DEPARTMENT OF COMMUNICATIONS

SEARCH 20

Communications Research and Development Forum

March 13-15, 1989

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Background Material

SEARCH 20

Communications Research and Development Forum

1. "Toward a National Research Network"
   National Research Network Review Committee, U.S.A.

2. "Special Programs for the Promotion of Information Technology R&D"
   OECD Summary

3. "Special Programs for the Promotion of Information Technology R&D"
   OECD Document

4. "Enabling Technologies: Springboard for a Competitive Future"
   Science Council of Canada (separate)

Toward A National Research Network

National Research Network Review Committee
Computer Science and Technology Board
Commission on Physical Sciences, Mathematics, and Resources
National Research Council

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NATIONAL RESEARCH NETWORK REVIEW COMMITTEE

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EXECUTIVE SUMMARY

The United States would benefit significantly from the creation of a national research network (NRN). The National Research Network Review Committee has evaluated the proposal for an NRN submitted by the Office of Science and Technology Policy (OSTP), and the committee strongly supports the concept presented. An NRN would create a computer network infrastructure to provide much-needed support to the scientific research community. Data obtained by the committee regarding current and anticipated research activities demonstrate that an NRN could dramatically improve the productivity and quality of output of the U.S. research community. Through these direct benefits, plus commercial spinoffs from associated computer and network research, an NRN could greatly promote U.S. competitiveness in a multiplicity of disciplines.

The OSTP proposals for an NRN have three phases, a structure the committee supports. In the near term (late 1980s), it would interconnect the existing networks that are fragmentary, overloaded, and poorly functioning. In the second phase (in the early 1990s), it would extend computer network support to researchers at more institutions than are currently served, in particular the smaller institutions not now served well, and it would significantly enhance the range and quality of network-based services provided to researchers. In the final phase (late 1990s) advanced technology and techniques would be deployed to provide a dramatic increase in speed and function to match the power of computers in use at that time.

The information-processing capability on the desk of most researchers today is awesome. The researcher's workstation is an indispensable tool in his daily research endeavors. However, his productivity is being severely hampered by his inability to effectively link his high-performance workstation to the supercomputers, to the large scientific databases, and to his colleagues in a fashion that allows him to incorporate into his research these other resources. What is needed is an accessible, user-friendly, high-speed NRN to provide these connections. The science research community currently sees a serious mismatch between today's high-performance processing engines and low-performance computer networks. This situation is extremely unfortunate for the United States, the nation that spearheaded networking technology 20 years ago.

National research network users (the scientific research community) have two principal sets of concerns. First, they want--and the committee believes they should receive--an operational network that is stable and predictable, offers high-quality performance, and does not require advanced knowledge of networking technology to use it routinely or to cope with occasional problems. While the OSTP proposals emphasize goals for high speed, the committee equally ranks the concerns for widespread access, user-friendly service-orientation, quality, and performance. Second, users--especially researchers in disciplines that have been less computer- and network-intensive to date--are concerned that federal funding for a research network not diminish federal funding for the conduct of research. The committee shares this concern.

To encourage the development and use of a widely accessible network service, the committee suggests that the NRN might provide (1) a universal basic service at some low to moderate speed for electronic mail at a low cost to users and (2) higher levels of service with an appropriate charging structure. A low charge for basic service would lessen the initial resistance that might otherwise be felt by first-time users and yet discourage the overloading that occurs with free networks.

There will always be a tradeoff between science research users' needs for a stable operational network and network researchers' desires for high performance using the latest networking technology. This latter desire arises both from the developers of network technology, who need a testbed for new ideas, and from that sophisticated class of users with advanced requirements. Because network technology is evolving, there will always be a current networking practice, developing network technologies, and research targets. The challenge underscored by the committee is to manage the progressive introduction of increasingly sophisticated technology without compromising users' ability to conduct the research for which the network is a tool. This may not be possible without substantial investment, and, even with it, compromises may be necessary.

The committee viewed the OSTP proposals as providing a general direction for the NRN, not a set of design specifications (which they were not) to be evaluated. Four areas of concern were addressed: technical considerations, funding, management, and commercial and specialty networks. The recommendations are summarized below:

Technical considerations. The technical demands for the first two phases identified by OSTP are not leading edge items. Indeed, during these phases the NRN will be catching up with the state-of-the-art technology. Phase 1 requires coordination; phase 2 requires careful attention to network management. However, achieving the high-performance network carrying the high volumes of traffic envisioned in phase 3 for the late 1990s requires computer and communications research using a clean-sheet approach that must begin now. The phase 3 network is dominated by technical issues, in particular those associated with network control but also including appropriate technology for switching, routing, multiplexing, processor interfaces, protocols, connection-oriented communications, and layered architectures. All of these areas offer opportunities for technology transfer to industry from the necessary research program.

Funding. There are a number of critical challenges associated with funding for an NRN. These challenges must be recognized and addressed up front, and the transition to a new research funding regime must absolutely lead to a stable funding mechanism or the NRN will never achieve the impact of which it is capable. There are two coupled issues here: (1) funding for network technology and (2) charging for network use. The committee recommends that economic incentives be provided to encourage industry to provide existing network technology to the NRN, but that the government provide funding for advanced network development in cooperation with industrial research efforts where possible. These funds for advanced development should be kept separate from funds allocated to running the operational network. A mechanism for providing (earmarked) funds to users to defray user charges for network use must be established. This mechanism should allow the user to choose among network services. An example of such a mechanism is the use of a voucher for network services.

This transition to user charges requires sensitivity to research users' concerns. For example, one challenge is to introduce charges for NRN use to researchers who may be accustomed to "free" service from such networks as Arpanet. User charges would allocate resources and inhibit excessive demand for use of finite network facilities. A charging structure would also make possible an eventual transition of the service to the private sector. While the economic principles are obvious, the committee recognizes that introducing charges will be difficult and will require compensatory changes in federal grant practices, such as providing for (additional) computer networking costs in research grants.

Management. The scope and scale of the NRN create an imperative for careful attention to key management issues. Good management is absolutely essential for maximizing the effectiveness of the investment in an NRN. It is a critical issue that requires early (and continuing) attention and action, and it is a nontrivial element of the total cost of providing network service. The overall problems are to engineer facilities and services to match demand and tune them to the expressed needs of users, to maintain them in an operational state, and to operate them economically. Network facilities management, operational service management, and process management (for example, introduction and phasing-in of user network services and facilities) each require commitment and resources now. The urgency of the management imperative is underscored by the committee, which points to inadequate service in existing research networks (notably Arpanet and the preexpansion NSFNET) and to the challenges implied by extending access to what could eventually be almost a half-million users in the research community. Poor management and the absence of user services are potential barriers that could prevent the NRN from realizing its potential. To overcome these barriers, an operating structure that does not now exist must be created. It should consist of a funding mechanism through normal government channels, an oversight committee, and an experienced research executive from the private sector for day-to-day management; in addition, one or more user groups should be established to provide input from and output to the user community.

Commercial and Specialty Networks. Discussions of an NRN can easily assume a stand-alone network, but the committee concluded that the proposed network must build on existing and anticipated commercial network facilities and network-based services. It encourages those responsible for developing and implementing the NRN to work with the common carriers and computer vendors; it also encourages long-range planning that would allow for the eventual transition of at least portions of a government-developed NRN to industry, because meeting the service and access goals of the network implies resources beyond the apparent capabilities of federal mission agencies or the National Science Foundation. The commercial network suppliers have decades of experience in network research and in providing accessible and reliable service to millions of users; it would be prudent to leverage this experience for the NRN.

We have a special opportunity with the NRN. We can give an enormous boost to U.S. competitiveness by providing this networking infrastructure. But we must not hesitate, for our foreign competitors are busy at work with their own national research networks (e.g., the RACE program in Europe and national network projects in Canada, Japan, and in newly industrializing countries such as Singapore, and so on). If we are successful in the NRN development, our competitive advantage will continue to grow as this unique infrastructure dramatically improves the quality of output and productivity of the research community of this nation.

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INTRODUCTION

In the United States today, data communications and data processing have finally converged in a way that now makes them inseparable. Unfortunately, however, the enormously powerful desktop workstations and centralized supercomputers used by the research community are currently being undermined by data networks that are seriously inadequate for their data communication needs. Current networks are not only deficient in bandwidth, they are also lacking in connectivity, reliability, heterogeneity, responsiveness, user-friendly dialogues, user support, and so forth. While a number of public and private networks currently serve all types of users, significant networking improvements are required to facilitate information movement for commerce, industry, and defense as well as research. Over time, the number of people seeking to communicate through computer networks will grow substantially, creating a need for networks that can accommodate heavy traffic. Data communications demand will change qualitatively, too. For example, more communication will be between computers at higher speeds than would be predicted from current uses such as electronic mail. Electronic mail itself will evolve to include graphics and images as part of routine messages.

Against this backdrop the computer networking goals of the research community can be identified. They include the following:

o Improved access to and interaction with research tools (for example, supercomputers, databases, and specialized software) that are shared, unique, and/or expensive.

o Improved interaction and collaboration among researchers (including, for example, large file transfers, real-time remote sensing, and electronic mail with embedded graphics).

Unfortunately, while the essence of research is the development and transfer of information, the committee concurs with the Office of Science and Technology Policy (OSTP) in finding that current networking and networking support for the research community are inadequate to meet researchers' present needs for such access, transfer, and interaction, let alone their future requirements.*

There is an opportunity here to remedy this shortfall, and in so doing, to leapfrog the world research community in a way that will dramatically enhance our competitive posture. The national research network (NRN) has been proposed by federal agencies and OSTP as a response to this situation. It would emerge through three successive phases as proposed by OSTP in A Research and Development Strategy for High Performance Computing (November 1987):

- o Phase 1. Upgrade existing facilities in support of a transition plan to the new network through a cooperative effort among major government users. The current interagency collaboration in expanding the Internet system originated by DARPA should be accelerated so that the networks supported by the agencies are interconnected over the next two years.

- o Phase 2. Upgrade and expand the nation's existing networks that support scientific research to achieve data communications at 1.5 Mbits/s for 200 to 300 U.S. research institutions. A 5-year period and a 45-Mbits/s backbone network are anticipated.

- o Phase 3. Develop a system architecture for a national research network to support distributed collaborative computation through a strong program of research and development. A long-term program is needed to advance the technology of computer networking in order to achieve data communication and switching capabilities to support backbone transmission of 3 Gbits/s with deployment within 15 years. Connections for at least 1000 sites are anticipated.

Physically, the early phases of the NRN would evolve from today's networks; the ultimate phase would be a significant departure from today's technology and would require advanced network research to be successful.

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*The situation was examined at a recent conference, National Net '88, where Ellen Hancock, vice president and general manager of Communication Systems, IBM, noted that there are new interdependencies within and among universities, government agencies, and the private sector, and therefore greater communication and collaboration between them. As the pace of research has increased, it has become increasingly important to share developments as they happen--there is no time to wait for the latest journal. Further, research consistency suffers where researchers cannot afford links to data sources of sufficient bandwidth; data are as reliable and valid as the tools used to collect, transmit, and evaluate those data.

Detailed specification of the network was beyond the scope of the committee's charter. The committee assumed that the NRN would contain the following elements: multiple underlying physical networks; elements from commercial (third-party), private, and government-sponsored research networks at different stages of maturity; a common naming and interconnection strategy; the potential for interconnection with other network users worldwide; and support for multiple protocols (although at the lowest level there would be a limited set of common protocols). Each of these features requires planning, analysis, and development work, some of which are discussed below.

An NRN could vastly enhance the productivity and the quality of output of the U.S. research community, already a world leader. In several fields (notably the physical sciences), the progress of research already calls for state-of-the-art networking services. Meanwhile, the proliferation of information-processing capability is arousing interest in networking in many other disciplines. This multidisciplinary environment raises a number of grand challenges whose solutions are attainable, in large part, through the networking capabilities recommended for the NRN.

The benefits of an NRN extend beyond the research community. First, research is now, and always will be, part of the nation's business. By furthering the conduct of research and the transfer of research to those who develop and use technology, an NRN could greatly enhance U.S. economic competitiveness. In addition, the specific results of the research required to achieve the NRN will advance the data processing and data communications fields significantly. That research will likely produce commercial spinoffs whose impact will extend well beyond the research community. Historically, networks developed for researchers (most notably Arpanet) have provided the foundation for commercial data communications networks. Without an NRN, the market might eventually provide the same capabilities, but not soon enough to meet national research needs and keep the United States competitive.

The committee endorses the vision of an NRN and its promise. The NRN would address important national problems, but a number of issues must be addressed if that promise is to be realized. Chief among them is the need to provide an operational network that is user-oriented as opposed to one whose focus is on network research. This need implies a focus on management as well as a customer-service orientation that has been absent from past research network efforts.

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COMMITTEE FOR INFORMATION, COMPUTER AND
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COMMITTEE FOR SCIENTIFIC AND TECHNOLOGICAL POLICY

JOINT MEETING OF EXPERTS ON THE SPECIAL PROGRAMMES FOR THE PROMOTION OF INFORMATION TECHNOLOGY R&D

17th-18th October 1988

Discussion Document

(Note by the Secretariat)

1. The attached Discussion Document proposes questions for discussion at the meeting. These questions emerge from the conclusions of the report on the "Special Programmes for the Promotion of Information Technology R&D" [ICCP(87)13(1st Revision)] prepared under the auspices of the ICCP Committee. They are set out in particular in paragraphs 10, 16, 24, 30 and 35.

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SPECIAL PROGRAMMES FOR THE PROMOTION OF INFORMATION TECHNOLOGY R&D

1. The report on the "Special Programmes for the Promotion of Information Technology R&D" [ICCP(87)13(1st Revision)] deals with the "pre-competitive" research effort launched by the governments of Member countries. In trying to reflect as faithfully as possible the spirit in which these programmes were designed and launched it came to adopt a very broad definition of the idea of "special programmes". Indeed, for many countries, particularly as regards information technologies, the action undertaken goes far beyond support of R&D in the narrow sense. It comprises a whole series of accompanying measures acting on both the supply of, and demand for, research and seeks to relate two systems, i.e. the production system and the system for the exploitation of knowledge.

2. From this angle, the logic of the report thus tries to bring out:

-- The reasons why special programmes for the promotion of information technology R&D have been launched (Chapter I);

-- The patterns imposed on these programmes by the very nature of the technological landscape in four key areas (Chapters II and III);

-- The relative scale of what has been done by Member countries (Chapter IV);

-- Steps taken along these lines to adapt and strengthen research exploitation systems (Chapter V);

-- Available indications of how these programmes will develop (Chapter VI).

3. The main results of the analysis are set out below.

1. Organisation and objectives of the programmes (Chapter I of the basic report)

4. The likelihood that the rapid technological development affecting information and communications technologies will continue, the scale of what is at stake and the general climate of fierce international competition have in most Member countries resulted in a series of initiatives to protect or strengthen national competitiveness in this area. Government involvement varies from country to country but is often considerable. In the early stages

at least even those governments strongly against intervention in industrial policy have considered it appropriate to take vigorous steps to stimulate the national research effort.

5. The feeling that Europe lags behind and the need for economies of scale while avoiding the dispersion of resources have moreover led to the rapid development of international information and communications technology R&D programmes in Europe.

6. The question of the nature and extent of the role of governments in this area nevertheless remains a subject of discussion in many countries.

7. In nearly all cases the setting up of special programmes illustrates (or at least did so in the early stages) the great importance attached to them: the programmes were frequently institutionalised as such, so as to give them a life of their own separate from both science and technology policy on the one hand and industrial policy on the other. It was sometimes necessary to relax certain legal principles (e.g. anti-trust or anti-cartel law) so as to allow firms to collaborate.

8. These developments show the complexity of the aims of the programmes, which link what are often extremely ambitious scientific and technological goals with socio-economic objectives (industrial restructuring, defence, creation of research networks, economic integration etc.). They also reflect the determination to mobilise public, industrial and university research potential in joint undertakings requiring the creation of new lines of communication between sponsors and participants with widely differing motivations and constraints.

9. Analysis of these motivations and constraints shows that, for each type of partner, participation in pre-competitive research involves a series of commitments, constraints and costs, as well as risks, all of which have to be allowed for if projects are to succeed and so as to avoid creating dangerous distortions in, for example, industrial competition or the general balance of a country's basic research.

10. The special programmes have developed quickly. Launched at the beginning of the 1980s, many seem already to have left behind their "heroic period" and to have started a new stage of exploitation of research findings and accumulated experience. Pre-competitive research may, as is normal, point the way to possible practical applications. Forms of organisation, procedures and mechanisms may no longer be adapted to new conditions in which former partners may become competitors.

<u>Question for consideration</u>:

How are government structures and commitments for IT support evolving? Can public/private sector collaboration which is emerging be preserved in a new context characterised by the growing importance of commercial considerations, and if so how?

2. The technological landscape and its monitoring
(Chapters II to IV of the basic report)

11. The major programmes of R&D in information and communications technologies are strikingly similar in terms of their objectives, in spite of the context specific to each programme, whether devised for economic or military purposes, or set up in a national or international framework. This similarity is not the result of any kind of fashion or imitation, but reflects the fact that programmes are necessarily defined on the basis of an assessment of promising key areas where investment is required, i.e. in line with a strategy drawn up by reference to a "technological landscape" which is the same for everyone and an understanding of which is of vital importance for decision-makers.

12. This landscape has been described from two broad standpoints: micro-electronics, computer architectures, software and artificial intelligence on the one hand, telecommunications, automation and industrial computing on the other.

13. Four main features, dealt with in turn, explain the shape of the new technological landscape. They are:

-- The increasing pace of miniaturisation and integration of electronic components opening the way to the coming stage of ultra large scale integration (ULSI);

-- The design of new computer architectures and the extension of applications of electronics to the processing of knowledge (and not only of information) which promote the two main objectives of the 5th generation of computers, i.e. supercomputers and artificial intelligence;

-- The increasingly marked convergence between computers and telecommunications opening the way to the rapid development of integrated service digital networks (ISDN) based in particular on the digitisation of transmission and switching functions and the extension of opto-electronics technologies;

-- Increasing integration of computers and manufacturing production processes, which is encouraging the development of the integrated automation of production and flexible forms of manufacturing.

14. Assessment of these four main trends and analysis of the content of the main special programmes relating to them show that there is considerable uniformity in strategic national choices: the new shape of the technological landscape imposes a number of compulsory points of passage and routes on technological development. The new landscape forms a kind of framework for strategic national decisions, ensuring that the various programmes have a common technological content.

15. This is why the design of each national (or international) programme will basically be the reflection of a compromise between two requirements:

-- Compliance with these compulsory technological routes, i.e. with the need to acquire the minimum echnological base required to exploit possible points of converge e and potential synergy.

-- <u>The promotion of specific technologies and products</u> so as to increase market shares, implying strategic choices as well as the abandonment of certain lines of development.

16. Differences between programmes thus primarily reflect the different forms taken by this compromise:

-- On the one hand some programmes (<u>supercomputer</u> and <u>Sigma</u> in Japan, <u>VHSIC</u> in the United States) seem <u>more directed</u> towards the development and marketing of precisely defined products;

-- On the other hand some programmes (Esprit for the EEC, Alvey in the United Kingdom) seem directed at more comprehensive technological development.

The programmes in the first category are characterised by a high level of concentration and centralisation: a small number of objectives, projects and participants, and discretionary power of government agencies in decision-making procedures. Programmes in the second category favour a different approach: numerous projects, many participants, broad objectives set in close co-operation with industry.

17. Most governments do not however have statistical instruments which are sufficiently reliable or accurate to constitute an "international instrument panel" to enable them to follow and influence in a fully informed way the trend of their national R&D on information and communications technologies. This is all the more paradoxical to the extent that this area is considered to be of crucial strategic importance and of vital significance for the future, in a situation of fierce international competition where inability to make real comparisons does not favour efficiency.

18. This situation is due to the fact that the scant available data are relatively old and are based on definitions which are too general and too out of date to have any significance or real interest today. Each country tries to use estimates of international efforts whose reliability is obviously uncertain. It will perhaps be necessary to have indicators based on the analysis of the technological landscape to shed light on the trend of research along the main lines imposed by that landscape.

19. However this may be, data at present available now fall into two main categories: information technologies (under the headings "electronics equipment and components" and "office machines and computers"), and "communications". The period covered is from 1981 to 1983-85.

20. For "communications" there are no data on the American effort. Figures for the European Community are extremely weak. Regular progress by Japan is to be noted.

21. In the area of "electronics equipment and components" the main efforts by Member countries are by Japan and the United States, with more than half the total, followed by the United Kingdom, Germany and France: the combined effort of these countries represents more than 90 per cent of the total.

22. As regards "office machines and computers" the role of the United States is much more marked since its share is over 50 per cent. The Japanese share shows an upward trend throughout the period. Here again, the 5 countries already mentioned account for over 90 per cent of the total.

23. In the two areas, the breakdown of efforts by sector of R&D implementation shows the special importance of the public sector in certain countries (Ireland, Norway, the United States, France and in particular the United Kingdom). Everywhere, the relative importance of the industrial effort is particularly striking. Various data moreover confirm the high intensity of R&D in the branches of industry concerned.

24. Other figures relate to numbers of scientific publications in two fields linked to microelectronics: "computers and electronics" and "electrical engineering" from 1975 to 1984. It can be seen that, with the exception of France and Japan, the trend in the different Member countries shows virtually no influence, in terms of publications, of the priority given to these areas.

<u>Question for consideration</u>

Analysis of the technological landscape involves institutional, economic and statistical problems in particular:

-- <u>Institutional</u>: Does preparation of government policies require analysis and follow-up of the technological landscape? How can this be organised and implemented so as to contribute directly to the making of strategic choices by all concerned?

-- <u>Economic</u>: does the existence of compulsory points of passage and of a hierarchy of relationships within the technological system itself (implying a series of phases which have to be crossed to reach a given objective) mean that, in the present state of international technological development, each country must necessarily follow in the technological trails of other countries before developing its own specialisations?

-- <u>Statistical</u>: do the present characteristics of the international distribution of R&D in information and communications technologies as shown by available data correspond to the reality perceived by national decision-makers? To what extent is this distribution a source of concern?

