a stronger position than Europe. In some European countries (notably Denmark) major efforts have been made in recent years to encourage the spread of new technologies within industry and commerce through information campaigns and specific financial support systems for the private sector. But the degree of attention varies. Moreover, the public policy efforts are based essentially on the spread of technologies within national borders.

Effective dissemination of the results from the Community's own research activities contributes to the goal of improving

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40 Science and Technology Policy Outlook, OECD 1988.

information . This is the purpose of the VALUE programme. But the impact of measures in this field is directly related to the volume of Community research activities. This is why complementary actions such as those carried out under the SPRINT programme to create more favourable conditions for innovation and technology transfer will need to be reinforced in the future. Outside experts have recently underlined the importance of a vigorous effort in this direction and called for a strengthening of the SPRINT activities[41], and a new and larger programme has now been proposed by the Commission.

The importance of stimulating demand for new technologies cannot be overstressed. A key issue is the availability of information about particular technologies and their expected returns. Organised "watch" programmes have proved to be very efficient in Japan. Consideration needs to be given in Europe to how to improve this information and to stimulate the consumer (of capital or consumer goods) to think about how new technologies could help satisfy his needs.

The role of Member Governments and the Community in standardisation and normalisation of technologies is also important in the context of shaping the market for adoption of technologies.

Industry must be encouraged to invest more in R&D, and top management should be more closely involved than is often the case.

A major effort is needed throughout industry and the services to improve awareness and information about new technologies so that the fruits of R&D can be widely and quickly spread.

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41 Evaluation of the first BRITE programme (1985-88) Research evaluation report n°25, CEC 1988.

(vii) Increasing coordination among national policies

5.21. Chapter III underlined the importance of increased coordination of national policies as a means of saving money overall, increasing the returns to R&D investment, encouraging the broadest use in the Community of "best practice" in research management, and ultimately leading to greater complementarity in national programmes. This is why Article 130H of the Single European Act expresses a political commitment on the part of the Community's Member States, in liaison with the Commission, to coordinate among themselves their policies and programmes at national level.

5.22. The first step in better coordination must be to improve mutual information and understanding about national policies. Such information about what others are doing will in itself contribute to future decisions on national programmes or policies. The second is to identify fruitful areas for more specific cooperation. These can be of a bilateral or multilateral nature. Some may be appropriate for Community-wide coordination. There are numerous formulas possible for developing cooperative activities (such as specific bilateral or multilateral agreements, joint agreements on national participations in major projects such as CERN, EMBO, or supplementary programmes in a strictly Community framework as provided for under Article 130L of the Single European Act). At Community level the formula of "concerted action" at, which has proved highly successful in the fields of health and environment and which requires a minimal amount of Community public funding, should be more widely used.

(viii) Improving the cohesion of the Community

5.23. The technology gap between the less-favoured regions (LFRs) and the more economically advanced areas of the Community is greater even than the economic gap (Chapter III). In most LFRs there is a lack of physical infrastructure for research and development; there is a chronic shortage of skilled scientific personnel; companies are less oriented towards innovation. Improving the RTD base is essential to ensure adequate growth and development in the LFRs.

5.24. The better coordination of national research activities will certainly have some spin-offs in regional terms. And the Community's VALUE programme will ensure the spread of research results throughout all the regions of the Community, helping to reinforce the knowledge base in the LFRs. Moreover, the Community's own research programmes have already promoted relations between researchers in LFRs and their colleagues elsewhere, encouraging the "trickling down" of best practice and experience. But substantial improvements in regional competitiveness cannot be tackled primarily through Community research programmes themselves. The main principle applying to the choice of research projects for Community support is that of excellence in scientific terms, and the evaluation of projects and programmes is based on purely scientific criteria. Excellence is a goal which is appropriate for all regions to strive towards. But scientific excellence will not be achieved everywhere without major improvement in the RTD fabric.

5.25. To achieve these improvements mechanisms other than research programmes themselves must be used. At a Community level new opportunities are offered by the reform of the Community's 3 structural funds, whose budget will be doubled by 1993. Actions needs to be focussed on infrastructure; stimulating innovative activities in industry; helping companies and institutes to prepare for participation in Community programmes; and technical assistance and evaluation. The Commission is already contemplating one specific action known as STRIDE[42]. This is not a research programme aimed at specific research goals. Nor is it a blueprint for RTD development prepared centrally. In keeping with the philosophy applying to the structural funds it is a framework for the development of initiatives to improve the RTD base in LFRs in partnership with the regions themselves. Other actions through the other structural funds may be considered.

5.26. It would be illusory to believe that the problem of the technology gap within the Community can be rapidly and easily bridged. Infrastructural development; training; the creation of an innovative capacity, all take time. But action through regional and social policy instruments will help to shorten the time-scales involved.

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42 Science and Technology for Regional Innovation and Development in Europe.

Better coordination of national policies would help to save money and improve the efficiency of resource use throughout the Community.

At the same time a particular effort is required to improve the RTD fabric in the less-favoured regions of the Community. Research programmes in themselves cannot provide a complete answer . A major action using regional and social policy instruments is needed.

THE EXTERNAL ASPECTS

(ix) Encouraging cooperation in RTD with third countries

5.27. Science and technology are increasingly international commodities. At the level of the firm there has been a rapid growth in recent years of cooperative ventures in R&D, often of a transnational nature. Among universities and between them and industry, relations of a transnational nature are already common. There is a growing international market in research scientists. And national policy-makers have recognised the value of access to the scientific and technological resources of third countries as a means of providing the new knowledge and expertise needed to sustain growth and development in their own countries. In the case of Europe there are particularly intensive scientific exchanges and significant industrial R&D cooperation with the USA.

5.28. By committing the Community to develop RTD cooperation with third countries and international organisations, Article

130G of the Single European Act recognises the importance for Europe's own long-term future of properly coordinated action in this field. The recent recommendations[43] of the OECD Council also urge Member States in their own mutual interests to promote scientific and technological exchanges. The further internationalisation of RTD is therefore inevitable. The issue is how best to organise international cooperation in such a way that it can be a "positive-sum" game in which all the participants have something to gain.

5.29. For the European Community cooperative activities must be focussed principally on three groups of countries, to whom different considerations apply, namely: other countries within Western Europe, and notably our **EFTA partners**, the other **industrialised countries outside Europe**, and the **developing countries**. Outside these three groups separate reflections are now needed on the basis for cooperation with the Soviet Union and Eastern Europe in the light of the new relationships now developing across the European continent; as well as on policies of RTD cooperation with the NICs that take into account, on a case-by-case basis, the position and prospects for individual countries.

5.30. As far as the **EFTA** countries are concerned, cooperation has been running since the establishment of COST in 1971. COST remains an important framework for cooperation on specific projects "à la carte" with other European countries. The Luxembourg agreement of 1984 between the Community, the Member States and the EFTA countries to create a European Economic SPace has led to an intensification of relations in the scientific field. Special bilateral cooperation agreements have now been concluded between the Community and 5 of the EFTA countries. The sixth (with Iceland) has recently been submitted to the Council for approval. These agreements provide for various forms of access to Community programmes. Alongside the Community framework EUREKA provides a useful basis for cooperation between companies and institutes from the EFTA countries (and Turkey) and those from the Community Member States themselves.

5.31. Cooperation within a strictly Community framework with **industrialised countries outside Europe** is less well-developed. At a commercial level, as noted above, a dense network of linkages in R&D between companies has been established across the Atlantic. Moreover, the tradition of transatlantic migration of

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43 Recommendations of the OECD Council about a general framework of principles relating to international scientific and technological cooperation, 21 April 1988.

European scientists goes back a long way. But these developments have occurred in the absence of a formal general framework for cooperation with the USA. It might now be appropriate to explore the scope for such a general framework, given the wealth of US resources and experience in the scientific domain and the opportunities and issues raised by the recent developments in the USA described in Chapter II. It would also be timely to take advantage of the new moves by Japan towards the international science and technology community in order to examine seriously the scope for mutually beneficial cooperative ventures which are unlikely to exacerbate commercial strains.

5.32. For the **developing countries** the situation is different again. Their problems are, in some respects, akin to those of the less-favoured regions of Europe, but their shortages of RTD infrastructure and skilled scientists and skilled manpower are more severe. These limitations in terms of indigenous resources put a powerful brake on economic and social development. In addition many of them face specific problems in the fields of agriculture, medicine and health, and the environment which require a particular research effort.

Europe has considerable experience and expertise in these research fields, partly as a consequence of colonial experience. But the expertise is often fragmented among different national institutes. Efforts are needed to coordinate national actions.

Some of the necessary coordination is already underway at Community level. Since 1983 the Community has been running with the LDCs a programme of R&D directed at the problems of tropical medicine and agriculture ("Science and Technology for Development"). Separately, since 1984 it has developed a flexible programme of scientific cooperation in Latin America, Asia and Mediterranean countries aimed at the integration of research workers in these countries into the international scientific community, the improvement of indigenous research capacities, and, latterly, exploring the scope for technology transfer.

These programmes are an important contribution to the Community's wider development policy objectives, and in the years to come RTD must play an increasingly important role in this context. Given the growing concern about **environmental** issues in the developing countries (soil erosion, industrial pollutants etc.) and the need to optimise the development and exploitation of the **natural resource base** and new and renewable energies, there is a growing need for a particular new and coordinated research effort in these fields. At the same time the wider consequences for the developing countries of scientific advances in, for example, materials and biotechnology will need to be considered further.

(x) Avoiding technological protectionism

5.33. The longer-term benefits of RTD cooperation at an international level can only be fully achieved if the transfer of knowledge and technology is facilitated rather than constrained. Historically the scientific world has been an open world in which results of research are widely published and discussed and taken up and elaborated by others. But the "industrialisation" of research and the growing importance of science to trade flows has increased the pressure to restrict the flow of information in order to preserve competitive edge.

5.34. This is a major issue for international cooperation, notably in the Community's relations with other industrialised countries, which has been addressed recently by the OECD in its Council Recommendation of April 1988 [44]. The Commission believes that Europe and the world economy as a whole would be the loser from a more protectionist scientific and technological world. LDCs would be even bigger losers. **The Community should therefore work towards ensuring the diffusion of research results and away from policies that restrict the flow of information.** The necessary corollary is that progress should be made in ensuring adequate regimes for the protection of intellectual and industrial property. The Commission therefore vigorously endorses the OECD Council Recommendation on the need to work towards this end.

Science and technology are international commodities, and international cooperation must be a fundamental element in European RTD policies. The Community must further cement its relations with the EFTA countries; explore new modes of cooperation with the other industrial countries, notably the USA and Japan; and build on its successful cooperation with LDCs.

One important issue affecting relations with third countries is the question of technological protectionism and potential restrictions on the flow of knowledge. The Community should work towards ensuring the diffusion of research results by third countries and away from policies to restraint the flow of information.

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44 See footnote n°31.

INFORMATION TECHNOLOGY AND TELECOMMUNICATIONS TECHNOLOGY ISSUES

INFORMATION AND TELECOMMUNICATIONS TECHNOLOGIES ISSUES

Introduction

The global R&D effort devoted to information and telecommunications technologies in the EEC for 1986 is evaluated at 14 billion ECUs, thus one half less than in the United States.

In Europe, almost all expenses are financed and carried out by industry, that devotes a considerable proportion of its turn-over (10.5%) to it.

Public financing plays a notable but minor role (29% in Europe against 37% in the United States).

The R&D effort in information and telecommunications technologies is characterised in Europe by a triple deficiency:

- a very marked scattering of efforts between 12 countries (ranging from 0.3% to 6% of the GNP, thus a factor of 1 to 20 of the effort rate);
- a high redundancy mainly for what concerns many national programmes and the critical mass insufficiency that can result of this;
- a rythm of actual growth that is slower than in the United States and Japan. Despite the recent constant increase of the R&D effort in the small countries of the European Community (Portugal, Greece, Ireland, the Netherlands), the slow progress of public and private budgets in the four countries realising 90% of the total (Federal Republic of Germany, France, Italy, United Kingdom) leads to a global annual increase of expenditures (8.4%) that, in the European Community, is still under that realised in the United States (+ 10.7%) and in Japan (+ 9.5%): thus, the gap seems to increase from year to year.

The existence, since 1984, of the Community's transnational cooperative research programmes (representing 3% of the total RDT expenditures in 1986) obviously cannot alone have an effort proportionate to the importance of the stakes and problems.

A. Information Technology (IT) Issues in the Context of the Competitive Position of IT Industry in Europe(*)

1. Initial Situation 1980 - 1984

To gain of the present status and trends within the European IT industry we need to review recent history. At the beginning of the 1980s the situation of the European IT industry attracted great concern. The European industry was characterized by a lagging IT market, low market shares, low R&D and low capital investments.

An analysis of performances of two groups of companies, including respectively the largest US and the largest European Information Systems companies, shows that from 1980 to 1984[1]:

- the revenue growth rate of US companies was higher both on the worldwide and the European market;
- the profitability of US companies stayed constantly higher;
- both capital expenditure and R&D were much higher in US than in Europe and still growing in US at a higher rate than in Europe;
- the projected growth of the leading US companies would have enhanced their dominant position in the Information Systems market, by the end of the decade.

Moreover, the balance of trade in IT products was negative, amounting to a deficit of 10.6 billion US dollars in 1984[2].

2. Actions and Progress (1984-1988)

Concerted action was taken by the European companies to try and rectify the position. These actions encouraged a new dynamism in the European IT industry and helped mobilise human, financial and technological resources to try and reverse the negative trends. There have been some acquisitions and numerous cooperative projects between European companies during the last five years. These have been partly inspired by entrepreneurial opportunities strongly stressed and supported by collaborative programmes such as ESPRIT.

We are now beginning to see the fruits of the combined efforts.

In strictly quantitative terms, the situation in the Information Systems industry is now quite different.

(*) All sources of data are listed in the annex.
Information Technologies (IT) comprises: Information Systems including software and services, Electronic Components, Industrial Automation Systems/Computer Integrated Manufacturing (CIM).

- In the European market, where market shares have not been affected by changes in exchange rates, the largest European companies have significantly increased their market share, bringing it close to 50 %, from 33 % in 1983[3].

- In the software and services market, representing more than half of the total Information Systems market, the European companies are holding a favourable position taking advantage of the strong growth of the market demand[4].

- European IT companies are now investing in R&D a proportion of their sales very close to that of US companies. Nevertheless the speed of necessary increase of R&D cost in the IT field has not yet slowed down[5].

- The strongest investment effort of European companies was in capital expenditure, which reached in 1987 a level higher than that of US companies, although still lower than the level of Japanese companies[5].

3. Remaining Weak Points

Although the European Information Processing industry seems on the way to overcome some of its traditional weaknesses, major problems still remain. These include:

a) The Information Processing industry represents in Europe only 26 % of the Electronic industry, against 33 % in Japan and 41 % in USA[6]. The fastest growing sector of the electronic industry (the Information Processing sector) has not yet in Europe a position able to provide an healthy condition to the whole electronic industry and in particular to the semiconductors industry.

b) The penetration of European Information Systems companies on overseas markets is still minimal (15 to 25 % of sales[3]), while the expanding European market is increasingly attracting tough competitors: Japanese manufacturers have not yet concentrated their efforts in Europe, but the rate of their growth pushes Japanese companies to expand overseas sales.

c) The balance of trade has not improved. On the contrary in 1986 the trade deficit in IT products increased to 13.4 billion US dollars[2].

d) The Electronic Components industry has not progressed in Europe at the same rate, making the Information Systems industry and other user industries even more dependent on foreign suppliers of critical and strategic components. The dependency on foreign suppliers for some key Microelectronics components is as follows:

   - 65 % of the most commonly used memory chips are produced by Japanese manufacturers. This share gets close to 90 % for the most advanced type of memory[6]. This situation has already pushed US manufacturers (both of semiconductor and computers) to join forces to establish new production capabilities in the USA;

- 89 % of the production of the most advanced microprocessor chips (32-bit) is concentrated in three US companies. The same three companies account for 55 % of production of the most commonly used microprocessors (16 bit)[6].

In a strongly competitive industrial environment, the European Microelectronics industry has the disadvantage of a low demand from the consumer electronics industry, the locomotive which led Japanese semiconductor industry to the present leadership position. Moreover, the Information Systems industry, the second driving force of Microelectronics, is much smaller in Europe than in the US.

e) The situation is similarly critical in certain types of computer peripherals. These represent an ever-increasing part of the value of Information Systems.

- Japanese and South East Asia manufacturers produce 90 % of worldwide production of tubes (CRTs) for display units, 95 % of flat panels based on Liquid Crystal Technology (LCD's) and are expected to get similar shares in other emerging flat panel technologies[7].

- US and Japanese manufacturers represent 90 % of the world production of printers and the European dependence is even higher for key parts: the core elements for laser printers are a monopoly of three Japanese companies[7].

f) A further and critical weakness is the lack of trained personnel. Estimates of the required number of trained personnel vary widely but it is clear that insufficient are being produced. As an example one recent estimate for the requirement of engineers trained in VLSI design was 5,000 per year in one recent estimate for the requirement of engineers trained in VLSI design was 5,000 per year in one Member State, namely Germany[8]. At the moment only about 3,000 per year are entering the workforce in the whole of the Community.

4. **Changing Priorities and New Actions**

The relative success in some areas of European IT serves to highlight the remaining problems. Continued action is required to tackle these as well as to consolidate the newly acquired competitive positions. Further efforts are called for by new challenges evolving (such as Japanese entry into European computer market or the recent new US initiatives in Microelectronics). The fact moreover that, in the light of the recent positive experience in collaboration, European companies are now ready to progress further on the road of integration of joint efforts and to subscribe in some selected areas to unprecedented commitment in cooperative R&D and to the subsequent downstream production investments, creates the need for a revision and an adaptation, and in some cases a substantial shift, of the priorities to date and in order to ensure the longer term viability of the Community strategy to strengthen and consolidate a competitive position worldwide of European IT industry and services.

To this end it is in the first place necessary:

a) to provide the economic climate and boundary conditions which allow full exploitation of the potential demand. This because the overall success of any R&D policy in the IT sector is closely related to the achievements in other sectors of Community policy, in particular the internal market and standardization;

b) to pursue further and strengthen on the one hand the current ESPRIT II policy of development of a European capability to design and produce application specific Microelectronics products (integrated circuits) capable of fully exploiting the potential of the most advanced semiconductor technologies and, on the other hand, to complement this by promoting and sustaining the creation in the Community of such leading edge technologies (0.3 micron CMOS technology by 1996) so as to secure to European electronics industry strategic independence of supply.

c) to secure, in particular, the ready availability of microprocessor technology in Europe. This is why a new initiative is necessary, which aims to develop a basis for a family of microprocessors with standardized architectures. Control of the microprocessor architecture (including the instruction set) will enable a hierarchy of standard interfaces to be designed and used for software development throughout IT user industries;

d) to provide the production capability for key peripherals in Europe.

e) to re-inforce certain well-identified topics such as Computer Integrated Manufacturing;

f) to prepare new actions promoting in specific areas of strategic concern training measures, which would help to overcome crucial bottlenecks on a Community scale.

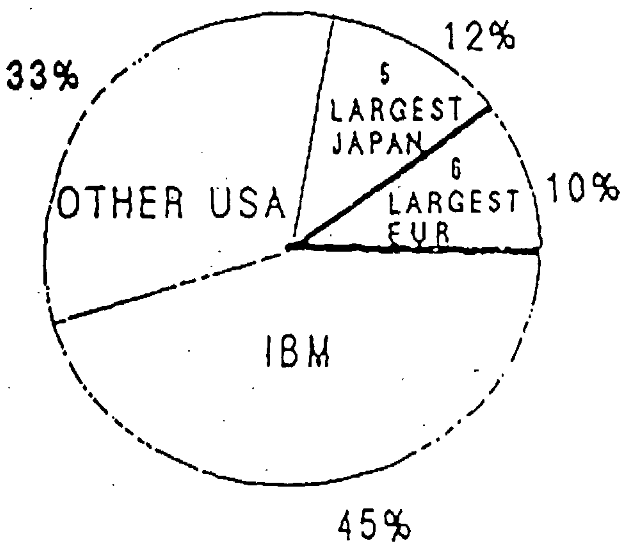
WORLDWIDE DP MARKET GROWTH (1983 - 1987)

	CAGR %
FUJITSU NEC HITACHI TOSHIBA MATSUSHITA	35.3
SIEMENS OLIVETTI BULL NIXDORF PHILIPS STC	26.4
DEC HP WANG APPLE	20.4
TOTAL DP MARKET	**17.3**
IBM	8.5
BURROUGHS SPERRY NCR CDC HONEYWELL	2.1

(DATAMATION)

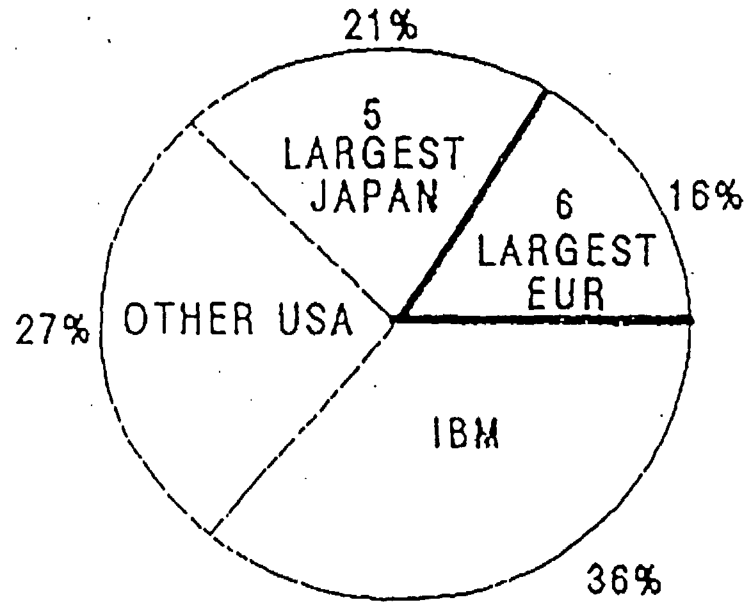
WORLDWIDE DP MARKET SHARES
(TOP 20 DP COMPANIES)

1984



98 BILLION $

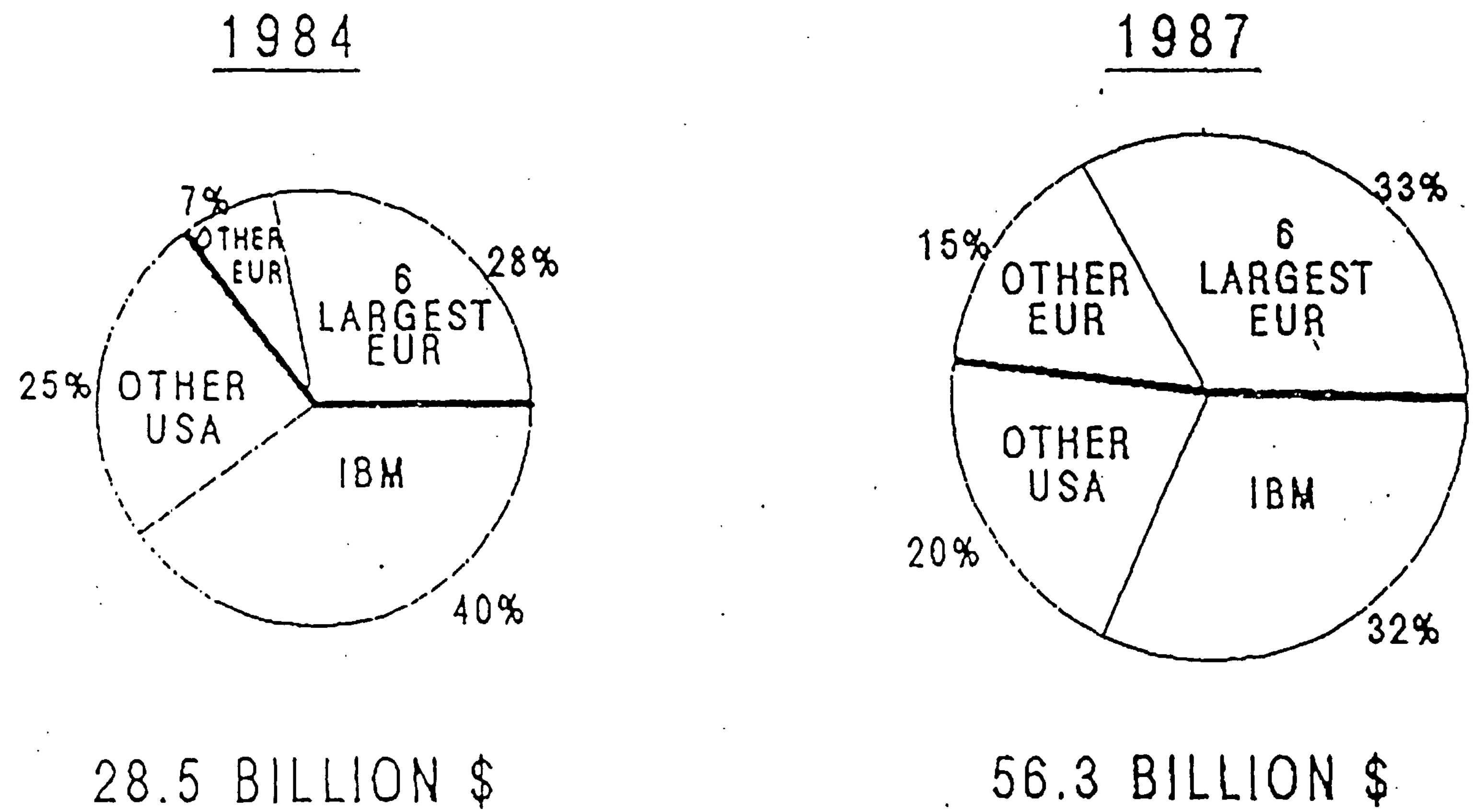
1987



141 BILLION $

(DATAMATION)

EUROPEAN DP MARKET SHARES
(TOP 25 COMPANIES)



ATAMATION)

KO-2

B. THE PERSPECTIVE OF ERMERGING TECHNOLOGIES IN I.T. AND THE NEED FOR REINFORCED BASIC RESEARCH

1. Background and rationale

The second half of this century is replete with examples of research ideas which, although conceived without even thought to applications, led to technological developments with major industrial and social impact.

Entire theoretical subjects studied and developed by philosophers and mathematicians are now providing essential tools for Information Technologies (IT) as well as all engineering areas that rely on the capability for rapid and massive computing and automated logical inference.

As a result there is a growing consensus that supporting basic fundamental research in IT is a solid investment whose payback, even if it does not come in the form of short term industrial applications, is rich.

In Europe, partly in contrast with the situation in the United States, IT related basic research is mostly carried out at universities and research institutes as most industrial laboratories are constrained to devote their efforts to the development of short to medium term applications.

In addition, it is the basic research environment in these institutions that provides the nursing ground for highly trained manpower, the demand for which is increasing much faster than the capability to supply it.

2. Issues of strategic significance for future informations technology development

They relate to: computer science, programming language, advanced robotics, machine learning, cognitive engineering optical and molecular computing.

a) A well recognized and broad long-term research goal in Computer Science addresses the predictable reliability, safety, security, integrity and correctness of complex, large-scale distributed systems. To work towards this goal, research is needed on formal specifications, testing and verification, fault tolerance, system architectures and on how to relax on the simplified abstractions of the real world underlying current systems design. It is intended that the ESPRIT basic research actions will enable a serious coordinated effort that will bring together European expertise in this area.

b) The design and specification of a concurrent programming language, the implementation of a provably correct compiler for that language and the specification and implementation of a provably correct operating system would provide the basis for a hardware computer, all of whose components have been verified through formal methods. To achieve this, expertise must be drawn together from areas ranging from automated theorem proving to VLSI design methods, including proof verification systems, compiler and operating system design and concurrent programming methodology. Available, but distributed throughout Europe, this expertise could be brought together to challenge recent advances in this area that have taken place mostly in the United States.

c) Many basic problems still have to be solved before a real autonomous mobile robot can be created. Corresponding to the components of such a robot, work is needed in basic research areas like planning of robot actions, autonomous navigation, design of world models, multisensor fusion, knowledge representation languages, design of hierarchical expert systems, distributed planning and machine learning.

d) In machine learning new logical tools are being sought in the direction of combining deductive approaches to learning with inductive ones into what is increasingly called concept learning. This requires extensive work in inductive building of decision trees, techniques into knowledge acquisition systems. Combining data base management and knowledge based techniques is also an area expected to attract ever increasing attention.

e) The emerging cognitive engineering approach to the design and analysis of complex systems develops models of human-computer-work interaction in real-life environments, models possible systems and their limitations as well as the work domain and its actors. It is a top-down, problem driven approach requiring basic research on the representation of complex work domains, cognitive control of work, error tolerance, representation of intentions and values and cooperative, distributed decision making.

f) Optical and molecular computing are areas where much fundamental research has to be carried out if the promises of the so called 6th generation computing systems are to be met. From the same viewpoint, recent superconductivity developments open the way for work on interchip (thick film) and on-chip (thin film) interconnections, sensors, shielding and new devices. An eventual deeper understanding of the phenomenon itself could provide even hitherto unsuspected information technology advances.

Sources of Data

(1) Booz, Allen and Hamilton study on "Trends and Objectives of the IT Sector in the Medium- and Long-Term" (Study carried out for the CEC in 1985).

(2) EIC - Electronics International Cooperation, "L'électronique dans le monde" - 1987

(3) Datamation - The Analysis is based on the Information Systems revenue of the Top 25 suppliers.

(4) IDC - Eurocast - Software and services - 1988

(5) Company reports - Companies in the group of the Top 25 for Information Systems revenue have been considered.

(6) Dataquest - 1988

(7) Consultronique - Study on "Opportunities for European Suppliers of Computer Peripheral Equipment" (Study carried out for the CEC in 1988)

(8) Markt & Technik, June 1985

A. Telecommunications technology

1. Initial situation

In comparison with the informatics sector, Europe has been sustaining a good position in telecommunications. This is due to the good technological capabilities in this field and to the close links established between telecommunications operators and industry, which contributed to secure very substantial market shares to european companies.

The Community balance of trade in telecommunications has therefore always been positive so far.

2. Changes occured during the last years

a) Since 1984

European telecommunications industry and operators are confronted with:

- a changing regulatory environment world-wide, which will lead to increased competition in the provision of equipment and services,

- technological challenges with the evolution towards digitalization of networks, ISDN and broadband networks and services (present european weakness in components is also a major challenge in this context),

- growing demand of keeping up the pace in terms of R and D effort and in investment, which require increased market base and better use of economies of scale, especially in public telephony.

The approach defined at Community level has allowed to establish consensus between telecommunications operators and industry on common concepts of evolution of network, including the establishment of a common strategic framework to develop concertation and technology for IBC networks, services and terminals.

In this context, Europe must:

- improve its overall capabilities in generic IT technologies (esp. components, software) which play an increasing role in telecommunications because of the convergence of technologies. The rising trade deficit in telecommunications with Japan and the United States against an overall commercial surplus is a clear evidence of this threat.

- address the issues of systems research and engineering of integrated services.

b) Since the launching of RACE

Since telecommunications operators, industry and users of the Community and the EFTA countries joined forces to address the development of an advanced telecommunications systems in Europe in the framework of RACE important developments have taken place:

1. The implementation of the RACE Definition Phase has proved the advantages and necessity of collaborating on a european scale in defining and developing specifications and common technological elements.

2. Japan and the US/Canada have completed their broadband overlay network unlocking the economic and competitive potential of advanced communications services. Broadband links to the customer (45 Mbit DS3) experience in the US a growth rate of 100% per annum. The FCC expects broadband links to go into the US homes within the next 3 years and an explosive growth of telecommunications services. Europe will consequently have to speed up and intensify its efforts.

3. The global optical network is rapidly advancing from the US via the pacific and the atlantic multiplying the transmission capacities linking different regions of the world economy.

4. The internationalisation of economic and social activities feeds a trend towards international service provision with strong economies of scale. For Europe this implies the need for the sector actors (operators, industry, service providers) to address their respective responsibilities in a consistent and agreed framework.

The interest and commitment by operators, telecommunications equipment industry and telecommunications users to the objectives of RACE has correspondingly increased.

3. New needs to address

In the light of the developments, the appreciation of the needs has evolved reflected in

a) an increased conviction that the market will demand advanced communications in the mid-1990s implying that the target date for Europe -wide introduction of integrated broadband services of 1995 may need to be moved forward to coincide with the 1992 objective of the completion of the internal market.

b) a growing interest to reinforce the work on HDTV with respect to its distribution inter alia via cable networks to exploit the achievements of the EUREKA HDTV work;

c) the recognition of the need to address the mid- to long-term implications for the telecommunications system in all its parts of the rapidly growing demand for mobile communications;

d) the necessity to extend the collaboration of operators and industry with service providers and users in application pilots to accelerate the emergence of economically viable services optimally adapted to the needs of the user.

4. New priorities for action

The specific adjustments and re-inforcements to be carried out relate to:

IBC DEVELOPMENT AND IMPLEMENTATION STRATEGIES

It will be necessary to revise the common functional specifications prepared by the RACE programme in the light of the verification and integration work carried out. Furthermore the new Part II technological activities will generate on one hand output for Part I and on the other hand the Part II activities will need guidance from Part I.

IBC TECHNOLOGY

Long Term Technological Issues

In the light of technological trends and the evolutionof the appreciation of demand characteristics the following technological issues need increased attention:.

* optical switching: technology and system integration

* coherent multichannel technique, progress towards integration into customer access connection and possibly integration with optical switching.

* specification and implementation of a signalling system for broadband networks

* consideration of special topologies for the customer access networks, interfaces to public networks, protocols, common functional specifications, interconnection of Customer Premises Networks

* broadband mobile technology, technology, integration into the terrestrial network and implications on the terrestrial network

* High Definition Television (HDTV), coding for HDTV, structure of distribution networks, distribution switching for HDTV signals

* network management and impact of advanced information processing technologies on network management.

PRE-NOMATIVE FUNCTIONAL INTEGRATION

Integration and Verification

Further systematic efforts are necessary and could benefit from collaboration on a European scale:

* integration of subsystems into systems where necessary to enable verification at system level

* verification of common functional specifications via integration of systems (network termination, customer access connection and local exchange) into a network testbed to enable verification at network level

* verification of common functional specifications on the broadband user network interface by integration of terminals and Customer Premises Networks (CPN) into network testbeds

* evolution from demonstrators and verification testbeds to a broader trial network and service testbed by exploiting the synergy among national testbeds.

Application Pilots

* enhancement of application pilots in such a way that they can use the future broadband facilities.

* improvement of usability of application pilots.

* pilot implementations of service elements.

B. Application technology

I. Rationale for Community action

When the framework programme was being prepared, it had been clearly perceived that in the field of generic technologies and common infrastructures as it is led in the framework of programmes such as ESPRIT and RACE, must necessarily be accompanied by a parallel effort of development of applications that offer a considerable potential of creation of activities, services and thus of new employment.

The objective is to prepare, in due time, the conditions favourable to the intensive exploitation of large basic technologies that are being perfected, by adapting them to the needs and specific constraints of the different categories of users (business, public administrations, social services, individuals) and thus implement, at Community level, a market of equipment and services that will bear the European industry, favour its international competitiveness and allow a response to the social and economic needs.

On the basis of initial studies, the Commission had identified the following as bearing application sectors:

- education and training (mainly for professional training),

- transport,

- medical science and health.

The very large consultations to which the Commission has proceeded since 1987 with the different groups of actors involved (dataprocessing and telecommunications industry, publishing industry, transport, health equipment, etc., scientific sectors, public authorities, user groups, telecommunication networks operators, standardisation organisations) have largely confirmed the socio-economic relevance of the sectors of priority application identified beforehand.

The three specific programmes - DRIVE, AIM, DELTA issued from this phase of strategic concertation - are concerned with the applications of information, telecommunications and audio-visual technologies in the fields of general interests services, management and security of road traffic, bio-medical dataprocessing and remote multimedia teaching.

These three fields present a certain number of common characteristics that justify a joint action at Community level:

- their economic and social importance is considerable in the Community and their costs weigh heavily on the collectivity and in particular on public finance. This charge can only be stabilised or reduced by a better cost/performance relation of the services offered;

- they very largely depend on the responsibility of the public authorities, who either define the regulations or manage an essential part of the infrastructures that form the basis of the services offered to the population;

- lastly, in these sectors, the users' needs are developing rapidly throughout the Community.

In the case of training, the European active population is faced with the necessity of constantly adapting its level of knowledge and experience to the rapidly changing techniques and professions. Now, the traditional structures of knowledge transmission lack of adaptation to the necessities of the re-training and re-adaptation of knowledge.

In the field of transport, the number of bodily accidents on the road, the waste of energy and atmospheric pollution that entail traffic problems demonstrate that the classic techniques of traffic management have reachd the limits of their possibilities.

In the field of health, although the progress in medical sciences has been very rapid during these past decades, a considerable effort remains to be accomplished to take the best advantage of them by further adapting the capacity of diagnosis and treatment to the specific needs of the patients and doctors.

Facing this lack of balance between the demand for services more adapted to the new needs and the present supply that does not allow to take them into account in a satisfactory way anymore, the new information, telecommunications and audio-visual technologies represent a major opportunity for the future.

The new technological supports that permit a multimedia and remote apprenticeship will allow everyone to study at a chosen time, desired rythm and in a place that suits one most (home, work, school). The concept of "teleteaching" has become a crucial factor of progress.

The information technologies are now a determinant factor bringing together patient and medical science. They allow the conception of a "telemedicine" that abolishes constraints due to distance, of "integrated" hospitals in which all equipment will function as a network, of health care adapted directly to the individual patient.

In the field of transport, they allow the conception of solutions adapted in a better way to the needs and the behaviour of the vehicle drivers, by putting at their disposal computerised tools and more flexible and safer information and communication infrastructures.

The range of technologies to be used and integrated to this effect is very large: personal computer, optical disk, microprocessor cards, new techniques of medical and educational imagery, computer languages similar to natural language, expert systems, mobile telephony, ISDN, broadband integrated network, HDTV, direct transmission by satellite, etc...

The problem now is to combine and integrate to a maximum the large range of technologies already available or in course of development, and thus optimise their gobal performance on a technological, economic and social point of view and avoid, by cooperative and concerted actions with all the actors concerned at the European level, the risks caused by the present proliferation of independent systems that would all be conceived in relation to a paticular, often exclusively national, point of view.

2. <u>Application of information technology and telecommunications in health care</u>

Member States spend a substantial proportion of their GNP on Health Care. In spite of determined efforts to limit further increase, costs are still escalating (cf. separate annex on health research).

Specific application of information technology and new means of communication can provide increased health care.

The reasons for this approach can be summarised as follows:

* The efficiency of health care may improve by linking all parties involved in diagnosing or treating one patient or the same group of patients.

* The goal of equal access will be a realistic one when the centralized expertise is disseminated to where the patient is.

* Managerial and financial aspects of health care will become transparent and comparable if modern informatics is applied.

* Industry will benefit from a more harmonious health care market than the very fragmented sector we know today.

Since introducing the AIM action in the Framework Programme, the rationale for it has strengthened by

- mounting interest of sector actors, in particular, national administrations of health care, industry and research,

- growing awareness that there is a good case for extending the cooperation beyond the scale of the Exploratory Phase.

- Areas to be strengthened are:

  a) specific diagnostic technologies such as for example imaging needs studies both on software and hardware specifications.

  b) agreed terminology and medical records. In medical health care there is a huge variety of data.

  c) A European strategy for a coherent IT & T structure in health care. The structural implications, and opportunities, of the new technologies need to be studied and acted on. Modern telecommunications can cut across existing structures, and revolutionize this professionals, hospitals, home care etc. need not continue.

Further efforts in Europe should address the following key subjects:

- Agreed terminology and record handling,

- Knowledge based medical systems and instrumentation.

- Establishment of network databases and computing facilities to link generalized as well as more specialized workstations e.g. in oncology, epidemiology and research.

- Integration of knowledge based systems into health care.

- Development of biosensors for monitoring and controlling various body functions (a field where Europe may still take a lead). A positive outcome would be of great importance for many categories of patients such as diabetics, patients with cardiac diseases, neurological disorders etc.

- Investigation of IT & T application to patients with sensory and motor handicaps, which would help these disabled persons to lead a more normal life.

Besides, there will be a continued need for addressing the non-technological issues, such as:

- Legal issues in connection with safe data handling

- Legal issues with respect to protection of privacy

- Training of personnel

- Ethical problems and patient acceptability.

3. Application of information technology and telecommunications in education and training

European governments and undertakings have become increasingly aware of the competitive and social value of training and of a skilled, educated workforce. Recent and foreseeable progress in information technology, telecommunications and broadcasting open up new possibilities of reaching a wider audience cost-effectively.

IT & T technology is a suitable tool to address this need because:

1. Education is essential for everyone, but there are finite teaching resources.

2. Currently, up to 600 hours are needed to produce one hour of good educational material. This can be reduced to cost effective levels.

3. It is one of the largest markets for good, integrated services that merge technology, content and processes.

4. By the year 2000, 18% of the population will be in education, training or retraining at any time.

5. Industry is becoming acutely aware of the need to maintain its skills base.

It will be essential for Europe to use all appropriate means to create an informed and educated workforce. This is the single most vital asset of an advanced service oriented group of nations.

This was the basis for the adoption of the DELTA Exploratory Action, which was confirmed by the experience gained since then in COMETT and DELTA.

Since the definition of the Framework Programme the case for collaboration at a European scale has further strengthened:

1. In the USA, government expenditure on projects like DELTA are estimated at well over 400 M US dollar per year.

2. An estimated USA market (1987) of 29 Billion US dollar attracts other competitor nations.

3. These developments are now being aggressively exploited.

4. They are potentially very significant, in an industry starved of good global solutions to become de-facto world standards.

5. Even small countries have used distance teaching using technology to overcome regional, cultural and geographical barriers.

In this context the specific European situation should be taken into account:

1. Europe is behind in terms of pilot testing and experimentation,

2. Nevertheless, it has a high level of education and training development activity, albeit fragmented,

3. There is a potentially potent source of high skill and expertise in learning technology, that works well, but is often sub-critical.

4. There is a goodwill for education not to be unduely restrained by tariff or administrative barriers.

5. The climate for innovators in this domain has never been better due to the volume of successful results from European collaboration such as ESPRIT and RACE.

There is a growing consensus in Europe to develop:

- solutions that allow for more cost-effective creation of high quality learning material,

- experimentation, prototyping and harmonisation of all aspects of ITT&B-based learning systems.

4. Application of information technology and telecommunications in transport

Road Traffic Administrations, Industry and Road Transport Users in the Community and in EFTA countries, becoming aware of the increasing problems on the European road network, have decided to join forces in the framework of the DRIVE programme to address the development of advanced systems using Information Technology, Telecommunications and Broadcasting which could help to improve the use of the existing network, in increasing their capacity and at the same time, reducing technical or human errors.

The rapid adoption of DRIVE took place against the background of:

- transport representing more than 6% of GNP;

- more than 10% of family budget being devoted to transport;

- car ownership in Europe representing 60% of the level in US, whilst congestion and poor routing costs an estimated 150 billion ECUs per year, and road accidents kill 55,000 people and injure 1,7 million annually in Europe, with a financial cost of an estimated 50 billion ECUs;

- progress in information technology, telecommunications and broadcasting offering new and effective solutions.

DRIVE has been prepared with the active participation of all public bodies concerned from all Member States, with the motor industry and the ITT&B industry. A full consultation with more than 60 organisations, has taken place, representing all interests (Industry + Users).

Since the DRIVE Programme has been taken up in the US and Japan in recognition of the competitive impact of road transport informatics which are likely to result in speedy progress. It seems very likely that imported solutions emerging from these initiatives will not be optimal for the European situation;

- European car manufacturers have committed themselves to the continuation of the work in the framework of Prometheus (EUREKA Project of European automobilemanufacturers);

- interest in traffic and transport manangement has increased;

- 3000 organisations, industries and Research Institutes from the Community and EFTA countries have expressed interest in DRIVE;

- new important R&D of pre-competitive and pre-normative kind have been identified by sector actors.

Future research needs include, notably:

a. Development of appropriate verification tools, which will facilitate the introduction of new equipment on vehicles or to infrastructure.

b. Longer term technological solutions, which will substantially increase the capacity of the road-transport network, improving safety at the same time.

c. Investigation in depth of the proposed systems, particularly those relating to public Transport, goods transport and vulnerable Road Users.

d. Concepts for the use of mobile communication as infrastructure for road transport information and guidance services.

e. The necessity to extend the collaboration of operators, industry and users in application pilots taking into account regional differences.

f. Development of proposals for integrated specifications for all major sub-systems building inter alia on the results of ESPRIT and RACE.

More specifically, this means:

- Development of a systems approach, which will consider the total transport environment in Europe and will include land use and general economic issues and specific regional requirements.

- Further development of transportation models to include elements of total transport performance and the specifications of advanced systems offering longer term technological solution; as well as development of a technoeconomic tool for evaluating the consequences of producing different components of Road Transport Informatics (e.g. showing the way they are channeled through different economic sectors and through different markets). This would be of use to other R&D programmes concerned with techno-economic evaluation.

- Investigation and development of longer term technological solutions, particularly relating to increasing capacity of traffic lanes; technologies for Public Transport and Goods Transport Intermodal Information Systems; and advanced systems for rural Road Transport.

- Integration of Traffic management and Transport Management systems, with the inclusion of all value added services.

- The synergy of similar technological solutions for all transport modes, addressing the issues of navigation, information, management. In addition exploitation of merging work of ESPRIT and RACE for maximisation of synergy with these actions.

- In the road safety context:

- advanced anti-collision devices in complex situations using longer term technological solutions;

- advanced man machine interfaces using longer term technological solutions;

- advanced co-pilot systems including corresponding servo mechanisms;

- improved sensors including in car biochip devices.

To prepae the way for implementation:

- Development of test beds for Integrated Road Transport Management Systems, including the interfaces with other modes for passenger and good transport; development of test beds for Advanced Road Safety Systems for urban and interurban Road Transport; and development of the verification procedures for licencing Advanced RTI Systems.

INDUSTRIAL TECHNOLOGIES AND MATERIALS

1. MAIN ISSUES FOR INDUSTRIAL R&D AND MARKET PERFORMANCE

1.1 The Market

Manufacturing industry, as the primary customer for industrial technologies and materials, is an established and essential part of the Community's economy and will remain so for the foreseeable future. It provides around 1050 billion ECU (1985) or 30% of GNP and accounts for 75% of the industrial work force of some 41 million people. There is a strongly positive balance of trade in manufactured goods (export/import ratio of 1,15 in 1987-Table 2.1). This is underpinned by sectors which have devoted considerable resources to maintaining their competitive edge and is particularly so in the manufacture of motor cars, chemicals, power cables and instrumentation. Nevertheless, some structural weaknesses persist and in particular the capacity to respond to growing demand in more developed markets. The considerable changes that have taken place in the relative size of world output across a range of manufacturing sectors is shown in figure 2.1. Comparing the performance of selected sectors in Europe, US and Japan, (see pages A1-A6) reveals large relative movements in output growth and thus the considerable pressure on European manufacturers in a dynamic market.

Table 2.1

EC Balance of Trade in Manufactured Goods
(billion ECU)

	Exports	Imports	Export/Import Ratio
1981 (EC10)	236	171	1.38
1987 (EC12)	289	252	1.15

Eurostat

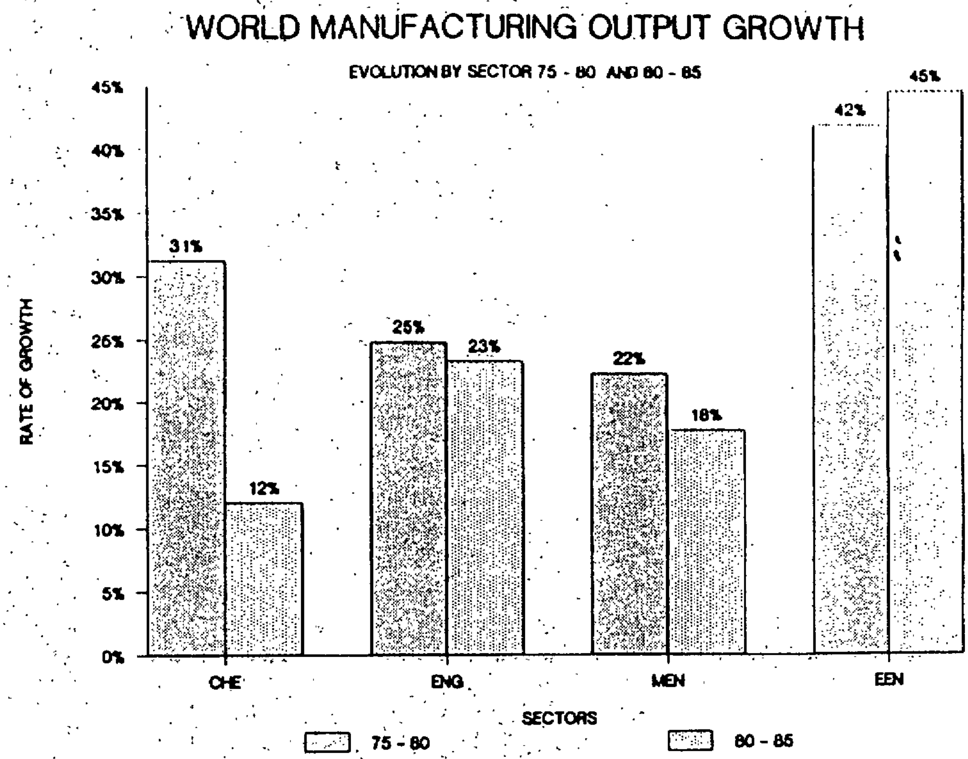
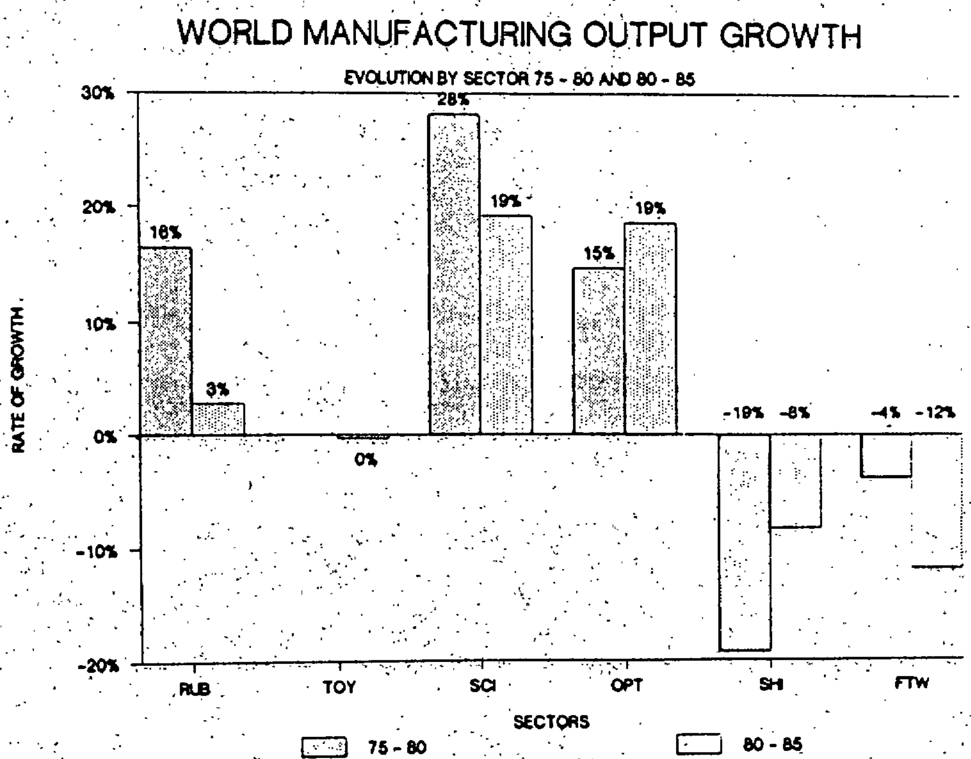


Figure 2.1 a



For legend see page A2

Figure 2.1 b

1 b.

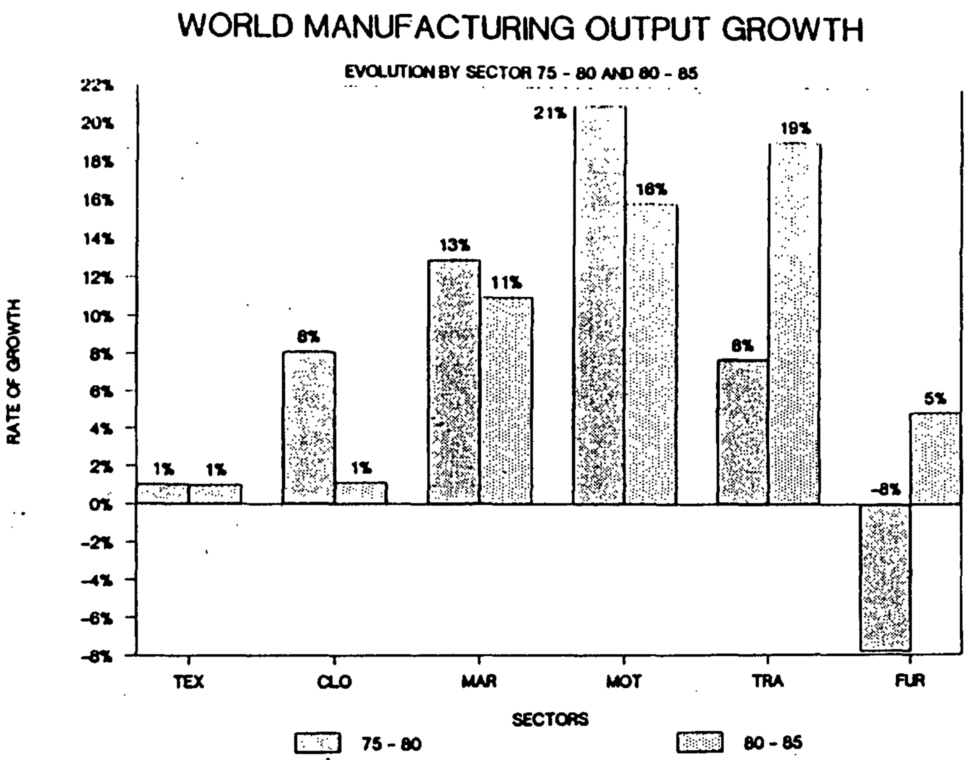


Figure 2.1 C

For Source/legend see page A2

However, in recent years there has been a marked reaction by European manufacturing industry to the pressures of ever widening and more competitive markets. This is visible in terms of the improved performance within the leading companies in many sectors. Maintaining market share means providing a better service than competitors. Increasingly, the requirement relates to the ability to supply, when required, small batches of high quality goods. The necessary flexibility requires major changes in the manufacturing strategy of most companies. Demolition of the barriers between the functions of marketing, design, purchasing or manufacturing, and after sales, within and between companies, will facilitate the identification of the technologies which are needed to improve performance.

1.2 Technology in Company Strategy

Different approaches to Industrial R&D strategy, such as focussing on product innovation or reducing manufacturing costs, must be applied singularly or in combination to sectors with a fast growing demand (such as instruments and chemicals) or those whose demand is stagnant (such as clothing, textiles, motor vehicles and food). The common element is that the performance of the European industries and those of the most developed industrial countries will be less concentrated on maintaining or increasing market share of the total market. Instead they will seek to capture the top end of the market by new or improved products often with a higher technology content in the product itself or in its means of manufacture.

The size of the so called 'top end' of the market will, to a large extent, depend on the technologies used and how they extend the efficiency to the customer's needs. The potential for increasing productivity and flexibility is greater in mature industries, as is the incentive to employ new technology. One indication of this trend towards the development of products having a higher added value is the movement towards materials having a greater 'expertise' content per unit weight, see figure 2.2. Already this 'dematuring' process is evident in established sectors, as demonstrated by the following examples:

- In the motor car industry, responsible for about 10% of industrial value added and employment, productivity increased by more than 30% between 1980 and 1987. After making losses in the early 1980s the industry became profitable in 1986 with profits estimated at 7 billion ECU for 1987. For this improvement against strong external

Relation between the quantity of materials in a product and the information content

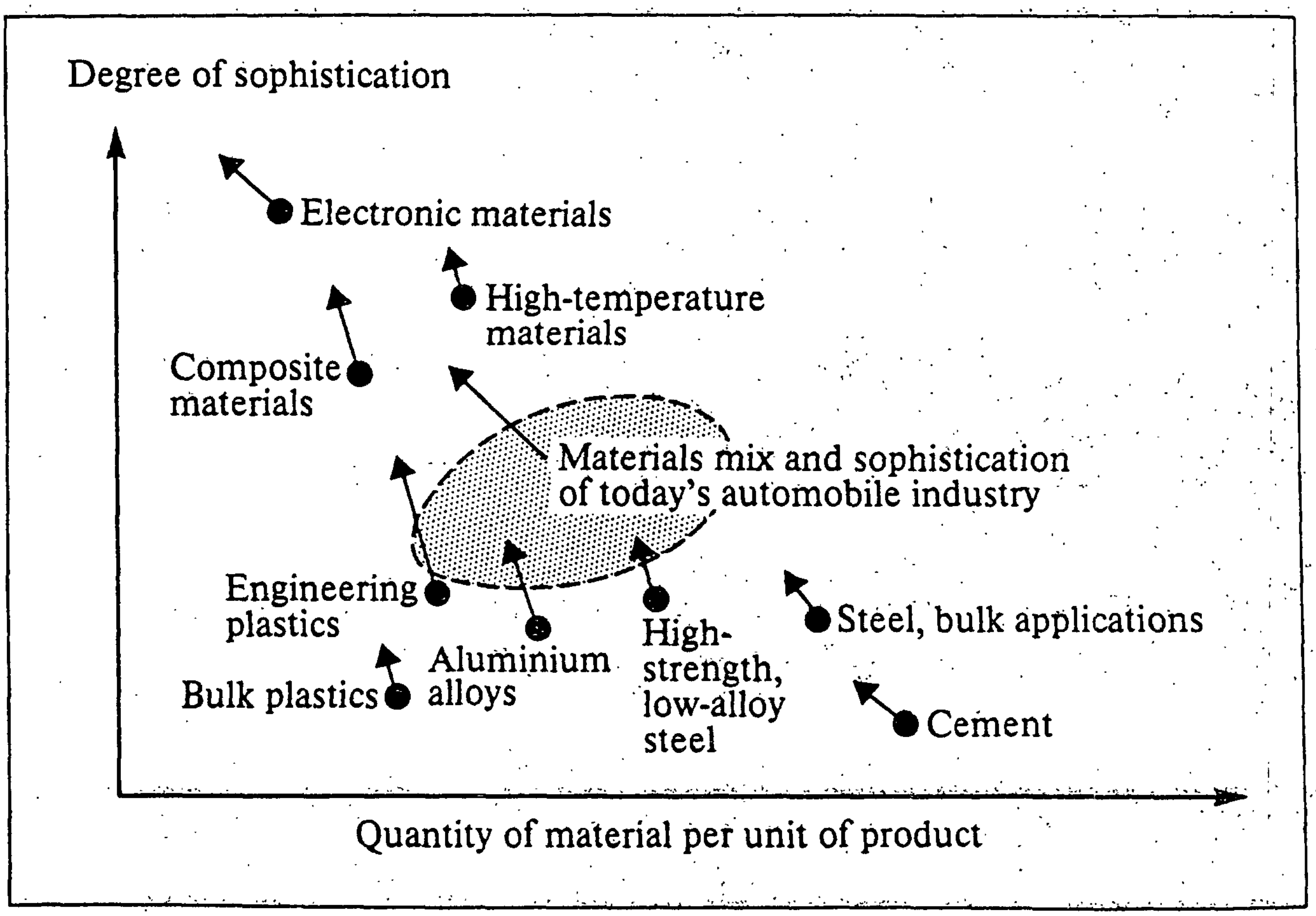
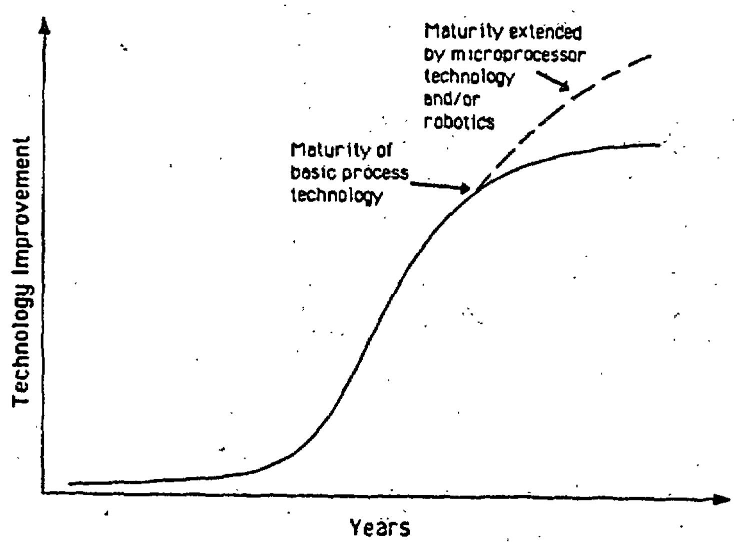


Figure 2.2

Source : ATAS Bulletin

pressure, a major contribution came from innovation in the organisation of production, heavily supported by technology.

- As a highly automated process industry, European power cable manufacturers supply 39% of the world production. To defend itself against import substitution policies in developing countries R&D is recognised as a means of maintaining technical leadership in areas such as insulation and fine protection.
- The clothing industry, employing over one million people, has improved its export/import ratio from 0.45 to 0.68 since 1980. Overall imports into the Community amounted to 9.6% of consumption in 1986 although for some items the figure was as high as 76%. Technology is recognised as offering a major opportunity although there are some very difficult problems to solve.
- The associated textile machinery sector manufactures 55% of world productions and exports 70% of output. Although recent commercial trends are not encouraging there is optimism that the more integrated manufacturing processes now required by users and which exploit advanced technologies will reduce the relative importance of market costs and so shift demand for textile production back to the Community. Current textile manufacturing process technologies such as weaving achieve extended effectiveness through advanced technology additions (see figure 2.3 and page A7)



Source KSA

Figure 2.3

- The machine tool industry has had a mixed performance with some companies being slow in moving to the technologies of numerically controlled tools. However some companies have been particularly successful in maintaining their position in world markets through technology leadership.
- The glass and wood industries have annual outputs of 16 and 19 billion ECU respectively. Though very different in nature, both contracted in the early 1980s. Technology innovations are allowing these sectors to benefit from their inherent environmental advantages.
- Last but not least the chemical industry has an annual turnover of some 230 billion ECU (1987) with an export/import ratio of 1,27. With the opening of markets the sector has demonstrated its technical strength in products and their production against growing international competition.

1.3 Barriers to progress

As enterprises become more dependent on expensive machinery, improvements are needed concerning the reliability and predictability of machine behaviour. Recognising the characteristics of Community industry consisting of few large and many medium sized and small enterprises, there is a particular need to reduce the complexity and cost of new production technologies and systems.

Exploiting new technology in products is essential whether directly, as in the use of new materials, or indirectly through improved design, reliability, servicing or marketing. Here the Community industry has generally been less successful than its competitors, particularly from the Far East. The Community now lags behind in the engineering aspects - performance and methods of component manufacture and new materials. Failure to exploit new materials to improve product performance, durability and reliability bars the Community from competing in rapidly expanding and traditional markets.

The challenge of the single integrated market highlights the growing requirement for uniform standards at a European level, which are the basis for effective communication between interested parties within industry and between industry and regulatory bodies. Results already emerging from European level programmes including BCR, ECSC Steel Research and COST suggest that research involving partners from several Member States can be a valuable step towards harmonisation of industrial practice.

Pre-competitive R&D - applied research not leading directly to commercially exploitable results - is an essential enabling instrument for competitiveness but may be too wide in application, of too long a time scale, or too risky to make it acceptable for funding by single companies, particularly SMEs. It is here that existing resources in Europe can be further exploited, building on the growing awareness of the benefits of collaborative activity. At the European level, R&D programmes have helped to reinforce this encouraging trend in bringing together the complementary expertise of those in industry and research organisations to specify, manage and implement the work required to underpin the competitiveness of European manufacturers.

Within Europe most R&D relating to industrial technologies and materials is believed to take place in industry. However, the available statistical information is generally too broad in coverage to provide an accurate picture of the true situation. It is estimated that spending by governments on industrial production and technology is some 3,7 billion ECU. In comparison, the Community's industrial research and development programmes such as BRITE/EURAM, Raw Materials and Recycling, and the ECSC Steel Research will commit only a relatively small percentage of this sum each year. Though within these programmes Community support will vary between a high level of overall R&D funding in a low research intensity sector such as clothing to a low level in a more research intensive sector such as chemicals. The figures on pages A8-A10, though incomplete, indicate the trends across Europe, US and Japan in overall R&D expenditure in a number of sectors:

- In the case of chemicals, it is particularly noticeable that the Japanese, starting from a much smaller base, are catching up with Europe through a higher rate of growth in R&D expenditure.
- The figures for motor vehicles suggest that after major efforts in the seventies, world manufacturers may have slowed down the increase in R&D expenditure, particularly in the case of US but also in Europe relative to Japan.
- The textile and clothing industry conducts very little R&D but it is worrying to see that Europe appears to have been decreasing expenditure relative to Japan and US.
- In the area of rubber and plastics, Europe appears to be maintaining its position against US and Japan.
- The position in machinery R&D expenditure, although increasing, is a cause for concern with Europe falling steadily behind both US and Japan.

Although Europe clearly has a substantial activity, it tends to be behind the US in absolute R&D expenditure and also falls below Japan in the rate of growth particularly between 1980 and 1983. The figures confirm the concern expressed elsewhere over the trends in total volume of research expenditure.

2. THE CHALLENGE FROM OUTSIDE EUROPE

Outside Europe it is, for the time being, the US and Japan which dominate the R&D scene in industrial technologies. However both have very different incentives and infrastructures supporting their advancement. One measure of success is the ability to retain or increase shares in world markets. Looking at the relative importance of industries across a basket of 12 important manufacturing sectors between 1980 and 1985, table 2.2 reveals that whereas 9 of the Japanese industries have held or increased market share this was only the case for one European and 4 American sectors.

TABLE 2.2 Gains and Losses in Share of World Markets 1980 to 1985

Sector	Europe	US	Japan
Electrical Engineering	L	L	G
Engineering for all industries	L	L	G
Mechanical Engineering	L	L	L
Rubber Products	L	H	L
Textile	L	L	H
Furniture	L	G	H
Machine Tools	L	H	L
Ship building	L	G	G
Optical Products	L	L	G
Scientific Instruments	G	L	H
Clothing	L	L	H
Chemical Industry	L	L	H

G = Gain, L = Loss, H = Held

After Arthur Anderson and Co. 1988

For many years Japan has had the reputation for being a copier of western technology. Many European manufacturing companies have studied the Japanese approach at first hand and now believe they have the capabilities, if properly used, to mount a successful challenge. There is a lot of ground to make up as Japanese products were now world leaders in 36 out of 40 technology intense product categories.

Japanese industry is structured in a way which avoids many of the problems associated with technology transfer in the West. Japanese industry does the research itself with internal technology transfer by production and research engineers working alongside one another during the development phase. While Government laboratories and universities play a relatively minor part in industry's R&D effort they do provide a pool of expertise for use by MITI and other agencies in planning and running Government sponsored industrial research programmes.

In 1981 MITI launched its project dealing with the revolutionary basic technologies essential to the establishment of the new industries expected to flourish before the end of the century. The 'Research and Development Project of Basic Technology for Future Industries' (JISEDAI) covered new materials, biotechnology and new electronics devices.

Last year a report prepared on behalf of MITI by academics and industrialists recognised the need to strengthen Japan's capabilities in fundamental research. Various means were proposed including the establishment of centres of research as a basis for encouraging exchanges of researchers between industry and universities. Another measure was to reinforce the JISEDAI programme, recognising that the areas of fundamental research which were expected to be important for industry at the beginning of the next century were: new materials; electronics; software; biotechnology; and biomaterials.

In the US a major factor in the advancement of manufacturing, design, and materials technology has been the Department of Defense support for R&D. In the Manufacturing Technology Programme alone there are approximately 500 projects active at any one time with an annual funding (in 1986) of approximately 200 million dollars. In its 25 years this R&D programme is recognised as having benefited both civil and military users with, in some instances, returns to the US amounting to billions of dollars.

The primary objective to support R&D capable of improving the economical, timely and reliable production of defence material, has meant that the programme has become a national focus for developments in manufacturing technology. In contrast to the low level of spin-off resulting from the development of defence equipment, the support for improving manufacturing performance among defence contractors has resulted in practices, products and systems which have found wide application in improving manufacturing effectiveness.

Nevertheless, as in Europe, there is concern in the US about the barriers to the commercialisation of new technologies. This is also considered in the Main Report. A major worry is the lack of integration and communication among functions within companies and a complacency and overdependence on the domestic market for growth opportunities. Foreign competitors, often but not always Japanese, were seen as having turned US technological development into their commercial product successes. There is a feeling that the benefits of emerging technology are too easily lost by weak laws and regulations, and ineffective enforcement for the protection of intellectual property rights in the US or overseas.

As to the future, the Department of Commerce considers the emerging technologies of particular importance to the end of the century to be: Advanced Materials; Electronics; Automation; Biotechnology; Computing; Medical Technology; and Thin Layer Technology. These priorities, not very different from those of Japan given above, reflect the importance of the production related technologies as almost all have a significant role to play in the control, operation, or effectiveness of manufacturing processes. However, in the shorter term the substantial funding for manufacturing related technologies from the Department of Defense supports the effective development of products and processes.

3. THE TECHNICAL REQUIREMENTS

In this section the generic industrial technologies underpinning the drive towards industrial competitiveness - for which research effort should be concentrated - are identified. Included are the improved technologies needed for the design and assurance of products and processes, for meeting the manufacturing needs of groups or sectors of industry, for improved manufacturing processes, together with those associated with the application and recycling of new and advanced materials and materials production. These R&D priorities for European industry have been established in conjunction with industrial experts.