Are international agreements and commitments necessary to ensure that the right data are collected? Does the analysis of the technological landscape which has been undertaken provide any assistance as to the categories which could be used?

3. The development of an exploitation system
(Chapter V of the basic report)

25. The achievement of the objectives pursued by the major programmes of pre-competitive research depends on the ability of industry to exploit the results, and no doubt also -- to an even greater extent -- on the ability of society as a whole to cope with technological progress. It is thus not surprising that, in all countries, R&D programmes in the strict sense are being extended by accompanying measures designed to create a favourable context for applications, to stimulate exploitation of results, establish new rules for the allocation of intellectual property rights, facilitate the creation of new networks and evaluate the effectiveness of what has been done.

26. The creation of a context favourable to applications relates in the first place to the training of personnel needed to apply the new technologies; several Member countries are developing national programmes of varying importance in this area. But the transformation of the general context also requires adaptation of organisations, better public understanding and social awareness of what progress in information and communications technologies involves. Programmes are currently being developed in many countries for these purposes.

27. Steps to stimulate the exploitation of results aim in particular to increase forms of collaboration among as wide a range of firms as possible, for example by setting up specialised "clubs". Many countries have moreover thought it useful to go further in allowing for structural differences within industry and have, for example, introduced special arrangements to make information and communications technologies more accessible to small and medium-sized firms. Consideration is also being given to following up "pre-competitive" research by R&D programmes more closely linked to practical applications. Another problem of concern to some Member countries is how best to deal with the economic implications of military technology. Lastly, it is seen that considerable attention is being given everywhere to how to make university/industry collaboration as attractive as possible to all concerned.

28. Problems in the allocation of intellectual property rights (IPRs) are inherent in all collaborative research programmes where participants contribute a stock of acquired knowledge in the hope of benefiting from the results. In this respect there exists a wide variety of approaches from country to country and from programme to programme. This can be a source of confusion, especially when some participants are active in a number of different programmes. Moreover, in a number of national and international programmes non-industrial participants are not in a position to benefit from the exploitation of research results to which they have contributed.

29. The new tendency to set up new research networks is one of the main characteristics of the current trend of R&D policies in the information and communications field. Whether national or international, the outcome of public, private or joint initiatives, these networks appear to be stimulated by a deep seated movement reflecting an essential requirement of technological development. Although collaboration between leading high technology firms seems to get under way relatively easily, links between universities and smaller and/or more traditional firms seem to pose difficult problems. At the same time, the international extension of networks brings with it the risk of growing complexity, confusion and the stifling growth of bureaucracy.

30. Attempts at evaluation have been made here and there. However they remain limited and, with rare exceptions, are not designed on a truly scientific basis. Strict and systematic public assessment submitted for evaluation by the scientific community must however be one of the conditions for bringing out successes and failings, a useful achievement if we are to learn from current efforts and improve the targeting and resources of future programmes.

> Question for consideration:
>
> Can the exploitation system for R&D findings in information and communications technologies in Member countries still be substantially improved? In what fields are improvements most urgently needed? How important are measures relating to social aspects? What could be the role of evaluations and how could they be improved and their results better taken into account?
>
> In particular, is there a need for consideration of measures at national and/or international levels to adjust the system of allocation of IPRs to the requirements of pre-competitive research?
>
> Do the tendencies observed in regard to publications reflect the fact that scientific results lag behind the setting of new priorities, or do they reveal a trend towards retention of information?

4. New orientations
(Chapter VI of the basic report)

31. Four new trends seem to be emerging in the development of a new generation of special pre-competitive research programmes.

32. The emergence of new research directions in the various fields, from semi-conductors to telecommunications. This movement bears out the fluctuating and changing character of the technological landscape, which needs to be kept under permanent observation.

33. The reinforcement of structures and research capacity which illustrates the growing importance of research teams which link industrial, university and government efforts. This "intermediate" research is bound to raise numerous problems, which goes to show that deciding how to pursue R&D policies in information and communication technologies is just as important as defining their objectives.

34. The development of comprehensive programmes through which some countries or groups of countries are endeavouring to embrace all the economic and social aspects of the new technologies. This trend implies problems for countries whose resources do not allow them to tackle such a wide-range of objectives, and means that the choices open to them are reduced or dependent on international programmes.

35. The growing importance of programmes for application of technological results already brought to light, of which there are more and more examples, particularly in Europe. Some of these programmes concern public or community services (education, health, road safety) while others are aimed at new markets (electronic funds transfer, telecommunications). "Prospecting" for possible uses of the new technologies in the adaptation of public services -- a favourite area for government action -- has however not gone beyond the inception stage.

Question for consideration:

Which new research orientations appear the most important for the future and call for government intervention in particular? Does the reinforcement of intermediate structures require transformation of the traditional roles of university and government laboratories? Do programmes which are more and more comprehensive and the growing importance of exploitation systems call for new efforts by governments and the strengthening of international co-operation?

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COMMITTEE FOR INFORMATION, COMPUTER AND COMMUNICATIONS POLICY

SPECIAL PROGRAMMES FOR THE PROMOTION OF INFORMATION TECHNOLOGY R&D

(Note by the Secretariat)

1. The attached document contains the General Report on Special Programmes for the Promotion of Information Technology R&D, which has been reviewed in the light of recent information and comments received. The Annexes -- also revised -- are circulated in a separate document.

2. The Report is distributed to the Committee for discussion, as agreed at the last session. For this purpose, an Analytical Summary has been prepared separately [ICCP(88)2], to highlight the main issues.

3. At the close of its discussion, the Committee will also be invited to decide whether an ad hoc meeting of experts should be called at the end of 1988 or early 1989 -- in co-operation with the Committee for Scientific and Technological Policy (CSTP) -- to hold further discussions on the report and its implications for policy and future work with respect to pre-competitive research.

4. For the immediate future, however, it is proposed that the Committee recommend the derestriction and publication of the report, taking account of amendments which might be proposed by National Delegations.

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SUMMARY

1. A number of special programmes for the promotion of R&D in information and communications have been developed by Member countries, at national and international levels, reflecting the general concern about the pervasive implications of these technologies for future development.

2. Various institutional arrangements, mechanisms and procedures have been designed to launch these programmes, occasionally calling for adaptation of existing legislation -- as in the anti-trust area -- to open the way for collaborative ventures. Some of these programmes are defined and implemented in the context of sectoral (e.g. defence) preoccupations, others are set on an interdepartmental, horizontal basis. On the whole, special decision-making bodies have been created, whose evolution over time seems to reflect a dual trend: towards greater and greater involvement of industry and users representatives on the one hand, and on the other towards a broader concept of the programmes in question to encompass some of the social and economic implications of IT development.

3. These are, therefore, extremely complex programmes. They have multiple goals, both implicit and explicit, which reflect the diverse interests of various participants and sponsors. Their modes of implementation usually call for special collaborative arrangements between industrial, academic and government partners. Government sponsorship is not always availabe and, when it is, its forms may vary extensively. Whatever the difficulties, however, there is ample evidence to indicate that the development of such programmes reflects the converging desires of government as well as industry.

4. To a large extent, this is a reflection of the fact that the R&D efforts which can be envisaged are increasingly chanelled by the state of technology towards certain pre-determined areas where international competition is acute. All programmes are led to explore certain routes in microelectronics and new computer architectures -- which are at the roots of the information revolution -- as well as in the key applications areas of communications and industrial processes. All programmes have, therefore, similar technological contents. Differences appear with respect to the product and market-related targets. Given the interrelations between the different technologies at stake, government interventions attempt to ensure that there is adequate balance in the development of national capabilities, that traditional sectors and institutions do not stifle new developments, and that the overall social and technological environment keeps pace with new developments, for example with regard to the adaptation of standards.

5. International comparison of the R&D efforts which have been launched by Member countries is hampered, however, by the very novel character of the field. The collection of data has not kept pace with the emergence of new requirements. In spite of the universally acknowledged importance of the IT area, there is no reliable body of statistics. What is available at the aggregate level in IT-related areas provides some evidence of increasing international concentration of efforts. It is not yet possible, however, to compare programmes in greater detail taking into account the common nature of some of the technological goals.

6. The substance of the programmes in question, however, is not limited to technological objectives as such. In attempting to set up ambitious efforts to speed up the emergence of new information and communications technologies, Member countries have been led to a reappraisal of the whole system of exploitation of research results. This includes, for example, demand-oriented policies to improve public understanding and awareness of the implications of the new technologies. It includes new collaborative arrangements involving government, industrial and academic research teams; recent emphasis has often been placed, in this connection, on special measures to facilitate and stimulate the participation of small and medium-size firms and of universities, thus expanding the new networks which are being developed.

7. These new networks extend to the international sphere, in particular in Europe, through the development of major programmes in information and communications R&D. These programmes should be viewed in the light of the overall goal of unification of the market within the European community. Beyond this, co-operative efforts remain relatively ad hoc. The potentialities for co-operation which might arise out of the common character of some basic research efforts remain largely unrealised. Difficulties may be due to the uncertain boundaries of pre-competitive research.

8. An especially important question, in this context, is that of Intellectual Property Rights (IPRs) and the distribution of potential costs and benefits among participants to pre-competitive research programmes. This issue becomes all the more important with the passage of time, as the programmes are redefined and move along closer to market opportunities. The multiplication of national and international collaborative programmes, each with its own IRP arrangements, is confusing. Furthermore, existing arrangements may not always provide, in some countries, sufficient enticement to smaller firms and universities.

9. The effectiveness of a programme will therefore be a factor of its ability to maintain a proper balance between its various technological goals, adjust to international developments, stimulate the participation of relevant research groups at the appropriate levels and provide opportunities for technology transfers which will make significant contributions to industry. Careful and continuous monitoring of the implementation of the programmes in question have been stressed in some Member countries as an essential instrument for policy-making and management, and significant progress have been made in the development of different evaluation methods and procedures.

INTRODUCTION

10. Two decades ago the world entered a radically new industrial age, formed by a whole range of new, rapidly advancing technologies: countless applications of microelectronics, computers and artificial intellegence, telecommunications, computer aided manufacture, new industrial materials, space technology, new energy sources, biotechnologies and an entire panoply of more specialised or, conversely, more heterogeneous technologies such as fine ceramics, robotics, opto-electronics, etc.

11. The sum of these technologies constitutes a technological change which could be without precedent from the standpoint of its magnitude, its consequences and, no doubt the rapidity -- the brutality even -- of its diffusion. This change is already having a noticeable impact on the functioning and structure of national economies, while at the same time reshaping international relations in many different ways:

- By constituting a new technological base for the economy, a base which is at the same time more productive and more economic in the use of resources;
- By renewing the functioning and orientation of traditional industries, while at the same time permitting the creation of new branches of industry and new services;
- By modifying the equilibrium of competitive advantage and the pattern of trade between countries, whose relationships of co-operation and competition are thus being totally recast.

12. The new technologies are thus of major strategic importance. The advantages that can accrue from exploiting them, and the sanctions that may result from the inability to do so, are causing governments to take an active interest in them and institute ambitious projects to encourage advanced technologies.

13. Considered as being at the very heart of the factors that will determine the future of industrial societies, the information and communications technologies have taken a leading place in these government programmes, as in the popular imagination of modern societies. Formerly totally separate, these technologies are now so tightly interwoven that they are breaking down the government and industrial structures that were not able to adapt to them in advance.

14. In many respects, the great technological advances of recent decades in the field of information and communications technologies have been determined by industry, and in particular by a small number of very large firms with world wide ramifications who are the only ones to have the technical, industrial and financial resources required to constantly innovate, to launch and sell new products, and to keep up with the constantly accelerating pace of technical change which requires the extremely rapid amortization of heavy capital investment. Thus, many countries that came in late are already "out of the race" and to take any part at all in the spread of new technologies and acquire the required competence, their enterprises and research institutions have no choice but to try to enter into co-operation or licensing agreements with the world leaders.

Government policies to promote information technologies

15. There was a time -- not so long ago -- when governments hoped to be able to programme, and even plan, scientific and technical progress in the hope of being able to control the whole chain (but is there really a chain?) of initiatives and events leading from the production of knowledge to the launching and diffusion of products. Alas, it had to be recognised that in the final anlysis it is easier to plan to reconstruct an economy ravaged by war or to harvest the fruits of an industrial revolution that started in the last century -- for here we know more or less where we are going -- than to remodel economies on the basis of a panoply of entirely new technologies. The fact is that we appear to be entering on a new industrial revolution. When over unknown territory, flying by the seat of the pants is much safer than relying on the automatic pilot!

16. The multiplication of uncertain factors makes the immediate future difficult to forecast, particularly when the actors are not necessarily able to identify and formulate the direction in which their actions day by day are leading. Once the storm has abated, it may perhaps be possible to draw charts. In the meantime the buzzwords are no longer "planning, obligation, discipline, hierarchy, co-ordination, continuity", as was formerly the case, but "adaptation, deregulation, flexibility, initiative, decentralisation".

17. Faced with international competition and the possibility of a new generation of technological advances, there is nothing more natural than to think of strengthening the very roots of technological progress -- and thus to extend and deepen the research effort, and in particular in the most costly, most complex and most uncertain fields, where private initiative is likely to be lacking, or in any case insufficient. In other words, for long term experimental research and development programmes that are too uncertain and too expensive for a single enterprise to normally be able to accept the risks. Hence the concept of "pre-competitive research" makes its tentative entry.

18. It is thus with the possible appearance of a new generation of information technologies in view, that a certain number of research programmes have been launched by Member countries. Obviously, their ambitions and the range of objectives pursued vary according to the available resources, the technological and economic level achieved and the strategic aims of the country concerned. However, from the standpoint of their technological content proper, the most ambitious of these programmes, launched at the

beginning of the present decade, are aimed substantially at the same objectives, whether we are talking of the Japanese programme (ICOT), the total set of American programmes (under the aegis of the Department of Defense and the private sector), the British programme (ALVEY), the French programme (FILIERE ELECTRONIQUE), the German programme or the European programme (ESPRIT). Other, less ambitious programmes, launched by other countries, cover one or other aspect of these. Chapter I below attempts to highlight the diversity of the objectives thus pursued.

The constraints of the "technological landscape" and the specificity of programmes

19. One may wonder about these resemblances, and one is clearly tempted to think that there must be some effect of fashion or imitation which, because of competition, incites certain countries to arm themselves, by means of research, against the advances that can be expected from the work undertaken by others. This diagnosis would be somewhat simplistic if it did not take account of the "technological landscape" -- i.e. the configuration of choices suggested by the present state of information technologies. The argument of Chapters II and III of this report endeavours to bring out the extent to which the options that can be envisaged are in fact circumscribed by a certain number of lines of force that do not allow very much diversity in the choice of objectives and impose a certain logic on all approaches (whether they be for civil of military ends), but which also define their specificity: in the basic technologies of microelectronics and computer architecture for the first, and in telecommunications and industrial activity applications for the second.

20. Admittedly, the wish to guarantee the progress of some of the technologies concerned had already, in the principal Member countries, caused the launching of major government programmes, aimed, for example, at the development of ever more powerful computers. But each of these programmes remained, whatever its relative size, one effort among others in a range of national research programmes in the countries concerned. In France, for example, the Plan Calcul of the sixties was directly under the authority of what were then the institutions responsible for scientific policy.

21. The demarcation that appeared at the beginning of the present decade gave new programmes a radically new configuration, giving them a distinctive appearance, characterised by specific management bodies, situated in the general movement of sectoral policies.

22. In addition, all these programmes have their own budget lines, which reinforces their specificity. They demonstrate a will to mobilise all the actors -- university, industrial and governmental -- of the research system.

The difficulty of making comparisons.

23. Any attempt to compare programmes, as is done in Chapter IV of this report, comes up against considerable difficulties, however. It turns out to be extremely difficult to obtain data which will allow international comparisons of the efforts in question, in terms of human and financial resources invested. Yet, such comparisons are required to clarify the policy options open to Member countries in this area, in order to assess the

effectiveness of ongoing programmes so that future ones benefit from past experiences, and draw lessons which will assist government decision-makers in the design of new major R&D programmes in information technology, as well as in other high-technology areas.

24. A major -- if not the major -- difficulty stems from the fact that the available data consists of institutional data, rather than groups of products: the industrial affiliation of the R&D performer rather than the technological field to which the research resources are allocated has determined the categorisation of R&D projects in the available statistics. Furthermore, the institutional affiliations in question originate from classifications which were established in the late 1960's and which no longer reflect today's industrial reality -- the more so in a sector such as "information technology related products" where changes have been extraordinarily profound over the last decade. For example, computers (or, rather, computer manufacturers) are included, as office equipment, in a group called "mechanical construction and machinery". Many countries still collect data which amalgamate "computers" and "other machines". Very few collect data for "Electronic Equipment and Components".

25. The result is extreme uncertainty regarding any assessment of public and private R&D expenditures in information technology.

26. There are no really reliable statistical tools in this field, and in any case in these "major programmes" a whole series of efforts of very different nature have to be included. In the case of Japan, for example, they are always civil programmes with exclusively economic aims, while as in countries like France, the United Kingdom and the United States, military programmes may also be included. However, it must be understood that even if they were identical research programmes, they would not be the same thing! The military domain communicates with the economy only through its own entry points and these obviously do not function in the same way as with civil programmes.

27. These are only examples, and there are many other considerations which at present affect the availability and reliability of R&D data in information technology. Of course, efforts are under way to overcome these difficulties, but they may not come to fruition in the near future. In the meantime, this report makes do with what is available, knowing that:

- The data are patchy and do not satisfactorily cover the range of Member countries;

- They do not cover consistently the areas of industrial activity it is supposed to cover;

- Much of them are "estimated";

- Uncertainties about definitions and categories make comparisons between the scales of the various efforts extremely hazardous.

Development of the R&D exploitation system

28. These difficulties are compounded in that the diversity of the programmes depends more on the methods of approach than on the actual objectives. The fact is that these programmes are extremely complex, multidisciplinary and trans-sectoral -- even trans-national -- and take the form of long-term strategic research with specific industrial goals. These programmes therefore call, as early as the planning stage, for the organisation of their links with the private sector and the transfer of the knowledge acquired to all interested parties. Hence the importance of mechanisms such as incentives for co-operation between firms and public establishments, encouragement of industrial research, the targeting of university research, the participation by heads of firms in the definition of aims, arrangements with regard to the allocation of industrial and intellectual property rights, measures to ensure the diffusion of the findings, etc.

29. As the analysis of the programmes concerned proceeded, it appeared to the authors that in many respects the definition and organisation of this research exploitation system sometimes dominated the other considerations. This to such an extent that it might be thought that, paradoxically, the research cannot be conceived without these various complementary measures which finally become as important as the research itself. The research -- however ambitious its objectives may be and however great the resources involved -- may appear almost as a pretext to enable the development of policies aimed at bringing far reaching change to the research system and its exploitation system, creating, nurturing and developing networks, and modifying the patterns of behaviour of individual and institutional actors. In this sense, research and development cannot be dissociated from "other ends" which make it in this particular case a veritable instrument for transforming the socio-economic environment -- in other words, an instrument of social engineering. The implementation of these big programmes does in fact make the authorities want to create a favourable environment for technological change, i.e. an environment that does not hamper innovation and its diffusion but, on the contrary, encourages it while creating the checks and balances essential for maintaining equilibrium of the key economic variables. A whole arsenal of measures is involved here, and they are so closely linked to research activity in the strict sense of the term that it appeared impossible to ignore them: this is the subject of Chapter V of this report.

30. Finally, and in spite of the budgetary uncertainties which prevent an overall assessment of the future of the programmes in question, an attempt is made in Chapter VI to identify emerging trends and new orientations.

Chapter I

THE MULTIPLICITY OF OBJECTIVES

31. The world is undergoing a technological revolution. Recent years have seen the almost universal acceptance of the view that the economic performance of commercial entities, countries, and regions is influenced to a major extent by their abilities to produce and exploit new technologies. This economic performance has in addition become increasingly the primary measure of the success of governments, and is reflected in their ability to generate employment and desirable social and cultural goods. On the negative side, the prospect of relative failure in economic competition is often seen as a question of survival. To support this contention one need only cite the recent upsurge in international trade frictions concerning, for example microelectronic components. The increasing rate at which technologies are developed and exploited has resulted in the emergence of new industries which are seen to be essential components of advanced economies, yet most did not even exist two or three decades ago: semi-conductor production has now replaced the steel industry as the world's largest consumer of capital (1987 OECD countries' investment in this area was about $7 billion).

32. Countries which intend to remain in the forefront of advanced development consider that it is <u>essential</u> for them to have a presence in these new world industries, for several reasons: their absolute size and growth prospects; the ability to produce high added value, especially at the early stages of a new industry or product's development; pervasiveness of new technologies even in traditional or more mature sectors of their economies, and also for military strategic motives. A prime example of this is of course the <u>information technology</u> industry.

33. In the 20th century a new phenomenon has emerged in industrial development; the integration of research into the routine operations of companies. This development is so pervasive that now, in the last quarter of the century we are witnessing a breakdown of the distinctions and relationships between <u>basic</u> research, <u>applied</u> research and development, particularly in their roles as key staging posts of the innovation process. Japan is often perceived to be at the forefront of this revolution. It is the economic success of Japan, coupled with the fact that she spends relatively less than other advanced countries on basic research, that has caused the previously dominant economies of the USA and Western Europe to carry out fundamental reorganisations of their R&D systems. The weakening position of certain Member countries in international trade, for example, is interpreted

less as a failure of investment in basic research than as the failure to capitalise on the knowledge they already possess by applying it to a series of innovations in product and process technologies.

34. A case in point is the intense competition, currently, in microelectronics technologies. The previous apparently effortless domination of the memory micro chip market by the USA has been successfully challenged by the Japanese (256kb) memory chips which followed a $100 million, 6-year research programme. Various countries have decided to respond to what is perceived as a technological threat with a technological programme. For example, in 1987, various US semiconductor firms formed, with government assistance, Sematech, the intention of which is to leapfrog existing products in this area with a new generation of chip technology. Doubtless, other countries will not ignore this, and may be expected to try and launch a countervailing challenge in their own right. Yet, it is far from clear whether any single country has the financial, human and institutional resources to do so successfully.

35. In the meantime, in fact, the position of Western Europe has been one of relative decline in the IT field, for a variety of reasons. Lack of investment, lack of scale economies, lack of entrepreneurial drive, inappropriate education and training are among the reasons put forward to explain this position of relative decline. Within each nation it is fair to say, there has been a recognition of 'technological slippage' in IT and a desire to do something about it. In most cases the response has been a national programme which reflects the national situation and preoccupations.

36. Each of these programmes can be viewed, in its own national or international context, as a reflection of diverse perspectives and a broad range of motivations and goals. However, and in spite of the differences in approaches with regard to policy-making in this area, certain key objectives hold true for a majority -- if not for all. This chapter attempts to bring to light these differences and similarities, and will examine some of the various patterns of decision-making adopted in Member countries, before reviewing the broad scope of objectives sought by the sponsors as well as by the participants in the programmes.

A. The Decision-making Machinery

37. Information technologies have presented a number of critical and unprecedented policy challenges to governments. They probably are the most pervasive technologies in this century, and their broad diffusion involves an unusually broad range of actors and agencies -- if not all actors and agencies. In response to their vast scope, some governments have at first attempted to maintain long-established political and administrative traditions, with autonomous shaping and implementation of R&D policies within agencies, as is still the case in the United States.

UNITED STATES

Organisation for Information Technology R&D

While there is no formal co-ordinating mechanism at the policy-making level, in the strict sense, the White House Office of Science and Technology Policy set up in 1983 a special group, the Federal Coordinating Council for Science, Engineering and Technology on Computing -- the FCCSET, or "Fixit" Committee -- to cover all federally-supported research in the advance information technology area, including both DOD and NSF activities. Fixit brings together the directors of the different programmes on a regular basis to exchange information on the R&D efforts carried out in their respective domains, and thus at least ensure some coherence at administrative level.

Science and Technology policies are only loosely co-ordinated in the United States, a feature which is particularly striking with respect to information technology R&D. The leading federal agency involved in this area is the Department of Defense, with programmes developed in line with its overall mission by the Defense Advanced Research Projects Agency (DARPA), the Strategic Defense Initiative Institute (SDII), and other services. On the civilian side the National Science Foundation (NSF), through its Directorate for Computer and Information Science and Engineering (CISE) -- created in 1986 -- plays a key role in the funding of basic research in the fields in question, while many other agencies are also involved to various extent.

38. In general, reliance on a purely pluralistic approach has not been found to be adequate: individual agencies have turned out not to be equally eager and innovative in exploring the long-term potential of the new technologies; the pressures of international competition have evoked a sense of urgency which could not be satisfactorily met by piecemeal approaches; and the broad nature of the goals which had to be pursued called for co-ordination and articulation between the varous facets (including research, development, diffusion of results, and education). In Germany, the central policy role in this area has, for example, been played by the BMFT.

GERMANY

The Organisation of the IT R&D Effort

With close to 60 per cent of the overall federal budget for research, the BMFT is the central body for the definition of technological policy, and in particular with regard to information technology. Other ministries, such as Posts and Telecommunications, participate to a smaller extent in the formulation policies in this area. In addition to federal ministries, provincial governments also play an important role, especially in connection with the support of research agencies. Other agencies, such as the DFG with respect to basic research, and the AIF for collective industrial research, also play a significant role in their respective spheres.

For the implementation of its policies, the BMFT often relies on the "Projektträger" system: private institutes are thus allocated responsibility for the design, the selection and the monitoring of specific projects.

39. Thus, many countries were finally led to recognise the need for a coherent approach to policy.

40. In the United States, it has even been proposed by a Defense Science Task Force, that a government council be created to overview national strategy in the electronics sector. Many countries have at least appointed cross-sectoral committees to review developments and recommend policies, or organised closely integrated strategies which transcend intra-departmental boundaries and attempt to create an R&D synergy among a broad array of actors.

41. The objectives of interagency co-ordination range from maximisation of resources (or at least, if new resources are not made available, of the effective re-allocation of resources), to oversight of possible gaps in research, and often extend to closer alignment of research and education with the needs of industry.

THE NETHERLANDS

Organisation of the Informatics Stimulation Plan (INSP)

In the Netherlands, a number of agencies are involved in various aspects of the promotion of information technology which includes the supply of information, education, and research. The largest financial contributions are those of the Ministries of Education and Science, Economic Affairs, and Agriculture and Fisheries. The entire programme is co-ordinated by a high-level interdepartmental steering committee, which includes representatives from the ministries mentioned above, as well as from the Ministry for Home Affairs and the Dutch PTT.

Within the Government, the implementation of concrete INSP measures is in the hands of official interdepartmental working groups, with the lead usually assigned to the ministry most directly involved in the area in question.

42. All national programmes are not, however, co-ordinated in such a comprehensive manner. In many cases, it is essentially the R&D component which is at the core. What should be noted, however, is the fact that many

countries have elaborated specific strategies in this area, thus removing the information technology-related research effort from the general structure of national science policy as in the case of the Alvey Programme in the United Kingdom, or of ICOT in Japan.

UNITED KINGDOM

The Alvey Directorate

The Alvey initiative in the UK must be seen in the context of continuity and change in national research over the past decades. The main agencies affecting research in the IT field have long been the Ministry of Defence (MOD) in defence electronics (over 50 per cent of total UK R&D spending is in defence-related activity), British Telecom (BT) (formerly the Post Office), in the telecommunications market, and the Department of Trade and Industry (formerly Department of Industry) with the IT manufacturing and user sectors. The Department of Education and Science has responsibility for funding academic research of IT, through the Science and Engineering Research Council (SERC, formerly SRC). Many other bodies have had inputs into policy formulation, for example the National Economic Development Office.

The general industrial policy has been explicitly non-interventionist. However, the IT sector is a major exception to this, the prime feature being the Alvey Programme, although there have been other programmes including several schemes promoting IT in manufacturing, in microelectronics, fibre-optics and opto-electronics, in public purchasing, and also 'awareness' programmes. A result of increasing concern at the poor performance of the UK IT industry in world and domestic markets, the announcement of the Japanese Fifth Generation Computing Programme, and the perceived importance of the sector generally, as well as an enthusiastic Minister for Information Technology, the Alvey Programme -- steered by the Alvey Directorate within DTI -- was an attempt to achieve collaboration between the main actors (DTI, MoD, SERC and industry) to improve the UK's international competitiveness.

JAPAN

The Organisation of ICOT

The main institutional feature of the 5th Generation Project has been the creation of a central laboratory. There were several reasons for this choice. Probably the most important factor is the technological structure of the project. Though too long term for industry to finance, it involves design as well as basic research and thus falls outside the formal remit of ETL. The enthusiasm of the group of ETL researchers motivated them to establish an environment more conducive to the way in which they wished the project to develop. At the same time, the long term nature of the work meant that many of the basic concepts involved had yet to be formulated and this would have made contracting out all the work to industry very difficult. The second major factor was that the institutional environment in Japan created severe obstacles to the movement of researchers between organisations. Workers in government laboratories are prohibited from carrying out any work in the private sector. The strongly held independence of ministries (particularly MITI, MPT and the Ministry of Education) inhibits the participation of academics and NTT in collaborative projects. University professors may in fact work up to a maximum of eight hours per week in either private or government laboratories. These barriers to mobility are enforced by the lifetime employment system applying to industrial researchers, academics and government personnel. Special arrangements must be agreed between all sides and because of this, exchange of staff can be very nearly impossible to achieve. The creation of a 'third sector' organisation, (of the type known in Japanese law as a Public Purpose Association) to which researchers could be seconded from industry and government (though not universities) without affecting their lifetime employment, provided a solution to this problem.

The financing of research projects presents additional constraints. National laboratory resources cannot be diverted to universities, and it is very rare for government laboratories to receive private sector money. Universities can receive a severely restricted total of private sector funds -- a special regulation on small donations allows each professor to receive up to Y 5-600,000 per subject. During the first phase of the 5G project it was not possible to come to an agreement with the universities but in the intermediate stage ICOT is unable to contract theoretical work from them. As individuals, academics have been involved in an advisory capacity throughout the programme. The financial structure of ICOT is complex. The organisation itself was established through industrial subscriptions. The ICOT budget is presently around Y 5,000 million, much of this is contracted out of industry for hardware and other items specified by ICOT.

43. These examples illustrate the fact that many governments have seen the development of information technology R&D as a special case, which called for extraordinary approaches, in view of their multidimensional objectives, which include technological targets, industrial restructuring, military/strategic aims, regional integration and networking, as well as other socio-economic objectives which are considered below. In view of the magnitude of these objectives, it was considered essential to pursue, on an unprecedented scale, the development of larger collaborative programmes in research. The basic concepts and modes of implementation however, have often fluctuated over time, as in the French case.

FRANCE

The three stages of French technological policy to promote the electronics industry

There were three successive stages: major programmes -- segments -- entire industrial chain ("filière électronique").

- The major programmes stage began in the early sixties. The best known is the Plan Calcul, which appeared as the symbol of the French desire for autonomy in strategic sectors;

- The liberal stage, as from 1974: the policy of segments replaced that of projects. In other words, priority was given to the traditional strengths of the industrial system (in particular telecommunications), in view of the international distribution of competences. The less competitive sectors were abandoned;

- The concept of the "Electronic industry chain" appeared in 1981. The field of information technologies is seen as a system in which no component can be abandoned for fear of a loss of coherence. The fact nevertheless remains that priority is given to consolidation of established positions as against the efforts that would have to be made to reconquer lost markets.

44. Governments have thus come to see as vital collaborative research in which industry, government research laboratories, and academic research units contribute their expertise to projects which will advance their respective industries' international competitiveness. For these reasons, it has been thought appropriate to establish special mechanisms, as close as possible to the core of industrial policy-making, with a view to facilitating the continuous involvement of industrialists in the definition design and implementation of the programmes in question. This type of consideration has been extended to the international sphere, as illustrated by the special arrangements which have been made for the European ESPRIT programme.

EC

The Organisation of ESPRIT

In order to launch the ESPRIT programme and manage its first phase, an an hoc Task Force was created which differed considerably from other EC Divisions as well as from national administrations. The overriding concern was to keep administrative staff to a minimum, with specialists from industry and research centres appointed on short-term contracts to follow the different projects and sub-programmes. As a result, the Task Force became in effect a very flexible pool of experts with considerable experience in information technology, which allowed it to establish a pattern of close co-operation with industry.

In the Summer of 1986, however, the Task Force was merged with DG XIII (Information Market and Innovation), a step which may be interpreted to reflect the view that the programme had matured beyond the "heroic" phase of design and launching, and had already accumulated enough experience to be safely integrated into the normal EC machinery.

45. Obviously, many of the arrangements which have been made specifically for the inception of the new information technology research programmes can only be temporary. New institutional mechanisms might be required to fully bring to fruition initial results, or to design and manage programme whose goals reach beyond generic, pre-competitive, research to seek for marketable products.

46. This is for example the ambition of the EUREKA programme.

EUROPEAN COMMUNITY

The Organisation of EUREKA

Eureka has only a very small secretariat, explicitly without authority, the sole function of which is to provide administrative, support for projects on which the governments of the participating countries have conferred the label "EUREKA", on the basis of proposals coming essentially from enterprises who envisage co-operation projects, with or without the participation of universities and public research establishments. There is no a priori thematic choice, each proposal being examined on its merits by the EUREKA Ministerial Conference.

47. Similar considerations played a role in the discussions with regard to the organisation of the next phase of the Alvey Programme, in the United Kingdom, as illustrated by the analysis of the "Bide Committee" (see Annex).

UNITED KINGDOM

The Reorganisation of Alvey

The Bide Report dismissed, as not practical, the possibility of placing sole responsibility for Alvey with industry, because of the difficulty of creating an industry-sponsored organisation which would be acceptable to all types of firms. It also dismissed the creation (somewhat along EUREKA lines) of a loose structure making use of the normal interactions between firms and between government and industry. It recommended that the organisation be placed within Government, and more specifically within the Department of Trade and Industry which has other relevant activities, an accumulation of experience in its various divisions, and potential influence with other departments and responsibilities for the co-ordination of European Community programmes.

With regard to the management structure as such, it was recommended that the main focus of strategic decision making should be a Board with a senior industrialist in the Chair, while Board members would represent the relevant span of interests (i.e. Government departments, industrial suppliers and users of IT, research councils and universities). There would be, reporting to the Board, an Executive Group operating within DTI with its own identity and with a leader, preferably drawn from industry, who would serve on the Board as Executive Director.

The report suggested that the Board and the Executive Group should remain as small as possible but not too small to jeopardise the implementation of th programme. They should have a separate identifiable budget within DTI.

Within the Department of Trade and Industry, a reorganisation took place at the end of 1987, which led to reallocation of responsibilities in the IT field. The former Electronics Applications (LA) Division has had its responsibilities divided into two: the microelectronics and advanced research functions, including gallium arsenide and superconductivity, have gone to the Alvey Directorate, which thus becomes a research division (and is to be renamed Information Engineering Directorate). The remaining work, in applied areas such as medical instrumentation, will go to the other division, named Information Technology Division.

B. The Sponsor's View

48. The scope of the goals which have been set for national programmes for the promotion of information technology vary from country to country. One of the determinants is the extent to which attention is paid to social and cultural factors. The objectives of Nordic co-operation in this area, for example, aim at ensuring that individuals "are given better opportunities to exploit new technological opportunities" and "are able to cope with the new problems which may accompany new technologies". In particular, the Swedish information technology programme is expected to "lay the foundations for proper exploitation of information technology", an overall objective which is given concrete expression through a number of specific aims.

SWEDEN

The Goals of the National Information Technology Programme

The specific goals assigned to the Swedish ITP, and whose implementation is distributed throughout the government administration, include:

-- the creation of a broad basic knowledge in society so that the implications of IT are understood;
-- the provision of people at work with better knowledge of the possibilities and consequences of IT so that they can take them into account in their work;
-- to produce more knowledgeable specialists in various fields, so that they can incorporate IT in their work in the best possible ways;
-- to provide a good supply of well trained researchers and engineers who can quickly master new technical advances in co-operation with users;
-- to develop pre-competitive industrial co-operation;
-- to facilitate the formation of new companies based on IT;
-- to facilitate the diffusion of the new technology throughout society;
-- to give users the opportunity to influence the technological development.

49. The R&D component of such programmes is thus set in a broad socio-economic context which often implies the development of research in the social sciences as well as in other disciplines, a close connection between research and education policies, and organised efforts to promote "awareness" of the new technological issues throughout the public.

50. These questions will be raised again in Chapter V in connection with the problem of increasing the effectiveness of the exploitation system for IT research. It remains, however, that most national programmes are less ambitious in scope, and are designed to respond to specific policy requirements: either those of international trade competition, or those arising out of strategic concerns in the defence sector.

51. An essential rationale in the implementation of an R&D programme in information technology is that of strategic industrial or commercial policy. Governments have considered that dependence upon imported products or technology is undesirable and may be vulnerable to monopoly manipulation, cost disadvantages in user industries, and even de-industrialisation as a result of substitution of traditional products and processes by new ones.

52. Such reasons have prompted many countries to seek to maintain, and even to increase the competitiveness of domestic industry, which is assumed to be dependent upon the formation of a technological knowledge base. Most European programmes (e.g. Alvey, ESPRIT) have this explicit objective.

53. The ability to acquire an adequate knowledge base, however, does not always entail the provision of public support. For example, collaborative research may be seen by firms to be a valuable exercise, as in the case of MCC, where the US government is determined to retain a non-interventionist industrial policy.

54. As in other fields, though, much support is also given to R&D as a consequence of essential national defence needs.

1. The Special Case of Defence R&D

55. Defence preoccupations have, in fact, played an essential historical role in this area, and continue to do so. The support which is generally given to new technologies -- and in particular to information technology -- in the defence context is relatively substantial in a number of countries such as France, Sweden, the United Kingdom, and the United States, and has always been the focus of much discussion. The actual impact of these programmes in the civilian economy remains a subject of much controversy in the absence of any yardstick or indicator which would make it possible to determine the extent and/or likelihood of "spinoffs". It is generally agreed, however, that technology transfer from the military to the civilian sphere is not straightforward and that much depends on the nature of the technologies being developed and on the ability of the national industrial potential to capitalise on the results of the defence-sponsored programmes.

56. In most countries, one of the important issues under consideration is the extent to which government industrial policies can develop mechanisms which will facilitate these transfers.

57. The United States constitutes a special case in this connection, since the federal Government has no explicit industrial policy and no Department or Ministry of Industry. Outside the United States, observers have aften been led to assume that such a policy is, in fact, being essentially conducted under the defense programmes. This is of course a tempting conclusion in view of the existence of evidence of the past contributions of DoD in the emergence of the American electronics and computer industries since the last world war; in view of the relatively huge volume of resources at stake in this context which amount to about 60 per cent of the whole federal R&D budget; and in view of the comprehensiveness of the programmes in question which do not merely fund R&D projects, but are also designed to reinforce the industry's ability to develop its independent technical effort and upgrade the level of technological competence required to submit bids and proposals. Additional confusion arises because the broad technological areas where international trade competition is extremely intense may also be those which are considered to have important strategic implications, as in the case of the semi conductor sector where DoD has sponsored the creation of Sematech, a new industrial collaborative research venture, as a result of the consideration that: "The erosion of the US semiconductor industry and the consequent decline of the high technology base on which both the US defence and economy rely (is) an unacceptable threat." (Report of the Defense Science Board Task Force on Semi conductor Dependency, quoted in Electronic News, 8.12.86).

58. It remains, however, that R&D programmes conducted under the sponsorship, procedures and mechanisms of the defence sector, and reflecting its specific goals, are not equivalent to civilian programmes. The US Department of Defense has an industrial policy which reflects the extent of its commitments, responsibilities and resources, which is not dissimilar in nature to industrial policies conducted by other US federal agencies in relation to, for example, their space, energy or environment missions. But the sum of these efforts does not really represent the equivalent of what constitutes industrial R&D policy in Europe and Japan, and which has no counterpart in the pluralistic US system.

59. The result is a quandary about whether or not to take defence-related R&D into account in the analysis of IT research efforts. To include it is obviously essential if one wants to obtain an accurate picture of the whole scope of programmes launched by governments to promote IT technologies. But it is also tempting to exclude it, or at least to set it apart, in view of the uncertainties regarding its implications for the civilian sector.

60. With this note of caution, this report will, however, proceed with a discussion of IT research programmes including defence R&D whenever possible, taken as one instance of a specific sectoral R&D policy. In any case, as will be noted below, the data which is available for international comparisons is not detailed enough to permit separate discussion of the defence-related programmes. One specific issue to be raised below in this context, however, is that of the relevance for commercial exploitation of these programmes.

61. The pattern of support of industrial IT R&D is thus vastly different among Member countries. One central question, however, remains common to all national contexts: how far can and should governments intervene to stimulate the development of information technologies through R&D? The most persuasive theoretical case to be made in favour of government involvement in pre-competitive research depends upon the public good argument. This is not often articulated, and is worth analysing in some detail.

2. Collaborative Research as a Public Good

62. It has long been recognised that the production of goods and services and the production of new knowledge involve quite different resource allocation considerations, and that, as a consequence, a competitive market system guided by profit incentives will underinvest in valuable knowledge generating activities. Furthermore, this problem of private under-investment grows increasingly acute as one moves along the spectrum from product/process development to basic research. With respect of the production of knowledge, markets have a tendency to fail, or at least allocate resources sub-optimally.

63. In the field of IT, collaborative research programmes are focused upon basic research and technology development of the strategic, enabling kind, where general principles are being discovered which are directly relevant to the production of known classes of products and their production processes. One would not expect private firms in principle to carry out such fundamental research without public support of some kind.

64. The main reasons for public support are found in matters of appropriability and risk:

-- Basic scientific and generic technological knowledge are international public goods with the result of research codified in scientific, engineering and technological journals, which can be accessed internationally at negligible resource cost. As with all public goods, basic knowledge is used and not consumed (non-rivalry in use) and there is a high cost of preventing access within the open international culture of academic science and engineering. If a private firm is to fund basic science and generic technological development it does so in the certain knowledge that its results will be available to others who did not incur the cost of research. This appropriability problem creates significant externalities and strikes at the root of the efforts. In short, there are no viable private property rights in basic scientific and generic technological knowledge. While it is most acute at the fundamental research end of the spectrum, the appropriability issue applies in some degree to all forms of knowledge generation. The patent and copyright system is an imperfect attempt to protect specific product and process knowledge from imitation, while in practice, firms and nations rely heavily on the tacit nature of much applied knowledge, on secrecy, and on lead times to protect their investments;

-- From an investment viewpoint, the more fundamental the knowledge sought the greater is the risk that commercially exploitable results will not be available within a relevant time scale. It is this factor which not only makes firms unwilling to invest in basic science and engineering but which also seriously limits the role of private capital markets in funding fundamental research. Loan capital is here quite inappropriate, and the provision of equity capital is limited by the time horizon of investors, and the impossibility of writing explicit contracts to specify what knowledge will be generated by which date. Even the high risk venture capital market is not primarily concerned with financing research projects per se but rather with financing development work within established small companies.

65. It is for these reasons of risk and appropriability that private firms account for a negligible proportion of fundamental research, while those that do engage in this activity to any significant degree are large diversified corporations able to self-insure project risks within a large research portfolio. Moreover, the applied research and development work undertaken by private firms is almost exclusively financed out of internal funds or from public funds.

66. Private unwillingness to invest in fundamental research is the primary economic reason for public support of science and engineering in the university system, and the reason why firms look to the universities for the knowledge to underpin future generations of technology. However, placing fundamental research, and applied research and development within different institutions raises obvious difficulties with respect to the timescales and cultures of business and academia. Sufficient difficulties with respect to the co-ordination of effort, definition of objectives, and transfer of results

to exploitation arise, so as to raise valid questions about the return investment in publicly funded research, and the appropriateness obtained from current institutional frameworks for translating knowedge into competitive technology.