3.1 Design and Assurance

The development of techniques to improve product and process quality, and the reliability and maintainability of structures, and manufacturing systems have a major affect on performance. Their costs have been estimated in one of the Member States to be some 10% of GNP and can typically range from 5-25% of company turnover and it is believed that a reduction by 70% of their present level through better management and control is possible. As the costs of quality are related to the imperfections and also costs of process and product assurance, a major task is to reduce the imperfection rate while reducing the assurance costs. The trend to low inventory manufacture underpins the requirements for reliability and maintainability.

In many sectors there is concern over limitations of available process control and the means by which the product specified is assured. New and improved sensors are required to control processes and their importance reflects increases in the scale and flexibility of systems. Optical engineering, if developed could satisfy needs in the areas of testing, detection and inspection.

Power control engineering, for control of speed or position in electric motors is at the base of advances in automation in all kinds of industry. Though there were strengths in the past, European and US manufacturers are now losing market share against Japan. Technological improvements are needed so that European manufacturers of process and production machinery can have access to the most suitable technology.

3.2 Application of Manufacturing Technologies

Here the requirement is to develop manufacturing practices in the leading sectors for others which have been slow to exploit the benefits in business performance. These will include a high proportion of SMEs, and have limited research and development capabilities themselves and so be dependent on the expertise and experience of other sectors. Application of modelling techniques is required to address problems in established industries, such as the filling of complex injection moulds, particle formation in atomisers, positioning of sensors in condition monitoring systems, noise generation in machinery or the design of composite materials.

A particular area where there are prospects to build on initial progress is in those industries based on the processing and use of flexible materials. Their importance is well illustrated by the Community's textile and leather related industries where some 3.5 million people are employed. In the clothing industry about 80% of production comes from SMEs, many of which have limited technical capabilities.

3.3 Manufacturing Processes

Improved techniques for shaping, joining and assembly, surface treatment, chemical processes and particle technology are fundamental needs for industry. Advancement of these processes is essential for securing manufacturing competitiveness. With regard to surface treatments the costs of corrosion prevention and effects amount to about 4% of GNP in industrial countries and similar figures apply to wear. In almost all surface treatment systems, the aspects of quality assurance, condition monitoring in service and control of the treatment process require further development.

In the case of technologies for shaping, assembly and joining further development is needed to exploit the full benefits of their incorporation into computer integrated manufacturing systems. There are also requirements for new processes with improved performance including high precision and faster operation. The availability of advanced materials both to be treated and also for use in the treatment process, challenge conventional practice.

Important advances in chemical manufacture will only result if there is collaboration between chemical manufacturers, users and suppliers of new technology or expertise. There is a particular challenge to produce improved catalyst systems while the supply is mainly local, and Europe is generally strong. There is requirement to optimise the design of membrane systems, such as to enhancing turbulence at the membrane surface and also techniques to inhibit fouling.Europe has been slipping behind in membrane innovation. The world market for membranes is about 400 mio ECU/year and is likely to grow significantly in the future as new applications for membranes are identified, such as gas filtration.

Research is need to overcome the inability to fully categorise particles, poor efficiency and size control within many conventional particle processes, and the difficulties in maintaining an even flow and distribution in the flow of powders and suspensions. Multi disciplinary expertise is required to tackle problems found in very different particle systems.

Advanced powder materials technology is limiting the achievement of potential benefits in areas such as aero and automotive engines, magnets, tool steels and electronic materials. There is an opportunity to build on European strength in some process areas to secure a share in a strongly competitive industry where the US leads production in powder and products valued at about 2 billion ECU, with Europe and Japan at about 1 billion ECU each.

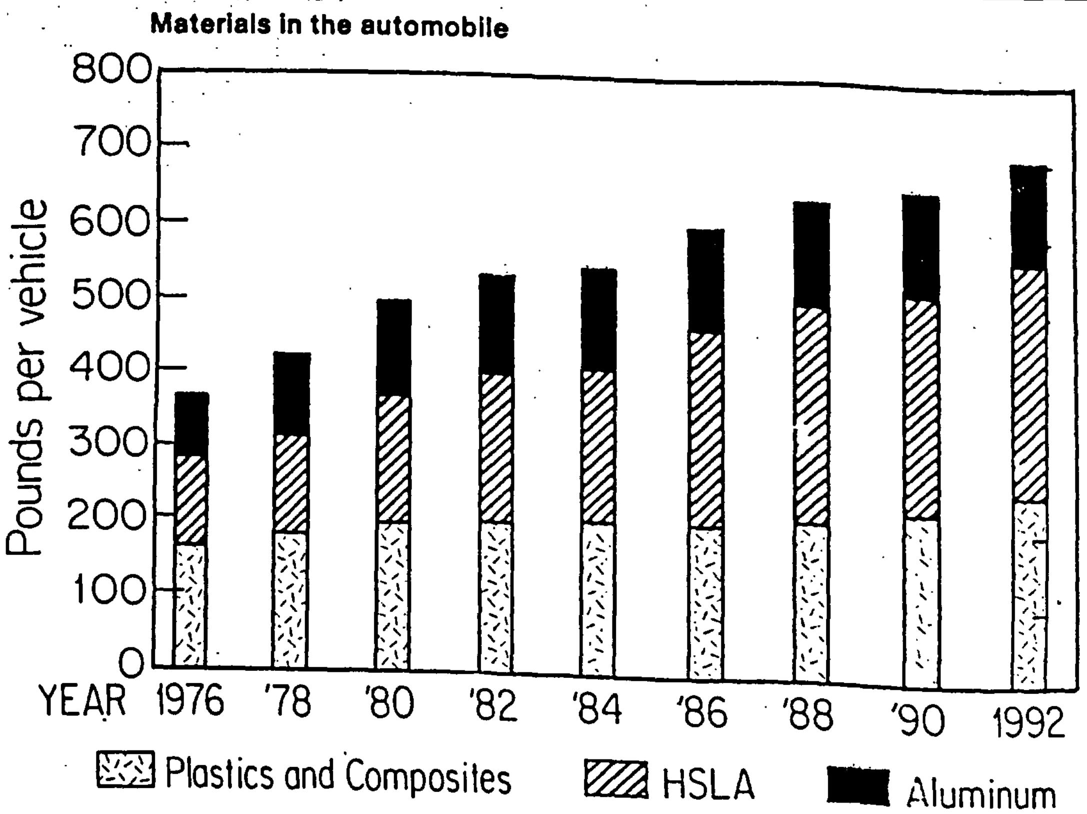
3.4 Advanced Materials

While new materials are often considered to be a 'horizontal' subject within a wide spectrum of industrial sectors, most major developments have arisen within aerospace, nuclear energy and more recently electronics and the automobile industry. The trend in application for the last sector is shown in figure 2.4.

The lack of adequate materials is a brake on developments such as magneto-hydrodynamics, fuel cells and high energy density performance materials. Europe is well placed to provide the multi disciplinary approach necessary for progress, but the US and Japan have been first to recognise a new awareness of materials. This is illustrated in table 2.3 for advanced ceramics.

For metallic based materials advances in processing and alloying technologies have considerably widened the design scope. But a major technological challenge is to establish a base of quality confidence in the new materials and improve processing techniques of these and more established materials so as to bring production costs to competitive levels. Anisotropic materials strengthened with particles or fibre reinforcement are required.

Materials having significantly improved magnetic, optical, electrical, and superconducting properties are needed to realise advances in a wide range of industries. Magnetic materials, for example, are indispensable in the electrical and computer industries. Building on European strengths in R&D, there is a requirement for developments which permit effective and economical exploitation as, for example, polymer-bonded anisotropic permanent magnets or massive segments of metallic glass for applications



Note: Increasing automobile usage (actual and projected) of certain materials, including high-strength low-alloy steels, in the United States, despite overall trend toward downsizing.

Figure 2.4

Source : ATAS Bulletin

International Comparison of R&D Efforts in Advanced Ceramics by Application Area

	Location		
Application	*United States*	*Japan*	*Western Europe*
Electronic applications: multilayer capacitors	10 to 15 MECU/yr	R & D spending unknown; said to hold 10:1 lead over US in number of patents and engineers	Not estimated
Gas sensors	No more than 1 to 2 MECU/yr	R & D unknown; said to hold 3:1 lead over US in number of technical papers and 10:1 lead in patenting	Probably similar to US level
Structural applications: heat engines	35 to 40 MECU/yr	Greater than $50 million/yr	Less than US: Germany and Sweden are the European leaders
Cutting tools	Probably no more than 1 MECU/yr	R & D spending unknown; 20:1 lead over US in patents for period 1973 to 1982	Probable more than US; Germany alone nearly even with the US in patents for period 1973 to 1982.
Optical applications: integrated optics	Approximately 10 MECU/yr	Slightly less than US expenditures	About half of US expenditures

Source: Black, Blum and Kalos

Table 2.3

which include electric motors, security systems, ore separation, medical equipment and magnetic levitation for transport.

High temperature superconductor materials, in which Europe played an early role, are expected to have a great impact in the medium and longer term on most of the high technology industry sectors, particularly in component design for reduced energy consumption. As many basic problems remain unsolved industrial breakthroughs will not be achieved without a systematic investigation of the operating mechanism and engineering problems.

The large potential of engineering ceramics depends on solving problems in properties and availability. In speciality powders, such as whiskers, there are supply difficulties within Europe. If this technology is to meet the users needs, there will have to be closer links with powder producers. The world market for engineering ceramics, including special glasses and amorphous materials, will be some 12 billion ECU within a few years. Currently European activity is low compared to US and Japan.

Developments are needed in Europe to respond to the trends of replacing general purpose polymer materials by functional materials. The world polymer market is of the order of 120 billion ECU, of which engineering polymers, including polymer matrix composites, amount to 5 billion ECU and are increasing in market share. Europe is a net importer of engineering polymers. The US with 70% of the world production and Japan with 10% are increasing market share at the expense of Europe currently with 10-15%. Currently the market for advanced materials is limited and mostly in the US because of the aerospace dependance. Growth will come from new approaches to design which allow cheaper materials to be developed and exploited, as in motor cars. Developments in recycling and recovery technologies are needed to respond to greater use of polymers in consumer products. The problems reflecting environmental consideration are significant as there are some 7000 types of polymer in circulation.

Improvements are also needed in more conventional materials in addition to the technologies which reflect the use of new and advanced materials. In particular more effective extraction, process and recycling technologies are required for critical materials to underpin their availability to users. Similarly improvements in the processing and application technologies of steel are needed to secure the competitiveness of European producers in world markets.

4. THE TASK FOR EUROPE

A competitive, technology based manufacturing industry is an essential element of the Community's economy. The overall task at European level is to establish an environment in which the industry can flourish. The technology related issues where action is needed are as follows:

4.1 R&D and Company Strategy

It is for industry to identify its future technological needs and take the necessary action. However, not all companies are well structured to undertake such a task. This weakness was highlighted during the recent evaluation of the BRITE programme as resulting from poor links between company planning, marketing, manufacturing and R&D functions. The analysis of particular areas that require renewed research efforts for European industry given in Chapter 3 has been developed together with industry. It will be further developed but should, already, be helpful at the level of the individual company. It will also signal the overall trend for further co-operation at European level.

4.2 R&D and Technical Barriers

Standardisation activity at the European level contributes to the breaking down of barriers to trade within the Community. Particularly in those areas with a rapidly advancing technology, there can be benefits for establishing links between R&D and standards related activities, so speeding up the effective exploitation of the R&D results.

4.3 The Balance Between Fundamental and Applied Research

A concern is how fundamental research, usually in universities and supported from public funds, should be balanced against research and development having a greater industrial focus. A close look should be taken at the balance between the fundamental and applied work to ensure that the inventive skills of academic researchers are encouraged but yet they have those links with industry which will ensure speedy progress through the research, design, development and application chain.

4.4 Education and Training

R&D can only be as good as the resources available. The human resource is strongly influenced by its education and formation. Several of the concerns expressed above should be reflected in the training of research managers.

At the management level the failure to convert research into profitable products and processes continues to be a concern within Europe. A fresh look needs to be taken at the preparation and training for managing innovation and the management of its implementation - not as an isolated activity but in an environment that is aware of the market place. In responding to the challenge of the Japanese invasion of the European market place many companies have reformed and re-organised and are now much better structured to make real gains.

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1985: Value-added in the EC, the United States and Japan by sector (1985, current prices)

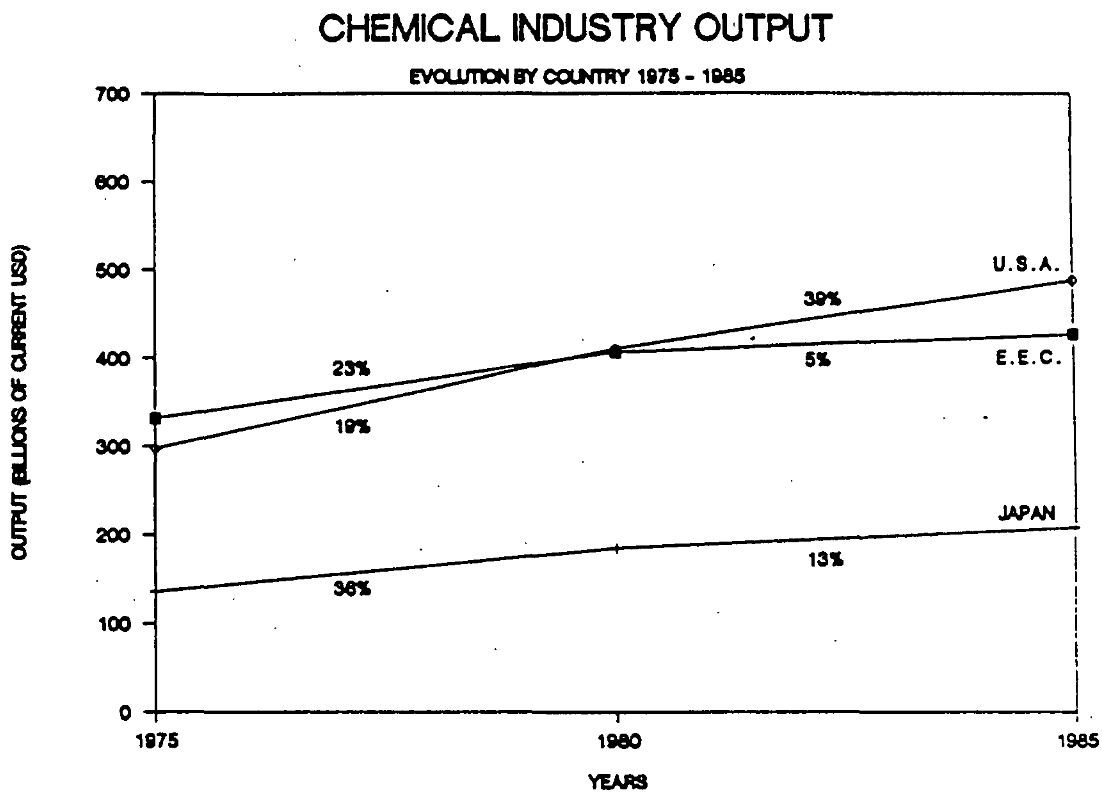
Branch	EUR 12 billion ECU	Japan billion ECU	USA billion ECU
Manufactured products	*825*	*505*	*1 024*
Ores and metals	35	24	30
Non-metallic minerals and mineral products	41	24	40
Chemical products	76	44	103
Metal products (except machinery and transport equipment)	73	68	84
Agricultural and industrial machinery	79	40	88
Office and data-processing machines, precision and optical instruments	25	20	80
Electrical goods	82	79	92
Transport equipment	92	49	145
Food, beverages, tobacco	129	56	108
Textiles and clothing, leather and footwear	66	40	53
Paper and printing products	57	14	113
Rubber and plastic goods	32	21	38
Other manufactured products	38	26	51
Building and construction	*180*	*128*	*245*

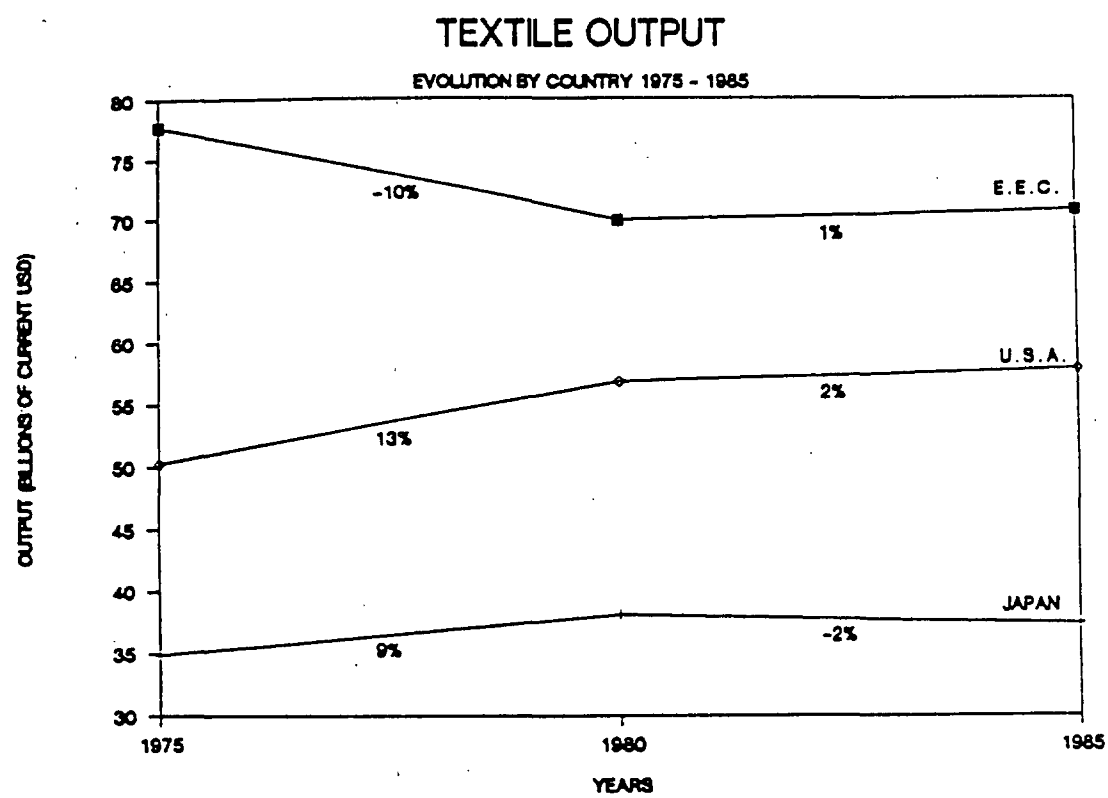
Source: Commission services (sectoral data bank-VISA).

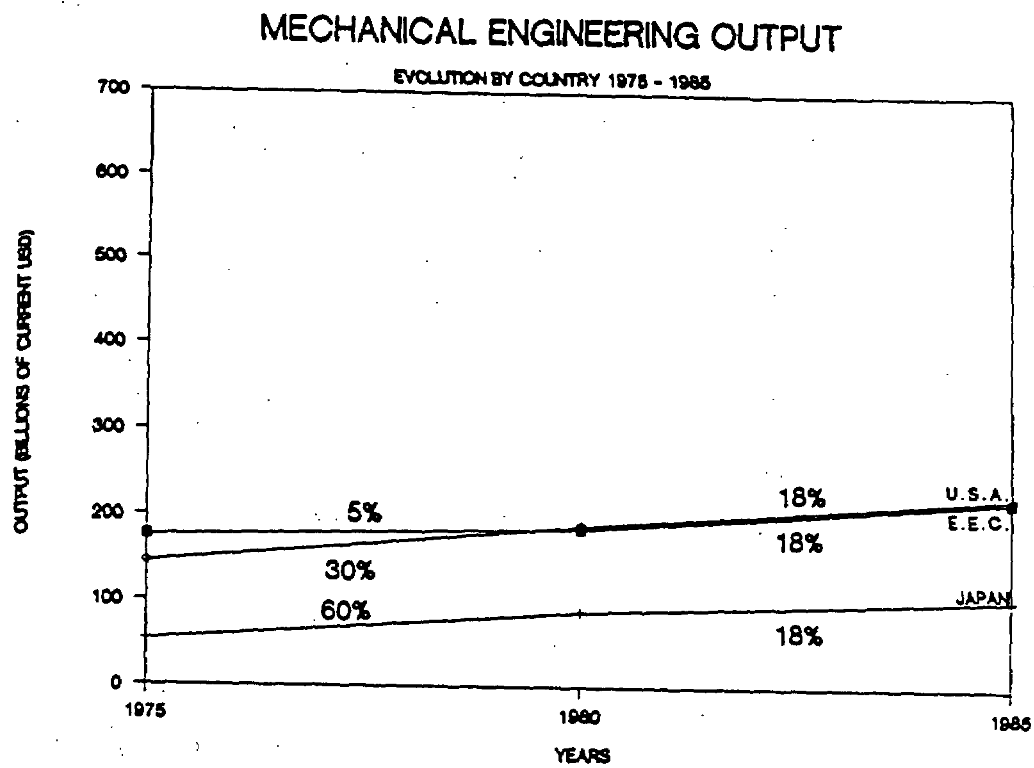
TABLE OF LEGENDS

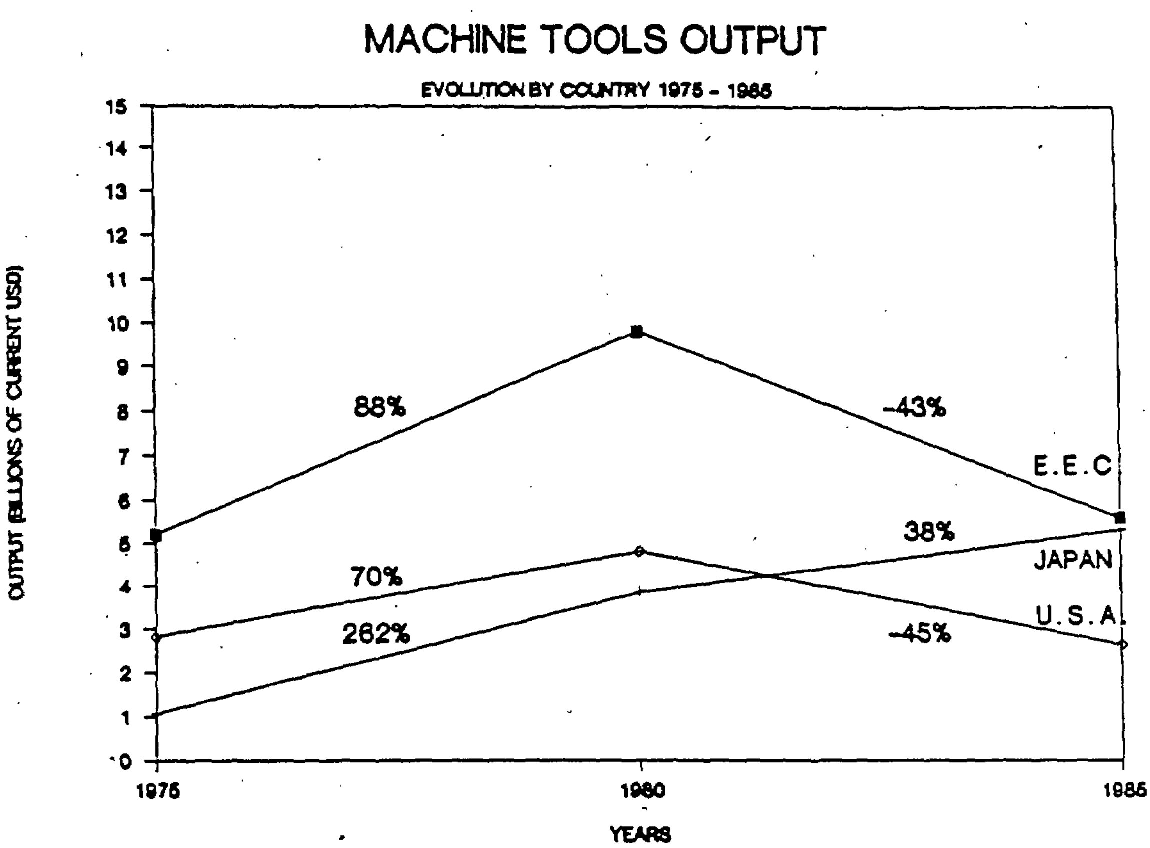
LEGENDS	SECTORS
CAT	Catalysts
CER	Ceramics (engineering)
CES	Ceramics (sanitary)
CHE	Chemical Industry
CLO	Clothing
COM	Composites
COO	Cooking Equipment
EEN	Electrical Engineering
ENG	Engineering and all. industries
FOR	Forgings and castings
FTW	Footwear
FUR	Furniture
HOU	Household Fittings
MAC	Machine Tools
MAG	Magnetic Materials
MAH	Materials Handling Equipment
MAN	Man Made Fibres
MAR	Metal articles
MAY	Machinery (Printing/Packing/Food)
MEN	Mechanical Engineering
MOT	Motor vehicle and parts
OPT	Optical Products
PLA	Plastic processing
RUB	Rubber Products
SCI	Scientific Instruments
SHI	Shipbuilding
TEX	Textile
TOY	Toys
TRA	Transport
WEL	Welding/Joining Equipment
WHI	White Goods

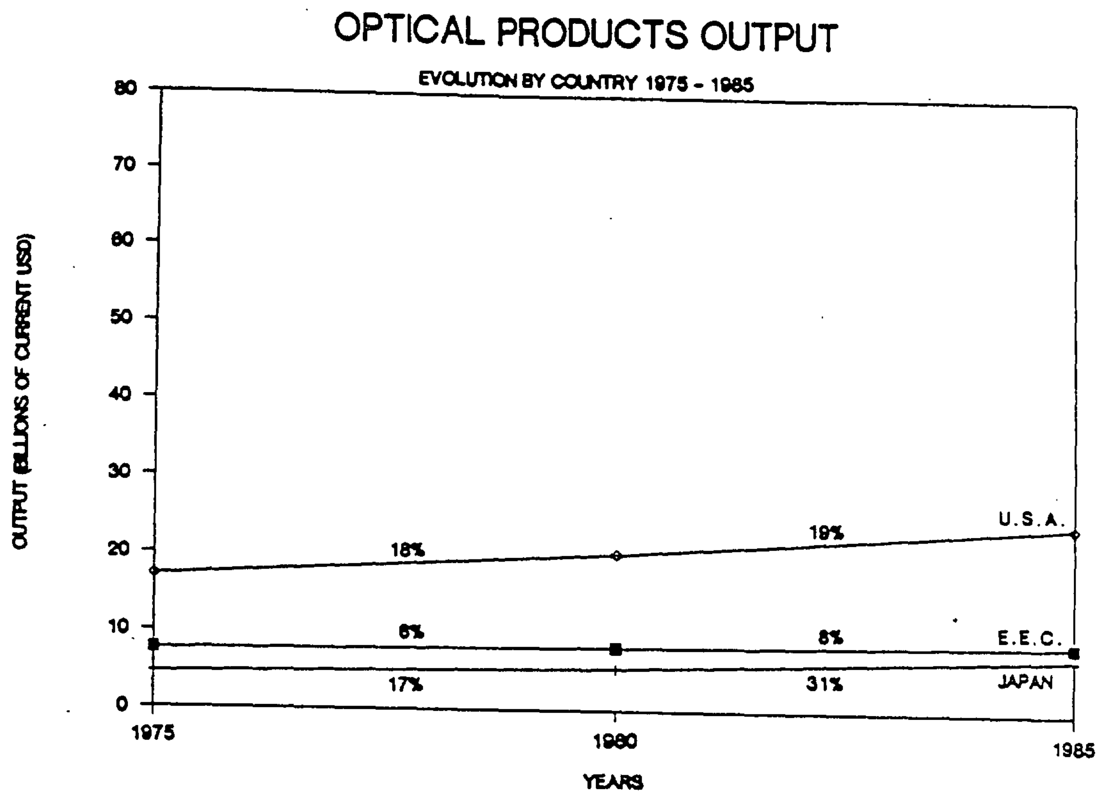
Source of materials on pages A3-A7, A9-A11 and figure 2.1:
and figure 2.1 Arthur Andersen & Co.

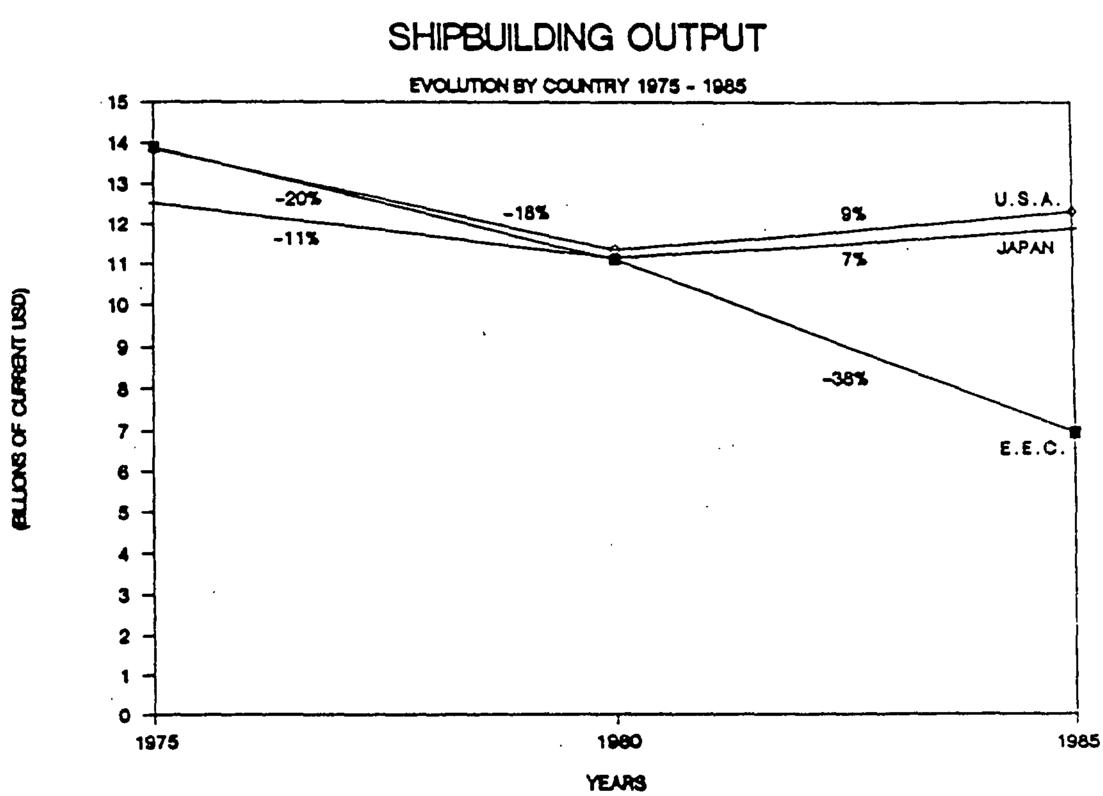

CHEMICAL INDUSTRY OUTPUT
EVOLUTION BY COUNTRY 1975 - 1985
OUTPUT (BILLIONS OF CURRENT USD)
700
600
500
400
300
200
100
0
1975
1980
1985
YEARS
U.S.A.
E.E.C.
JAPAN
23%
19%
39%
5%
36%
13%

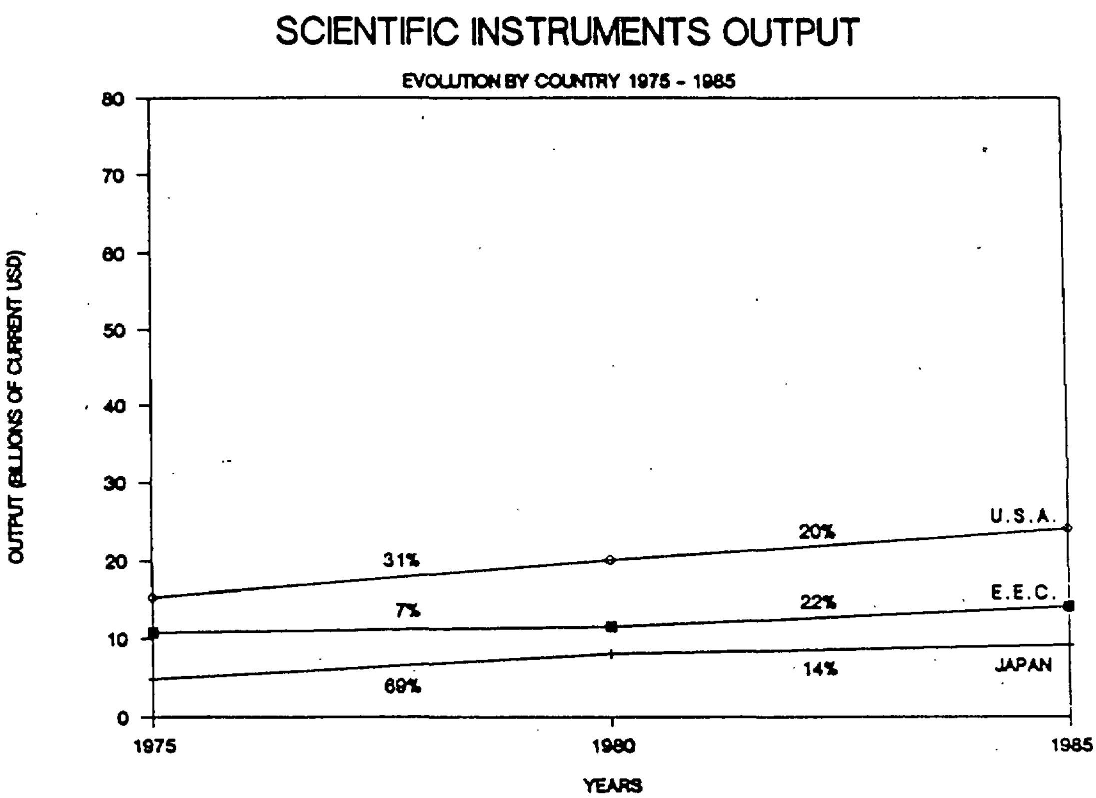

TEXTILE OUTPUT
EVOLUTION BY COUNTRY 1975 - 1985
OUTPUT (BILLIONS OF CURRENT USD)
80
75
70
65
60
55
50
45
40
35
30
1975
1980
1985
YEARS
E.E.C.
U.S.A.
JAPAN
-10%
1%
13%
2%
9%
-2%


MECHANICAL ENGINEERING OUTPUT
EVOLUTION BY COUNTRY 1975 - 1985
OUTPUT (BILLIONS OF CURRENT USD)
700
600
500
400
300
200
100
0
5%
30%
60%
18%
18%
18%
U.S.A.
E.E.C.
JAPAN
1975
1980
1985
YEARS


MACHINE TOOLS OUTPUT
EVOLUTION BY COUNTRY 1975 - 1985
OUTPUT (BILLIONS OF CURRENT USD)
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
88%
70%
262%
-43%
38%
-45%
E.E.C
JAPAN
U.S.A.
1975
1980
1985
YEARS


OPTICAL PRODUCTS OUTPUT
EVOLUTION BY COUNTRY 1975 - 1985
OUTPUT (BILLIONS OF CURRENT USD)
80
70
60
50
40
30
20
10
0
18%
19%
U.S.A.
6%
8%
E.E.C.
17%
31%
JAPAN
1975
1980
1985
YEARS


SHIPBUILDING OUTPUT
EVOLUTION BY COUNTRY 1975 - 1985
(BILLIONS OF CURRENT USD)
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-20%
-11%
-18%
9%
7%
U.S.A.
JAPAN
-38%
E.E.C.
1975
1980
1985
YEARS


SCIENTIFIC INSTRUMENTS OUTPUT
EVOLUTION BY COUNTRY 1975 - 1985
OUTPUT (BILLIONS OF CURRENT USD)
80
70
60
50
40
30
20
10
0
1975
1980
1985
YEARS
U.S.A.
E.E.C.
JAPAN
31%
20%
7%
22%
69%
14%

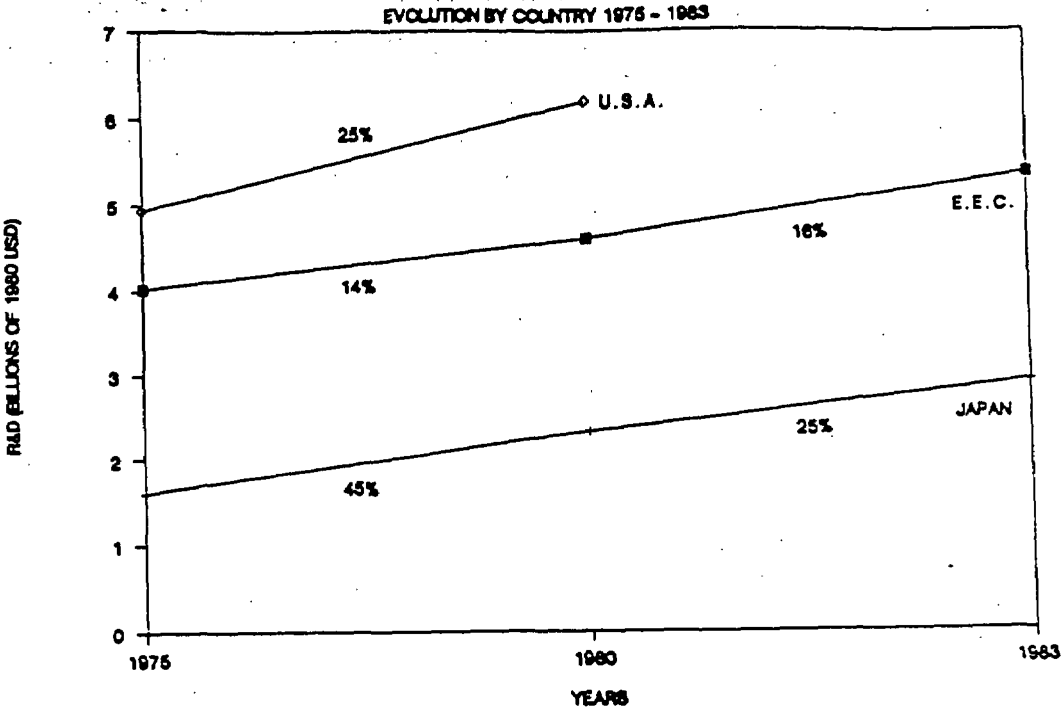
Industry		Technological improvements: yesterday	→ today
1.	All textile manufacturing processes	Manual	Computer adjustment/control
2.	Raw materials	Natural fibre	Synthetics Artificials
		Natural filaments (silk)	Synthetics continuous filaments
3.	Yarn spinning, winding	Manual	Automatic piecing, creeling, doffing
4.	Woven fabric	Narrow	Wide width
5.	Fabric dyeing	Batch	Continuous processing
		High	Low liquor ratio
		Atmosferic	Pressure
6.	Carpet formation	Manual	Weaving Tufting Nonwoven

Source KSA

Examples of changes in the textile industry that have increased some aspect of productivity

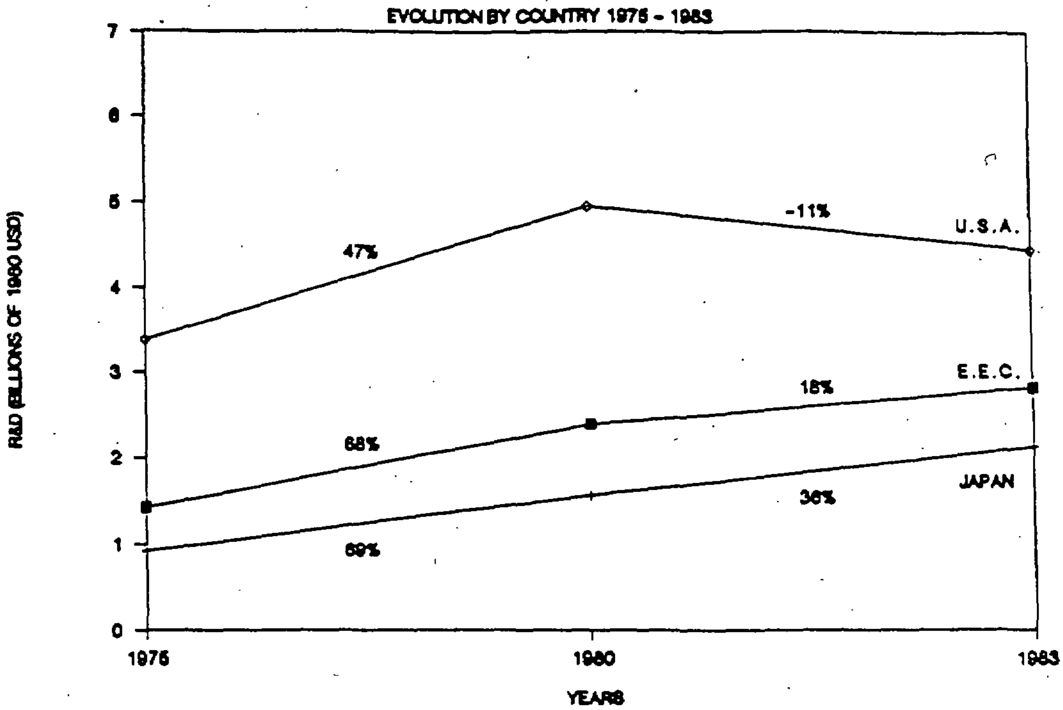
CHEMICALS OVERALL R&D

EVOLUTION BY COUNTRY 1975 - 1983

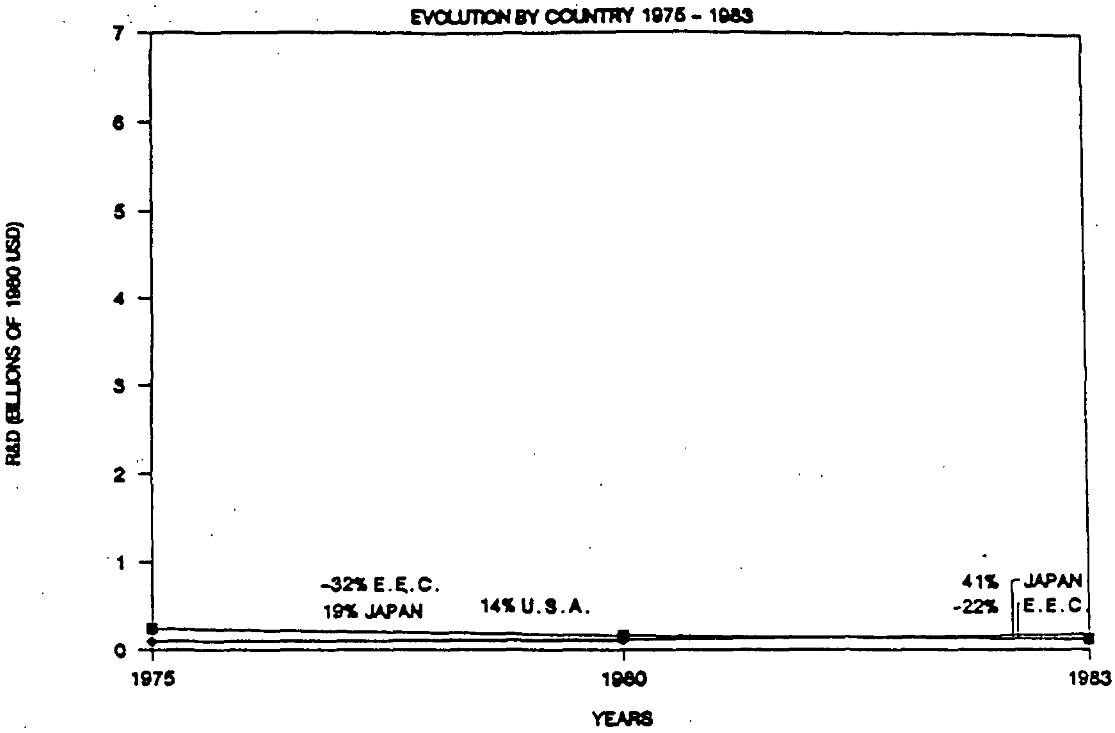


MOTOR VEHICLES OVERALL R&D

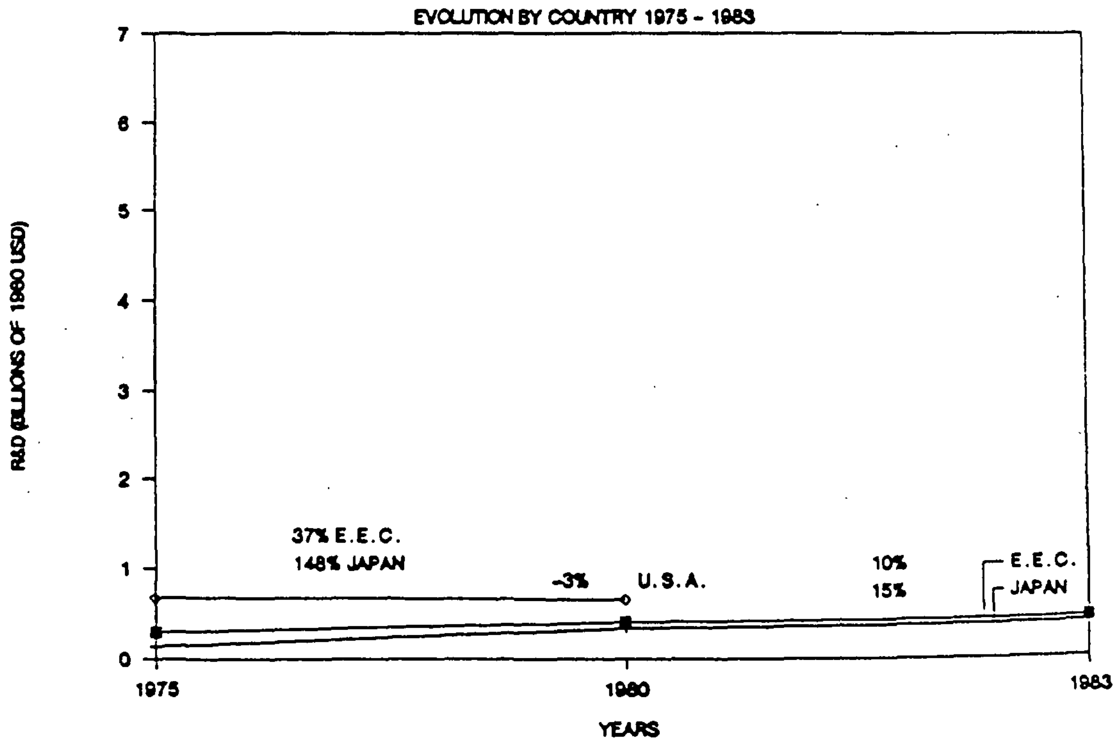
EVOLUTION BY COUNTRY 1975 - 1983

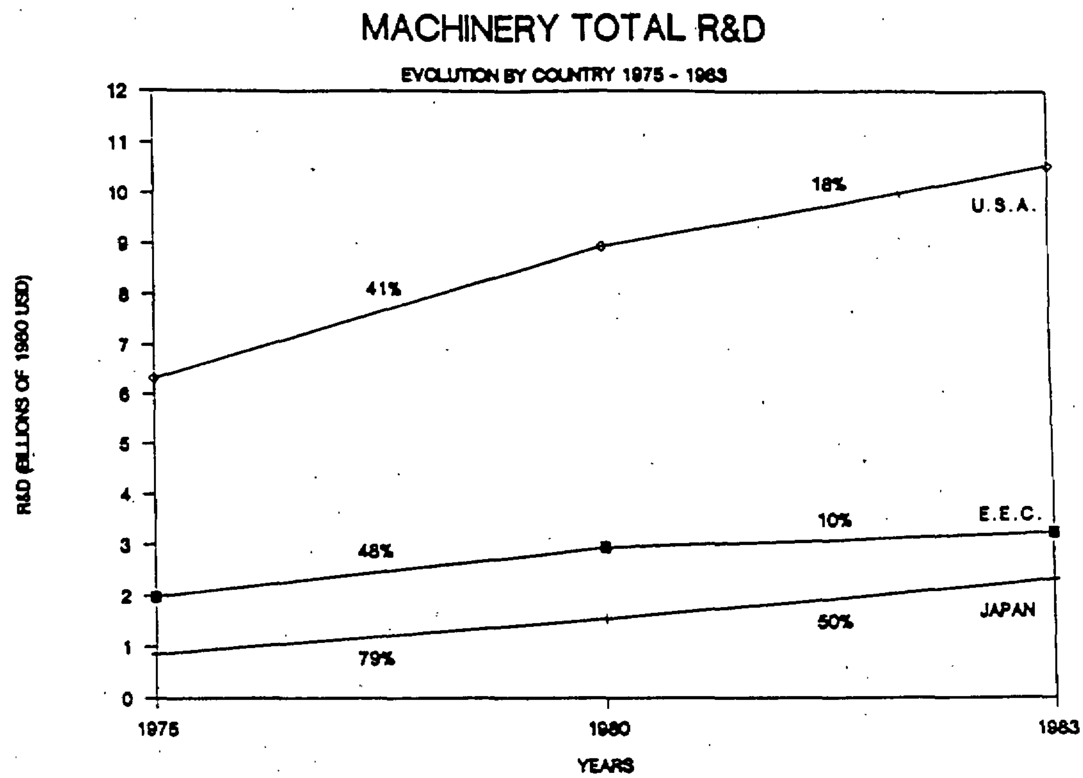


TEXTILE AND CLOTHING OVERALL R&D



RUBBER AND PLASTICS OVERALL R&D




MACHINERY TOTAL R&D
EVOLUTION BY COUNTRY 1975 - 1983
R&D (BILLIONS OF 1980 USD)
12
11
10
9
8
7
6
5
4
3
2
1
0
41%
18%
U.S.A.
48%
10%
E.E.C.
79%
50%
JAPAN
1975
1980
1983
YEARS

ANNEX 3 : AERONAUTICS

MARKET SITUATION

The aeronautical industry is without doubt a very important industrial sector in Europe (Fig. 1). The establishment of a strong and competitive industrial base in this field is a contributing factor to a strong and powerful economy and to the prosperity of the population.

During the 1980-1986 period the European aeronautics industry has captured 25,9% of the world-market. This represents average annual sales of about 9,900 - MECU's. Forecasts for the 1987-2010 period reveal an appreciable further increase in the world market leading to average annual sales of about 14,800 MECU's (Fig. 2).

A convincing example of the technological capability of European aeronautics industry is the penetration of "Airbus Industrie" in the category of medium range aircraft (Fig. 3). This has provoked a series of vigorous reactions from the USA where the Administration has declared its support for a new national thrust to reassert US leadership in world aeronautics.

World scheduled passenger traffic is rapidly increasing (Fig. 4).

Increased competition for the capture of the expanding market must be expected, notably for civil aircraft (Fig. 5), not only on the part of the USA but also from Japan and the Newly Industrialised Countries (Brazil, Korea...).

(0051.JC)

FIG. 1.

EC AERONAUTICS

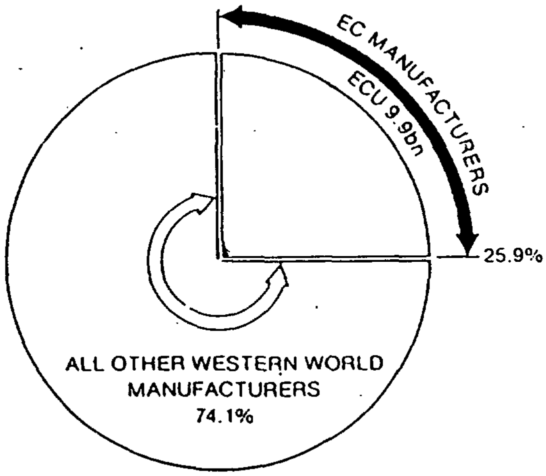
THE EUROPEAN INDUSTRY, based on 1985 statistical data: (excluding engine and equipment companies)

EMPLOYMENT :	200,000 persons
TURNOVER :	16,000 million ECU
ANNUAL RESEARCH & DEVELOPMENT Expenditure :	2,400 million ECU
ANNUAL RESEARCH & TECHNOLOGY Expenditure : (Excluding the Product Development Content of R&D)	370 million ECU

(Source : EUROMART Study)

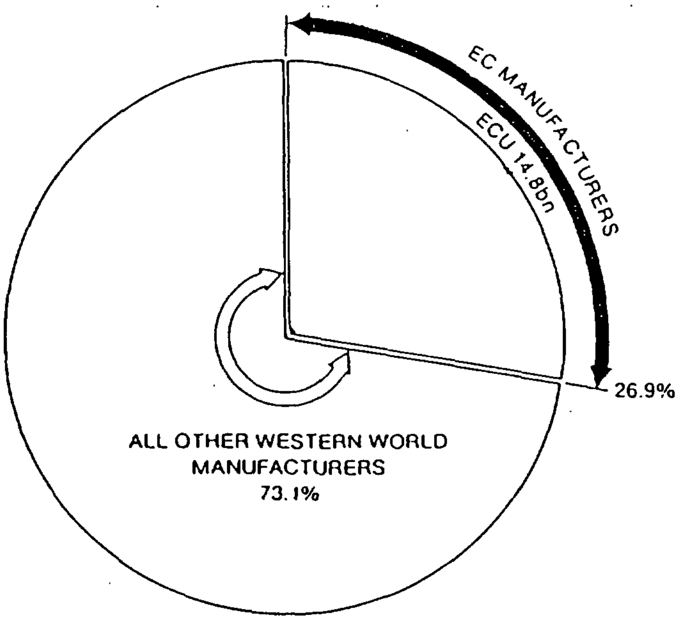
ALL-AIRCRAFT MARKET ANALYSIS, PAST AND FUTURE

Charts show average annual value (at 1987 prices) of aircraft deliveries over the periods indicated



PERIOD 1980-1986

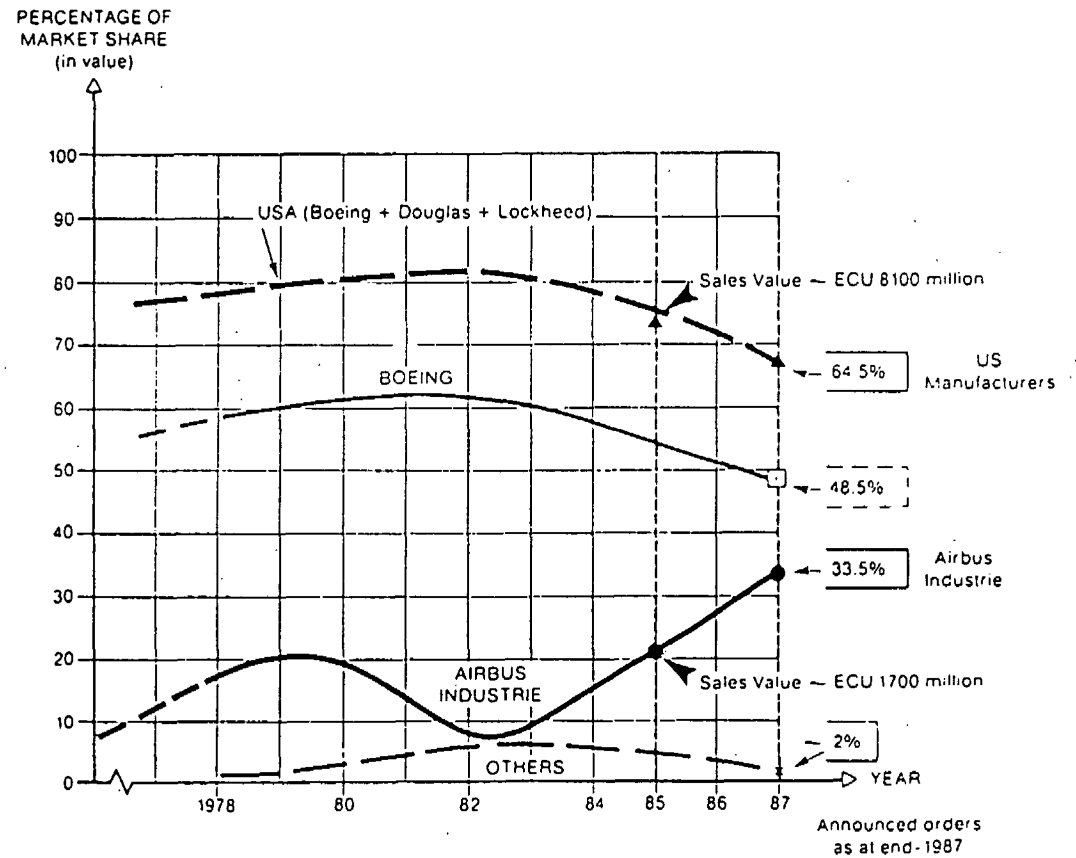
Average annual value of total market = ECU 38.3bn
(ECU 268 bn over the whole period)



PERIOD 1987-2010

Average annual value of total market = ECU 55bn
(ECU 1323 bn (at 1987 prices) over the whole period)

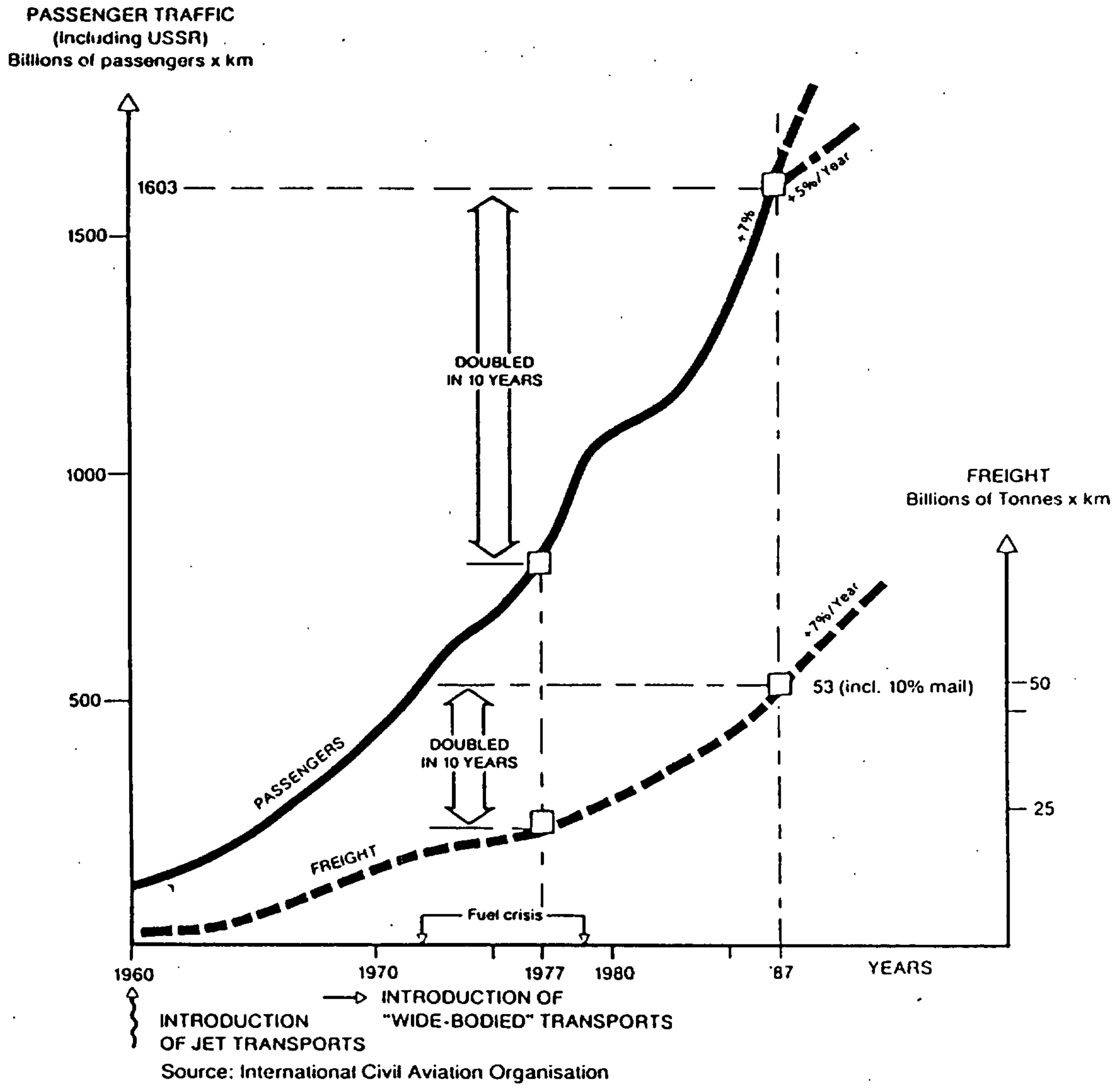
(Source : EUROMART Study) **FIG. 2.**



The market for large civil jet transport aircraft (more than 100 passengers) over the past ten years (1987 prices)

(Source : EUROMART Study)

FIG. 3.



World scheduled airlines traffic

FIG. 4.

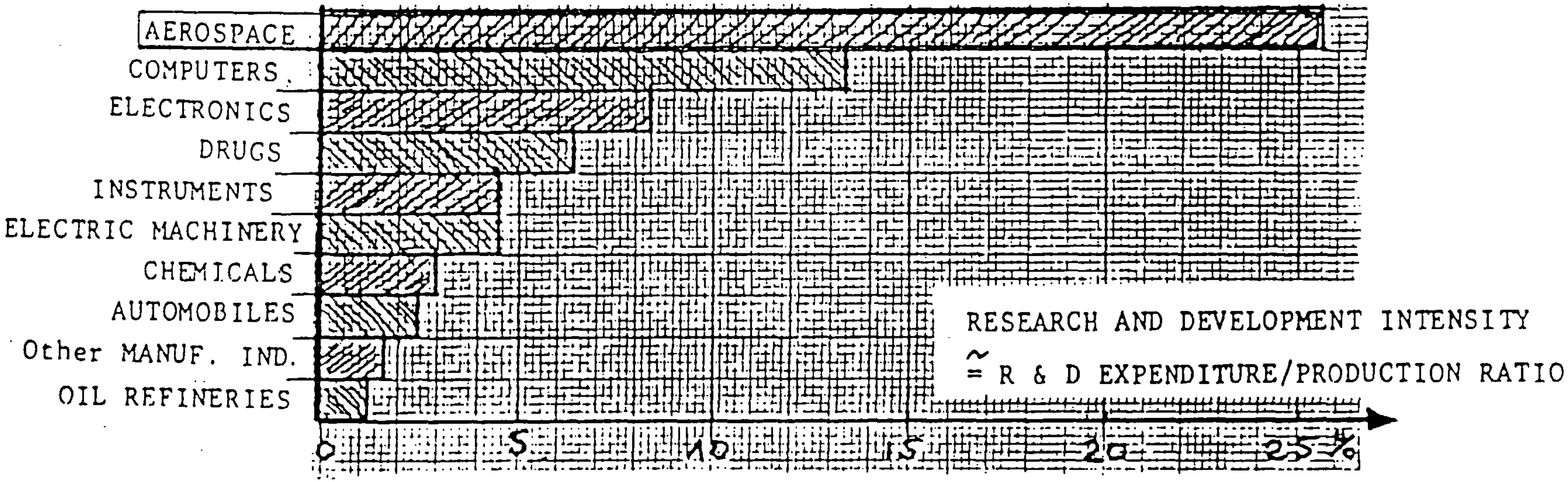
PRESENT AND FUTURE MARKET ANALYSIS

AIRCRAFT CATEGORIES	AIRCRAFT DELIVERED 1980–1986					FORECAST DELIVERIES 1987–2010				
	All Manufacturers		EEC Manufacturers only			All Manufacturers		EEC Manufacturers only		
	Units	Value (Bln ECU 1987)	Units	Value (Bln ECU 1987)	Value of Market Share (%)	Units	Value (Bln ECU 1987)	Units	Value (Bln ECU 1987)	Value of Market Share (%)
CIVIL										
Commercial Transports										
>360 Seats	228	19.03	0	0	0	1450	148	0–200	0–20	0–14
281–360	211	13.20	0	0	0	1650	109	550	36	33
201–280	438	21.56	283	14.77	68.5	1600	84	650	34	40
141–200	734	17.43	0	0	0	3250	79	1150	30	38
81–140	764	13.02	160	2.00	15.4	2050	34	750	12	35
51–80	2	0.02	0	0	0	2000	16	1250	10	63
20–50	794	3.46	530	2.07	59.8	2350	11	1050	5	45
15–19	967	1.80	226	0.50	27.8	1900	5	750	2	40
Supersonic						0–120	0–25	0–50	0–10	0–40
General Aviation										
Business Jet	2401	15.10	504	4.42	29.3	8600	60	2150	21.5	36
Private	16000	2.00	n.a.	n.a.	n.a.	70000	10	10500	0–1.5	0–15
Utility	n.a.	n.a.	n.a.	n.a.	n.a.	1600	5.4	800	3.5	65
Helicopters	5210	9.23	1980	2.69	29.1	12000	22	4800	8.5	40
Convertiplanes	—	—	—	—	—	600	9	150	1.5	17
CIVIL SUB-TOTALS		115.85		26.45	22.8		592–617		164–196	28–32

(Source : EUROMART Study)

FIG. 5.

(averaged from 11 main countries inside O.E.C.D., period 1970-80)



AEROSPACE INDUSTRY IS THE LEADER, AMONG THE 11 "HIGH TECH" INDUSTRIES INSIDE THE O.E.C.D. COUNTRIES, FOR R & D INVESTMENTS

which means:
- * A HIGH DEGREE OF INTERNATIONAL TRADE (EXPORT / IMPORT ↗)
- * A PREDOMINANCE OF PRODUCT INNOVATION

(Source : EUROMART Study)

FIG. 6.

The situation is more favourable for the USA aeronautics industry because it enjoys a vast and uniform market and because of the knowledge and the infrastructure provided by the execution of important programmes financed by the Department of Defense and NASA for the military and the space sectors.

RESEARCH AND TECHNOLOGY NEEDS

Competitive air transport demands continuous improvement in aircraft production costs (design, manufacturing, validation), airline operational costs through improvements in performance and fuel consumption, facilities to reduce delays at airport and in flight, aircraft maintainability while meeting operational requirements (safety, environment, punctuality, comfort, etc.).

The required level of technological competence can only be achieved by persistent and substantial efforts in research and technology which implies the development of a long term strategy.

The aerospace industry, more than any other, depends on advanced technology to ensure competitiveness. It is a leader in R/D investments (Fig. 6) and in the application of new technologies to its products and also benefits other industries by spin-off at the same time as it develops and applies its own technologies especially in the fields of design and production.

It also exercises an important role as the industry which makes use of the most advanced scientific research, acting as a centre for the transfer and diffusion of these technologies to other industrial sectors.

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Because of the specific high technology characteristics of the aerospace sector the United States administration uses this sector to develop and apply advanced technologies which are then adapted and utilised by other sectors engaged in development (Automotive Engineering, High-Temperature Furnaces, Industrial Control Systems, Testing and Production Methods). The value of this spin-off is immeasurable and it makes a major contribution to improving the country's economy.

The technologies needed by the aeronautical industry require a high level of competence for their realisation in a number of diverse areas, such as the sophisticated analysis techniques required for aerodynamics, the design of complex structures, the evaluation and methods of use of advanced materials, the integration of electronic techniques into complex operational systems, and design and implementation of new manufacturing methods.

This level of indispensable technological competence can only be attained by a continuous, intense effort in the domain of research and technology acquisition, and it requires a long-term strategic programme. An example showing the timescales involved is that it can take five to six years to develop a new technology, five years more to incorporate this into a new product followed by maybe ten years of exploitation of the product to recoup the investment made.

Consequently, it is necessary to establish a strategy at a European level in order to avoid the danger of loosing the competitiveness of the European aeronautics industry, which could lead to a progressive deterioration of its position in the world market.

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EUROPEAN ACTION

The acquisition of the complex technologies and the required support equipments require a wide application base.

The national centres (O.N.E.R.A.[1], D.F.V.L.R.[2], R.A.E.[3], N.L.R.[4], C.I.R.A.[5], I.N.T.A.[6]) in the major aeronautical countries are actively involved and contribute to progress in aerospace techniques with their fundamental research, complementing university laboratories, with their applied research, preparing long and medium term projects and with their direct technical assistance to industry, either by making the testing potential of their centres available or by studying problems raised by actual projects under development or difficulties encountered on operational equipment.

Some international collaboration on aeronautical research is implemented in organisations like GARTEUR and AGARD on the basis of concerted action and on specific topics. But the acquisition of the complex technologies and the required support equipments requires a wider application base. This can be organised in Europe by collaboration at community level.

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1 O.N.E.R.A. Office National d'Etudes et de Recherches Aérospatiales (France).

2 D.F.V.L.R. Deutsche Forschungs- und Versuchsaustalt für Luft- und Raumfahrt (F.R.G.).

3 R.A.E. Royal Aerospace Establishment (U.K.).

4 N.L.R. Nationaal Lucht-en Ruimtevaartlaboratorium (Netherlands).

5 C.I.R.A. Centro Italiano Ricerche Aerospaziali (Italy).

6 I.N.T.A. Instituto Nacional de Tecnica Aeroespacial (Spain).

(0051.JC)

For the development of prototypes, EUREKA is involved in a number of market-orientated projects (EUROFAR, Amphibious Flying Boat, SAMOVAR, etc.).

In the longer term the improvement in the capabilities of the European industry will necessarily involve a progressive reorganisation of the industry. In the meantime, there is a need to implement a programme, without delay, at Community level. This programme will be based on a series of measures following the conclusions of a study supported by the Commission and undertaken by nine major European aircraft companies.

These measures concern :

- increased co-operation in research and technology activities;
- concentration on key technology areas identified in new joint requirements;
- provision of additional funding resources to support this increased effort.

The Commission plans, via these actions, the double objectives :

- of enlarging the European technology base by involving the largest possible participation in the programme, by universities and national research centres;
- of reinforcing the current position of the European aeronautical industry in world markets.

In the context of such a large and wide-ranging programme to enable Europe to attain in the future the objectives defined in the Commission strategic plan, a two year pilot programme is being proposed.