67. A variant of the 'public good' argument may also be applied to the exploitation stage. It is a commonly observed phenomenon that the first entrant to a new market, or producer of a new product, often fails to profit from the innovation. Subsequent entrants to a market learn from the mistakes or experience of the pioneer and thus gain market advantage. The advent of more applications-oriented programmes, with market or user-led emphasis can be rationalised by this argument. Firms will be less hesitant to pioneer new developments if government and fellow collaborators share in the risks and costs of innovation, and possibly also in subsequent developments. This will be of particular importance in a fast moving industry such as IT.

3. Industrial Restructuring

68. A reason for collaborative research cited by several programmes, for example by Alvey and ESPRIT, is that UK and European IT firms are either not large enough, or not well enough integrated, to effectively meet the threat posed by Japan and the US. Collaboration in research could help achieve scale effects. Similar arguments have also prevailed, however, in the US, to stimulate collaborative research between smaller IT firms faced with foreign competition.

UNITED STATES

The Microelectronics and Computer Technology Corporation (MCC)

MCC was launched in 1982 as a permanent institution, explicitly as an American reaction to the Japanese 5G announcement. Ten companies signed up in that year, but no research could be done before the Justice Department had given its approval, entailing effectively a declaration that MCC would not fall foul of anti-trust law. It has its own central laboratory in order to benefit from the advantages of co-locating researchers and to make it possible to manage co-operative research within a broad grouping where boundaries between individual MCC programmes were shifting.

Research began in January 1984 with thirty-five people. While MCC is wholly an industrial effort, with no state involvement, membership is only open to companies substantially owned or controlled by American citizens. Its first chairman and chief executive officer described the absence of IBM, AT&T and Texas Instruments from MCC as "my security blanket against further concern from the Justice Department" (Datamation, 15th May 1984). It is recognised that, in attempting to deal with the perceived Japanese threat, those MCC companies active in the computer industry also strengthen their hands against IBM with its $4 billion R&D budget. "It's like another element of the federal budget, as is General Motors. That has been our history, that as an industry matured and the cost of R&D became very high, you only had a few giant corporations because everybody else fell out. MCC really is an effort to keep middle-sized companies independent and still able to play the game" (Inman in Computerworld, 10th June 1985).

As of October 1986, MCC comprised approximately 450 persons. Of the 390 members of the technical staff, 65 per cent were hired directly by MCC and 35 per cent were employees of shareholder companies. The membership fee is $1 million, with further contributions for participation in individual programmes of the MCC.

69. It could be argued that if industrial leaders and governments were genuinely concerned by the inability of certain branches to compete effectively, due to the relatively small individual firms, then they have a choice of two alternative policies; either non-intervention resulting presumably in the overwhelming of the domestic IT industry in question, or else directed reorganisation of the industry to form bigger units capable of meeting the challenge.

FRANCE

Action Plan for the Electronics Sector (PAFE)

The strategy for improving the situation was based on traditional practices in French industrial policy, and electronics came under a resource-mobilising programme. Quantitative objectives were set for the 1983-87 period with macro-performance standards for 1987 being defined, i.e. real growth in production of 9 per cent against un underlying trend of 3 per cent; the creation of 50 000 jobs, instead of a downtrend towards a net loss of 10 000 jobs; a surplus of FF14 billion against a foreseeable deficit of FF20 billion.

These quantitative objectives were to be achieved by energetically improving national competitiveness in each sub-sector, the major goal of PAFE being to achieve technological independence in integrated circuits and the computer field. National industrial "champions" were selected to lead the effort in each case.

By using objectives to define scenarios, it is clear that the PAFE planners were basing themselves on the interventionist spirit of France in May 1981. But they were also looking back, implicitly but obviously, to the most successful experiment in modernisation and industrial reconstruction in France's history: the First Plan (Monnet Plan) of 1947-1952 which had succeeded in spectacularly developing six sectors considered at that time to be "strategic" (coal mining, electricity, the iron and steel industry, construction materials, transport and agricultural machinery).

The PAFE was not set in an international context from the outset. It was not until over a year after the programme was adopted in September 1983 that France made the first attempts at achieving some complementarity between the French vision of the electronics sector and European action.

These overall goals and approaches have been under review by the new Government after the March 1986 election. Budget allocations, which were initially reduced in the 1987 budget have been revised upwards and a new "Information Technology Programme" is being developed.

70. In the light of past experience, however, most governments will be wary of excessive intervention as well as absence of intervention in the restructuring of industry. From this perspective, supporting R&D collaboration seems a rather weak but realistic option open to government in the hope that it may lead to more permanent arrangements such as mergers. Large scale R&D pre-competitive programmes may provide an opportunity to stimulate reappraisal by industrialists of their strategies with research and economic constraints.

71. A further aspect of IT policy which appears paradoxical is the enthusiasm with which governments have taken to supporting research, when in other industries their basic philosophy is one of non-intervention. This has resulted in the peculiar situation where governments with "no" overall industrial policy (i.e. a non-intervention policy) have a well-developed IT policy.

72. This is, of course, to a large extent a reflection of the "public good" character attributed to certain aspects of research which have been discussed above. In Japan, for example, it has been asserted that the role of government is to supplement the market mechanism and private enterprise with respect to R&D, and to create a favourable atmosphere which will stimulate R&D initiatives in the private sector. As a result, a programme started in 1981, "Research and Development Project for Future Industries" with the mission to pioneer in designing new functional systems for high technology industries such as space and aeronautics, nuclear energy, new electronics and biotechnology. Another programme, the "Large-Scale Project", was also started in 1981 to provide high speed calculation ability in connection with government-sponsored R&D aiming at an improvement of the technological infrastructure in areas such as weather forecasting, energy development, earthquake prediction, etc.

73. The potential for applications of information technology is so broad that government intervention in R&D seems unavoidable -- at the very least in order to ensure that overall social goals are taken into account.

74. One additional step in the formulation of a more interventionist R&D national policy is the selection by governement of areas of allegedly great future commercial promise within the IT field. As will be shown below, there are technological constraints on the choices which can realistically be made and many of the major national and international programmes under way have broadly similar objectives and coverage of technical areas. These promising areas may therefore eventually turn out to be over-populated, highly

competitive, and result in few profits. Hence the attractiveness, in particular for smaller countries, of attempting to develop a "niche" strategy, rather than attempt to try for a "broad front" strategy.

75. This is a need which may be felt to be particularly acute, depending on the structure of the industrial system, as in Finland where the smallness of firms is said to require special measures to promote high risk investment in R&D. In Sweden, the national information technology development plan (NMP) "is not to make industry self-sufficient in standard components, but to develop and secure the ability of the electronic industry to design and produce, quickly and effectively, critical electronics components for the rest of the 1980s", with a view to "generate more exports and a greater ability on the part of the national industries to participate in major procurement and co-operation projects, to reduce dependence on foreign countries".

76. The choice of areas of specialisation not yet pre-empted by others, however, may be very difficult, given the relatively well-defined nature of the technological field under exploration by all countries which will be described below. As a result, and to achieve the kind of technological "fine-tuning" which is required, the planning process itself will often be set up on a collaborative basis, as in Finland, with representatives of industry, the research community and public administration.

4. International Programmes and National Competition

77. The motivations for establishing international, mainly European, collaborative research programmes, are generally similar to those for national programmes. European firms are thought to require collaboration to achieve the scale necessary in research and in market size to compete successfully with US and Japanese firms.

78. The more general aims of the European Community are an additional objective, such as market harmonization, and establishing overall industrial policies. A longer-term objective may even be, as with national programmes, the restructuring of the IT industry to improve its external competitiveness.

EC

ESPRIT

The selection of ESPRIT projects is to reflect four broad strategic criteria:

-- Contribution to the competitiveness of the Community IT industry;

-- Effect on the structure of the European market towards greater harmonization;

-- Strategic importance to maintain and improve technological co-operation within the Community;

-- Contribution to Community-wide collaboration in R&D.

79. A major concern for national governments is the co-ordination of policies and programmes at national and international levels. In many areas European collaboration is sought in order either to achieve the scale of markets or research efforts required. National programmes have been seen to be necessary not only as an "entry ticket" to international programmes, but also as a necessary condition for their exploitation.

80. A difficult issue concerns the extent to which a national government should try to influence its own organisations and firms in their applications to international programmes. At one level this is simply a problem of avoiding duplication, but more serious issues can arise owing to the existence of divergent interests between government and firms. To give three examples: a firm in one field may decide upon a strategy of international collaboration as providing the strongest technical and commercial solution to its requirements, while a government may decide upon a policy of encouraging the growth of a strong domestic base by means of internal collaboration, despite a recognition that this may start from a weaker base.

81. A second example concerns 'vertical' collaborations at an international level. A UK firm, for example, could arrange collaboration under an international programme with a foreign 'downstream' company, which itself is in competition with other UK firms. The overall advantage of this collaboration to the UK would be difficult to assess.

82. In some cases, the destabilising risks of international programme are increased by the fact that universities may see international collaboration as a way of replacing declining national government funding.

83. European collaborative research programmes are a special case, since their goals must be assessed in the light of an overall concern for the future of Europe in new technologies. In addition to R&D efforts as such, they will often include significant standardization elements, as in the case of RACE in the telecommunications area.

84. Recent years have, in fact, seen a proliferation of European collaborative research programmes in IT. Europe, however, does not have the long tradition of would-be pre-competitive research enjoyed, for example, by Japan. It is nevertheless a fundamental mistake to see these European initiatives as being aimed solely at narrow technological goals in an attempt to catch up with Japan and the US (coverage of technology areas by programmes is shown in Table 1). The various programmes must be seen to be multidimensional in their objectives.

85. Many analyses have been made of Europe's relatively poor performance in the IT field, and there has been growing agreement on its causes:

- On the demand side, despite the efforts of the EC, the 'domestic' European market is fragmented, and does not give the advantages of a large home market enjoyed by the US and Japan. The markets are generally open to international competition, with the only significant exception being telecommunications in which protectionist trading or purchasing policies have been responsible for lack of competitive industrial performance rather than encouraging it;
- On the supply side, many of the largest European firms are small when compared to the giants of international trade: IBM, AT&T, Hitachi, etc.

Table 1

PROGRAMME	ALVEY PROGRAMME	ESPRIT	ICOT	MCC	EUREKA
TYPE	UK National	European Strategic Programme of Research in Information Technology European Community	Institute for New Generation Computer Technology Japanese National (international invitation)	Microelectronics and Computer Technology Corporation US National	European Community (12 countries) EFTA countries (6 countries) (including Switzerland, Sweden, Iceland, Finland, Austria & Turkey) (19 European Countries)
OBJECTIVES	Promotion of the competitiveness of the UK IT industry by encouraging the development of 5th generation computer enabling technologies	To provide the European IT industry with the technology which it needs to become and stay competitive with the US and Japan within the next decade	Development of 5th generation (non-von Neumann) computing technologies, and technologies of Artificial Intelligence	Maintaining the competitiveness of medium sized US companies against the Japanese commercial threat (and IBM?)	To raise the productivity and to strengthen the competitiveness of the participants industries on a worldwide basis, thus contributing to lasting prosperity and employment, by provision of a framework for international technological cooperation between firms and research institutions in the field of advanced technologies.
	(also, both Alvey and ESPRIT have subsequently emphasised the objective of establishing a tradition of collaboration in their respective industries)				
FUNDING	50% government	50% European Community	100% government	100% industry	No special funding, unless by individual government initiative.
STRUCTURE	Distributed programme	Distributed programme	Central research institute	Central research institute	Distributed programme
STAFFING	Company/university own personnel	Company/university government lab personnel	Seconded/industry (40%)	Free market recruitment (60%)	Participants own personnel; small secretariat
START DATE	May 1983	Pilot phase 1983-4; Feb 1984	October 1981	1984	Launched July 1985, First projects announced November 1985
DURATION	5 years	5 years, + 5 year extension	10 years 1981-91	permanent research institute	No fixed term
BUDGET	£350 m over 5 years	750 Mecu	1986 (provisional) ¥5,500m	1986 budget $65 m	Estimated cost of present projects 3.5 billion ECU
STAFF NUMBERS	(distributed programme) approx 2,200 at peak (1987)	(distributed programme) 7,200 man-years over 5 years	approx 50 research staff (+ approx 300 ICOT related researchers in industry)	280 research staff (1985) target 400	400 entities (108 projects)
STRATEGY FORMULATION AND PROPOSAL ASSESSMENT	At beginning of programme	Annual re-formulation and call for proposals	3 stages: 1982-83 basic technology 1985-88 subsystem development 1989-91 5G computer working prototype construction	Continuous	No strategy: continuous project proposal assessment
UNIVERSITY INVOLVEMENT	encouraged	encouraged	seconded staff	university links and some secondees	participation encouraged
SMALL FIRMS	participants	participants	excluded	excluded	participation encouraged
RESEARCH COVERAGE	"Enabling technologies": - VLSI - Man-machine interface - Software Engineering - Intelligent knowledge-based systems Applications - 4 Large Scale Demonstration Projects	"Generic technologies": - advanced microelectronics (inc CAD) - software technology - advanced information processing Applications - office systems - computer integrated manufacturing	- parallel processing architectures - AI technologies	- human factors technology - software technology - AI/knowledge based technologies - VLSI/CAD - database technologies - semi-conductor packaging and interconnect - parallel processing	Information Technology Robotics and Manufacturing (inc lasers) Biotechnology and Medical Technology New Materials Environmental and Transport Technologies Energy Marine Technology

86. Various governments in Europe have in the past followed domestic policies which have been mutually contradictory: some aspects of policy would strive for a better articulation with international considerations, and others reflect sectoral preoccupations, which were seen to require the maintenance of several competing companies, in cases such as the UK's rejection of a merger between GEC and Plessey in 1986.

UNITED KINGDOM

Collaboration vs. Competition: GEC and Plessey

GEC was in 1984-6 the 14th largest company in the world selling defence electronics, telecommunications equipment, and electronics systems, while Plessey was 21st in this league. In the UK they supply between 25 per cent and 30 per cent of the total UK output of electronics components and capital equipment, with a larger share in some important segments.

In 1986, GEC made a £1.2 billion takeover bid for its rival, Plessey. The takeover was contested, and referred to the UK's Monopolies and Mergers Commission which recommended against the government's acceptance of the bid, on the primary ground that a takeover would significantly reduce competition in the UK's domestic defence electronics market.

The Department of Trade and Industry, supporting GEC, argued in favour of the merger. (Plessey increased its R&D spending in the five years up to 1984/5 by 227 per cent, reaching £303 million).

The Ministry of Defence's arguments were accepted, and the takeover stopped.

GEC and Plessey are members of several Alvey projects together.

5. The Future of Domestic Competition

87. This episode exemplifies several of the issues facing governments and companies:

- -- The trade-off between national and international competitiveness involved in decisions on takeovers;
- -- Whether R&D should be carried out in collaborative programmes (national or international) or within companies;
- -- How far should IT policies be subordinated to other issues of economic, industrial or social policy, for example in this case, defense procurement policy;
- -- How far should government intervene in issues of industrial R&D.

88. A government may thus be caught in a spiral of increasing intervention in the IT research effort. This arises due to the pressures of international competition and because the weight of the public sector in the national economy will entail special commitments and responsibilities -- the more so in the case of countries which undertake significant public programmes in high technology areas such as defence, space or energy. These programmes will lead to the underwriting of technological developments responding to advanced specifications, will provide initial markets for the resulting products via government procurements, and will promote the development of industries which may or may not eventually turn to civilian applications. Eventually the government will be faced with the question of "how far to go too far" in order to safeguard a national industrial capability in the area.

89. This type of dilemma is particularly acute in areas where the industrial cost of entry is high, such as in supercomputers. In the United States, for example, this is an area where the federal government has had an essential historical role in the development of the industry, because of its importance as a prospective buyer of equipment (in particular in the defence, space and academic research sectors): in 1985, more than 50 per cent of the supercomputers in the United States were owned or leased by the government. In 1982, the DoD accounted for 70.5 per cent of the federal government supercomputer R&D expenditure of $17 million. This obviously entails special responsibilities when a government decision can deeply affect the survival prospects of the industry. This was recognised, for example, by the President's Science Adviser in 1983, when he asked the Departments of Energy and Defense to explore potential supercomputer initiatives: "Our national interests require that we maintain a dependable domestic capability to meet our needs. We can't permit foreign manufacturers, whose development costs may be heavily subsidised by their governments to jeopardise that capability".

90. It is becoming increasingly apparent therefore that the objective of maintaining domestic competition often conflicts with the need -- prompted by economic considerations -- to increase the industrial ability to compete internationally.

91. In some cases governments have followed 'national champion' policies, whereby a single company has been favoured, for example by research funding or public purchasing policy, in an attempt to help it achieve an internationally competitive status. The apparent failure of these various national policies in the 1960s and 1970s as judged by increasing lack of success in international trade leagues (e.g. the EC semiconductor industry's share of world markets fell from 13.9 per cent in 1978 to less than 9 per cent in 1984) has caused governments to look at the next level at which economies of scale can be achieved, and also at other reasons for industry's relative failure.

92. In other cases -- for example in the United States' telecommunications industry or through the French "Programme of Applications de la Filière Electronique" before 1986 -- competitiveness has been sought through an effort to increase the number of potential "champions".

93. Another question raised by the pre-competitive research programmes is that of technology transfer and measures to be taken to facilitate the exploitation of research results. European universities and research institutes may well be in the first rank, but the main problem in areas such

as microelectronics is how to use the work of researchers in manufacturing industry. A major part of Japanese success has been this ability to use the results of research, combine them with manufacturing technology, and get reliable products produced at low cost in a short period of time. The Japanese VLSI programme is typical of this success. The programme, run from 1976 to 1979, developed the technologies for 64k and 256k random access memories, and also enabled Japanese companies to produce in volume at low cost.

94. All the pre-competitive research programmes recognise the need to improve exploitation methods, though not all address the problem directly. Neither Alvey nor ESPRIT programmes directly address the questions of manufacturing economics. They have the objective of producing 'enabling technologies', and the responsibility for exploitation is placed on individual participants, and yet, as one observer has stated:

> ".... it is generally recognised that, if research effort is not transformed into competitive advantages it will become merely an academic exercise and, ultimately a waste of resources."

95. An interesting point here is that most of the programmes in question have been specifically designated '<u>pre-competitive</u>', that is they are not intended to produce final products for the market, but to assist in producing the enabling technologies, standards, etc., more economically and for the other reasons given elsewhere in this paper. There is a fundamental distinction between projects (or programmes) which stop at the pre-competitive stage, and those which go on to encompass manufacturing technologies, or even include 'market-pull' policies. Yet Alvey and ESPRIT successor programmes seem likely to move downstream by including end-users as participants in projects. In some respects the 'pre-competitive' label attached to programmes may rapidly become a reflection of the past stages of the programmes in question rather than a reflection of their true character.

96. As products move downstream, different issues arise particularly with respect to the distribution of benefits.

C. <u>The Participants' View</u>

1. <u>Firms</u>

97. Many difficulties are encountered by firms undertaking collaborative work. Even Japan with its long experience of such programmes and which has served as a model for other countries, encounters many of these problems. Therefore it is important to understand the reasoning underlying collaboration.

98. It is convenient to distinguish between <u>horizontal</u> collaboration, in which firms collaborate with their competitors, and <u>vertical</u> collaboration, in which they collaborate with complementary firms. Complementarity may exist even if firms supply similar products, so long as these are in different markets.

99. Companies undertaking research face a trade-off between cost and time. More money spent on a project will generally result in faster, or better, results. In a fast-moving technological area, with only a brief window of

opportunity for its products, time saved can make the difference between success and failure before products are superseded by further developments. Collaboration may enable a firm to achieve a superior trade-off by the application of more resources to a piece of work. In addition, the combination of several firms' knowledge bases and expertise may even allow a move to a superior choice of trade-off by combining new skills.

100. The following reasons for collaboration amongst firms may be identified:

-- Risk sharing. Uncertainty about the technological outcomes of alternative R&D options means that to be sure of picking the best one a firm must cover several options. This may be beyond the resources of a single firm, so by pooling resources with other firms it is possible to insure against making the wrong choice. Clearly the benefit is dependent upon the effectiveness of conditions for technology transfer;

-- Cost sharing. Where there is a single research option, but associated costs are too large for a single company to bear, it is sensible to enter into collaboration. In addition to pure cost sharing, the indivisibility of R&D facilities or equipment may also be overcome;

-- Complementarity. Collaboration may take place between firms with different knowledge-bases, where their specialist skills can be combined to mutual advantage to address a particular problem. Even where knowledge bases are similar, it is possible that synergistic effects may arise through overcoming rigidities in a single firm's perspectives;

-- User-supplier collaborations. A special case of complementarity arises where the relationship between participants is that of user and supplier. This type of collaboration will be closer to the market than some purely technological ventures. Studies of innovation have repeatedly emphasised the importance for success of meeting user requirements, and users benefit from early experience of, and influence over, the outcome;

-- Standards projects. In the field of IT the importance of standards is hard to overemphasise. Firms which gain acceptance for their own approach gain a significant market advantage, and once established, standards are hard to replace. The conditions for standards acceptance include the formation of a critical constituency of users, which may be established through agreements between firms. Collaboration can provide both the means for developing standards and also the crucial market acceptance;

-- Knowledge transfer. Collaborations may be entered upon with the aim of acquiring knowledge from other parties. This can be on the basis of an equal exchange or can involve trade-offs for other inputs, or cash. Industry-academic collaboration may be motivated by this, with academics receiving funding, equipment, or access to technology in exchange for knowledge transfer to industry;

-- Defensive collaboration. A firm may enter collaboration as an insurance against the success of other firms or collaborations, or to keep a watching brief. In extreme cases the objective may even be to disrupt a threatening collaboration.

-- Precursor to other links. A collaboration may be used by firms as a precursor or trial for pursuit of long-term closer links, either in collaboration, in exploitation, customer-supplier relationships, or even a full merger.

101. Despite these potential gains from collaboration, there are also costs and potential problems associated with such undertakings.

-- Overheads. It is almost inevitable that two or more firms working together will function less effectively than would a single entity undertaking the same task. New routines must be established, procedures and decision-making rules determined. Firms with dissimilar management structures may find difficulties at the interface. Many decisions may have to pass through additional points and may be delayed. Where work takes place on different sites, delays in communication may result;

-- Leakage of proprietary information. It is rarely the case that all collaborators begin from an equal position of knowledge and skills. Expensively acquired knowledge may have to be distributed, or may 'leak' through close contact to competitors. Collaboration agreements will generally make provision for access and protection for background knowledge, but this will not solve the problem entirely;

-- Uneven benefits. A competitor may benefit to a greater extent from this collaboration, either through the generation of new, or more appropriate intellectual property rights (IPR's) or a greater ability to exploit results;

-- Loss of control over projects. Unless collaborators have identical interests, projects will represent a degree of compromise in definition and implementation, which may reduce benefits to an individual firm;

-- Loss of flexibility. Contractual commitment, and longer term goodwill, may require the continuation of a firm's participation in a research project past the point at which it would have withdrawn if in sole charge. Termination costs, financial and less tangible drawbacks must be considered a potential problem;

-- Vulnerability. In an interdependent collaboration, withdrawal of a crucial partner may jeopardise a project. Duplication of functions to insure against this risk would lead to excessive numbers of participants with all that this involves in costs and delays, and also would dilute the benefits to each participant;

-- Market relationships. Collaborations between customer and supplier may hold dangers for the supplier if the customer has an unrestricted access to the resulting IPR's. The customer may acquire enough information to manufacture its own needs, or even begin competing for third-party business, so collaboration agreements must recognise and eliminate this possibility;

-- Dangers of take-overs. Participants in collaborations, especially relatively small firms, may find that their knowledge base becomes important enough for a partner to wish to acquire the whole company, and thus achieve a consummate, if unwelcome, collaboration.

102. Taking into account these influences on collaborative research, the overall view of many companies, as judged by their involvement in programmes, is that collaboration is worthwhile, on a national, and eventually on an international, basis.

103. At the very least, from the perspective of governments, national programmes will play a useful role in spreading awareness of the opportunities and challenges of the new technologies. This was found, for example, in Denmark, where the national technology development programme (TDP) was reported to have led about 50 branches to investigate their respective status in relation to information technology, many of which developed plans of action to stimulate increased use of the new technology and started campaigns aiming at their member companies. Thus, many companies were said to have considered the possibility of introducing information technology, or even introduced information technology applications, earlier than they would have done in the absence of such a programme.

104. To translate the resulting knowledge from pre-competitive research into competitive products and processes, however, is another, much more complex undertaking. It requires that research goals be selected in accordance with industrial and market prospects, and that participating firms are able to combine the research outputs with specific, tacit knowledge and engineering skills, together with complementary capital, organisational and marketing assets. It is not merely a question of quality of the research. When the Bell system was dismantled in the United States after 1984, a section of Bell laboratories was hived off, relabelled Bell Communications Research Inc. ("Bellcore"), in order to serve the research and engineering needs of the new local operating companies. In January 1987, however, US West Inc., one of the seven regional Bell companies announced its intention to leave Bellcore: the company believed that joint research undertaken at Bellcore on behalf of all the operating companies failed to reflect the industry's growing competition, particularly between the operating companies themselves. US West felt that Bellcore should have developed and expanded proprietary exclusive research and development activities for individual companies. The company has given notice of its intention to sell or dispose of its stock in Bellcore in order to develop other mechanisms for its research needs.

105. One could argue that, in this case, the research setting was adapted to long-term work, rather than to the kind of product-oriented projects which a new highly competitive market might require -- and which is not necessarily the most favourable context for collaborative industrial research. Rather than permanent institutional arrangements, this situation may call for "à la

carte" co-operation, as occurred for example in Norway when a major R&D project called "VLSI-circuit design" was launched in co-operation by agreement between two government technical institutes and several large firms who funded 70 per cent of the cost. As a result, a new company was started in 1983 and is now established internationally in VLSI design.

106. This question of exploitation of research results is discussed separately below.

2. Academic and Other Research Organisations

107. The involvement of academic institutions, technological universities and government research establishments strengthens greatly the case for collaborative research. In the current state of IT, fundamental scientific and engineering research provides a necessary input into the development of the knowledge base. For the reasons outlined above, these research skills are often not located with industry but in other academic and research organisations. In drawing together the institutions with different comparative advantages, collaborative research programmes can be hoped to have a profound effect on the effectiveness of the national research effort. Academic skills are focussed upon fundamental research questions of strategic significance. They tend to offer an important channel to monitor international scientific and technological developments, and explore the opportunities for adaptation of foreign advances to national requirements.

108. Collaboration raises awareness in academics of the requirements for competitive market exploitation and the timescales to which industry must operate. Access to the frontiers of knowledge alerts industry to significant trends in exploitable research and, within the collaborative club framework, this knowledge is disseminated widely throughout the industrial community. Without collaboration these links would be ad hoc and incapable of generating a focussed, critical research mass. Exchange of manpower between industry and basic research institutions is facilitated and the greater mutual awareness of the different cultures of industry and basic research should surely improve the ability of universities to supply appropriately educated scientific manpower. From an instrumentalist, investment view of science, collaborative programmes would seem indispensable to the attainment of a greater return for the national research effort.

109. Collaboration between the industry and university worlds has expanded significantly in all Member countries since the 1960s under the pressure of many factors such as the quest by academic researchers for new sources of support, a new awareness in industry of the importance of long-term research for its own future needs (in terms of research results as well as the training of personnel in developing fields), and -- most importantly -- a new convergence in high technology related areas between the research pre-occupations of industrial and university laboratories. These developments, however, have been particularly significant in the United States where the diversity and flexibility of the university system has made possible a broad range of co-operative arrangements with firms, building on a long-standing recognition of the importance of education and research. the last decade has, in fact witnessed a number of spectacular -- "megabucks" -- research contracts between large firms and several leading universities. This trend has been facilitated by several legislative changes which have either

opened the way for more active academic interest in the exploitation of research results (for example in allowing universities to own patent rights on the outputs of government-funded projects), for an extension of industrial co-operative involvement through more liberal interpretation of anti-trust laws, or through the provision of fiscal incentives for collaboration.

110. For example, several major computer vendors -- such as IBM, Digital Equipment Corp., Apple Computer Inc., Hewlett-Packard Co., Wang Laboratores Inc., NCR Corp., Honeywell Inc. -- have made commitments in recent years to contribute about $200 million in cash and equipment to universities. These policies are largely without parallel in Europe, except in so far as some of these American companies have made gifts on a smaller scale there.

111. In Japan, however, donations and "long-term loans" of equipment to universities and colleges play a significant role in outfitting research and edcuation institutions, although firms remain by and large reluctant to enter into active research co-operation. As noted above in relation to the organisation of ICOT, various factors place severe constraints on the extent to which government and academic researchers may work in, or for, private institutions. Various formulas have been sought, for example, in the setting up of the ICOT project, to circumnavigate all these obstacles.

112. Co-operation between firms and universities in research in the United States, however, has gone one step further in the information technology area with the advent of joint industrial undertakings such as the Semiconductor Research Corporation (SRC).

UNITED STATES

The Semiconductor Research Corporation (SRC)

The SRC was established in 1982 as a non-profit foundation linked to the Semiconductor Industry Association 'to conduct research which will include scientific study and experimentation directed toward increasing knowledge and understanding in the fields of engineering and physical sciences related to semiconductors' (SRC Annual Report, 1984). It funds basic research on microelectronics at universities, and describes as its mission:

-- To identify the scientific and technology needs of the American integrated circuit industry;

-- To develop a long-range strategy for advancing the integrated circuit capabilities of its members;

-- To carry out research that implements this strategy while at the same time enhancing the manpower resources of the industry;

-- To disseminate information and transfer technology to its members.

Members pay a membership fee to SRC proportionate to their turnover in microelectronics and enjoy five benefits:

-- Participation in the definition of a research programme that is many times larger than the fee each company pays;

-- Lead time with respect to the disclosure of research results;

-- Participation in interactive research meetings with investigators;

-- Access to a planned data base on research activities and results;

-- Royalty-free access to patents and copyrights that may result from the research.

SRC therefore provides smaller corporate members with access to 'generic' research which they could not individualy afford to undertake. Larger members view SRC primarily as a form of training school. Information produced with SRC support is, however, subsequently diffused through normal research publication mechanisms and technical meetings. Members have the right to royalty-free exploitation of patents resulting from SRC-funded research.

In 1983, SRC supplied some $6 million in research funds. It was possible to begin operations very rapidly because the Corporation decided not to create delays by debating research goals or funding procedures in great detail. It was only in the 1984 funding round that more formal application and evaluation procedures were initiated. In this respect, the SRC probably benefitted from the absence of government money. This allowed it to ride roughshod over the notions of 'fairness' which tend to be introduced when public funds are at stake. The SRC supplied some $13.3 million in funding to universities in 1984; $17.3 million in 1985; and budgets for 1986 and 1987 stood at approximately $20 million. In 1984, 57 per cent of SRC funds went to the six universities regarded by SRC as belonging to 'tier one': Cornell, CMU, MIT, Stanford and the University of California at Berkeley. The remainder was split between a further twenty-eight institutions. By 1987, the SRC involved over 40 universities and 65 firms (33 of them members of the Semiconductor Equipment and Materials Insititute, inc., Chapter). The United States Government also had a stake in the SRC by this time, its contribution stemming from a number of agencies e.g. DARPA and DOE, but co-ordinated by the NSF.

SRC is to focus funding in three 'centres of excellence' (Cornell, Berkeley and Carnegie-Mellon) and another seven programme centres which it is hoped to develop into centres of excellence. By the end of 1984, SRC estimated that it was funding research by 201 faculty members and 231 graduate students. Three years after its creation, over 1 000 people and 100 organisations were involved with the corporation, though staffing levels at the SRC headquarters in North Carolina still stood at a mere 28 in January 1987.

113. When one moves closer to manufacturing processes, however, different forms of co-operation must be developed. In the United States, the concerns of the semiconductor industry have led them to plan the creation of a joint programme -- "Sematech". In Belgium, similar technological goals with another approach has entailed a regrouping of universities to better respond to industrial needs, through the Interuniversity Microelectronics Centre (IMEC).

114. The mix of political, technological and institutional considerations involved in each case may thus lead to different arrangements, each of which carries its specific benefits and costs.

BELGIUM -- UNITED STATES

IMEC and SEMATECH

In Belgium, the three universities of Leuven, Ghent and Brussels have formed an independent company, the Interuniversity Microelectronics Centre (IMEC) to work on the technologies and manufacturing processes needed for the next generation of semiconductors. The launch of IMEC was backed by the Belgian government which provided the basic resources needed to set up and equip a new R&D centre. Less than a year after its opening, the company was carrying out advanced research in conjunction with more than 70 companies worldwide. This collaboration can take two forms: the centre may invite scientists from industry to work on problems of common interest; it may also carry out complete research projects and develop whole manufacturing processes which may then be transferred to the client company. IMEC's universtiy roots (it is linked by computers to universities and industrial high schools) has prompted it to make it possible to involve students in the design and manufacture of chips -- thus playing a key role in their technological training.

In the United States, the need to pool resources in the semiconductor research and development area has also been widely acknowledged. The major US manufacturers intend to join forces in setting up "Sematech" -- a company that will be expected to develop chip technology and manufacturing processes to exploit them. Substantial support is expected from the federal government which is to become involved because of strategic defence implications in this area. The resulting organisation would be very different from IMEC.

115. One note of caution should be sounded in any case. The encouragement of universities to concentrate on exploitable areas of science, and even to be 'market led' in choice of research projects, brings with it the danger of concentrating on short-term work to the detriment of longer term, fundamental research. Results from this type of basic research can often be the most significant in the long run, even by narrow economic criteria, though the risks and even time-scales are open to great uncertainty. For example, the reorientation of university microelectronics research towards silicon and away

from more exotic materials could, in the long run, undermine the ability of firms to move to newer technologies as diminishing returns to research set in for silicon-based technologies. The balance of advantages here is difficult to evaluate.

116. An additional impact of collaboration on universities may be noted. The research fields being addressed often have no identifiable pre-existing community, as they are still developing and defining boundaries, for example in the field of 'man-machine interface' (MMI). One of the most powerful influences that large scale research funding can have is to focus the work in such immature fields on aspects having significance for applications. To the extent that this may serve the purpose of making research more relevant to industry, this may be a good thing; to the extent that it inhibits free development of the field, the arguments given above hold.

117. In the Alvey Programme's MMI area, academic psychologists have not been involved significantly, and have criticised the programme for their exclusion. On the other hand, the Director of the Alvey Programme has criticised academic psychologists for their lack of flexibility in not adapting to the requirements of an MMI research effort.

118. Most collaborative programmes encourage, or even depend upon, the involvement of universities, yet problems do exist for academics who wish to join collaborations. First is the high entry cost. Programmes are generally designed around commercial entities which are expected to contribute perhaps 50 per cent of total costs of projects, in the expectation of future profits from results. This is clearly impossible for many universities and research institutions which may not have the financial resources to enter into what may be risky commercial ventures, or may even be prohibited by their constitutions from doing so, as are Japanese universities. In some cases, university involvement has only been possible by the use of 'creative accounting' which enables existing overheads to be included as contributions to the costs of projects. A further difficulty is that the returns from such research are gained from commercial exploitation of products: again universities may be unable or unwilling to carry out such exploitation. Arrangements may have to be made to trade off financial contributions for rights to exploit resulting intellectual property rights.

119. Universities may also find that they cannot comply with some of industry's requirements regarding commercial confidentiality. The objective of academic researchers is to publish papers and achieve wide dissemination of results, which may be in contradiction to their associated firm's wish to keep results secret, for a time at least. It may be hard to impose commercial conditions on some researchers; for example, many researchers in the Alvey Programme are postgraduates who are not 'employees' of a university, and, again, they may wish their results to be publicly disseminated.

120. From industry's point of view, different imperatives pertaining in universities may cause other frictions. One frequent problem is the need of firms to work to deadlines, especially in fast moving research areas. Universities are not usually geared to this style of research, and it may be difficult to foster a new attitude amongst tenured academics. Similarly, traditional university systems may not have relevant structures to enable contracted research to be carried out. In Alvey a major delaying factor was

due to the need to recruit researchers on short term contracts to carry out this work. US universities are more used to this type of funding and manage to operate a system in which researchers can be given incentives and yet maintain continuity. The administrative departments of universities must also be geared up to handling this new type of funded research.

Chapter II

TECHNOLOGICAL SOURCES OF THE INFORMATION REVOLUTION

121. The transition from very large scale integration (VLSI) to ultra large scale integration (ULSI) on the one hand and the race for supercomputers and knowledge processing systems on the other constitute the two major challenges of the final years of this century in the field of information technologies.

122. The striving for an even greater degree of integration, based on continuing improvement in integrated circuit technology, will be considered in the first section. Determined by the elimination of a certain number of technical obstacles which will be reviewed, the progress of integration is synonymous with lower costs, improved processing power and greater reliability of both microprocessors and memories.

123. While the first four generations of computers are conventionally identified by reference to the technology of the basic components (vacuum tube, transitor, integrated circuit, VLSI), this is because technological progress was concerned mainly with the hardware components of the system, without any real change in architecture and software. With the race for the fifth generation, however, the specific orientations of technical progress are changing. In other words, while technical progress in basic components must not be neglected, it is essentially basic changes in architectures (abandonment of sequential processing), software production (software engineering) and the information processing mode (algorythmic or symbolic) that dominate. It is from this set of improvements that the two major products of the fifth generation are being born: supercomputers and knowlege processing systems (artificial intelligence). The supercomputers differ from their predecessors in that they have considerably increased power obtained in particular thanks to new architectures. The knowledge processing systems will make it possible to develop, on the bais of symbolic processing, new applications: expert systems, high level man-machine interfaces and intelligent robots.

A. Microelectronics

124. The concept of microelectronics can hardly be imagined without that of "integration", i.e. the performance of electronic functions, first simple, then increasingly complex, in a single micro-unit. Integration, or the replacement of individual components by integrated devices, is thus the basic

trend, characteristic of the evolution of products in microelectronics. The pursuit of integration, a vital factor in reducing costs and increasing reliability, rests essentially on the technical evolution of the basic unit of the integrated circuit, the transistor, as regards both its design and its miniaturisation.

125. The technological improvements made to the transistor, which generate a continuous increase in the complexity of manufacturing equipments, as well as the scope and limits of integration, will be reviewed in turn. This analysis will lead to the conclusion that this overall technological dynamic has an impact on microelectronics products, which become ever "cheaper, larger and faster". A consideration of the tendency for capital costs to increase and for the price of products to decrease will make it possible to describe the fundamental characteristics of the microelectronics economy.

1. Transistor design and miniaturisation

126. As the vital component in the circuit, making it possible to amplify electric currents, the transistor is a discrete component, i.e. a separate device manufactured from silicon in which a specific quantity of impurity is introduced ("doped" silicon). This is the basic unit of the circuit, on which most of the technological improvements are focussed.

Two large transistor families

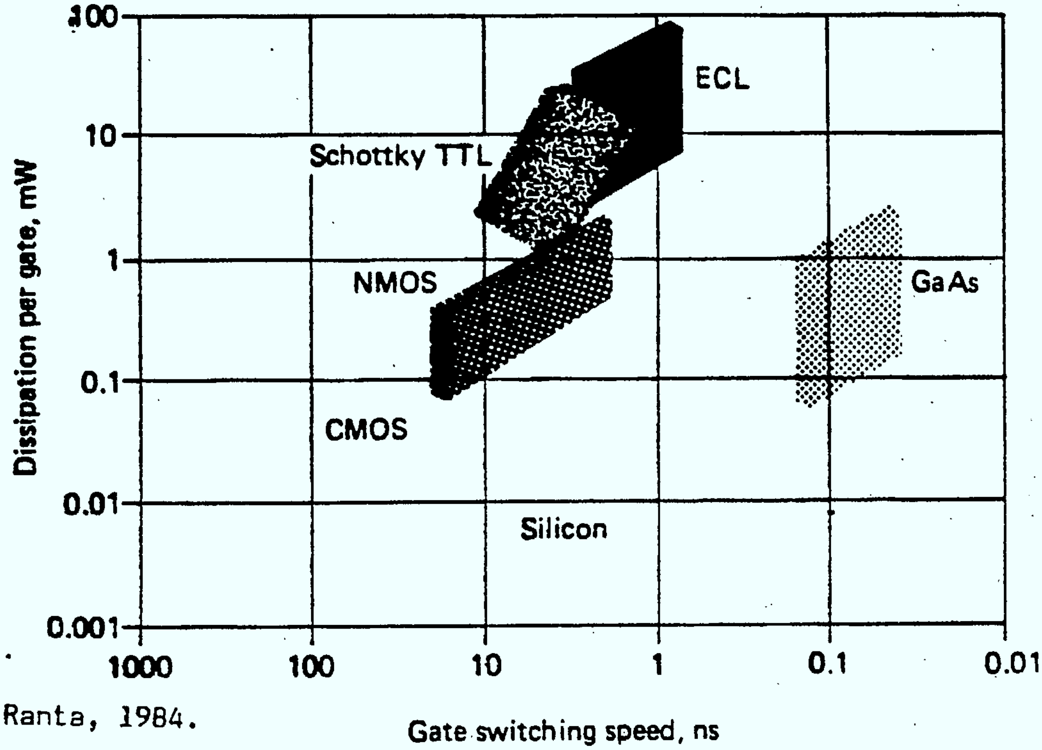
There are two large transistor families: bipolar transistors and MOS (Metal-Oxide Semiconductor) transistors. Bipolar-type technologies were the first to spread at the end of the 1950s. MOS technologies have developed much more recently.

The main bipolar technologies are: Transistor-Transistor Logic (TTL); Emitter-Coupled Logic (ECL); The Schottky (after the name of a German physicist); the 12L. The main MOS technologies are pMOS, nMOS, CMOS and SOS.

127. The speed of operation of the basic gate, which determines the processing power is the main parameter by which the evolution of transistor performance can be measured. It is important to keep in mind that speed and consumption are interdependent in a microelectronic circuit: by applying more power, greater speed can be obtained. Today, the most rapid logic circuits are based on bipolar transistors (transistor-transistor logic -- TTL), but they consume a lot of power. Circuits based on field-effect transistors (MOSFET), use less power, but are also less rapid. Within this second family, circuits based on the complementary MOS transistors (cMOS) are becoming faster without consuming more power. The dilemma between speed and consumption (see Graph 1) thus becomes less acute due to technological progress.

Graph 1

THE SPEED-CONSUMPTION DILEMMA



Source: J. Ranta, 1984.

128. The two great families of integrated circuits correspond to the two types of transistor mentioned -- bipolar and MOS. Bipolar devices, whose main quality is high switching speed, were developed first. Today, the use of MOS devices is becoming more predominant. We shall see below that the main reason for the present domination of MOS transistors is not so much due to their low consumption as to their compactness, which makes them particularly suitable for large scale integration: the record density of components on a chip is held by MOSFET technologies. As shown in Table 2, bipolar circuits have by no means fallen out of fashion.

Table 2

TRENDS IN MARKET SHARES OF MOS AND BIPOLAR TECHNOLOGIES

Type	Sales (US$ billions)			Annual Average increase 1980--1990
	1982	1985	1990	%
MOS	5.4	12.0	33.6	26
Bipolar	4.7	8.0	14.4	15
Total	10.1	20.0	48.0	22

Source: Immonen, 1983.

129. The technological evolution of the transitor since its invention after the second world war, reveals a striking trend towards the miniaturisation of this component. As R. Ayres (1987) points out, the speed of this movement is due to the existence of a virtuous circle involving the different characteristics of the transistor: each reduction in physical size brings a corresponding reduction in energy consumption per unit of operations. This latter reduction brings in its turn a reduction in the time required for heat dissipation, which increases the speed of operation and makes it possible to create more compact circuits. Thus, miniaturisation is an essential condition for integration, as we shall see below. It is also a factor in increasing speed and reducing the cost of operations.