(0051.JC)

The particular objectives of this pilot phase are :

- to provide a firm foundation for co-operation between European aeronautical industries in research and technology acquisition and to involve in the projects universities, national research centres and SME's;
- to commence the research projects which have a degree of urgency and are important for the future capabilities of the European aeronautical industries;
- to compile, verify and complete the information base and knowledge required for technological development;
- to gain experience in the organisation and functioning of a programme of this type and to define the required long-term actions.

The areas of key technology identified for the pilot phase are :

- aerodynamics and flight mechanics
- materials
- acoustics
- computation
- airborne systems and equipment
- all electric aircraft
- propulsion integration
- design and manufacturing technologies.

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Introduction

The significance of biotechnology

Japan's Ministry of International Trade and Industry in 1988 forecast the world market for "bio-related industries" as $ 514 billion. In a paper in 1981, a futures group within the European Commission (1) had pointed out that, in a modern developed economy, over 40 % of manufactured output, or 20 % of GNP, was biological in nature or origin. Estimates of market potential for biotechnology have varied over several orders of magnitude, depending on the writer's choice of a narrow or a broad definition; but as was pointed out, "human beings are 100 % biological" (1). Radical advances in biological understanding and related technological or manipulative abilities were therefore bound to attract not only commercial, but widespread political attention, and a certain degree of public disquiet in at least some cultures. The current OECD study on the "long-term economic impacts of biotechnology" has not suggested dramatic near-term growth of new markets; but has acknowledged a different significance by a subtle change of title : "Economic and wider impacts of biotechnology". It is a pervasive technology.

Biotechnology is not a scientific discipline in its own right but, rather, a cross-roads of different sectors of knowledge - including biochemistry, genetics, microbiology, physiology, morphogenesis among many others - which contribute to the intelligent use of nature and natural processes. It is the technology of living matter, from which many biotechniques have emerged to the immediate benefit of health care and hygiene, agriculture, the food industry, the environment, the health and chemical industries. Biotechnology is about the purposeful management of living systems, ranging from the control of a microorganism in a fermenter, to the maintenance of a small planet with a population of 5 to 10 billion human beings.

In the following sections, details are presented of some of the most dynamic areas of the "bio-revolution". The sequencing of the human genome, "the map of man", is a challenge which has seized the imagination of scientists and laymen alike. Section (A) sets this in the broader context of genome analysis of various complex organisms, since neither scientific enquiry nor practical applications can be anthropocentrically constrained.

Man depends for his existence and his environment above all on plants and their constituents. The penetration of the bio-revolution, the "molecularisation" of plant science which is expanding the role of biotechnology in agriculture, is described in Section (B).

The application of biotechnology to agriculture has attracted fears that it will stimulate ecologically devastating monocultures; but as has been rightly pointed out by one of the world's leading environmental institutes, "A biotechnology attentive to natural history may provide some of the most powerful tools to reduce the pressures on genetic resources and enhance the value and conservation of wild species". (2)

Section (C) describes some of the practical steps and political developments in defending the diversity of mankind's genetic resources, a task in which biotechnology is increasingly called upon to assist.

The advances in biotechnology offer the prospect of progress not only to the management of our environment, animal and vegetable, but above all to the understanding of man himself. Of immediate social and commercial relevance in defending man against disease has been the understanding of his own immune system, and its stimulus (by vaccination) to produce antibodies. Since the development of cultured, immortal hybridoma cells for the production of monoclonal antibodies is one of the great triumphs and most productive innovations of the bio-revolution, it is appropriate to present (Section D) a review of recent progress and challenges in immunology.

The bio-revolution is a molecular revolution, and is transforming research methods and the prospects for breakthroughs even in that most daunting intellectual challenge, understanding the human brain itself : section E outlines some current challenges in neurobiology. This subject is of interest not only for clinical applications (the understanding of Alzheimer's disease is of obvious importance for the ageing societies of the developed world), but for the development of "neural computing". Developers of the most sophisticated parallel processing computers contemplate with awe - and with detailed interest in its mechanics and methods - the speed, performance and compactness of the human brain.

Following this presentation of some of th most significant domains, the final section of this annex gives an overview of the Community initiatives in biotechnology.

The biotechnology race ?

Given the ultimately enormous economic and social significance of biotechnology, governments of even the most "non-interventionist" persuasion have rushed to support biotechnology. U.S. federal support is estimated by the OTA (3) to have amounted in 1986-1987 to \$ 2.7 billion. Japan's long-term technology forecasts (1987-2015) underpin a strong emphasis on biotechnology as a priority to bring their pharmaceutical and other bio-related industries towards international competitiveness in the 1990s. Modest government expenditure figures on R&D belie a competent, coherent and long-term-oriented strategy for biotechnology.

Thus it has been unsurprising to see various consultant reports, including those used by the US Congressional Office of Technology Assessment, placing Europe in the bronze medal position behind the entrepreneurial vitality of the USA, and the systematic thrust of Japanese consensus policy.

However, the "Olympic games" include many diverse sports. Europe has many "golds", and although its fragmentation and diversity are at first seen as a weakness, the "old colonialists" of Europe have used their centuries of experience to be the most effective internationalists in many markets around their world. In the entrepreneurial climate of the USA, small companies have to shout loudly to attract venture capital, contract research customers, and new investors willing to bid up the value of the company's shares. With less noise and a greater emphasis on in-house activity, the profitable and internationally successful giants of Europe (in chemicals, in pharmaceuticals, in agrochemicals and in food - are no less effectively developing an international position.

Europe is spending less on biotechnology research than the USA : a few hundred million, perhaps a billion Ecus on publicly supported research. But no simple judgement can be made on the outcome of the "race". The U.S. is thought to lead in the number and vitality of small entrepreneurial start-ups - some $ 3 billion has been invested in these during the period 1976-1986 (3); but many are acquired, or do their contract research for Japanese and European multi-nationals. Total current private sector R&D expenditure in biotechnology (including biotechnology activities of major companies) is estimated by the OTA at some 2.0 billion in 1987, some $ 1.2 billion by "dedicated biotechnology companies", and some $ 800 million by major corporations.

Based perhaps on a somewhat broader concept of "biotechnology company", the European Commission's biotechnology concertation unit has identified some 448 companies in Western Europe, numbers as follows :

EUROPEAN COMMUNITY				OTHER EUROPEAN STATES (EFTA)	
Belgium	37	Italy	34	EEC	388
Denmark	19	Luxembourg	1	Austria	2
France	76	Netherlands	33	Finland	6
Germany (w.)	46	Portugal	2	Norway	7
Greece	2	Spain	12	Sweden	28
Ireland	11	UK	115	Switzerland	17
		Total EEC	388	Tot. West.Eur.	448

3. Internationalism and Information

One of the characteristic features of biotechnology is its internationalism. Whether for access to markets for maximum return, or access to science and technology for maximum efficiency in research, development and innovation, a biotechnology company has to be conscious of competition and opportunity on a world scale.

One response to this has been the proliferation of strategic alliances between companies. These may be joint ventures, equity purchases, licensing agreements, marketing agreements, or research contracts. Many of them are transnational, EC-US, US-Japanese, or EC-Japanese. Their existence complicates any simple picture of comparative research expenditures by region, since there is continuous information flow through published information channels, via the inter-company agreements, and by the frequent transfers of individuals in a dynamic industry.

Even the largest companies recognise that their continued competitiveness depends upon effective exploitation of a rapidly changing base of knowledge, most of it external to the company's own resources. The challenge of managing this constantly changing interface has led to growing emphasis on information services and infrastructure, a field in which Europe is most seriously behind the USA (4), and in which the advantages of the federally centralised facilities, e.g. of the National Library of Medicine (and its fast-growing National Biotechnology Information Center), build upon their computer-sophisticated home market (40,000 general practitioners have personal computers in their surgeries) the basis for potential global dominance.

Because of its information-intensive character, biotechnology has been the basis for a growth industry in advice on patenting issues. There are many controverses arising as the new intellectual breakthroughs in understanding seek commercial return on the research investment by expanding into the traditional application areas of the life sciences.

Added to the already familiar consensus about the regulation of biotechnology, the patenting and information infrastructure illustrate the many points at which international competition in biotechnology depends upon public policy. For a review of these issues, see (5).

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A Molecular investigation of the genomes of complex organisms

The challenge

The genome specifies all the rules which, through interaction via the phenotype with the environment, determine the survival and the reproduction of an organism. Up to now, the molecular structure and the regulation of this genetic information has remained largely inaccessible. New techniques in DNA sequencing, as well as improvements in the handling of biological information, have now created an unprecedented situation. There are scientific means available to decipher completely the genetic programme of any organism. The tool kit is composed of techniques to separate chromosomes, cloning and sequencing methods, ordered DNA libraries, genetic linkage maps, data bases and computer software.

DNA sequencing of whole genomes will require a vast amount of work, especially if one hopes to investigate the structure of higher eukaryote genomes. It seems therefore of the utmost importance to organise and make proper choices for a productive strategy. It is clear that, as such, the sequence of a genome of a single entity will be of very high basic value; it seems also clear that determination of the sequence of several genomes will increase the potential interest of sequence determination by a very high factor. Indeed, at the simplest level, sequencing will make available all signals that are important for the core machinery, responsible for gene expression and replication. A further important result will be that we shall have access to information corresponding to the ecological niche of the organisms considered. Indeed, the DNA sequence information that remains present after the core sequences have been subtracted, represents information specific to each type of organism. This will make understandable the way by which typical instances of various organisms cope with their environment.

The next domains which will be fertilised by knowledge of total genome sequences is the study of the evolution of species. This will result both from comparisons of sequences of a given organism, and comparison of homologous sequences in different organisms. A major consequence will be that we shall have pathways relating known structures (at the three dimensional level) to unknown structures. This, most probably, will bring a major support to the general problem of prediction of protein tertiary structure, knowing only their primary structure.

Finally, when we shall be in a position to start sequencing genomes of multicellular eukaryotes, we shall start obtaining specific information on genes involved in cell differentiation. In general it can be hoped that knowledge of the genes will help understand a variety of biological phenomena in a way more directly accessible than the usual converse way (i.e. going from the biological phenomenon to the gene).

The United States are seriously contemplating the possibility of sequencing the human genome, and Japan is making an endeavour to invite international cooperation for this ambitious task to be placed under the umbrella of its proposal for a Human Frontier Science Programme. The primary interest of sequencing the human genome goes with the wide-ranging medical applications at stake. Many human diseases are indeed under genetic control, and knowledge of the molecular structure of the disorders could lead to vast new markets in diagnostics and therapeutic agents (cf. Health annex). Beyond its scientific significance, a project of this dimension would obviously result in technological spin-off and the development of instrumentation of wide biotechnological use.

Progress throughout the world

The United States are already engaged in some steps of the human genome enterprise. Total federal funding to genome projects amounted to 32-34 Mio $ in 1987. Projected spending of NIH in 1989 is estimated at 28 Mio $, and DOE proposes 18 Mio $ for the same year to carry out technological and instrumentation connected research. The NSF would also provide some support through grant programmes. However, it is generally accepted that a budget of 200 Mio $/year would be necessary to provide the comprehensive support that would be required. The dimension of the task, and some lack of coordination between the many interested organisations, both public and private, may create difficulties before the human genome sequencing project can deliberately take off. In the meanwhile, several smaller genomes are subject to pilot sequencing work, in the United States as well as in other developed countries.

The Japanese position appears particularly strong from the technological angle. The automation of sequencing techniques is an area in which much work is being done, funded both by industry and by the government. Robots have been developed, based on US approaches. The University of Tokyo is very strong and many of the industry people involved in the development of automated sequencing/mapping equipment are their former students. Much more so than its European counterpart, Japanese industry is making efforts to commercialise the results of research and development in this field.

Developments in Europe

Several Member States as well as the Commission of the EC have already invested much thinking, and sometimes money, in defining the partnership Europe could offer in this major international effort. It is a fact that Europe cannot accept a minor role. It has many of the required skills and resources, and has acquired much experience in coordinating work across State boundaries. Its reputation that it is bound to coordinate policies and actions in all areas of Community competence turns out to be its real force. The task of sequencing the genome of a complex organism is one which will require much division of labour and network integration.

France has allocated already 1.4 Mio $ to sequence regions of the human chromosomes of particular medical importance, and to develop data processing systems. The UK Medical Research Council set up a coordination committee, and is in the process of working out its strategy to be approved at government level. The German DFG has been allocating 500.000 $/year for the last three years for research on the human genome. Cloning, data handling and instrumentation are the 3 main fields on which discussions were organised in a recent national meeting, to be convened again on a regular basis. A 50.000 kbase chromosomal region associated with mental retardation has been selected by Italy for complete sequencing, in collaboration with the Salk Institute. The cost to the Italian government will be about 10 Mio $. A EUREKA programme was also approved which covers some of the technological aspects of sequencing work, with a British and a French company involved.

However, even the largest European country cannot rely on its own forces to compete with the US and Japan where the initiative received earlier attention. It is still remarkable that the Community has the privilege of being first in 1988 to organise on a transnational basis a coordinated project to sequence one chromosome of yeast. This objective brings together in the framework of the BAP Community programme as many as 35 laboratories during a period of 2 years. The target, proportionate to the modesty of the funds available, is a reasonable choice before the international scientific community will embark on the human genome. The latter - 1000 times the scale of a bacterial DNA - is so large that one has to perform several intermediate studies in order to permit scaling up. This means that eukaryotes with small genomes such as yeast, be it only for this reason and not for their own interest, should be considered first.

Other discrete steps have been taken, using existing programmes or new proposals under the second Framework Programme, to organise transnational research on small-scale sequencing projects : Drosophila is considered under the Stimulation action, and the human genome will be for the first time the subject of Community research under the initiative of Predictive Medicine.

From needs to priorities

The different projects that have been briefly outlined involve a significant amount of work : as example the smallest project (1000 kb) requires at least 25 man x year of work, and the project of sequencing a bacterial genome would require five times that figure. Choices are needed for the Community to tailor its effort at an international level.

- The participation of the Community in the human genome project is both a strategic necessity and a chance offered to scientists and industry; this participation still has to be defined in terms of scientific contributions, commercial consequences and ethical guidelines; the coordination of the European response is taking shape in the framework of the Japanese initiative for a Human Frontier Science Programme.

- The completion of the total sequencing of the yeast genome, of which only one chromosome is under analysis; this is the unique strength of the Community that it was first to embark on a completely co-ordinated project using this lower eukaryote, accumulating information and creating skills largely applicable to the human genome later on; the Community must keep with it this modest advantage.

- The participation of the Community in international projects addressing other genomes of high commercial significance (B. subtilis, Arabidopsis thaliana).

- The organisation of an industrial involvement in this whole endeavour, taking care of technological spin-offs in the software and instrumentation areas, as well as of legal, ethical and commercial consequences of exploiting the accumulated biological information.

- Concomitant support to basic science in the areas of molecular biology, cell physiology, protein chemistry and enzymology, to secure that the structural information massively disclosed be also interpreted and exploited in Europe through an adequate research infrastructure.

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B Molecular foundations of plant biotechnology

The roots of our green planet

Plants are mostly studied in function of their agricultural and economic importance; yet, in spite of elegant investigations in e.g. photosynthesis, they have not received the right attention on many aspects, such as totipotency or metabolisms, with direct bearings on agriculture and industry.

Totipotency is a unique property of plants. In contrast with other living beings, they can develop into normal embryos and regenerated organisms ultimately, without necessarily passing through fecondation. The identification of molecular signals to control these unusual processes is an essential research step for the understanding of reproductive mechanisms in agriculture and forestry.

Plants are also endowed with complex and original bio-synthetic pathways, which often find no equivalent in any other living organism. The products of these biosyntheses have attracted the interest of chemists for centuries and have opened up a wide diversity of markets for health and chemical industries. Their structures and biosynthetic routes are however poorly known (if known at all) in some of the 9.000 plant species partially studied so far. But 300.000 plant species with potential interest still are keeping most of their metabolic secrets beyond scientific grasp.

Limited efforts have recently been engaged to fill some of these gaps through research at molecular level. However, they have been always subcritical and in no proportion to the overwhelming importance of plants to regulate the biosphere and to support most of human activities. There are thousands of animal genes isolated so far, for a hundred plant genes only; and the excess of blood proteins compared to the number of whole plant proteins that could be studied still is by two orders of magnitude. Nevertheless, food, feed, fibres, wood, drugs, solar energy capture all are derived from plant essential features, which are exploited merely on empirical bases. It is unthinkable that the significance of any of these functions, and products thereof, may fade away in a foreseeable future.

The situation worldwide is however rapidly changing, and a new deal in plant sciences is about to be established. The dramatic leap has come from the implementation of new research tools such as cell culture and regeneration methods, T-DNA transfer systems, site-directed mutagenesis, molecular probes for genes and gene expression, etc. The rapid arrival on the market side of unconventional products with a high profile (engineered symbiotic agents, seeds with specific resistances) raised much industrial interest, resulting in substantial restructuration of the agriculture-based industry. What is occurring in the United States and in Japan is particularly significant.

The world scene

American teams have been very fast at applying the whole panoply of molecular tools mentioned above, to build up leading expertise in plant gene expression and plant development. They recorded many world firsts over the last 3 years, such as creating the first tobacco with an engineered resistance to mosaic virus, the first tomato with an engineered resistance to the hornworm, the first transgenic sunflowers and oil seed rapes, the first chloroplast genetically transformed, etc. This race towards meaningful research achievements has been made possible also because many industrial companies participated directly in the effort. Besides the expected seed and agro-chemical firms that were first in the business, several pharmaceutical and oil companies among the major ones started to have significant "green" commitments, starting from the purchase of local seed companies to secure the access to genes. They have also contracted research to universities, although to a lesser extent than in the pharmaceutical field.

One of these big companies is even known for having established in Europe more contracts with universities in the EC than was possible through the BEP Community programme during the same period. Other forms of research commitments have been flourishing, such as the purchase of small R&D service companies, the reinforcement of in-house research capacities or the participation in consortia. Established in 1986, the Midwest Plant Biotechnology Consortium in particular brings together the expertise of 14 universities and the driving forces of 31 industrial companies (including from pharmaceutical and electronic sectors) for target-oriented research in the field of agricultural biotechnology. The research environment is particularly favourable in the US because of market prospects (5 billions $ for seeds, and the projection to 100 billions $ in 1995 for all biotechnology products in agriculture), and after favourable provisions had been made in 1985 by the US Patent and Trademark Office for granting patent protection to plant varieties, including those resulting from genetic engineering. The only pitfall before modified agricultural species are brought to the field and new bio-rational practices implemented in agriculture stays with the question of conjectural risks. Pressure groups have caused prejudice to the prosecution of experimental work, and federal agencies have not yet been able to control the situation. This difficulty, which was particularly amplified in the US where public debates have always been part of the political life, could give Europe a competitive advantage if only the Community was able rapidly to define common regulations for the introduction of modified organisms. However, irrespective of the somewhat confused regulatory status, the USDA makes now provisions for a substantial support to basic plant research. Although it accounts for only 6% of the Federal budget, ranking third after NIH and NSF in biotechnology spendings, USDA has constantly increased its biotechnology budget since 1982. Its new Plant Science Centres (10 million $ in 1987) have been set up to encourage the best in basic plant research. These will address the areas of plant engineering, rhizosphere dynamics, carbohydrates and ecological processes in priority. Cooperation and multidisciplinarity are the major ingredients of the new recipe, which provides evidence for the real obstacle which American plant biotechnology is facing : the lack of a basic understanding, at physiological and molecular levels, of the make-up of agricultural species.

Japanese plant biotechnology is not less spectacular, although it could give the impression of being more limited in scope.

A major strong point in Japanese plant science has always been the study of secondary metabolites. Apart from describing the structure, biosynthesis and physiological functions of these compounds, a large effort has been put in increasing their production. This was attempted through plant breeding and through plant cell culture. In Japan so many groups were and are still involved in this approach that they have obtained an unique technological skill, non existing in any other country. Now that improvement of plant cell lines for secundary metabolite production will become possible through genetic engineering, their capacity for plant cell fermentation will in the near future give Japan a leadership in the production of these compounds, which can be of the highest importance to the fine chemical industry and the pharmaceutical industry.

Due to the strategic importance of agriculture, Japan also has a long lasting interest in developing crop improvement facilities. At present the major effort is geared towards rice, wheat, barley and soybean. The future trend will be to include rapeseed. Their present major successes are in adapting the gene transfer techniques to new plant species. With these techniques, they have been particularly successful in engineering different rice cultivars. At present it is the only country where in some institutes and companies one can find greenhouses full of engineered rice plants.

Outstanding research is also carried out in the laboratories of different big industries. Each year the best students of the major universities are contracted by the leading industry. All have started in-house plant biotechnology research, some have even purchased seed companies in Japan and abroad. Likewise other parts of the developed world, this move is seen not only on the side of the traditional food industry or agricultural companies, but also by the major chemical companies, the fibre and paper companies, oil companies and even cement and electric industry. Most are active in research and production of several major crops (rice, wheat, beans, even corn) vegetables (tomatoes, potatoes, cabbage) but also fruits (citrus, melon, strawberries, grapes), medicinal plants and ornamentals.

In summary, with a much larger number of skilled scientists and technicians than the whole of the EEC countries, Japan is well prepared for a major biotechnology effort.

Their weakness stems from the fact that developed skills are not much used for asking fundamental questions in plant molecular biology. And yet, the fruitful applications of gene transfer techniques depend on e.g. cell regeneration through organogenesis or embryogenesis. Success in gene isolation relies on high standards in molecular biology techniques and also on a proper understanding of plant physiology to characterise the required gene product. Quite some fundamental knowledge is still needed to optimise the current effort.

The role of Europe

Even in a fast moving world, Europe has up to now been able to maintain a leading position in plant biotechnology, owing to the activity of pioneering groups and to the promotion effect of national and Community programmes. As a result, European achievements can compare very favourably with those of the US. The first monocots (onion, daffodil, asparagus and rye) were genetically transformed in Belgium, Germany and the Netherlands; the first receptor of a plant hormone cloned in Germany; the first nitrogen-fixing heterologous Rhizobium in association with an engineered legume in Denmark; the first regulatory gene of a storage protein cloned in Italy from maize, etc.

EEC Member States have been very fast at using this momentum, as they reinforced or even frequently created numerous laboratories and centres for plant research. The Community placed itself at the forefront of the area, but it must make sure the benefits will stay with it. Losing competitiveness in this phase of rapid expansion would result in a loss of opportunities to exploit imagination. In addition, it is of particular advantage that this European impetus can be tuned and amplified by capitalising on the experience from the Community programme for biotechnology R&D (BAP : 1985-89). BAP was very well received and provided a reliable test for the interest and promises which lie with the scientific and industrial communities in this area.

The pattern and development of industrial interest parallels very well that observed in the US and Japan, crossing all traditional branches of industry. After a period of hesitation in the early eighties, when small R&D companies were flourishing in the States, there are now many indicators of an intense and far-looking industrial activity by established European firms :

- recruiting university staff, particularly massively the last five years;
- setting up new in-house biotechnology laboratories, in almost all branches of bio-industry;
- restructuring quite intensively the market;
- joining new representative bodies (EBCG, GIBiP);
- cooperating in research (BAP, EUREKA, Clubs, etc.);
- supporting basic research (European Institute of Technology EIT, private foundations, etc.);
- buying American seed and R&D service companies.

About 25 companies of various sizes and professional affiliations joined a new club, the Green Industry Biotechnology Platform (GIBiP), to interface with the public, consumers and regulatory bodies, and to develop common ideas in the fields of research and intellectual property. Their expectations are for a major European effort in plant biotechnology and for harmonised regulations allowing research results to be applied in Europe and preferably not on other continents systematically.

Community needs and opportunities

The foreseeable applications which could promote the welfare and the competitiveness of the Community would fall under three policy objectives :

- agricultural competitiveness,
- environmental care, and
- consumer safety.

Community agriculture is faced with the urgent need to increase its competitiveness while keeping in harmony with the environment. Both objectives, competitiveness and environmental protection, can be either antagonistic as they might have been occasionally in the past, or preferably compatible when based upon judicious technological options. The reconciliation of these equally important issues stays with the right balance of "bio-rational" to chemical practices in agriculture. That is to say with the design of alternative methods in plant nutrition and crop protection that would base productivity on genuine biological processes under genetic control, rather than on external supply of chemical fertilizers or pesticides exclusively. This "bio-rationality" is becoming more conceivable with the advance of modern biotechnology and the demonstration that early applications, such as microbial fertilizers or in-built genetic resistances, are already becoming feasible.

Through the pervasiveness of molecular approaches, more attention can also be given to the molecules of quality, those associated with innocuity, flavour, nutritional value, texture, etc. of many plant products. If one could identify them, control their synthesis and tune their functional activity, the molecules of quality would make the real difference between a surplus and a deficit crop : e.g. between a surplus barley of low feeding value and a deficit barley more adapted to animal diet; between a surplus wheat of poor baking quality and a high gluten wheat as demanded by the miller's trade, ... Quality and precise characteristics will increasingly become the discriminating factors of plant products on the market side, and biotechnology is giving a new opportunity to focus on molecular determinants of these parameters.

Last but not least, the interactions of crop plants with other native species of the agricultural environment can be monitored and, hence, predicted as they never could before. This should permit real ecological management of land uses, in both the short term and long term interests of Community citizens.

In order to apply the results of modern biology to these Community policy objectives, the Commission has formulated new programmes aiming to promote the relevant developments. What is required is a collaborative effort, not only multinational (as in any Community programme), and multi-disciplinary, as is usual in biotechnology, but in particular based on closer partnership, in R&D, between agriculture, industry and science. Such is the aim of the ECLAIR programme (European Collaborative Linkage of Agriculture and Industry through Research : 80 MECU, 1988-1992). The biological advances can be used to enable agriculture to develop products (of plant, animal or other origin), better adapted to market needs (food and, increasingly, non-food) ; thus opening up new growth opportunities for European agriculture, promoting competitiveness and respecting the need to maintain and enhance the environment.

A related programme, FLAIR (Food-Linked Agro-Industrial Research, 25 MECU, 1989-1993), similarly applies the fruits of modern biology, but with a particular emphasis on the interface betwwen the food production system and the consumer. The keywords are quality, safety, nutrition, and the application of the new technologies to these ends.

These programmes of feasibility research and development, looking at possible exploitations of biotechnology breakthroughs at the interface of agriculture, industry and the environment, have evolved in close connection with the Community programmes of biotechnology R&D (BAP : 1985-89, then BRIDGE : 1990-94). The programme BAP, in particular, is placed at the fore-front of research and will find in ECLAIR, FLAIR or the programme for coordination of agricultural research, the logical receivers of the type of enabling techniques or instrumental knowledge that is created. Conversely, the application-oriented programmes constitute the testing ground where bottlenecks are identified and can very appropriately feed back scientific ideas into the more basic ones.

At this stage, the point will be made that none of the existing programmes of the research-development-application line will for ever perform as they did throughout the eighties, without caring for the necessary forward thinking into the principles of life which underly biological sciences.

None of these objectives of Community significance can be reached just by extrapolating the ongoing research effort. Scientific and technical obstacles have now shifted from the technological end to the biological end of bio-technology.

In the same way as biotechnology R&D activity and agro-industrial research mutually enhance each other, there need to be a stronger commitment into basic areas where knowledge is expected to become limiting for further expansion of biotechnology to take place eventually.

This is a job for Europe

Genetic and molecular techniques have attracted attention, they have become particularly precise and powerful, but they still can be applied only to the emerged side of the iceberg which represents living matter. The hidden principles regulating plant functions and metabolisms now need to be elucidated, before useful work can proceed at a scale of macro-economic significance. Know-how has outstripped knowledge, so that technology will be limited in scope until technology has served the purpose of producing the necessary understanding of agricultural objects; what could also be called "new plant physiology".

Five major areas are proposed for joint research in Europe :

- flower induction, gamete development and sexual recognition processes

- control of plant cell development and morphogenesis

- information at plant-microbe interfaces

- genetic and metabolic controls of quality traits

- molecular investigation of the genome of Arabidopsis thaliana as model for all plant genomes and reservoir of gene probes (chromosome isolation and sequencing, cloning of large fragments and complementation systems, transposon mutagenesis, homologous recombination).

Each of these areas has specific bearing on activities in seed or process industry. Underlying these focal points of interest, common biological processes of the basic cell machinery will have to be addressed in priority : signal perception/transmission, regulation of development, genome organisation, gene-function relationships. The horizon of the researcher in plant molecular biology is opening up into a revised vision of plant cell physiology, e.g. how genetic units are set into motion through molecular interactions with either adjacent cells or the environment; and how the regulated genetic programmes lead to new metabolic functions which support the expression of so many plant features for agriculture and industry. An adequacy of physiological/ biochemical knowledge with the extended array of new analytical/ genetic techniques at molecular level is what pressingly calls for the convergence of multiple skills and wide-ranging cooperation schemes. At present, the developed skills must be used for asking the fundamental questions of plant physiology, before meaningful applications can be further devised.

Significantly enough, this is an analysis which closely meets American and Japanese science evaluations. Europe must neither be bypassed by the expanding knowledge base of others who are conducting strong actions in this area, nor be overruled in strategic discussions on genetic resources (cf. also section C : Diversity of genetic resources). It must hold a strong negotiating position when defining the new international distribution of research tasks, or the needs to rationalise networks of biological resources, the latter with the participation of Lomé Treaty countries in particular.

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C Diversity of genetic resources

Plant resources

The production of biotechnological innovation will be limited by the ability of scientists to capitalise on genetic variability. The access to genetic resources and to gene banks will become the major factor of a continuing progress. Thirld World countries will therefore take advantage of their strategic position in the tropical areas as being the hosts of most living species on the earth. They sit on a reservoir of genetic variability that attracts considerable interest. To take just an example, a major seed company recently provided the USDA with 1.5 million $ to inventorise and collect 20,000 genotypes and wild species of maize in South America.

The position of developing countries sometimes appears contradictory : on the one hand, they would like to maintain a free international exchange of plant genetic resources for the benefit of their own agriculture; as a matter of fact, they would fear that the best adapted genetic material could result from the breeding work of laboratories in the North and be made accessible to them under restrictive conditions. The executive director of the United Nations Environment Programme (UNEP) warns "the control and patenting of biotechnology applications (including modified plants) by the developed countries could further disadvantage developing countries". But, on the other hand, developing countries would consider it desirable to control and possibly regulate the export of genetic resources from their territories. The FAO conference has always supported the adoption of an international agreement for the preservation and exploitation of world plant genetic resources. Industrialised countries have however raised opposition against what they would consider over-regulation in the field, which is already under the competence of the International Board for Plant Genetic Resources (IBPGR).

The scientific community now enters the political debate by raising the threat of a rapid erosion of plant genetic resources : within 10 years, thousands of plant species will unavoidably disappear. The proposal to set up a world gene bank gets substantiated, but does not receive an American approval because of the existence of a national collection in the US.

The International Board for Plant Genetic Resources (IBPGR), established since 1974 by the Consultative Group on International Agricultural Research Centres, has pursued as an objective the promotion of international networks of genetic resource centres.

Collection, conservation, documentation, evaluation and use of plant germplasm are the activities this organization intends to cover worldwide. IBPGR can be praised for significant and impressive achievements. Its relationships with FAO have however proven to be contentious and, technically, much is left to be desired. With very few exceptions (rice, sugar cane, potato, alfalfa ...), the acquisition, maintenance and evaluation of major world crops is simply not organized and the breeders collections, next to being private, are indeed under risk that they get disrupted or lost. The evaluation of the germplasm and its utilization, necessary to sustain breeding activities, is not carried out properly. This would require an international agreement on an integrated catalogue with meaningful descriptors : collection sites, ecological characteristics, stress/resistance behaviour, agronomic traits, using more and more molecular probes and chemical signatures in conjunction with botanical descriptions as becomes possible. This information system should obviously be computerized.

Particularly relevant will be the description of genes and of their sequences, expected to become available at an accelerated rate. Gene banks should be designed in a way to facilitate the search for desired genes in gemplasm collections. Biotechnology is providing opportunities to increase the functionality of offsite-maintained plants, particularly through in vitro culture, biochemical blueprints and, may be more futuristic, the preservation of isolated genetic information in the form of DNA or RNA. The applications of rDNA technology to germplasm evaluation and management have hardly began, but are likely to become of increasing importance.

In Europe, awareness of species diversity is growing and is giving raise to discrete initiatives. A European Standard List of Animal and Plant species has been set up by the Council of Europe. The production and standardization of species diversity checklists and the development of species diversity database networks is the first priority. But taxonomic work goes on declining further in academic institutions and it is becoming an urgent task to revitalize this key discipline of the life sciences by having it revisited, in particular, with the contribution of molecular biology.

Animal resources

In contrast to the breeding situation in Japan and the USA, the selection of races of domestic animals in Europe has developed into an outstanding tradition for hundreds of years. This has led to the development of many valuable animals adapted to many useful productions under different environmental conditions. However, due to an immediate competitivity requirement, there is a clear tendency for these races to disappear, replaced by a small number of uniform ones, highly selected for massive productivity in an artificial environment and depending on supplied feed. In order to preserve this exceptional genetic capital now in danger, it would be worth improving the methods of genetic preservation of embryos and collections of them.

Ecological monitoring

The ignorance of the true taxonomic structure of natural microflora is a critical deficiency in our current knowledge. The majority of bacteria present in a given ecosystem are not readily cultured in vitro and are experimentally silent. Hence the inability to identify and classify satisfactorily a substantial proportion of those microorganisms. The dynamic interaction of microorganisms in particular ecosystems cannot be analyzed properly, although it is now expected that molecular microbial ecology should allow, in conjunction with sophisticated instrumentation for data capture and automation of microbial identification, new insight into the functioning of ecosystems.

DNA probes and monoclonal antibodies must be developed for many more microorganisms, and especially for those composing biotechnologically important ecosystems. Analytical instruments with higher resolving power (gas chromatography, mass-spectrometry ...) need to be further improved to work on very large numbers of isolates. The data must be evaluated and organized into adequate information base.

What is urgently needed in Europe is the organization of multidisciplinary groups capable of exploiting new technologies and molecular methods and of applying them to integrated studies of microbial ecology in target ecosystems, especially those susceptible of being subject to new agricultural practices or introduction of foreign species. The priorities would be :

- instrumentation for high resolution automated microbial identification;
- banks of specific probes;
- monitoring, at molecular level, of gene flows in microcosms;
- standardization of model microcosms;
- microbial interactions in ecosystems moved away from equilibrium;
- relation of microbial processes to the overall flux of energy and matter;
- ecosystem modelling with predictive capacity in the event of a perturbation.

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D Immunology

Over one thousand journals today bear witness to the scale of scientific and biomedical activities conducted under the heading of "Immunology". In presenting a brief résumé of the current situation in this complex and fast-advancing biological discipline, three aspects should be highlighted. Firstly, as a fundamental science, immunology has provided basic research with many challenging problems. A central issue has been the basis for the diversity of antibodies, the mechanism by which an organism has the ability to produce millions of different antibody molecules, with a relatively low number of genes. Secondly, immunology is highly implicated in medicine (especially prophylaxis) with, for example, a predominant role in defence against bacterial, viral and parasitic attacks. Thirdly, immunology provides exquisitely specific analytical tools, finding practical applications in many fields and, especially, since the discovery of monoclonal antibodies. These have made it possible very cheaply to detect and to quantify viruses, bacteria, parasites and the presence of specific molecules such as hormones, toxins or pollutants.

During the recent years, immunology has brought a huge contribution to science. Since 1980, immunological research has been rewarded with three Nobel Prizes out of eight attributed in physiology and medicine (1980 : B. Benacerraf (EU); J. Dausset, (F); and G.D. Snell (EU) - 1984 : N. Jerne (DK); G. Köhler (FRG) and C. Milstein (UK) - 1987 : S. Tonegawa (J). This demonstrates the exceptional vitality and impact of immunology on medicine and science.

Immunology is a widely dispersed discipline. It is based on teams of collaborating researchers, grouped in university departments or institutes of relatively modest size (10 to 100 people), and having high competence in biochemistry, molecular biology and medicine.

Certainly, the best immunological research is conducted in the United States, which has the largest number of research groups. The quality of their work is greatly assisted by the excellence of the research infrastructure, as exemplified by the collection of cultured cells at the ATCC (American Type Culture Collection), or the Jackson collection of mice which have no equivalent elsewhere in the world. There are excellent teams in the U.S. in every sector of immunology.

The development of immunology in Japan is relatively recent. However, they possess many teams of high quality such as that of T. Tada (working on T suppressor lymphocytes and lymphokines) in Tokyo, T. Kishimoto (B cell stimulatory factors) and T. Honjo (molecular genetics of the immunoglobulin synthesis and T cell receptor) in Osaka. Immunology has progressed extraordinarily quickly in Japan, and it is difficult to predict its development in the near future, owing to the potential which lies with a young generation immunologists, mostly trained however in the United States.

Europe is an old and traditional region with excellent capabilities in immunology. The present situation in both basic and clinical or applied immunology is rather good, with highly qualified teams : but the most competitive studies, requiring large contributions of genetic engineering, are located in the States or in Japan (T cell receptors, interleukins ...). Non-Community countries, such as Sweden, Finland or Switzerland, have excellent immunology research. A major contribution to immunology has been the establishment in Switzerland of the "Basel Institute for Immunology". This institute is entirely devoted to basic immunology and is totally supported by the private pharmaceutical firm Hoffmann- La Roche.

Unfortunately, European efforts and results have very often been developed and exploited in the United States before being employed in Europe : monoclonal antibodies are one of the most striking examples. The Nobel-prize-winning discovery was made in Cambridge, England; but US commercial firms (Hybritech, Becton Dickinson, Ortho-Diagnostics) have taken the largest part of the market (for example, monoclonal antibodies for human lymphocyte typing).

The Commission of the European Communities has already recognised the importance of immunology and supports research involving this discipline in programmes such as the "Biotechnology Action Programme", "Stimulation", "Medical Research" and "Tropical Medicine". This effort is considerable and can contribute to the progress of immunology and its application. Nevertheless, this effort is dispersed and aims at so many goals that it cannot be considered as a significant contribution to immunology.

Many major problems in applied immunology remain unsolved : such as a better evaluation of the potential of the human immune system ; better control of immunosuppression in order to improve the success of heart, liver, or other organ grafts; the production of human specific antibodies against many aggressive agents (virus, bacteria, toxins, chemical drugs ...); improvement in the treatment of autoimmune diseases, etc.

A basic challenge currently facing immunology, is to improve the presentation of antigens to organisms in order to get strong and longlasting immunities. Very promising progress in virology (for example in understanding the AIDS virus) and in parasitology (the major diseases in the world are parasitic) have been achieved, leading to a better understanding of these infectious agents. However, to be transformed into efficient, safe and cheap vaccines, the new engineered substances must meet the requirements of the immune system in order to be effectively recognized. Those requirements are still poorly understood. A collaborative effort in Europe on such a subject could be a valuable contribution to the improvement of the major problems of human (and veterinary) medicine as well as a considerable help to pharmaceutical firms developing vaccines.

E. **NEUROBIOLOGY**

The study of the human brain and nervous system includes a multiplicity of disciplines from physics, chemistry and information science to zoology, psychology and medicine. All of these areas contribute to the understanding of the nervous system from a cellular, molecular and biochemical point of view as well as going same way to elucidate the higher brain functions such as problem solving language and memory.

How the brain functions has been the subject of intense interest ever since it was recognised as the centre for intelligence, thought and sentiment. The scientific study of the brain began in the early part of the last certuary when certain brain functions were pinponted and the nervous tissue found to be composed of individual cells (neurons). Neuroscientists are still however working on the study of many of the more complex processes of the brain such as memory, how sensory information is interpreted and the processes involved in voluntary movement. Some of the work being carried out will have direct application to the understanding and possible treatment of certain neurological disorders. The brain's incredible computer power his become a major subject for research with scientists hoping to emulate some of its capabilities in the building of 'neurocomputers' – computers whose structure is based on that of the brain.

Neurobiological Research

The diverse topics being undertaken in neurobiological research are an indication of the complexity of the subject. Considerable breakthroughs have been made in recent years in the fields of molecular cellular and intercellular analysis of the nervous system. In particular, scientists have been successful in identifying and isolating the specific molecules responsible for the transmission of an impulse from one neuron to another and the complex processes involved in the modulation or control of the nerve response. While neurotransmitters are produced in minute quantities in the neurons, using recombinant DNA techniques, they can be generated in sufficient quantities to be studied in detail using protein sequencing methods. This information is necessary to provide a full understanding of the chemical basis to the nervous system.

Neurobiology has benefitted from several interdisciplinary successes enabling the study of the nervous system both'in-vitro' and 'in-vivo'. The bringing together of molecular biology and genetic engineering has permitted the study of nerve cells in culture where the environmental conditions required for their growth and function have been identified. These techniques have also brought to light the mechanisms by which neurons identify each other and form their complex interconnections. Cell culture is currently being used in the study of how myelinating cells (those specialised cells which insulate neurons and allow impulses to be conducted), may be transplanted to victims of such diseases as multiple sclerosis where myelination has broken dowon in this way, repair may be possible.

The observation of the brain in-vivo using scanners has been possible since the early 1970's. Conventional X-rays are coupled to a computer which reconstructs multiple images of the brain. The technique of Nuclear Magnetic Resonance (N.M.R.) is one of the most recent tools available, providing exceptionally high quality images based on the magnetic properties of the brain tissue. While these techniques allow the anatomical study of the brain, researchers are working on the development of magneto-encephalography a technique which, by detecting the changes in electrical activity of the neurons will help to identify diseases such as epilepsy whose causes evade other invasive diagnostic tools. There have also recently been developments in the use of radio-labelled substances injected into the bloodstream which are traced by a detector coupled to a data-processor. This technique provides information comparable to that of a scanner but in addition, information on the complex blood-brain barrier. A whole series of radiotracers now exist which help in the identification of thromboses, blockages, haemohorrages, ect. It is envisaged that by combining the results of these examinations surgeons will be able to carry out surgery with the maximum amount of precision.

Neurocomputing

Since the 1940's parallels have been drawn between the functioning of the human brain and computing machines. Attempts to emulate the brain have proved largely unsuccessful. In recent years however, there has been an explosion of enthusiasm and investment in the United States and Japan in the possibility of developing neurocomputers. In the United States, in particular, federal agencies, universities and private companies are making important financial commitments.

Scientists are hoping that through the understanding of the functioning of the brain they can build a neurocomputer - a computer which is structured like the brain and which like the brain can learn for itself without programming. The way in which the brain processes information is extrodinarily efficient and it is envisaged that neurocomputers would be vastly superior to conventional machines. The brain differs from ordinary computers in several important ways including its ability to carry out simultaineous processing, learning and active reasoning. While computers have been trained to play chess at world level, to rediscover important physical principles, such as Ohm's law and to answer questions on the unstated implications of information fed to them, they are a long way from being considered intelligent. The function of the brain is not based solely on logic as is a computer, as problems of certain complexity only experience based on learning can find a solution.

Initiatives in the United States and Japan

In the United States, interest can be measured by looking at the attendance figures of major conferences on neurocomputing; in 1985 only 30 participants attended a meeting at Santa Barbara. By 1987 2000 people attended an international conference at San Diego. It is estimated that more that fifteen 'Start-up' companies are operating in the field, in the United States.

AT&T's Bell laboratories have succeeded in building silicon 'neurons' based as the nerve cells of the garden slug. The model can simulate the learning of which the slug is capable.

Another American company has developed a device which imitates the retirn of the eye while another has invented a device to read handwriting and feed the information to a computer.

Japan has launched a major initiative in science entitled 'Human Frontiers' in which neurocomputing will play a major role.

Neurobiology in Europe

European laboratories are very active in neurobiological research and many of the important discoveries have been made here. American companies are showing interest in European expertise. A large investment has recently been made by an American Pharmaceutical Company in the University of Oxford's pharmacology department where research is being carried out on the treatment of brain diseases. In return for its investment, the company will get the intellectual property rights to the work which it funds.

Community Initiaties in Neurobiology

The Commission of the European Communities has been supporting neurobiological research (in particular the study of inter-cellular communication) under the Science Plan since 1984. As an extension of its interest in the subject the Commission introduced the BRAIN (Basic Reseach Adaptive Intelligence and Neurocomputing), initiative in 1987, following the recommendations of the Committee from the Development of European Science and Technology (CODEST) which advises the Commission on new trends in Science. The purpose of the initiative is to support research collaboration between member states and to promote the design of machines that emulate the brain's function. Eight project are currently being supported by BRAIN. These are :

- *the development of connectionist models for neurocomputing - a mathematical way of simulating the brain's calculating capacity*
- *the design of a neurocomputer with learning abilities*
- *the study of the use of neural networks for data processing*
- *the determination of the level of complexity necessary for a computer to start to function in a simular way to the brain*
- *the study of the neural networks determining the relationship between the brain and the movement of the eyes and of the head*
- *the study of dynamic connectionist models for the recognition of designs and graphs*
- *the investigation of sensorimotor strategies involved in visually guided arm movements with a view to applying this*
- *the knowledge to robotics and computer vision*
- *the study of the basic operations involved in the cerebral cortex of primates in controlling a reaching movement.*

Other initiatives being supported by the European Community include a project to develop a computer programme which will help in the diagnosis of muscular and nervous diseases. This project is being supported under the ESPRIT programme (European Strategic Programme for Research and Development in Information Technology) and involves five teams in the United Kingdom and Denmark.

This expert system is capable of taking information from medical equipment measuring the electrical characteristics of nerves and muscles and providing a likely list of diseases as well as suggesting tests and treatments. It is planned to extend the range of diseases diagnosed to about five hundred and to further develop the follow-up provided by the software.

Neurocomputing is a multidisciplinary field which includeds neurobiology, psychology, materials science, informatics and computer science. The projects being supported by the BRAIN initiative reflect this diversity and will provide a comprehensive base for Europe's participation in the development of a neurocomputer. In September 1988 some 80 scientist will take part in the first evaluation of BRAIN at Oxford University where the second stage of the programme will also be discussed. Through such initiatives the European Community plans to increase its support of neurobiology.

F Biotechnology

R&D in Europe

The relative weakness of Europe in certain areas of biotechnology is not due to an inadequate research potential, which is often very highly developed, but to the fragmentation and isolation of national research and training efforts and to the absence, at national and transnational levels, of adequate concertation and contextual support for research, development and exploitation.

It is with the aim of overcoming these deficiencies that all Member States have now placed biotechnology at a high position in their national priorities, and increased accordingly their support to national institutions. Policy awareness has become such that support is also been organised under different departments, and across several professional branches. The same occurred at the initiative of major European companies, although it can be shown that these frequently invested as much research funds overseas as within the Community.

Next to funding, national and Community programmes have been able to provide a forum for research leaders to coordinate work at a large scale, avoiding gaps and emphasising priorities. The scientific community now realises that biotechnology R&D must be carefully conducted, leaving room for speculative research but addressing in priority the needs of the society. Biotechnology operators have themselves developed a higher degree of transnational integration, through the European Federation of Biotechnology (EFB) and through the establishment, on the industrial side, of the European Biotechnology Coordination Group (EBCG), the constitution for the Commission of the E.C. of a biotechnology working group attached to the Industrial R&D Advisory Committee of the CEC (IRDAC), and the creation of Green Industry Biotechnology Platform (GIBiP). Other major international research initiatives took shape more or less simultaneously : particularly relevant to biotechnology R&D are EUREKA and the Human Frontier Science Programme, respectively at the applied and the basic ends of biotechnology and with which the Community established formal links. In existence for already three years, Eureka now comprises more than 200 projects involving about 800 companies and research centres from 19 European countries. Of these, 13 % (as per July 1987) are falling under the biotechnology area. Biotechnology is a typical field where Community actions and Eureka projects can be strategically aligned, industry-led projects being put in a position of taking up for development purposes scientific results which rapidly build up the framework of basic programmes. The Commission of the European Community is itself implementing several priority actions specifically designed for improving the competitiveness of European biotechnology. One of these actions aims at the establishment of a Community network for training and research and has been executed, since 1982, in the framework of two successive Community programmes, the Biomolecular Engineering Programme (BEP) from April 1982 to March 1986, and the ongoing Biotechnology Action Programme (BAP), for the period 1985-1989.

The pioneer programme : BEP

BEP was the first Community initiative in the field of biotechnology. Its objectives were to contribute, through transnational efforts in research and training, to the removal of bottlenecks which inhibit the application of molecular and cellular biology to agriculture and to the agro-food industries. With a budget of 15 Mio ECU, BEP supported 91 training contracts and 103 cost-shared research contracts with public and private laboratories in the Community. In the area of genetic engineering, several significant contributions, such as a gene cloning in Streptococcus bacteria exploited by the cheese industries, the characterisation and isolation of more than 20 plant genes of high importance for agriculture or genetic transformation in plant species belonging to the monocots, resulted from the programme; 53 cooperation agreements were established between laboratories in different Member States which involve the exchange of equipment and staff and the execution of joint experiments. Permanent transnational working parties have been set up for each research sector in the programme (*).

The current programme : BAP

Objectives for research and training

The programme, inherently pre-competitive, is oriented towards medium and long term objectives essential for the strategic strength of European industry and European agriculture. It deals with the two following aspects:

- the establishment of a supportive infrastructure for biotechnology research in Europe (sub-programme on contextual measures).

- the elimination, through research and through training, of bottlenecks which prevent the exploitation by industry and agriculture of the materials and methods originating from modern biology (sub-programme for basic biotechnology).

Areas covered

Research and training

Contextual measures

- Bio-informatics: the interface between biotechnology and information technology (data capture, data banks, computer-assisted design, etc.)

- Collections of biotic materials (upgrading and integration of existing collections, enhancement of techniques)

(*) For an evaluation and a detailed review of the scientific results obtained in the framework of BEP, see the final report of the programme (Biomolecular Engineering in the European Community, 1172 pages, E. Magnien Ed., Martinus Nijhoff, 1986).

Basic biotechnology

- Enzyme engineering: bioreactors of 2nd generation, stability of enzymes, protein design

- Genetic engineering: applied to micro-organisms important for industries, to plants and soil micro-organisms, to animal husbandry

- Technology of cells cultured _in vitro_ (micro-organisms in continuous cultures, regeneration of plant cells, new methodologies for animal cells)

- _In vitro_ tests to screen new molecules created by industry for their biological activity and possible toxicity

- Methods of assessing possible risks associated with modern biotechnology.

Concertation of national and Community policies

- A range of information, liaison, evaluation and initiation tasks to ensure that Community policies affecting biotechnology are both relevant and consistent within the Commission and in relation to the outside world.

Implementation of research and training activities (*)

1. Long-duration training contracts available to both junior and senior research scientists involving travel from one Community country to another.

2. Multiannual marginal- or shared-cost research contracts with public sector or private research bodies.

3. Regular meetings, dissemination of information and results, and on-site visits.

Dimensions

The programme, recently extended to Spain and Portugal, has a total budget of 75 Mio ECU and foresees, for research and training:

300 - 350 training contracts
some 380 research contracts.

(*) : for information see the publications, available upon request, issued every year by the services of the Commission on all matters related to the programme (results of contractual research, proceedings of meetings, catalogue of contracts, reviews of main achievements, statistics on response to call for proposals, statistics on cooperation ...)

Response to the call for research proposals and transnationality of the programme.

The selection criteria included the transnationality of the research proposals and expressions of interest originating from industrial partners.

A total of 1550 proposals were received of which 80% were transnational. Budgetary constraints were such that only 387 of these proposals could be accepted for funding.

Participation of industries

The research presently conducted in the framework of BAP, at the date of December 1988, is executed by 90 transnational groups of laboratories which have agreed to join their efforts and to work together. Fifteen per cent of these transnational groups include one industrial partner.

The proportion of projects implemented in the framework of BAP which are supported by an expression of interest from one or several industrial firms amounts to 83%. In all, 150 expressions of interest for specific projects in the programme have been transmitted by industrial firms to the services of the Commission.

In addition, there is now a regular demand from industries to attend the various types of contractors meetings ("sectoral", "horizontal", "spontaneous") which the Commission services organise at regular intervals in the framework of BEP and BAP and to have access to all data and information (proceedings of meetings, books of abstracts, annual reports, catalogue of contracts ...) arising from these programmes. As particularly well illustrated in the sector of the programme dealing with the genetic engineering of plants and of soil microorganisms, "European laboratories without walls" (ELWW) are presently being constituted which bring together the laboratories participating to Community research and the industries specifically interested by this research and the exploitation of its results (*).

(*) Methods, materials and results circulate freely within each ELWW and an important part of the research work is implemented as a totally integrated joint effort. Approximately 30 ELWWs have been constituted and launched in BAP and this number should considerably increase within BRIDGE. For further information see "European Laboratories Without Walls : focused precompetitive research", R. van der Meer, E. Magnien and D. de Nettancourt in Trends in Biotechnology, 5: 318-321, 1987.

The future programme : BRIDGE

The Commission services are now proposing orientations on the nature and objectives of the programme (BRIDGE - Biotechnology Research for Innovation, Development and Growth in Europe) which will take, in 1990, the succession of BAP. These orientations have been defined on the basis of past achievements in BEP and BAP and through recommendations received from a panel of Independent Experts, the European Parliament, industrial organisations and the CGC Biotechnology.

BRIDGE is to be subdivided, as was BAP, into two actions :

Action I for Research and Training, Action II for Concertation. Ninety per cent of the total budget will be devoted to Action I and 10% to Action II.

Action I

The main tasks of Action I will be to develop cooperative basic research and training through research adapted to the long term needs of the Community. This implies, for the removal of bottlenecks resulting from gaps in basic knowledge, the reinforcement of existing networks of ELWWs and their extension to new areas considered of high significance for the Community. Alternatively, larger targeted projects will be implemented, when necessary, for removing bottlenecks originating from scale or structural constraints. A very substantial effort is foreseen in the area of normative research and, in particular, with regard to the assessment of risks possibly associated to the release of genetically engineered microorganisms. The research and training programme outlined in tables 1 and 2 is to be subdivided into four sectors :

- information infrastructures
- enabling technologies
- cellular biology
- normative research

The programme, as outlined, takes into account but still very insufficiently, the recommendations made in the present report for Community activities on the "molecular foundations of plant biotechnology" and on the "molecular investigations of the genomes of complex organisms".

Action II

Action II (Concertation) will cover a range of monitoring, information and collaborative activities to provide and facilitate the effective application of biotechnology to the social and economic objectives of the Community and of the Member States (table 2).

Related R&D activities

ECLAIR (80 Mio ECU for the period 1989-1993)

ECLAIR (European Collaborative Linkage of Agriculture and Industry through Research) will be the first multiannual programme of the European Communities for biotechnology-based agro-industrial research and technological development. Through such research development work, it will contribute, in the medium and longer terms, to enhancing Europe's competitiveness in the economic activities - industrial and agricultural - based on the life sciences and biotechnology.

FLAIR (25 Mio ECU from 1989 to mid-1993)

FLAIR (Food-Linked Agro-Industrial Research) is a programme proposal concentrating exclusively on the food sector and, particularly, on the processing-distribution-consumer end of the food chain. The long term objective of FLAIR is to contribute to the competitiveness of Europe's food industries, and to improved consumer protection and confidence, by strengthening the links between them through research and development. The Commission proposes to achieve this objective by launching a programme of concerted actions and cost-shared actions. The projects seek to promote the close collaboration between research and industrial groups, by their participation in research and technological development on food quality, hygiene, safety, toxicology, nutritional and wholesomeness values.

Table 1 : Biotechnology research and training activities proposed for implementation in the framework of BRIDGE (1990-94)

Information structure

- culture collections ;
- processing and analyses of bio(techno)logical data ;

Enabling technologies

- protein design/molecular modelling ;
- biotransformation ;
- gene mapping, genome sequencing, novel cloning methods ;

Cellular biology

- physiology and molecular genetics of industrial microorganisms ;
- basic biology of plants and associated organisms ;
- biotechnology of animal cells ;

Normative research

- safety assessments associated with the release of genetically engineered organisms ;
- *in vitro* evaluation of the toxicity and pharmacological activity of molecules.

Table 2 : Biotechnology concertation activities proposed for implementation in the framework of BRIDGE (1990-94)

- Coordination of Commission activities ;
- Concertation of activities of Member States ;
- Provision of information on the advantages, limitations and safety of biotechnology to politicians, scientists and the general public ;
- Formation and growth of small and medium-sized biotechnology firms.

RD&D Non Nuclear Energy

Motivation

The need for Europe to face energy challenges has been reconfirmed numerous times by the European Council over the past years. The energy strategy of the Community emphasizes coherence of far-reaching planned actions in the energy field, as well as the necessity of an increased effort to reduce the dependance on oil (energy-saving, development of alternative fuels, diversification of supply and demand) and to facilitate the adaptation of the European industry to the energy market. Since 1974, these objectives constitute the most important Community options in the domain of R&D.

Until the year 2000, pursuit of these options should ensure a reinforcement and above all a larger scope of R&D activities according to the main aims : independance, security regarding the long term supply, environmental protection, competitivity, safety. At European level the framework programme consists of 3 major themes on energy research : nuclear fission, controlled thermonuclear fusion, non-nuclear energy and the rational use of energy. Moreover, the demonstration programmes for energy savings and coal and the support programme for technological development in the field of hydrocarbons have allowed to make important progress in these fields.

Numerous achievements have been noted in each field. However, continuation of Energy research is essential even though economic conditions temporarily favour access to energy. In fact, RD&D will determine the long term future of energy and if no actions are taken today, serious problems may result in the more or less distant future.

Three major factors should influence the choice of the energy RD&D options :

* the forecasts of energy demands in Europe and in the rest of the world.
* the evolution of energy resources and comprehension of their exhaustion.
* protection of the environment.

These factors pose many responsibilities and R&D must establish the means for society to face them. At the dawn of the XXIst century, when already one can perceive a limit to the availability of certain forms of energy and the consequence of environmental damage at global level, it is vital to merge all research efforts by means of optimal management of the energy policy.

The establishment of the great internal market can only reinforce this conviction : the harmonisation of norms and laws and the necessity of maintaining competitiveness often find their answer in technological research.

Progress to date of the European RD&D action

The Commission has not allowed itself to be influenced by the temporary fluctuation of energy prices when defining its policy in the field of non-nuclear energy R&D. At the european level neither its R&D programme launched in 1975 nor its demonstration programme, initiated three years later, have suffered any harmful blows.

The financial commitments of the Community do not show yearly oscilliations as some national budgets do. Even though the last four-year budget was reduced upon request of certain Member States, it still continues in the range of previous budgets, with unaltered and even enriched objectives and has remained at a creditable level, in any case above the minimal critical level. Generally speaking and despite a slow decrease in public spending on non-nuclear research, one may observe that the relative shares for the three main poles between 1980 and 1988 have remained stable : energy savings (28 %), coal (34 %) and hydrocarbons (about 10 %), renewable energies (28 %). Nevertheless, a more detailed survey of these aggregates may indicate substantial shifts between programmes.

More precisely : What are the strong and weak points of the Community's and the membre states programmes in the field of non-nuclear energy ?

Community action, composed of three major fields : energy saving, fossil fuels and renewables, has backed the research of the member states. The tables 4.9 (a;b) illustrate respectively the budget of the EC member states and the Community in 1987.

For 15 years Europe has worked in the field of energy conservation thanks to the vigorous R,D&D policy at national as well as at Community level. A lot has been said and written around the statement which implies that the cost has been the main, if not the only factor responsible for effecting a reduction of the consumption, and that is true for a large part. But, the influence of the cost itself has also generated research efforts which appear to be durable. The cumulative impact of 15 years of efforts has procured great benefits thanks to the fundamental structural changes which have occured in the production machinery and also in the psychological approach of the individual and collective actors.

The Community objectives have been achieved and even surpassed.
Following a decrease of about 20 % between 1973 and 1980 (preceded by an increase of 63 % between 1960 and 1973) the European consumption of primary energy stabilized, and only fluctuated between 1000 and 1100 Mtep.

All the sectors of R,D&D have shared this successful result. Space heating which represents about 40 % of European consumption is the first domain - at least in the new building sector - to make rapid progress. The insulation and ventilation techniques and also the recovery of heat have led to a substantial increase in savings, currently up to 50 % and more. The passive solar contributions have shown the strength of the European R,D&D and the attempts to retrofit old buildings have been fruitful. Active solar contributions have been limited to water heating and are relatively well developed in southern Europe. The economic conditions and certain technical constraints are the reasons that active solar could not play its role as originally foreseen. The same holds true for heat pumps. They might come into play in a decade's time. The unsolved technical difficulties and the lack of economic competitivity have limited its application to the tertiary and industrial sectors where scale effects and "intelligent" putting into operation have given them a chance.

With respect to the rational use of energy in industry, the R&D endeavours have been more diversified due to the numerous energy saving possibilities one might find and also due to the considerable potential to quantitatively reduce energy consumption (European industrial consumption accounts for 35 % of the total consumption). New processes and industrial products appear year upon year rendering older products obsolete. This renovation, as well as the modernisation of the industrial equipment have unobtrusively introduced new techniques with a reduction in energy consumption and pollution (the latter is also a consequence of indirect R&D effects).

Numerous factors have contributed to a reduction of the consumption in industry, and it is worthwhile to emphasize the remarkable results obtained in a dozen years in Europe and elsewhere on the thermal level, as for example a better comprehension of combustion phenomena or heat transfer.

Among the recent advances which have benefitted european technology one should underline the importance of the improvements in measurement, control and regulation of energetic processes. They have benefitted enormously from the popularization of electronics, new collection methods, data gathering and processing.

Let us also refer to the development of heat distribution systems and co-generation which have undergone a satisfactory expansion in Europe.

At present, Europe may be proud of an industry which knows how to apply the most advanced techniques, regarding energy efficiency, even though due to the historical ties in certain traditional branches penetration of new ideas has been somewhat slow in comparison to younger industrial competitors.

Amongst other research to improve the energy efficiency and the endeavours spent on primary energy, it is necessary to highlight the R&D efforts devoted to the main secondary energy vector, i.e. electricity. From a classical electro-technical viewpoint, one should not forget the remarkable success of turbo-alternators, the unit power of which has doubled every ten years, and also the modern methods of grid control, revolutionized by the use of computers. But the most advanced and original research concerns the field of fuels cells, electro-chemical storage and cryo- electricity. These sectors have been explored for years, but fundamental and subsequent applied research has given them a new youth and an interest that will always be with us.

Fossil fuels (solid, liquid and gaseous), the most spread out and used of all, used will remain the major resource for a very long period of time. Whatever may be the economically interesting stock, fossil fuels today are of increasing concern as far as the scientists, environmentalists and even the public and politicians are concerned.

Besides the toxicity of the pollution caused by their combustion (SO_2, NOx, dust) which can be controlled if one wants to pay for it, the fear of warming up the planet by a greenhouse effect due to CO_2 seems to be more and more justified, at least in the long run. Because we are "condemned", and without doubt for several generations, to make abundant use of these fuels, we should appréciate all the more the efforts that are made for their clean use and reduction of their consumption, by means of savings and efficiency at the consumption level, by an improved efficiency and a better yield at every stage of exploitation, preparation, purification, transformation up to the end use. The Community R&D has been in charge to respond to those concerns.

Hydrocarbon research must increase the economically exploitable reserves. Hence, exploration techniques have made big progress, allowing to increase significantly the rate of success of drillings. The drilling techniques reach a greater efficiency - drillingspeed as well increased reliability - especially in the deep sea and offshore drillings.

In this field, very promising techniques as horizontal drilling appeared. The development of offshore production techniques, in particular in deep sea, has achieved well performing submarin techniques using automation and robotics, whereas support of floating production units and new concepts of platforms were developed.

An extension of basic knowledge has accompanied technological research, notably in the geological field concerning the mechanism of formation and migration of hydrocarbons. More generally speaking, physico-chemical conversion problems have taken up an important share of the hydrocarbon R&D action.

Endeavours of RD&D in the field of solid fuels are fully justified by the coal potential and by the more immediate concern to protect the environment against the effects of very abundant impurities in solid fuels. The combustion and conversion techniques remain at the centre of research planning and are studied actively in Europe (in particular in the FRG but also in the UK and the NL). These activities are rather diversified and the obtained results are of varied importance. If in spite of its efforts Europe seems to be late in comparison with the USA and Japan regarding combustion techniques with coal-liquid mixtures, it should be realized that fluidized bed combustion is an area where Europe has a good research tradition.

Prototypes exist in almost all Member States and some installations of important size are in operation.

Other investigations have accompanied those just mentioned, as for example liquefaction and gasification of coal, production of methanol derived from coal and combustion of lean gases.

The variety of RD&D areas is very vast and Europe occupies a more than creditable place. Generally speaking, one might say that all the investigated processes operate well, or at least correctly, when applied to coal of good quality. The problems arise when dealing with poor fuels, which are abundant but more heterogeneous, less reactive, polluttant, dirty and dusty.

Since 1974, a vast area of renewable energies has seen intensive research activities in the whole world and more particularly in Europe. It consists of a wide variety of sources : solar, wind, small hydropower, biomass plus urban waste, geothermal, marine energy.

During the last 15 years, Europe has carried out R.D & D. in all these fields. Even if not the first, measured by the variable financial and manpower input by different countries, Europe possesses in all these fields a high degree of theoretical and practical knowledge. As soon as the economic circumstances allow or a technical breakthrough takes place Europe is highly likely to occupy almost immediately a favourable position. One should not forget that the majority of the renewables are non-pollutant, and hence public opinion is favourable. In certain cases, the energetic aspect gives way to the protection of the environment, as for instance in bacteriological treatment of animal and vegetable waste and the incineration of household waste, which renders these processes generally attractive, even if the energetic profit itself is not always significant.

Given the broad domain of scientific disciplines and technologies used in the field of renewable energies, one can only present here a concise overview of some outstanding achievements which are characteristic for some 15 years of European research and development.

Photovoltaïc conversion techniques have enjoyed, in Europe as well as in the USA and Japan, a frank technical success, most certainly constrained by an economically less favourable context. The european industry, even if it only ranks in 3rd place with somewhat more than 10% of the global production, disposes of the most advanced techniques and has already attained a substantial turnover, especially with regard to export. The efforts of RD & D which have been skilfully coordinated by the Commission (incl. JRC) include pilot installations and demonstrations concerning tests and certifications in order to obtain world wide recognition of European norms and quality standards.

The european countries have abandonned the idea of electricity production by concentration of solar energy by means of a field of heliostats. The technically difficult concept facing climatological hazards and unfavourable economic factors, explains this failure, although a number of interesting data has been obtained for other research areas.

Wind energy has been strongly developed in northern Europe and several european countries have demonstrated the quasi-competitivity of this form of electricity production coupled to the grid. Concerning small units, up to 2-300 KW, an industrial production exists where european manufacturers are perfectly competitive.

The utilisation of energy from biomass is in itself a broad and multidisciplinary area and the RD&D prior to this usage has several branches : harvest and transformation to energy of waste, which is strongly stimulated by european RD&D; specific cultures of energy production; harvest, transport and preparation of solid biomass including the development of boilers on biomass fuel; combustion and gasification of biomass; treatment of effluents and liquid waste.

The potential of biomass is large; in addition Europe disposes of a considerable expertise in agriculture. These two elements have ensured that R & D , in the field of biomass, should attract numerous applications of which the first results are already encouraging.

With respect to geothermal energy, Europe has also excellent R D & D and exploitation experience. Although high enthalphy geothermal energy is fully under control and increasingly used throughout the world, low enthalphy energy on the contrary is difficult to exploit, due to the absence of a continuous warm source close to the location of utilization. More fundamental research concerns very deep drilling in hot dry rocks, injecting water and recuperating steam at high pressure. These projects are in progress in Europe, USA and Japan. Finally, geothermal is an area where technological and economical information is readily transferred due to the association of public bodies, large energy producers and important consumers. The Commission has, by its coordination and financing of numerous programmes, strongly contributed to this situation.

Concerning energy, environmental and economic modelling, Europe has a number of centres of excellence cooperating in the Commission's programme.

This is a field where the european studies are well recognized. They concern both tools for analysing supply and demand of energy and those for investigating the interface between energy, economy and environment. These well known studies, and in particular "Energy 2000" and the "Costs of Non-Europe" have seen the light of the day, due to the tools for analysis and modelling and have allowed decision-makers to clarify a number of political choices in the area of energy and economy.

Indications for the future

Of all the instruments at the disposal of the Community for managing its energy policy, R&D is one of the essential elements determining the energy future in the long run. The time horizons 2010-2020 and beyond are of great interest to R&D endeavours today. Hence, today's research is geared towards the hopes for resources that may be available in 25 or 30 years.

It is difficult to organize an energy research programme on a prospective basis undistorted by temporary events. One may observe that during the past six years, the dominant views on the future of energy changed considerably, and so have the principal objectives of the energy policy and the RD&D priorities. These rapid evolution of long term views illustrate the difficulty of designing an RD&D strategy, which by its very nature aims at the long term.

Despite the difficulties of appreciation, RD&D has to ensure that three key questions are answered. Will the energy available in 2020 meet the needs of our economy ? Will this energy be available at a reasonable and stable price ? Shall this energy be clean ?

The outlook of the European Community on energy is such that an average growth rate of the needs in terms of primary energy of about 1.1 % per year from now on up to the year 2010 is foreseen. It will reach a level of annual consumption of around 1.5 Milliard toe, against 1 Milliard toe in 1985. The world energy consumption might reach 14.000 Mtoe, against 7.500 in 1985. With regard to forecasts on a longer term, (2025, 2030), many publications on the subject have been presented by different authors. Even if one records a ratio of 3 between the highest and lowest predictions, one may nonetheless conclude from these studies that

* the energy demand will in general maintain a slight increase in the industrialized countries, slowed down by the progressive saturation of the parc of domestic equipment, the steady reducing speed of the activities of the heavy industry and the constant progress of techniques;
* the technological development will continue sufficiently flexibly with respect to the energy prices in order to follow the evolution of energy demand.

The development of technologies, using fuels other than oil, in order to reduce their costs and to pass the threshold to gain access to an unlimited resource (e.g. fusion) constitutes an important motivation for energy research.

In the long run, these perspectives will collide with two obstacles : the availability of energy resources and the shorter-dated environmental constraint.

If one examines global energy resources of all kinds, one discovers an abundance of energy that could meet the requirements of mankind for the next few centuries. But one must realise, on the one hand, that energy is unevenly dispersed in geographic terms and on the other hand, that it exists in forms not readily adaptable to consumption either due to the high extraction and transformation costs or due to serious ecological problems, which may arise.

To be more precise, the classical forms of energy (oil, gas, uranium, coal) should allow us to reach the beginning of the 21st century without physical shortage nor any particular effort in prospection (one should not exclude tensions on the market resulting from psychological or political actions). If a large prospection effort in oil, gas and uranium were maintained, the reserves discovered could maintain a production level sufficient to secure the needs up to 2025-2030. By that date, the physical limits will have been reached. However, coal is very abundant and will remain available for centuries.

The production and utilisation of energy have their ecological consequences at every step in the fuel cycle. Public opinion was affected at the end of the sixties by the energetic impact on environment. Different problems appeared, notably the thermal pollution of water by power plants, the destruction of soil and surfaces by the exploitation of open pit mining, air pollution, acid rain, the reliability of nuclear reactors, waste treatment and storage of radioactive waste.

Two problems are at present of major concern to the public. Primarily the acid rain caused by the utilisation of fossil fuels (SO_2 and NOx emission) and secondly the radioactivity related to the operation of nuclear reactors and storage of nuclear waste. A third point regarding the greenhouse effect caused by CO_2, is starting to draw the attention of the public via the media (as a consequence of the Toronto conference June 1988). The increased consumption of fossil fuels will only reinforce the need for pollutants emission constraints, a problem to be solved by R&D.

RD&D orientations

What should european research do in view of these perspectives and constraints ? What can be expected from the technology ?

From what has been said three time horizons can be distinguished and for each the problem of security of supply is of a different nature :

- Up to 2000, the greatest threat lies in a sudden supply interruption or a steep price-increase of crude oil as a result of tensions of a geopolitical character. The techniques employed for the use or the production of conventional fuels other than crude oil are not sufficiently developed. The strategy to be adopted in order to avoid tensions on the oil prices should be based on two themes : demand reduction and increase of supply capacities. In this respect it is necessary to:

    * Develop techniques which reduce the liquid fuel demand, both by the use of equipment with more efficient liquid fuel consumption in cases where liquid fuel is specific and cannot be replaced (ex. transport) and by means of equipment which is adaptable for the use of other forms of energy where substitution is possible (multi-fuel boilers).

    * Develop techniques which allow the increase in oil production, in particular by prospection and exploitation of new fields and by reactivating drained oil fields.

- For the period 2000-2020, one might hope that production technologies for fuel, competitive to oil and produced from coal and gas will be operational. The generation of electricity will still rely on hydro, coal and nuclear.

- On a longer term, beyond 2020, it will be required to find solutions for the replacement of fossil fuels and uranium (LWR) for which the fields will be practically exhausted. In this period the only available conventional source of energy will be coal.

  The mentioned elements have been broadly utilized as a basis for reflexion by numerous countries and by the Commission in order to establish their RD&D programme, to develop energy technologies able to satisfy the energy supply at short, medium and long term and to secure a smooth transition into the XXI century.

  It may be useful to structure RD&D programmes according to this main sense of direction into the following five categories according to an IEA classification :

    * Technologies able to extend the availability of the energy carriers of our present supply system at short and medium terms;

    * Technologies more efficient in energy consumption;

* Technologies exploring renewable energies;

* Technologies with a high production potential in the future, but which presently still contain a high technical and economic risk;

* Technologies with the same assets as the above categories, for which the R&D has a horizontal character.

The first category concerns in the first place those technologies improving exploration and exploitation of liquid and gaseous fuels, and solid fuels. Regarding the offshore exploitations, the conception and design for the achievement of submarine production at high sea require important progress. The same holds for techniques to protect health and environment and to increase safety.

Research on solid fuels should concentrate on rendering these resources less pollutant, more efficient (which will imply emissions' reduction) and easier to use. It is urgent to do so because the quality of the main part of the world's resources is low and particularly detrimental to the environment. It appears that the combustion in fluidized bed and gasification are interesting to develop on the short term, as they reduce the pollution inherent to coal conversion. On the longer term, liquefaction, gasification in situ and combined cycles with magneto-hydrodynamic (MHD) energy conversion are promising.

Parallel to the research on fossil fuel, the possibility to develop technologies for CO_2 abatement at the source has to be examined.

Research on conventional nuclear and fast breeders should also increase the availability of energy in Europe on the short and medium terms.

Considerations regarding nuclear safety can be found in annexe 9.

The main but not exclusive objective of technologies that use energy in a more efficient manner is the reduction of fuel demand and of investment needs for large power plants. These technologies may also reduce the impact on the environment and in particular reduce the tension between energy supply and demand. The necessary research items are :

* introduction of energy efficient vehicles in the transport sector, development of engines with improved efficiency and lighter materials. Electric cars are also a possibility; therefore it is necessary to develop low weight batteries of high energetic density with multiple loading and unloading facilities.

* in the industrial sector : introduction in industry of efficient processes with reduced energy needs in high energy consuming sectors such as the iron, steel, aluminium and other basic material industries. In general, global energy management in industry should include measurements, control, regulations, recycling of lost energy, recycling of products of high energy intensity etc.

* with the residential and tertiary sectors reduction of the energy demand is possible by refurnishing existing buildings and construction of new buildings with high energetic efficiency. The techni-

ques are already well-known: for example insulation, passive solar architecture, "intelligent" cooling and heating systems, district heating and heatpumps. Regulation of control and measurement techniques based on micro-electronics can strongly contribute to the demand reduction. An increase of energy efficiency in household appliances should be clearly monitored.

The contribution of renewable energies to the global energy supply (with the exception of hydropower and biomass combustion) will remain small in the near future. It is well known that these energies can have a regional importance and could be adapted and utilized in the developing countries reducing their demand for oil products and hence contributing to a relaxation of world tension regarding the demand for oil.

These energies represent a very high potential. Even if some of them have already reached a commercial maturity (passive solar heating, geothermal, wind energy, biomass and small scale photovoltaïcs), further improvement and extension of their area of application is essential. Large scale solar photovoltaic must for that matter be considered on long term from a cost reduction viewpoint. R & D in this field must be continued in order to improve the efficiency and to ensure a long life time and low degree of maintenance of the installations. In general development of energy storage systems, improvement of knowledge regarding the availability of resources, comprehension of energy needs which can be met by renewable energies, examination of technological aspects and of production of small scale components for regional application and the assembling of information on the potential of renewable energies remain subjects for further development.

The final objective of technologies of high potential, containing high technical and economic development risks is to substitute gas and oil sources, the reserves of which will unavoidably become exhausted. They concern mainly, fusion reactors. This subject will be dealt within annexe 6.

Horizontal research concerns the four preceding fields of activity and includes in particular basic technologies, reduction of the impact on the environment, transport and storage of electricity and the development of energy systems using hydrogen.

Research and development in systems analysis and modelling is fundamental and by its very nature horizontal.

The research orientations which have been discussed are of interest for the future of energy in Europe, but also in the world. A good number of them have already been embarked upon in the United-States and in Japan and in particular those which concern the short and medium term energy future. The European Community has, by consequence, a double motivation to promote the research orientation already discussed and the next pluriannual energy R&D programme illustrates this preoccupation.

Conclusions for the future

The construction of a future for energy in Europe will be dominated by two factors : technological innovations and the protection of the environment.

The environmental dimension is steadily growing in importance due to the conciousness of the population. It is inconceivable to continue an important nuclear programme if one is not convinced of the safety of its installations. It is equally inconceivable to launch a large coal utilization programme without consideration of the effect that acid rain and greenhouse effects have on the ecosystem.

With respect to the energy problems on short and medium term it is absolutely necessary to continue research in energy saving because it is one of the best ways to increase the security of supply and to diminish the energetic impact on the environment and to ensure cleaner and more efficient combustion of fuel, in particular that of coal.

In function of the medium term problems, the main problem to be solved is the extension of liquid fuels available in Europe as well as the development of liquid or gaseous fuels derived from coal, gas or biomass in order to substitute oil. The efforts undertaken at the European level and in particular by the Commission are proportionally superior to those of the IAE, although signals from the US and Japan seem to indicate that research in this field has become more intense.

The long term horizon for energy implies that a definite effort should be undertaken in Europe in the field of nuclear reactors which should lead to a substantial cost reduction of fast breeder reactors and a design of intrinsically safe reactors and acceptable by the population.

The effort in the field of renewables should be maintained because in the long run renewables could contribute significantly to energy supply when prices and costs of other forms may have increased significantly and when the environmental constraints may become more difficult to overcome. The main emphasis of this research should be laid on to reduction of exploitation costs.

Regarding fusion, there is still a very, very long way to go. When the technical demonstration phase has been accomplished, the technique should prove economically feasible.

One should not forget that energy R&D will not be carried out in isolation but in parallel with other research, with possible cross fertilisation, allowing the creation of new concepts by new combinations of technologies. All technologies may indirectly have spin-off on energy demand and contribute to new technologies for energy production.

For example, research on materials (e.g. supraconductors) can have a significant effect on the transportation and storage of energy. The subject of radioprotection in the "life quality" programme of the EC may provide impacts on the conception and acceptance of nuclear power by public opinion.

Thank to mankind's inventivity and technological innovation, solutions to energetic problems should always be found, but they have come at the right moment so that the change-over from oil to other forms of energy may be smooth.

One should not, due to pressure of temporary events or action groups, abandon a research subject without an in-depth analysis of the advantages and inconveniences of the techniques concerned. The Commission must maintain and intensify its action considering the needs of energy RD&D in collaboration with its Member States, even if the oil price were at $10 per barril.

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CONTROLLED THERMONUCLEAR FUSION

1. Fusion as a potential energy source

Every source of energy has its own economic, health and environmental costs, and risks.

The need for the development of a diversity of widely accessible long-term energy sources - which show promise of being not only technologically feasible but also acceptable from the economic, safety, environmental and proliferation points of view - is therefore being perceived more and more accurately.

Because controlled thermonuclear fusion has the potential of becoming one of the energy sources sought for, industrialized countries have been grappling with R&D on a long-term and priority basis in this field. Fusion has the long-term potential to open a new way of power generation, making a moderate impact on the environment, having inherent safety, and utilizing practically inexhaustible and readily accessible fuels. As the fuel consumption of future fusion reactors will be very low the electricity generating costs of a commercial fusion reactor will be dominated by capital investment. For instance, the amount of primary fuel consumed to generate 1 Million kWh of electricity in a fusion plant is about 35 grams of lithium converted into tritium and 10 grams of deuterium, as compared to, for example 240 tonnes of oil or 360 tonnes of hard coal in a fossil-fired plant. It is, however, too early to make definite statements on fusion as an economically competitive energy source; preliminary studies of the cost of fusion indicate that it is of an acceptable order of magnitude. A substantial contribution by fusion to the world energy supply cannot be expected before well into the next century. The long-term potential of fusion justifies to vigorously continue its development, whatever can be the short-term fluctuations of oil price. Fusion could bring an essential contribution to the reduction of the economic, ecological and political vulnerability of Europe in the next century.

2. European Actions

In view of fusion's potential advantages for Europe and the size and duration of the R&D required for its eventual implementation, Community member countries decided to integrate their individual national efforts into a single European programme which would support and coordinate the activities of all the specialized laboratories located in Member States. Since then, these laboratories have been bound to the Community by contracts of association which provide for Euratom participation in personnel and financing. The Commission has full executive responsibility for the programme and is assisted by a consultative committee for the fusion programme (CCFP), composed of national experts. In addition, a joint undertaking has been established for the JET project; a JET Council has the responsibility for the management of this undertaking whose chief executive and legal representative is the director of the project. The collective nature of the Community fusion programme and its remarkable spirit are testified to by several decisions of the Community's Council of Ministers. These describe the Community fusion programme as "a long-term cooperative project embracing all the work carried out in the Member States in the field of controlled thermonuclear fusion. It is designed to lead in due course to the joint construction of prototype reactors with a view to their industrial production and marketing". Such a venture is sufficiently attractive for non-member states to have joined with full rights and duties the European fusion effort (Sweden, Switzerland).

The main reasons for conducting research and development in the field of fusion on a Community basis are :

- the scale of the human and financial resources required, which suggests that such a development could hardly be carried out on national basis;
- the long time-scale of the effort (extending into the next century) needed to arrive at the construction of the reactor;
- the existence of a collective need, common to all Member States;
- the realization of a European market for European industries in domains of high-technologies;
- in the event of success, the opening-up of a wide Community market for the European reactor;
- to provide a potential partner of comparable size to the 3 other world fusion programmes, fostering thereby international collaboration in the field of fusion;
- the quality of the European Fusion Programme whose leading position is acknowledged worldwide, and to which Sweden and Switzerland are fully associated.

Fusion is therefore in line with the criteria pertinent to Community R&D programmes.

3. Objectives and content of the programme

The path towards fusion reactors for energy production can be divided, albeit arbitrarily, into three stages : demonstration of scientific feasibility, of technological feasibility, and eventually of economic feasibility. These steps are not independent and interfere in many respects. The Community fusion programme has been able to concentrate on the most promising line, the toroidal magnetic confinement, and within this approach to maintain the necessary breadth. Presently, with JET (Joint European Torus), the medium-size tokamaks and their foreign equivalents, we are still primarily in the scientific stage. The Next European Torus (NET), now in the pre-design phase, is conceived at present as a device which should fully confirm the scientific feasibility of fusion in a first stage and the technological feasibility in a second stage.
Within this strategy (JET and other tokamaks, NET, DEMOnstration reactor), the main objectives for the programme (1st January 1988 to 31 March 1992) recently adopted by the Council of Ministers are :

- to establish the physics and technology basis necessary for the detailed design of NET; in the field of physics and plasma engineering this implies the full exploitation of JET and of several medium-sized specialized tokamaks in existence or in construction, and in the field of technology the strengthening of the current fusion technology programme;
- to embark on the detailed design of NET before the end of the programme period if the necessary data base exists at that time (but not before the next revision foreseen for January 1st, 1991);
- to explore the reactor potential of some alternative lines (mainly Stellarator and Reversed Field Pinch).

The above-mentioned adopted programme concerns only JET and the General Programme (NET, Technology, and physics and plasma engineering conducted in the associated laboratories). The fusion activities of the Joint Research Centre, which from a scientific and technical point of view are fully integrated within the overall fusion programme, are, however, governed by another Council decision. In current money, the amount of Community resources available for the period (4 1/4 years) mentioned above (exclusive of JRC, Sweden and Switzerland) is estimated at 735 MioECU, of which :

- 406 MioECU are for the general programme (rate of financing by the Community varying between 25% and 100% according to the priority character of these activities)
- 329 MioECU are for JET (80% financing by the Community).

To such an amount of 735 MioECU incurred by the budget of the Communities, corresponds nearly 1,100 MioECU to be incurred by the national administrations and other sectors at national level, so that the overall expenditure for fusion (exclusive of JRC, Sweden and Switzerland) for 4 1/4 years will amount to about 1,800 MioECU.

4. Present situation in Europe

Scientific and technical achievements place Europe in the forefront of world-wide magnetic fusion research, as it has recently been acknowledged at the Conference organized by the International Atomic Energy Agency (IAEA) at Nice this year (12 to 19 October, 1988).

- JET, the flagship of the Community fusion programme, is the world's largest experiment. It achieved its initial objectives for the basic performance phase on time and in budget, and the implementation of the extension to full performance is well under way. It has made a large step towards the demonstration of the scientific feasibility of fusion. At halfway stage of the scheduled experimental programme, JET has not only reached plasma (ion and electron) temperatures above 100 million degrees (and, even, ion temperatures up to 150 million degrees, i.e. ten times hotter than in the centre of the sun) but also achieved the required plasma density and the necessary confinement time for a reactor, but not at the same time. Nevertheless, the highest "fusion product" (density x temperature x confinement time at the same time) was obtained on JET and corresponds to one fourth of the necessary value for "breakeven" (total fusion power equal to additional heating power). JET is the only machine to have achieved confinement times greater than one second. The record plasma heating current of 7 million Amperes is more than twice that of any other fusion experiment.
- The European medium-size tokamaks contribute in a powerful way to the progress of fusion and to the success of JET by experimenting with different configurations and exploring new heating methods

and by developing new diagnostics. As an example, the so-called "magnetic divertor" operation on the ASDEX tokamak at Garching (D) has led to the discovery of the favourable "H-mode" confinement.

- Europe is also leading in research on Stellarators and Reversed Field Pinches (alternative configurations to the tokamak).
- The construction and commissioning of new devices proceeds according to schedule. The largest superconducting tokamak in the world - TORE-SUPRA at Cadarache (F) - has started operation in April 1988 and should reach its full performance (1.7 million Amperes and plasma pulse of 30 seconds) in two-year's time. The (modular) advanced Stellarator WENDELSTEIN-VII-AS at Garching (D) has just come into operation. Other machines: ASDEX-UPGRADE (Garching, D), RFX and FTU (Padova and Frascati respectively, I), COMPASS (Culham, UK) and TCV (Lausanne, CH) are in the construction phase.
- European industry has built all these devices (to give an example, more than 98% in cost of JET contracts has been placed within Europe) and has already been entrusted with some long-term advanced development. Its involvement should make a qualitative and quantitative jump when a decision is taken on the start of the engineering design of NET.
- NET is in the pre-design phase. The main performance specifications have been tentatively selected, resulting in a coherent set of parameters which is presently being used for further optimization and for guidance of the technology programme.
- The orderly implementation of the technology programme is an important achievement of the recent years. The main part of the work is oriented towards NET, but there are also longer term activities. Efforts are concentrated in the fields of superconducting magnets, tritium, blanket, remote handling, materials, safety and environment.

Outside magnetic fusion, a "keep in touch" activity is maintained in the field of laser-fusion, and muon-catalysed fusion is kept under review.

The Community approach, which has made possible the setting up of the JET Joint Undertaking (1978) and of the NET-team (1983), has led also to the implementation of an intensive collaboration between the fusion laboratories. Most of the Associations do work for another Association and all of them work for JET and for NET through different types of contracts and agreements. The Community Fusion Programme has efficiently built a true scientific and technical community of large and small laboratories, readily able to welcome newcomers, and directed towards a common goal. Among the many dispositions taken to ensure the true Community character of the Fusion Programme, staff mobility deserves a special mention : each year more than 200 professionals (out of a total of about 1,200 professionals) are sent, via "mobility contracts", to work outside their home laboratory for periods up to 1 year. JET represents an extreme case in this domain, since this mission-oriented project is run by personnel from the national organizations, which committed themselves to re-integrate their staff after termination of secondment to JET.

5. International collaboration

This leading position of the Community fusion programme makes Europe an appealing partner for international collaboration both in bilateral frames (Canada, Japan, United States) and within multinational organisations (OECD, IAEA). While in the past international collaboration was mostly the object of agreements on specific points, it takes at present wider and more substantial aspects :

- Bilateral Framework Agreements. The situation is the following with :
  Canada : Memorandum of Understanding signed in March 1986.
  USA : Agreement of Cooperation signed in December 1986
  Japan : the text of the Agreement has been agreed upon at the technical level and the procedure aiming at a Council decision approving the Conclusion of the Agreement started in September 1988, so that the signature is expected for the end of 1988.

- Implementing Agreements in the framework of the IEA (OECD)
  * Tokamaks :
  o TEXTOR (signed in 1977): 15 years duration
  o ASDEX and ASDEX-UPGRADE (signed in 1985): 10 years duration

- o THE THREE LARGE TOKAMAKS (JET, TFTR and JF-60), signed in 1986): 5 years duration
- * Alternative lines :
- o STELLARATORS (signed in 1985): 5 years duration
- o REVERSED FIELD PINCHES : in preparation and possibly to be concluded at beginning 1989
- * Technology :
- o LARGE COIL TASK (signed in 1977) : joint experiment concluded and final report in preparation
- o FUSION MATERIALS (signed in 1981) : Annex I discontinued, duration of Annex II of 10 years, Annex III in preparation
- o SAFETY AND ENVIRONMENTAL ASPECTS OF FUSION : in preparation and possibly to be concluded at beginning of 1989.

Quadripartite cooperation on an International Thermonuclear Experimental Reactor (ITER) under IAEA auspices

The Agreement of participation by the European Atomic Energy Community in the ITER Conceptual Design Activities, together with Japan, the Union of Soviet Socialist Republics, and the United States of America, has been signed in February 1988. The four large fusion programmes of the world (EC, Japan, USA, USSR) have decided to coordinate their efforts aiming at a specific goal : producing by 1990 through a collaborative effort of four parties having equal status and making equal contributions a conceptual design of an ITER, and coordinating supportive research activities. Such a collaboration has been made possible because these four programmes have similar strategies towards the demonstration fusion reactor. The NET activity, which will continue as planned until a possible international solution offering convincing guarantees is found for the Next Step, forms the focal point for this collaboration. Indeed, not only the technical site for joint work on ITER conceptual design activities has been chosen to be the same as the site of the NET-team (Garching, D), but also the reference parameters chosen preliminarily at the end of the definition phase for ITER are similar to those of NET.

The importance of this world-wide collaboration is such that ITER was explicitly mentioned in the joint Statements of the Washington and Moscow summits between President Reagan and General Secretary Gorbachev.

Finally, following the approval by the Council of the conclusion by the Commission of a Memorandum of Understanding between EURATOM and the Government of Canada on the involvement of Canada in the EURATOM contribution to the ITER Conceptual Design Activities, this Memorandum was signed on October 3rd, 1988. The quadripartite collaboration on ITER is statutory so that any collaboration to ITER by any other country should be implemented through one of the four partners.

6. Situation in the world

As already mentioned there exists, besides the EC fusion programme, three other large programmes having similar strategies: sequential demonstration of scientific, technological and commercial feasibility with some differences on the necessary overlapping between the three phases. As far as staff and funding are concerned, each programme is also comparable to the EC programme in the field of magnetic confinement.

- US programme : It follows both the magnetic confinement approach (two thirds of overall expenditure) and the inertial confinement approach (one third).

  Within the magnetic confinement approach, the tokamak line is intensively followed with TFTR (the US equivalent of JET), and D III D mainly.

  Scientific progress and limitation in funding have led the US magnetices fusion programme to narrow its previously very broad spectrum of activities. It is actively supporting its research work on alternative toroidal configurations but has sharply decreased its efforts on magnetic mirror configurations. A Compact Ignition Tokamak (CIT) is in the design phase : this high field tokamak should allow to study experimentally the physics of a burning plasma.

  The US inertial confinement programme is the largest in the world : its future development is difficult to predict, in particular because of its many links with military programmes (SDI).

- Japanese programme

  Although Japan is a late-comer, fusion research has received high priority in Japan in particular under the initiative of the Japanese Atomic Energy Commission. The Japanese effort is now at a level comparable to the one of the EC and of the US.
  The magnetic confinement effort is well illustrated by the large tokamak JT-60 in which a plasma current of 2 MA could non-inductively be driven. JT 60 needs modifications in order to improve its performances. The stellarator line (Heliotron-E is the largest stellarator in the world) and other alternative lines are also investigated.
  A comprehensive inertial confinement programme of high quality is underway in a specialized Institute of Osaka University. It is totally unclassified.

- Soviet programme

  The Soviet Programme has produced brilliant results (Tokamak is a Soviet concept !); at present it is characterized by a large number of well trained physicists, relatively modest technological realizations (no device of the size of JET), and a wide spectrum of activities. Here also, the tokamak line receives the largest attention. A new tokamak with high magnetic field (TSP) came into operation at the beginning of 1988; it is designed for tritium operation. A superconducting tokamak T 15, similar to the European TORE-SUPRA already in operation, is nearing completion.

7. Near-term issues of fusion

Tokamaks will continue to occupy the forefront of magnetic fusion research. The most impressive results so far in fusion research have been obtained in these devices : the "fusion product" (ion temperature times ion density times confinement time),which is the best figure of merit on the way to the reactor, has increased by almost four orders of magnitude during the past 20 years and is now only a factor 4 away from breakeven, and slightly more than one order of magnitude from ignition, which is our longed for milestone marking the achievement of the proof of the scientific feasibility of fusion. The principal key to such progress has been the increase in gross machine parameters and the relative simplicity of the tokamak concept. The last untouched

physics problem so far, alpha-particle heating, should become accessible to experimentation in about 3 years from now, when TFTR, JET and TSP will enter their phase of tritium operation.
The technological problems associated with Deuterium-Tritium fusion reactors, which will have to breed their own fuel (tritium) in a blanket containing lithium and surrounding the reacting plasma, have gradually been revealed by the many conceptual reactors designs produced within the world fusion community over more than a decade. These studies have also evidenced that achieving the potential environmental and safety advantages of fusion will not materialize automatically but will depend in a large measure on designs specifically tailored to this end, in which the use of low-activation materials could play an important role. They have shown also how economic competitiveness will depend on attaining plasma and engineering performances which are not yet assured.
Although some mysteries still remain, the conclusion of the scientific phase of fusion is now in sight, and it is therefore timely to plan for the Next Step device on the road towards a prototype reactor.
Next Step machines are at present in the pre-design phase both within the large fusion programmes (for example, NET in the European Community) or in the quadripartite venture : ITER. ITER, whose definition phase has just come to an end, is conceived as a tokamak device which, to quote from its Terms of Reference, "will provide the data base in physics and technology necessary for the design and construction of a demonstration fusion power plant". It is estimated that three decades of R&D will be required before such a demonstration reactor can become operational.

With the Next Step, there exists the need not only to develop, test and demonstrate technologies applicable to future fusion reactors, but also to define safety standards for these reactors. And it will be only during the construction and exploitation of the Next Step that we will reach a sufficient basis to evaluate with some certainty the overall potential of fusion as an energy source.

As in the case of any major decision on high technology, a decision to embark on the detailed design of the Next Step, will have a strong political component. This decision shall be substantiated on three different grounds :

- A sound scientific and technical basis is needed : work in progress on both the scientific and the technological sides makes us reasonably confident about this point.

- The scientific Community should present convincing safety, environmental and, as far as possible, economic arguments in favour of fusion. So already now, long before the characteristics of a practical reactor are known in some detail, it is essential, even if very challenging, to undertake a systematic and continuous assessment of fusion's potential to achieve attractive combinations of environmental, safety and economic characteristics. International collaboration should be used to its maximum extent to make progress in these fields where it could be particularly helpful. Indeed, first steps are being taken in this direction in the framework of the IEA.

- Concrete plans should be developed on how the major fusion programmes could take full advantage of a wide international cooperation, cooperation which could lead to a single device or to the joint planning of Next Step activities. Indeed international cooperation will become more and more a necessity if we want to make the most efficient use of the resources of the world fusion community. These include, as a particularly precious element, a highly qualified staff, whose dedication will be a necessary condition for the success of the Next Step, but whose full utilization requires that the Next Step be undertaken as soon as technically feasible.

It should be stressed that International cooperation, even if extrapolated to an unprecedented level, cannot substitute for strong "domestic" programmes. The four large fusion programmes of the world are at present working together in the ITER Conceptual Design Activities to provide, at the end of 1990, a design which will then be available for all Parties to use, either in their own national programme or as part of a larger international cooperative programme. Some of the ITER Parties have also national plans to embark at about the same time on the detailed design of a similar Next Step. It is difficult to make any prediction on the framework in which the Next Step(s) will eventually be built, but all options should be kept open in order to lay the ground for a decision to start the realization of the Next Step(s) early in the nineties.

8. Financial Implications for Europe

By virtue of its important objectives, its excellent record, its technological interest and its absolute Community character, fusion should remain one of the most important R&D programmes of the Community.
The Community funding foreseen within the recently adopted fusion programme amounts to about 200 MioECU per year (including JRC fusion activities) corresponding to an overall yearly expenditure for Fusion in Europe of about 450 Mio Ecu. While the physics activities in the European fusion laboratories will have the tendency to decrease in the long term, the technology will increase so that one could foresee the need of a roughly constant level of funding for research outside (but supporting of) the Next Step proper.

The present and very preliminary cost estimates for the construction of the Next Step amounts to some 3,000 MioECU. The detailed design would cost about 10% of this figure, i.e. about 300 MioECU. Such detailed design will last at least three years so that almost 100 MioECU per year will be necessary for the Next Step proper during the design phase, to be initiated possibly in 1991/92.
In subsequent years, JET would be phased out, and NET would progressively take up momentum insuring continuity (with gradual expansion) in the use of the human, technical and financial resources. As far as the construction of the Next Step is concerned, this phase could start around 1995 and last about six years. The necessary increase of Community funding will depend on :

- whether such Next Step will be built on a Community basis (NET) or at world level (ITER). The construction of the Next Step by four parties instead of one alone would represent for each one, in spite of all difficulties, a reduction in cost of about a factor 3.
- which framework will be established at Community level (a Joint Undertaking, as for JET, with 80% Community funding, or some other scheme ?).

Within the strategy of the Community fusion programme, a milestone for the assessment of these financial implications will be the next revision (to be preceded by an independent evaluation) of the programme foreseen on 1 January 1991. At that time it would be appropriate to decide when to start the detailed design of NET, taking into account the results of the ITER Conceptual designed activities (due to be completed at the end of 1990).

ENVIRONMENT

A. INTRODUCTION

1. The environment, its protection, and the quality of life for Man, are subjects of high public and policy interest. Pressures for improved environment protection, continue unabated. They are fueled by incidents such as the pollution of the Rhine, the ozone hole, algal bloom in the North Sea and the death of seals; by improved communications and relentless press coverage; and by greater public awareness reinforced by growing recreation and leisure activities. The Community's policies inevitably reflect these pressures. Environment protection is a Community issue in its own right. It is also included, under the European Single Act, as an important element in other Community and wider policies for industry, agriculture, fisheries and aid to developing countries. Such policies must increasingly seek to predict and prevent natural and man-made problems of the environment. We cannot continue to be reactive to the problems of the day; we must probe the future.

2. Thus, environmental research*, is directly linked to a well defined Community policy. It has to respond to specific problems derived from the Environmental Action Programme; this imposes certain prerequisites in the content of the programme.

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* The term "environmental research" in this context does not include problems linked to nuclear energy and radioactive pollution (cf. annex 9).

3. Unlike other programmes which are aimed at advancing technologies in order to increase Europe's competitivity world wide, environmental research has to identify the constraints to technological developments, imposed by the need to maintain or even improve the quality of life in Europe and to protect our resources. It should help to overcome the conflict of interest between economy and ecology. The benefits from environmental research can therefore not be measured in direct economic terms.

4. Under the pressure of environmental legislation, technologies for the abatement of environmental pollution, without any doubt, have conquered a substantial market. This is of considerable economic significance. The basis of such technologies is, however, not substantially different from that which applies in the production cycle. Their promotion is very much a problem of adaptation and demonstration and to a lesser extent of fundamental research. In certain areas, however, in particular in the development of new, low-emission production technologies, Community environmental research has an important role. Through the definition of norms and standards the Community will have a considerable impact on industry, and an association of industry to research activities in this field seems advisable.

5. Many environmental problems have a global dimension, such as global change or stratospheric ozone depletion. In such areas, European research cannot be separated from the world-wide effort which expresses itself in programmes such as IGBP (International Geosphere-Biosphere Programme). In these areas the role of the Community programme is to assist in providing coordinated European input to the global efforts, thus strengthening the position of Europe in a world-wide context.

B. RESEARCH TRENDS AND NEEDS

6. The complexity of environmental problems makes a breakdown to specific research areas very difficult; the traditional separation of problems by media (air, water, soil) has been abandoned in favour of a holistic view. To a certain extent, research problems may, however, be categorized under three interdependent sets:

- understanding the basic phenomena
- detection and interpretation of environmental changes
- prevention of the degradation of the environment.

The most important environmental issues are addressed in the following, with an indication, as far as possible, of the research requirements identified.

7. Climate and Climate Change - the Greenhouse Effect. We are dependent upon climate and its variability for our survival. Climate controls the basic parameters of our water supplies, agriculture and forestry, energy and water requirements, and transport infrastructure. Societies have evolved to cope with their characteristic climates and associated extremes. But climate is variable not only in terms of longer term oscillations (eg glaciations). Individual events and long term trends can have major impacts upon the environment and on socio-economic structures.

8. There is a scientific consensus that a significant climate change will occur during the next century as a result of human activities. Greenhouse gases such as CO_2 and their climatic effects may be the biggest single issue or threat facing man and the environment as we enter the 21st Century. As with all climate issues, we will need to understand the processes involved and to develop the means to predict change and its consequences. This includes investigation of cloud-radiation interactions, ocean circulation and air/sea fluxes, and effects of CO_2, warming upon the melting of the ice caps together with the consequences for Europe and for developing countries.

9. It is important to note that there is no complete explanation of natural and man-made fluctuations in climate, and that there are no reliable methods for their prediction especially at regional and local levels. Also, some interactions between

climate change and environmental pollution are obvious, but others are more subtle. There are, for example, strong suspicions of the interactions between atmospheric pollutants, climate extremes and climate change in the phenomena of forest decline.

10. Sea-Level Rise could be one of the most striking consequences of climate change. Over the past 100 years, global mean sea level has risen 10-15 cm. Future warming from the greenhouse effect could lead to a sea-level rise of 50-100 cm by the year 2025. The coastal lowlands of the North Sea Basin, Atlantic Seaboard and Mediterranean would be vulnerable to such a rise. These include many of our most fertile agricultural and densely populated areas as well as deltas, estuaries, sand dunes and wetlands of recreation, amenity and conservation interest. This applies equally to developing countries and especially to those already under threat by frequent and extreme climatic events. They would all be subject to erosion, inundation, salination and storm surges which would overcome sea defences designed to meet lower mean and extreme sea levels.

11. Climatic Change Impacts on Land, Water and Other Resources. This is a much more complex area because of the possible regional variations in climate change. But how can climate variations and changes affect our basic resources? What are the means of predicting climate extremes such as droughts, floods, severe frosts, snow storms, tides and wave surges? It is these events that cause such heavy tolls of life and property.

How can we forespell the impact of changes in temperature and rainfall and variations in extreme events upon agriculture, forestry and water resources, and which remedial or adaptive measures can be envisaged?

12. Natural Hazards. Many natural hazards aggravated by the action of man, link with the issues described above thus underlining the horizontal and vertical dimensions of environmental and climatological research. The interactions between these sectors are critical in terms of mutually reinforcing protection policies.

Processes involved in salinisation, erosion, flash flooding and wildfires have to be better understood to protect man, livestock, crops and forests from local catastrophies.

13. Seismic Hazards are also of concern especially in those areas in tectonicly active areas. No European country is entirely free of risk. Man-induced hazards are also of concern in the older industrialised countries with abandoned deep mine workings. Our aims are to understand and measure strong motion phenomena, and to develop seismic hazard monitoring, data and information, and warning systems.

14. Stratospheric Ozone. The appearance of holes above the polar regions alerted us to the depletion of the Earth's protective ozone layer by chlorofluorocarbons (CFC's) and other chemicals. Whilst initial actions have been taken to control CFC emissions, there are strong indications that depletion continues, posing serious global threats to man and the environment from increased UV irradiation.

At the same time, depletion and/or redistribution of ozone could have feedbacks on climate. The possibility of reinforcement of climate changes induced by the greenhouse effect cannot be ignored, over and above any possible effects of increased UV irradiation. Causes, processes and rates of change involved, and their possible consequences need to be better understood.

15. Air Pollution, and Its Effects on Terrestrial and Aquatic Ecosystems. Increasing emphasis is being placed upon problems of photooxidant pollution; and on more complex issues such as the interactive effects of mixtures of pollutant and other stresses upon trees and forests in relation to forest decline, of pollution and land use upon aquatic systems, and of defining pollution climates including the actual fluxes and critical loads to sensitive parts of ecosystems.

16. Assessment of Chemicals. There is a lack of standard procedures which reduce the use of vertebrate animals, and take advantage of developments in the assessment of mutagenicity, carcinogenicity, cellular toxicity, metabolic activity and structural activity relationships of new and existing chemicals. Procedures for assessing both abiotic degradation, and the pathways and ecological effects of chemicals, must also be developed.

17. Environment and Human Health. A target orientated and preventive approach to the protection of the groups most at risk throughout the Community includes, inter alia, the development of population monitoring methods and systems to identify such groups, and to detect and measure preclinical effects (eg nephrotoxicity, neurotoxicity, biological markers). These can be applied to studies of both indoor air quality and general environmental quality, and their effects on man. The most challenging and urgent priority, however, is to overcome the notorious problems of developing Community-wide approaches to epidemiological surveillance in co-operation with WHO and other international agencies.

18. Toxic Waste Disposal. Intractable wastes continue to create problems of disposal. Often, advances come by changes in manufacturing processes and in new products which reduce established problems - a major force in the improvement of environmental standards. Yet they sometimes create new problems. Modest advances will continue to be made but spectacular progress

is unlikely without the development of new, clean technologies. The potential exceptions may lie in the applications of computer assisted optimisation processes, although current evidence suggests the latter need to be tailored to specific disposal processes and wastes.

19. Soils and Groundwaters. There is profound concern in Europe about the state of our soils, their conservation and their optimal management as a sustainable resource. Initiatives in the Community must be based on sound scientific guidelines. We need to understand the reactions of soils to management practices which accelerate erosion, desertification, etc.; to excessive fertilisation; to waste disposal; and to many forms of pollution (eg acidification), together with their mediating effects upon surface and groundwater quality. The significance of soil-derived particulates and associated chemicals in river, estuarine and marine pollution, is becoming increasingly apparent.

20. Freshwater Quality. The primary need is to develop the techniques and methodologies to sample rapidly, a wide range of complex and potentially hazardous chemicals, notably in the organo-metallic and non-volatile groups. These include pesticides, and their breakdown products. Progress is also needed in understanding the transformations, fates and effects of such chemicals. Increasing attention must be paid to the riverine inputs of these chemicals to, and their behaviour and impacts in estuarine and inshore marine systems.

21. Quality of the Marine Environment. As examplified by recent events the main issue is the eutrophication and contamination of the rather closed regional seas surrounding the European continent, the North Sea, the Baltic and the Mediterranean. An understanding is needed of the sources, fates and stresses of contaminants from rivers and other sources, of nutrient dynamics and of algal blooms.

22. Conservation of Species and Habitats. European ecosystems support a wide range of habitats and associated species, albeit often man-made in the past. Few are truly natural but they are the remnants of semi-natural ecosystems - the refuges and staging posts of endangered flora and fauna, and the last islands of natural genetic diversity. Research must aim to define the critical loads which such systems can support, and to develop methods for their sustained management and restoration.

23. Basic Research on Processes and Ecosystems. Progress on applied issues is frequently dependent upon advances in basic knowledge. For example, understanding the processes involved in forest decline requires us to work on the basic physiology of trees to determine how they react to various stresses. Findings at the sub-cellular, cellular and whole organism level must be interpreted in terms of impacts upon populations and ecosystems. This, in turn, requires us to understand the behaviour and population dynamics of species, predator:prey relations, and the structure and functioning of ecosystems. Thus, forest ecosystem research is important underpinning to applied research on forest decline, acidification, and the impacts of climate change.

24. Cultural Heritage. Europe's cultural heritage is our legacy from the past, and our testament to the future. The academic and social values of this heritage are enormous, and they often play a crucial role in the economies of member countries. We must, therefore, provide the scientific basis of protecting a vast range of irreplaceable objects made with different materials and exposed to a wide range of climatic and environmental stresses.

25. Major technological hazards. To a large extent, man interacts with his environment. Natural hazards such as erosion, landslides and seismic shocks are often exacerbated by man's activities. However, one has only to mention Seveso, Chernobyl,

Frenchman's Flat, Flixborough or Bhopal, to realise that major technological installations imply potential major hazards. Statistically, most dangers to the public and the environment arise from the manufacture, storage and transport of bulk flammable and/or toxic chemicals. Therefore, the phenology and early dispersion of chemical releases, combustion, and risk analysis taking into account the human factor require further research.

26. Biotechnology and the "Sunrise" Industries. Traditional heavy industries continue to loose importance. The effects of new technologies upon the environment are by and large, beneficial. New technologies of production are bringing enormous economic benefits. However, they raise important questions for the environment. Biotechnology has attracted the greatest public concern in this context. The consequences of deliberately or accidentally releasing engineered organisms or even genetic material are scarcely understood. The need for adequate safeguards based on science, is paramount. Other new technologies also pose threats by their use of complex chemicals of uncertain environmental impact and the production of toxic and complex effluents, albeit in small qualities.

C. ACTIONS IN EUROPE

27. The Community and its member countries rightly target their resources upon the environmental issues which concern their citizens and impact upon their environments, societies and economies. These issues may be of local concern or regional or global in scale. But even with local concern there is much commonality in their natures, and in the methodologies and technologies for their investigation and amelioration. Europe is thus not an island but it is an integral part of the global community in terms of environmental problems, their study and their resolution. Appropriate co-operation between the Community and

non-member European states (eg EFTA), Economic Summit countries, developing countries and the full range of Governmental and non-Governmental International organisations, is thus both inevitable and essential. A similar co-operation can be envisaged in the future with East European countries.

28. Community research has to take, of course, fully into account what is done by industry, national research programmes, and within other transnational frameworks, in order to ensure optimum benefits from its resources.

29. Industry was until recently rather defensive in environmental matters, but makes now, under the pressure of tougher legislation and public opinion, considerable efforts, also in R&D. Industrial research is closely linked to the advancement in production processes; the economic pressure to reduce energy and raw material consumption and to avoid unnecessary wastes leads to new production processes which normally imply benefits for the environment. Environment-related R&D in industry can therefore not be considered on its own right; substantial resources, however, are allocated to the improvement of down-stream abatement processes.

30. All Member States have more or less substantial R&D programmes on the environment, which in part are, of course, aimed at problems of regional character and to monitoring environmental quality. There are, however, important components of national programmes of a very basic nature which should be progressively integrated into a European context. Flexible means ("concerted actions") have been developed in the past for this purpose and they turned out to be efficient.

31. Except for some EUREKA projects and a few cooperative projects implemented in particular by ESF, no major cooperative mechanisms of European scale exist. All COST projects in the environmental field are implemented through and under full integration of the relevant sections of the Community programme.

32. Environment research has been part of the Community research programmes since 1972, within the JRC programme and through contract research and coordination within the COST framework.

33. In the context of the framework programme, a major review of the aims and the means of implementation took place, leading to a review of the JRC activities as well as to a proposal for two programmes through contract research:

- STEP (Science and Technology for Environmental Protection)
- EPOCH (European Programme on Climatology and Natural Hazards)

submitted to the Council in November 1988. These are complemented by a new programme on Marine Science and Technology (MAST).

34. The new Community programmes STEP, EPOCH and MAST treat most of the important environmental issues mentioned above, to be pursued with vigor. While it is important generally to develop the means for flexible and responsive actions to emerging issues, the following research requirements were given particular emphasis in these programmes.

35. Global Environmental Research (GER). The coincidental developments mentioned earlier which are resulting in rethinking of our approaches to global environmental issues get due attention. The NSF Earth Systems Science Report is breathtaking in scope. The Community's study of remote sensing R&D pointed in the same direction. STEP, EPOCH, MAST and the JRC Programme contain important elements of GER which must be welded into a co-ordinated and multidisciplinary European efforts, an effort that encompass elements of other Community programmes in agriculture, aid and industry. But certain elements have immediate priority. Europe should play a major role in the IGBP.

(i) Climate and climate change and its consequences are now seen as probably the biggest challenge to mankind over the next few decades. The European inputs to international research on Global Climate Models and the development of scenarios appropriate to Europe and its regions, and to developing countries; and on priority problems such as sea-level rise will undoubtedly throw up specific issues requiring Community research action. Additional European inputs will be necessary to investigate climate change implications for European and world trading, and for aid to developing countries.

(ii) Stratospheric ozone depletion and its consequences. The European move to co-ordinate EC/EFTA research should be treated by a special task force.

(iii) Wider implications. The rapid evolution of GER is going to require co-ordinated European initiatives in remote sensing (with ESA and others) of earth resources, processes and phenomena. It will require significant inputs from biologists working on biogeochemical processes such as the carbon cycle, at global level. The task is massive but must not be shirked. We must also consider responsive policies and actions to climate change in terms of energy production options, improved sea and flood fences, groundwater protection (eg against saline intrusion), etc.

36. These developments at global level impinge upon many other European programmes. Current work on clean technologies, for example, could assist in deciding future energy options. The proposed Community Initiative in Biology has a critical role to play in respect of biogeochemical processes.

37. Regional and local environmental issues. These issues which concern the regional or local environment and human health are not less important than research dealing with the global environment. The following issues are of growing concern and require more Community action.

(i) Human health. Development of highly sensitive and rapid methods for identifying and estimating internal dose and early reversible effects of exposure to a range of environmental stressors in groups at risk; progress in epidemiological surveillance through suitable interconnection of health statistics with environmental data.

(ii) Air Pollution and its effects. Research on such issues as forest decline, early specific indicators for forest decline, tree physiology, air/land use/water quality interactions, and improvements in the means to conserve European monuments.

(iii) Soils and Groundwaters. Public and political concern about the state of our soils and groundwater is growing throughout Europe. Priority must be given to the study of problems of contamination and, in Mediterranean countries, to those of erosion and desertification. More emphasis should be given to the off site consequences of contamination and erosion for the quality of surface and groundwaters.

(iv) Marine research. Ways must be found of further co-ordinating European actions and facilities in this field in flexible but cost effective programmes, in co-operation with competent international bodies.

The Community has important roles to play in co-ordinating research which contributes to the North Sea Task Force and to similar activities in the Mediterranean.

(v) Ecosystems Research. The need for baseline ecological monitoring and research was stressed earlier. The need to understand the structure and functioning of terrestrial, aquatic and marine ecosystems and their constituent organisms is assuming increasing importance in so many contexts - agriculture and environment, marine pollution - to name a few. There is a particular need to study and understand relict and threatened European ecosystems such as wetlands, montaine systems, clean deep lakes, coastal saltmarshes and lagoons and upland bogs.

INFRASTRUCTURE AND FACILITY REQUIREMENTS

38. The above environmental issues raise the basic question of whether or not Europe has the infrastructure and facilities to achieve its ambitions in research at regional and global levels. In many cases we have facilities at national level (eg research vessels) but they are deployed on a range of issues from local to global, and may be restricted in capacity or funding, or by age and design. A fundamental part of our research programmes must be to review infrastructure and facilities to improve their co-ordination and cost effective deployment, and to plan for future needs in support of likely research priorities. The following are important items for consideration and assessment in Europe.

(i) Research Vehicles. In the longer term, the design and compatibility and the development of research vessels must be planned at European level. The case for a European ocean drilling vessel to operate in support of, or in succession to the US ODP ship, is already being examined. Work on manned and autonomous submersibles for use in research must be prosecuted. Also, aircraft for stratospheric research; Europe must develop a co-operative facility. Industry has an important role to play in these areas.

(ii) Data Networks and Bases. Global research will require much more European effort devoted to developing scientific data and information services (eg seismic hazards, pollution data, ecological reference monitoring). European policies for these need to be developed, along with policies for research computing, not least for supercomputers capable of storing and analysing massive quantities of data, and modelling environmental processes on a global scale. The experiences of the oceanographers, meteorologists and climatologists in Europe, will be vital here.

E. SUMMARY

39. The main issues for future environment and related research were reviewed, and, at the hand of a few examples, the position and role of the Community and of Europe in a larger sense in this context was indicated. The importance and priorities of Community research programmes are confirmed in terms of detecting and combatting current and future environmental problems. Also their contributions to the well-being of society, to employment and the economy, and to European trade are becoming increasingly evident while new areas of research offer real prospects of Europe contributing in major ways to global sustainable development, and assistance to developing countries.

40. A wide range of environmental issues requiring research was identified. But there are certain issues which require special attention.

(i) Co-ordinated European contributions to global environmental research including stratospheric ozone depletion, climate and climate change, desertification, and resource management.

(ii) Basic ecological monitoring and research on ecosystems end environmental processes - essential underpinning to a wide range of applied problems.

(iii) Co-ordinated European research on the marine environment and its problems, especially in our regional seas but linked to global programmes.

(iv) Supporting socio-economic research on environmental problems and options for their solution.

(v) Development in co-operation with industry of new technologies for research and environmental improvement.

41. Important infrastructure issues which must be tackled and solved to provide essential support to European research were also identified.

(vi) Development of appropriate and flexible co-ordination procedures especially at EC/EFTA level.

(vii) Development of rigorous research assessment, planning, implementation, and evaluation procedures including those for efficient conversion of results into policy and practical actions.

(viii) Assessment, planning and provision of essential research facilities and services such as research vessels, aircraft, computers, data bases, information networks, and advisory and information services.

(ix) Special investment in remote sensing and geographical information systems to support global environmental research and to exploit its results.

(x) Improved co-ordination with, and positive European inputs to international governmental and non-governmental bodies, working in the above fields.

42. These actions must be supported by adequate resources, especially skilled manpower, efficient communications and equipment in the relevant organisations of the Commission, Europe and its Member Countries.

ANNEX 8

HEALTH RESEARCH

1. INTRODUCTION

In spite of the enormous progress made in fundamental biology, several groups of diseases threaten human health; in the less-developed countries malnutrition and parasitic diseases (e.g. malaria, schistosomiasis, filariasis, trypanosomiasis and leishmaniasis) dominate the scene, while the newly developed viral disease AIDS spreads with appalling rapidity. A real problem here is the need to support expensive R&D action for a market which, though driven by pressing needs, is dramatically deficient in financial resources. Various agencies, both public (e.g. World Health Organization) and private, are active in this field, yet, in spite of some recent advances in the treatment of parasitic diseases, those needs are far from being satisfied.

In the industrialized world bacterial diseases are largely controlled through antibiotics and hygiene, and many viral diseases are greatly reduced or indeed eliminated (e.g. smallpox) through effective vaccination campaigns. However, many health problems still require fundamental and applied research, namely some viral diseases (e.g. AIDS, and diseases caused by slow viruses), degenerative and immune diseases, genetic diseases, traumatology and poisoning, as well as problems of procreation and ageing. In these parts of the world, the cost of health is high and still increasing, (more than 200,000 million ECU yearly in the EC). In Western European countries the health market has a very special feature, namely that the funds used to satisfy it are largely public (about 80% of the EC health expenditure) as compared with only 40% in the USA. At the same time, however, public investment in medical and pharmaceutical research in the EC is only about half that of the USA. The European health industry is generally competitive; however, the relatively modest support which fundamental health sciences receive from European governments induces some large European firms to transfer their research laboratories to the USA. A key issue for the future is the interaction of health policies with the large high-technology market of health industries, exploiting, whenever possible, the economy of scale provided by the large internal market. In human health, "half-way" solutions (e.g. the treatment of tuberculosis around the turn of this century - by lengthy isolation in sanatoria - or of poliomyelitis in the 1930s) are often expensive while "all the way" solutions (e.g. antibiotics in the treatment of tuberculosis or vaccines against poliomyelities) are often cheaper in the longer term. Research has an irreplaceable role in the pursuit of "all the way" solutions, and Europe should develop a proper strategy for their continued achievement on an appropriate scale.

2. MAIN ISSUES FOR R & D

Health has been defined by the World Health Organization as "A state of complete physical, mental and social well-being and not merely the absence of disease or infirmity"(1). That reflects a very positive and wide-ranging outlook on this subject - which is by definition one that vitally affects every single citizen, whether living in Europe, U.S.A., Japan or the rest of the world. This universality of the importance of the subject is progressively being recognized by countries at governmental as well as at individual level, and there is a general tendency for richer nations to spend a higher proportion of their gross domestic product (GDP) on health.

In September 1988 the Office of Health Economics in London published a 'Briefing' on "Health Services in Europe: 1988", and this provides a most valuable and up-to-date commentary on the increasingly important and increasingly costly question of the provision of health care in Member States.

Table 1 reveals the levels of public and private health expenditure as a percentage of GDP, (1984):

	Total	Private	Public
Sweden	9.4	0.8	8.6
France	9.1	2.6	6.5
Netherlands	8.6	1.8	6.8
West Germany	8.1	1.7	6.4
Ireland	8.0	1.1	6.9
Switzerland	7.8	-	-
Italy	7.2	1.1	6.1
Denmark	6.3	1.0	5.3
Belgium	6.2	0.5	5.7
Great Britain	5.9	0.6	5.3
Spain	5.8	1.5	4.3

Source: OECD (1987) 'Financing and Delivering Health Care', Paris

The author, George Teeling Smith, comments:
"The table shows both the public expenditure on health and total expenditure as a percentage of each country's gross domestic product (GDP). The figures are largely what would be expected from the description of the various countries' health schemes. France, for example, shows the substantial margin between public finance and total expenditure which is largely covered by private 'top-up' insurance. Sweden, on the other hand, which is another high spender, covers

1 Constitution of the World Health Organization: Basic Documents, 15th edition, 1961.

almost all its costs from public funds. The amount covered by private expenditure in Sweden represents 0.8 per cent of GDP, as against 2.6 per cent in France. Britain, also, covers almost all of its health expenditures from public funds: private expenditure accounts for only 0.6 per cent of GDP. By contrast, again, the Netherlands leaves 1.8 per cent of GDP to be covered by private expenditure, reflecting the large proportion of the population covered by private insurance. In West Germany private expenditure amounts to 1.7 per cent, suggesting a relatively high expenditure for the 9 per cent of population privately insured. In general, the continental schemes allow greater freedom for the public to spend directly on health care in addition to public expenditure.
Overall, Spain and Great Britain are the lowest spenders, and France and Sweden the highest. As has often been pointed out in the past, there is a general tendency for richer nations to spend a higher proportion of GDP on health".

His conclusions are extremely pertinent to any consideration of health services provision in the next decade and beyond:

"It is clear from these brief descriptions of the national health schemes in different European countries that there is a considerable variation in their approaches to the problem. Methods of funding vary: the ownership and organisation of the facilities varies; the way doctors and others are employed and paid differs; and the extent to which individuals must pay part of the costs themselves also varies.... There is, however, one common similarity. No country believes that it has an entirely satisfactory solution to the question of how best to cover the health needs of its population at an acceptable price....

More fundamentally, in 1992 the European market is intended to be unified, and it might be expected that some degree of uniformity in the provision of health care should follow.... It is clear that it will be extremely difficult to introduce any integrated system of health insurance or European health service for the European Community as a whole. Even within individual countries there are variations, without any clear indication of which variant is superior. The priority must be for cautious experiment, and rigorous evaluation, rather than radical change.

Above all, what is lacking in such an evaluation is any measure of the outcomes of different systems of health care. The unique contribution of the European Commission after 1992 could be to organise and sponsor the evaluative studies which have so far largely been absent.
Any more drastic form of European Community interference, in the present state of ignorance, would be unwise. Health economists have in recent years been developing the tools with which to make the necessary evaluations. So far they have been used only on a limited scale. However, there is no reason why, with appropriate resources, larger international studies should not now be undertaken.

One concept under discussion at present is to limit the free provision of health care to the relatively less affluent and to those suffering from some form of medical catastrophe - whether it is a costly acute medical crisis or a long-term chronic disease. The nearest approach to this policy in Europe so far appears to be the Dutch model. A study some years ago suggested that the health status of the Netherlands was comparable to that in Britain and France.(2) These latter countries had widely differing types of cover, but both provided comprehensive health care for the whole population through their national schemes. But according to the information received from the Netherlands during the preparation of this 'Briefing', the Dutch do not consider their present position satisfactory. They are considering more extensive cover. Clearly, therefore, other countries - and Europe as a whole - need to be cautious in pursuing the concept of limited cover only for the less affluent and for the catastrophically sick.

On the other hand, there is almost universal concern at the rising cost of comprehensive free health care. Perhaps some balance needs to be struck. But once again the keynote must be evaluation. The brief reports from the various countries collected for this study still suggest general public satisfaction with their health care, even though the providers and the organisers realise its shortcomings....

If changes are to be made, and in particular if a greater degree of uniformity across Europe is to be achieved, the changes must increase an already relatively high level of public satisfaction rather than reduce it. This, above all, must be the message for the Eurocrats as 1992 approaches...."

As well as these economic and organizational factors another major aspect must increasingly be taken into account - the ageing of the population, often called the "Greying of Europe". This key issue has been explored in an Occasional Paper written in March 1988 by Mr. M. Freisinger for the European Commission's own Division of "Forecasting and Assessment in the field of Science and Technology". Under the title of "The Over-Fifties", Mr. Freisinger has summarized the position as follows:

"The interest in the demographic processes today results mostly from the apprehension that these changes could affect the efficiency, stability and equity (3) of societies which are in an internationally competitive environment.

1) Some Selected Demographic Trends: 'Explosion', Ageing Populations, Stagnation and Decline

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2 Maynard A and Ludbrook A (1981) 'Thirty years of Fruitless Endeavour?' In: Van der Gaag J and Perlman M (Editors), Proceedings of the World Congress of Health Economics, North Holland.

3 See Chapter: 'Some Theoretical Propositions and Concepts' in Padoa-Schioppa, T., et al; 'Efficiency, Stability and Equity - A Strategy for the Evolution of the Economic Systems of the European Community', Oxford, 1987, p. 17.

Until the year 2050, it is estimated that the global population will double to 10 billion. As a consequence of the changing fertility trends, the future demographic increase will be lower than at the time of the so-called 'population explosion'. Given the assumption of an increasing average life expectation, there will be a further cause for the relative shift in the ageing population on a global level.

This ageing process is significant in industrialised countries. Compared with the USA and Japan, Europe has an exceptional position. Until the year 2000, the population of the European Communities, the United States and Japan will still increase (2000: EUR 12 - 330 million, USA - 268 million, Japan - 120 million compared to 1984: EUR 12 - 321 million, USA - 236 million, Japan - 120 million) but after the year 2000 the demographic development of the total population will be marked by stagnation, and in the case of Europe (EUR 12) by a partial decrease.

Between 1900 and 1950 the proportion of elderly (more than 65 years old) in Europe had increased by about 50%. In the period 1975 to 2075 this proportion of the population will increase in the more developed countries by about 72%, (from 10.5% to 18.1%).

In the age group of eighty years and over the estimated rate of growth in the more developed countries is 153%, (from 1.7% to 4.3%). As a consequence of this trend, the average life expectation in this period would increase from 33.6 to 39.6 years.

Within the European Community, the total population figures until the year 2000 will decrease in Belgium and the Federal Republic of Germany. The same will apply after the year 2000 in Denmark, Luxembourg and the Netherlands.

Because of the net reproduction rates of the 1980s, the population figures in Greece, Portugal and Spain will be more stable. All countries in the European Community - including Ireland - now reveal decreasing reproduction rates between 1970 and 1980.

The large number of births of the so-called 'Baby Boomer Generation' will represent in the first half of the twenty-first century the growing proportion of the elderly.

The proportion of Over-Fifties in Europe until the year 2000 will only increase from 31% to 33%. This means a growth in this age group of about 10.4 million people, bringing it to a total of 110 million. In the Federal Republic of Germany, Belgium and Denmark, the population share of the Over-Fifties until the year 2020 will increase to 49%, 41% and 42% respectively.

With regard to the increase in the Over-Fifties age group from 1985-2000 France, the Netherlands, the Federal Republic of Germany, Portugal and Spain will be above the average European growth rate (10.4%) in the European Community. Until the year 2010, this growth rate will be 48% in the Netherlands, and 31% in France.

The number of very old people (more than 70 years of age) in the European Community will decrease at a negligible rate until 1990 (1985 - 33.1 million to 1990 - 32.7 million). Around the year 2000 this number will increase again to 37.4 million.

The number of women in the elderly age group will increase considerably compared to the number of men. This unsymmetrical distribution of both sexes will be very significant, especially in North America, Europe and the Soviet Union.

From a regional point of view the demographic ageing process in the European Community is presented very differently. In particular, in industrial centres and overcrowed regions it would seem that the ageing process of the regional populations will be above average"....

"In the field of health, the demographical changes create a quantitative increase of age-typical illnesses. At the same time, the estimated number of persons in family networks which would be able to give care to the elderly will decrease. With regard to the experience that nowadays only 5 - 10% of the older people requiring care live in special institutions and the assumption that the number of single households - especially within the older population - will undergo a large increase, the question is posed: what are the possible and probable other forms of organisations and conditions for organising the everyday life and care of older and very old persons? Many elements in this sphere will depend on changing life-styles and mental attitudes.

The growing demand on services for the elderly leads in the health sector to the necessity for a reorganisation in part (education, internal care, structure in hospitals) and beyond it to an increasing relevance in medical, medico-technological and pharmaceutical performance in prophylactics, early perceptions and therapy of age-specific illnesses."

Against the above background information it can be seen how crucially important health provision is; this underlines the need for a continuing expansion of research into all aspects of the subject, so that individuals can justifiably expect to benefit from advances in knowledge denied to their forebears. New techniques, in particular those of molecular biology, have started to make possible a greater degree of progress in health research than has ever been possible previously - these efforts must be strongly encouraged and steadily enlarged.

3. INTERNATIONAL COLLABORATION

Perhaps uniquely, and probably reflecting its universality of personal relevance and importance, health is a research field where international cooperation is not only readily forthcoming but is actively sought on a steadily increasing scale. The tradition of widespread dissemination of research results by publication is a long-established one in health matters and so, fortunately, health is not a "competitive" subject vis-à-vis the U.S.A. and Japan as is the case in so many other areas such as information technology or telecommunications. Many research workers do not consider their careers to be sufficiently rounded without having spent some time in the U.S.A., so much so that the acquisition of a "BTA" is widely thought essential for professional advancement to top research posts -the acronym stands for "Been to America". This degree of international experience-gathering is one of the most benefical and self-evidently valuable aspects of modern career progression in health research, and all Member States must continue to play their part in this.

4. WHAT NEEDS TO BE DONE IN EUROPE

To look ahead to the developments needed in Europe, both in the next few years and beyond, necessitates a careful and thoughtful look at the nature of health research itself and the goals which should be sought. Dr D.F. Horrobin, Director of the Efamol Research Institute in Kentville, Nova Scotia, Canada ([4]), has expressed this point well:

"One of the simplest and best definitions of science is John Ziman's ([5]) term 'reliable knowledge'. Medicine is a science with a purpose, the improvement of patient care. When reliable knowledge has been used to improve patient care, the record shows that scientific medicine has been a resounding success. But recently we have failed to keep firmly in view the true aim of medicine. Medicine has acquired the attitudes of pure science where things are done with no clear practical end in terms of benefit to the patient. It is the damaging proliferation of technologies which have no proven value in terms of cure, care or comfort which has led to soaring costs without any patient perception of substantially greater clinical success. Unless we rigorously keep in mind the idea that the standards we now apply to new drugs should be applied also to every form of innovation in medical care, we face the spectre of arbitrary and unreasoning political and economic intervention in the medical care system."

Dr M. King, University of Leeds, United Kingdom ([6]) has enlarged on this concept, stressing the patient's point of view and rightly drawing attention to the international aspects of the subject:

"Make the community master

The best interests of the individual sick patient in bed have always been the ultimate objective of the best medical care. The ultimate authority, economy, and convenience of patients collectively, rather

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4 Oxford Textbook of Medicine, Oxford University Press, Oxford; 1987, p. 2.3.

5 Ziman, J. 'Reliable Knowledge'. Cambridge University Press, Cambridge.

6 Oxford Textbook of Medicine. p. 3.1.

than that of ourselves, their physicians, have been given less attention. Hence the increasing dissatisfaction of many communities, both rich and poor, with the services they get, and the importance of making these services acutely sensitive to communal need. Communities must, wherever possible, be given a bigger say, and indeed the ultimate responsibility for the services they get. Listening for this still small voice, obeying it, and encouraging it to speak up, decide, and take charge, must in future become an integral part of medicine. It is also one of the major inspirations of the section which follows.

Health for all by the year 2000
Comprehensive primary health care (PHC)

What can we do to prevent disease, disability, and untimely death in two-thirds of the world's people, especially those locked into absolute poverty? The most hopeful solution is comprehensive primary health care, and this was defined at the international conference held by WHO and UNICEF at Alma Ata in Soviet Asia in 1978. The Declaration of Alma Ata which followed this meeting has as its aim:

> The attainment by all people of the world by the year 2000, of a level of health that will permit them to lead a socially and economically productive life. Primary health care includes, at least, education concerning the prevailing health problems and the methods of preventing and controlling them, the promotion of an adequate food supply and proper nutrition together with a sufficient supply of safe water and basic sanitation. It also includes maternal and child health, family planning, and immunization against the major infectious diseases, as well as the prevention and control of locally endemic diseases, the appropriate treatment of the common diseases and injuries, and the provision of essential drugs."

A worthwile research organization in health - such as will help to achieve the above aims - demands nowadays an increasingly wide range of skills, and this need in Europe is certainly in line with the needs as seen from outside this continent. Professor P. Wasi from Mahidol University, Bangkok, Thailand ([7]) has made a particularly relevant comment concerning this breadth of need and closeness of cooperation:

"Vast areas of research are needed to support PHC including health policies research, information research and development, health services and health manpower research, health economy research, management and evaluation research and technical research needed to support health services. While biomedical research may concern individual scientists or research units, health services research is an integrated approach which may involve on the one hand the policy makers and programme administrators and on the other the people and the community. This new type of research needs a new mechanism for research promotion and management. Medical Research Councils, while good for biomedical research promotion and management, may not be

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7 Oxford Textbook of Medicine, p. 3.7.

equipped to deal with health services research. A co-ordinating mechanism involving the Ministry of Public Health, the Universities, and the Medical Research Councils is desirable."

It is precisely that balance between "Governmental" health activities and those of "Medical Research Councils" which is so well struck and maintained in the committee structure for the Commission's own Medical and Health Research programme (vide infra), and which is so necessary if research discoveries are to be implemented at an early date by policy-makers on the Governmental side - it is a very efficient mechanism supported by all MS.

The subjects which particularly need to be concentrated upon in the coming years include AIDS and Cancer, as well as diseases which particularly affect an ageing population, as will increasingly come to be the case in Europe. There has been an excellent recent survey of the scene by Sir Walter Bodmer in his Presidential Address to the British Association for the Advancement of Science in September 1988, and some short extracts indicate the way ahead:

"The new biological revolution is having its impact in most areas of biological and medical research. Had AIDS been discovered as a disease even just 15 years earlier, it would not then have been possible to identify the causative agent as a virus, through that to devise tests to identify those that have been exposed to the virus, and then begin to design effective strategies for the development of vaccines against the virus and for treating the disease. All of these possibilities are taking place within an incredibly short time, following the initial description of AIDS only a few years ago. AIDS may now, and for some years in the future, be a serious epidemic but were it not for the genetic revolution, the disease could have been a total catastrophe.

Cancer is not a single disease but a wide variety of diseases which can affect any organ or tissue of the body. Nearly one third of the population will at some time be affected by cancer, and about one fifth will die from it. Though many advances have been made in cancer treatment, and simply stopping cigarette smoking could prevent 30 % of all the cancers, effective prevention and treatment especially of the relatively common cancers such as those affecting the bowel, the breast, the stomach and the lungs, is still a challenge for future research. In these cancers only treatment at early stages is usually truly effective. A better understanding of cancer at a fundamental level is undoubtedly the best and, ultimately, the only effective way to advance substantially its prevention and treatment. This, again, is where the new biology is leading to major advances.

The techniques of genetic engineering and working with cells that can be manipulated in the laboratory are beginning to reveal those errors which are critical for the development of cancer. Through this we are beginning to learn how the fine processes which control the normal growth of cells are deranged in a cancer and so, how these changes may either be detected sufficiently early for treatment to be effective or may form the basis for more specific and effective forms of treatment. When, at some time in the future, cancer is a disease which can be prevented and treated as effectively as tuberculosis and most other infectious diseases can now, the credit for this will largely be due to the new revolution in biology. A similar story could be told for the study of heart disease, or of mental disease which is accompanied by the great challenge of understanding the detailed functioning of the human brain.

Advances in physics and in chemistry have been as essential for the study of biology as they have, for example, for the development of computers. X-rays and radioactivity, and the instruments which use and measure them, have been particularly important in biomedical research.

X-rays are not only used to diagnose and treat cancer and other diseases, but also to probe the structure of complex molecules. Structure largely determines function, and so it is only through establishing the three-dimensional structure or shape of proteins that we can hope, eventually, to understand the way they work. Then the protein engineer can design modifications, or chemicals to enhance or block a protein's function, and so provide new 'designer'drugs for effective disease treatment. The higher the power of the X-ray source, the larger and more complex the structures that can be solved. In these areas the biologists and physicists now work hand in hand, helped by the power of modern computers.

Radioactivity is used at each step in the analysis of the genetic language. Thus radioactive tracers, and the films and instruments which measure radioactive decay, are essential tools for the genetic engineer.

X-rays, because they can penetrate bodily tissues, have been the classical basis for imaging the body from the outside in order to diagnose abnormalities indicative of disease. 'CAT'scanners, which are dependent on the application of sophisticated computer analysis, have enormously refined the X-ray picture. Recently, even more remarkable advances in imaging have come from new physical techniques, based on 'nuclear magnetic resonance' or MRI, for magnetic resonance imaging as it is now called. Using MRI, pictures of the brain appear to come to life and, may for example, reveal the smallest tumours. Radioactive tracers, which when injected into a patient can home in on a particular organ or tumour and then be viewed from the outside like X-rays, provide another new approach to the diagnosis of diseases. Using yet another new type of scanner, a small amount of radioactive fluid injected into the blood stream can yield pictures of the blood flow in the brain, which can identify regions involved in the control of speech and reasoning.

There seems to be no limit to the ingenuity of the physicists and the electronic engineers in providing new approaches and instruments for the measurement and detection of biological functions in living organisms. The power of computers is as important for the control of these instruments and the analysis of the data they produce, as it is for the banker, the airline company, the aeroplane or the physicist with his huge machines for studying the fundamental properties of matter.

Science, including technology and engineering, now pervades virtually all aspects of our daily lives and is the essential basis

for our future health and prosperity. Our industry depends on it, and therefore so does the whole basis of our economy. There is hardly any public policy issue that does not in some way, involve scientific questions. The advances I have described in the biological and physical sciences, and their prospects, show that the scientific revolution now has a greater potential than ever before for immeasurable improvement of our wealth and welfare. The challenge is to achieve this potential.
The Nobel Prize in Economics for 1987 was awarded to Solow for his demonstration that technology is the main determinant of economic growth. Since today's basic science is largely the foundation for tomorow's technology, Solow's conclusions clearly imply a good economic return for an investment in scientific research.
Technology in its broadest sense is the application of science or knowledge to practical ends, most often in an industrial context. Though scientific understanding is not a pre-requisite by any means for the success of a technology, technological progress nowadays increasingly depends on scientific advances. Major new technologies, such as genetic engineering, often depend, as I have described, on the combination of a series of scientific advances in technique and understanding, brought together to create a new technology. Once that major step has been taken, many further gradual changes, improvements and additions to the technology, in due course enormously improve its efficiency. This improvement is a form of evolutionary process, whereby pivotal changes are followed by gradual evolution, and only the fittest, namely those which are most productive economically, survive in the long run."