130. The extent of this trend may be understood by means of an indicator, line width, i.e. the size of the smallest component of the circuit, which fell from 30 microns (30 millionths of a metre) in 1960 to 1 micron in 1980.

131. It would appear that in the future we can expect line widths of 0.1 microns, which will probably be the threshold beyond which devices can no longer function in the same fashion. Theoretically, the minimum size of the transistor is calculated by J. Mayo, 1986, at one-ten millionth of a centimetre per side, giving a surface area of $10^{-8}cm^2$. To achieve such threshold sizes, the use of pencils of rays in engraving techniques should be gradually replaced by newer technologies which will be more suited to finer and finer designs (X-ray lithography).

New transistors

German researchers at the IMT (Fraunhofer Institute for Microstructure Techniques) in Berlin, in collaboration with the industry, have just achieved an important breakthrough. They are in fact preparing to be the first to market, through the Cosy-Microtec company that they set up a year ago, the tools necessary to manufacture a chip using X-rays coming from a particle accelerator. Thanks to this technique, IMT has already obtained prototype transistors with a line width of 0.3 microns. This is a remarkable achievement in view of the fact that the Japanese NTT company recently presented a prototype memory chip containing transistors whose structures were "only" 0.7 microns wide.

Source: M. Fantin, 1987

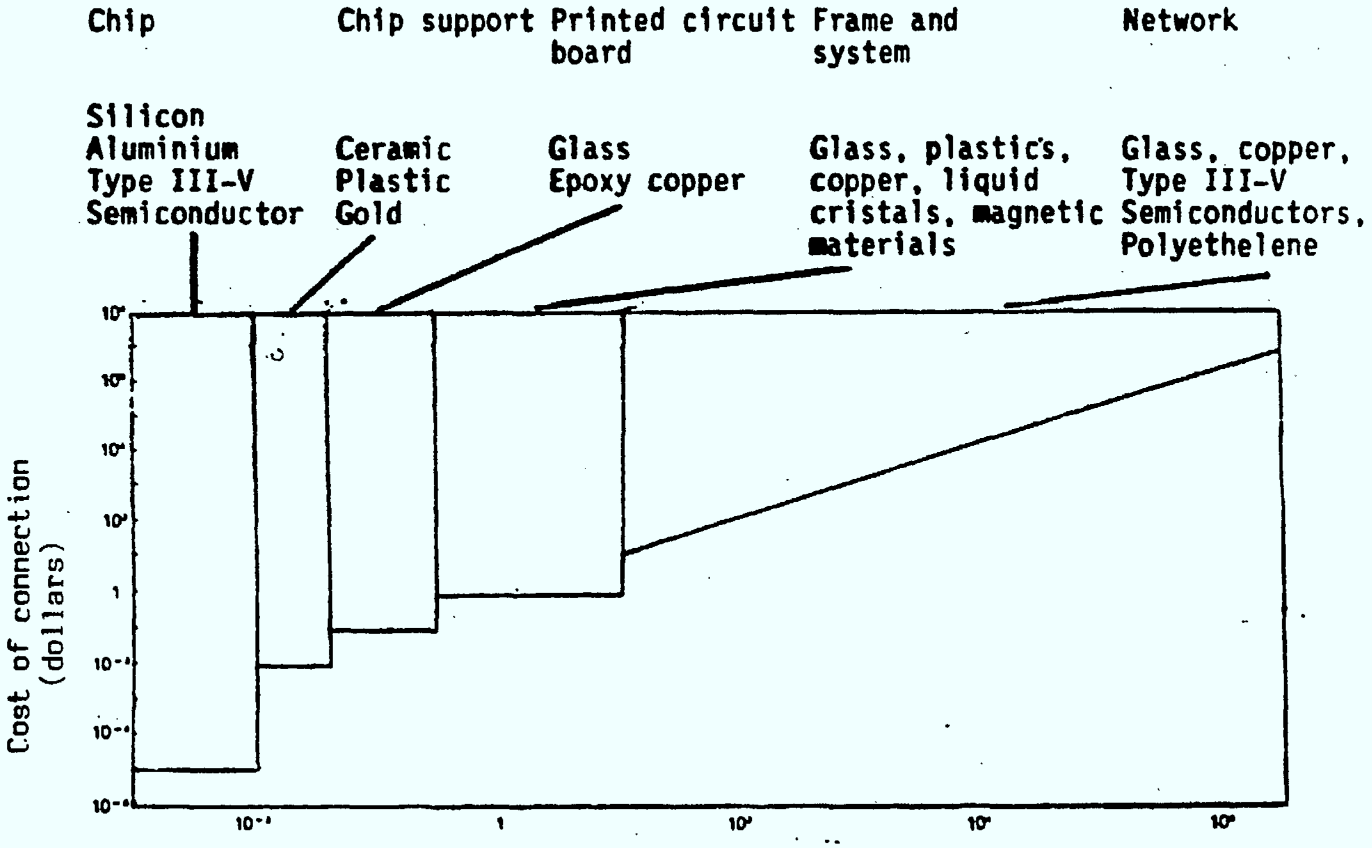
2. The trend towards integration

132. The other major trend in the technological evolution of semiconductors, that can be distinguished from that towards the miniaturisation of transistors, is integration, i.e. the replacement of discrete components by devices making it possible to house all the logic components of the circuit on a single silicon chip. The integrated circuit is thus an assembly of transistors, resistors and conductors housed on a single chip of semiconductor

material. Integration is the vital factor in reducing the cost of information processing hardware. As J. Mayo (Graph 2) demonstrates, the vital component in the cost structure of such a device is the cost of the connections between the components, both at the level of a silicon chip and that of an international telecommunications network. Naturally, the longer the connection, the greater the amount of material used and hence the higher the cost.

Graph 2

COSTS OF CONNECTION AS A FUNCTION OF DISTANCE



Distance from the centre of the chip (metres)

Source: Mayo, 1986.

133. Thus, whatever the complexity of interconnections within a chip, each connection costs less than a hundredth of a cent. On the other hand, connections between the chip and its environment are considerably more expensive (roughly 7 cents, or 1 000 times the price of a connection within the chip). The main reason for integration is thus to concentrate the maximum possible number of connections in the place where they are least expensive.

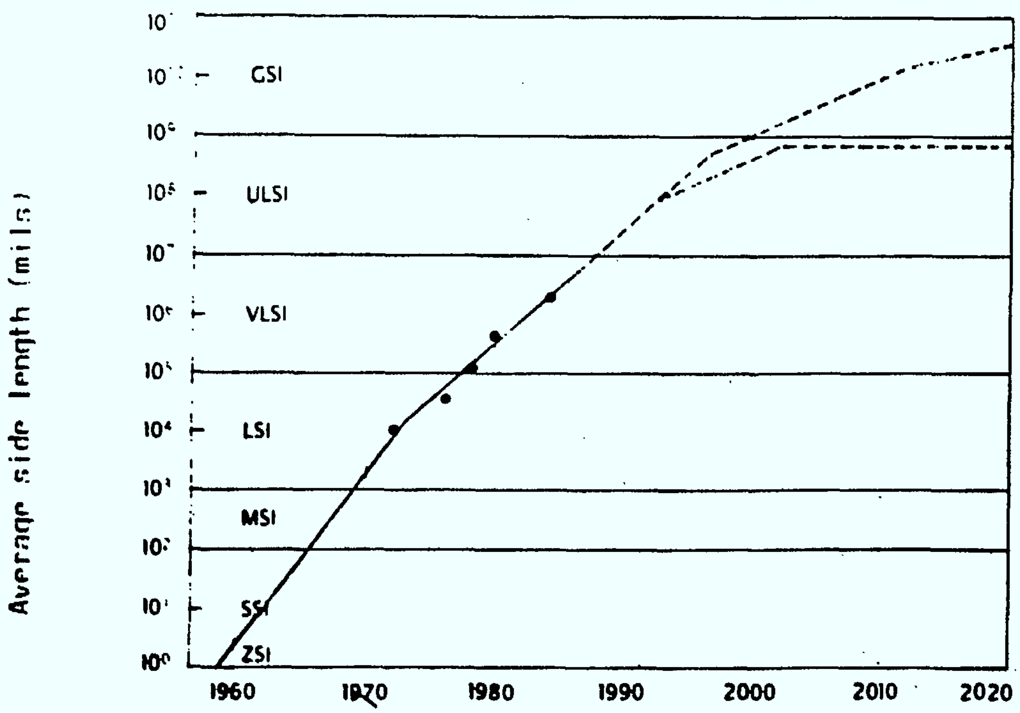
134. The first generation of such circuits was characterised by small scale integration (SSI) with ten or so bits (a bit, or binary number, is the basic information unit) per device. The second generation, medium scale integration (MSI) produced devices containing 10 to 100 bits. The third generation, large scale integration (LSI) greatly accelerated the phenomenon, leading to the marketing of devices with 10 000 bits. Very large scale integration (VLSI) makes it possible to achieve a figure of 100 000 bits.

135. It should also be pointed out that the type of transistor (bipolar or MOS) is not without its effects on integration: the absence of insulation makes p-MOS and n-MOS very compact. With respect to circuits using bipolar transistors, MOS circuits can pack roughly four times as many components on the same area of silicon. This is why MOS technologies are dominant in large scale integrated circuit manfacture at present, even though the switching time is slower than for bipolar technologies. Nevertheless, progress in manufacturing techniques and better knowledge of the materials involved, tend to blur the differences between the two technologies: with a strong increase of the density of polar circuits on the one hand, and on the other with an improvement of the speed of MOS systems. A gap remains, however, between these two families of circuits.

136. The limits to integration are set by the relationship between the size of the biggest chip and the size of the smallest transistor (miniaturisation). Taking into account the limits of miniaturisation which have been discussed above, the maximum size of the chip therefore acquires crucial importance (Graph 3).

Graph 3

THE INCREASING SIZE OF THE CHIP



Source: Immonen, 1983.

137. The maximum size of the chip depends on the possible presence of microscopic faults in the silicon. The bigger the chip, the greater the probability of its being faulty, and hence unusable. The present limit is $1cm^2$, but might be able to reach $10cm^2$. Since transistors cannot occupy more than 10 per cent of the surface of the chip, since they have to be surrounded by connections and insulating areas, and since the size of each transistor cannot be less than $10^{-8}cm^2$, a chip will be able to contain a maximum of 100 million transistors. At present, chips can contain 2 million components. In other words, we shall be able to increase the complexity of circuits only by a further factor of 50.

138. To arrive at this level (100 million transistors), it will first be necessary, as mentioned in relation to new engraving techniques, to complete the process of miniaturising the transistor. An effort will also have to be made to increase the size of chips by reducing the number of faults in the silicon. To achieve this it will be necessary to have a better knowledge of structural faults and automate the manufacture of chips to an even greater degree. Quality control procedures will have to be constantly improved. These two major lines of research (transistor miniaturisation and increasing chip size) correspond to a strategy of saturating silicon-based technology. Once the limits of silicon have been reached, attention will be switched to other materials and other types of circuit. Using gallium arsenide, for example, more rapid and even more complex integrated circuits can be produced. Thus it is hoped that with this material it will be possible to build three dimensional circuits, where the components will be assembled in superimposed layers and no longer simply deposited on the surface of the chip.

Table 3

EVOLUTION OF THE GALLIUM ARSENIDE MARKET

million $

Segment	1984	1986	1988	1990	1992
Busines	5	23	90	299	702
Communications	10	43	149	470	1021
Consumer	4	30	123	359	758
Data processing	6	26	116	344	865
Government	61	179	395	681	1157
Industrial and instrumentation	8	41	170	494	1113
Total	94	342	1043	2637	5614

Source: Eden, 1983.

139. Competition between the silicon and gallium arsenide technologies has now been modified by the arrival on the scene of a third technical solution, based on the use of superconducting materials, whose properties make it

possible to use Josephson junctions. Thanks to these properties Josephson junctions can perform the same microelectronic functions as semiconductors but with a far higher performance, in particular from the standpoints of speed and energy loss. The problem is that these performances can be achieved only at very low temperatures. Thus there is now competition between three technologies, offering new possibilities for integration and miniaturisation.

140. It should be noted that all the technological improvements mentioned have resulted in the increasing complexity of the manufacturing process (use of CAD, new engraving procedures, quality control and testing equipment). But these improvements have also brought about a great improvement in microelectronics products, as regards both cost and performance.

> **The new tools for miniaturisation**
>
> Although there is an acute controversy among scientists and industrialists about future engraving techniques, X-ray microlithography may turn out to be the most promising. This technique generates very precise structures, with resolution extending to 0.3 microns. However, an accelerator (synchrotron) is required in order to apply such X-ray lithography, and broadcast an intense electromagnetic flow.
>
> In view of this new technology, the attack through plasma will probably play an increasing role in miniaturisation.

3. The dynamic of products

141. Integrated circuits can be divided into two broad categories:

- Microprocessors, which offer on a single chip the functions equivalent to those of a computer's central processing unit, and which are integrated circuits produced directly by component manufacturers.

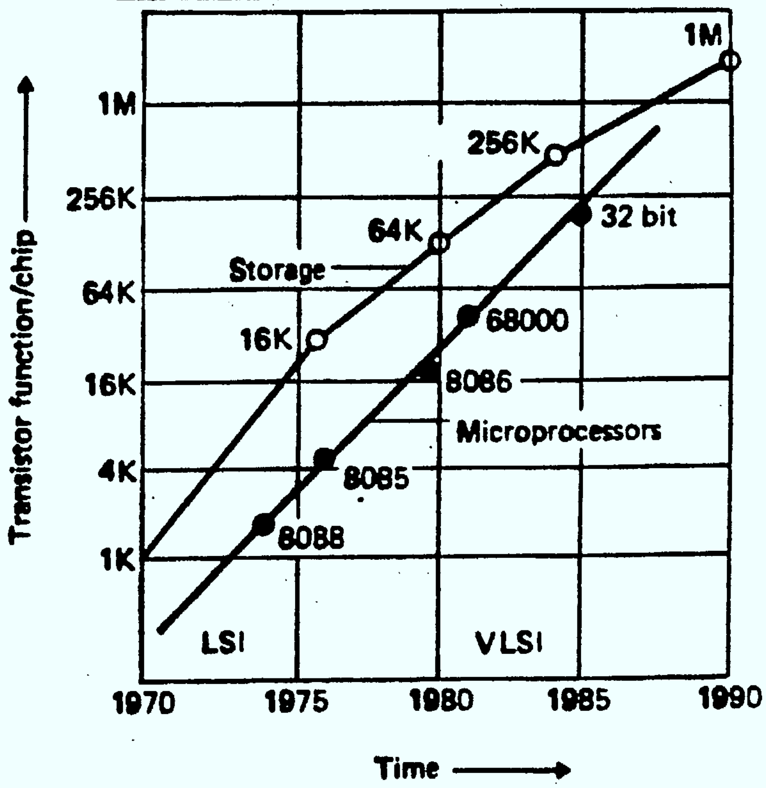
- Memories, which are semiconductor devices storing information in the form of electrical charges. A distinction is made between random access memory (RAM) which can be used for both reading and writing, and read only memories (ROM).

142. The evolution of these two products is essentially based on the phenomenon of integration, as indicated by Graph 4. If the microprocessor is classified simply according to the number of bits (binary digits) that it can handle in one operation (a number known as word length), it is thus now already in its fourth generation, having passed successively from 4 bits to 8, 16 and 32. Similarly, a random access memory chip now commonly contains 16 000 binary digits (16 K bits). Memories of 64 K then 256 K have since appeared.

143. This evolution obviously has an impact on the cost of these products, as shown in Graph 5 which shows the reduction in cost per bit of random access memory.

Graph 4

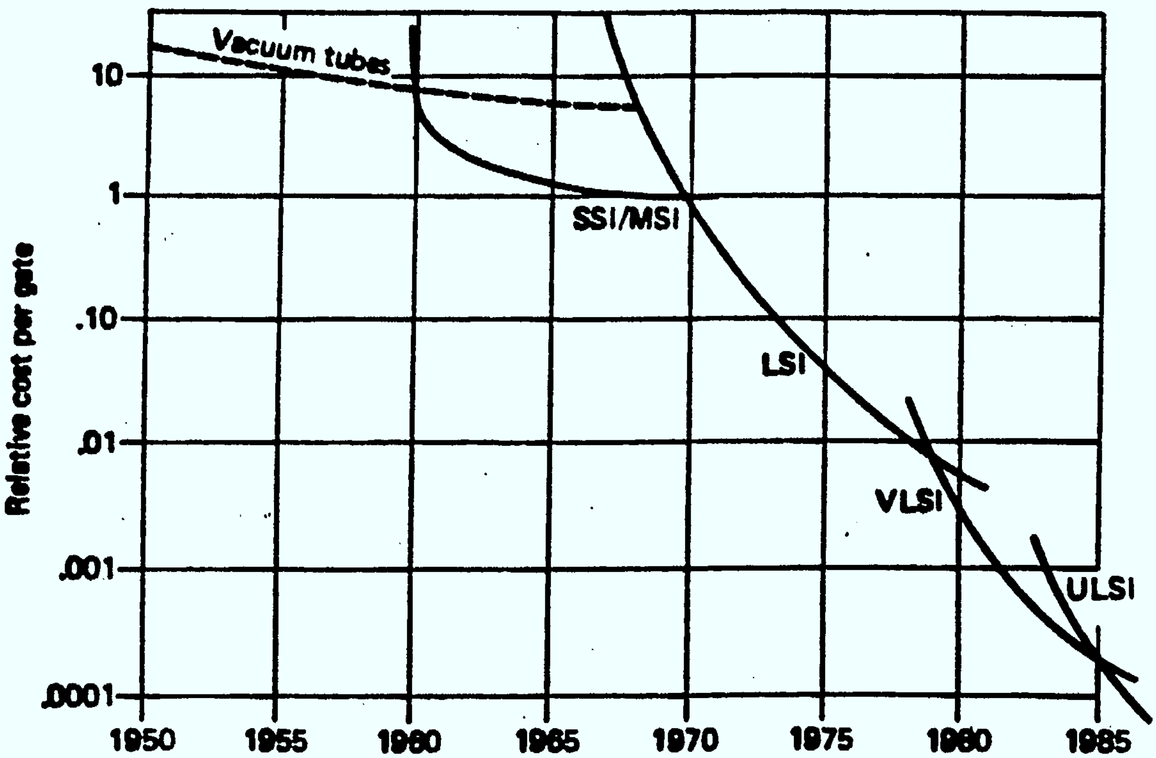
EVOLUTION OF MEMORY CAPACITIES



Source : Ohman, 1982

Graph 5

REDUCTION IN THE COSTS AS A RESULT OF INTEGRATION



Source : Ayres, 1987.

144. In parallel with this reduction in price, largely due to integration, the performance of products has been enhanced. The performance of a microprocessor is measured in terms of the speed of the circuit, its energy consumption and its reliability. This improvement in performance is closely linked to the phenomenon of integration.

145. In the case of memories, the performance is measured also by the access time to the stored information. On this basis, there is a hierarchy between the different types of memory which will be taken into account when discussing computer architecture. Thus memories based on bipolar and MOS technologies are characterised by shorter access times as compared with the older systems of tape, disk and drum.

146. There is, finally, a gradual development of custom-made circuits which are designed according to the specifications and norms set by the customer, as opposed to standard circuits. Thus, and according to the respective degree of specificity, one may distinguish among "full-custom", "standards cells", "gate arrays" and "programmable logical arrays - PLA". Table 4 brings to light the chief characteristics of the four types of custom-made circuits.

4. The microelectronics economy

147. Three main features characterise the microelectronics economy: technological improvement (reduced size of components and increased density of chips), reduction in the price of products and, lastly, increasing complexity of production equipment and hence increasing capital costs. According to Osborne (1979), the extent of the technological improvements that have effected the field of microelectronics can be best illustrated by imagining that similar progress had occurred in the field of aeronautics. In that case, the Concorde would now be capable of carrying half a million passengers at 20 million miles an hour! Continuing this analogy, Osborne shows that if the price of travelling by Concorde had fallen at the same rate as that of microelectronics products, an air ticket would now cost less than a penny. However, these technological improvements have been obtained only by using ever more complex production structures and equipment, thus increasing the capital costs.

5. The technological landscape as the framework for national strategic choices

148. The logic of technological evolution pointed out above explains why R&D support policies do not significantly vary from one country to another: the aims are identical (ULSI, improved bipolar and MOS technologies, research on silicon and gallium arsenide, new engraving techniques and the use of CAD to manufacture circuits), the only things that change being the resources devoted to the programmes and the organisational structures. The reason for this uniformity is due to the importance of the technical and economic determinants which, as it were, strictly encompass the choices.

149. The boxes that follow concern the strategic choices of the United States, Japan and the EC (through the Esprit programme) and show that nevertheless this restriction on the choices does not mean that the different countries do not have a certain margin of autonomy as regards the type of product to be marketed. Thus, as is shown by the VLSI programme and the

Table 4

CHIEF CHARACTERISTICS OF CUSTOM-MADE CIRCUITS

	Custom		Semi-custom	
Circuit	Full custom	Standard cells	Gate arrays	Programmable Logical circuits
Order of magnitude of design cost	2 000 - 10 000 KF	50 000 - 200 000	1 000 - 20 000	1 000 - 3 000
Length of development	1 - 2 years	2 - 3 months	4 - 6 weeks	1 - 2 weeks
Number of logical gates	30 000 - 50 000	10 000 - 30 000	3 000 - 10 000	1 000 - 3 000
Order of magnitude of the volume of a production series (units)	100 000 - 1 000 000	50 000 - 200 000	1 000 - 20 000	1 000
World market (billion FF)	14	1	7	2
Yearly growth rate (%)	21	65	32	26

Note: Semi-custom circuits are used to achieve configurations which are not excessively complex and are designed for small-scale production. Custom-made circuits become unavoidable, however, as soon as a certain level of complexity is reached and as production series become important enough to justify high development costs.