One most topical development, and one which is certain to prove most productive economically is that of Predictive Medicine:

Predictive Medicine: Human Genome Analysis

The EC has recognized the great and still increasing importance of genome research, and details of current and planned activities are given in Annex 4, "Biology", notably those involving yeast and plant genomes. Research involving the human genome will take place under the heading of "Predictive Medicine", as indicated above.

It has become clear that having access to a "human gene dictionary" will prove as fundamental to biology and medicine as a working knowledge of anatomy or chemistry. But to date, nobody even knows exactly how many genes we have. The best estimate leaves a very wide margin: from 50,000 to 100,000 human genes.

Each gene is a unique fragment of DNA (deoxyribonucleic acid), the long, thread-like substance that contains the instructions for the survival and propagation of every living organism, from a blade of grass to an elephant. In the nucleus of each human cell, these genes are strung along the 23 pairs of chromosomes. Finding the location of individual genes on a chromosome and analyzing these genes down to their chemical components (nucleotides) is only now becoming possible on a large scale, thanks to new techniques derived from recombinant DNA technology.

Knowing the position of these genes and then zeroing in on them are major steps towards finding new methods of preventing or treating the 4,000 inherited diseases recognized so far that are caused by single-gene defects.

Beyond these rarer conditions, gene mapping will give doctors a new understanding of such widespread ills as hypertension, heart disease, certain cancers and diabetes, which are caused by the joint action of several genes. It will explain who is particularly vulnerable to these disorders and how to prevent their onset, or at least reduce their symptoms.

Most significantly, research on these aberrant genes will enable scientists to analyze normal life processes with extraordinary precision. Gene mapping and analysis will be key tools of biology in the 21st century. They will enable scientists to decipher how human beings function at their molecular level - how the information stored in DNA becomes translated into the myriad messages and complex feedback systems that tell the billions of cells in our bodies how to keep us alive and healthy.

Since about one third of human genes are turned on in the brain, for instance, gene mapping will give researchers powerful new ways to investigate how the brain functions. And as researchers identify the genes responsible for growth and development, they will find clues to the enduring mystery of how a fertilized egg evolves into a unique, mature human being.

Two kinds of gene maps are now being created. One, the genetic linkage map, shows the distance between various genes and markers as calculated from the frequency with which they are inherited together. Genes that lie close together on a chromosome generally stay together during meiosis - the formation of egg and sperm cells - when some segments of the chromosomes recombine. Geneticists have calculated that if a gene and a marker on the same chromosome are separated only 1 percent of the time, the distance between them is approximately 1 million base-pairs of DNA. (Base-pairs are the pairs of complementary nucleotides that form the DNA double helix).

By contrast, physical maps show the actual distances between landmarks on the chromosomes, regardless of inheritance. These distances are measured in base-pairs of DNA, and the ultimate physical map would be the precise sequence of base-pairs in a given stretch of DNA.

So far, only small portions of the human gene dictionary are available. But even these have, for example, unravelled the basis for the commonest form of muscular dystrophy, and solved at a biochemical level the age-old riddle of the control of colour blindness, which is a comparatively common defect amongst European men.

The Predictive Medicine Programme will contain the following strands:

- improvement of the resolution of the human genetic map, i.e. creation of a map of the human genome, consisting of DNA markers, which would enable researchers to locate genes easily and quickly;

- the setting up of ordered clone libraries, i.e. of collections or ordered sets of DNA fragments which fully represent the DNA present in the entire genome, selected chromosomes or chromosomal fragments;

- the improvement of advanced genetic technologies and, through a training programme, the spreading of these advanced technologies throughout the Member States.

In the course of the programme, new genes will be localized, cloned and sequenced - many of these will be disease related. In addition, substantial improvements will be made in the following advanced genetic technologies:

- New reagents, such as restriction enzymes,

- Methodology for cloning large DNA fragments and for the transfection of chromosomes,

- Gene vectors adapted to human cells in vitro,

- Methods for the detection of a particular gene in a cell,

- New computer software for the storage, collation and analysis of DNA sequence data.

Medical and Health Research

The Commission itself has had a research programme in the medical and health field since 1978, and its steady enlargement has been a very significant one. The current Medical and Health Research Programme (1987-1991) is the fourth one, (MHR4), and the growth of the programme clearly reflects both the increasing knowledge of it in Member States and the increasing interest of research workers in taking part in transnational collaboration through "Concerted Actions" without the award of direct research support from the EC:

Programme	Duration	No of Concerted Actions	National teams participating
First	1978-1981	3	100
Second	1980-1983	7	230
Third	1982-1986	34	1,400
Fourth	1987-1991	72	2,500 +

The main reasons for conducting MHR4 by means of the concerted action method arise from the following two facts:

. most national research programmes in the field of medecine and health consist of a large number of relatively small projects, predominantly orientated to disease-related targets and carried out by many scattered and relatively small research teams, often working independently at universities, hospitals, etc.

. there is not yet a common health policy and, therefore, the existing national research policies/strategies differ widely as between the national organizations competent in medical and health research.
Accordingly there are also differences in the structure of these organizations as well as variations in their ways of working, of categorizing research work at national level, and of defining priorities.

The principal characteristics of such a coordination programme are that the Member States themselves:

. select the research projects for coordination at Community level and hence participate wholly or partly in the programme according to their interests and available facilities;

. execute the actual R & D work in their participating institutes and totally finance it from national resources according to the rules and procedures applicable to their national programmes; and
. consequently determine the scale of the coordinating activities and ensure the overall programme management.

The Commission is responsible for the coordination at Community level of the national research contributions to the programme and the finances needed for that purpose, which are modest (about 3 - 4 % of the global costs of the research contributions from the Member States) but of high return value due to their great catalytic effect. In the EC it is estimated that the yearly global expenditure on health care is at least 200,000 million ECU; of this sum around 1,500 million ECU is spent on medical and health research.

The MHR4 programme aims at promoting:

. Community actions in jointly defined research areas considered critically relevant to the solution of major health problems, and
. Coordination of national research policies/strategies through programme implementation by, or in close association with, the competent research organizations of the Member States.

The main objectives of this European collaboration are to:

- optimize the capacity and economic efficiency of health care efforts, and thus to combat their steadily mounting costs, by initiating or implementing concerted projects in defined areas considered as critically relevant to the solution of major health problems and their effects on occupational health;

- increase the efficiency of relevant R&D efforts in the Member States through the mobilization of the available research potential of national programmes and through their gradual co-ordination at Community level; and
- improve scientific and technical knowledge in the R&D areas selected for their importance by all the Member States, and to promote its efficient transfer into practical application, taking particular account of potential industrial and economic development in the areas concerned.

Specific research and coordination EC programmes are advised upon by Management and Coordination Advisory Committees (CGCs), and the MHR4 programme has CGC No 9 which is itself entitled "Medical and Health Research". It is made up of senior medical, scientific and administrative Member State representatives who work at policy-making levels in their own countries, and they are therefore well qualified, together with their own nominated national experts, to consider future health research needs for the EC. They accordingly set up earlier in 1988 special Programme Working Parties (made up of experts in the subject fields within the six MHR4 research Targets) to review the content of the fourth programme and to help to establish as a basis for discussion the subjects to be included in the fifth programme, (already being planned for 1992-1996). The deliberations of all the expert Working Parties were considered by the parent CGC in June 1988, and a consolidated document agreed entitled "Research Gaps and/or Research Opportunities". This expresses in the form of research needs the current state of the art in Medical and Health Research in the opinion of the most senior EC committee in this field, and accordingly it warrants inclusion in full in this Annex. The order follows that of the six research Targets formally agreed upon prior to the approval of the MHR4 programme in 1987, and those Targets provide between them a full coverage of Medical and Health research:

1.) TARGET I.1 CANCER RESEARCH

Area I.1.1 Cancer research training scheme

In order to promote training in cancer research in Europe, a fellowship programme is considered to be an extremely important and effective means of support; this is the single most immediately constructive measure which can be taken, and the first 22 fellowships were awarded in June 1988.

Workshops to provide for further education of European oncologists will also be most valuable.

Area I.1.2 Clinical treatment research

Support for clinical treatment research has so far been channelled mainly through the European Organization for Research and Treatment of Cancer (EORTC), but it could also be directed towards other groups if sufficiently promising projects are submitted in the future.

Area I.1.3 Epidemiological research

Main areas for research on cancer epidemiology in the EC could best be determined on the basis of three criteria : the global importance of a particular problem which could be tackled by European scientists; the existence of favourable conditions in the EC as a whole or in part for the study of specific cancers or of exposure to particular carcinogenic substances; and the existence of EC-specific cancer-related public health problems.

Area I.1.4 Early detection and diagnosis

Development, or further development, of methods regarding:

- Colorectal cancer
- Prostatic cancer
- Malignant melanoma
- Early diagnosis of cancer using monoclonal antibodies
- Radioimmunoasssays of various markers
- DNA analysis with probes
- Chromosome analyses.

Regarding breast cancer and cervical cancer, major questions remain open:

- Specific methodological aspects
- Social aspects, e.g. compliance
- Evaluation of screening and early diagnosis programmes
- Exchange of information between various screening groups.

Area I.1.5 Drug development

- Clinical testing of high-technology biological products, especially of those products which cannot be tested in experimental animal tumour systems. Examples are interferons, cytokines, interleukins, growth factors, etc.
- Preclinical studies in human tumour xenografts in nude mice
- Tumour targeting, using synthetic microspheres, liposomes and monoclonal antibodies linked to chemotherapeutic agents, cell-toxins or radio-active isotopes
- Development of the methodology for large-scale chemo-intervention studies, (with retinoides for instance)
- In vitro studies on human tumour cells for preclinical screening.

Area I.1.6 Experimental (fundamental) research

- Oncogenes, growth factors and their receptors, cytokines
- Anti-oncogenes and repressor-substances
- Gene regulation
- Hereditary cancers
- Genomic changes in cancer cells
- DNA-repair
- Cell adhesion and de-adhesion
- Plasma membrane composition and cell surface molecules
- Proteases, secretion and regulation
- Angiogenesis factors
- Viral integration in the genome
- Soluble mediators.

2). **TARGET I.2 AIDS RESEARCH**

This Target is so recent that what follows is, exceptionally, a list of work planned or already in progress in 1988 - the research gaps and/or opportunities thus mainly fall between the various headings below.

Area I.2.1 AIDS Disease Control and Prevention

1.1 Monitoring of trends of HIV infections in specific population groups
1.2 Statistical analysis and mathematical modelling of HIV infections
1.3 Heterosexual transmission - prospective follow-up
1.4 Prospective study of children born to HIV-positive mothers
1.5 Assessment of preventive strategies
1.6 HIV infections among intravenous drug abusers.

Area I.2.2 Viro-immunological Research

2.1 Production and assessment of purified research reagents
2.2 Testing and quantitation of HIV infections, (antigens, antibodies and nucleic acids)
2.3 Pathophysiology and immunology of HIV-related diseases
2.4 Immunogenetics of AIDS
2.5 Design, synthesis and evaluation of new antiviral compounds
2.6 HIV variability at genomic, antigenic and biological level
2.7 Vaccine development
2.8 Development of animal models, (excluding chimpanzees).

Area I.2.3 Clinical Research

3.1 Clinical trials on opportunistic infections
3.2 Oral problems related to HIV infections
3.3 Clinical studies and trials of HIV infections.

3.) **TARGET I.3 AGE-RELATED HEALTH PROBLEMS**

Area I.3.2 is considered to be particularly relevant to present and future needs, as has already been mentioned earlier. Although diseases occurring at all ages need research studies, and the MHR4 programme provides for this, an emphasis will be placed on those diseases of particular relevance to the increasing proportion of older people in Member State populations.

Area I.3.1 Reproduction

- Environmental and genetic influences on reproduction and development
- Male reproductive functions with specific reference to infertility.

Area I.3.2 Ageing and Disease

- Identification of the biological, psychosocial, cultural, environmental and economic determinants of healthy ageing, e.g. cross-

national longitudinal studies to describe the age-related transition from health and autonomy through handicap to dependence
- Identification of risk factors for an older person's loss of autonomy, and minimization of that risk through preventive measures and more effective services, e.g. community intervention studies on elderly populations
- Production of meaningful data which can be compared internationally
- Multidimensional assessment of functional disability.

Multidisciplinary activities will be particularly encouraged.

Area I.3.3 Disabilities

- Prevention of disability
- Prospects for the treatment of disability where the present state of knowledge permits
- Strategies for medical and social care.

4.) **TARGET I.4 ENVIRONMENT AND LIFE-STYLE RELATED HEALTH PROBLEMS**

Area I.4.1 Breakdown in human adaptation

- Health risks assessment
- Early pathological markers of environmental exposure (mechanisms of homeostatic breakdown)
- Research into environmental and life-style factors relating to:
  . Cardiovascular diseases
  . Neurobehavioural and neurotoxicity problems
  . Biological monitoring of individual exposure
  . Immunotoxicity
  . "Sick building syndrome".

Area I.4.2 Nutrition

- Methodological issues of the nutrition-health relationship
- Research into objective biological markers of those dietary patterns which could be related to specific diseases
- Evaluation of the effects of different national prevention programmes at EC level
- Research into the effects of certain food products, of chemical additives and of contaminants including human milk.

Area I.4.3 Consumption of illicit drugs

(Illicit drugs, tobacco, alcohol and prescribed drugs)

- Comparable databases
- Monitoring of school-age populations
- Drug abuse and the immune system
- Detection of the effects of newly-synthesized drugs of abuse
- Evaluation both of existing treatment programmes such as methadone programmes and of social rehabilitation or self-help programmes
- Abuse liability, i.e. the factors affecting the maintenance of compulsive drug-seeking behaviour

- Changes in life-style due to European mobility and drug consumption
- Evaluation of the impact of completion of the EC Internal Market, tax harmonization, and national drug control policies.

Area I.4.4 Infections

- Hospital infections
- Hypersensitivity and allergy
- Chronic respiratory distress and asthma
- Enteric infections (immune response; use of municipal sludge in agricultural applications; "Montezuma's revenge")
- Users of illicit drugs
- Congenital toxoplasmosis
- Infectious mononucleosis
- Legionnaires' disease
- Lyme disease
- Tumour patients.

5.) TARGET II.1 MEDICAL TECHNOLOGY DEVELOPMENT

Area II.1.1 Diagnostic Methods and Monitoring

- Biomedical signal acquisition
- Imaging techniques.

Area II.1.2 Treatment and Rehabilitation

- Simplified and low-cost technology
- Ambulatory monitoring technology.

Area II.1.3 Technical and Clinical Evaluation

- Lithotripsy
- Percutaneous transluminal coronary angioplasty
- New biomaterials and implants
- Appropriate techniques for the relief of urinary incontinence
- Appropriate techniques for the relief of speech impairment.

6.) TARGET II.2 HEALTH SERVICES RESEARCH

Area II.2.1 Research on prevention

- Diseases of the locomotor system such as arthritis and low back pain.

Area II.2.2 Research on care delivery systems

- Appropriate care for terminally ill people
- Impact of "non-orthodox" medicine (e.g. homoeopathy, acupuncture, chiropractice) on health care expenditure.

Area II.2.3 Research on health care organization

- Community expectations and consumer participation in health care organization
- Health care in disaster situations
- Health interview surveys as part of health information systems
- Quality assurance in health care.

Area II.2.4 Health technology assessment

- Health scenarios in respect of technological developments and health economy
- Economic appraisal linked with clinical outcome, both in condition-specific and in general health status.

Implementation

The continued expansion of the MHR programme along the lines mentioned above will implement the wishes of the Member States with regard to health research, and the success of this programme is clearly shown by the steadily increasing numbers of European terms wishing to work on a transnational basis. All member countries participating in 'COST' (European Cooperation in the field of Scientific and Technical Research) are eligible to take part in the programme or in any combination of its six research Targets; in addition to the EC Member States, five other COST members are already participating, namely Austria, Finland, Norway, Sweden and Switzerland - all of these have chosen to work in between three and five of the six Targets. Informal liaison arrangements also exist with the National Institutes of Health in the USA and with the Canadian national health research authorities.

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Nuclear Fission energy - Safety

Introduction

The Countries of the Community, because of their different degrees of energy dependance and levels of economical development have applied different energy policies. The disparities found during the 70's have lately increased after the Chernobyl accident. However a great number of nuclear power stations have been built in Europe. Initially they were of the gas-graphite type, followed by the light water reactors at the beginning of the 70's while the development of liquid metal fast breeders was continued. At the same time, a powerful nuclear industry was developed in the most committed countries (France, United Kingdom, W. Germany) both in the construction of power stations and of the upstream and downstream fuel cycle. The power stations which have been commissioned, namely the light water reactors have reached a remarkable degree of maturity, both in their design and their exploitation. While this maturity has been confirmed the national R&D programmes financed by public and community funds focussed on safety aspects of the protection of man and the environments against specific development aspects. Although the production of nuclear energy compared to oil and coal is less polluting for man and the environment, this evolution was logical because of the potential risk by wrongly controlled use of nuclear energy and in case of an accident. The TMI accident in the USA in 1979 confirmed this trend. The impact of TMI on public opinion has revived in most of the European countries the worries of the Ecologists' movement toward nuclear risks. This preoccupation involves nuclear power stations, fuel cycle facilities, problems of storage and the elimination of radioactive wastes.

The Community's activities in this field derive from the Euratom Treaty that recognized the development of a strong European nuclear industry. This development was to be achieved with respect to health of the public and of involved workers. Regarding this a certain number of arrangements were foreseen in chapter III of the Treaty.
At present the Community Research Programmes in the nuclear energy fission field are mainly related to safety and radioprotection; the exceptions are the programme on the nuclear fuel and the actinides, part of which is related to development of fast reactors and the programme on safeguards and fissile materials management that supports international activities controlling the peaceful utilisation of nuclear energy. Research on radioprotection has been a major Community action since the enforcement of the Euratom Treaty. Research on the safety of reactors, on the management and storage of radioactive wastes and on the decommissioning of nuclear power stations, where Community action is very important, will be examined in the world context and also in the Community perspective.

A. Reactor and Safety

1. Principal objectives

The safety of reactors concerns the design, the construction and the operation of power stations, and it is achieved by acting on two levels: the prevention of accidents and the reduction of the consequences if the preventive measures were not able to avoid the accident. The measures applied to arrive at these objectives are largely based on the results of the research programmes. The orientation of these programmes has been influenced as far as the safety of water reactors is concerned by the TMI accident. Before TMI this type of power station had acquired a high degree of maturity. Prevention was directed toward a better understanding and improvement of the quality and reliability of materials, of components and systems rather than improvement at the level of design. The limitation of accident consequences was restricted to the area of design basis accidents, that is those events which could be dealt with by the safety systems working as assumed in the design of power stations.

After TMI, emphasis shifted towards the prevention of accidents by systematic utilisation of experience and, because of the important role played by the operator in the development of this accident, on human factors. Quite a number of studies are devoted to human reliability. There is an attempt to simulate the role of operators and to include them in risk studies and probabilistic safety studies, where the principal aim is to verify that all possible scenarios of incidents and accidents have been taken into account in the design and the operating rules. Since TMI the limitation of consequences of accidents has shifted towards the study of severe accidents beyond the design basis in order to evaluate the extent of existing safety margins and to optimise accident management. The Chernobyl accident has not changed this orientation of safety which is presented in a schematic form but has greatly increased the necessity to take into account more and more severe accidents whose probability of occurrence is very low. For the fast breeder reactors the problem of safety is considered differently and the research programmes are intended to analyse the phenomenology of the accident and the behaviour of materials, components and systems with the aim of improving the design and conception of future plants.

One can say that now research on the safety of proven reactors is justified at the operational level, in normal and accidental conditions, and for reactors now being developed at the design and construction level.

2. The safety of reactors outside Europe

At the beginning of the 60's the USA launched a very important programme on the construction of light water power plants. In 1976, this programme was slowed down by the Carter administration while the development of fast reactors was retarded and was practically stopped in 1979 after the TMI accident. The development and construction of American light water reactors was based on multi-disciplinary research programmes. A large part of this research dealt with safety, notably all the work used by the NRC to establish the detailed regulations for the construction and operation of these reactors. The results of these programmes have been largely available to those countries importing reactors from USA, in the frame of licensing and bilateral agreements. In 1979 the TMI accident provoked a reorientation of research programmes on safety in the USA and other countries. Without doubt the TMI accident has led to a systematic internationalisation of American programmes with the direct financial participation of European and Japanese partners and the involvement of these partners in the execution of these programmes in American laboratories. At the time of the TMI accident the American budget for the research of water reactors was 50% bigger than European budget. When new programmes following TMI had been completed this budget was decreased and now one can notice both on the industrial level and governmental organisation a trend to R&D research on inherently safe reactors.

The Japanese have at present a budget for R&D for water and fast reactors similar to the European budget of 1970 for light water reactors. Japanese programmes have lately been disclosed to European countries as a means for international cooperation. There is little information on research programmes of USSR but it is clear that their accelerated construction of nuclear plants of the VVR type (light water) and RBMK (graphite light water) and their development work on fast breeders are based on a very big research programme. However the Chernobyl accident caused by a RMBK reactor has shown that the USSR's main preoccupation is not at the same level as in the Western countries. Since the Chernobyl accident there is an overture from the Soviets for international cooperation in the field of research namely on nuclear safety.

Besides the above mentioned three countries Canada has developed important research programmes on safety for the CANDU type reactors, heavy water moderated and light water cooled.

3. The safety of reactors in Europe - what is Europe's position in the international context - successes and failures

The development of European nuclear programmes has only been possible due to a major effort at the research level. One must consider on the one hand the generic safety research and applied research on light water reactors and on the other hand the R&D of fast breeder reactors.

In the first area the level of competence of member states reflects more or less the size of their nuclear power programmes.

The German, French, British and Italian programmes are multidisciplinary and cover many problems in connection with safety. The British programme has been directed lately towards specific problems of water reactors but it has profited from the experience acquired at the end of the 60's on SGHWRs. The Italian programme is smaller than those of Germany, France and United Kingdom. The research activities in Belgium, Netherlands and Spain are of a more specific nature.

Originally European countries relied very heavily on American programmes through cooperation agreements and the exchange of information permitting Europeans to confirm American results and to acquire knowledge and a level of competitive competence. Specific areas such as the strength of components, structure of primary circuits, study of design basis accidents and thermo-hydraulic phenomena were favoured. Programmes in W. Germany and France have progressively increased and now benefit from a steady exchange of information with the USA. In 1978 prior to the TMI accident, the USA boasted a budget on research of safety reactors that was 50% higher than that of the all the Members States of the Community combined.

The TMI accident of 1979 shifted emphasis of European research programmes towards severe accidents, until then neglected due to their low probability of occurrence. Special attention and much work was spent on the evaluation of source terms in various levels of accidents. Thermohydraulic accidents focussed on loss of coolant accidents; the methods of probabilistic safety analysis and evaluation of risks were developed and improved. The inclusion of the human factor as a contributing element of significant value to global risks became the subject of many investigations.

By 1985 as these programmes reached completion, there was a tendency to the allocation of funds to safety research programmes in both the USA as well as the countries of the Community. The Chernobyl accident however put a stop to this tendency by renewing the necessity to study the phenomenology and severe accident management more systematically.

The JRC research programme on the safety of reactors progressed along parallel lines. In 1987 the amount expended by the Member States and the JRC on the safety of water reactors was more than twice that of the USA (238 MECU to 113 MECU of USA). The JRC programme alone accounts for 15% of the combined European effort.

Proven reactors, especially light water reactors have been an undisputed success in Europe, not only on an industrial and technical but also on a safety level. European power plants that accumulate more than 1000 reactor-years of operation can boast an existence free of severe accidents. Their design safety and regulation safety are on a par with American plants and their operational safety, that of control and operation is better than in the USA where a certain complacency contributed to TMI.
The concentration of operating responsibility to a limited number of companies, the standardisation of equipment and vigilance at all stages have allowed Europe to attain a higher level of reliability and safety. As a result, European research programmes are now competitive with those in the USA to the point where the latter is even envisaging participating in a French Community programme "PHEBUS-fission products". In the past it was mainly European partners who participated in USA programmes.

In the area of fast reactors, R&D activities are very closely connected and are coordinated in the frame of the Club of Five consortium (France, RFA, UK, Italy and Belgium) and the scientific and technical results are at the level of the extensive resources utilized. The JRC participates significantly in European research in the area of fuels, and analytical and experimental activities in the modelling of large core accidents. As far as the fast breeder is concerned European success in joint development between France, RFA and Italy of the SUPERPHENIX prototype plant and its failure would certainly question in the future this type of reactor: in fact the political influence caused by the Chernobyl accident in conjunction with an accident in 1987 of the auxiliary system of SUPERPHENIX, which had nothing to do with the safety of the station, risks to delay or even jeopardise the commercial advent of this reactor and questioning the EFR reactor (European Fast Reactor) which was launched by a group of utilities of the countries of the Club of Five (EFRUG).

4. What remains to be done in Europe? Which are the gaps to fill and what are the new opportunities to seize?

Research on the safety of light water reactors has to be pursued in Europe. A great number of the programmes launched 10 years ago have finished or will finish soon, especially the work on thermohydraulics and source terms. However, the Chernobyl accident reactivated the necessity of taking into account the possibility of severe accidents, and leads to the analyses of the phenomology of less probable accidents within an increasing number of accidental scenarios. The phenomena for which some research will have to be conducted more thoroughly falls into the following areas but the list is not exhaustive: cooling of corium inside and outside the vessel, the phenomena of interaction between corium and concrete resulting in the production of aerosols, phenomena in connection with the behaviour of hydrogen in the containment, a leaktightness, possibility of venting and filtration and evaluation of corresponding releases.

The results of these investigations should be used to define severe accidents management procedure, and methods of sophisticated remote handling should be worked out. The study of behaviour and modeling of operators in disturbed situations to include in probabilistic should also be pursued.

In recent years some studies have been carried out for economical reasons on the possibility of extending the life of the plants to 35-40 years instead of the 25-30 years initially foreseen. Some research work already exists on the structure of primary circuits especially the steel of the vessels. Also other materials, components and systems will be involved where it is necessary to study the combined effect of ageing in hazardous environments (radiation, temperature, etc...). In spite of the importance of these research topics which need some more investigations, the high degree of performance and reliability of the present installations is the consequence of the solution of most of the problems in the corresponding research programmes. It is likely that the level of safety research activities will decrease progressively.
Therefore one should understand the necessity to maintain a team of competent researchers and research facilities with the aim to utilise efficiently the experience accumulated, that is to say all knowledge pertaining to the operation of the plants can be utilised to improve reliability and safety. This team should be able to cope effectively and promptly in case of an accident s tuation.

Fast breeder reactors safety research is still being conducted, as opposed to that of light water reactors, and the work will depend on the political choice of the member states regarding the future of this type of reactor. In the possible hypothesis that a decision is so delayed as to correspond to a moratorium the salvage of acquired knowledge will be obtained only by maintaining a minimum activity and competence.

As far as new opportunities to be taken, increased interest has arisen with the reactors of the new generation i.e. : optimisation of fuel utilisation (spectral-shift reactors), new designs of improved inherently safe reactors (power limited to 100 MWe). The development of these reactors will require studies and research on safety. It is noted that interest has been shown for small inherently safe reactors by smaller countries and by those where the Chernobyl accident has made an impact.

As regards the energy strategy one can see that the production of nuclear energy is a necessity in the short term for a certain number of European countries and in the long term for most of them. This form of energy in normal conditions of operation is less polluting than other forms of energy of fossil origin. Requirements in connection with the protection of the population and the preservation of the environment are the necessary counterparts for the development of human activities, in particular industrial activities. This is why the Commission, confronted with the potential risks of nuclear energy utilisation from bad control or in case of an accident, had in the 70's given broad priority to actions in the area of safety.

At present concerning energy strategy, some member states have made some irreversible choices, others under the pressure of public opinion, particularly after the Chernobyl accident, are hesitating or are on the verge of renouncing the use of nuclear energy.

The Commission must play its role as a European public service in reinforcing its activities and initiatives in the area of reactor safety in order to ensure that the countries of the Community who have chosen nuclear energy have taken all the possible guaranties with regard to the health of the population and the environment and to bring to these populations and their neighbours the guaranty of a thorough independent evaluation.

The Commission's actions should also help the countries of the Community who are as yet non-nuclear to reach a decision not influenced by pressure groups and subjective psychological arguments but based on objective technical arguments.

As far as the action to be initiated or perceived to be pursued at the Community level one can make the following considerations. In the past Community research on reactor safety covered generally speaking the area where member states carried out national programmes. The Community contribution was complementary to this programme and benefited from the support of countries which did not have a large research infrastructure. In the future taking into account the general trend of internationalisation of safety research and a certain decreasing of funding of these activities, it will assist most probably in a better optimisation of the existing human resources and facilities. Accordingly, Community research can play a significant role and with the JRC has the appropriate means to do so.

As an example one can choose two categories of action which could with advantages be treated at Community level:

- problems where the phenomenology transcends frontiers: the source term is a typical programme in this connection

- general safety problems not specific to certain types of plants: mechanical and material problems, aging, probabilistic risk assessment methodology human factors, phenomenology of severe accidents.

Common exercises such as Round Robins (for example the PISC programme) or benchmark exercises (such as those carried out on PRA or source terms)should be used to carry out such actions. One should foresee an extension of this type of activity to exercises of comparison of methodologies followed in different countries, comparison of the system of codes employed, modelling, safety margins etc... The aim being the demonstration of the equivalent the margins of safety in various countries of the Community and an incentive in member states to choose common analytical tools (modelling code packages) validated and proven by all. In accident management and the reduction of radiation doses of workers the progress of remote handling techniques will play an important role. The proposition of the Commission for a Telemanipulation programme in hazardous and disordered nuclear environments (TELEMAN) will contribute to the development of much needed knowledge.

The development of second generation reactors, namely those with inherently safe characteristics and a range of advanced reactors (high temperature reactors), will commence in the years to come and will demand big efforts from constructors. Efforts will need to be accompanied by studies and research in the area of safety. The Commission should support the action carried out in this direction and participate in related studies.

B. Nuclear fuel cycle, Radioactive waste management and Decommissioning of nuclear installations

1. General

The nuclear fuel cycle includes the total of activities which is necessary for the supply of fuel for nuclear power plants ("front-end" of the cycle) and for the treatment and possibly recycle of spent fuel ("back-end" of the cycle) : Front-end : - Extraction and treatment of uranium ore - Conversion into appropriate form for enrichment - Enrichment (increase in U-235 contents) - Manufacture of fuel elements for reactors ; Back-end : - Reprocessing of spent fuel (possibly) - Remanufacture of fuel elements (possibly) - Management and disposal of the produced waste (and of the spent fuel if not reprocessed)

Some of these activities raise from classical industrial sectors, e.g. mining industry; others are special industrial activities often of high technology character such as enrichment and reprocessing; finally the management and the disposal of radioactive waste produced by the nuclear power plants and the associated fuel cycle facilities, to which should be added the decommissioning of nuclear installations shut down, are activities linked with environmental safety and protection and don't contribute (at least directly) to the development of nuclear energy. All these industrial activities are characterized by the presence of radioactivity and by the necessity to respect the strict rules of radioprotection.

Mastering of the front-end of fuel cycle emancipates from the dependence on supply of enriched uranium Mastering of the back-end, characterized by the mastering of the reprocessing process, gives access to plutonium, governs the supply of fuel for fast reactors and permits, on longer term, a quasi-total independence in nuclear energy matters. Such mastering however has appeared to be out of reach for the majority of the Countries, because of the high technology and the important investments necessary and finally because of the links existing between the applied technologies and the production of fissile material for military use which give rise to various constraints (secret, international treaties like NPT).

In summary, the nuclear fuel cycle includes a number of activities often of a high technology character and of strategical and commercial importance.

2. Situation outside the Community

Outside the Community, the USA not only mastered but had the world monopoly for the production of enriched uranium from after the war until the early seventies. Since then, the Federal Government followed a policy of disengagement, leaving to the private industry the possibility to finance on its own both the R&D and the new fuel cycle facilities. Given this situation and the one on the domestic nuclear market, there was no reply from the private industry; the civil reprocessing industry has been stopped and the facilities dismantled; the enrichment industry survived thanks to the old installations which were successively shut down as they were low profitable in using the old gaseous diffusion technology; the industrialization of the ultracentrifuge process has been stopped; the R&D programme is focussed on the laser enrichment process which could put new life into this US industrial sector by mid '90. Today Europe is exporting enriched uranium to the USA. One can however state that, thanks to the military programmes, the USA keep the knowledge to a level which enables a possible revival by the end of the century. The management of radioactive waste is not much developed in spite of the large budget provided by the electricity producers. All progress is in fact blocked by the complex political-social-juridical machinery of a federal state which is faced to the problem of storing in one or several states the waste produced on the whole territory.

The USSR masters the total fuel cycle and is in particular an important exporter of enriched uranium; reprocessing activities on an industrial scale are practised as well with a view to supply the russian fast reactors and for military use; little detail is known about these facilities.

Japan continues with persistence its effort to master the total of fuel cycle phases; success was already achieved on reprocessing thanks to a close cooperation with France which provided the technology and know-how; at present spent fuel is being reprocessed in the Tokai-Mura prototype plant or in the United Kingdom and/or France; a large plant with a capacity of 800 t/y is under construction at Rokkasho Mura and is scheduled to be operational by 1995. Japan considers it necessary to develop the utilization of plutonium as nuclear fuel in order to guarantee its nuclear independence (Japan has no uranium ore mines). Japan remains still dependent upon USA and France for supply of enriched uranium; however, a prototype with a capacity of 200 tons SWU/year followed by a plant of 1500 tons SWU/year, using the ultra-centrifuge technology, should on short term guarantee the japanese supply; for the long term the advanced enrichment technique by laser is being studied. A long and important effort is made on the management and disposal of radioactive waste; vitrification of high level waste should start from 1990 onwards and disposal in geological formations in the beginning of next century.

China masters also to a certain degree the fuel cycle, mainly as a consequence of its military programmes; an enrichment plant, by gaseous diffusion, is operational since 1965 and a pilot facility for the reprocessing of LWR fuel should go into service in 1996. The management of radioactive waste is the subject of a recent effort and a long term programme has been launched for the study of disposal of waste in deep geological formations.

India, Pakistan, South Africa, Brazil, Argentina, etc. do not master on an industrial scale the entire fuel cycle, but have prototype or pilot installations for enrichment or reprocessing. Their development is curbed by international measures concerning exchange of technology with proliferation risk.

3. Situation in Europe - What has to be done ?

The Community is the part of the world where the fuel cycle has been mastered at the most in all its phases, and developed both on an industrial scale and in a commercial sense.

Large uranium enrichment facilities are operational since at least one decade; they apply the gaseous diffusion technique (Eurodif company, plant in France) or the ultra centrifuge process (Urenco company, with plants in the Netherlands, the Federal Republic of Germany and the

United Kingdom); they supply Europe and export on the world market this in competition with the USSR and USA. The enrichment by laser which process should replace by the end of the century the too expensive gaseous diffusion technique, is subject to important research programmes, especially in France. It concerns here a sector of high scientific quality and of very advanced technology, of which mastering on an industrial scale could contribute to the energy independence of the Community in the first part of the next century. Taking into account the difficulties, the cost and the stake, a cooperation within the Community could be most desirable.

The reprocessing of spent fuel is likewise applied on an industrial scale at different levels in France, the United Kingdom and the Federal Republic of Germany. The plant at La Hague in France is the largest in the world and would within a few years be accompanied by the Thorp plant at Sellafield in the United Kingdom and by the Wackersdorf plant in Germany, the latter with a lower capacity. A certain concertation exists between these three big ones on reprocessing via the United Reprocessors company. Finally the industrial development of the fuel cycle stages involving uranium - plutonium for light water reactors is under way in these same three countries which, only together with Japan, seem to achieve its complete mastering in the near future.

The importance of investments to consent to these different installations, in order to obtain a profitable capacity, excludes practically initiatives from smaller countries. Nevertheless, other Member States of the Community, in particular Belgium, are closely associated with the countries mentioned above on various fuel cycle phases (e.g. fuel fabrication).

The management of radioactive waste is in particular developed and supported at R&D level in most of the countries of the Community having a nuclear programme. (For example, the two existing commercial vitrification processes are from french and german origin). The disposal in deep geological formations is likewise being studied with large financial means.

Research in the area of radioactive waste has been and is currently supported at Community level by a shared cost programme 1985-1989, with a budget of 62 million ECU which is already the third five year programme on this subject, and a directly research programme 1984-1987 executed by the Joint Research Centre at Ispra.

The shared cost programme includes, in its first part, studies on waste management and research and development actions on system studies, treatment and conditioning of radioactive waste, qualification of engineered barriers, the development of repositories, the safety of geological disposal and the elaboration of management policies. A second part concerns the construction and/or exploitation of underground facilities open to joint activities : in the underground facility in the clay at Mol, Belgium, (HADES project) the belgian nuclear research centre SCK/CEN cooperates with french and british companies in the framework of activities supported by the Community programme and the tests in the Asse salt mine in Germany continue with participation from the Netherlands, France and Spain.

The programme of the Joint Research Centre at Ispra covers three big items : management of radioactive waste and fuel cycle, safety of waste disposal in geological formations and feasibility of waste disposal into ocean sediments.

Moreover, in all countries having nuclear power programmes there exist nuclear installations being shut down of which only a small number have been dismantled and, in the future, more and more large installations will arrive at their end of normal lifetime. Research activities in this area in Europe were rather dispersed at the beginning. A more systematic and coherent action has been undertaken at communitary level and a shared cost community programme 1984-1988, with a budget of 12.1 millions of ECU, has been put in place, which aims at a joint development of the management of installations shut down and the waste arising at dismantling. This programme covers mainly, in its first part, research and development actions on the long term integrity of structures, decontamination, dismantling techniques, treatment of specific waste, containers of large dimensions and system studies, and, in its second part, trial of new techniques under real conditions in the framework of decommissioning operations at large scale.

Politico-strategical, military and commercial aspects have generally impeded or discouraged possibly initiatives at community level on most of the nuclear fuel cycle phases of which some are moreover safeguarded by secrets. This explains also the present concentration of community R&D on activities having a public service or safety character (Community R&D programmes on management and storage of radioactive waste, the decommissioning of nuclear installations).

In the future, the main action should remain on safety and the environment, that is to say the storage of waste and the dismantling of installations. To a much lower degree than the industrial toxic waste it is true, these are the two main daily nuclear problems in the beginning of the next century.

With regard to nuclear wastes the new programme 1988-1991 of the Joint Research Centre includes studies on the treatment and solidification of reprocessing waste, waste characterization and the safety of geological disposal. A new five year 1990-1994 shared cost programme on management and disposal of radioactive waste is under preparation. The main lines of the present programme will be maintained by introducing some modifications, for example, in increasing the activities on natural analogues and in enlarging the supporting activities to the projects on construction and/or exploitation of underground facilities.

In the field of decommissioning of nuclear installations, the new shared cost programme 1989-1993, approved by the Commission on the 19th of July 1988 with a budget of 31.5 million ECU, conserves also the main lines of the previous programme. However, to the research and development actions, an action on qualification and adaptation of semi-autonomous telecommanded handling systems has been added. The part regarding practical testing of new techniques should be carried out in the framework of decommissioning operations performed at large scale in the Member States.

As regards the basic research supporting the fuel cycle activities, research on actinides constitutes an element of importance.
This research implies high cost, high risk, licensing problems and unusual safety precautions, which exclude universities and conventional national research institutions from entering into the field. It thus constitutes an excellent examples for the beneficial effect of Community efforts providing facilities which otherwise could not have been available.
Actinide Research, executed almost exclusively at the European Institute for Transuranium Elements, is dealing with the investigation of properties, handling risks and possibilities of technological application of the heaviest elements in the Periodic Table, elements all of which are radioactive and some fissile.

All the activities related to fuel cycle have to be carried out in such a way as to guarentee the peaceful use of the nuclear materials concerned and the work on safeguards and fissile materials management responds to a Community obligation to implement nuclear safeguards in the framework of the Euratom Treaty, the Non Proliferation Treaty and nuclear material supply agreements with third countries. The JRC through its research and development programme, acquires the basic scientific knowledge and gets acquainted with new technologies needed to provide, later on, an effective support to safeguards inspectorates of the Commission (DG XVII) and of IAEA. Fissile materials management by plant operators, which has an impact on the implementation of safeguards, will influence the orientations of the JRC's specific programme. Efficient cooperation, including task sharing, with ESARDA (European Safeguards Research and Development Association) and with the US Department of Energy, has been established to minimize duplication efforts in R&D activities.
In the safeguards area, the research will be oriented towards :

- The study of the safeguards and fissile material management techniques and the demonstration of the way they can be integrated in the inspection and plant operation activity.
- The performance assessment instruments and devices under realistic field conditions.

Due to the strong demand for training of Euratom and IAEA inspectors in the use of measurement systems, substantial increase of this training activity is foreseen.

C. Radiation Protection.

1) Aims of Radiation Protection.

Radiation Protection aims to protect man and his environment from the possible harmful action of ionizing radiation. Man is exposed to the following sources of radiation of which natural exposure followed by medical diagnostics are the most important one:

- natural sources (cosmic radiation, "external" radiation from natural radionuclides in man's environment, "internal" radiation from natural radionuclides in the body including inhaled radon and its daughter nuclides),
- exposure in the context of radiological medical diagnostics,
- exposure from industrial activities such as nuclear power production.

In line with the expanding use of ionizing radiation in nuclear industries and medicine and the increased concern of the public about radiation risks, it is imperative that man and his environment be adequately protected. The persons of concern in this respect are workers in nuclear industries who receive their exposure mainly in an occupational context and the general public which is exposed primarily to natural sources and medical diagnostic irradiation. Radiation protection research is needed to provide the scientific background for the establishment and updating of basic safety standards and regulations in radiation protection. Such research must also help the relevant authorities to reach rational decisions on the development of technologies involving exposure to radiation and on crisis management in case of an accident. Radiation protection research in general and the CEC Radiation Protection Programme in particular thus have a central role in all policies related to nuclear development.

Consequently, research in radiation protection aims to define more accurately:

- the various sources of natural, medical and industrial exposure, how these sources reach man via environmental and other pathways and how they contribute to human exposure,
- the biological effects of radiation, particularly from low doses, the most prevalent type of exposure, as well as the consequences of accidental exposure to high doses and how these can be prevented or treated,
- the problems related to the management of radiation protection of workers in nuclear industries as well as the possible consequences of exposure to the population in the neighborhood of such installations,
- the potential radiological consequences of radiation accidents, their management and the development of countermeasures,
- the realistic assessment of the risks from the different types of radiation exposure, how they compare to other risks in the industrialized society, and how radiation protection can be implemented in an optimal way.

2.History and Present Status of Radiation Protection:

Radiation protection research and regulatory activities started soon after the discovery of X-rays and artificial radioactivity. Interest in radiation protection research expanded rapidly during the fifties and sixties in response to the development of nuclear energy and the fear of nuclear warfare. It has declined somewhat in recent years, but interest in radiation protection has been renewed as a consequence of the Chernobyl accident. Radiation protection has been, in many respects, a pacesetter for protection against other harmful agents in man's environment. The understanding of radiation exposure, effects and risks has made considerable progress, and radiation protection philosophy, regulations and practices have followed closely the expanding scientific knowledge, providing a stimulus and methods for protection from other harmful agents.

Nevertheless, as a result of this progress, the remaining gaps and uncertainties have become more apparent, and other problems have arisen in relation to the development of new technologies involving radiation exposure and the management of radiation accidents. Public acceptance of such technologies will depend on an understanding of what radiation is, how it acts, what hazards it presents under operational conditions and after accidents and how the benefits of radiation application are perceived. Substantial social and economic considerations are obviously involved in the development of technologies involving exposure to radiation.

The scientific information used to develop radiation protection philosophy, concepts and practices comes from many various sources and requires the integration of information from several disciplines. Research in the Community is of a high scientific and technical level and, largely as a result of the Commission's programme, has achieved a large degree of coordination and integration. It is crucial, however, that adequate research effort be continued so that the expertise now available in the Community, needed for the every-day protection of man and essential for crisis management in times of an emergency be maintained in the future.

Community research in radiation protection contributes a considerable share, in the order of one third, to the worldwide activities in this area, and the interchange of information, the discussion on common research priorities and even joint experiments among Community institutes and those in other countries are very intensive. This interchange has recently received a boost through newly concluded memoranda of understandings by the CEC with the USA and Canada. It is characteristics for radiation protection that certain international organizations play an important role in the scientific assessment of risks and in recommendations for regulations, for example the International Commission on Radiological Protection (ICRP), the International Commission on Radiation Units and Measures (ICRU), the United Nations Committee on the Effects of Atomic Radiation (UNSCEAR). Community scientists and the CEC Radiation Protection Programme participate actively and decisively in the activities of these organizations.

3) The Role of the Commission in Radiation Protection

The EURATOM Treaty has given the Commission an important task in both regulatory and research activities in radiation protection in the

Community and has linked these two activities together. Indeed, since its conception the Radiation Protection Programme of the Commission of the European Communities has become an integral and important part of European research efforts in radiation protection sponsoring directly more than 30 % of all the relevant research in the Community and coordinating about 80 % of this work. This coordination and cooperation of research have allowed Member States to concentrate on those topics which they considered of priority with respect to energy production, health and environmental protection, and underlying basic research while relying on their partners in the Community and the coordination by the Commission's Programme for information on other subjects or for the use of special installations. This complementary structure with intensive cooperation and very little duplication of effort has been one of the most successful aspects of the Commission's Radiation Protection Programme resulting not only in a remarkable interdependence of European radiation protection research but also in substantial savings to Member States.

4) Future Needs in Radiation Protection:

Protection of human health, i.e., of workers and the general public, and of the environment are goals which will continue to be important for the future. The Radiation Protection Programme thus remains an essential element in the Commission's policies to protect human health and to develop safe sources of energy. Consequently, radiation protection research in Member States as well as the Commission's Radiation Protection Programme should continue at the present level of funding thereby maintaining the scientific, economic and politic advantages gained by the Community approach.

It should be emphasized, that radiation protection has now entered a particularly critical phase because the number of competent scientists has declined substantially and will continue to do so unless support for training and research can be provided. At a time when technologies involving radiation in general and nuclear power in particular meet increasing resistance by the public, a loss of Community expertise in this field could have economic and social consequences which could harm the European development to a considerable extent.

The Commission's services have prepared a document of the Community Research Needs in the Field of Radiation Protection for the Period 1990-1994.

These needs concentrate on

A) Human exposure to radiation and radioactivity.
   - Measurement of radiation dose and its interpretation.
   - Transfer and behavior of radionuclides in the environment.

B) Consequences of radiation exposure to man; their assessment, prevention and treatment.
   - Stochastic effects of radiation.
   - Non-stochastic effects of radiation.
   - Radiation effects on the developing organism.

C) Risks and management of radiation exposure.
   - Assessment of human exposure and risks.
   - Optimization and management of radiation protection.

BASIC RESEARCH ANNEX 10

The speed of scientific development in the later 20th century dictates that scientists must grapple with processes of change both at the macro and micro scale. So a comprehension of dynamic non linear and complex phenomena is fundamental to progress in all spheres of science and technology. In many cases the greatest benefits from science have been derived from what was originally judged to be 'useless' scientific enquiry. Despite the ever decreasing gap between fundamental investigations and economically significant applications the view is still current among science policy makers and industrial leaders that science (at least publicly funded science) has to be practiced not for the pursuit of new knowledge but for the sake of technological and industrial applications with direct economic benefits. By its very nature basic research moves into unknown territory and few can judge in advance what might be the future consequences or applications of the new knowledge to be acquired. It was Faraday who most neatly compared asking about the usefulness of new scientific discoveries with asking what a newly born baby was good for. To take a crude example, if past scientific research had been limited to mission-oriented and socially relevant topics we might now have better candles and oil lamps than our forefathers but nothing making use of electricity.

There is no room for complacency however. Although Basic Research has led to breakthroughs on many fronts and is both fuelling transformations in society and helping it to adapt to these changes it is subject to fashion and inertia at certain points. Thus there are topics which for years polarise the efforts of hundreds of scientists. In the same way, technologists and industrialists find themselves trapped in the inertia and rigidity of a system where attitudes still block free interchange between countries, between disciplines and between the academic and industrial sectors. So there is a tendency to pursue marginal improvements in fields which are already well developed rather than more topical or promising themes. It must be said that many politicians, often more interested in short term results are also too little oriented to substantial innovations.

In this context Europe, with its wealth of humanistic, scientific and technological culture, with its pluralism and diversity of traditions, its methods of organization and production, its patrimony of knowledge, experience, history, professionalism and urban centres (as Professor Colombo, Chairman of ENEA, wrote ten years ago) is ideally placed, indeed better placed than any other zone, to maintain a fresh dynamic and unfettered approach to Basic Research. And we must do so if we are to keep abreast of social transformations, live up to the expectations that Europe's citizens have of its scientists and of its politicians, and overcome the continuing imbalances in the world economy so that all countries can develop their full potential.

For the purposes of this report the rapidly expanding and combining fields of science have been grouped into four main areas :

1)- Physics

2)- Mathematics

3)- Chemistry

4)- Earth Sciences

This is by no means to ignore the importance of life sciences which are dealt with in other annexes to this document.

1) P H Y S I C S

From the subnuclear world of elementary particles to the whole of the cosmos, physics examines phenomena across a range whose breadth and diversity is truly breathtaking. Although it is concerned with fundamental questions about the origins of the universe and the structure of matter, its impact extends far beyond the satisfaction of man's desire to understand nature.

Physics bears a special relationship with most of the sciences. Progress in physics has touched almost every science, by contributing theoretical concepts and experimental techniques and its applications have changed our daily lives. Inventions such as the transistor and the laser have generated entire industries - microelectronics and optical technology for instance - with revolutionary consequences that will continue to transform our society. At the same time remarkable developments such as X-rays and the most recent nuclear magnetic-resonance imaging have improved the human condition. Whether it is the magnificent complexity of proteins and nucleic acids or the grandeur of the universe, physics provides the principles and models to carry out the necessary studies.

Recent discoveries in physics are among the greatest achievements of our time. Synchrotron radiation sources and tunneling microscopy have made possible new classes of experiments. Fusion research continues to progress towards the goal of new energy sources; Particle accelerators and telescopes are being used in order to give the answer to the nature of energy and matter and their transformations. All these developments confirm the old axiom that physics is fundamental to all the natural sciences, a field where the sum of the parts accounts for more than the total.

Europe's position in physics is a reflection of the position common to all the natural sciences. Here as elsewhere Europe has a long scientific tradition, promising scientific potential and results which are first rate, especially in basic research; at the same time, however, there are chronic weaknesses such as a continuing seepage of talent into better resourced environments outside Europe, an inadequate and outdated infrastucture, barriers between traditional areas and between physics and other disciplines, between the different sectors (whether academic or industrial) and of course between the various national scientific communities. By no means the least of the weaknesses in European physics is the widespread difficulty that is experienced in turning basic knowledge into successful industrial applications.

In physics perhaps more than elsewhere, the experimental facilities needed are increasingly sophisticated and costly. At the same time existing equipment grows more rapidly obsolescent as technological breakthroughs are made. There remain barriers of mutual suspicion at least between basic and applications-oriented research although it is increasingly difficult and unrealistic to separate the two. In many fields physics is moving closer to other disciplines and this is reflected by a growing awareness of the need for a matching multidisciplinarity of approach and the development of altogether new fields at the interfaces.

Lastly and again in common with other areas of science one of Europe's biggest weaknesses is the fragmentation of physics into restricted national scientific circles and the wasted strength and potential this represents compared with our competitors.

Physicists have always sought to uncover the ultimate structure of matter, the elementary particles from which the infinite variety around us is built, and to formulate the laws that bind these constituents together building up nuclei, atoms, molecules, stars and galaxies.
Progress in the last few years has led to the belief that the answers to these questions are close at hand. The subnuclear world of 'elementary particles', which was once likened to a zoo, has become a gratifyingly orderly place : we now possess a standard model of the universe as being made of
quarks and leptons, bound together by force-carrying particles.

Quantum chromodynamics seems to be proving the correct theory of the strong nuclear force. Weak and electromagnetic forces have been unified in a single gauge-field theory. And the current objective is to develop a Grand Unification scheme which will embrace the three fundamental forces, gravity, the unified electromagnetic-weak and the strong nuclear force, that control the behaviour of all bulk matter and of biological, chemical and nuclear phenomena.

The contribution of Europe, where many of the most recent discoveries were made, has been outstanding, both at the theoretical and experimental level. Much of the success is due to CERN, the European centre for High Energy Particle Physics. Designed initially to respond to the ever growing costs of experimental facilities for Subnuclear Physics, it has become the meeting place of the European scientific community working in the field, the melting pot for new ideas and a centre of excellence, where major advances have been achieved : the discovery of a -meson's rare decay mode which had escaped detection in previous U.S.A. experiments, was followed some years later by the discovery of neutral currents and more recently by the discovery of the W & Z particles, which established the theoretical predictions for a unified electromagnetic and weak force. These results represent impressive triumphs of accelerator art, experimental technique and theoretical reasoning. In fact, CERN's engineering skills as well as the accumulated know-how and the numerous spin-offs such as the superconducting magnets technology are additional sources of success. The world's biggest particle accelerator, LEP, is currently under construction, an undertaking whose forbidding costs at national level dictated a joint effort. CERN has indeed served as an encouraging example for many similar joint initiatives, either in the same field such as HERA in Hamburg or in other fields such as Space (ESA) and Nuclear Fusion (JET).

Recent progress in particle physics has generated stimulating ideas in cosmology which is also concerned with the nature of forces and constituents of matter. Grand Unified theories are tested through their cosmological implications and questions on the origin and the evolution of the universe might find the right answer in scenarios inspired by elementary particle physics.

Astrophysics is not the only discipline to have benefited from its interaction with particle physics. The same is true for statistical mechanics and condensed matter physics. Further, the needs of particle physics for advanced computational methods have led to the development and implementation of new computer architectures.

Within the handful of scientific discoveries that have revolutionized society is the discovery of semiconductors, upon which the computer and communication technologies were based. A stream of new materials with remarkable qualities is already flowing from laboratories: glass that bends without breaking, plastics as tough as steel, metals that stretch.
Plastics and composite materials, transistors and semiconductor chips are but a few of the practical consequences of research in condensed-matter physics.
Of all the branches of physics, this has the greatest impact on our daily lives through the technological developments to which it gave and gives rise. The field's claim is in fact that it holds the record for converting basic science into sophisticated industrial technology on a time scale of 5 to 10 years. It is equally true that technological achievements provide a feed-back for more fundamental research. It is a field, where the interplay between science and technology is unique and therefore a field where joint community effort is required in order to face the challenge from both the U.S. and Japan. Community activities should in particular encourage initiatives that will help break down the barriers between basic and applied research. Moreover, the experimental infrastructure required becomes quite rapidly obsolete and the new equipment even more expensive. Community efforts should aim at a better exploitation of the existing facilities and should reinforce the collaboration, whether existing, as in the case of ILL at Grenoble, or not.

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In fact, in recent years the emphasis has shifted towards non-classical systems : from organic conductors and liquid crystals to superconductors and superfluids, from amorphous and metastable materials to the highly speculative quasi-crystals, spectacular results have been produced.

Much of the early collaborative research in these fields financed by the Community has been supported by the Stimulation Action.

Superconductivity, the ability of electrical currents to flow without resistance in certain conductors, is a phenomenon of great intricacy, that has led to remarkable and essential applications in the most ambitious technologies, with an explosive growth in the technical and industrial spin-offs : from medical diagnostics imaging to the world's biggest particle accelerator, from fast-switching devices to fusion research.

It is estimated that by the year 2000, the worldwide economic impact of superconductivity will be tens of billions of ECUS which may explain why recent discoveries in novel superconducting materials have created such an excitement in the world scientific community. The high potential for still wider applications makes superconductivity an attractive and challenging area for further research and development. This is indeed a field where joint European action is urgently needed, a reality which has already been faced by the relevant scientific departments of the Commission.

Once held to be a theoretical tool for understanding 3-dimensional real systems, one-and two-dimensional models have become a physical reality with striking technological applications. We now have quasi-one-dimensional magnetic systems and quasi-two-dimensional systems of layered compounds. These modern low-dimensional materials have properties which include a non-classical behaviour of the electronic conductivity and apart from their technological interest they have themselves been the source of fundamental discoveries such as the fractionally quantised Hall effect. Heterojunctions, quantum-well heterostructures and superlattices, that is deliberately designed quasi-two-dimensional structures, are achievements of a revolutionary nature for the future of more sophisticated lasers, detectors, higher-speed transistors and advanced optoelectronic devices.

One of the most remarkable advances in the last decade was the creation of artificially structured materials, including superlattices and two-dimensional electron gases. These materials possess properties that can differ considerably from those of their constituents in the bulk state and these properties can be tuned in desirable ways. In particular the method of ion implantation has made it possible to create materials with new properties that can not be produced by more classical means.

Research within the past decade has shown also that as materials are subjected to more extreme physical conditions, they display new or special properties. On the other hand, the development of new experimental tools, such as the intense synchrotron radiation source and vacuum tunneling microscopy, capable of a high resolution probe, have shifted the emphasis in condensed-matter physics to systems more interesting than the classical ones from a scientific and technological point of view.
To complement these, new theoretical tools, such as renormalization group methods and the imaginative use of the computer have been used to embrace ever-more complex phenomena : imperfect and disordered systems, strongly perturbed rather than equilibrium ones, systems with surfaces and interfaces, are now at the forefront of scientists' attention.
Studies of condensed matter at ever lower and higher temperatures, at higher magnetic and electric fields, at higher and lower pressures and at much higher purities will continue to provide us with materials and properties ever more surprising and interesting from a technological point of view.
It is a field where progress has and will depend on highly sophisticated and modern equipment, such as Molecular Beam Epitaxy (MBE) machines and vacuum tunneling microscopy. The high cost of such apparatus is forbidding for many European laboratories, and a Stimulation activity of scientific exchanges could give access to existing equipment for more European scientists.

Having started from the study of liquid crystals based on small organic molecules, more effort is currently being devoted to those formed by polymers, colloidal suspensions and biological structures. The variety of substances exhibiting the large number of unusual macroscopic phenomena found uniquely in the liquid-crystal phase is in fact the reason why a great deal of research is being undertaken at present. Their non-linear response to rather simple external forces and the subsequent complex structural changes have provided a rich testing ground for theoretical ideas in the fields of non-linear phenomena, molecular ordering and phase transitions.

Quasi-crystals, an even more recent discovery, are materials which may prove to possess major industrial interest. The study of their physical properties and their atomic arrangement has just started, following the fabrication of large samples in the laboratory.

The most dramatic device created and used in optics, as well as in almost every branch of science, medicine and industry, is the laser. Its uses include atmosphere analysis, laser surgery, laser printing, laser chemistry, home electronics and manufacturing as well as basic research into the optical properties of materials, which has made possible today's ultralong-distance optical-fibre communications systems.
Semiconductor lasers can nowadays send signals exceeding a billion bits of information per second and electro-optic, magneto-optic and accuto-optic devices have already found speciality applications.

Community Stimulation support to the European Joint optical Bistability (EJOB) project made it possible to produce not just the first optical version of a transistor in the world, but also proved the feasibility of an all-optical computer. Optical bistability has also become a new arena for the study of non-linear systems, turbulence and chaotic motion.

The field of nonlinear dynamics, instabilities and chaos is in fact undergoing a period of rapid extension. A new mathematical language and way of thinking about nonlinear dynamics has been developed by mathematicians and, more recently, by physicists. Computer techniques have been essential for experimental studies of complex dynamics. The engineering community is also performing crucial research in fluid mechanics. It is a field of a highly interdisciplinary nature with widespread possible applications to superconducting devices, astrophysics and biology. It is a field where the Stimulation Action can play an important role by encouraging and strengthening multidisciplinary and multisectoral research. Details of current activities, results and future trends will be mentioned in the chapter on Mathematics.

Although the physics of the nucleus itself is among the least understood fields of basic sciences, the principles and techniques of nuclear physics have been used for years in a large number of applications : from solid-state physics to molecular genetics, from food technology to forensic medicine, from mineral prospecting to cancer therapy, with nuclear fusion promising to be a new energy source. Nuclear medicine has by now been firmly established as a standard part of modern medical pratice. Specifically tailored radioisotopes and accelerator beams are used for both diagnostic and therapeutic procedures and X-ray radiology and nuclear magnetic resonance tomography are two of the most valued techniques for diagnosing disorders of the brain and blood circulation as well as malignancy.
Medical instrumentation is in fact one of the many areas where the contribution of physics has been outstanding and where Community support will produce results that will directly improve the human condition.

2) MATHEMATICS

In the history of Modern Mathematics one does not speak of 'Revolutions'. Unlike the Physical Sciences, progress in Mathematics does not necessarily require you to prove yourself wrong as soon as possible' (R.P. Feynman). A proven mathematical result stands for ever. Nevertheless we can distinguish periods of intense activity during which new trends appear resulting in deep and lasting changes in methodology, goals and perspectives. Mathematical Science, like all other sciences is currently undergoing such a period of transition. This is manifest in a variety of ways. First, we are witnessing rapid progress in scientific results. Some long standing problems have been solved, new ones are being formulated. New fields are opening up in the frontiers of knowledge (topology, geometry etc...). Entire branches, which have been developed separately, are coming into contact. The advent of high speed computers has revolutionized whole subjects from abstract mathematical logic and number theory to the most applied areas of numerical analysis and modelling. But what may be more important is the change in methods and perspectives. The barriers between different branches are gradually disappearing. The old distinction between pure and applied mathematics is becoming less and less visible. Mathematics and mathematicians are coming out from their ivory towers and finding their inspiration in contact with other sciences. In this respect they go back to the tradition of the old Masters such as Poincaré, Hilbert or Cartan whose fundamental contributions in pure mathematics were often made in response to outstanding problems in other sciences. In the same way we see today abstract fields such as topology, K-theory or non-commutative geometry which are finding direct applications to the classification of defects in crystals or the theory of elementary particles. Even more important is the fact that some of these mathematical theories are being developed precisely to answer questions raised in the context of problems in physics. The theory of infinite dimensional Lie algebras is being developed jointly by mathematicians and physicists.

In the limited space available we cannot review the whole of this exciting and rapidly changing field. We choose to mention only a single example not because it is intrinsically more important but simply because it illustrates very clearly the interdisciplinary character of modern mathematical research. The example chosen is the mathematical theory of non-linear phenomena and the geometrical ideas that are revolutionising the theory and applications of dynamical systems.

Most real-world problems confronting the analyst being neither linear nor even nearly linear fall outside the domain of traditional closed-form analysis. At the present time we are witnessing a spectacular blossoming of non-linear dynamics made possible on the one hand by great theoretical strides in Poincaré's topological approach and on the other by the wide availability of powerful digital and analogue computers. This has been stimulated and sustained by important and exciting new applications that have multiplied throughout the biological, ecological, social and economic sciences, far beyond the still vibrant tradional fields of mechanics, physics and chemistry.

Indeed, wherever the time evolution of a natural or man-made system needs to be modelled and explored, the subtle and versatile techniques of dynamical systems theory are being invoked.

A significant element in this major thrust which nicely epitomizes its most advanced theoretical, computional and experimental features is the discovery and delineation of chaotic motions in remarkably simple deterministic models from a galaxy of disciplines ranging from population dynamics and meteorology to lasers and particle accelerators. The recent discovery of quite large regimes of chaos in the long-familiar, sinusoidally driven Duffing and van der Pol oscillators emphasizes just how much was missed by the classical analysis of ordinary differential equations.

With the advent of high speed computers, it might have seemed that dynamical systems theory would simply fade away. But quite the reverse is true and it is indeed one of the fastest growing fields of interdisciplinary mathematics. The reason is that on the one hand the problems it raises and the challenges it sets to pure mathematics are truly fascinating and on the other its broad yet precise geometrical ideas are vitally needed to guide the analyst through the bewildering variety of complex behavior that he is likely to encounter.

Time evolutions must normally be modeled by non-linear equations for which closed form analytical solutions are unobtainable. They are however readily integrated numerically by routine computer algorithms so that the response from given starting conditions is easily established. But the starting conditions of a real system are never known precisely and may be totally unknown : what initial conditions should be assumed for a complex model of the atmosphere or an oilrig at sea in a developing storm ? So since the motions of a non-linear system can depend crucially on these conditions, a formidable task begins to emerge. How can we hope to explore the responses from all possible starts ?

Clearly we need some overview of what can happen in the evolution of a system and how this is influenced by the starting conditions. Here we have our first major guidance from dynamical systems theory in the concept of an attractor. Typical, dissipative dynamical systems exhibit a start-up transient, after which the motion settles down towards some form of long-term recurrent behaviour. Motions from adjacent starts tend to converge towards stable attracting solutions.
The simplest is a stationary equilibrium point at which all

motion has ceased. The archetypal example of this, studied experimentally by Newton, is the pendulum. From whatever starting values of position and velocity, this returns to its vertical hanging state, damped by air resistance and other forms of energy dissipation.

Introducing more technical language, we say that in the two-dimensional abstract phase-space whose co-ordinates are displacement and velocity all possible motions appear as non-crossing spirals converging asymptotically towards the resting state at the origin. This focus in the phase portrait of all possible motions is called a point attractor.

Secondly we have the periodic attractor. If a thin steel strip is driven into resonance by an electromagnet carrying an alternating current, the strip will normally settle into a steady vibration at the frequency of the forcing. After a small knock, transients will slowly decay and the stable fundamental oscillation will be re-established. But given a bigger disturbance an entirely new state may be observed. Different starts of a given system may thus lead to alternative final states with multiple attractors coexisting in a state of competition.

A third, recently discovered, attractor, whose unexpected features have generated an explosion of interest, is the strange or chaotic attractor that captures the solution of a perfectly deterministic and well defined equation into a state of steady but perpetual chaos. But although a single time history possesses an aspect of true randomness, a comprehensive phase-space investigation reveals an underlying order in the ensemble of all trajectories whose elucidation is a major topic of research amongst mathematicians and physicists. It is the final settling in the multidimensional phase space of a large dissipative system to attractors of low dimension that validates our presentation of general concepts via specific equations of low dimension.

Multiplicities of all three attractors can coexist in the phase portrait of a given system so that in simulations and experiments a bewildering variety of final time histories may be generated by different starts. Clearly analysts and experimentalists should be vitally aware that such apparently random non-periodic outputs may be the correct answer and should not be attributed to bad technique and assigned to the wastepaper basket as has undoubtedly happened in the past.

This description of multiple attractors is not in the least fanciful or rare. Multiplicities of competing steady states, including chaos are constantly being discovered even for very simple non-linear systems (eg Duffing's equation).

Now even the most exact of the physical sciences, the coefficients of any model are never known with absolute precision. So having previously discussed the physical stability of final states of a given system, we must explore the stability of the modelling process itself. Would we get roughly the same answers if our equations had been slightly different. This question is formalized in the concept of the structural stability of a phase portrait.

Many systems are in a slowly evolving environment so their coefficients and parameters undergo gradual change. Then, if the evolving system is in a steady state of equilibrium, periodic oscillation or chaos, the prediction of any sudden change is of crucial importance. Such bifurcation of behaviour will occur when the phase portrait undergoes a qualitative change of topological form at a point of structural instability.
An important distinction is between those catastrophic bifurcations at which there is finite rapid jump to a new steady state and subtle bifurcations in which the change in response manifests itself in the smooth growth of a new local attractor after the bifurcation point.

As we mentioned already this fascinating theory grew out of a cooperative effort among mathematicians and scientists from all disciplines. It has already revolutionized our understanding of long standing problems such as the problem of turbulence which have resisted all previous attempts at quantitative analysis. It has been a long time since we last witnessed such a fruitful collaboration. Nor is it yet at an end. We are still actively involved in it and we are looking confidently forward to even greater discoveries.

3) CHEMISTRY

The Chemical industry has been one of the most important factors in the economic development and social change that has taken place in Western Europe over the last thirty years. This is an intrinsically innovative sector characterised by the manufacture of new products and materials which integrate with and replace natural ones, calling for different processes and technologies from those known hitherto.

As indicated in many recent reports on the subject, notably that which surveyed opportunities in the Chemical sciences under the chairmanship of Professor George Pimentel of the University of California, this is a time of major opportunity for advances on a number of fronts. These advances arise from continuing progress in our understanding of the phenomena of Chemical change and the molecular complexity involved in it. This growth in understanding is reflected in the ever more rapid rate of discovery of new compounds. At the same time techniques used in Chemistry are expanding and more and more importance is being attached to the use of new instrumental techniques, which hold out the promise of an excellent ratio of results to expenditure on machinery. For example, the chemist is now using extremely sophisticated and more and more costly instruments and diagnostic aids : lasers, spectroscopic instruments, the electron microscope, the tunnel-effect microscope, NMR neutron diffraction and synchrotron light. Many laboratories can afford no more than a few of these instruments. At the same time a great deal of work on the frontiers of the discipline and on the interface between it and disciplines such as physics or biochemistry is heavily dependent on modelling and computing facilities. It would seem that at a European level there is a need for existing instrument resources to be pooled and made available to chemists in Member States which might not yet be in a position to provide access to the whole range of instruments and techniques themselves. At the same time, given the rapidity of developments in instrumentation certain existing facilities could make good use of assistance with the expense of necessary upgrading activities.

Promising areas

Exciting dicoveries in a number of areas at the forefront of chemistry can be anticipated. For example in chemical kinetics (to use a term coined in the Pimentel report), the effect of photon absorption by an atom or molecule can be studied. The best-known example which has captured the attention and motivated the work of numerous chemists and biologists is photosynthesis. Even though the hopes placed in the use of solar radiation to dissociate the water molecule into hydrogen and oxygen on the pattern of living mechanisms have not yet been crowned with success, the research done has nevertheless led to the discovery of an impressive series of stages in photosynthesis and has laid the foundation for extremely fruitful applications, for example hydrogen production by dissociating alcohol or the production of optically active aminoacids. These new processes in which molecules interact in intense photon fields are made possible by the powerful lasers now available, which can probe chemical reactions on a time scale that is short compared to the lifetime of any transient substances that can be said to possess a molecular identity. Another field highlighted in 'Opportunities in Chemistry' is theoretical chemistry (application of quantum mechanics to chemistry), one of the fields in which Europe dominates. It should be emphasized that its leadership has been made possible by measures such as the establishment of major computer centres accessible to numerous laboratories and opportunities of exchanging computer programmes, which have encouraged widespread cooperation at European level.

One of the areas of quantum chemistry now undergoing major development involves the calculation and characterization of intermediate structures and transition structures in organic reaction models. The possibility of calculating analytically the energy gradients and second derivatives of wave functions has started to transform the methods used to study chemical reactions. It is possible to study the various reaction paths and to select those that are the most probable. Most of the calculations are carried out on models of simple chemical systems and are used as a reference for a family of similar systems. Qualitative models of the topology and energy properties of potential surfaces have been developed so that it is now possible to interpolate between the available experimental data, given that only a limited number of models can be analysed numerically in detail.

Catalysis is another field undergoing major transformation. Fundamental advancesin heterogeneous, electrochemical, photochemical and enzymatic catalysis are being made. As chemistry is essentially the art of economically converting abundant substances into useful products, the study of chemical processes and the conditions under which reactions can be improved and speeded up inevitably accounts for much of the research effort. In particular the study of catalysis and catalysts, i.e. substances that can speed up chemical reactions without themselves being consumed in the reactions, has always played an important role from both the scientific and the economic aspects. It is even more useful to be able selectively to modify the role of various intermediate reaction so as to promote a given final product at the expense of others.

Research into catalysis is today enjoying a new lease of life as a result of the new instruments available and the analytical and digital techniques that have recently been developed. Relatively simple models have been developed to represent the electron properties of simple molecules (carbon monoxide, hydrogen) during crucial stages of catalytical reactions; these theoretical results can then be compared with experimental ones. With these models it has been possible to collect essential data on the elementary stages of catalysis. An understanding of these models will eventually facilitate the design and development of new catalysts for industry.

It should be pointed out that recently a combination of favourable conditions has emerged and should lead to interesting results. Numerous new techniques and a range of extremely efficient instruments are now available to researchers.

Surface chemistry and the study of metallic clusters have also undergone significant developments in recent years so that catalysis research has now ceased to be "black magic", as it was sometimes dubbed in the past, and become an exact science.

The American analysis highlighted the role of chemistry in systematic strategies for the discovery and design of novel materials. In this 'most dramatic frontier of materials science' several techniques are being developed. One of them is Intercalation chemistry. Some solids consist of layers or fibres. Under certain conditions foreign substances, ions or molecules, can be accommodated between these layers or fibres. Originally, intercalation chemistry was developed in the field of lamellar solids. Now the concept has spread to all phenomena where guest ions or molecules are reversibly inserted into a solid. There are numerous intercalation compounds in nature : some of the micas, our bones and our teeth are examples. The most attractive applications of intercalation compounds are to be found in the area of materials.

Several examples can be given. By intercalating lithium or sodium ions in lamellar dichalcogenides (derived compounds of sulphur, tellurium or selenium), the conductivity of the system is greatly improved. The advantage of such systems is that energy per unit mass is four to five times higher than that of conventional lead accumulators.

Manufacturers have also shown interest in the applications of intercalation compounds of graphite : graphite compounds are often good conductors (in some cases nearly as good as copper) which would give exceptional energies per unit mass (ten times that of lead accumulators).

As progress in chemistry accelerates the traditional border between organic and inorganic chemistry is disappearing and the use of modern instrumentation is leading to techniques which quicken the discovery and testing of new reaction pathways and strategies involving synthesis. Some of the most spectacular results have been obtained with zeolites (silicates in which sites are wide tunnels). Other applications have been found in light displays, in particular with tungsten oxide WO_3. Over and above their many applications, new and extremely promising synthesis routes have been developed, based in particular on topotactic reactions (reactions after which some of the main structural elements present in the initial compound are found in the final compound). In this way a new titanium oxide has been developed and is today used as a catalyst support. Vanadium disulphide VS_2, a compound that was not known previously, has also been successfully prepared.

Following on from the synthesis of materials and making use of their ability to deal with molecular complexity chemists are helping to investigate and clarify the molecular origins of biological processes.

Chemists are today faced with increasingly complex problems of synthesis. They need to produce more and more sophisticated molecules but often the conventional organic synthesis methods are no longer adequate for this work. There are in nature substances capable of transforming simple molecules into thousands of different molecules and macromolecules having hundreds of thousands of atoms. These transformations are carried out with outstanding efficiency and accuracy. Chemists have therefore started to study the abilities of enzymes and are trying to profit from the lessons to be learned from nature.

In any organism the constituents of living matter are synthesized by means of chemical reactions catalyzed by specific effective substances, the enzymes. The extraordinary speed and enormous selectivity of the reactions induced by enzymes are due to their conformation in space - the reagent is trapped in a cavity of the enzyme. To imitate the chemical action of enzymes without copying their complete chemical structure is one of the ambitious aims of synthesis chemists.

The most promising approach, although also the most complex, is to synthesize a molecule of a different chemical nature from an enzyme but behaving in the same way, so as to catalyze a specific product that is useful to the chemist. The aim is to manufacture catalysts based on enzymes that are just as efficient but differ fundamentally from the usual catalysts by their organisation in space. The artificial enzyme must be capable of recognizing its substrate and transforming it into one product only, even if several are theoretically possible. The artificial enzyme must have a genuine catalytic activity - it must not be consumed in the reaction, must be capable of producting the reaction on a large number of substrate molecules one after the other and finally must release the product into the environment.

Whilst the benefits of achieving this will be very great it is clear that major progress can be made only by encouraging interdisciplinary research collaboration, between biological and chemical research teams.

4) EARTH SCIENCES

As the preservation of our environment through intelligent and sensible use of the earth's resources assumes ever greater importance, the earth sciences are gaining fresh economic and political significance. At the same time, this scientific sector is undergoing radical change as it moves on from the disciplines of observation to those of experimentation and modelling. Moreover, because its very subject is the whole earth, this research is essentially of an international nature.

With this shift from making observations of static and successive situations to the reconstruction and explanation of the mechanism of evolution, the earth sciences as they are conceived today call for a global approach supported by numerous accurate analyses. The research relates to both structures and materials on all scales from the atomic structure of crystals to the texture of rocks and even the dynamics of plate tectonics.

Several types of activities can play a federating and stimulating role for the European scientific community. The direct and indirect study of the deep structure of the lithosphere is one example : today more is known about the surface of the moon, Mars or Venus than the sub-soil of the earth.

Crystals, the very constituents of the earth, still present numerous problems, if not as regards their structure at least in their genesis. The demand in high technology for flawless crystals has led to considerable advances in the knowledge of crystalline imperfections and growth modes. However, phase transitions and interface problems still call for both theoretical and experimental research. This is a field in which the transfer of basic research results to applications could be particularly fast and beneficial.

Space observations provide the key to the study of the Earth as an integrated system. From these observations by satellites and space platforms a large volume of detailed data can be collected. This data can be utilised in numerical and conceptual modelling which together with the traditional earth-science disciplines can help to obtain a scientific understanding of the earth as a whole. One of the most obvious benefits of this increase in understanding has been the improvement in the accuracy of weather prediction which resulted from the numerical simulation of the atmosphere with high-speed computers.

The Atmosphere

The effect of human activity on the atmosphere has caused marked changes in recent years. Since the industrial revolution alone, the amount of Carbon dioxide released into the air through the burning of fossil fuels has increased by almost 25% and this is anticipated to double within the next 100 years. Carbon dioxide insulates the earth preventing heat radiation. As a result, the temperature of the earth has been rising at an unprecedented rate such that there have been noticable changes in precipitation patterns. Other so-called "greenhouse" gases have been increasing in concentration at an even greater rate than Carbon dioxide and it is estimated that their effects can be even more pronounced than CO_2.

Apart from causing changes to the atmosphere through the burning of fossil fuels, man has also destroyed large tracts of vegetation resulting in a further increase in atmosphere Carbon dioxide levels and a depletion of Oxygen sources.

The changes in the atmosphere as a result of the activities of man are difficult to assess but they are clearly of great importance. It is necessary to measure and document these changes globally and to identify causal relationships between them.

OCEANOGRAPHY

The ocean sciences are a relatively new and highly promising area of research and development. Scientific activity has, in a very few years, moved from the descriptive to the explanatory or even the predictive stage. It touches on a sphere of essential knowledge which our vanishing resources and the need to protect our environment have put in the spotlight.

Since it is, at one and the same time an enormous reserve of raw materials and foodstuffs, a gigantic dustbin, a primary factor in climatic balance and the world ecology, and, lastly, an environment the understanding of which can add to the fruitfulness of numerous branches of the life sciences, the ocean is a hugely rewarding field of study.

Oceanography is an inter and multidisciplinary of a field in which there is hardly any real demarcation between basic research and more applied research activities. Cross-fertilization between disciplines is essential here.

It is also a science in which the scale of the problems is such that they naturally call for international cooperation and in which the size of the technical resources needed leads (and should more often lead) to the joint establishment, between various partners in different countries, of one shared research tool. Programmes to study large-scale phenomena are very difficult to organize and finance. Lastly, cooperation is required between the Community and the developing nations who possess vast tracts of sea.

As far as sectors of scientific activity are concerned (physical, chemical or biological oceanography), there is at present a need to focus more on large-scale phenomena (in time or space), but choosing the appropriate scale in time or space poses many problems because studies of the various dimensions are closely interdependent.

Coastal zones

Stretching as they do right to the edge of the continental shelf, these zones are the locus of strong interactions between the continent and the oceans and for this reason they are doubly interesting. On the one hand the key to an understanding of the overall workings of the oceanic system is a basic knowledge of ocean.continent interface phenomena; which can be studied in these zones. On the other hand they are an area of the sea where intense biological activity (in the form of wastes) is most marked.

Bearing in mind the direct socio-economic implications of a greater knowledge of the physical, chemical and biological phenomena taking place in these zones, research into continent/ocean interactions and into coastal ecosociology is of paramount importance. It calls for new or reinforced interdisciplinary work.

On the basis of work undertaken in this way by a number of disciplines it is possible to move towards the development of conceptual and forecasting models which will lead to a better understanding and by the same token a more thorough mastery of the workings of coastal ecosystems.

Research will basically require the availability of an infrastructure of marine stations and experimental installations. The Community has great potential in this respect, a quality which currently constitutes a considerable asset.

Secondly the vitality of scientific and technical progress in this field is very much a function of the resources (particularly human resources) which are available, and the extent to which integrated approaches within a multidisciplinary system are possible. At this level certain weaknesses must be admitted, arising in part from the lack of resources dedicated to certain sectors and also from a certain fragmentation of work (particularly so far as the universities are concerned).
But if the Community can :

- build up the multidisciplinary character of research centres and the cooperation between specialized centres;

- promote cooperation between marine stations and university centres, which are often widely separated geographically.

The effectiveness of European R & D in this field could be greatly enhanced.

<u>The Great Deeps</u>

The deep ocean is a gigantic ecosystem, a deeper knowledge of which is a vital prerequisite for making use of or exploiting the material which lies hidden there. Whether, for example, to ensure that waste products dumped into the abyss by man are safe and innocuous, or to exploit the areas containing polymetallic nodules, it is first necessary to learn more about the meiofauna, the relief and the phenomena (e.g. hydrothermal) which exist at these depths. This knowledge will only be gained via interlinked R & D work in a number of sectors (geology, geochemistry, geophysics, chemistry, biology, bacteriology, maritime engineering, etc...) and the availability of complex and frequently onerous observation and analysis techniques.

In the overall world R & D ranking in this field, Europe's scientific community occupies an entirely honorable position, with some particularly strong points (in geology, geophysics, sedimentology and research techniques, for instance). However, it is clear that where the Community has the advantage, its lead is precarious. This is particularly true so far as methods of exploring and analysing the great deeps are concerned. The Community was the first to have multibeam acoustic sounders, which were a revolutionary tool.

Today this method is being overtaken and new technologies are coming forward, including lateral sonars which are able to analyse a greater volume of acoustic information from much larger areas of ocean floor. These new technologies are emerging outside the Community, which might give attention therefore to the joint development of large "instruments" (such as ships) and major projects.

The interface between ocean and atmosphere

The ocean is one of the vital components of the climatic system and as far as the atmosphere is concerned, it fulfils three essential functions : storage, transport and interchange of energy. These are not independent functions in the ocean since they are bound by the law of energy conservation; they are not independent of interchanges with the atmosphere either since the ocean is a system which is coupled to it. At the interface, energy is exchanged in various forms (heat, mass and movement) and on various scales. All this therefore makes up a group of complex physical phenomena, which are further complicated by the differences in reaction time between the ocean and the atmosphere.

Knowledge of "ocean and atmosphere" phenomena is closely linked to and interdependent with climatology know-how, of which it forms a subset. Depending on progress in the science of earth-atmosphere exchange phenomena, a natural complement to this science, and understanding of these phenomena is essential in order to be able to predict climatic variability over a longer period than is possible at the moment. In this way tools more rigorous than those which exist at present could be made available for the planning of various economic balances (particularly in agriculture) or to warn of the irreversible imbalances which human activity can bring about (the danger of too great a quantity of carbon dioxide in the atmosphere, for example).

To this end it will be necessary first to have available a fund of basic knowledge which is still lacking in order to arrive at a more complete understanding of ocean dynamics or physical phenomena related to the ocean/atmosphere link. To develop this knowledge will mean first of all continuous systematic and wide-scale observation of the ocean, with access to considerable resources (satellite remote measurement, tomographic grid squaring, automatic measurements via groups of buoys) and, lastly, a capacity to analyse and assimilate the data which has been gathered.

The very size of the problem and of the field in question has brought about the implementation of huge international projects in which the European scientific community has played a large part. In this way major discoveries have been made (about energy transfers for example) which are a promising basis for future developments.

The problems and the field involved go well beyond the Community's geographical limits and interests. Nevertheless it is very much in the Community's interest to strengthen still further the scientific and technical potential it possesses in this sphere.

Certain specific objectives should therefore be pursued :

- the improvement of mathematical models to simulate intraoceanic flows,
- the encouragement of cooperation between teams of different disciplines (physical oceanography and chemical dynamics by way of example) in order to make a contribution to the development of conceptual tools facilitating the explanation of such basic phenomena as the nitrogen or carbon cycle at ocean/atmosphere level;
- building up the human resources available for research work in this field by giving aid for training and the recruitment of new researchers for existing teams.

Biological aspects of earth sciences

Biological processes exert an important influence on the global system. The earth's ecosystems are highly vulnerable to changes in the external environment. The diversity that is to be found has developed over billions of years and evolution can be accuratedly documented through the study of sedimentary rocks, ocean sediments and ice-cores. The changes which have occurred in the climatic conditions may also be monitored in this way and their influence on the biota estimated. This knowledge is of vital importance to the understanding of recent changes.

The distribution of life on earth is largely determined by the physical climate system which in turns depends on the variation on solar heating with latitude. The physical climate processes which include circulation patterns, precipitation, evaporation, vegetation etc are currently being elucidated using satellite techniques.

The cycling of the principal chemical constituents of the earth (Carbon, Nitrogen, Sulphur and Oxygen) are all dependent at some stage on biological processes. This cycling ties in with the production of "greenhouse" gases and determines the extent of the pollution of the atmosphere. While satellite observations are a useful tool for studying biogeochemical cycling, it must be supplemented by in-situ sampling.

The distribution of rainfall, snow, evaporation and runoff on the earth governs the extent and productivity of biomass. Changes in land use can affect the global climate through hydrological alterations.

The Solid Earth

Current areas of investigation of the solid earth include the study of continental deformation and evolution, the structure and convective patters in the mantle and the dynamo-mechanism of the earth's core itself. New tools such as Very Long Baseline Interferometry (VLBI) and satellite laser ranging are being used to measure continental separation. By gaining an insight into plate deformation, earthquakes may be predicted with greater accuracy. Satellites are now able to provide date for models of plate motions and establish connections between mantle circulation and tectonic activity.

The source of earth's magnetic field arises from the core, the detailed structure of which is not yet well known. By studying the earths' magnetic field the core's structure may be elucidated and geological history calibrated.

The evolution of the earth is closely interlinked with the evolution of life upon it and by continuing to study geology a better comprehension of the evolution of the Earth may be achieved.

THE EXPLOITATION OF SPACE

Space can be tackled from a number of different angles : knowledge, getting there, using it as a field of human activity. At a national and/or multinational level (the ESA for example), all of these aspects are now being tackled and are the subject of considerable work.

Nevertheless, bearing in mind the Community's scientific and technical objectives and the needs as well as the existing potential in this field in terms of Europe's scientific competitiveness, a Community activity would seem to be both necessary and opportune in one particular sector : the use of space as a study medium.

For space is, as a laboratory, something special. Whilst it is possible to create hypergravity situations on earth it is not possible to create prolonged conditions of weightlessness. And already microgravity seems to be useful, sometimes even vital, for the study of many phenomena.

Two subjects are of particular concern in this respect :

(a) Space biology and medicine, which seems certain to be at the origin of major practical spin-offs (so far as biology and basic physiology are concerned, through the knowledge that will be gained about the effects of cosmic rays and gravity on living organisms). Up to now the knowledge gained by (and for) space flights has made it possible to develop atraumatic systems of measuring circulation the echotomographic study of organs, the use of which can now be anticipated in hospital medicine.

(b) The study of physico-chemical processes under conditions of micro gravity and the discovery and development of new materials with special properties (electrical, magnetic, optical or mechanical). Apart for these problems, which are linked to the development of raw materials in classic "terrestrial" conditions, it is also important in this sector to improve our knowledge of the role of microgravity in materials science.

For whilst gravity cannot have an influence on the ideal structure of a solid it certainly can on fluids. Furthemore as solid materials are often prepared via a fluid phase (steam, melting pot or solution) gravity might be expected to have an effect on the properties of the growth environment and hence the actual structure of a solid, that is to say its properties.

Bearing in mind the knowledge which is already available here, together with its interest (both scientific and practical) and the promising prospects which these two sectors hold out, they seem to be excellent bets for the future and really ought to benefit from an increased R & D effort. This would mean supporting basic research work so as to complement the theoretical foundation now to hand, and it would also mean that there would have to be adequate resources (both human and financial) as well as the "tools" for weightlessness studies (towers, aircraft, rockets, satellites, orbiting space stations).

Only the U.S.A. and the U.S.S.R. themselves posses all the necessary facilities for this type of R & D. It would seem that these two countries devote considerable resources to the field. In the Community only a few countries (acting on their own, via bilateral cooperation or collectively within the ESA) play any part in the exploration of this new area of scientific and technological investigation, and they only devote fairly modest resources to it, for a number of reasons.

ANNEX 11

SPACE

In its communication (COM 88 417 final) of July 1988, "The Community and Space: a Coherent Approach", the Commission reviews Europe's position in space, its strengths and weaknesses; it shows that, increasingly, Community policies and activities have a bearing on the evolving space field and vice-versa; it concludes that there is a need and opportunity for the Community to play a broader and more active role in space, a role which must be complementary to the one of ESA and the national agencies.

As things stand, the overall verdict on Europe's space activities seems to be altogether positive: space is an area in which, by establishing the ESA, Europe opted from the outset for cooperation, and that cooperation has rapidly led to some spectacular successes, such as the Ariane launcher, Spacelab, Meteosat , the Giotto mission, and the European Communication satellite system.

Created in 1975 out of the merger of the first European cooperative structures (ESRO and ELDO), the task of the European Space Agency is to develop and promote, for exclusively peaceful purposes, cooperation among European states in space research and technology and their space applications, with a view to their being used for scientific purposes and for operational space applications systems.

The first generation of programmes developed by the ESA amply attained their objectives giving Europe technological and industrial capability, in particular through the Ariane launcher and the applications technology (telecommunications and meteorology). By deciding in The Hague in 1987 to launch a new generation of programmes (the heavy launcher ARIANE V, the Hermes spaceplane, and the participation in the international Space Station through the Columbus programme) Europe firmly established its presence and its ambitions in the field of space. The new ESA long-term plan not only maintains the continuity of the scientific research programmes and the continued development of applications technology, but also represents a leap forward in both qualitative and quantitative terms.

However, alongside the strenghts to which these successes testify, Europe's space effort also suffers from a number of weaknesses. While a great deal of effort has been put into the development of space systems, there is still a need for a matching effort to encourage exploitation of the potential offered by these techniques.

In its Communication, the Commission defines how it can contribute to the realisation of Europe's ambitions in space and proposes six action lines that will guide the future development of its activities in this field of space. These action lines concern R&D and also other aspects of space relating to Community policies or competences (industrial, commercial, legal, etc.).

For what concerns R & D, the Commission has identified several areas in which the Community strategy for research and technological development (RTD) could complement and support the research effort of the space agencies.

1. Improvement of the synergy between the Community technology programmes and those of the space agencies.

Implementation of the new ESA programmes (Ariane V, Hermes and Columbus in particular) will call for the acquisition of new knowledge and technological expertise in a number of generic fields also relevant to other industrial sectors: information and communications technologies, robotics, advanced materials, aerodynamics, man-machine interface, reliability and safety of complex systems, quality control, energy sources, medical sciences and technologies, etc.

A comparative analysis of the technological requirements of the ESA programmes and the objectives of the Community's research programme shows many points of convergence. A large number of Community programmes are concerned: Esprit, Brite, Euram, RACE, medical and health research, radiation protection, non-nuclear energy, several JRC programmes and new programmes in the aeronautical sector and on robotics in hostile environments (Teleman).

Regular exchanges of information and coordination with the ESA are therefore indispensable both at the planning level and in the implementation of research programmes so as to avoid duplication and facilitate use by the space industry of the technologies developed under Community programmes.

The space programmes also generate new knowledge and technologies that could be used by non-space industries.

The space agencies' efforts to exploit technological opportunities could benefit from the experience and support from the Community activities to promote technology transfer and innovation.

2. Space technologies and facilities: tools at the service of research.

2.1 Study of our planet: climate, environment and impact of human activities.

Earth observation satellites are a major source of information for the development of climate models and the study of the impact of human activities on climate and environment.

The development of new remote sensing techniques and the gradual establishment of a world space observation network make it possible to plan for the systematic study of the planet and its global change (in particular greenhouse effect and depletion of the ozone layer) leading to the acquisition of knowledge vital to the more efficient management of our environment and of human activities.

Since this is a problem that has international implications and raises major issues for society, Europe must organize itself so as to play an active and consistent role in international programmes relevant to these areas (in particular the programmes Global Change and Mission to Planet Earth). It must rapidly define its objectives and priorities and set up the necessary mechanisms and resources enabling it to participate on a more even footing with the United States and the USSR.

Consultations with the parties concerned are being pursued to define the appropriate modalities to stimulate and coordinate efforts at European level and to ensure that there is a proper balance between space missions and the requirements of the scientific community.

2.2 Microgravity: encouraging preparations for the use of the orbital infrastructure

Like the United States and Japan, Europe is spending large amounts, mainly within the ESA, on setting up an orbital infrastructure which will greatly increase the opportunities for microgravity experiments,in particular, in the fields of advanced materials and biotechnology.
The ESA activities are focused essentially on the financing; a major additional effort is therefore needed to prepare for the use of this experimental potential.
Under existing research programmes the Commission intends to encourage a few collaborative projects that will bring

together various user groups on particularly promising subjects. At the same time it will continue its consultations with the ESA and other parties concerned in order to determine more precisely the priority objectives and procedures for a possible Community programme, on a wider and more ambitious scale, that would complement the activities of the ESA and the Member States.

3. Research and development to promote applications of space systems

3.1 Earth observation

The Community is already active in this field with the JRC's remote sensing programme which covers: research and development on methods and techniques for the interpretation of space data, pilot projects to demonstrate applications useful to the implementation of Community policies (agriculture, aid to development, environment) and training.

The Commission intends to broaden and expand its efforts not only for the requirements of its own policies but also to contribute to ensuring the optimal exploitation of the space sensing techniques in general.

Additional actions considered necessary include in particular:

- to stimulate through shared-cost projects, European cooperation and coordination in R&D on methods and techniques for processing and interpreting satellite data with particular attention to the needs of the users.
- to promote , in cooperation with the space agencies, the establishment of European experimental facilities (in particular airborne sensors) needed to prepare for the use of data produced by new types of sensors.

3.2 Telecommunications

Through its R&D activities the Commission will help to promote the development of applications of satellite systems, whether under the RACE programme (development of technologies for a pan-European integrated broadband telecommunications network), the new Delta programme (distance learning applications) or specific projects concerning the adaptation of ground equipment to the Third World Market.

SCIENCE & TECHNOLOGY POLICIES AND TRENDS

IN THE MEMBER STATES

Nov. 1988

S & T IN BELGIUM

1. General policy objectives.

At the beginning of 1986 the Minister for Science Policy declared that spending level of Belgium for R&D activities compared with the G.D.P. was insufficient and Belgium had to catch up with its neighbours and mainly with its closest neighbour : Netherlands.

Since that time the situation has changed somewhat and the emphasis is more on the means and incentives to encourage industry to increase its investments in R&D activities rather than increasing the public budget for research. Public financing should become more selective in choosing research programmes to support national public investment programmes. However, fundamental research will be the subject of increased attention. A number of measures have been devised to streamline the whole structure of the public financed R&D including drafting a new statute for government researchers.

Another topic of science policy is increased Belgian participation in European research programmes.

2. Priorities.

In the period from 1983 to 1986, the following were regarded as priority areas for projects designed to "mobilize" Belgium's industrial and scientific potential :

- data processing;
- aero-space (E.S.A. activities and new airliners);
- new materials;
- microelectronics (mainly introduction of microelectronics in SME);
- telecommunications;
- oceanography (pollution control).

In these fields, special attention was paid to possible ways of integrating national initiatives within the framework of a common European approach.

In the period since 1986, more emphasis was put in "stimulation" programmes and these relate, among others, to :

- artificial intelligence;
- life sciences.

R&D activities in space sector have also increased.

The following table gives some hints of the shift in priorities in Government funded research.

Breakdown of provisional R&D budgets by objectives in 1986 and 1987 (%).

Objectives	Provisional budgets 1986	1987
Exploration and exploitation of the earth	2.5	3.1
Infrastructures and general land-use planning	0.6	0.7
Control of environmental pollution	2.4	2.2
Protection and improvement of human health	2.1	3.0
Production, distribution and rational utilization of energy	10.1	9.5
Agricultural productivity and technology	7.2	7.6
Industrial productivity and technology	16.2	12.8
Social structures and relationships	0.7	0.5
Exploration and exploitation of space	7.3	9.8
Research financed from general university funds	22.8	22.3
Non-oriented research	20.5	23.6
Other research	6.1	3.8
Total financing of civil R&D	98.5	98.9
Defence	1.5	1.1
Total financing	100.0	100.0

Source : EUROSTAT : Government financing of R&D in Community countries.

3. Implementation.

3.1. Legal framework and institutional mechanisms.

For the Government funded research, different Ministries, concerned with R&D activities, supply the Interministerial Committee for Science Policy with their budget proposals which are presented in an annual "programme" through the Minister for Science Policy. The final decision on this "programme" is eventually taken by the Ministerial Committee for Science Policy.

The Minister for Science Policy (also Deputy Prime Minister and Minister for the Budget) plays a coordinating role within the government with regard to scientific and technological development. However, coordination does not extend to whole "science budget" because a significant part of this budget is the direct responsibility of the different Ministerial Departments concerned.

It must be noted that a recent law (August 1988) sets up federal structures for the Belgian State and a part of the responsibilities in the formulation of science policy is shared among the regions, the linguistic communities and to national authority. Nevertheless, responsibility for Community and international R&D activities rests with the national authority.

3.2. Strategy and research bodies.

The five following "action lines" are another element in the current strategy for the implementation of Belgian science policy :

1. Increased support for fundamental research;
2. Increased cooperation between universities and industry;
3. Promotion of greater private sector investment in R&D through State "incentives";
4. Large scale coordination of public authority involvement in science policy;
5. Maximum encouragement of participation in international projects.

Among the most important bodies implementing RD activities, other than University research institutes are the following :

- F.N.R.S. National Funds for Scientific Research (fundamental research);
- I.R.S.I.A. Institute for the encouragement of scientific Research in Industry and in Agriculture (applied research);
- C.E.N. Centre for Nuclear radioelements.
- I.R.E. Institute for radioelements.

4. National Resources.

4.1. Personnel (1)

Exact figures for R&D personnel are not available for recent years. It is estimated that :

Total R&D personnel (full time equivalent f.t.e.) : about 32,000 units (1983)

About 10,000 units (1985) are scientists or engineers employed by industry.

New administrative measures are being prepared to give scientists opportunities to move from university to private industry without jeopardising their career.

4.2. Financial means (2)

Government financing of R&D in 1987 : 673.2 Mio ECU (provisional budget)

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(1) Source : SPPS (1988).

(2) Source : OSCE (1988)

Defence R&D as % of total R&D Government appropriations : 1.1 % (1987)
Gross domestic Expenditure for R&D (GERD) : 1,542.6 Mio ECU (est.) (1985)

5. International cooperation.

Senior officials in charge of S&T research state that participation in present and future European cooperation in the field of RTD is a priority element in Belgian research policy.

So, the commitment of Belgium's potential to programmes implemented by European Communities or to EUREKA (Belgium participates in 27 EUREKA projects, as of 01.07.1988) will necessitate the allocations of appropriate resources at national level.
Belgium is represented in almost all international research organizations (CERN, EMBO, ESA, Airbus 330-340).

S & T IN DENMARK.

1. General policy objectives.

Science and Technology has been a top priority area since the mid-1980s in Denmark. Public Research & Development spending increased in the 1980-86 period by about 8 % per year (1980 = 100), one of the highest trends in the Community. The aim is to have a global national Research & Development Expenditure of 2.28 % of GDP by the year 2000.

In 1985 total R&D expenditure (GERD) amounted to about 1.26 % of the GDP. This placed Denmark in the category of the EC Member States with a medium degree of R&D spending per capita (at the same level as Italy, for example) but in a better position than Ireland, Spain, Portugal and Greece.

R&D is performed in the business sector (55 %), the higher education sector (24 %) and in public institutes (21 %) (with reference to R&D expenditure 1985 figures). The trend in R&D execution indicates, like the trend in R&D funding, a shift towards the business sector.

The policy objective with respect to research at universities and other institutions of higher education is to maintain freedom of research and a large measure of autonomy, but at the same time changes are desired in the research and teaching world. To great extend, this demand for change is reflected in budget planning and in terms of appropriations.

2. Priorities.

The Government intends to increase the collaboration between the relevant technical bodies at home and abroad, and to put more emphasis on concentrated inputs into developments areas with promising short or long terms economic prospects.

The newer initiatives include :

- Encouragement of collaboration between enterprises and centres of expertise in long-term technological development with government co-financing of co-operative industrial projects;
- Implementation of co-ordinated development programmes in areas vital to Danish trade and industry which call for a concerted inter-ministerial effort and comprehensive government initiatives in support of basic research and technological development and diffusion.

Emphasis will be put on :

- Improvement of researcher training and strategic research planning;
- Increased coordination and priority setting in the overall effort aimed at urban activities;

- Statements on agricultural and fisheries policies emphasize the increasing degree to which primary production industries are dependent on development efforts in the processing industry.

The technology - oriented R&D is mainly concentrated in the manufacturing sector which accounts for 20 % of the country's GDP. In the field of high technology, priority has been given to the following topics : Information Technology, Materials Research and Basic Biotechnological R&D.

The break down of the public R&D funding by groups of objectives indicates the priorities of the Government.

Breakdown of provisional R&D budgets by objectives in 1986 and 1987 (%).

Objectives	Provisional budgets 1986	1987
Exploration and exploitation of the earth	1.3	1.5
Infrastructures and general land-use planning	2.4	2.3
Control of environmental pollution	1.5	1.3
Protection and improvement of human health	3.3	4.8
Production, distribution and rational utilization of energy	6.7	4.4
Agricultural productivity and technology	7.0	8.5
Industrial productivity and technology	20.6	16.2
Social structures and relationships	4.3	3.6
Exploration and exploitation of space	3.1	2.6
Research financed from general university funds	29.5	32.1
Non-oriented research	19.7	22.3
Other research	0.1	-
Total financing of civil R&D	99.5	99.6
Defence	0.5	0.4
Total financing	100.0	100.0

Source : EUROSTAT : Government financing of R&D in Community countries.

3. Implementation

Research in Denmark is mainly the responsibility of the Ministry of Education and Research. The Ministry of Industry is responsible for technological development in trade and industry. In fact each ministry has responsibility for supporting research related to its functions (agriculture, energy, etc). The coordination is assured by the Ministry of Education and Research. The Research Directorate within this Ministry is also responsible for the coordination of the Danish participation to the EC Research and Demonstration Programmes, and to OECD in the field of S/T.

The trend in R&D funding is shifting, as in most EC Member States, to more industrial financed R&D. At present, the business sector funds about 49 % of the country's GERD. This places Denmark among those Member States where the business sector's contribution to the global national Research & Development spending is highest. Only in the FR of Germany and in the Netherlands the share of this sector was higher in 1985.

In Denmark there are no giant manufacturing enterprises which can provide a "technical drive" as in most European countries. The manufacturing industry is dominated by enterprises of small and medium size by international standards. Only about 80 manufacturers have a workforce of more than 500.

The national objective of industrial research policy is to develop and diffuse new technologies to these rather small industries through a service network, development programmes and co-financing.

The Developing Fund and Government Product Development Grants are the two schemes which jointly administer the part of technological promotion policy devoted to the co-financing of enterprise development activities.

In 1986, the commitments through these schemes amounted to 314 Mio DKr (about 40 MECU) and 171 Mio DKr (about 21 MECU) respectively. The sum of the two schemes represent approximatively half the total R&D costs of the Danish trade and industry.

Tax Incentives are additional instruments to promote industrial R&D and innovation. According to a tax law from july 1981 costs of research can be deducted from taxable income. A new tax law from December 1987 provides for a 125 % tax deduction for expenditures in the framework of the participation in BRITE, RACE, ESPRIT and EUREKA.

4. National Resources.

4.1. Human Resources (1)

The total of R&D workers in Denmark in 1985 was about 20,000 (full time equivalent), broken down as follows : researchers 43 %, technicians and others 57 %.

The industrial sector employed about 50 %, the higher education sector and the Government institutions about 25 % each.

The number of researchers per 1000 labour force equals to 3.1 (1985).

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(1) Source : Danish research administration and OECD.

4.2. Financial Resources.

The Danish R&D funding in 1985 showed the following break down :

Business sector :	3,759 Mio DKr	469 Mio ECU	49 %
Government funds :	3,567 Mio DKr	445 Mio ECU	46 %
Other fund :	366 Mio DKr	45 Mio ECU	5 %
Total	7,692 Mio DKr	959 Mio ECU	100 %

Source : Danish Research Administration.

The national R&D budget amounted to 4,036 Mio DKr (about 509 Mio ECU) in 1986. This corresponded to a ratio of the national R&D budget to the national budget of 1.55 %. The Government appropriated 0.4 % of the national R&D budget to defence R&D (1986) (1).

The financial contribution towards the R&D Expenditure in the public sector in 1985 came mainly from the Ministry of Education and Research (54 %), the Ministry of Agriculture (8 %) and the Ministry of Energy (7 %) (2).

For R&D promotion in Danish industry the Ministry of Industry provided roughly 1/4 of the public R&D expenditure. Estimates in the 1987 Finance Act indicate 1,050 Mio DKr (nearly 135 MECU) for this purpose (3).

5. International Cooperation.

Danish research and technology relies on the accessibility of results, regardless of source, and are dependent on wide international co-operation among researchers, institutes and laboratories irrespective of nationality. About 5 % (225 Mio DKr or 32 MECU) of the national Research & Development resources are attributed to the participation in international co-operation including the EC Research & Development programmes. Furthermore the participation in the Nordic research co-operation is of great interest to the country.

The EUREKA scheme was highly welcomed by Denmark. The Government's Action Plan earmarks 110 Mio DKr (about 14 MECU) for participation in the period 1986-1990. Denmark participates in 27 of the 213 EUREKA project (situation as of 01.07.1988).

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(1) Source : OECD.

(2) Source : Danish research administration.

(3) Source : OECD.

Nov. 1988

S & T POLICY IN FRANCE

1. Objectives.

The Government's Research Policy can be summarized as follows :
- priority to industrial research ;
- to maintain and even increase, in volume, the means for basic research ;
- to encourage or develop collaboration between fundamental and applied research ;
- to encourage the involvement of the entire industrial sector in the national research effort ;
- to provide a reasonable support to the "grands programmes" of technical development ;
- to promote the development of european co-operation.

During recent years, there has been an increase in R&D financing as percentage of GDP from 2.01 in 1981 to 2.31 % in 1985 and the target is to reach 3 % by 1990. In France research has been designated as a national priority.

2. Priorities.

The on-going programmes give a clear indication of the prevailing priority choices.
Programmes are of two main types :

- technological development programmes (PDT) with the objective to achieve large technological goals in nuclear energy, space aeronautics, telecommunications, electronuclear equipments;

- national programmes which regroup the actions of the Research and Technology Funds (FRT) and aim to promote the diffusing of basic technologies through many industrial branches.

The national programmes, which are subdivided in thirty-three priority research actions, are the following :
- Biotechnology
- Alimentation
- Medical research
- Human and social sciences
- Technology and production
- Electronics
- Research on land use & Transports
- Natural resources
- New materials
- New chemistry
- Research for development.

Breakdown of provisional R&D budgets by objectives in 1986 and 1987 (%).

Objectives	Provisional budgets 1986	1987
Exploration and exploitation of the earth	1.5	1.4
Infrastructures and general land-use planning	3.2	3.2
Control of environmental pollution	0.5	0.4
Protection and improvement of human health	3.8	3.6
Production, distribution and rational utilization of energy	7.1	6.7
Agricultural productivity and technology	3.6	3.6
Industrial productivity and technology	12.1	10.6
Social structures and relationships	2.9	2.7
Exploration and exploitation of space	5.8	5.9
Research financed from general university funds	11.8	12.0
Non-oriented research	15.1	14.7
Other research	1.6	1.1
Total financing of civil R&D	69.0	65.9
Defence	31.0	34.1
Total financing	100.0	100.0

Source : EUROSTAT : Government financing of R&D in Community countries.

3. Implementation.

3.1. Legal Framework and Institutional Mechanisms

Each year, the R&D national policy in France is described in great details in a report entitled "The State of Research and Technological Development" annexed to the annual Budget (Projet de Loi de Finance).

Since June 1988, a new Ministry for Research and Technology (MRT) has been created who is responsible for the S&T policy. The Space policy is under the Ministry of Post, Telecommunications and Space. Other Ministries have also an important role in animating scientific and technical activities. Coordination is assumed by MRT through the procedure of the establishment of the Civil Budget for R&D (BCRD).

3.2. Decentralization

Among the several actions to promote decentralization, one can mention the following :

- The "Contrats de Plan Etats-Régions", as well as joint agreements linking national research institutes with the regions, have been devised to bring the decision making closer to the periphery. The central state remains however the prime mover.
- The number of regional innovation and technology transfer centres (CRITTs) has been increased. Their activities mainly concern areas which are essential to the development of the regional industrial structure of small and medium-sized firms.

Some of the main actors for a concerted regional policy are :

- Regional Delegates for Research and Technology (DRRT) with a role to provide information and promote awareness of the regions concerning the national policy; to co-ordinate research and technological development activities at regional level; to organize the technology transfer; to encourage the diffusion of scientific and technical culture and information;

- The representation of research organisms in the regions.
  The principal research organisms have been endowed with representatives in the regions in order to facilitate the dialogue between the different research partners.

3.3 Industrial Research

Industrial research in France as compared to public research has not yet reached a level similar to its main competitors, not only in terms of research financing by the companies, but also in terms of the share they are taking in research execution. This is due to the fact that in France the public research centres have a long tradition of being the main research actors and as such they continue to weigh heavily in the overall national R&D structure.
In 1986, 43 % of the GERD was financed by the enterprises as opposed to 57 % by the administrations and 58 % of the GERD was performed by the enterprises as opposed to 42 % by the administrations. The largest share of the increase in industrial expenditures on R&D came from big national enterprises and high technology groups.

ANVAR has the mission to help companies to take more benefit from the results of technological development programmes, and will more and more favour small and medium size companies (for which it devoted 80 % of its credits in 1987) as well as the creation of new enterprises.

Loans on favorable terms provided mainly by the ANVAR should help set up applied and goal oriented Research programmes with the aim to develop collaboration between the various bodies involved : public research establishments, industry or firms in the services sector, technical centres and research companies under contract.
Such programmes should make it possible to allocate public funds to sectors in which the need for strong research stimulation is being felt.

3.3.1. Direct Support to Industrial Research

Direct support goes through thematic programmes funded by the "Fonds de la Recherche et de la Technologie - FRT" mainly devoted to basic technology, the so-called "generic" or "diffusing technology".

There has been a significant increase in direct aid to industrial research granted in the form of subsidies or repayable aids which the State or its public establishments tend to give for innovation projects or research presented by industrialists.

3.3.2. Indirect Support
The tax credit in favour of research consists of a reduction in income tax of enterprises representing 50 % of the increase in volume, from one year to the next, in their R&D effort, with a ceiling of 5 millions F.
In 1988, this ceiling of 5 millions francs will be raised to 10 million francs in cases where the enterprises present a research programme in collaboration with a university, a research centre, or another enterprise.

ANVAR has proposed for Small Medium Enterprises (SME) a financial aid in hiring high level researchers. For each researcher hired, the SME will receive 150,000 F (22,000 ECU), half of it at the moment of recruitment and the rest one year after hiring.

3.4. Research Training

The French government has devised the following mechanisms :

- Research grants financed directly by the previous ministry responsible for Research and higher Education
- Aids for training financed directly by public research organisms
- Industrial agreements for training by research (CIFRE)
- Centres for the technology training of engineers by research

4. National Resources

4.1. Human Resources (1)

In 1985, there were 273.014 people (full time equivalent) working in Research, from which 102.336 researchers.

4.2. Financial Resources (2)

Gross Domestic Product (GDP) : 674.8 Billion ECU (at current prices and exchange rates (1985)
Gross Domestic Expenditure for R&D(GERD): 15,587.4 Mio ECU (1985)
GERD / GDP : 2.31 % (1985)
R&D Budget : 10273.1 Mio ECU (1986) (3)
R&D Budget / National Budget : 6.34 % (1986)

In 1986, 43 % of GERD was financed by enterprises. This figure is considered low as compared to FRG and Japan and that is the reason why the strengthening of industrial research figures among the top priorities of the French government.
In 1986, the R&D financing for research in Defence represents 32.5 % of the total R&D government appropriations.

5. International Cooperation.

France participates in all the programmes included in the E.C. framework Programme.
A great importance is also attached to the International co-operation in R&D. Under a French impulse, three international initiatives have so far been launched :
the International Co-operation in the domain of Technology, Growth and Employment (TGE) (Versailles 1982), the EUROPEAN NETWORKS (Council of Europe, Paris 1984) and EUREKA (July 1985). France participates in 105 EUREKA projects (as of 01.07.1988).

Among European cooperation in which France participates, the following can be mentioned : C.O.S.T.; CERN; ESA, THE EUROPEAN SYNCHROTRON RADIATION FACILITY (E.S.R.F.) and other heavy equipments;...

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(1) Source : Projet de Loi de Finances pour 1988.

(2) Source : OCDE

(3) Source : OSCE

Nov. 1988

S & T IN THE FEDERAL REPUBLIC OF GERMANY.

1. General policy objectives.

Science, research and technological development are a mainstay of the German economy's innovative capacity. The orientation of the S & T policy in the Federal Republic of Germany is directed by the following closely interrelated precepts :

- adherence to the principle of "freedom of research" and promotion of individual initiative;
- accordance with the principle of "subsidiary funding"; the Government therefore acts with restraint vis-à-vis R&D in industry and acknowledges "entrepreneurial self-reliance";
- a positive attitude to technological progress and economic growth.

The country's gross domestic Expenditure on R&D (GERD) was 2.66 % of GDP in 1985. Estimates for 1987 indicate a GERD of 2.8 % of GDP. These figures are very close to the comparable indicators of Germany's main competitors on the world market USA and JAPAN and ranks it in first place amongst its partners in the EC.

2. Priorities.

In accordance with the guidelines and objectives the Federal Government will focus on the following fields :

- Increased promotion of basic research through joint financing by the Federal and Länder governments according to existing agreements.

- Expansion of "preventive" research (particularly : ecology, health, climate research).

- Promotion of research and subsidiary funding of industry in the area of market-oriented technologies particularly :

  - information technologies and materials research;
  - the completion of the Airbus family;
  - biotechnology with emphasis on genetic engineering, molecular biology and regenerative raw materials;
  - selected physical technologies (laser, thin-film technology);
  - regenerative energy technologies.

- Improvement of the basic conditions for introduction of innovations in small and medium-sized companies.

- Strengthening of areas of research with long-term prospects (nuclear fusion, polar research, space research).

- Expansion and intensification of international cooperation.

- Research and responsible discussion about the impact and implication of technology.

The percentage break down of the public R&D funding in groups of objectives indicates the priorities which are attributed by the Government.

Breakdown of provisional R&D budgets by objectives in 1986 and 1987 (%).

Objectives	Provisional budgets 1986	1987
Exploration and exploitation of the earth	2.1	1.9
Infrastructures and general land-use planning	1.9	1.9
Control of environmental pollution	3.3	3.3
Protection and improvement of human health	3.0	3.2
Production, distribution and rational utilization of energy	10.5	8.7
Agricultural productivity and technology	2.0	2.0
Industrial productivity and technology	14.3	15.3
Social structures and relationships	2.3	2.3
Exploration and exploitation of space	4.5	4.9
Research financed from general university funds	31.8	31.5
Non-oriented research	11.8	12.3
Other research	0.1	0.2
Total financing of civil R&D	87.6	87.5
Defence	12.4	12.5
Total financing	100.0	100.0

Source : EUROSTAT : Government financing of R&D in Community countries.

3. Implementation.

The responsibility for the German S/T policy is partly with the Länder Governments, which are responsible for the universities and their R&D, and with the Federal Government mainly with the Federal Ministry for Research and Technology (BMFT) which directs the non-university R&D.

In laying down the guidelines for its policy the Government is supported by independent institutions like the German Research Society (DFG), and the Max Planck Society (MPG). The link between science and industry is provided by the Fraunhofer Society (FhG).

Research, development and innovation, which today form the major part of R&D expenditure, are considered as fundamental and necessary tasks of the firms. There is agreement between government and industry that disadvantages in international competition cannot be overcome by government financing. The appropriate efforts have to be made by the firms themselves, the government's R&D policy having the task of creating an environment for private innovation that is conducive to performance and growth.

Particular importance however is attached to the role of the SMEs which, in the Government's view, are an important factor for the performance and competitiveness of German industry.

The promotion of R&D in industry by indirect measures and tax reductions is based on incentives, but the definition of the content of the R&D is left to the firms themselves. The development of these appropriations and tax concessions to industry over the last years gives the following pictures :

Year	1983	1984	1985	1986	1987*
Global Government Mio DM contributions Mio ECU	852 375	982 439	1,185 532	1,258 591	1,139 550

Source : Bundesbericht Forschung 1988 (BUFO) * : estimates

The promotion of R&D in specific areas of technology or of product groups focused mainly on microelectronics, manufacturing techniques, microperiphery components and biotechnology. The development of this spending, the so called indirect specific financing, are as follows :

Year	1983	1984	1985	1986	1987*
Global Government Mio DM spending Mio ECU	151 66	161 72	133 60	135 63	117 57

Source : BUFO 1988 * : estimates

4. National Resources.

4.1. Human Resources (1)

The number of researchers per 1000 labour force equalled to 4.8 in 1983. The total of R&D workers in the Federal Republic of Germany in 1985 was 398,328 (full time equivalent), broken down as follows : researchers 36 %, technicians 30 %, others 34 %.

The industrial sector employs by far the largest part of the R&D personnel (about 2/3) of which 34 % are researchers and 31.4 % technicians. An increase of 10.3 % of the R&D personnel was registered between 1983 and 1985 in this sector.

In the other sectors the researchers form the greatest part of the R&D staff. In the universities 42.7 % are researchers but this figure was slightly decreasing between 1983 and 1985.

4.2. Financial Resources (2)

The national R&D budget amounted to 21,375 Mio DM (10,049 Mio ECU) in 1986. This corresponded to a ratio of the national R&D budget to the national budget of 4.2 %. The Government appropriated 12.4 % of the national R&D budget to defence R&D (1986).

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(1) Source : BUFO.

(2) Source : OECD (provisional data).

The country's R&D expenditure has increased substantially in recent years, mainly the industry's part (61 % of the total R&D expenditure in 1987). The tables below indicate the development over the last years.

R&D expenditure share by financing sectors.

	1981	1983	1985	1986	1987
Federal Government As % of total R&D spending	26.3	25.9	24.6	24.0	24.3
Länder Governments As % of total R&D spending	16.2	14.7	13.7	13.5	13.4
Industry As % of total R&D spending	56.1	57.9	60.3	61.1	61.0
Private non-profit inst. As % of total R&D spending	0.4	0.4	0.3	0.3	0.3
Total domestic financed R&D As % of total R&D spending	99.1	98.9	98.9	98.9	98.9
From abroad funded R&D As % of total R&D spending	0.9	1.1	1.1	1.1	1.1

Source : BUFO 1988

Over 90 % of the Federal research appropriations are provided by four Federal ministries, the Federal Ministry for Research and Technology (BMFT), the Federal Ministry of Defence (BMVg), the Federal Ministry of Economic Affairs (BMWi) and the Federal Ministry of Education and Science (BMBW). The BMFT supplied some 55 % of the funds in 1987.

5. International Cooperation.

The Federal Republic of Germany, with its heavily export-oriented economy, has a great interest in international cooperation.

In 1987 the funds which went abroad or to international organizations amounted to about 8 % of the Federal Government's R&D appropriations. According to estimates the expenditure from government and industry will amount to some DM 1,700 million (about 630 million ECU) in 1987.

The Government attaches great importance to EC research and technology policy. It sees safeguarding Europe's economic, industrial and technological capabilities by coordinating and promoting R&D as another means of uniting Europe.

EUREKA is seen as a cooperation beyond national boundaries in which economic activities can be pursued by appropriate coordination. The German industry particularly wants standards to be harmonized at an early stage and in parallel with research and development. German firms and research institutes are participating in 66 of the 213 EUREKA projects. The German participation to these projects was estimated to 1,150 Mio DM (about 575 Mio ECU) (as of June 1988).

Nov. 1988

S & T POLICY IN GREECE.

1. Objectives.

The main objectives set by the 1988-92 National plan for research and technology are :

- Creation of the necessary infrastructure with increasing importance to the creation of human research and managerial potential.
- Formulation of specialised sectoral programmes in agriculture, industry, energy, etc. Particular efforts will be made to promote the development of high technology.
- Diffusion of S & T information (creation of networks).
- Promotion of technology transfer and international cooperation.
- Encouragement of innovation.

GERD as a percentage of GDP has increased steadily from 0.21 % in 1981 to 0.35 % in 1985. The aim is to reach 0.65 % in 1992.

2. Priorities.

High priority has been given to :
- Industrial research Development Programme;
- Social and human sciences;
- Information technology;
- Biotechnology;
- Energy;
- Agriculture.

Breakdown of provisional R&D budgets by objectives in 1986 and 1987 (%).

Objectives	Provisional budgets 1986	1987
Exploration and exploitation of the earth	5.5	7.1
Infrastructures and general land-use planning	0.4	0.3
Control of environmental pollution	3.4	2.1
Protection and improvement of human health	9.3	7.4
Production, distribution and rational utilization of energy	2.6	3.6
Agricultural productivity and technology	24.9	26.0
Industrial productivity and technology	8.7	11.2
Social structures and relationships	6.4	7.3
Exploration and exploitation of space	0.6	0.4
Research financed from general university funds	26.9	25.3
Non-oriented research	6.1	6.7
Other research	2.2	0.3
Total financing of civil R&D	97.1	97.7
Defence	2.9	2.3
Total financing	100.0	100.0

Source : EUROSTAT : Government financing of R&D in Community countries.

3. Implementation.

3.1. Legal Framework and institutional mechanisms.

The law (1514/85) on the "Development of Scientific and Technological Research" has been promulgated and aims at setting the foundations for a new policy with concrete objectives and organization of the R & T activities related to Greece's socio-economic development.

The General Secretariat for Research and Technology (G.S.R.T.) is an autonomous body within the Ministry of Industry, Energy and Technology and is responsible for the drawing up and the implementation of the five-year plan for Research and Technological Development, the elaboration of new programmes, the promotion of technological development, the activation and development of Research and Technology potential, the importing and exporting of know-how, research evaluation and coordination of R&D activities between the various actors.

There are, however, other ministries that organise and fund their own R&D activities over which the G.S. R.T has not, so far, any jurisdiction. To improve consistency and to promote coordination, all the competent ministries have participated in the preparation of the new Plan (1988-1992).

3.2. Research Centres and Universities.

Intense efforts will be made to attain the larger possible participation of Greece in programmes issued within the framework of bilateral agreements.

In order to improve the technical infrastructure, efforts are made to draw a greater advantage from the EEC programmes, FEDER, etc. and to make a more efficient use of the existing research equipments by the research units and universities.

With the exception of Universities who are free to choose the topic of their research, public financing of research centres and institutes will depend on their ability to obtain grants from third parties (specially from the EEC), to work closely with the production sector, to contribute in the technological development of the country, to execute programmes of a greater national or social interest and to promote the country's reputation in the domain of research.

Efforts are made to institutionalize concrete research incentives to researchers and technicians, which with their own initiative will bring to the research centre or institution external subsidies from financing organizations or income from services, or selling of products.

In order to bring Research closer to the production sector, the <u>Cofinancing Programme</u> has been devised according to which Higher Education Institutions (Universities or Technical Colleges), or research centres can submit proposals for financial subsidies of some research projects provided that they have previously managed to obtain 30 % financing of the total cost of the project from a production unit or a social body.

3.3. Industry.

Until recently Greek firms have been little involved in technological research activities, and the research work carried out in State research institutions have been cut off from the productive branches of the economy.

The following measures have been adopted in order to encourage research in the industry :

- In the Industrial Research Development Programme, it is foreseen a subsidy of 40-50 % of the research work carried out by an enterprise.
- In the law 1262/87, it is foreseen a subsidy for the establishment or expansion of laboratories in the enterprises.
- There is a possibility of deducting research expenses from the taxable sum and amortization of research equipment costs within three years (Law 1731/1987).
- Financing the creation of prototypes by the Greek Organization for SME and handicraft (EOMMEX) and the G.S. R & T.

3.4. Technology Transfer.

A new law 1733/22.09.1987 on "Transfer of Technology, Inventions and Technological Innovations" has been recently passed which aims to assist the firms with technology transfer into Greece, and endogenous technological development. The law provides for the establishment of an organization for industrial property rights which will be in charge of monitoring the application of this law.

In order to solve effectively the problems of technology transfer in some selected industrial sectors and the linkage of research with production, some technical sectorial companies have been created for technical assistance to the existing SME in those sectors.

3.5. Patents and "Know-how".

To promote the role of patents in the exploitation of the research results and the innovation, Greece modernised the national legislation covering this sector with the enactment of the law 1733/1987 mentioned above and the ratification of the European Patent Convention. In collaboration with the European Patent Organization, a five year programme has been formulated for the development of the corresponding Greek Organism (OBI).

3.6. Innovation.

In 1982, the Greek Organization of Small and Medium Enterprises and Handicraft (EOMMEX) started a programme for the promotion of innovation in the SME in Greece. In this way a Central Innovation and Technological Development Directorate (DIKTA) was created as well as 5 local offices of innovation in five different cities of Greece.

4. National resources.

4.1. Human Resources (1)

Number of researchers per 1000 labour force : 0.8 (1983).
To reverse the acute problem of "brain-drain" Greece is determined to proceed with the creation of the proper working conditions in order to attract back some of the eminent Greek scientists who work abroad.

4.2. Financial Resources (2)

Gross Domestic Product (GDP) (at current prices and exchange rates) : 42.8 Billion ECU (1985)
Gross Domestic Expenditure for R&D (GERD) : 148.9 Mio ECU (1985)
GERD/GDP : 0.35 % (1985)
Percentage of GERD financed by industry : 26.3 % (1985)
R&D Budget : 99.5 Mio ECU (1986) (3)
R&D Budget/National Budget : 0.67 % (1986)
Defence R&D as a % of total Government appropriations : 2.7 % (1986).

5. International Cooperation.

The participation of Greece in the Community R&D programmes has increased substantially over the period 1984-1987, and the total Community funding for this period reached the sum of 38.6 Millions ECU. Bilateral and multilateral agreements for cooperation on R & T exist between Greece and several countries from the Western and Eastern bloc.

For example, within the framework of a bilateral agreement between Greece and Germany, a unique solar energy village (435 dwellings utilising seven different energy systems) has been constructed in the Athens area.

Among the activities devised within the framework of bilateral collaboration, 40 % (in number) will concern exchange of scientists and the other 60 % joint application programmes. Greece participates in 8 EUREKA projects (as of 01.07.1988).

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(1) Source : OECD.

(2) Source : OECD

(3) Source : OSCE.

Nov. 1988

S & T IN IRELAND

1. General Policy.

During 1987 Irish Science and Technology was considerably reorganised. A Minister for Science and Technology was appointed for the first time. The Ministry of Science and Technology is located within the Department of Industry and Commerce.
Within a wide general programme of rationalization of Government activity, Ireland's major public scientific and technological institutions were amalgamated.

Government has accompanied this reorganization with a shift of S & T focus towards fostering a greater effort by indigenous firms in science and technology.
At a time of widespread cuts in all Government expenditure the Minister for Science and Technology allocated £ 2.5 m (3.2 MECU) additional to earlier budget provision. Indigenous development played a major part in the programme set out (1).

" This programme :
- will support the placement of the best and brightest science and engineering graduates in industry;
- will develop centres of excellence and applied research in our higher education institutes;
- will establish a national programme of technological innovation to extend and enhance existing research grant schemes administered by the National Board for Science and Technology;
- Institute for Industrial Research and Standards to acquire much needed test equipment so as to give Irish industry the range of services needed in today's circumstances."

2. Priorities.

S&T Strategic Research Programme emphasizes application-orientated research and has identified Biotechnology, Engineering, Advanced Materials and Information Technology as priorities.

Additional Policy aims consistent with concentrating natural S&T effort on indigenous firms are :
i) increasing the innovation rate in Irish enterprises;
ii) tackling the structural barriers of industry which inhibit better technological capacity and performance.
iii) developing a modern information and intelligence network.
iv) accelerating the adoption and application of new industrial technologies.
v) creating greater awareness of the importance of science and technology and an improved climate for entrepreneurship.

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(1) New Science and Technology Development Programme"
Dr S. Mc Carthy, Minister for Science and Technology, Dublin, 11th June 1987.

vi) mobilising and optimising public and publicly funded S & T agencies and services in support of the innovation drive by ensuring coordinated programmes of actions within and between agencies by :

- supporting mobility of personnel;
- making efficient use of scarce national facilities;
- gaining maximum benefit from international cooperation;
- focussing selectively on areas of technology assessed as priorities;
- ensuring viable quality programmes with prospects of successful outcome assumed by good management and technical capability of the teams.

vii) participating wherever possible in collaborative R&D.

The South East Region, one of the weaker regions in S&T, has been declared a pilot region for S&T related economic development.

Table 1

Breakdown of provisional R&D budgets by objectives in 1986 and 1987 (%).

Objectives	Provisional budgets 1986	1987
Exploration and exploitation of the earth	0.7	0.6
Infrastructures and general land-use planning	3.9	4.2
Control of environmental pollution	0.8	1.0
Protection and improvement of human health	4.9	3.9
Production, distribution and rational utilization of energy	1.2	1.1
Agricultural productivity and technology	27.3	24.2
Industrial productivity and technology	26.1	27.2
Social structures and relationships	8.0	10.0
Exploration and exploitation of space	1.1	2.3
Research financed from general university funds	23.9	23.0
Non-oriented research	2.1	2.5
Other research	-	-
Total financing of civil R&D	100.0	100.0
Defence	-	-
Total financing	100.0	100.0

Source : EUROSTAT : Government financing of R&D in Community countries.

3. Implementation.

In the wide ranging changes conducted in 1987 and implemented in 1988, the primary policy and resources management agencies were changed.

The National Board for Science and Technology (NBST) - the primary S&T policy advising and co-ordination agency and the Institute for Industrial Research and Standards (IIRS) - the primary S&T application agency - have been amalgated to form the new body EOLAS.

An Foras Taluntais (AFT) - the Agricultural Institute - the primary agency for agricultural research and ACOT - the primary agricultural training and development agency have been amalgamated to form the new body TEAGASC - The Agriculture and Food Development Agency.

The functions of the environmental Research Institute (AFF)- have been either taken into the Dept of Environment or given to TEAGASC or EOLAS. The functions previously carried out by the Medical Social Research Board and Medical Research Council were subsumed into the new Health Research Board.

All fee earning S&T services have been forced to seek higher returns. Dependence on fee income has undoubtedly resulted in greater efficiency in the provision of S&T services. There is a danger, however, that non-fee earning developmental work will be curtailed at the expense of fee-earning activities.

Overall reduction in exchequer funding of S&T activities has resulted in the curtailment of certain S&T activities, particularly those which are not fee earning.

4. National Resources.

4.1. Personnel (1)

Considerable reductions in staff at the main public S&T institutes have also been sought as part of Ireland's general drive to reduce public expenditure in its attempt to overcome the economic difficulties arising form its foreign debt.
The number of researchers in Ireland per 1000 Labour force is 2.8 %.

2. Financial Resources.

S&T has had a small budget increase in 1987 despite widespread cuts in most other spending departments. Government Expenditure on S&T increased in real terms by 1.4 % per annum average from 1981-87. Current expenditure on S&T increased by 3 % per annum in real terms 1985-87. However R&D Expenditure as % of GDP has remained around 0.8 % of GDP. All of Ireland's R&D expenditure is Civilian R&D.
S&T Expenditure has declined in Agriculture and Energy and increased in S&T for the Manufacturing Sector.
Table 2 provides pattern of expenditure.

Table 2

GOVERNMENT EXPENDITURE ON SCIENCE AND TECHNOLOGY, 1982-1986 IR£ MILLION

	1982 (IR£m)	1983 (IR£m)	1984 (IR£m)	1985 (IR£m)	1986* (IR£m)	(MECU)
Voted Current Monies	213.2	221.5	237.7	258.9	278.4	363
Voted Capital Monies	34.2	38.5	34.4	34.7	46.6	61
Non-Exchequer Monies	24.4	49.4	62.9	70.4	73.3	96
Total	271.8	309.4	335.0	364.0	398.3	520

* Budgetted expenditure

Source: NBST

(1) Source : NBST Annual report.

Current expenditure, which represents mainly labour costs, provides a better guide to overall activity levels. Total current expenditure increased by 3.1 % in real terms between 1985 and 1986.

The Government component of this expenditure has, however, decreased in real terms between 1981 and 1986, with current expenditure decreasing by 2 % and capital by 1 %. This decrease in exchequer funding had been matched by a real increase in non-exchequer income of 68 % between 1981 and 1986.
Indigenous firms contribute one third of total expenditure by firms in Ireland on R&D. In 1982 of 5,652 owned firms only 74 had formal R&D departments, only 231 conducted any R&D.

There was a drop in funding for R&D due almost entirely to a reduction in Government support for the Agriculture Sector. Agricultural R&D expenditure has decreased in real terms by 17.7 % since 1981.

Government support for R&D in the Manufacturing sector has grown steadily however since 1981 - recording a real growth of 99 % over the five year period to 1986. GERD/GDP is 0.8 %. R&D to support manufacturing is now the largest element of State R&D activities.

The higher education sector was the other major recipient of Government funds for R&D, indirectly through the general education block-grant from the Department of Education and the Higher Education Authority, and directly through specific research-support schemes.

5. International Cooperation.

As a small economy, peripherally located, Ireland regards international S&T participation of crucial importance and seeks participation. In Community programmes in which Ireland participates, it is very successful relative to population size.

It regards the main benefits as enhancement of the scientific and technological competence by offering it :

i) the means to develop an outward orientation and participation in the wider world of science;
ii) opportunities for sharing the costs of specific research programmes and facilities;
iii) the means to access specific scientific and technical information and to gather technological and commercial intelligence;
iv) opportunities for acquiring technology through licensing and other methods of transfer.

Ireland participates as of July 1988 in 6 EUREKA projects.

Nov. 1988

S & T IN ITALY

1. General Policy Objectives.

Scientific research and technological development are a current priority for the Italian Government and business enterprises.

The ratio Gross domestic Expenditure on R-D (GERD)/Gross Domestic Product (G.D.P.) increased from 0.74 % in 1980 to 1.40 in 1988.

The overall objective is to increase the GERD for the next 4 or 5 years in a such way as to reach the ratio GERD/GDP value of about 2.4 % comparable to that of other Community countries such as France and U.K.

For research personnel, between 1969 and 1985 Italy was the second country (of the OECD geographical area) to show the highest annual increase rate for researchers (about 5.9 %).
A particular effort will be made in training and recruiting young scientists for which a serious shortage is foreseen in the near future.

Italian researchers are also eager to develop more than before as much international cooperation as possible.

The percentage of scientific papers published by Italian scientists with foreign co-authors is the highest of all OECD countries.

2. Priorities.

Specific priorities are set in the field of advanced technologies in order to give an edge to Italian industry in the competition for supplying the internal and foreign markets.

A major emphasis will be put on the following sectors :

- biotechnologies and fine chemicals ;
- electronic data processing (micro- and molecular electronics) ;
- new materials (semi-conductors, ceramics, etc.) ;
- thermonuclear fusion ;
- broadband telecommunications ;
- optics and lasers ;
- advanced transport ;
- satellites and space crafts ;
- biomedical instrumentation ;
- educational training technique.

One field of research is to be reduced in importance, viz, nuclear fission because the majority, in a national referendum in 1987, expressed a negative position towards the continuation of electricity production with the present generation of nuclear reactors. However, research is continuing at a reduced scale on an "intrinsically safe" fission reactor.

The following table highlights the shift in the priorities between 1986 and 1987 in government funded research.

Breakdown of provisional R&D budgets by objectives in 1986 and 1987 (%).

Objectives	Provisional budgets 1986	1987
Exploration and exploitation of the earth	1.1	1.4
Infrastructures and general land-use planning	0.9	0.8
Control of environmental pollution	1.0	0.9
Protection and improvement of human health	4.4	4.5
Production, distribution and rational utilization of energy	17.4	11.1
Agricultural productivity and technology	3.7	3.5
Industrial productivity and technology	19.1	19.1
Social structures and relationships	1.1	1.2
Exploration and exploitation of space	6.9	9.3
Research financed from general university funds	28.6	31.9
Non-oriented research	7.0	6.6
Other research	0.4	1.9
Total financing of civil R&D	91.6	92.2
Defence	8.4	7.8
Total financing	100.0	100.0

Source : EUROSTAT : Government financing of R&D in Community countries.

3. Implementation

Several ministries, research bodies and industry are responsible for carrying out R&D activities. At present the Minister for S&T research has a certain amount of coordination power for the public financed R&D. A law, approved by the Senate and now presented to the other branch of the Parliament, will set up a Ministry responsible for University and the scientific and technological research.

The Minister for University and S&T research will have his own budget and should be in a position to coordinate the whole public financed R&D activities and to draw guidelines for the private funded research via fiscal and other incentives to industry.

The most important decision-making body at ministerial level, which has an overall competence in all matter concerning the Italian economy, is the C.I.P.E. (Interministerial Committee for Economic Planning). The new Minister, above quoted, will be a permanent member of C.I.P.E.

Among the largest bodies, other than University Institutes,responsible for carrying out research, the following can be quoted :

- C.N.R. (National Research Council) ;
- I.N.F.N. (National Institute for Nuclear Physics) responsible for research in high energy physics ;
- A.S.I. (Italian Space Agency) established in June 1988 ;
- I.S.S. (Central Institute for Public Health) ;
- E.N.E.A. (National Organization for R&D of Nuclear and new Energy sources).

The targeted projects ("progetti finalizzati") promote applied research with reference to well-defined topics involving the adoption of multi-disciplinary methods and having recourse to integrated scientific skills at different levels, e.g. the Universities, C.N.R., industry and other central, regional and local administrative bodies.

In addition to the attainment of specific economic relevant goals in the short term, the targeted projects are concerned with the medium-/long-term examination of particular problems affecting production and social development.

As far as industrial R&D is concerned, it must be noted that the general picture produced by the examination of the statistical indicators of industrial research reveals the tendency of Italian industry to give priority to products having an average technological content.

The share of industrial R&D in the formation of the GERD has these last years been about 50 % of the total, but industry's share as a performer of R&D was about 57 % in 1985.

4. National Resources

4.1. Personnel (1)

Total R&D personnel (full time equivalent f.t.e.) : 117,887 units (1985)

Total R&D Scientists and Engineers, Researchers (f.t.e.) :63,759 units (1985)

Number of researchers for 1000 labour force : 2.7

(1) Source : O.C.D.E., Paris : Main S&T Indicators 1988.

The higher education system of Italian universities delivers only one qualification in natural sciences and engineering while three types of university qualifications (diploma, degree and doctorate) are required for being in line with most Western countries.
In order to cope with the shortage of researchers forecast for the coming years it is planned to recruit 50,000 young researchers in the next five years.

4.2. Financial Means (1)

Government financing of R&D in 1987 : 4,754.5 Mio ECU
(provisional budget)

Defence R&D as % of Total R&D Government Budget : 7.8 % (1987)

Gross domestic Expenditure for R&D (GERD)in 1985 :6,307.3 Mio ECU

GERD / GDP : 1.33 % (1985)

5. International Cooperation

Senior officials in charge of S&T research think that participation in research projects based on international cooperation at both European and non-European level is essential for maintaining Italian science and technology in the orbit of more advanced countries.