Source: Benchimol, 1987

commercial success of 64 and 256 K RAMs Japan has opted for the production and marketing of standardized components, mass produced and aimed primarily at the consumer goods industries. The United States on the other hand seemed to react to the Japanese advance by turning to the market for sophisticated, specific-purpose components (armaments, space, etc.). Lastly, the strategic options preferred by Esprit show that the EC does not have any particular leaning towards one or other of these two poles.

UNITED STATES

The Technological Choices

Technological policy in favour of semiconductors rests on four pillars: the Strategic Computing Program (SCP) and the Very High Speed Integrated Circuit Program (VHSIC) were developed in the framework of defence policy, while the Semiconductor Research Project (SRC) and the Microelectronics and Computer Technology Corporation (MCC) were developed by civil research.

The military programmes

The SCP programme includes a semiconductor component which encourages research into silicon and GaAs technologies and VLSI systems. This programme is administered by the DARPA (Defense Advanced Research Projects Agency). The overall budget for this programme, which was US$63.2 million in 1985 will rise to US$130 M in 1989 before stabilising at US$100 M until 1993. But for a few exceptions, the DARPA provides 100 per cent of the funds.

The VHSIC programme had two objectives: to attract the attention of the semiconductor industry to military needs, and to reduce the time required to incorporate new generations of microprocessors into weapons systems. This programme was launched in 1980 and is to continue until at least 1989 on the basis of a budget of US$101 M in 1988 and US$58 M in 1989. A notable initial success of the VHSIC was the fact that the electronics industry is now aware of the economic interest of the military market. VHSIC is trying to effect a link between silicon-based components and military equipment. This is divided into three phases: phase 1 is concerned with 1.25 micron chips, phase 2 will test systems with 0.5 micron chips, and phase 3 is concerned with the more speculative development of integrated circuit technologies.

Many research groups are participating in phase 1: Honeywell, Hughes, Perkin-Elmer, IBM, Texas Instruments, TRW, Motorola, Sperry, Westinghouse, National Semiconductor, Control Data Corporation, Harris, Carnegie Mellon. Only Honeywell, IBM and TRW are in contact with phase 2. The industrial impact of VHSIC is particularly significant in the field of equipment. With respect to the civilian impact of the programme, it is clear tht the costs and problems of industrialisation have been under-estimated: the stress on military equipments and the lack of attention on large-scale manufacturing have limited the scope for civilian spin-offs.

The civilian programmes

The SRC was created in 1982 as a non profit foundation linked with the semiconductor industry association and aimed at developing research including scientific and experimental studies. Financed by the members of the Association, the SRC provide US$6 M in 1983 and US$13.3 M in 1984. The budgets planned for 1986 and 1987 are in the order of US$20 M a year. Forty universities and 65 firms were involved in 1987, with the greater part of the funds going to the centres of excellence, Cornell, Berkeley, Carnegie and Mellon.

The SRC research policy is clearly defined with respect to the perception of the Japanese threat in the field of semiconductors. After having given priority to basic research, SRC projects have become progressively more oriented towards industrial co-operation programmes.

Unlike the SRC, the MCC has its own research centres. It was created in 1982 in response to the Japanese announcement of the Fifth Generation plan. In the seven major programmes developed by the MCC, the ULSI/CAD project is basically concerned with semiconductors. Ten companies expressed interest as early as 1982 in developing co-operation programmes within this framework. The absence of IBM, ATT and Texas Instruments shows that to a certain extent MCC is not simply a US response to the Japanese threat, but also the response of medium-sized firms to the threat of the giants.

*
* *

Two military and two civilian programmes: the former are temporary projects, while the latter constitute permanent institutions.

In 1986, the semiconductor industry association (which already supports the SRC programme) set up a committee to consider establishing a group of integrated circuit manufacturers, capital equipment manufacturers and integrated circuit users with a view to acquiring 16 megabit dynamic RAM technology. This group, known as Sematech, would be 50 per cent financed by the Department of Defense.

In parallel to these industrial initiatives, the army proposed the launching of the Defense Semiconductor Initiative (DSI), which for a sum of US$1.7 billion over five years would develop co-operative research projects with industrial consortiums.

JAPAN

Technological Choices

Technological policy in favour of semiconductors can be divided into three phases: the initial VLSI project, the actions developed in the framework of the supercomputer project, and the actions developed in the framework of the Fifth Generation project.

The VLSI project

In the period 1976-79, the VLSI project was perceived by foreigners as being the principal vector of the Japanese offensive on the 64 K/bit dynamic RAM front. Although this point of view was contested by the Japanese themselves, the fact remains that this project served as a model for numerous foreign initiatives, and in particular the American MCC and SRC programmes. The VLSI project was unusual in its scale (US$29.1 billion from MITI and US$44.6 billion from industry). The firms assisted reinvested about 15 per cent a year of their turnover in R & D and 20 per cent in capital equipment. As from 1981, the VLSI technological research association has registered over 1 000 patents per year.

The supercomputer project

In the framework of this project, MITI has announced its intention to devote approximately US$215 million to semiconductor research. The project has three major objectives: better crystalline network structures, multi-layer semiconductor structures, and tools capable of working in any environment. The research will also be concerned with gallium arsenide and the technology of Josephson functions. Also in this framework, Fujitsu and Ohri are developing High Electron Mobility Transistor (HEMT) technology. This technology, based on the characteristics of GaAs, will also no doubt produce integrated circuits on a large scale in the years to come.

The supercomputer project involves the six major firms as well as ETL and the University of Tokyo. The overall budget is US$23 billion over eight years (1987-95). According to the specialists, this project is to be a battlefield for three competing technologies: Josephson, abandoned by IBM, but developed by ETL, Fujitsu, NEC and Hitachi; HEMT and GaAs technology.

The Fifth Generation project

The Fifth Generation project, administered by MITI is carried out in the ICOT (Institute for New Generation Computer Technology) created in 1982. This project has two components that are particularly concerned with semiconductors: VLSI architecture and intelligent VLSI CAD systems. One of the aims of the research is to develop silicon-based VLSI tools with over 20 million transistors. Two major projects are oriented towards the production of VLSI chips. One of them studies VLSI algorithms to find out what functions can be performed on VLSI chips, and how they can be incorporated. The other project is focused on VLSI CAD systems, i.e. systems to assist in the design and manufacture of VLSI circuits.

EC

The Technological Choices of ESPRIT 1

The microelectronics sub-programme of Esprit 1 was allocated 24.5 per cent of the funds, the total budget being 166 ECU, enabling 45 projects to be financed. The main activities of this sub-programme have been concerned with:

-- The miniaturisation of MOS and bipolar transistors (realisation of a line width of 1 micron and establishment of design rules for widths no greater than 0.7 micron);

-- The use of computer aided design and testing of circuits (CAD/CAT).

These two activities constitute the heart of the sub-programme, involving 12 and 17 type A projects repectively. The importance of the CAD/CAT work in particular is due to the key position occupied by this aspect with respect to the other research activities.

-- The development of integrated circuits based on gallium arsenide.

Beyond the framework of ESPRIT as such, a number of multinational consortia have emerged. For example, Bull, Siemens and ICL have created a common center; Philips and Siemens co-operate to develop MOS and bipolar circuits; Thomson and SGS intend to develop jointly active memories of 4 and 16 megabits. Finally, Thomson has recently been approached by Siemens and Philips to collaborate on technologies for sub-micron integrated circuits.

Lastly, it should be noted that the West European microelectronics industry has not been able to position itself clearly with respect to on the one hand the Japanese option in favour of producing and marketing standardized products for the consumer goods industry, and on the other the US option which seems to favour the production and marketing of sophisticated products destined for such sectors as armaments, space, etc. Faced with these alternatives, Europe is hesitating: on the one hand it does not seem to have completely abandoned the field of standardized products, as shown by the Philips and Siemens Megachip project, while on the other the scientific and technical potential of France and the UK appear to be better suited to an option of the US type. The strategic orientations of Esprit reflect this ambiguous position.

EUROPE

... And of EUREKA

It is a project concerning microelectronics that undoubtedly occupies the first place, from the standpoint of size, in the Eureka programme. This is the JESSI (Joint European Submicro Silicon) project in which Philips, Siemens and Thomson are involved, which aims at developing electronics below 0.5 micron for the years 1995 to 2000. This project is to run for about ten years and the predefinition phase alone has been estimated at DM 10 M.

FRANCE

The Technological Choices

The measures taken before 1986 in the framework of the Plan d'Action pour la Filière Electronique in favour of semiconductors include civilian programmes and a sizeable military programme.

The civilian programmes

. Applied research programmes:

-- Integrated circuits (83-86), FF 3 billion;
-- Renewal of passive components (83-87) FF 800 million.

. Co-ordinated research programmes:

-- Silicon, microelectronics, type III-V semiconductors.

. National project:

-- VLSI, CAD.

The military programme

. Very high speed integrated circuit (CITGV) programme under the direction of the Délégation Générale de l'Armement, a programme intended to accelerate the incorporation of integrated circuits in weapons systems.

. Thomson is co-ordinating a consortium working on bipolar technology, while Matra and Electronique Serge Dassault are working on MOS technology. The programme was planned to run from 1983 to 1988 and has a total budget of FF 500 million.

GERMANY

Manufacture of semiconductors

BMFT (Federal Ministry for Research and Technology) support for the manufacture of semiconductors is centred on two main activities:

-- The submicron work which includes in particular support for the Megaprojekt, a co-operation project uniting Siemens, Philips and the German and Dutch States, aimed at the large-scale production of 4 Megabit dynamic RAM and 1 Megabit static RAM. The total cost of the project has been estimated at DM 3 billion over a period of five years (84-89).

-- The materials activity is concerned with the development of technologies not based on silicon, i.e. in particular the development of GaAs technologies. The overall budget is DM 200 million over a period of four years (84-88).

UNITED KINGDOM

Manufacture of semiconductors

Action to promote the development and industrialisation of semiconductors comes in the framework of the Alvey programme. Inclusion of VLSI was at the insistence of the Ministry of Defence, which manages this project. Unlike the other parts of the programme, the VLSI and VLSI CAD aspects seem to be more oriented towards applied research and industrialisation. As at the beginning of 1986, 48 VLSI projects had been accepted.

GERMANY

The Microperipherals (MP) programme
(1985-1989: DM 400 million)

The MP programme provides three types of aid:

i) Specific indirect aid for the development of modern and compatible microperipherals. To qualify for this aid, a firm has to carry out a research strategy of two phases, preparation and development, for a period not exceeding two and a half years. The maximum subsidy per firm is DM 400 000 (DM 800 000 if the firm integrates all aspects of the manufacture of sensor components: hybrid techniques, integrated circuits, thin layers, semiconductor technology). In any event, the subsidy cannot exceed 40 per cent of the total cost of the operation. The costs that qualify for subsidy are clearly identified.

Enterprises in any branch of industry can receive specific indirect aid, provided that they manufacture or plan to manufacture sensors or sensor components, and that their annual turnover is over DM 1 million and they already have equipment of a certain complexity in this field.

ii) Direct aid for collective aid projects is provided only for projects considered to be of high technological and financial risk, but with a chance of providing results of value to an entire activity. The topics encouraged are concerned with:

-- Micromechanics for sensors;
-- Integrated optics for sensors;
-- Chemical sensor technology;
-- Basic technologies for powerful components.

iii) Lastly, aid for technology transfer is based on reinforcing the activity of the VDI Technology Center (publications, workshops, seminars, participation in fairs). The solid state Physics Research Institute of the Fhg (Munich) will be open to SMEs for information and experiments.

B. New Architectures and Artificial Intelligence

150. While the last two decades have been marked by fantastic progress in the hardware components of computer systems, it is likely that the beginning of the 80s saw the start of a new era, characteristed this time by a continuum of technological transformations affecting the methods of organisation, rules and programmes that enable these systems to be used. Two factors seem to be at the root of this change:

-- First, it had become more and more urgent to design new architectures in order to try and match overall computer performances with the advances achieved in the field of elementary components;

-- Second, the prospects opened up by knowledge processing systems (artificial intelligence) are considerably modifying the possibilities for applying information technologies, from the qualitative standpoint as well as quantitative (expert systems, intelligent robots, speech recognition systems).

151. The future of information technologies thus now depends very much on new architectures and knowledge processing systems.

152. In order to be able to deal in a synthetic fashion with extremely complex developments, one may distinguish between two characteristic objectives of the fifth generation of information processing systems: supercomputers on the one hand and artificial intelligence on the other. We shall then consider the transformations affecting architectures, a line of development primarily oriented towards increasing the power of computers, before reviewing the factors concerned with the emergence of and prospects for artificial intelligence and presenting the substance of special programmes devoted to this range of objectives.

1. Supercomputers and knowledge processing systems: the differences

153. Special US and Japanese programmes are developing in two distinct directions of research and application: supercomputers on the one hand and Fifth Generation computers on the other. It is important not to confuse these two categories of technological systems. The development of supercomputers responds to the growing need of civilian and military scientists, for example for weather forecasting, research into basic physics, etc.. These are digital calculating machines processing data algorythmically. They differ from earlier computers in that they are much more powerful, this increase in power being obtained in particular -- as will be shown below -- through the use of new architectures. Integrated circuit technology and control of connections and links (size, heat dissipation) also constitute technological problems likely to hinder the progress of this type of system. KIPS (Knowledge Information Processing Systems), on the other hand, are planned to process knowledge (symbolic processing) through modelling the cognitive processes of the human being, in particular through heuristic rules. Knowledge processing systems will need digital supercomputers to process signals in real time, while raising totally new problems concerned with the integration of a capacity to learn, an understanding of natural language, expert methods of reasoning, etc. While the supercomputer fits into the normal line of development in data processing systems, KIPS represent a break in the trend by dealing with knowledge processing. This explains why there are quite distinct programmes involved which, in Japan, have separate budgets and planning.

2. New architectures and increased power

154. Computer architecture is to be understood as the way in which the different components of a computer system are organised with respect to one another. Von Neumann's architecture designates the principle on the basis of which virtually all known digital computers work today. At the outset it is appropriate to stress the contrast which has already been underlined between the enormous progress and improvement in microelectronic components and the relative stability of computer architecture. The architecture developed by the US mathematician Von Neumann in 1945 thus remains dominant. It can be described as the association of three basic components (input and output ports, central processing unit, memory) to permit the processing of data and the execution of operations on a sequential principle.

155. In addition to the organisation in three components described above, von Neumann architecture is characterised by a sequential principle in the processing of data and the execution of operations. Such an architecture,

known as SISD (single instruction stream -- single data), remains limited as regards processing speed, since it can execute only one instruction at a time and on a single data item. The maximum calculating speeds possible with the von Neumann architecture have therefore now been achieved. The impossibility of going any faster is due to the sequential nature of the operations. What is more, this type of architecture cannot avoid the underutilisation of the present processing capability of a computer, to the extent that the links (buses) between the logic unit and main memory soon become saturated. Questioning this conventional architecture means splitting up the memory between thousands of integrated circuits, in order to give each logical element the memory it needs. The transfer of information will thus take place over less than a milimetre between the memory and the processing elements, associated in the same integrated circuit on a single chip".

156. The concept that now seems best suited to challenge this traditional architecture is that of parallel architecture. Parallel processors are machines in which a large number of logic elements work simultaneously.

The principles of new architectures

Two lines of enquiry are open to the designer who seeks to increase the speed of computers:

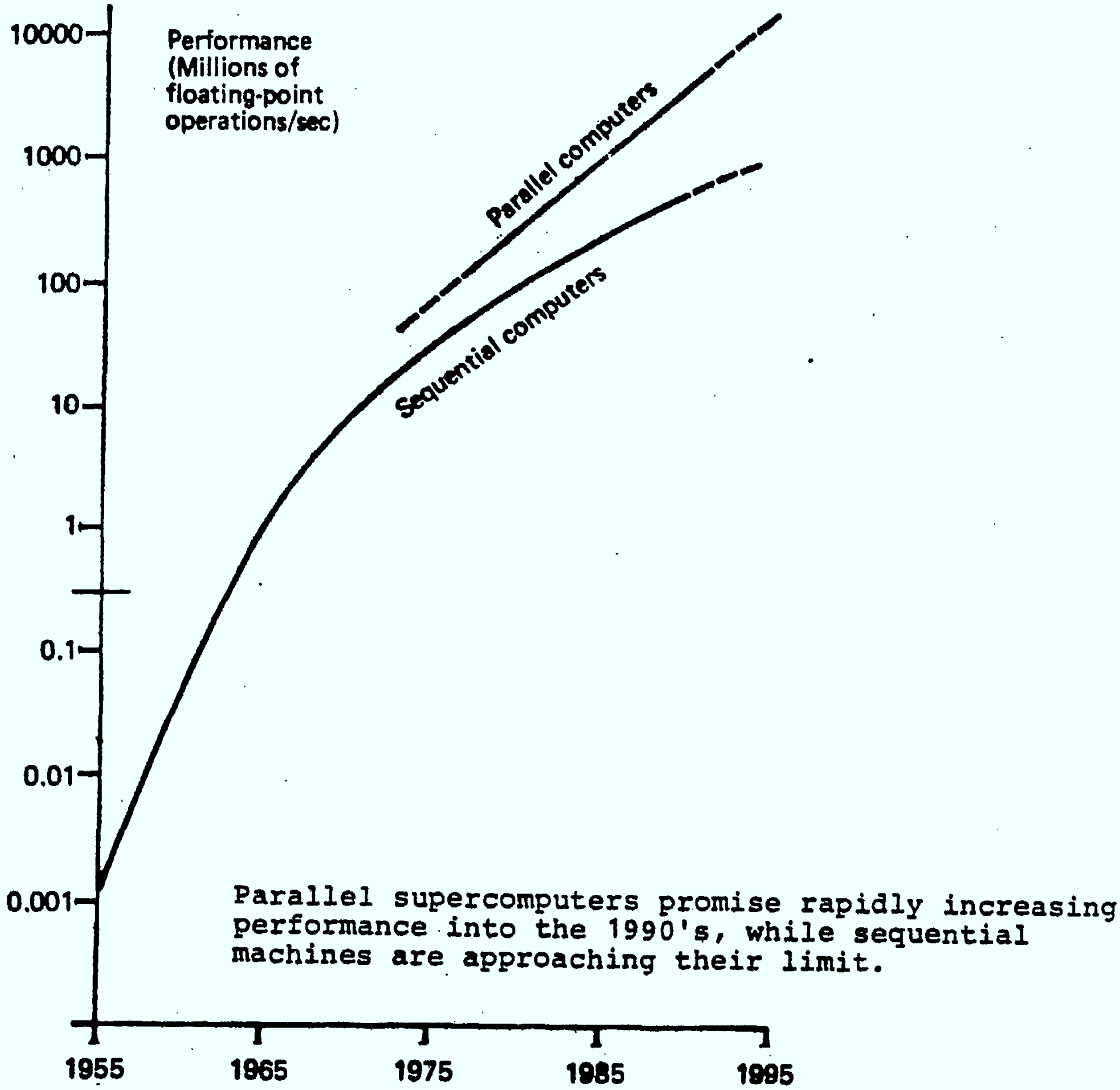
-- on the one hand, the development of faster processing units by reducing the time required to access the memory and by saturating the processing system, which is to say by allowing a given function to start an operation while the previous ones are not completed (simultaneous calculation);

-- on the other, by connection of several processing units to undertake simultaneous calculations, thus creating parallel computers.

157. By substituting new parallel architectures (non von Neumann architectures) for those that can only execute one instruction on one data item, thus by splitting the task to handle the calculation better, the speed of the computer is considerably increased. A megaflop (Mflop) corresponds to 100 000 floating-point operations per second, and the most powerful computers of the mid-80s (Cray X MP, Cyber 205, Control Data 7600) already reach a speed of 60 to 100 Mflops. The United States and Japan are aiming at a speed of 10 000 Mflops in 1990 with a multiprocessor machine having almost 1 000 arithmetic units in parallel.

Graph 6

EVOLUTION OF THE POWER OF THE LARGEST COMPUTERS
IN VON NEUMAN AND PARALLEL ARCHITECTURES

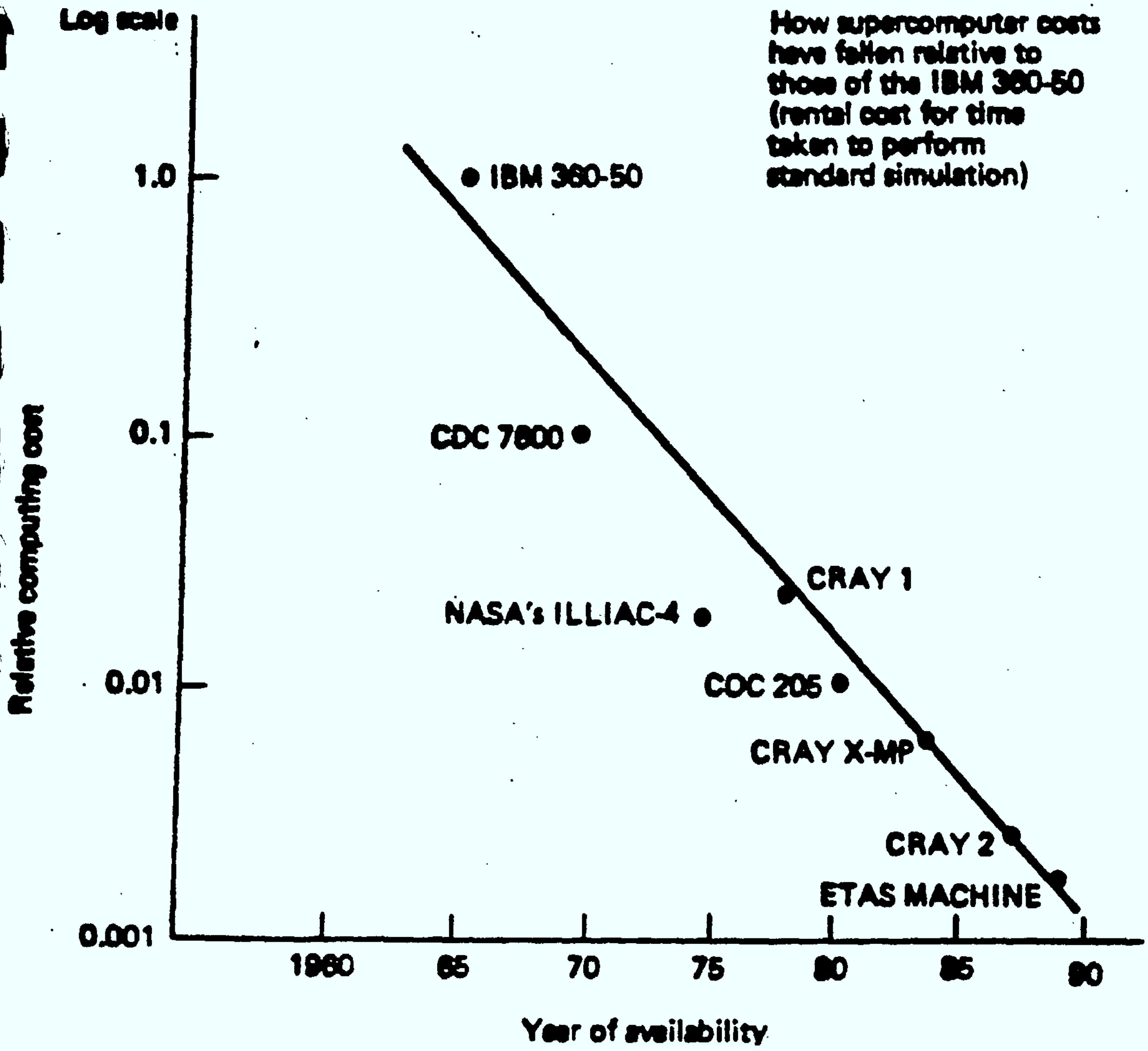


Source: T. Johnson and T. Durham, 1987.