Moreover, there is not only an attempt to open Italy's science programme to international cooperation on a broad scale but also a desire for interaction and adjustments between Community or international programmes and national projects.

Therefore the Italian scientific world has expressed its interest for participation in the first and second Community framework programmes mainly in large Community actions such as ESPRIT, RACE, Fusion, BRITE and EURAM.

Italy is present in 59 EUREKA projects (as of 01.07.1988) and participates to EMBO and other international research organizations.

Italy is an active member of CERN as well as of the European Space Agency (ESA) and about one half the Italian funds for space research are allocated to the ESA projects.

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(1) Source : OSCE

Nov. 1988

S & T IN LUXEMBOURG

1. General Policy Objectives.

Up to 1987 all the R&D activities in the Grand-Duchy were carried out by private enterprises. A law approved in March 1987 by the Parliament gave power to the Government to set up a certain number of Public Research Centres (PRC). These centres will be financed by public funds. Moreover a certain amount of public money is set aside for special scholarships designed to train researchers.

With the establishment of PRC the Government wishes to foster industrial innovation through the transfer of research results to private enterprise. Nevertheless the role of Government in the whole process of technological innovation shall remain only and exclusively as an encouraging role, with business enterprises managing entirely the function of innovating their products.

2. Priorities.

The broad guidelines of the science policy for the publicly financed research are set out by a special Commission "Research and Innovation" of the Parliament and professional Guilds are consulted for advice.

One of the most important priorities is the training of highly specialised researchers in all fields.

Cooperation with foreign scientists is also considered of primary importance given the limited fields of coverage of the PRCs now operational.

Particular attention is devoted to the transfer of results, gathered in public research establishments, to industrial innovation.

Specific priorities are the following :

- data processing and bureautics (software);
- micro-electronics;
- biotechnology for the protection of the human health and for the environment;
- new materials (mainly for steel and chemical products, ceramics and composite materials).

3. Implementation.

The Interministerial Committee for Research and Technological Development, whose members are appointed by the Government, is responsible for coordination and funding of Government financed research and training scholarships. Moreover, this Committee acts as an advisory body for the Minister responsible for scientific and applied research (the Minister for Education and Youth).

At present, only three PRCs are operational but other three or four more are planned and they will be progressively established in the next four or five years.

Industry is, at present, totally responsible for funding its research activities which are mainly carried out in about ten sectors :

- steel, rubber and metal products;
- metallic building structures;
- chemistry, thermoplastics and powder metallurgy;
- electric house appliances.

More than one half of the industrial research is performed in cooperation with foreign firms.

The new Government structure for fostering industrial innovation set up measures and incentives to industry for investments in R&D activities and in :

- feasibility studies in SME;
- prototypes;
- pilot plants;
- services processes;

4. National resources.

Statistical data (expenditure and personnel) on research activities are not yet systematically collected by Luxembourg statisticians, however the new ministerial structures, recently set up, shall be in position to do so in the very near future.

5. International cooperation.

National authorities and Luxembourg scientists have indicated their interest for Community and international cooperation and this is demonstrated by the fact that the possibility to work in the PRCs of Luxembourg is also offered to foreign scientists.

Luxembourg cannot be present in all the research fields so the choice of participating in international projects is imposed by the need to complement the national effort by international participation.

Luxembourg's participation in international programmes is limited to three EUREKA projects (CERISE, COSINE and IQ133), to two Community programmes, ESPRIT, and BRITE and to COST.

Nov. 1988

S & T IN THE NETHERLANDS.

1. General Policy Objectives.

The formulation of the Dutch science policy for the next 10 to 15 years will be determined by the following three issues :

- Aspiration of a scientific basis in the 1990's for the benefit of its key societal functions.

- Achievement of an important role in research in the process of internationalization.

- Endeavour for a well balanced development and application of science and technology at economic, social and cultural needs.

The total R&D expenditure (GERD) increased remarkably in the recent years and will amount to 2.4 % of the country's GDP in 1988. This ranks the Netherlands under the high R&D spending EC Member States. The Netherlands will spend 10,682 Mio Gld (about 4,600 MECU) in 1988. This corresponds to an increase of 3,7 % with reference to 1987. Only the Netherlands, France, U.K. and the FR of Germany contribute more than 2 % of the GDP for R&D.

2. Priorities.

The largest share of R&D is performed by the private sector (about 2/3 by the multinational corporations). The general expansion of the technological base in industry mainly in the SMEs, is a key target of the Dutch technology policy.

Concerning the Government financed R&D five main issues have been set out in the 1988 plan :
- fundamental and strategic research;
- replacement of and investment in research equipment;
- international orientation and cooperation;
- promotion of and innovation in specific research fields;
- throughput of know-how within the research system and the society.

Beside the general priorities, the 1988 Science Budget notes a number of specific subjects or medium term trends :
- Major developments in biology with emphasis on : biotechnology, marine and ecological research environmental problems (cross-boundaries), energy, healthcare.
- In the fields of fundamental and strategic research : high-energy physics, neuro-informatic, geophysics, microelectronics, Information Technology, optical techniques and superconductors.
- In medical/behavioural science and humanities the gaps between fundamental research and professional practice have to be closed.
- The assessment and public diffusion to these new technologies to avoid unforeseen consequence for society is a major concern.

The percentage break down of the public R&D funding in groups of objectives indicates the priorities which are attributed by the Government.

Breakdown of provisional R&D budgets by objectives in 1986 and 1987 (%).

Objectives	Provisional budgets 1986	1987
Exploration and exploitation of the earth	0.6	0.6
Infrastructures and general land-use planning	4.2	4.6
Control of environmental pollution	3.0	3.1
Protection and improvement of human health	2.2	2.5
Production, distribution and rational utilization of energy	4.6	4.0
Agricultural productivity and technology	4.4	4.3
Industrial productivity and technology	14.8	17.6
Social structures and relationships	3.5	2.4
Exploration and exploitation of space	2.9	2.8
Research financed from general university funds	43.1	40.7
Non-oriented research	9.8	10.3
Other research	4.3	4.3
Total financing of civil R&D	97.4	97.2
Defence	2.6	2.8
Total financing	100.0	100.0

Source : EUROSTAT : Government financing of R&D in Community countries.

3. Implementation.

The Government's responsibility for S/T is borne by :

- The Ministry of Education and Science as regards fundamental and long term research. This Ministry administers a large share of the Government financed R&D (about 54 % in 1988).

- The Ministry of Economic Affairs deals with innovation-oriented R&D and the different stimulation schemes (about 24 % in 1988).

- Other Ministries are responsible for the support of particular research related to their functions.

The decision making is based on a broadly structured network of advisory bodies. S/T Policy is prepared by the Council for Science and Technology, chaired by the Prime Minister. The Policy is partly market-oriented, aiming to improve competitive strength of the Dutch industry.

The structure for R&D funding and promotion is organised as follows :

a) Government-financed fundamental and strategic research is submitted to the principles of task-related funding.
   - Block grants apply for free research at the universities and the research promoted by the Netherlands Organizations for Applied Scientific Research (TNO);

- Specific grants provide for the performance of well defined programmes;
- Customer designed projects or conditional funding are exceptional cases.

b) Policy-oriented research (at specific research institutes) is contracted out by various ministries.

c) Innovation-oriented R&D schemes to stimulate the effort of the industry are promoted by the Ministry of Economic Affairs. The most important schemes and programmes in this context are :

- The INNOVATION STIMULATION SCHEME (INSTIR) (a five year programme) focusses on SMEs. It provides support to the R&D labour cost, its financial volume amounted to 360 Mio Gld (nearly 150 MECU) for the 1984-1989 period.

- The TECHNOLOGICAL DEVELOPMENT SCHEME (TOK) offers risk-bearing loans at 5 % interest.

- The SME Business Research Programme (OMK Project) stimulates firms to carry out advanced research by granting about half of the project costs.

- The STIMULATION of BUSINESS-ORIENTED RESEARCH by COLLECTIVES offered 10 Mio Gld (about 4.3 Mio ECU) in 1987 (for research and feasibility studies).

- The BUSINESS-ORIENTED TECHNOLOGY STIMULATION PROGRAMME (PBTS) focuses on specific areas such as IT, Material Technology, Biotechnology and Medical Technology.

d) The Government as purchaser and first buyer plays an important role in the Dutch innovation stimulation policy.

4. National Resources.

4.1. Human Resources (1)

The number of researchers per 1000 labour force was 3.7 in 1983. The total of R&D workers in the Netherlands in 1985 was slightly above 61,000 (full-time equivalent).

The industrial sector employs about half of the R&D manpower mainly in the electrical and the chemical sectors.

The Dutch R&D Performing Organizations employed 27,550 R&D workers in 1985. The overwhelming part (54 %) carried out R&D at the universities and technical universities.

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(1) Source : OECD.

4.2. Financial Resources (1)

The national R&D budget amounted to 4,093 Mio Gld (about 1,700 Mio ECU) in 1986. This corresponded to a ratio of the national R&D budget to the national budget of 2.4 %. The Government appropriated 2.6 % of the national R&D budget to defence R&D (1988).

The trend in R&D funding shifted, as in most EC Member States to more industrial financed R&D. This sector increased it contribution to the country's GERD between 1985 and 1988 from 50.2 % to 55.3 % (estimate).
The total R&D expenditure by source of funds is given below :

	1985	1986	1987	1988*
Public sector (% of total)	43.5	41.6	40.6	40.1
of which				
Universities	18.4	17.1	16.8	15.4
Other public	25.1	24.5	23.8	24.7
Private sector (% of total)	51.1	53.5	54.7	55.3
Others (% of total)	5.4	4.9	4.7	4.6
Total Mio Gld	9,119	9,909	10,297	10,682
Mio ECU	3,632	4,127	4,412	4,577
as % of GDP	2.18	2.31	2.39	2.40

Source : Wetenschapsbudget 1989, Ministry of Education and Science
* : estimates

5. International cooperation.

Industry and Government are convinced that the high costs and the rapid succession of innovation cycles in new technologies require an adequate market and consequently a broad international cooperation. In this context the Ministry of Education and Science published a comprehensive report dealing exclusively with "the Internationalization of Education and Research".

The Government appreciates the shape of the EC Framework programmes with its action lines and the strong emphasis on industry oriented programmes and the industry welcomes the cooperation beyond national border.

The Dutch participation in EUREKA is very important amounting to 550 MECU or 14,4 % of the total project costs. The country is involved in 52 of the 213 projects (as of 01.07.1988).

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(1) Source : OECD.

Nov. 1988

S & T IN PORTUGAL

1. General Policy Objectives.

In the XI Government programme (APRIL 1987) the main goals for R&D development were announced as follows :

- The maximum utilization and valorization of all national resources of every type;
- Promotion of innovation;
- National contribution to the enlargement of scientific knowledge;
- Promotion of public expenditure on R&D, as well as private expenditure, in order to bring portuguese level towards other developed countries; creation of a new budget heading for science and technology.

2. Priorities.

The methodology applied to achieve these goals will be to institutionalize a "budget for science and technology" to define expenditure in this sector.
A long list of other aims which must be taken into account is also included in the Government programme.

They concentrate on :

- Measures to stimulate and increase greater research activity by Portuguese firms and especially within firms;
- Increase the linkage between research facilities in the education domain and firms;
- Improve the quality of S&T personnel and the career opportunities for researchers;
- Stimulate and support the S&T regional demand;
- Strengthen S&T information services and improve the technology transfer process;
- Encourage Portuguese participation in international programmes, particularly EEC programmes.
- Seek research programme opportunities with African countries (Portuguese speaking).

Breakdown of provisional R&D budgets by objectives in 1986 and 1987 (%).

Objectives	Provisional budgets 1986	1987
Exploration and exploitation of the earth	10.2	9.0
Infrastructures and general land-use planning	8.9	10.5
Control of environmental pollution	3.0	3.4
Protection and improvement of human health	0.2	0.2
Production, distribution and rational utilization of energy	5.0	4.7
Agricultural productivity and technology	14.4	14.2
Industrial productivity and technology	7.3	6.2
Social structures and relationships	0.2	1.3
Exploration and exploitation of space	-	-
Research financed from general university funds	35.5	30.5
Non-oriented research	1.8	0.5
Other research	13.5	19.5
Total financing of civil R&D	100.0	100.0
Defence	-	-
Total financing	100.0	100.0

Source : EUROSTAT : Government financing of R&D in Community countries.

3. Implementation.

Since 1986 there has been considerable change and new investment in Portuguese Science and Technology. The establishment of the Superior Council for Science and Technology working in conjunction with JNICT (Junta Nacional de Investigacao Cientifica e Tecnologica) contributes to the planning, global co-ordination and balancing of sectoral science, technology and research policy.

JNICT, which is under the auspice of the Ministry for Planning and Territorial Administrations plays a unique role in Portuguese S & T Policy since it simultaneously represents the "supply" side as well as the "demand" side of S & T and steadily promotes the best interests of all, internationally and nationally.

Action Programmes.

These are integrated R&D programmes, going from fundamental research to increase research values in industrial application through an effort to stimulate Portuguese scientific groups. The aim of these programmes is the medium-term development of the S&T field, selected by its strategic position in the national development.
JNICT started by launching "action programmes" for horizontal fields :

- Biotechnologies;
- Microelectronics, Informatics, Robotics;
- Material Sciences and Technologies;
- Marine Sciences and Technologies.

These actions programmes are privileged instruments of scientific policy, which enable through the co-ordination of human, material and financial efforts the following actions to be undertaken :

- Training of human resources in three areas - scholarships, probations, training -;
- reinforcement of R&D strategy for productive sectors already established, involving firms and universities;
- technological approach to new fields, as yet with limited significance within the Portuguese industrial body.

LNETI (National Laboratory for Industrial Engineering and Technology) is the connecting research institution between research units, universities and firms and promotes the technical base for development of high technology units. It devotes much of its research (60 %) to industrial technologies.

4. National Resources.

4.1. Personnel

Table 2 summarizes the allocation of personnel numbers of the National Research Laboratories and illustrates the concentration in Industrial and Agriculture Research.

Table 2

S&E Staff of the National Research Laboratories.

Laboratories	Field of activity	S&E Staff
INIA	Agricultural Field	296
INIP	Fishing	150
LNIV	Veterinary Sciences	103
LNETI	Industrial and Energy technologies	493
LNEC	Civil Engineering	300
INMG	Meteorology	112
IICT	Tropical Sciences	150
IH	Hydrography	71
TOTAL		1.675

Source : JNICT 1987.

4.2. Financial Resources. (Table 3)

R&D Expenditure in 1986/87 doubled 1985's allocation with plans to steadily increase it to reach 1 % of GDP by 1990. JNICT budget has been increased 4.5 fold during the last four years.

Table 3

R & D Expenditure
(end of period values)

Years	Public institutions		Total		Against previous Year %	% GDP
	M Esc	MECU	M Esc	MECU		
1986	13.470,4	96,2	20.440,7	146,0	-	0.47
1987	18.554,3	115,9	28.440,7	175,9	37,7	0.57
1988(*)	22.108,2	130,15	35.370,7	202,1	19,2	0.61
1990(*)	43.136,0	227,0	65.456,8	344,5	-	1.00

(*) Estimates.
Source : JNICT.

5. International Cooperation.

In a small rapidly developing economy, the need for external technology far outweighs its current national ability to provide it and far outweighs its export of technology.
International participation in R&D is increasing rapidly since Portugal joined EEC and Portugal more than doubled its participation in Community programme from 1986 to 1987 as well as securing EUREKA participation (13 projects, as of 01.07.1988). Bilateral S&T agreements have also been established with U.K., Spain, Germany, France and an interchange of Scientists and technologists with Brazil in the last 3 years.

1. Objectives.

The national plan (1988-1991) for scientific research and technological development focuses essentially on the following objectives of general interest :

- improvement of knowledge and progress in innovation and technological development;
- conservation, upgrading and optimal exploitation of natural resources;
- economic growth, promotion of employment and improvement of working conditions;
- development and strengthening of the competitive capacity of industry, trade, agriculture and fisheries;
- development of public services and more particularly those concerning housing, communications and transport;
- improvement of health, social security and the quality of life;
- strengthening of national defence;
- protection and conservation of Spain's artistic and historic heritage;
- encouragement of creativity, the development and dissemination of culture in all forms;
- improvement in the quality of education;
- adaptation of Spanish society to the changes brought about by scientific development and the new technologies.

In Spain GERD as a percentage of GDP has increased from 0.4 in 1981 to 0.53 in 1985. The Spanish Government is determined to increase the national R&D efforts even further, to levels comparable with the other advanced European countries.

2. Priorities.

The first national plan defined three main priority areas :
-information and production technologies,
-natural resources, agricultural and food technologies,
-quality of life.
The importance that has been attached to these areas is clearly demonstrated by the following table :

Breakdown of provisional R&D budgets by objectives in 1986 and 1987 (%).

Objectives	Provisional budgets 1986	1987
Exploration and exploitation of the earth	5.3	7.7
Infrastructures and general land-use planning	3.4	0.2
Control of environmental pollution	0.4	2.0
Protection and improvement of human health	4.0	8.6
Production, distribution and rational utilization of energy	12.3	3.1
Agricultural productivity and technology	4.9	6.7
Industrial productivity and technology	17.1	21.5
Social structures and relationships	0.9	0.9
Exploration and exploitation of space	4.8	8.8
Research financed from general university funds	18.1	19.8
Non-oriented research	20.6	8.5
Other research	2.4	3.3
Total financing of civil R&D	94.2	91.1
Defence	5.8	8.9
Total financing	100.0	100.0

Source : EUROSTAT : Government financing of R&D in Community countries.

3. Policies and Implementation.

3.1. Legal framework and institutional mechanisms.

A set of laws has been recently promulgated to modernize and unify the legal framework for R&D and technological innovation. The law 13/86 on the development and general coordination of scientific and technical research, amongst other things, provides for :
i)the establishment of a national plan for scientific research and technological development which will be instrumental in harmonizing the country's science and technology effort in the medium term;
ii)harmonization and redefinition of the legal status of the various public research centres (OPIS).

The **Interministerial Science and Technology Commission** (CICYT) is responsible for the whole of the government's science policy and is made up of representatives from the nine ministries responsible for R&D activities (chairman : Minister for Science and Education);

Other institutions involved are a **standing committee** (Comision permanente), the **general council for science and technology** for co-ordination between Autonomous Communities and central government, the **Advisory Council for Science and Technology** consisting from representatives from public and private sector, the **joint committee of the National Assembly** (Cortes) for monitoring the implementation of the national plan and the **general secretariat for the national plan.**

The Spanish constitution gives central government the responsibility for general promotion and co-ordination of scientific and technological research. However, the 17 Autonomous Communities also have responsibilities for scientific research and technological development and have set up their own bodies for the planning, management and implementation of R&D activities. The various ministries and research institutes have already transferred to the Autonomous Communities management and implementation responsibilities for several research units, while maintaining centralized planning and co-ordination. However, according to existing legislation, international relations are the exclusive responsibility of central government.

3.2. Education and training.

The recently adopted law on university reform has created a more flexible legal framework for R&D activities in universities, encouraging in particular contracts with private companies and the temporary recruitment of research scientists. It allows research scientists who work on contracts concluded with public or private bodies to receive supplementary remuneration.

Various programmes for the training of scientific staff are managed not only by the Ministry of Education and Science but also by the Autonomous Communities, by various ministerial departments and by private foundations.

3.3. R&D in undertakings.

This sector (public and private undertakings) is responsible for slightly over half the R&D carried out in Spain.

i) Public undertakings

In public undertakings most research is done in the Instituto Nacional de Industria (INI) which is an independent public holding company although it is subject to economic policy directives laid down by the government.

The two sectors with the greatest intensity in R&D are, first the defence and aeronautics industry with efforts often taking place in an international co-operation framework and second the motor industry.

ii) Private undertakings

In 1987, R&D expenditure by private companies represented about 0,7 % of their turnover, but it was very unevenly distributed not only between different sectors but also within each sector.

Tax incentives for R&D in private companies consist of a deduction of 10% of total R&D investment from the taxable amount.

The technological development programmes for companies known as "concerted plans" are mainly intended for technological development projects at the pre-competitive stage. They take two different forms :

1. Research is carried out by the company that proposed the project or in co-operation with other companies ; in that case the aid consists of an interest-free loan covering up to 50% of the total cost of the research.

2. Research is carried out in co-operation with public research centres, in which case funding may cover up to 50% of the part for which the company is responsible and 100% of the part carried out by the public research body. The total funding may not exceed 80% of the total cost.

Since Spain has joined the Community, it is becoming less rare for manufacturers to invest jointly in R&D and technological innovation in association with universities and public research centres and with the benefit of state funding which may be as much as 70% of the total.

3.4. Innovation.

The Centre for Industrial Technological Development (CDTI), is a body for the implementation and development of the industrial innovation policy and, through a number of co-operation agreements, has taken on the role of technological adviser for the Autonomous Communities.

In addition to several functions that it performs, it constitutes also a sort of public bank specialized in loan operations on extremely favorable terms, to companies wishing to undertake innovation activities.

3.5. Technology transfer.

The ratio of technology imports to technology exports was only about 24.4% in 1986, and technology transfer expenditure represents 0.3% of the GDP, almost half Spain's R&D expenditure.

A regulation enacted in 1987, has liberalized the purchase of foreign technology and the provision of foreign technical assistance for Spanish firms and abrogated earlier legislation. An administrative procedure of verification prior to transactions has been set up for statistical purposes.

4. National Resources.

4.1. Human Resources (1)

In 1983, the number of researchers per 1000 labour force was 1.0. In 1987 there were 19.000 researchers (full time equivalent).

4.2. Financial Resources (2)

Gross Domestic Product (GDP) (at current prices and exchange rates) : 216.2 Billions ECU (1985)
Gross Domestic Expenditure for R&D (GERD) : 1,444.4 ECU (1985)
GERD/GDP : 0.53 % (1985)
R&D Budget : 801.7 Mio ECU (1986) (3)
R&D Budget / National Budget : 1.46 % (1986)
Strengthening of national defence is one of the main objectives set by the national plan and this is the reason that defence R&D appropriations represent 5.8 % of the total Government appropriations in 1987.

5. International cooperation.

Spain has concentrated its international co-operation effort mainly on Europe (both bilaterally, mainly with the Community countries, some EFTA and COMECON countries and multilaterally within the large European research organizations and installations) and on the developing countries, especially the Latin American countries.

Spain participates in all the R&D programmes of the EEC, in the European Space Agency (ESA), Airbus programme, EUREKA programme (Spain participates in 55 EUREKA projects, as of 01.07.88), CERN, EMBL, ESRF, ILL.

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(1) Source : PLANICYT

(2) Source : OECD

(3) Source : OSCE

Nov. 1988

S & T IN UNITED KINGDOM

1. General Policy Objectives.

The three main themes running through the UK Government's support of civil science and technology are the importance of maintaining and enhancing quality in science and technology activities; increasing the economic and social returns (including quality of life) from science and technology; and better management, greater concentration and selectivity of science and technology activities. The Government has considerably strengthened its central structure.

2. Priorities.

Whilst there is an annual review of Government R&D Funding and in future there will be a more centralised R&D focus in the public expenditure survey, there is no overall U.K. Government R&D budget. Each Department determines its individual R&D programmes in the light of its own policy objectives and priorities.The Department of Education and Science has overall responsibility for R&D in the higher education sector and Research Councils.

In addition, the Government has begun a searching review of R&D priorities across Government, defence as well as civil, with a view to increasing the contribution of Government funded R&D to the efficiency, competitiveness and innovative capacity of the United Kingdom.

Whilst the "searching review of R&D priorities" is still underway it is possible to discern a number of broad policy assumptions as suggested by the UK's Chief Scientific Adviser. He drew attention to four broad assumptions :

"- better industrial and commercial exploitation of science;
- focussing Government support for industrial innovation on technology transfer;
- adopting a more international approach to R&D;
- contracting out more of the R&D which Government requires for its own purposes and further concentrating Government's intramural spending on fulfilling an intelligent customer role."

and placed most importance on achieving much better exploitation of UK science.

Table 1

Breakdown of provisional R&D budgets by objectives in 1986 and 1987 (%).

Objectives	Provisional budgets 1986	1987
Exploration and exploitation of the earth	1.7	1.7
Infrastructures and general land-use planning	1.4	1.6
Control of environmental pollution	0.7	1.5
Protection and improvement of human health	3.7	3.3
Production, distribution and rational utilization of energy	4.6	3.6
Agricultural productivity and technology	4.6	4.3
Industrial productivity and technology	6.7	9.9
Social structures and relationships	1.3	1.2
Exploration and exploitation of space	1.8	2.6
Research financed from general university funds	14.9	15.3
Non-oriented research	6.8	3.3
Other research	0.2	0.5
Total financing of civil R&D	48.4	48.8
Defence	51.6	51.2
Total financing	100.0	100.0

Source : EUROSTAT : Government financing of R&D in Community countries.

The changes in technological objectives taken as a whole is mainly due to the increases allocated to industry and space.

For industry, the increase reflects almost exclusively the development of general research.

Space appropriations tend to reflect commitments under multinational cooperation programmes.
In contrast, funding for energy research shows a substantial fall which mainly affect nuclear research and in particular nuclear fission research.
Finally, the reduction of more than 50 % in non-oriented research appropriations affects almost all disciplines.

3. Implementation.

S & T structure has been strengthened by Government into central structure within the Cabinet Office under the Prime Minister with ACOST as expanded advisory body. The Chief Scientific Advisor reports to Prime Minister. The S & T Assessment Office assists Departments, Research Councils and University Grants Committees (UGC) in evaluating R&D expenditure proposals.

U.K. Government is determined to secure greater industry funding of R&D and also to ensure that industry takes more responsibility for R&D. 46.1 % of Gross Expenditure on R&D in 1985 was funded by industry.

Virtually all "near-market" research initiatives, should be the subject of commercial judgement and therefore should be the responsibility of industry.

In medium and long-term research, Government accepts more responsibility; however there is a tendancy even here to regard research as a long term investment option.
Basic research is almost entirely the responsibility of Government. The Government also has a major role in funding strategic research, often in collaboration with groups of firms. The Government, in its response to the Education, Science and Arts Committee Report 1986-87, committed itself "to maintain and enhance the strength and quality of the science base".

Criteria used on the distribution of the science budget revised in 1987 are
1. Internal Factors of Excellence - Timeliness & Pervasiveness.
2. External Factors - Exploitability, applicability and significance for education and training.
3. Financial Factors - Benefits and Costs.

Concentration of location and subject is occurring due to equipment expense and width of modern research. Two-thirds of SERC's research grants goes to 16 universities.

Emphasis has shifted away from individual project support to collaborative research. Greater attention is also being paid to non-project support such as technology transfer schemes.

4. National Resources.

4.1. Human Resources in S&T.

The number of scientists and engineers engaged in research and development per million population in 1986 is given (1) as 1540 for the U.K. (2,090 - W. Germany, 3,110 - USA, and 4,440- Japan).
Universities in general in the U.K. tend to be quite small. One third of University have less than 3.000 students. Approximately 70 % have less than 5.000 students. Only 8 universities, which includes the very large (London, Oxford and Cambridge), have more than 7.000 students.

Total members employed in R&D declined by 10 % from 1981 to 1985 but this declined has now been halted.

4.2. General funding of R&D.

Total Government expenditure on R&D in 1985/86 as set out in table 2 was 6,745 MECU which represents 1.3 % of GDP in the U.K. and 3 % of total Government expenditure.

Funding of R&D has provoked considerable debate in the U.K. The universities and longer term research projects have expressed substantial reservations about Government policy funding.

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(1) UNESCO Statistical Yearbook.

While some of the reservations and criticism must be seen as position taking in advance of the Government review there has been a growing undercurrent of unease over what is felt to be "inadequate funding of S&T".

Table 2

Government Expenditure on R&D.

	Outturn		Estimates	
	1984/85	1985/86	1986/87	1987/88
Total Civil Departments	1,610	1,466	1,381	1,369
Total Research Councils	860	788	801	869
University Grants Council	1,068.2	998	999	1,040
Total Civil	3,537	3,252	3,185	3,279
Total Defence	3,688	3,494	3,331	3,410
Total all Government(net)	7,225	6,745	6,518	6,689

Source : U.K. Annual Review 1987.

5. International cooperation.

There is a clear and long recognised need for the U.K. to collaborate internationally on technological matters. The benefits of international collaboration on R&D can be considerable; costs per participant are reduced; the risks associated with advanced technologies are more widely spread; new markets are easier to open and establish; or European R&D can more easily achieve the scale needed to compete with the US and Japan.

The U.K. Government supports international collaboration in R&D. However, since collaboration can also add costs the Government must be certain that collaborative projects make the best use of scarce and valuable resources.

The new central structure will address priorities for international collaboration, including the allocation between Departments of resources.

A growing number of U.K. firms see their future in Europe, partly stimulated by initiatives like ESPRIT and EUREKA, and recognise the importance of collaborating with other European partners if they are to remain competitive, open up market opportunities and survive - perceptions which, judging for example by continuing commitment to EUREKA, are shared by firms and Governments elsewhere. In EUREKA, the U.K. are particularly keen to encourage U.K. led projects. As of July 1988, of EUREKA list projects, the U.K. participate in 73 projects.

REGIONAL TRENDS IN SCIENCE & TECHNOLOGY

Commission of the European Communities

STRIDE

SCIENCE AND TECHNOLOGY FOR REGIONAL

INNOVATION AND DEVELOPMENT IN EUROPE

Report to the Community Programmes Division, DG XVI
of the Commission of the European Communities

by

THE NATIONAL BOARD FOR SCIENCE AND TECHNOLOGY

DUBLIN

FINAL REPORT

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Document

EXECUTIVE SUMMARY

INTRODUCTION

. THIS STUDY WAS UNDERTAKEN ON BEHALF OF THE COMMISSION OF THE EUROPEAN COMMUNITIES, PREPARATORY TO THE INTRODUCTION OF A NEW COMMUNITY INITIATIVE OF SCIENCE AND TECHNOLOGY FOR REGIONAL INNOVATION AND DEVELOPMENT IN EUROPE (STRIDE), AIMED AT THE LESS FAVOURED REGIONS (LFR'S) OF THE COMMUNITY.

THE OBJECTIVES OF THE STUDY WERE TO DETERMINE THE RELATIVE TECHNOLOGICAL CAPACITY OF THE REGIONS OF THE COMMUNITY - AND, IN PARTICULAR, THE TECHNOLOGICAL DEFICIT OF ITS LESS FAVOURED REGIONS; AND, ALSO, TO EVALUATE INTERNATIONAL BEST PRACTICES FOR GENERATING EFFECTIVE REGIONAL TECHNOLOGICAL CAPACITIES.

IN ADDITION, THE STUDY ANALYSED THE IMPACTS OF EXISTING COMMUNITY SCIENCE AND TECHNOLOGY PROGRAMMES ON ITS LFR'S, AND SPECIFIES THE COMPLEMENTARITY BETWEEN THESE PROGRAMMES AND THE PROPOSED STRIDE INITIATIVE.

TECHNOLOGY AND REGIONAL DEVELOPMENT

THE ROLE OF RESEARCH AND TECHNOLOGY DEVELOPMENT (RTD) IN FUELLING ECONOMIC GROWTH AND MODERNISATION IS NOT DISPUTED, EVEN IF THE PROCESS BY WHICH THIS TAKES PLACE IS COMPLEX, AND PRECISE QUANTIFICATION REMAINS ELUSIVE.

THE STUDIES OF BOTH SCIENTISTS AND ECONOMISTS ALL POINT TO THE SIMPLE REALITY THAT STRONG ECONOMIES ARE BASED ON RESEARCH AND TECHNOLOGY.

RTD - RESEARCH AND TECHNOLOGY DEVELOPMENT - DESCRIBES A COMPLEX OF ACTIVITIES RELATED TO THE GENERATION, ACQUISITION, TRANSFER AND USE OF TECHNOLOGY. IT INCLUDES RESEARCH, DEVELOPMENT, DEMONSTRATION, TECHNOLOGY TRANSFER AND TECHNICAL INNOVATION. IT COVERS THE SPECTRUM OF KNOWLEDGE GENERATION, TRANSFER AND APPLICATION.

R&D INTENSIVE INDUSTRIES ARE INNOVATIVE, PRODUCE MORE NEW PRODUCTS, HAVE HIGHER LEVELS OF PRODUCTIVITY, EXPAND THEIR EMPLOYMENT BASE MORE RAPIDLY AND ULTIMATELY ARE MORE COMPETITIVE THAN TRADITIONAL AND LOW TECHNOLOGY BUSINESSES.

FOR THESE REASONS THE STRONG NATIONS IN EUROPE AND THE WORLD, CONTINUE TO INVEST HEAVILY IN RTD.

IN MORE GENERAL TERMS, IT IS ACCEPTED THAT STRONG NATIONAL ECONOMIES ARE BASED ON STRONG LOCAL ECONOMIES. IT IS ALSO AGREED THAT THE REGIONAL ECONOMY, NO LESS THAN THE NATIONAL OR INTERNATIONAL ECONOMY, NEEDS A CONTINUOUS PROCESS OF TECHNICAL CHANGE AND INNOVATION.

THE DYNAMICS OF THIS PROCESS WILL VARY BETWEEN REGIONS. THE TECHNOLOGY ACQUISITION BEHAVIOUR OF LOCAL ENTERPRISES, THEIR SOURCES OF SUPPLY AND MODES OF ACCESS TO TECHNOLOGY WILL REFLECT THE UNIQUE RTD ENVIRONMENT OF THE REGION. BUT, IMPROVEMENTS IN THE QUALITY OF THIS ENVIRONMENT FOR LOCAL ENTERPRISES, EITHER IN LOCAL RTD GENERATING CAPACITY, OR IN THE TECHNOLOGY TRANSFER AND ASSIMILATION CAPABILITIES OF THE REGION WILL, CETERIS PARIBUS, HELP THE ECONOMIC PERFORMANCE OF LOCAL ENTERPRISE AND HENCE IMPROVE REGIONAL AND NATIONAL ECONOMIC PERFORMANCE.

THE ECONOMIC PERFORMANCE OF A REGION IS, THEREFORE, A REFLECTION OF WHETHER ITS ENTERPRISES ARE TECHNOLOGICALLY INNOVATIVE AND DYNAMICALLY GROWING, OR TECHNOLOGICALLY BACKWARD AND DECLINING.

HOWEVER, THE COMPLEX NATURE OF THE DEVELOPMENT PROCESS OF REGIONS MEANS THAT A CONFLUENCE OF MANY RTD FACTORS IS REQUIRED. ISOLATED RTD ELEMENTS WILL, IN GENERAL, NOT BE SUFFICIENT. THIS IS THE INTERNATIONAL EXPERIENCE.

INTERNATIONAL DEVELOPMENTS

THE ROLE OF TECHNOLOGY IN THE DEVELOPMENT OF REGIONS HAS BECOME INCREASINGLY RECOGNISED IN RECENT YEARS. THIS REPORT SHOWS THAT AS A CONSEQUENCE, THERE HAS BEEN AN EXPLOSION OF INITIATIVES AIMED AT RAISING THE RTD POTENTIAL OF REGIONS IN COUNTRIES SUCH AS THE USA AND JAPAN.

IN THE U.S. MANY STATES TRY TO REPLICATE LOCALLY THE RESULTS OF ROUTE 128, THE RESEARCH TRIANGLE OF NORTH CAROLINA AND SILICON VALLEY. OVER 40 STATES NOW HAVE LOCALLY DRIVEN RTD PROGRAMMES.

A UNIQUELY JAPANESE EXPERIMENT - TECHNOPOLIS - IS DESIGNED TO DECENTRALISE TECHNOLOGY AND TO BUILD STRONG SELF-STANDING TECHNOLOGY BASED LOCAL ECONOMIES OUTSIDE THE MAIN CITIES OF TOKYO AND OSAKA.

IT IS NOT AIMED SIMPLY AT ATTRACTING INDUSTRY TO REGIONS. IT IS DESIGNED TO ACHIEVE THE MAXIMUM DEVELOPMENT OF EACH REGION'S EXISTING RESOURCES AND SPECIALISATIONS.

THERE ARE NOW 18 RECOGNISED TECHNOPOLIS REGIONS IN JAPAN, EACH WITH IT'S OWN INTEGRATED TECHNOLOGY BASED DEVELOPMENT PROGRAMME .

IN CONTRAST, EUROPE LAGS BEHIND.

THERE ARE SOME EXCEPTIONS, HOWEVER. FRANCE, FOR EXAMPLE, HAS A LONG ESTABLISHED POLICY OF REGIONALISATION OF RTD. IN ADDITION, THERE IS A NOTICEABLE TREND TOWARDS SPECIFIC REGIONAL RTD INITIATIVES EMERGING OF LATE WITHIN CERTAIN MEMBER STATES NOTABLY ITALY, AT BARI IN PUGLIA, GREECE, AT HERAKLION IN CRETE, DENMARK AT HIRTSHALS IN NORTH JYLLAND, SPAIN AT CADIZ IN ANDALUCIA AND IN THE SOUTH EAST REGION OF IRELAND. OTHERS ARE DESCRIBED IN THE REPORT.

BUT THESE EXCEPTIONS APART, THE NATIONAL GOVERNMENTS OF MEMBER STATES HAVE NOT TO ANY SIGNIFICANT EXTENT RECOGNISED THE NEED FOR A STRONG REGIONAL DIMENSION IN NATIONAL SCIENCE AND TECHNOLOGY POLICIES. AND WHILE MUCH OF THE NATIONAL RTD INFRASTRUCTURE MAY BE REGIONALLY LOCATED, IT'S ORIENTATION IS BY AND LARGE NATIONAL AND INTERNATIONAL.

THE REPORT, THEREFORE, MAKES THE CASE FOR A NEW APPROACH TO SCIENCE POLICY - WHAT MIGHT BE TERMED 'MICRO SCIENCE POLICY' - WHICH WOULD BE FIRMLY FOCUSSED ON THE REGION AS THE UNIT OF ACTION.

SUCH MICRO SCIENCE POLICY WOULD BE DIRECTED TOWARDS THE MORE ORGANIC DETERMINANTS OF REGIONAL DEVELOPMENT, SUCH AS HUMAN AND INTELLECTUAL RESOURCES, SKILLS, RESEARCH, TECHNOLOGICAL CAPACITY AND INNOVATION, AND WOULD SEEK TO ESTABLISH A SELF-GENERATING DYNAMIC IN A REGION.

THIS TYPE OF UPGRADING OF REGIONAL POLICY HAS BECOME AN IMPORTANT POLICY DEBATE IN RECENT TIMES AND, IN PART, REFLECTS A CONCERN ABOUT THE ABILITY OF INDUSTRIAL POLICY TO ASSIST DEVELOPMENT OF PERIPHERAL AND DISADVANTAGED REGIONS IF IT CONTINUES TO FOCUS ON INDUSTRIAL LOCATION STRATEGIES.

COHESION

WITHIN THE COMMUNITY, TECHNOLOGICAL ADVANCE CAN MAKE A MAJOR CONTRIBUTION TO BRINGING ABOUT GREATER ECONOMIC CONVERGENCE AND COHESION BETWEEN MEMBER STATES AND REGIONS.

BUT, THE BULK OF THE COMMUNITY'S RTD RESOURCES ARE CONCENTRATED IN THE CENTRAL OR CORE REGIONS AND IN THE LARGER AND STRONGER MEMBER STATES.

THE PERIPHERAL AND LESS FAVOURED REGIONS HAVE A LOWER LEVEL OF INVESTMENT IN RTD, HAVE WEAKER RTD INFRASTRUCTURE AND OTHER RELATED INSTITUTIONAL RESOURCES AND ARE SLOW TO ADOPT NEW TECHNOLOGY AND TO INNOVATE. THE CORE REGIONS DOMINATE IN THE INTRODUCTION OF NEW TECHNOLOGY WHILE PERIPHERAL REGIONS ARE THE LATE ADOPTERS. MORE FUNDAMENTALLY THEY LACK A VIGOROUS TECHNICAL AND ENTREPRENEURIAL CULTURE.

THIS STUDY DEVELOPS A NUMBER OF NEW INDICES WHICH REVEAL THE EXTENT OF THE TECHNOLOGICAL DISPARITIES WHICH EXIST WITHIN THE COMMUNITY, AND WHICH ARE NOW A SERIOUS OBSTACLE TO ACHIEVING COHESION AND INTEGRATION.

THESE DISPARITIES EXIST BOTH BETWEEN MEMBER STATES AND BETWEEN THE REGIONS OF MEMBER STATES.

ALMOST ALL THE FACTORS WHICH DRIVE TECHNOLOGICAL DEVELOPMENT, FAVOUR THE CORE REGIONS - COMMUNICATIONS, INFRASTRUCTURE, ACCESS TO SKILLS AND MARKETS, INFORMATION AND SERVICES AND MANY OTHERS.

THIS IS A CUMULATIVE PROCESS. AN AGGLOMERATIVE DYNAMIC TAKES OVER ONCE A CRITICAL MASS IS REACHED. THE STRONG GET EVEN STRONGER.

THIS NATURAL TENDENCY OF RTD TOWARDS AGGLOMERATION REINFORCES EXISTING DISPARITIES AND MAKES THE PERSISTENT LOW LEVEL EQUILIBRIUM OF THE LESS FAVOURED REGIONS (LFR'S) MORE ENDEMIC AND DIFFICULT TO BREAK.

DISTORTIONS AND DISPARITIES IN THE COMMUNITY'S RTD CAPABILITIES ARE THUS BECOMING DEEPROOTED. THIS IS CREATING BARRIERS TO LESS FAVOURED REGIONS ENTERING AND SHARING THE DOMAIN OF MODERN TECHNOLOGY BASED TRADE AND COMMERCE IN THE COMMUNITY.

DISPARITIES WILL WIDEN AS TECHNOLOGY ADVANCES, AND THESE COULD BECOME A PERSISTENT AND PERMANENT FEATURE OF FUTURE ECONOMIC PROGRESS IN THE COMMUNITY, SLOWING DOWN THE OVERALL RATE OF ADVANCE.

THE DRIVE TOWARDS A TECHNOLOGICAL COMMUNITY MAY THEREFORE LEAVE MANY STANDING STILL. IN THE LONG TERM, THE PROGRESS OF ALL WILL BE RETARDED UNLESS POSITIVE ACTION IS TAKEN TO INFLUENCE THE NATURAL AGGLOMERATIVE AND CLUSTERING TENDENCIES OF TECHNOLOGICAL DEVELOPMENT.

TECHNOLOGY GAPS

THIS REPORT QUANTIFIES, FOR THE FIRST TIME AT REGIONAL LEVEL, THE SIZE AND EXTENT OF THE TECHNOLOGY GAPS WHICH HAVE EMERGED BETWEEN THE PERIPHERAL/LESS FAVOURED REGIONS AND THE MORE DEVELOPED PARTS OF THE COMMUNITY.

THE EVIDENCE WHICH HAS BEEN ASSEMBLED POINTS INDISPUTABLY TO THE NEED FOR NEW COMMUNITY POLICIES FOR THE TECHNOLOGICAL DEVELOPMENT OF THE PERIPHERAL AND LESS FAVOURED REGIONS.

LESS FAVOURED MEMBER STATES REPRESENT ONLY 10% OF THE R&D ACTIVITY IN THE COMMUNITY, WHILE THEY REPRESENT 40% OF ITS POPULATION. THEY TEND TOWARDS TECHNOLOGICAL DEPENDENCY, HAVE WEAK RTD INFRASTRUCTURES AND HAVE A POOR RTD UTILISATION CAPACITY IN THEIR INDUSTRIES.

THE DANGERS OF A 'TWO-SPEED' COMMUNITY ARE EVIDENT. DIFFERENTIATED INITIATIVES FOR THE LFR'S ARE JUSTIFIED. BUT, CAREFULLY BALANCED COMMUNITY PROGRAMMES WILL BE REQUIRED IN ORDER TO AVOID A PERSISTENCE OF THE TECHNOLOGICAL GAP BETWEEN LESS FAVOURED AND MORE FAVOURED MEMBER STATES.

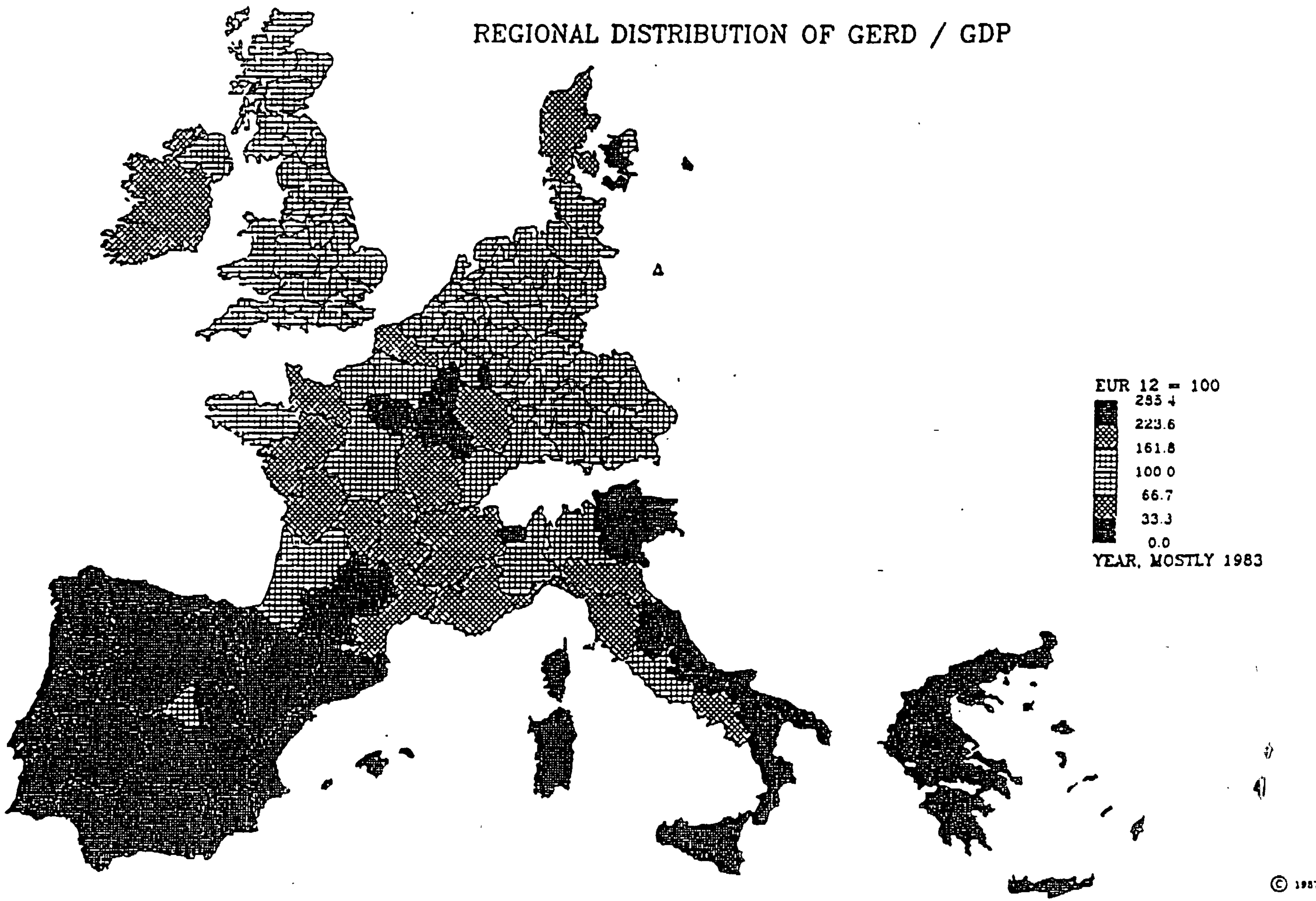
THE AVAILABLE EVIDENCE SHOWS THAT THE MOST TECHNOLOGICALLY DISADVANTAGED REGIONS ARE PORTUGAL, GREECE, SPAIN, IRELAND AND THE REGIONS OF SOUTHERN ITALY.

MANY REGIONS HAVE ALMOST ZERO RTD CAPACITY. THEIR TECHNOLOGY LEVEL CAN BE A FACTOR OF 100 TIMES LOWER THAN THAT OF MORE DEVELOPED CORE REGIONS (SEE MAPS SHOWING THE REGIONAL DISTRIBUTION OF GROSS EXPENDITURE ON R&D AS A PERCENTAGE OF GDP, AND BUSINESS EXPENDITURE ON R&D AS A PERCENTAGE OF GROSS VALUE ADDED).

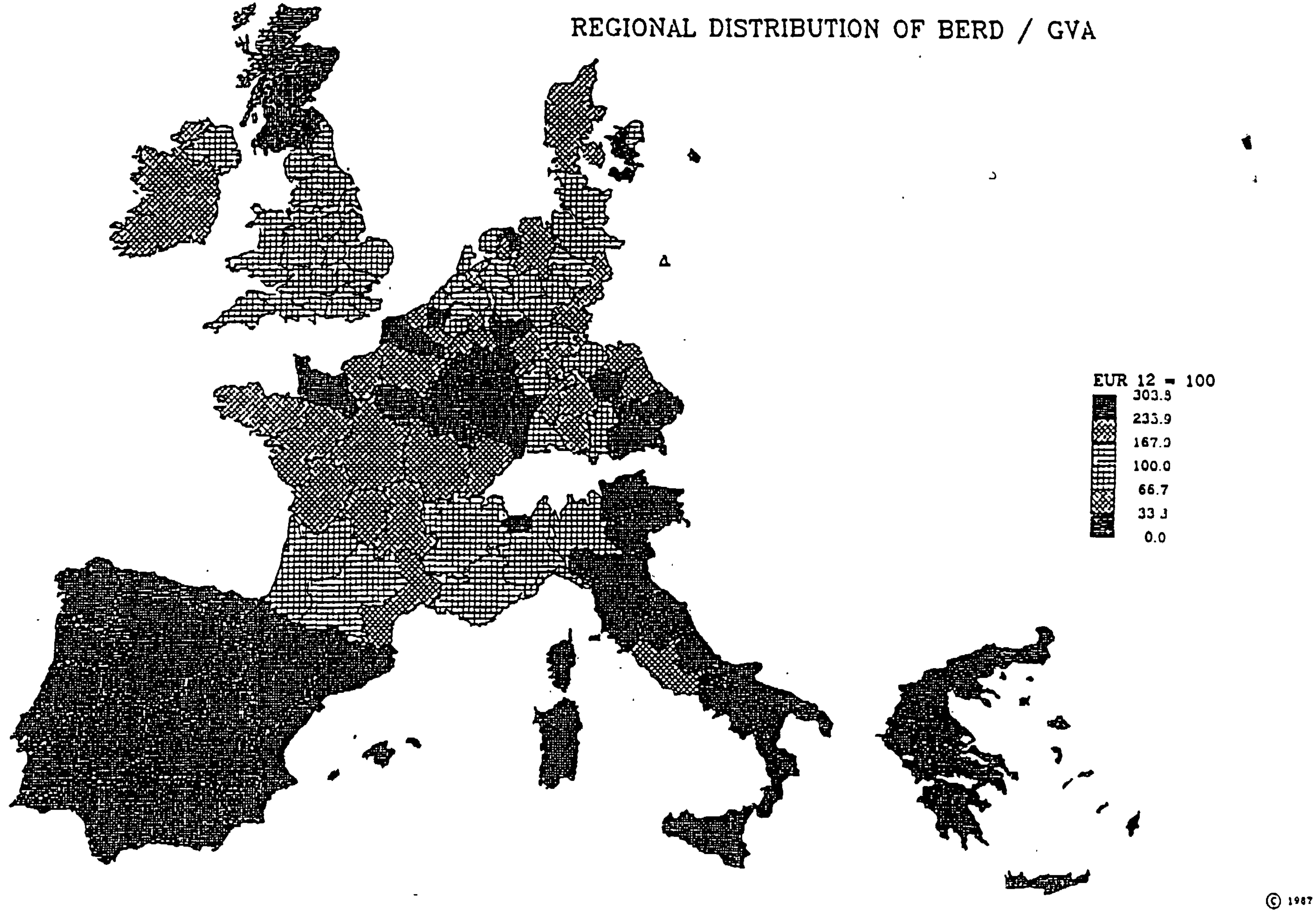
THE SCALE OF THE TECHNOLOGICAL GAP IS ESTIMATED AT 7 BILLION ECU PER ANNUM. THIS INDICATES THE LEVEL OF ADDITIONAL ANNUAL INVESTMENT WHICH LESS FAVOURED MEMBER STATES WOULD REQUIRE IN R&D TO REACH AVERAGE COMMUNITY LEVELS.

A GAP OF THIS MAGNITUDE SUGGESTS THAT SOLUTIONS WILL BE LONG-TERM.

REGIONAL DISTRIBUTION OF GERD / GDP



REGIONAL DISTRIBUTION OF BERD / GVA



ECONOMIC VERSUS TECHNOLOGY GAPS

IN ALL CASES THE TECHNOLOGY GAP IS CONSIDERABLY WIDER THAN THE ECONOMIC GAP. FOR GREECE, FOR EXAMPLE, THE TECHNOLOGY GAP IS ALMOST TEN TIMES THE ECONOMIC GAP. YET, IT IS THE ECONOMIC GAP WHICH IS FORMALLY RECOGNISED IN COMMUNITY POLICIES. THE SYMPTOMS ARE TREATED, BUT NOT THE CAUSE.

THIS REPORT PRESENTS THE CASE FOR FORMAL ACKNOWLEDGEMENT OF THE EXISTENCE OF TECHNOLOGICAL DISPARITIES AND FOR THE ESTABLISHMENT OF NEW COMMUNITY RTD POLICIES AND PROGRAMMES TO ADDRESS THEM.

A CONTRAST OF THE ECONOMIC AND TECHNOLOGICAL GAPS OF ITALY, IRELAND, SPAIN, PORTUGAL AND GREECE, AS A GROUP, IS SHOWN OVERLEAF.

EXISTING COMMUNITY S&T PROGRAMMES

CURRENT COMMUNITY SCIENCE AND TECHNOLOGY POLICIES AND PROGRAMMES ARE BASED ON EXCELLENCE, AND ARE AIMED AT COMMUNITY-WIDE PROBLEMS. THEY ARE NOT DIRECTED TOWARDS STIMULATING REGIONAL DEVELOPMENT OR REDUCING REGIONAL DISPARITIES.

MONIES ALLOCATED FOR COMMUNITY RTD ARE ONLY A SMALL PROPORTION OF THE TOTAL RTD EFFORT IN MEMBER STATES, REPRESENTING LITTLE MORE THAN 1% OF NATIONAL R&D SPENDING.

THE POTENTIAL BENEFITS FOR LFR'S FROM COMMUNITY PROGRAMMES MUST BE CONSIDERED IN THIS CONTEXT.

NONETHELESS COMMUNITY RTD PROGRAMMES OFFER MANY OPPORTUNITIES TO LFR'S. IN PARTICULAR THEY OFFER ACCESS TO A CONSIDERABLE VOLUME OF RESEARCH AND ARE A VALUABLE SOURCE OF CONTACTS WITH EXPERTISE AND INFORMATION IN OTHER REGIONS. ALSO, THE PSYCHOLOGICAL AND ATTITUDINAL BENEFITS ASSOCIATED WITH PARTICIPATION IN COMMUNITY RTD MAY BE AS IMPORTANT TO LFR'S AS THE MORE OBVIOUS AND DIRECT FINANCIAL GAIN AND PREFERENTIAL ACCESS TO RESULTS.

PARTICIPATION IN LINKAGES AND NETWORKS THROUGH INVOLVEMENT IN THE FRAMEWORK PROGRAMME AND INDEED IN OTHER PROGRAMMES SUCH AS SPRINT, FOR EXAMPLE, IS PARTICULARLY IMPORTANT FOR PERIPHERAL REGIONS (SEE FIG 2 FOLLOWING).

MAP 5 FOLLOWING ILLUSTRATES THE REGIONAL DISTRIBUTION PER CAPITA OF OVER 7,000 COMMUNITY RTD CONTRACTS.

Technological and Economic Gaps of Italy, Ireland, Spain, Portugal and Greece - in Aggregate.

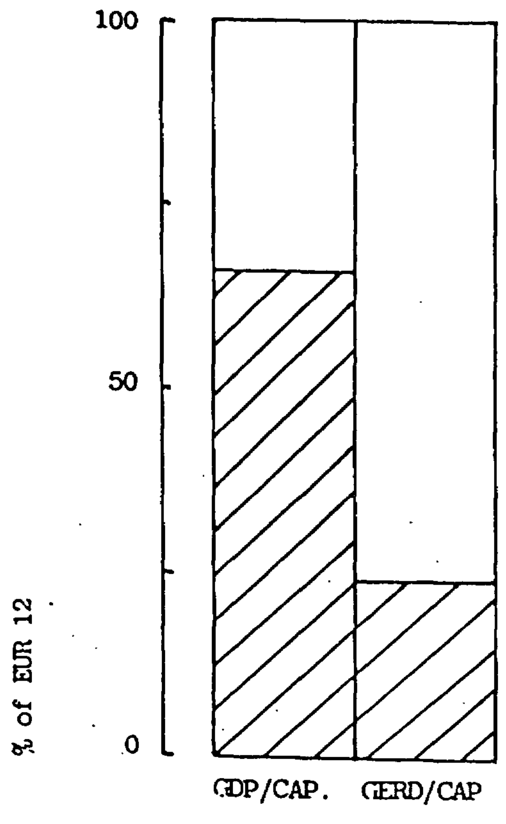
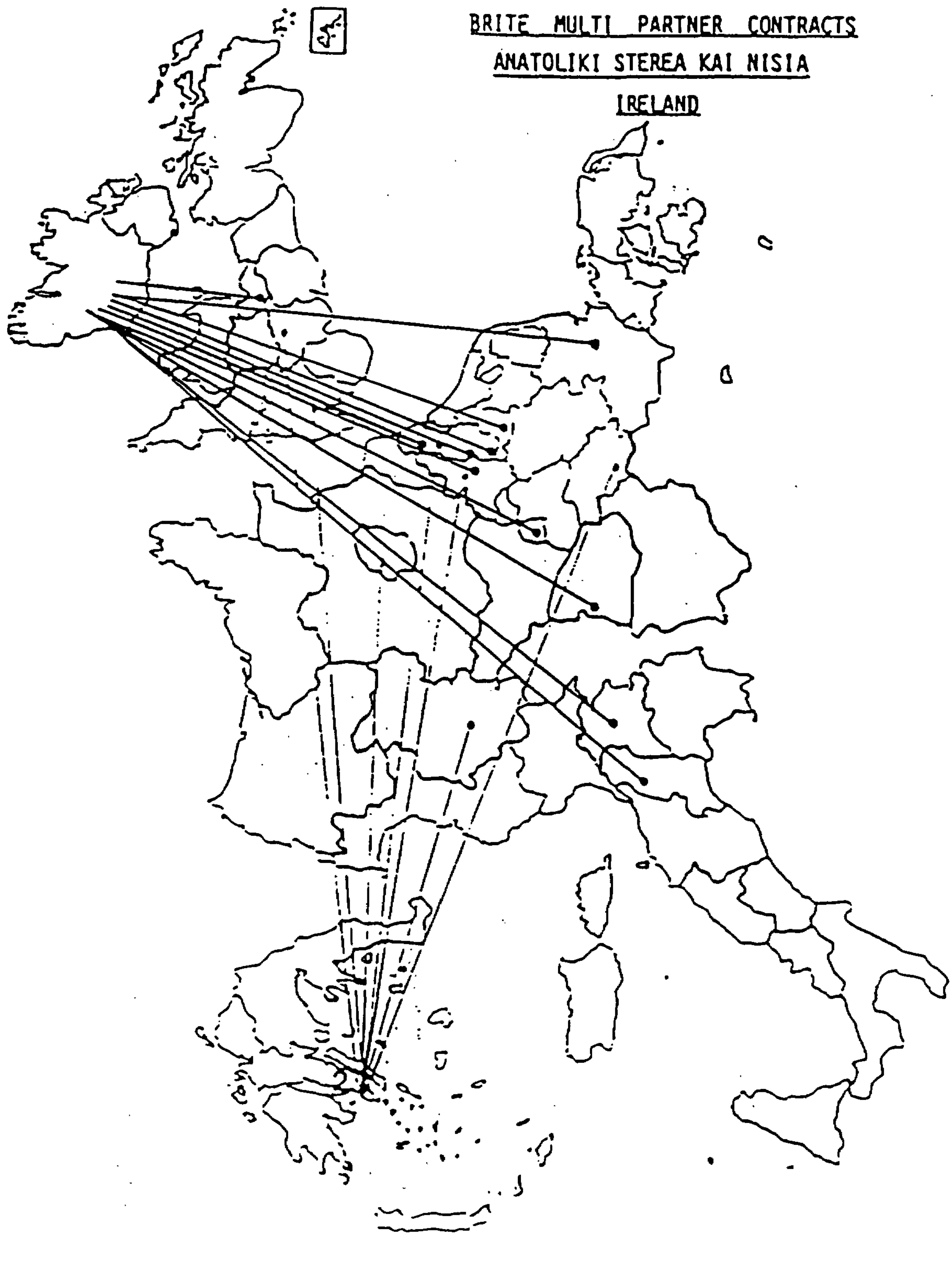
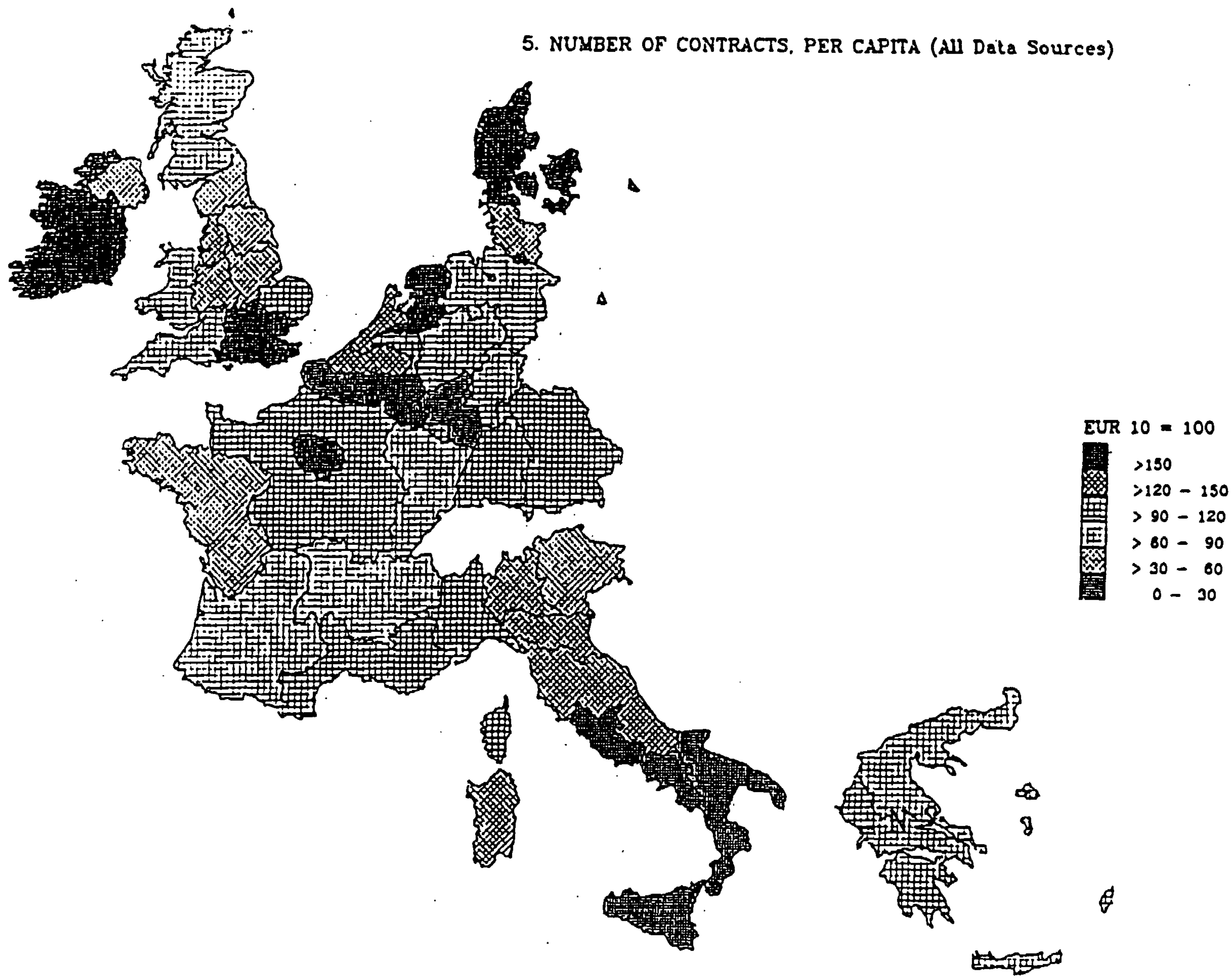


FIG 2.


BRITE MULTI PARTNER CONTRACTS
ANATOLIKI STEREA KAI NISIA
IRELAND

5. NUMBER OF CONTRACTS, PER CAPITA (All Data Sources)



N = NATIONAL TOTAL

PARTICIPATION BY LFR'S HAS BEEN STRONGEST IN PROGRAMMES RELATED TO NATURAL RESOURCES AND ENERGY, BUT HAS BEEN WEAK IN THE CORE TECHNOLOGY PROGRAMMES AND HAS INVOLVED INDUSTRY ONLY TO A LIMITED EXTENT.

STRIDE COULD ENHANCE THE BENEFITS TO LFR'S BY STRENGTHENING THE CAPACITY TO PARTICIPATE IN COMMUNITY PROGRAMMES AND BY DEVELOPING THE CAPABILITY TO ACCESS AND UTILISE THE RESULTS OF THE COMMUNITY RESEARCH, PARTICULARLY BY SMALL AND MEDIUM SIZED ENTERPRISE (SME'S).

SPECIFICALLY, PARTICIPATION COULD BE ENHANCED, FOR EXAMPLE, BY:-

- A REGIONAL SOURCE OF INFORMATION ON FORTHCOMING COMMUNITY RTD PROGRAMMES AND ON POTENTIAL TRANSBORDER PARTNERS AND SOURCES OF EXPERTISE

- A REGIONAL FOCUS OR CENTRE CAPABLE OF ASSISTING IN THE FORMULATION OF PROJECT PROPOSALS

- DEVELOPMENT OF THE EXCELLENCE AND CRITICAL MASS NECESSARY TO BE REGARDED AS A POTENTIAL PARTNER IN COMMUNITY RTD PROGRAMMES

- FOCAL POINTS OR CENTRES CAPABLE OF ASSISTING THE MORE EFFECTIVE DISSEMINATION OF INFORMATION ON THE RESULTS OF COMMUNITY RTD PROGRAMMES

- CENTRES, INCLUDING WITHIN COMPANIES, CAPABLE OF DEMONSTRATING TECHNOLOGY DEVELOPED BY COMMUNITY RTD PROGRAMMES

- DEMONSTRATION PROGRAMMES ALONG THE LINES OF THE EXISTING ENERGY DEMONSTRATION PROGRAMMES BUT FOCUSSING ON NOVEL APPLICATIONS OF TECHNOLOGIES DEVELOPED BY OTHER COMMUNITY RTD PROGRAMMES AND OF PARTICULAR RELEVANCE OF LFR'S

- COMMUNITY FACILITIES: WHEN A NEW RTD OR TEST FACILITY IS ENVISAGED, CONSIDERATION COULD BE GIVEN TO THE POSSIBILITY OF SITING THIS IN AN LFR, ASSUMING THIS IS COMPATIBLE WITH THE DEVELOPMENT STRATEGY OF THE LFR AND WITH THE REQUIREMENTS OF THE MORE ADVANCED REGIONS

- NETWORKS OF REGIONAL TECHNOLOGY CENTRES FACILITATING LINKAGES BETWEEN LFR'S, ENCOURAGING EXCHANGE OF EXPERIENCE, COOPERATIVE ACTIVITIES AND TRANSFER OF COMMUNITY RTD. ESTABLISHMENT OF LINKS WITH EXISTING E.C. PROGRAMMES IN THIS AREA, PARTICULARLY SPRINT, AND THE NEW SME ACTION PROGRAMME.

STRIDE SUPPORT FOR RTD INFRASTRUCTURE WOULD PROVIDE A PARTICULARLY EFFECTIVE COMPLEMENTARY ACTION.

ENHANCED UTILISATION OF RESULTS COULD BE ASSISTED BY

- DEVELOPMENT OF DEMONSTRATION PROGRAMMES
- IMPROVED INTER AND INTRA REGIONAL LINKAGES AND NETWORKS
- STRENGTHENING OF REGIONAL RTD CAPABILITY

THE POSSIBILITY OF INFRASTRUCTURAL FACILITIES SERVING A NUMBER OF LFR'S SHOULD BE CONSIDERED. FACILITIES WHICH ENABLED RTD COOPERATION ON PROBLEMS OF PARTICULAR INTEREST TO A NUMBER OF LFR'S WOULD ALSO BE OF VALUE.

OVERALL, A SIGNIFICANT ADVANCE IN THE CLOSER LINKING OF STRUCTURAL POLICIES WITH SCIENCE AND TECHNOLOGY POLICIES WITHIN THE COMMISSION COULD BE MADE BY HELPING TO IMPROVE THE BASIC TECHNOLOGICAL INFRASTRUCTURE OF THESE REGIONS. THIS OUGHT TO BE A PRIMARY OBJECTIVE OF THE NEW REGULATION.

REGIONAL RTD MECHANISMS

THIS REPORT PROPOSES NEW STRUCTURAL MEASURES SPECIFICALLY TARGETTED AT IMPROVING THE TECHNOLOGICAL INFRASTRUCTURES AND NETWORKS OF THE DISADVANTAGED AND LESS FAVOURED REGIONS.

THESE COMPRISE A RANGE OF RTD MEASURES IN 6 BROAD CATEGORIES, AS FOLLOWS:-

- RESEARCH AND ADVANCED TECHNOLOGY DEVELOPMENT;
- HIGHER EDUCATION INDUSTRY LINKAGES;
- TECHNICAL EDUCATION AND SKILLS DEVELOPMENT;
- APPLIED RESEARCH AND TECHNOLOGY TRANSFER;
- ENTREPRENEURSHIP ASSISTANCE;
- RTD PROMOTION AND TECHNICAL AWARENESS.

SEE TABLE 7.1 FOLLOWING.

TABLE 7.1 MAIN CATEGORIES OF RTD MECHANISMS

A	**RESEARCH AND ADVANCED TECHNOLOGY** 'Leading edge' facilities primarily concerned with the generation of knowledge, as distinct from its immediate application, and mostly, though not always, located on or in close proximity to a first class University. Non-physical support schemes for basic or fundamental research would be included.
B	**HIGHER EDUCATION - INDUSTRY LINKAGES** Mechanisms and programmes with the primary aim of encouraging and promoting closer interaction and partnerships between 3rd level Colleges and industry.
C	**TECHNICAL EDUCATION AND SKILLS DEVELOPMENT** Facilities for technological education and training, provision and upgrading of specialist skills for scientists and engineers and preferential encouragement for industry to employ scientists and engineers.
D	**APPLIED RESEARCH AND TECHNOLOGY TRANSFER** Mechanisms and programmes to assist or promote the transfer and applications of technology. The orientation is essentially applied and developmental, with the emphasis on practical applications.
E	**ENTREPRENEURSHIP ASSISTANCE** A wide range of mechanisms exist to help the entrepreneur or small business bring new ideas to the market. These provide business and commercial services and training to start up entrepreneurs who have the technology but have difficulty in organising and paying for other services.
F	**RTD PROMOTION AND TECHNICAL AWARENESS** Programmes and mechanisms to improve technical awareness and appreciation with the aim of encouraging manufacturers and industry generally to modernise and upgrade their level of technology.

WITHIN THESE 6 CATEGORIES A TOTAL OF 56 INDIVIDUAL RTD MECHANISMS WERE IDENTIFIED. CONSOLIDATING THESE MECHANISMS INTO A CORE GROUP PRODUCED THE FOLLOWING 10 'PHYSICAL' AND 10 'NON PHYSICAL' MECHANISMS.

PHYSICAL RTD MECHANISMS

- CENTRES OF EXCELLENCE
- SCIENCE PARKS
- UNIVERSITY-INDUSTRY RESEARCH CENTRES
- CAMPUS COMPANIES
- INDUSTRIAL LIAISON OFFICES
- APPLIED RESEARCH AND TECHNOLOGY CENTRES
- BRANCH PLANT PROGRAMMES
- TECHNICAL INFORMATION CENTRES
- INNOVATION CENTRES
- RESEARCH EQUIPMENT SCHEMES

NON PHYSICAL RTD MECHANISMS

- COOPERATIVE RESEARCH SCHEMES
- SKILLS PLACEMENT
- CONTINUING TECHNICAL EDUCATION AND TRAINING
- MOBILITY AND EXCHANGE PROGRAMMES
- DEMONSTRATION
- RTD EXTENSION AND CONSULTANCY
- ENTREPRENEURSHIP TRAINING
- TECHNICAL AWARENESS PROGRAMMES
- NETWORKS
- SUB-CONTRACTING AND SUB-SUPPLY

APPROPRIATE RTD MECHANISMS

SELECTING THE MOST APPROPRIATE INSTRUMENTS OR MODALITIES - THE RTD MECHANISMS - TO MATCH DIFFERENT REGIONAL CAPABILITIES IS VERY IMPORTANT, IF MONIES ARE TO BE WELL SPENT.

THIS SELECTION MUST BE BASED ON A PRECISE ASSESSMENT OF LOCAL CONDITIONS AND CIRCUMSTANCES. IN THIS PROCESS IT IS ESSENTIAL THAT CONSIDERABLE AUTONOMY IS ALLOWED TO THE REGIONS THEMSELVES.

THIS REPORT DEMONSTRATES A WIDE VARIATION IN REGIONS' RTD CAPACITY. THE CAPABILITY TO ABSORB RTD THEREFORE, AND THE SPEED AT WHICH THIS CAPABILITY CAN BE BUILT WILL VARY BETWEEN REGIONS.

REGIONS HAVE TO FIND THEIR OWN PATHS TO PROGRESS - THEIR 'VOCATION REGIONALE' - BUILDING ON THEIR RTD STRENGTHS, AND WITH A REALISTIC ASSESSMENT OF WHAT IS POSSIBLE, RATHER THAN WHAT MIGHT BE DESIRABLE.

BUT THIS LOCAL AUTONOMY WILL BE BEST EXERCISED WITHIN THE FRAMEWORK OF GENERAL GUIDELINES WHICH CAN BE PROPOSED IN ORDER TO ASSIST REGIONS IN MATCHING MECHANISMS TO REGIONAL NEEDS AND TO REGIONAL TYPES.

FOR EXAMPLE, THE KEY FACTORS OR CONSIDERATIONS WHICH SHOULD BE TAKEN INTO ACCOUNT IN SELECTING MECHANISMS ARE IDENTIFIED IN THE REPORT. BASICALLY, THESE FALL INTO TWO GROUPS:-

- FACTORS KNOWN TO INFLUENCE THE PERFORMANCE AND EFFECTIVENESS OF THE MECHANISM ITSELF, E.G. ITS SENSITIVITY TO DISTANCE FROM CLIENTS, AND

- FEATURES OF THE LOCAL RTD LANDSCAPE WHICH WILL INFLUENCE THE REGIONS ABILITY TO INSTALL AND EFFECTIVELY OPERATE PARTICULAR MECHANISMS, E.G., THE COMPOSITION AND AVAILABILITY OF LOCAL SKILLS, THE STRUCTURE OF LOCAL INDUSTRY, PARTICULARLY THE PRESENCE OF SME'S.

THE PROBLEMS FACING SME'S IN THE TECHNOLOGY ARENA ARE PARTICULARLY ACUTE, AND VERY IMPORTANT IN CONTEXT OF THIS STUDY, BECAUSE OF THEIR ROLE IN THE ECONOMIES OF THE LFR'S. INTERNALLY, THEY WILL TEND TO HAVE LOW SKILLS, POOR APPRECIATION OF TECHNOLOGY AND LIMITED CAPACITY TO ACCESS EXTERNAL SOURCES OF TECHNICAL ASSISTANCE. BUILDING IN-HOUSE RTD CAPACITY IN SME'S IS CRUCIAL BUT MUST PROCEED ON A CAREFULLY PLANNED AND STRUCTURED BASIS.

COMMISSION PROGRAMMES ARE EMERGING WHICH CAN COMPLEMENT STRIDE, PARTICULARLY THE SPRINT PROGRAMME, THE BIC PROGRAMME OF DGXVI ITSELF, AND THE NEW SME ACTION PLAN. ESTABLISHING APPROPRIATE LINKAGES BETWEEN ALL THESE INITIATIVES WILL BE IMPORTANT.

IN SELECTING RTD MECHANISMS REGIONS ARE ADVISED TO ADOPT A PORTFOLIO APPROACH. THERE IS NO SINGLE RTD MECHANISM WHICH WILL MEET ALL REQUIREMENTS.

PORTFOLIOS OF RTD MECHANISMS APPROPRIATE TO PARTICULAR REGIONAL SITUATIONS ARE SUGGESTED IN THE REPORT. FOR EXAMPLE, FOR REGIONS:

- WITH A CONCENTRATION OF SMALL CRAFT FIRMS, OR SME'S;
- WITH A CONCENTRATION OF LOW TECHNOLOGY INDUSTRY;
- WISHING TO STIMULATE A HIGH RATE OF NEW FIRM FORMATION.

THE DATA PRODUCED IN THE REPORT SHOWS THAT NOT ALL REGIONS HAVE THE CAPACITY TO MAKE FULL USE OF THE WHOLE RANGE OF AVAILABLE RTD MECHANISMS. SELECTIVITY WILL BE REQUIRED.

FOR EXAMPLE, REGIONS WITH A VERY LOW EXISTING RTD CAPACITY WILL BE LIKELY TO BENEFIT MORE FROM PROGRAMMES BASED LARGELY ON TECHNICAL EXTENSION AND ADVISORY SERVICES THAN FROM ADVANCED RTD CENTRES.

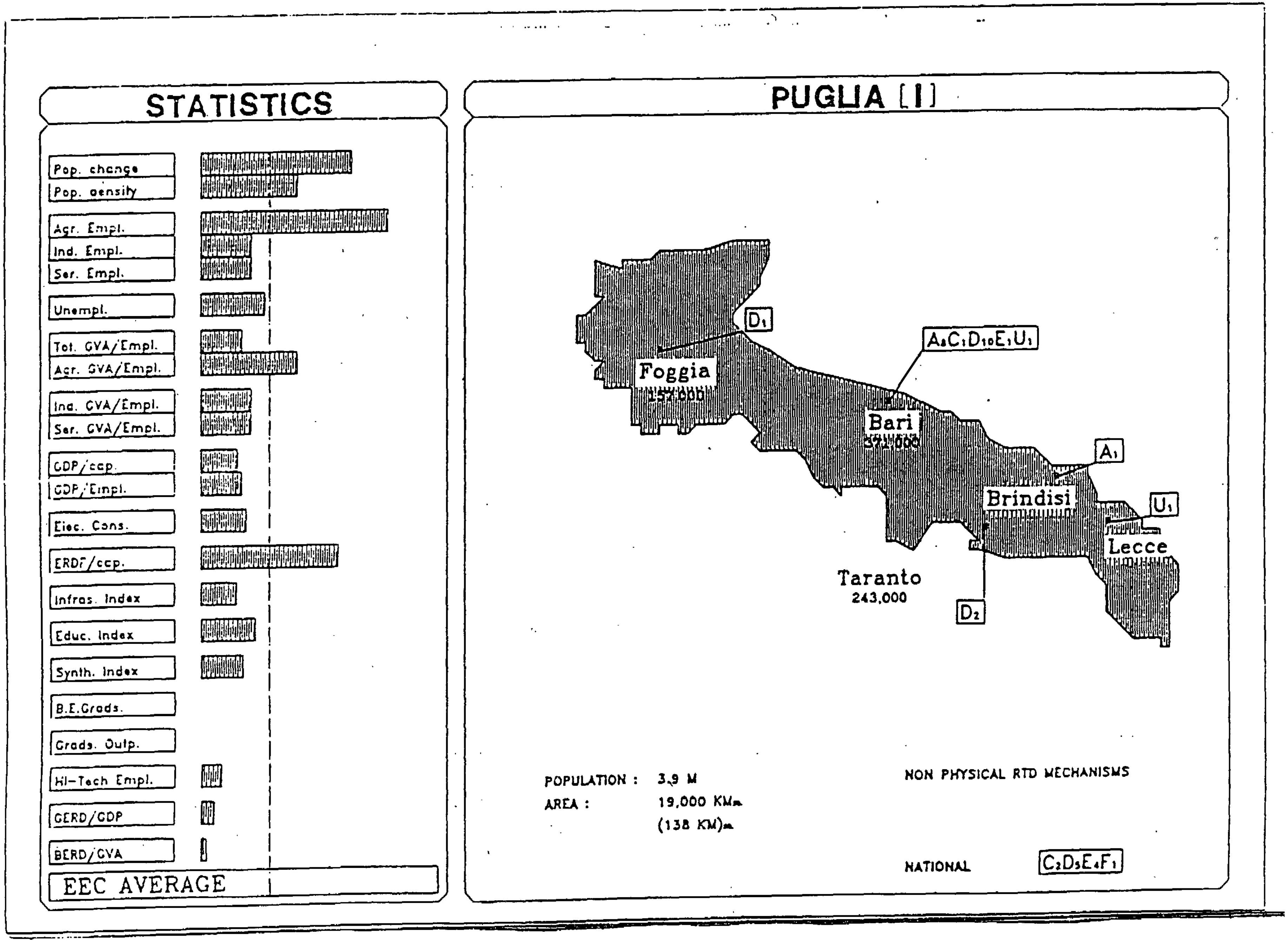
BUT, APART FROM A FEW EXCEPTIONAL CASES, IN GENERAL TERMS, THE LESS FAVOURED REGIONS, WHICH ARE THE KEY TARGET GROUP FOR THE NEW REGULATION, MUST HAVE ACCESS TO THE FULL RANGE OF RTD MECHANISMS.

REGIONAL PLANNING

PARTICIPATION BY REGIONS AND MEMBER STATES IN STRIDE SHOULD BE IN ACCORDANCE WITH A WELL PLANNED AND PROGRAMMED APPROACH. THIS SHOULD BEGIN WITH THE PREPARATION OF COMPREHENSIVE REGIONAL PLANS FOR THE DEVELOPMENT OF APPROPRIATE REGIONAL RTD CAPACITY. IN THE REPORT, A PROCEDURE FOR THE INTEGRATED PROFILING OF REGIONS IS PRESENTED. THE PROFILES OF MIDI PYRENEES AND PUGLIA WHICH FOLLOW, ARE EXAMPLES.

THIS QUANTITATIVE PROFILING PROCEDURE SHOULD BE COMPLEMENTED WITH AN INCISIVE QUALITATIVE ACCOUNT OF THE MOST IMPORTANT RTD STRENGTHS AND WEAKNESSES OF THE REGION. IN THIS, THERE IS NO SUBSTITUTE FOR LOCAL KNOWLEDGE. THE INVOLVEMENT AND COMMITMENT OF LOCAL ACTORS WILL BE CRUCIAL. THE IMPORTANCE OF THIS LOCAL PLANNING LIES BOTH IN THE PRODUCT AND THE PROCESS.

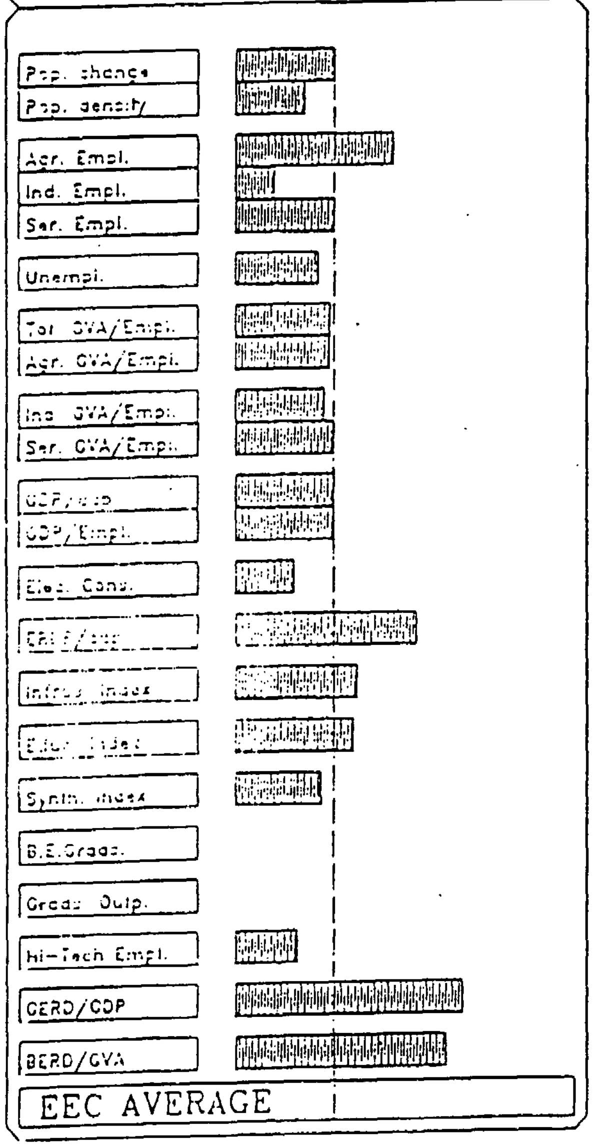
THE REPORT EMPHASISES HOWEVER THAT THE ESTABLISHMENT OF SINGLE ELEMENTS OF RTD INFRASTRUCTURE WILL NOT OF ITSELF BE SUFFICIENT. INTERACTION AND COMMUNICATION BETWEEN THE VARIOUS ELEMENTS OF THE LOCAL RTD INFRASTRUCTURE MUST BE PROMOTED.

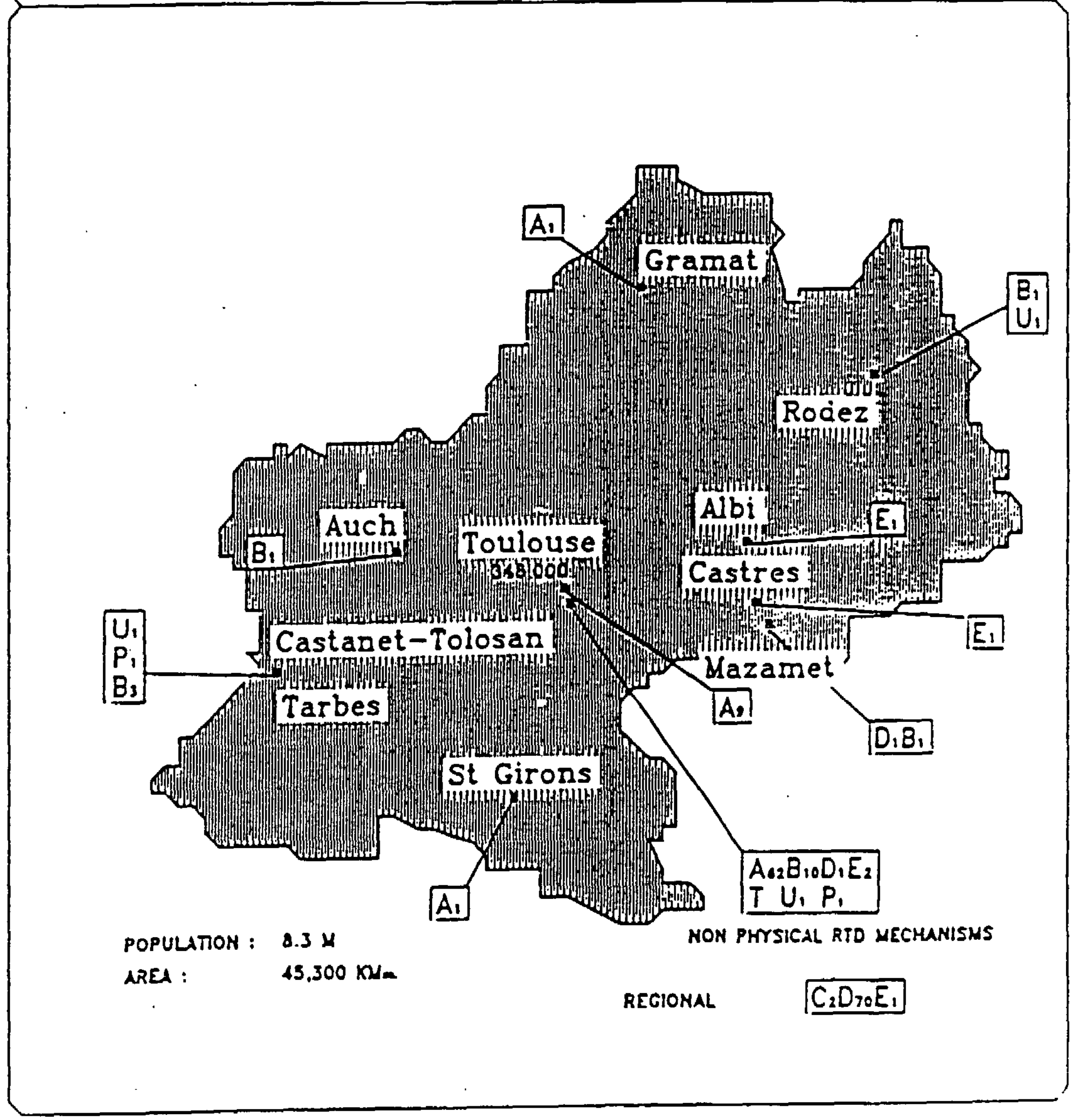


STATISTICS
Pop. change
Pop. density
Agr. Empl.
Ind. Empl.
Ser. Empl.
Unempl.
Tot. GVA/Empl.
Agr. GVA/Empl.
Ind. GVA/Empl.
Ser. GVA/Empl.
GDP/cap.
GDP/Empl.
Elec. Cons.
ERDF/cap.
Infras. Index
Educ. Index
Synth. Index
B.E.Grads.
Grads. Outp.
Hi-Tech Empl.
GERD/GDP
BERD/GVA
EEC AVERAGE
PUGLIA [I]
D_1
$A C_1 D_{10} E_1 U_1$
Foggia
157,000
Bari
372,000
A_1
Brindisi
U_1
Lecce
Taranto
243,000
D_2
POPULATION : 3,9 M
AREA : 19,000 KM²
(138 KM)²
NON PHYSICAL RTD MECHANISMS
NATIONAL
$C_2 D_5 E_4 F_1$

MIDI PYRÉNÉES [F]

STATISTICS





REGIONS MAY EVEN COMPENSATE FOR LACK OF PHYSICAL INFRASTRUCTURE BY INTENSIFICATION OF LOCAL INTERACTION WITHIN THE EXISTING STRUCTURES. THIS IS WHY A SYSTEMS PERSPECTIVE IS ESSENTIAL IN PLANNING THE DEVELOPMENT OF LOCAL RTD STRUCTURES. A NETWORK APPROACH IS CRUCIAL, LINKING LOCAL ELEMENTS CLOSELY TOGETHER.

SUCH A REGIONAL DYNAMIC IS NOT EASY TO ACHIEVE. BUT IT IS EVIDENT THAT IT IS NOT SIMPLY THE PRESENCE OF UNITS OF RTD INFRASTRUCTURE, BUT THE DEGREE OF INTERACTION BETWEEN THEM, WHICH IS THE DETERMINING FACTOR IN LOCAL INNOVATION. A KEY FOCUS FOR STRIDE THEREFORE, MUST BE TO STIMULATE LOCAL NETWORKS AND COMMUNICATIONS, AS WELL AS INSISTENCE ON THE ADOPTION OF A SYSTEMS APPROACH TO LOCAL RTD PLANNING BY THE REGIONS.

GUIDELINES FOR THIS LOCAL PLANNING PROCESS CAN BE SUGGESTED:-

- ASSESS THE RTD RESOURCES AVAILABLE TO THE REGION - REALISTICALLY;

- HAVE A VISION OF THE REGION'S FUTURE AND IMPLEMENT IT WITH OPERATIONAL STRATEGIES WHICH BUILD ON EXISTING STRENGTHS - RATHER THAN ON ASPIRATIONS OF WHAT MIGHT BE;

- ORGANIC GROWTH AND DEVELOPMENT FROM AN EXISTING BASE IS PREFERABLE TO STARTING FROM A 'GREEN FIELD' SITUATION;

- FIND WAYS OF ACCESSING EXCELLENCE, PARTICULARLY IF IT EXISTS OUTSIDE THE REGION. BUILD SYSTEMATICALLY AND DON'T LEAPFROG. TECHNOLOGICAL DEVELOPMENT IS INCREMENTAL AND COMPLEX;

- KNOW THE CONTOURS OF THE REGION'S RTD LANDSCAPE - IN DETAIL. UNDERSTAND THE LOCAL NETWORKS AND COMMUNICATION MECHANISMS - BOTH FORMAL AND INFORMAL;

- MATCH THESE CONTOURS WITH PORTFOLIOS OF APPROPRIATE RTD MECHANISMS - SELECTED AND DESIGNED LOCALLY;

- AVOID A 'SINGLE SHOT' APPROACH - NO ONE RTD MECHANISM WILL SUIT ALL SITUATIONS;

- PAY PARTICULAR ATTENTION TO KEY FACTORS WHICH INFLUENCE THE PERFORMANCE OF THE MECHANISMS SELECTED; STUDY THE PERFORMANCE OF SIMILAR MECHANISMS IN OTHER REGIONS;

- DON'T INSTALL ADVANCED TECHNOLOGY MECHANISMS IN A LOW TECHNOLOGY LOCATION. STRATEGIES WHICH DO THIS CARRY A HIGH RISK OF FAILURE;

- DEVELOP THE REGIONAL RTD INFRASTRUCTURE AS AN INTERLOCKING AND INTERACTIVE SYSTEM;

- EMPHASISE AND STIMULATE FUNCTIONAL INTERACTION WITHIN THE REGIONAL RTD SYSTEM THROUGH LOCAL NETWORKS AND LINKAGES; ESTABLISH BRIDGES TO RTD INFRASTRUCTURES OUTSIDE THE REGION;

- WORK TOWARDS ESTABLISHING A CRITICAL MASS - A 'SEUIL CRITIQUE' IN SELECTED AREAS; BE SELECTIVE, SO AS NOT TO SPREAD RESOURCES TOO THINLY;

- ESTABLISH FLEXIBLE NON-BUREAUCRATIC SYSTEMS; LOOK FOR RESULTS, NOT FOR PROCEDURES;

- SECURE INVOLVEMENT OF LOCAL BUSINESS AND COMMERCIAL INTERESTS. IF POSSIBLE, ENCOURAGE PRIVATE SECTOR INTERESTS TO DRIVE THE STRATEGY;

- ENCOURAGE LOCAL INITIATIVE AND LEADERSHIP, IT IS THEIR REGION, THEIR JOBS, THEIR CHILDREN, THEIR RESPONSIBILITY AND THEIR FUTURE - WHO ELSE WOULD BE MORE COMMITTED TO GETTING IT RIGHT?

- STIMULATE ALLIANCES OF KEY PLAYERS. IDENTIFY LOCAL CHAMPIONS;

- ENCOURAGE LOCAL COMPETITION FOR RESOURCES. FRIENDLY COMPETITION WILL IMPROVE THE QUALITY OF PROPOSALS;

- PURSUE INDIVIDUALISTIC PATHS TO PROGRESS. KNOW YOUR 'VOCATION REGIONALE';

- EMPHASISE HOW THINGS ARE DONE - NOT WHAT IS DONE. ULTIMATELY, THE FORM IS MORE IMPORTANT THAN THE SUBSTANCE;

- "ACT LOCALLY - BUT THINK GLOBALLY".

OBJECTIVES FOR STRIDE

ANY ATTEMPT AT AN 'A PRIORI' SPECIFICATION OF RTD MECHANISMS FOR PARTICULAR REGIONAL TYPES IS PROBLEMATIC.

NONETHELESS, IT CAN BE SAID THAT SOME COMMON PRINCIPLES CAN BE IDENTIFIED FOR STRIDE FOR ALL REGIONS, IRRESPECTIVE OF THE DETAIL OF THEIR LOCAL SITUATION. THUS, IT IS POSSIBLE TO ARTICULATE THAT THE BASIC PURPOSE OF THE NEW REGULATION IS TO MOBILISE REGIONAL RTD RESOURCES IN ORDER TO STIMULATE SELF GENERATING REGIONAL DEVELOPMENT. STRIDE SHOULD PRIMARILY AIM TO:-

- RETAIN AND ATTRACT SKILLED MANPOWER;
- PROVIDE A LOCAL CAPACITY FOR TECHNOLOGY TRANSFER AND APPLICATION;
- STIMULATE AND ASSIST NEW TECHNOLOGY BASED START-UPS LOCALLY; AND
- IMPROVE NATIONAL AND INTERNATIONAL RTD LINKAGES.

THESE ARE THE ESSENTIAL PRINCIPLES OF A TECHNOLOGY STRATEGY FOR ALMOST ANY LFR; SKILLS RETENTION, TECHNOLOGY TRANSFER, LOCAL TECHNOLOGY BASED START-UPS AND LINKAGES.

BENEFITS OF STRIDE

THE BENEFITS TO BE ACHIEVED BY THE NEW PROGRAMME WOULD INCLUDE PRINCIPALLY:-

- AN IMPROVED CAPACITY IN REGIONS TO EXPLOIT, AND TO SHARE IN THE BENEFITS OF TECHNICAL PROGRESS;
- AN IMPROVEMENT IN COMMUNITY COHESION AND INTEGRATION; AND
- A MEASUREABLE REDUCTION, IN THE LONGER TERM, IN THE ECONOMIC AND SOCIAL DISPARITIES BETWEEN REGIONS.

IMPACT OF STRIDE

FOR LATER EVALUATION, IT IS IMPORTANT TO ARTICULATE CLEAR AND QUANTIFIABLE OBJECTIVES AT THE OUTSET. THE IMPACT OF THE NEW PROGRAMME SHOULD BE ASSESSED ON THE BASIS OF:-

- A MEASURABLE IMPROVEMENT IN THE STOCK OF REGIONAL RTD RESOURCES OF BOTH INFRASTRUCTURE AND SKILLS;
- A MEASURABLE NARROWING OF THE TECHNOLOGY GAPS
- A MEASURABLE INCREASE IN THE PARTICIPATION OF ASSISTED REGIONS IN COMMUNITY RTD PROGRAMMES.

ELIGIBLE REGIONS

THE EVIDENCE ASSEMBLED IN THIS REPORT PROVIDES CLEAR JUSTIFICATION FOR A DIFFERENTIATED COMMUNITY RTD INITIATIVE FOR THE LESS FAVOURED REGIONS. BECAUSE OF THE VARIATION IN TECHNOLOGICAL, ECONOMIC AND SOCIAL CONDITIONS IN THESE REGIONS, THE STRIDE INITIATIVE MUST BE FLEXIBLE TO ACCOMMODATE VARIOUS CATEGORIES OF LESS FAVOURED REGIONS.

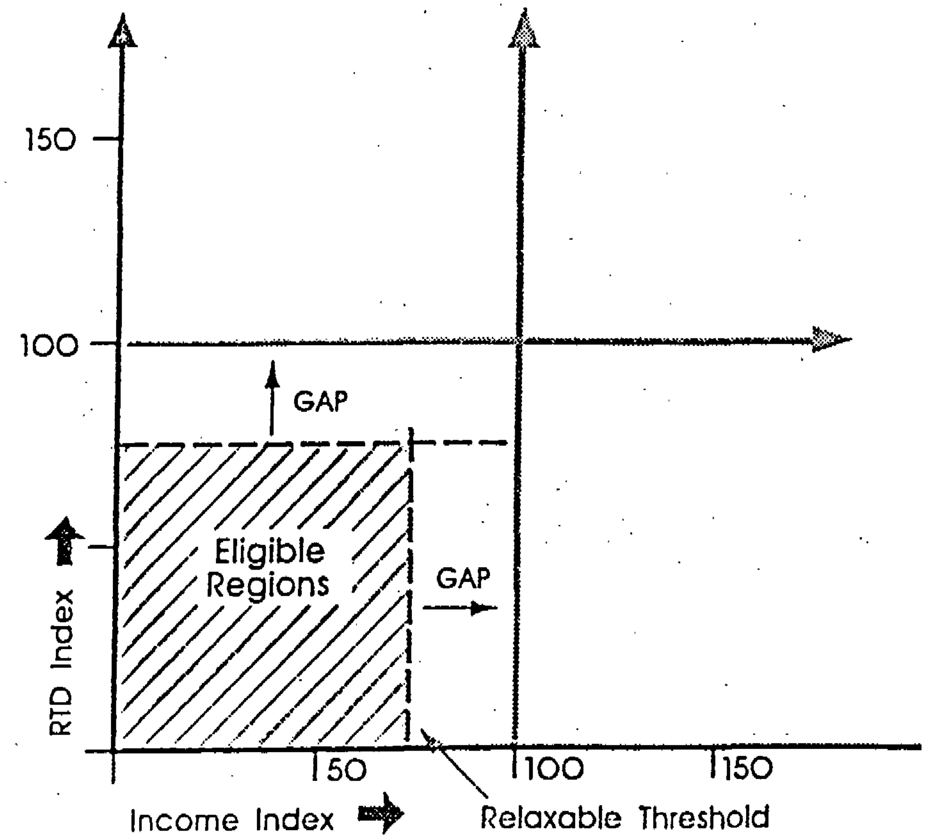
TO BE ELIGIBLE FOR ASSISTANCE IT IS PROPOSED THAT A REGION BE SIGNIFICANTLY DISADVANTAGED BOTH ECONOMICALLY AND TECHNOLOGICALLY.

THIS TWO-CRITERIA 'AND-GATE' PROCEDURE IS ILLUSTRATED OVERLEAF.

'SIGNIFICANTLY DISADVANTAGED' IS DEFINED BY THE AUTHORS AS BEING MORE THAN 25% BELOW THE RELEVANT COMMUNITY AVERAGE.

IN ADDITION, ALTHOUGH CERTAIN REGIONS MAY NOT SATISFY THESE CONDITIONS PRECISELY, THEY ARE NONETHELESS DISADVANTAGED FOR A COMPLEX OF OTHER REASONS. TWO GROUPS IN PARTICULAR, ARE CONSIDERED - INDUSTRIALLY DECLINING REGIONS AND LAGGING REGIONS IN THE MORE ADVANCED MEMBER STATES.

ELIGIBILITY CRITERIA



Criteria

Below 75% of Average EEC Income per Capita

or

Below 75 on the Synthetic Index

or

Designated "Industrially Declining"

or

Designated "Lagging Region"

and

Below 75% of Average EEC RTD Index

IN SUMMARY THEREFORE IT IS PROPOSED TO DISTINGUISH THREE CATEGORIES OF REGIONS FOR ASSISTANCE:-

- CATEGORY 1 - LOW INCOME, LOW RTD

  A CORE GROUP OF REGIONS WHICH ARE BELOW 75% OF AVERAGE EEC PER CAPITA INCOME LEVELS OR BELOW 75% ON THE SYNTHETIC INDEX AND BELOW 75% OF AVERAGE EEC RTD LEVELS.

- CATEGORY 2 - INDUSTRIALLY DECLINING, LOW RTD

  REGIONS OF INDUSTRIAL DECLINE WHICH HAVE BELOW 75% OF AVERAGE EEC RTD LEVELS. THESE ARE THE REGIONS OF MEMBER STATES BASED ON THE COAL, STEEL, SHIPBUILDING AND OTHER DECLINING INDUSTRIES. THEIR PRECISE DESIGNATION IS A MATTER FOR DGXVI.

- CATEGORY 3 - LAGGING, LOW RTD

  SELECTED REGIONS OF MORE DEVELOPED MEMBER STATES WHICH ARE RELATIVELY DISADVANTAGED - SOMETIMES REFERRED TO AS 'LAGGING REGIONS', WHICH HAVE BELOW 75% OF AVERAGE EEC RTD LEVELS. THEIR PRECISE DESIGNATION IS AGAIN A MATTER FOR DGXVI IN CONSULTATION WITH THE RELEVANT MEMBER STATES.

THE PRIMARY GROUP OF REGIONS, THOSE OF CATEGORY 1, WHICH COMPRISE THE TARGET GROUP FOR THE NEW REGULATION WOULD, ON THE BASIS OF THE ABOVE CRITERIA, ENCOMPASS ALL REGIONS CURRENTLY THE SUBJECT OF THE COHESION DEBATE. THEIR PRECISE DESIGNATION IS HOWEVER A MATTER FOR THE COMMISSION USING THE ABOVE-MENTIONED CRITERIA.

APPROPRIATE RTD MECHANISMS

WHILE THE PRECISE IDENTIFICATION OF APPROPRIATE MECHANISMS FOR A REGION MUST BE BASED ON A DETAILED EXAMINATION OF EACH REGION'S RTD STRENGTHS AND WEAKNESSES, IT IS NONETHELESS POSSIBLE TO IDENTIFY, A PRIORI, BROAD GROUPS OF RTD MECHANISMS, APPROPRIATE TO THE THREE CATEGORIES OF REGIONS LISTED ABOVE. THIS, THEREFORE, INTRODUCES A THIRD FORM OF ELIGIBILITY CRITERION NAMELY, 'APPROPRIATENESS'.

IT IS PROPOSED THAT CATEGORY 1 REGIONS SHOULD QUALIFY FOR THE FULL RANGE OF RTD MECHANISMS AS SHOWN IN TABLE 1.

WITHIN THE CATEGORY 1 GROUP, SOME REGIONS WHICH HAVE AN EXTREMELY LOW LEVEL OF RTD AND HAVE THEREFORE NOT GOT A THRESHOLD CAPACITY WILL REQUIRE A MORE SELECTIVE TREATMENT. THESE WILL REQUIRE SPECIAL EMPHASIS INITIALLY ON CREATING THE BASIC PRECONDITIONS FOR PARTICIPATION IN THE FULL SPECTRUM OF STRIDE MECHANISMS. PRIORITY ATTENTION MAY HAVE TO BE GIVEN TO HANDS-ON TECHNICAL ASSISTANCE, EXTENSION AND ADVISORY SERIVCES, AND TECHNICAL AWARENESS PROGRAMMES FOR THESE REGIONS.

THE MECHANISMS AVAILABLE TO CATEGORY 2 TYPE REGIONS - THE REGIONS OF INDUSTRIAL DECLINE - ARE SHOWN IN TABLE 2. THE MAIN RTD PROBLEM IN SUCH REGIONS MIGHT BE EXPECTED TO BE THE CONVERSION AND MODERNISATION OF AN OLD OR AGEING RTD INFRASTRUCTURE. STRONG TRADITIONS OF INDUSTRY AND SKILLS WILL EXIST BUT THESE WILL NEED TO BE UPDATED. A PRIMARY TARGET WOULD BE THE STIMULATION OF INDUSTRIAL AND PRIVATE SECTOR R&D AS WELL AS SUPPORTING NEW TECHNOLOGY BASED FIRM FORMATION.

FINALLY, CATEGORY 3 REGIONS - THE LAGGING REGIONS OF THE MORE ADVANCED MEMBER STATES, MAY EITHER HAVE RTD CAPACITY WHICH IS UNDERUTILISED OR HAVE ACCESS TO RTD INFRASTRUCTURE IN OTHER REGIONS OF THEIR OWN COUNTRY. A REDUCED SET OF RTD MECHANISMS IS PROPOSED, CONCENTRATING MAINLY ON STIMULATION TYPE MEASURES SUCH AS NETWORKS, LINKAGES, PARTNERSHIPS AND CONSULTANCY. TABLE 3 PROVIDES DETAILS.

CONCLUSION

TECHNOLOGY GAPS WILL WIDEN IN THE COMMUNITY UNLESS ACTION IS TAKEN NOW. WHILE THE STRONG WILL GROW STRONGER, MEMBER STATES AND REGIONS WHICH ARE AT A LOW LEVEL OF TECHNOLOGICAL DEVELOPMENT WILL EXPERIENCE GREAT DIFFICULTIES IN CATCHING UP.

STRESSES BETWEEN THE CENTRE AND PERIPHERY WILL INCREASE IF THE TWO SPEED TECHNOLOGICAL EUROPE, WHICH IS NOW RAPIDLY EMERGING, BECOMES ESTABLISHED.

AS TECHNOLOGY ADVANCES THE AGGLOMERATION OF TECHNOLOGICAL STRENGTH WILL CONTINUE IN THE CENTRES WHICH ARE ALREADY STRONG. THE TECHNOLOGY GAPS COULD BECOME A PERMANENT AND PERSISTENT FEATURE, SLOWING DOWN THE OVERALL LEVEL OF ADVANCE.

TABLE 1 APPROPRIATE RTD MECHANISMS FOR CATEGORY 1 REGIONS

RESEARCH AND ADVANCED TECHNOLOGY
Specialist Research Centres
Advanced Technology Centres
Centres of Excellence
Research Equipment

HIGHER EDUCATION - INDUSTRY LINKAGES
Research Parks
Science and Technology Parks
Teaching Companies
Research Equipment Schemes
Cooperative Research Centres
Cooperative Research Ventures and Consortia
Campus Companies
Industrial Liaison Offices
Transfer Points
Sponsored Chairs
Cooperative Workshops/Symposia
Industrial Fellowships

RTD MANPOWER AND SKILLS DEVELOPMENT
Skills Placement Programmes*
Special Employment Incentives*
Training/retraining for Scientists and Engineers
Continuing Education and Training
RTD Curriculum Improvement
Exchange Programmes
Mobility Programmes

APPLIED RESEARCH AND TECHNOLOGY TRANSFER
Branch Plant Programmes
Linkage and Sub Supply
Demonstration*
Networking
Applied Research and Technology Centres
Technology Applications and Design Centres
Extension and Advisory Services*
Technical Information and Assistance Centres*
Technical Consultancy Services*

ENTREPRENEURSHIP SUPPORT
Innovation Centres
Incubation Centres
Business and Technology Centres
Inventions Services
Patents and Licensing Services
Product Searching
Technology Acquisition Services
Small Business Courses
Entrepreneurship Training
Product Development Courses
Enterprise Forums/Workshops

RTD PROMOTION AND GENERAL AWARENESS
RTD Exhibitions
Technology Fairs
Referral Centres*
One Stop Shops*
Information Intermediaries*
Technical Information and Awareness Programmes*
Task Forces*
Newsletters and Technical Bulletins*
RTD General Promotion/Awareness*
Research Associations
Workshops
Scientific and Technical Attaches

* Most appropriate for the least favoured subset of Category 1 Regions.

TABLE 2: APPROPRIATE RTD MECHANISMS FOR CATEGORY 2 REGIONS

- ASSISTANCE FOR CONVERSION, ADAPTATION AND MODERNISATION OF THE EXISTING RTD INFRASTRUCTURE
- ASSISTANCE FOR STIMULATION OF BERD, PARTICULARLY
  - RESEARCH EQUIPMENT FOR INDUSTRY
  - CONTRACT RESEARCH
  - TECHNICAL CONSULTANCY
  - SKILLS PLACEMENT
  - RESEARCH ASSOCIATIONS
  - HIGHER EDUCATION-INDUSTRY PARTNERSHIPS
  - TEACHING COMPANIES
  - TRANSFER POINTS
- ASSISTANCE FOR NEW TECHNOLOGY BASED STARTUPS, PARTICULARLY
  - INCUBATORS
  - INNOVATION CENTRES
  - CAMPUS COMPANIES
- ASSISTANCE FOR UPDATING SKILLS, PARTICULARLY
  - TRAINING AND RETRAINING FOR SCIENTISTS AND ENGINEERS
  - CONTINUING TECHNICAL EDUCATION AND TRAINING
  - MOBILITY AND EXCHANGE PROGRAMMES

TABLE 3: APPROPRIATE RTD MECHANISMS FOR CATEGORY 3 REGIONS

PRIORITY TO ESTABLISHMENT AND DEVELOPMENT OF NETWORKS AND COMMUNICATIONS. IMPROVE LINKAGES TO NATIONAL AND INTERNATIONAL RTD ACTIVITY.

EXCLUSIVELY STIMULATION TYPE MEASURES, PARTICULARLY SUPPORT FOR:-

- RESEARCH NETWORKS
- RESEARCHER MOBILITY SCHEMES
- TRANSFER POINTS
- INDUSTRIAL LIAISON OFFICES
- UNIVERSITY-INDUSTRY COOPERATIVE RESEARCH PROGRAMMES
- TECHNICAL CONSULTANCY SERVICE FOR SME'S
- RESEARCH EQUIPMENT SUPPORT SCHEMES
- INDUSTRIAL FELLOWSHIPS
- TECHNICAL WORKSHOPS AND SYMPOSIA

POLICIES WHICH ADDRESS THE BASIC FABRIC, FOUNDATION AND FRAMEWORK FOR TECHNOLOGICAL DEVELOPMENT IN THE LESS WELL OFF REGIONS NEED TO BE PUT IN PLACE AS A MATTER OF URGENCY. UNLESS THIS IS DONE, THE 'QUALITATIVE LEAP' TOWARDS THE 'TECHNOLOGY COMMUNITY' MAY BE A STEP FORWARD FOR SOME BUT WILL LEAVE MANY STANDING STILL. IN THE LONG TERM THE PROGRESS OF ALL WILL BE RETARDED.

NBST/DUBLIN/AUGUST 1987

COMPARATIVE TRENDS IN THE USA, JAPAN AND EUROPE

Brussels, 22 February 1988

COMPARISON OF COMMUNITY MEMBER STATES S/T POLICIES

COPOL 88

THE EUROPEAN S/T "SPACE" IN THE INTERNATIONAL CONTEXT
RESOURCES AND CONDITIONS FOR COMMUNITY COMPETITIVENESS

Extracts from the Working Paper prepared by P. BARTOLI
Contract n° PSS*0008/F

S&T POTENTIAL OF E.E.C. COUNTRIES

OVERALL STATISTICAL COMPARISONS AND CONSEQUENCES OF POLITICAL PARCELLING

Comparing S&T potentials of Member States with those of their major partners, especially the United States and Japan, implies primarily to look at general statistical agregates. The studies prepared for the former COPOL meeting of CREST have extensively touched these aspects, and so, in the first section, we shall merely actualize the main results.

Then, in order to make this first analysis more accurate, we shall try, in the second section, to improve the conclusions drawn from quantitative comparison by taking into account the consequences or European political parcelling on its S&T efficiency compared with those of the US and Japan.

SECTION I : THE R&D POTENTIAL OF THE ECONOMIC COMMUNITY MEMBERS COMPARED TO THAT OF ITS MAJOR PARTNERS, THE US AND JAPAN

We shall review, in this section, the main basic data concerning the bulk of R&D expenses, their rate of growth within the first half of the eighties and the priority given to R&D among economic activities in the different countries. Finally we shall examine the involvement of industry in national R&D efforts which, partly, is a condition for the effectiveness of these efforts, as we shall see in the second part of the report.

I - VOLUME

- In 1986 the cumulative R&D expenditures of the member countries approached 70 billion Ecus, twice the amount recorded in 1979, and the number of research workers rose from 350 000 to 500 000 (EPT) over this period*.
- With 120 billion dollars devoted to R&D** i.e. 119 billion Ecus (1 Ecu = 1.010 dollar according to purchasing power parities : ppp), the American expenditure is approximately 3/4 higher. Japan's is in the neighbourhood of 9 200 billion yen, i.e. 41 billion (ppp 1 Ecu = 223.2 yen) which is 1/3 lower.

The repective growth rates of R&D activities in the different countries, analysed along with monetary variations, leads us to believe that for 1987 the relative gap should remain with the US and decrease with Japan.

In the 1981-1986 period evolutions have been in favour of our partners: het gap has widened noticeably with the US and has narrowed with Japan.

This comparison of overall R&D expenses of the countries involved leads us to a first evaluation of the general effort of the Member States. It is often necessary to complete this by a second comparison restricted to civilian R&D expenses in order to take into account the special features of military R&D and tis varying importance in the different countries. In this case the accuracy of statistical material is lower, so we shall use only ratios and not absolute figures (graph II).

In 1986, the civilian R&D expenses in the US was no more than a quarter above the one of EUR 12, and the Japanese expense was a third lower. In this comparison the gap between partners is narrower than in the comparison of overall R&D expenses, especially between the US and EUR 12. Since 1981 the gap with the US remained unchanged, and the gap with Japan narrowed.

Both analyses, whose results must be combined to give a realistic evaluation of R&D potentials, show that R&D expense in EUR 12 is obviously below the level of the US, but exceeds widely that of Japan. But the tendencies points out a lower dynamism in the Community. This appears better when considering growth rates.

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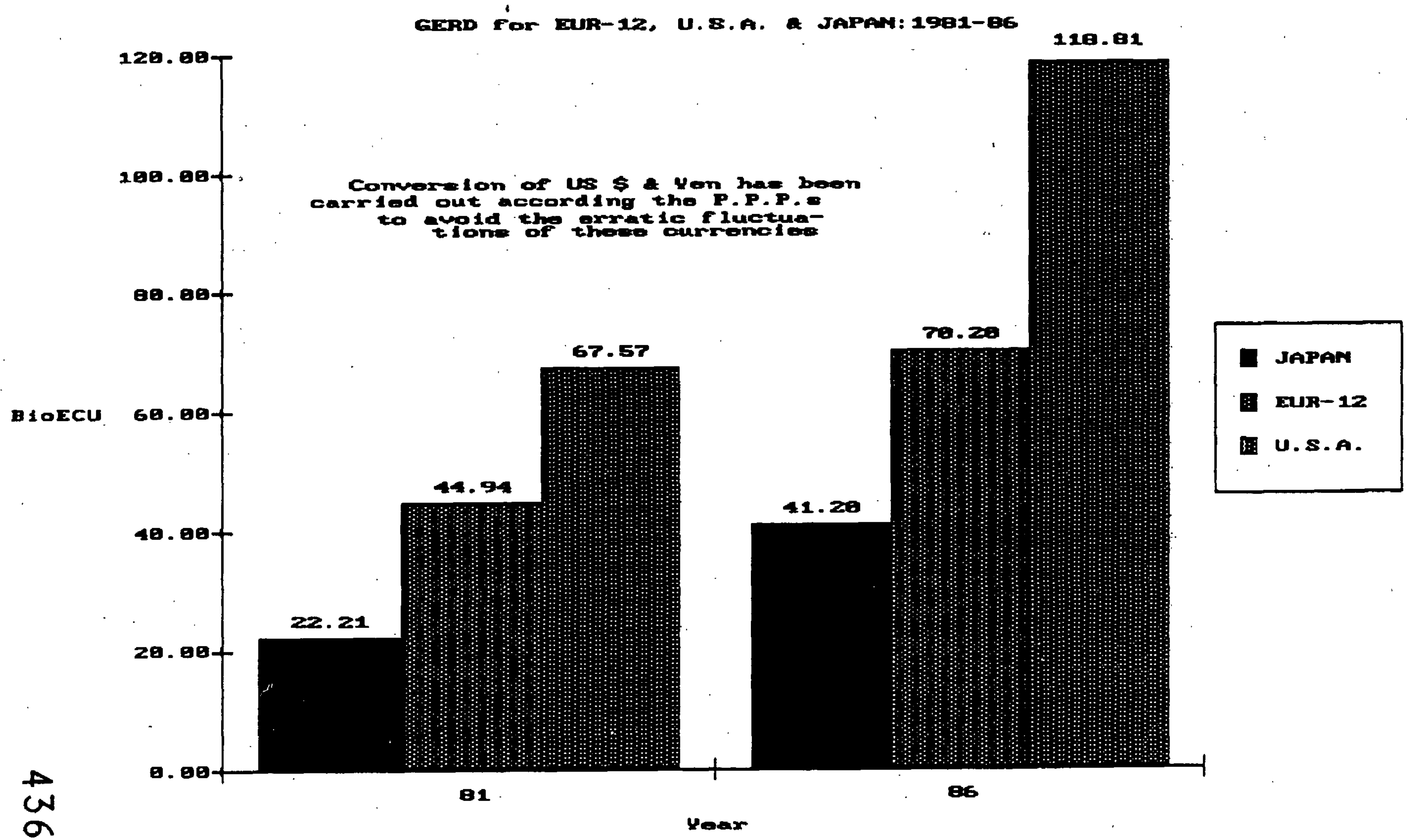
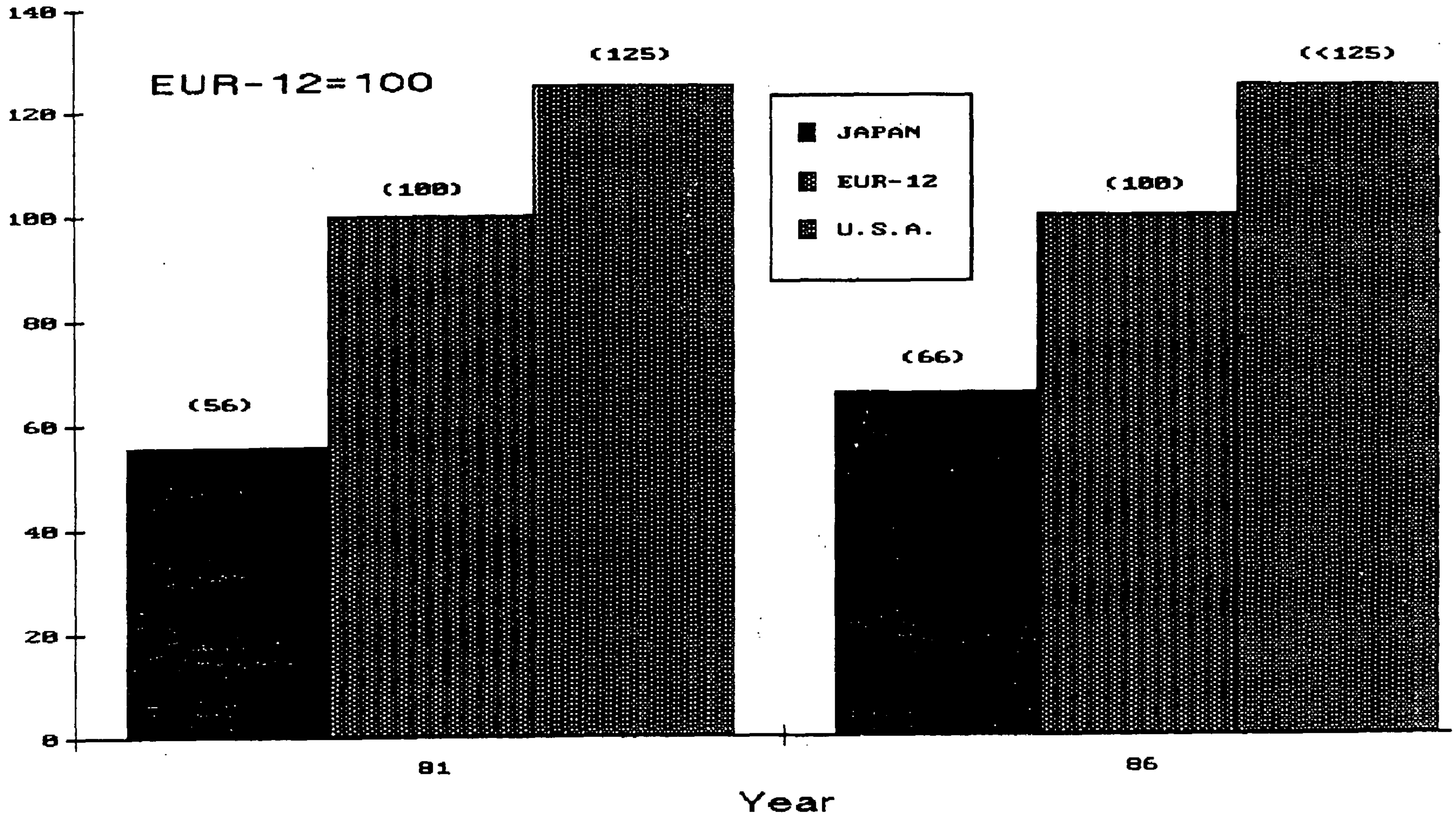
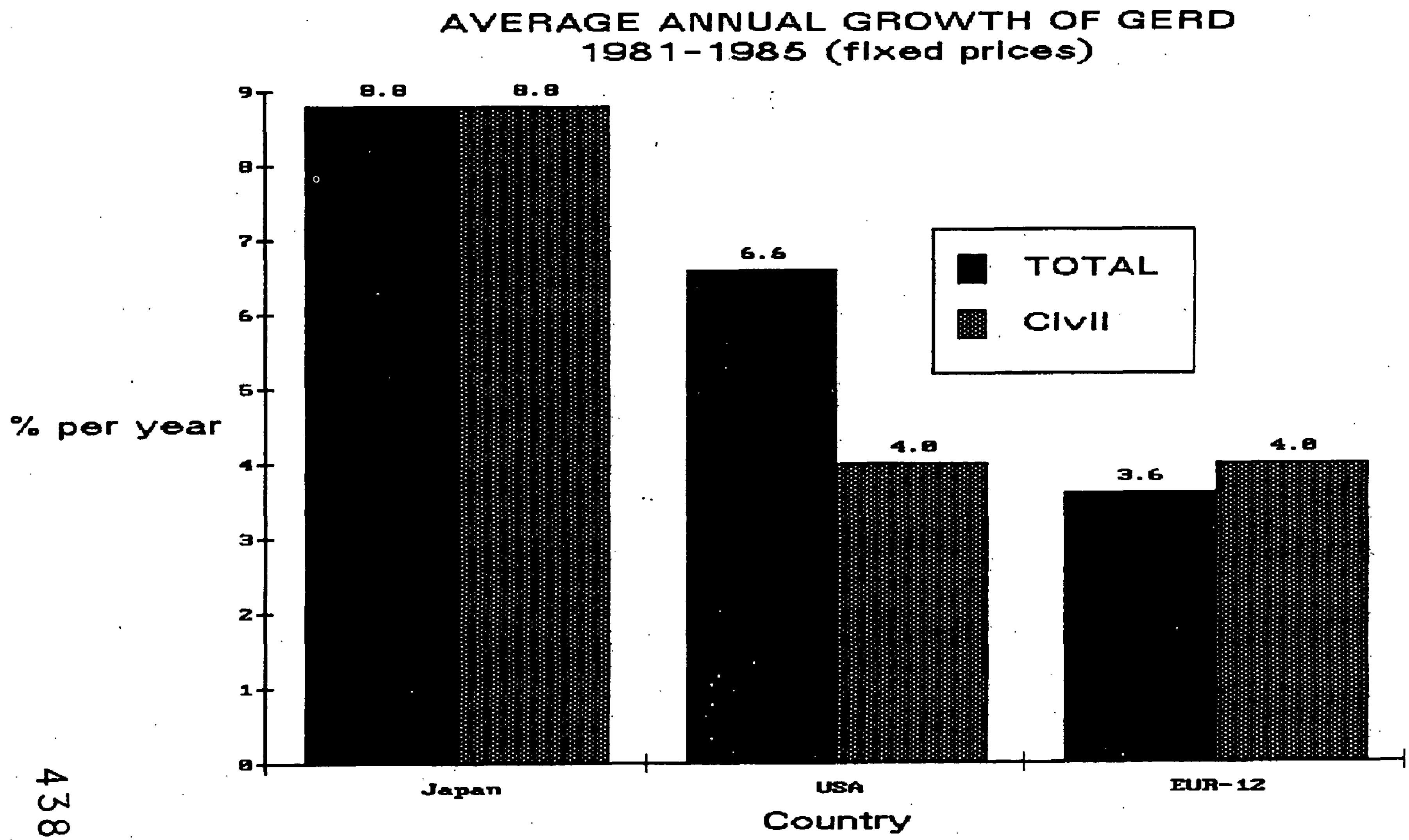
* Figures estimated from data already available in certain countries.

** OECD figures.


GERD for EUR-12, U.S.A. & JAPAN:1981-86
Conversion of US $ & Yen has been carried out according the P.P.P.s to avoid the erratic fluctuations of these currencies
BioECU
120.00
100.00
80.00
60.00
40.00
20.00
0.00
22.21
44.94
67.57
41.20
70.20
118.81
81
86
Year
JAPAN
EUR-12
U.S.A.

Civil GERD for EUR-12, U.S.A. & JAPAN: 1981-1986




AVERAGE ANNUAL GROWTH OF GERD
1981-1985 (fixed prices)
% per year
9
8
7
6
5
4
3
2
1
0
8.8
8.8
6.6
4.0
3.6
4.0
TOTAL
Civil
Japan
USA
EUR-12
Country

II - GROWTH RATES

Between 1981 and 1985 R&D expenditures increased by an average of 3.6 % per annum in volume within in EEC, at a rate which was substantially lower than of the US : 6.6 % which itself is well below the Japanese progression: 8.8 %, more than twice as fast as in the EEC.

When applied to civil research, the comparison of progression rates gives results which are considerably different, because the progression of civil appropriations was almost non-existent in the US. The result is that total civil expenditures (public and industrial) for R&D increase approximately at the same rate as in the US and in Europe, but Japanese growth is always twice as strong :

EEC	4 %
USA	4 %
Japan	8,8 %

III - INTENSITY OF THE R&D EFFORT

Another indicator of the research effort in a country is given by the ratio of the gross expenditure of R&D to the gross domestic product GERD/GDP, which evaluate the priority given to the scientific and technical development among all other economic activities.

In 1985 this ratio reached 208 % in the US and in Japan*. Of the European countries, only the FRG approached this level with a ratio neighbouring 2.7 % while it was in the range of 2.3 % in the United Kingdom and in France, at 2 % in the Netherlands (neighbouring the EEC average) and 1.3 % or less for the other member countries.

If once again we restrict our analysis to civil research, the country classification is considerably modified.

The Japanese effort in civil R&D with a ratio neighbouring 2.7 % appears to be far superior to those of the US and the EEC member countries which are in the range of 1.8 % and 2 %. And again the FRG is the only member nation whose civil effort is equal to that of Japan (between 1.5 and 2.6%).

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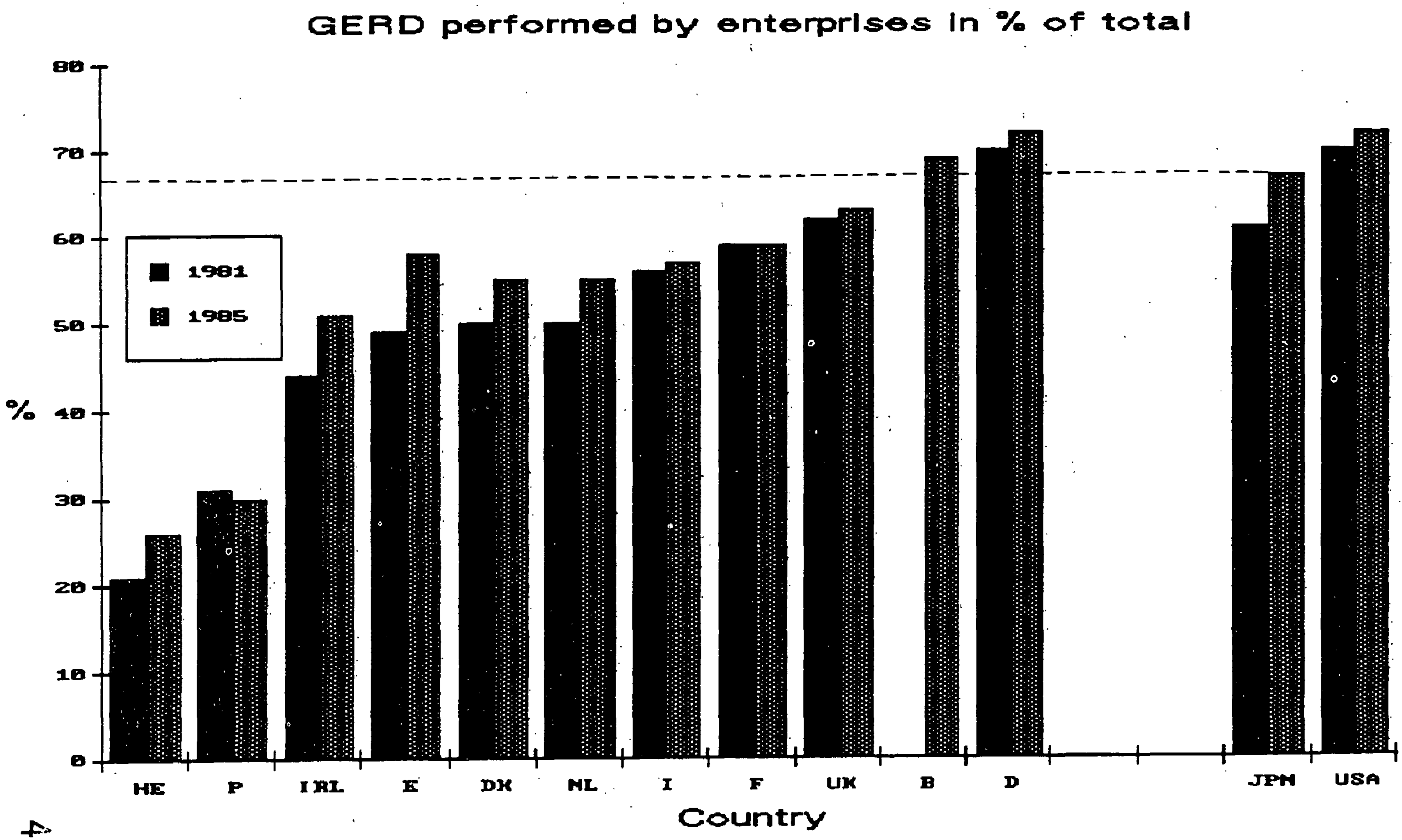
* Japan : non-adjusted OECD figures.


GERD performed by enterprises in % of total
80
70
60
50
40
30
20
10
0
%
1981
1985
HE
P
IRL
E
DK
NL
I
F
UK
B
D
JPN
USA
Country

IV - CONTRIBUTION OF INDUSTRY TO R & D POTENTIAL

VI-I/ Execution of R&D work

In the United States, more than 70 % of R&D exependitures are made in industry, and this level was maintained throughout the 1980's. This strong contribution on the part of private enterprises is explained notably by the fact that a large portion of military research is subcontracted to them.

In Japan, the corresponding ratio (DIRDE/DIRD) is also high; it was in the neigborhood of 68 % in 1985. But unlike the United States, here we are dealing almost exclusively with civil research and the industrial portion has registered a strong increase since the beginning of the 80's (61 % in 1981) due to the dynamism of industrial financing and the weak progression of R&D appropriations.

Among the member nations, two countries alone present similar characteristics: Belgium (69 % in 83) and the FRG (72 % in 1985).

IV-2/ Financing of R&D work

It is in Japan that the contribution by businesses to the financing of R&D is by far from the highest (more than 70 % in 1985) and moreover it has been growing rapidly since the beginning of the 80's (62 % in 1981). In fact, appropriations play a very minor role in businesses' financing of R&D work. They therefore enjoy total financial independence in the conduct of their R&D programmes, which is not the case in the United States and in certain member countries.

Among the European countries, only the FRG approaches Japan with a financial contribution on the part of industry of 61 %. As for the other EEC member states, the rate which characterizes them falls below or approaches that of the United States which is 48 %.

CONCLUSIONS

In conclusion, the funds devoted to R&D activities for the EECc are still well below those of the Unites States, while the Japan is catching up.

And what is more serious is the fact that R&D investments show even less dynamism: between 1981 and 1985, the growth of expenditures was twice as great in Japan and one half higher in the United States. As for the place granted to R&D in the economic activity as a whole, and measured by the ratio, it is very much lower than that of our partners (2 % against 2.7 % and 2.8 %) and the gap is on the increase.

Lastly, the distribution of the R&D effort between industry and the public sector shows that industry's contribution is lower in European countries, which puts them at a disadvantage in relation to the new conditions of S&T developement and in particular the importance of the valorization of research and the spreading of technology.

These quantitative comparisons, which in the last analysis are rather dulling for the EEC, moreover neglect a serious handicap which affects the R&D potential of the entire EEC: the EEC does not constitute a homogeneous whole. It is parcelled out into twelve components some of which are extremely unlike one another and present insufficient synergies. We shall look at the consequences of that situation in the next section.

SECTION II : CONSEQUENCES OF POLITICAL PARCELLING

In the preceding section, which dealt with the comparison of the means implemented by the Economic Community and their partners, we considered the European S&T space as a coherent whole. But this is not the case: political parcelling introduces partitions and often leads to diverging choices. And for this reason, it is presently an illusion to consider that European S&T potential is equal to the sum of the potential of its members. To be realistic, it would be fitting to attribute to the latter a reducing coefficient representing the loss of effectiveness which affects the European mosaic compared to a homogeneous national space.

This reference to the parcelling of the Economic Community is not new. But it has taken on particular acuteness in the realm of S&T for two reasons. First of all, the differences between member nations are much more acute in S&T matters than in other domains. Secondly, because throughout the world, recent developments in scientific policy have foscused on the means of better organizing the synergy of S&T efforts and of better valorizing the results of this work on the economic level.

These different actions necessarily imply cohesion and an increased fluidity in the S&T system on which they are operating and adapt very poorly to a lack of fluidity in exchanges among men due to political parcelling, which they interpret as obstacles to the circulating of men, limitations to company action, and the absence of synergy in public actions.

Obstacles to the circulating of men

This is a major handicap, because S&T progress is first of all the result of the circulating of knowledge, the confrontation of experiences and, in a broader sense, of contacts between men. More generally speaking, exchanges within the European scientific fabric are undermined by political parcelling.

The obstacles, which concern lengthy travel on the part of scientists, have been mentioned on many occasions and are well known. First of all, there are differences of language, mentality, culture, which imply a psychological effort to adapt which is sometimes difficult for some. Then there are differences between the administrative and social systems of the member nations, which are behind numerous material problems encountered by research workers and their families. Lastly, there are difficulties in seeing to it that the equipment necessary for carrying out experiments can circulate from one country to another.

Limits on action by companies

Although the free circulation of goods is ensured by the Rome Treaty, political parcelling creates another compartmentalization of markets through the play of the standards of taxation and public markets. The unique European market of 1992 should remove this obstacle, but for the moment this situation reduces the freedom of action of businesses, restricts their capacity to invest in S&T development, and sometimes excludes them, because the minimum effective investment thresholds are becoming higher and higher in certain realms of advanced technology: semiconductors for example.

Moreover, the habit of a certain protection against foreign competition within national borders has created introverted behavior in a large portion of the industrial fabric, thereby reducing the tendency to cooperate, notably in S & T matters, as testified by the weak development of technological joint ventures, compared to what we observe in the United States or in Japan.

Only the firms which have learned to act beyond borders and to go get technologies wherever they are in the world, are capable of bypassing these obstacles. But they then are sometimes more tempted by direct access to the world market than by a limited action within the European space.

The absence of synergy in public action

It is true that recently we have witnessed a certain harmonizing of S&T policies. Nonetheless, the traditions of gövernmental action differ, just as do the structures of research systems. The result is a staggering in the implementation of incentives and the instruments utilized are offen different. Sometimes even orientations are divergent. Incentives and support provided by the public authorities are thus limited to the national perimeter and do not have the repercussions of measures taken by the American Administration or the Japanese Government.

Moreover, political parcelling often implies the duplication of S&T activities in realms where the public powers are the main customer. This is very often the case with respect to military equipment, a field in which cooperation is still an exception. But the absence of cooperation is also noted in certain civil domains, for example railway transport, a field in which up until recently, competition between nations, tempered by serveral only too rare exceptions, was the rule. The amounts at stake in this respect are huge, and the duplication of activities appears as a real problem.

Thus political parcelling reduces the effectiveness of S&T activity in the European space and lead to a shadowing of the quantitative comparisons of the preceding section which looks upon Europe as though it were a homegeneous whole. We shall see in the second portion that another factor is to be taken into consideration in comparisons with the US and Japan : we are speaking of the very rapid progress achieved by these two countries toward greater effectiveness of their S&T apparatus.