158. This increased power, connected with new architectural design, will also be partly based on new components (GaAs, Josephson) as a substitute for silicon circuits, and also on the control of links and connections. One meets here again with the phenomen often encountered in information technology of increases in power coupled with reduction of costs:

Graph 7

FASTER AND CHEAPER



Source: Nasa Ames Research Center (Economist, 11.8.84)

3. <u>In search of Artificial Intelligence</u>

159. The term artificial intelligence (AI) designates the incorporation of strategies of knowlege and cognitive processes in computerised systems on the basis of an analysis of the nature of these strategies and processes as they are developed by the human brain. With AI, we pass from the stage of data processing to that of knowledge processing.

160. Software, whose only arm is the reasoning of formal logic, is necessarily limited. While it is very appropriate to the solution of simple problems, methods based on formal logic quickly lead to a "combinatory explosion" as soon as the problem becomes complex, and the number of paths that the program has to explore increases exponentially as the problem becomes more complex. Thus a problem based on logic alone is only a very partial and stunted imitation of the intelligent behaviour of a person confronted with a difficult problem.

161. It would therefore appear that the identification and modelling of the reasoning and cognitive strategies of the human being constitute an essential precondition for the development of AI. The basic methods involved are:

-- Heuristic methods (empirical rules that limit the field of research and directly orient the programme towards the most likely solutions);

-- Methods of breaking down a complex problem into a series of simpler sub-problems;

-- Methods of reasoning by analogy.

162. On top of integrating these different knowledge strategies, the second pillar of IA is the improvement of the computer's capacity to learn. This aim was for a long time one of the locomotives of AI research: the design of programs that learn by experience thanks to the use of metaheuristic rules (heuristic rules used to discover other heuristic rules).

163. The main components of AI are:

-- Expert systems, based on the idea of modelling the behaviour of experts confronted with a problem in a particular field. In an expert system, heuristic rules play an essential role. But high level, user-friendly man-machine interfaces are also required.

-- Man-machine interfaces involving the comprehension of natural language; voice recognition, the processing of language and accoustic processing are two basic approaches working towards image recognition. Systems capable of recognising a two dimensional image and find imperfections on a product are already on the market, but systems capable of understanding a three dimensional environment, thus capable of constituting the "eyes" of an intelligent robot, have scarcely passed the prototype stage.

-- Intelligent robots: as a system, they have to incorporate an impressive number of new technologies. There are many still unsolved problems in the way of producing this type of device.

164. It can be observed that the main lines of research whose development appears essential if devices endowed with artificial intelligence are to be produced, are concerned essentially with languages (PROLOG, LISP, etc.), architectures (parallel, with data flows) programming methods (automatic) and fields linked with these different aspects.

165. Although AI systems are likely to see enormous (and essential) improvement in the years to come, some are already beginning to slowly spread in our economies, as suggested by the two following tables. The first shows the prospects for AI marketing, starting in 1985, and the second summarises the possibilities for AI applications in different sectors of activity.

Table 5

AI MARKET

Year	Demand for AI software (all industries)	Market for AI software (information service industries)	Market for AI hardware	AI market size (software & hardware)
1985	¥190 billion (0.07%)	¥25 billion	¥68 billion	¥93 billion
1990	¥960 billion (0.28%)	¥130 billion	¥250 billion	¥380 billion
1995	¥4,800 billion (1.2%)	¥660 billion	¥890 billion	¥1,600 billion
Average rate of growth, 1985-1995	38%	39%	29%	33%

Source: ICOT, 1987.

Table 6

POSSIBILITIES FOR THE SECTORAL DIFFUSION OF AI

Industrial sector	Expert systems	Intelligent robots	Image recognition
Basic material industries	Plant repair & inspection, production/distribution management, plant operation management Decision-making support	Plant repair & inspection, product inspection, production lines	Qualitative product inspection, resource exploration, plant diagnostics, diagram reading, material analysis
Living-, home-related industries	Production/distribution management, personnel training, operation management, accounting, legal consultation, decision-making support, planning	Fire extinguishing, tasks in germ-free, dust-free environments, production lines, various inspections	Advanced research, product inspection
Machining & assembly industries	Machine repair & inspection, diagnosis of malfunctions, production/distribution management, product development support, automated design, personnel training, information management, operation supervision, process management and design, database retrieval, planning simulations, general office automation, surveys & planning, customer management	Advance machining & assembly, work in harsh environments, automated decision making in production lines, tasks in civil engineering & construction, repair of power lines, detailed inspections	Product inspections, advanced research, remote sensing, comparison of parts, discrimination of humans, automated part mounting
Commerce, finance, insurance, law, accounting	Business strategy, customer/distribution management, analysis of companies & markets, malfunction diagnostics, fund management, general business & management operations, database services, credit checking, personnel training, stock analysis, evaluation of contracts, medical records and damage, legal consultation & decisions		Medical examinations, comparison of images, reading ledgers
Transportation, communications, electric & gas utilities	Optimization of schedules, office automation, compiling departure & arrival schedules	Work in harsh environments, repair & inspections, automated sorting	Image data retrieval, diagram reading
Information processing, software industries	Media-Mix, advanced VAN, software development		
Medical, education, public agencies	Diagnostics support, CAI, grade processing, selection of courses & guidance, consultations	Assistance in treating patients, automated check-ups	Visual inspections of medicines, X-ray diagram analysis, cell/CT analysis, comparison of seals, documents

Source: ICOT, 1987.

4. Some observations on software engineering

166. The emergence of software engineering represents another major event which characterises the new configuration of the technological landscape. The expression "software engineering" refers to the whole set of methods used to pre-define the various stages of a project (definition of needs, development of prototypes, design, programming, tests and maintenance), their respective functions, their articulation, their needs in terms of resources and time. These methods rely on the Computer Aided Software Engineering (CASE) systems which have had a rapidly growing market since 1987.

167. It is undeniably the programming stage (the translation, with different languages, of the procedure defined by the analyst into a sequence of instructions which can be implemented by the computer) which had up to now been the focus of research, while other stages suffered from a lack of productivity. Software engineering opens the way to substantial progress in these areas. It is now only the initial phase of definition and specification which remains excessively manual (1).

UNITED STATES

An overall view of the special programmes

Here again it is necessary to distinguish between military programmes (SCP: Strategic Computer Program, Software Initiatives, SDI: Strategic Defense Initiative) and civil programmes (NSF: National Science Foundation; MCC: Microelectronics and Computer Corporation).

-- Military programmes

The contribution of military programmes to the research effort in software and artificial intelligence is based on three activities: i) The Strategic Computer Program, which is a military initiative for Fifth Generation computers. From US$30 M in 1984, the SCP will reach US$130 M a year by 1989. As shown in the following table, this programme is centred on AI.

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(1) For more extensive treatment of these questions, see the OECD study: Software: An Emerging Industry, ICCP, OECD, Paris, 1985.

Strategic Computer Program (SCP)

structure and goals

Major goals	Develop a broad base of machine intelligence technology to increase national security and economic strength
Military applications	Autonomous systems Pilot's associate Battle management system
Technology base Intelligent functionality	Vision Speech Natural language Expert systems Navigation Planning and Reasoning
Technology base Systems architecture	High-speed signal processing Symbolic processors General-purpose systmes Multi-processor software
Technology base Microelectronics	Silicon and GaAs technology VLSI systems
Infrastructure	Networks Research machines Rapid machine prototyping Implementation systems, foundries Interoperability protocols Design tools

ii) The software initiatives of the DoD, which are active in three directions: promotion of ADA as a very high level language to enable the unification of the programming of computer systems for radar, guided missiles and weapons system control. The STARS (Software Technology for Adoptable Reliable Systems) project, aimed at improving the productivity and reliability of software production.

Lastly, the Carnegie Mellon software engineering Institute, which is destined to become a centre for advanced technical research and development for military applications.

iii) The Strategic Defense Initiative (SDI) programme requires the devlopment and use of Fifth and even Sixth Generation computers. Whatever the outcome of Star Wars may be from the standpoint of defence this programme constitutes an extremely important attempt to create the biggest system of computers and real time communications ever built. It remains obviously difficult to assess the extent to which it may constitute a source of technology for the civilian economy.

-- The civilian programmes

A distinction should be made between:

-- The actions of the National Science Foundation, which is a programme of US$200 M, based on four national university centres and joined by the Carnegie Mellon Centre of Excellence in 1986. The objective of this initiative is to train a considerable number of people in the field of man-supercomputer communications. Three other federal agencies receive funds for supercomputers: NSA (National Security Agency), the Department of Congress and, above all, NASA.

-- The action of the MCC (Microelectronics and Computer Technology Corporation, see above). Of the 7 programmes of this institution, 6 concern the fields of software architecture and AI:

Software technology
Interconnection systems
AI and Knowledge Based systems
Man-machine interfaces
Data bases
Parallel processing

A programme on advanced integrated architectures has also been launched to co-ordinate the four activities concerned with this field.

Major government sources of artificial intelligence R&D funding

	Estimates	
	Low	High
National Science Foundation	5.0	6.0
National Institutes of Health	3.5	4.2
Office of Naval Research	1.2	1.4[b]
Air Force Office of Scientific Research	2.5	3.0
Defense Advanced Research Projects Agency[c]	15.0	20.0
Total	27.2	34.6

[a] Sources indicate that these levels have obtained for the past several years, and with the exception of DARPA, are expected to remain stable or increase modestly in the near term

[b] This does not include $800,000 in robotics research, some of which is in artificial intelligence

[c] This represents the base level of DARPA funding before the initiation of the "Strategic Computing" program (begun in fiscal year 1984)

SOURCES: NSF numbers from *Summary of Awards* publications of the Division of Computer Research, FY 1982-83, and the Division of Information Science and Technology, FY 1981-82 and 1983, National Science Foundation. NIH numbers from Susan Stimler, Director, Biomedical Research Technology Program, Division of Research Resources, National Institutes of Health. ONR numbers from Paul Schneck, Leader, Information Sciences Division, Office of Naval Research. AFOSR numbers from David Fox, Director, Division of Mathematics and Information Science, Air Force Office of Scientific Research. DARPA numbers from Ronald Ohlander, Program Manager, Defense Advanced Research Projects Agency.

Source: OTA, 1984.

JAPAN

An overall view of the special programmes

Japan is the first country where programmes concerned with supercomputers and knowledge processing systems have separate programming and budgets.

i) The characteristics of the supercomputer programme (1981-89) were mentioned in the previous section. Let us simply recall that this project, based on software and architectures, receives 23 billion yen.

ii) In the minds of the Japanese, the Fifth Generation project seems to have taken over from the VLSI programme in 1987. The striking feature of the Fifth Generation project is the absence of precise objectives determined in advance. The Fifth Generation computer looks much more like a set of synergies to be exploited than a definite system design. For this reason, the major interest of 5G is the aim of exploiting the synergies between four fields hitherto considered separately: AI, programming languages, distributed processing and VLSI technology, without any concrete and operational goal (very powerful supercomputer or knowledge processing tool) being defined. It is worth pointing out that the launching of this programme is partly the result of the Japanese firms' lag behind IBM in Fourth Generation computers. The 5G is oriented towards a market share in a new field, that of knowledge processing and symbolic programming. A total of $450 million will be distributed over nine years (1982-91), with only $45 million for the first three years. The sum provided by industry should amount to $850 million.

iii) The software automation programme (1976-81), aimed at improving the Japanese supply, concerned over 100 small firms, for a total budget of US$600 M. Taking over from this, the Software Industrialised Generator and Maintenance Aid (SIGMA) is oriented towards the same objectives: improving quality and productivity, promoting software engineering, etc. The SIGMA budget amounted to 25 billion yen, 3 million of which was allocated in 1985, to both firms and universities.

EC

The activities of Esprit 1

Of the five Esprit sub-programmes, two are more particularly concerned with software. First, the sub-programme "software technology", and second, the sub-programme "advanced information processing".

	1984-85	% total funds	Number of projects
Software technology	128 M Ecus	18.7	42
Advanced information processing	150 M Ecus	22.2	44

i) The general objective of the "software" sub-programme is the development of software engineering. It is aimed to establish rigorous formal methods that will replace the techniques presently used and to define a common environment that can be used as standard for future development. The main project in this field is the PCTE (Portable Common Tool Environment), developed by six large firms (Bull, GEC, ICL, Nixdorf, Olivetti and Siemens).

ii) The advanced information processing sub-programme is concerned with artificial intelligence. It is clear that this sub-programme fairly closely resembles the US MCC programme (see above). Another European initiative also recalls the objectives of this sub-programme, the ECRC (European Computer Industry Research Center), a joint research centre set up in Munich by Bull, ICL and Siemens. There are however differences between these programmes: while MCC and ECRC are private initiatives and concern a small number of partners, the Esprit sub-programme on the other hand supports 38 distinct projects involving a considerable number of partners throughout Europe.

The normative approach has acquired a growing importance. In the perspective of the OSI (Open System Interconnection) developed by the International Institute of Standards, computers and peripherals should eventually be able to communicate. Thus, the Commission will determine each year the technical work required to ensure inter-operability of systems.

GERMANY

Special programmes

Germany is attempting to achieve two major Fifth Generation objectives through several programmes:

i) The new computer structures programme (1984-88, DM 160 M). The biggest project in this programme is SUPRENUM, to produce a super fast computer for number crunching. This project is the German response to the Japanese and US supercomputer projects.

SUPRENUM will be based on the MIMD principle (Multiple Instruction -- Multiple Data). The project involves research centres (KFK, GMD, KFA, universities) as well as firms.

ii) The projects relating to artificial intelligence: the German Research Association (DFG) has launched an 11 million DM priority programme in AI, and the Federal Government has allocated DM 750 million to 45 projects proposed in the framework of ESPRIT. The knowledge processing and pattern recognition programme (1984-88, DM 200 M). This programme pulls together all the artificial intelligence projects funded by BMFT.

FORECAST ANNUAL EXPENDITURE

DM million

	1985	1986	1987	1988	TOTAL
Knowledge processing	15.0	20.0	30.0	25.0	90.0
Pattern recognition	20.0	30.0	35.0	25.0	110.0
Total:	35.0	50.0	65.0	50.0	200.0

iii) In the computer and software CAD programme (1984-88, DM 160 M), where co-operative research is particularly encouraged to develop computer aided software engineering with the aim of improving quality and productivity in software production.

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* *

168. It is clear that R & D support policies do not differ significantly from one country to another: the targets are identical and the special programmes of the different countries have a similar technological content. This relative uniformity is due, as shown above, to the existence of certain technical paths that must be followed: the technological landscape circumscribes national strategic choices. There nevertheless remains some margin of freedom, in particular as regards the products to manufacture and the market segments to aim at.

169. Thus, while Japan has opted for the production and marketing of standardized components, mass produced and destined essentially for the consumer goods industry, the United States has chosen the segment of sophisticated components with specific applications. From this viewpoint, American firms seem to be much better prepared to win the second set, relating to custom-made circuits.

170. It thus appears that in the final analysis the technological content of national programmes results from this confrontation between a certain number of compulsory technological points of passage and some options "freely" chosen as regards products and markets.

Chapter III

THE NEW ADVANCED TECHNOLOGIES IN TELECOMMUNICATIONS AND INDUSTRIAL PRODUCTION

171. Two sectors have been radically transformed since the appearance of information technologies: telecommunications on the one hand and manufacturing production on the other. In each case, there is a noticeable trend towards a rapid convergence with the information technology sector.

172. Each of these two sectors will be reviewed in turn, pointing out the major trends in their technical development and describing the main national and European programmes, whose prime objective is to accelerate the spread and intensify the use of information technologies within these two sectors.

A. Telecommunications

173. Two broad groups of technological improvements have to be discussed before we can consider the complexity of options in the telecommunications field:

-- First, the trend to digitization of transmission systems and packet switching;

-- Second, the arrival of opto-electronics as a transmission medium in competition with coaxial cables, radio beams and satellites.

174. A description of some of the basic concepts in telecommunications, will be followed by a discussion of each of these two lines of developments. The phenomenon of convergence between telecommunications and information technology will then be addressed. This global process of evolution is leading both to the diversification and the integration of the services supplied by the telecommunications sector. In the context of the main characteristics of the telecommunications economy, this chapter will go on to refer to the special United States and Japanese programmes and the European RACE programme, all aimed at stepping up the R&D effort in this field.

1. The bases of telecommunications

175. The purpose of telecommunications is to transmit information over a distance. This transmission may be from one point to another (telegraph, telephone), or the information may be broadcast from one transmitter to many receivers, without any return path (radio and television broadcasting). These two types of telecommunication do not follow the same technical or economic rules, but they do contain certain common basic features. These are first of all the association of two essential operations: transmission (the transport of information) and switching (routing the information in the required direction). At any given time, a technical innovation in one of these two areas creates a disequilibrium and constitutes a pressure for innovation in the other. Other common base elements can be identified in the broad lines of technological development in the sector. Here there are on the one hand evolutions in the transmission media (material: optical fibres, cables, wave guides; or non material: radio beams, satellite links) and on the other hand evolutions concerning the transmission and switching logics.

FROM ANALOGUE TO DIGITAL

Analogue communication is based on representing one value by another value which varies continuously following exactly the same pattern as the first. The vibration of the air and its variations when a sound is emitted can be continuously followed by electromagnetic variations transmitted over a distance: that is analogue transmission. Numerical or digital communication is based on representing a value by another value which cannot exactly follow the first but can take only certain discrete values, which can then be coded in bits.

Analogue systems have three major disadvantages: one concerns the quality of the transmission, the second the transmission capacity and the third the functionally limited nature of applications.

In the ideal case, analogue signals reach the receiver in exactly the same form as at the point of departure. In practice, however, there are many perturbations that become superimposed on the analogue signal, thus causing deterioration of the message. This problem is mitigated by using amplifying repeaters, but these are themselves the source of thermal noise and cross-modulation that cannot be totally avoided. The situation is totally different when the information is transmitted in digital form. In the system known as pulse code modulation, not the whole of the voice signal is transmitted, but only samples taken at very short intervals of time. The digital signal can take only certain discrete values, for example 0 and 1 (binary form). Since it is characterised by the single alternative presence or absence, the digital signal has the advantage that it can easily be regenerated. This faculty means that the degraded signal can be rid of all the noise and interference picked up along the transmission line. The digital information can thus be restored without any degradation.

The second advantage of the digital signal is concerned with increasing the transmission capacity. Since the whole of the signal is no longer transmitted, but only samples, the same line can be used to transmit in turn and cyclically the samples corresponding to 30 conversations which can be separated at the receiving end to reconstitute the 30 telephone signals in their usual form. This technique thus makes it possible to have high density lines, and it is equally well suited to the simple lines of 30 telephone channels just described and to high traffic links (coaxial cables), radio beams and satellite transmission.

Lastly, the third advantage is the universal nature of the digital system. The digital channel is in fact completely defined by its binary transmission rate, thus being quite different from the analogue channel which is defined by a number of parameters and is therefore in practice suited to only a single type of signal (telephone or broadcast). The digital channel on the other hand can be used to transmit data or images (by line and point) as well as the human voice.

Thanks to these three types of advantage, the shift to digitization has constantly accelerated in all types of transmission (cable, radio beam, satellite) despite the necessary installation of terminal equipment whose role is to sample and bundle the signals at the transmission end and perform the inverse operation at the receiving end.

176. Four factors, specific to the sector, must be considered because of the role they play in stimulating the technical changes mentioned above. First, there is the problem of regeneration of the message: attenuation of the signal as it travels means that the information has to be periodically regenerated, which considerably adds to the cost, so that there is a constant search for low-attenuation transmission media. Second, there is the problem of the saturation of transmission channels, or in other words the transmission capacity. Multiplexing makes it possible to divide the capacity of a single transmission circuit in such a way as to transmit several messages at the same time, so that there is also a search for transmission media that permit this technique. Third, there are problems of size and weight, particularly crucial in the case of satellites. Fourth, there is the problem of integrating services within a universal network. There is therefore a search for a transmission logic which in its design is transparent to the signals (human voice, image, data) that are carried.

2. <u>Digitization of transmission and switching</u>

177. The first area of telecommunications to benefit from the upsurge in digital techniques was transmission. In the case of analogue transmission, the information to be transmitted is reproduced in the form of electrical signals following the same pattern. In telephony, for example, the network is analogue when the electrical signal is the exact replica, though in a different physical form, of the voice signal. It is thus the <u>analogue</u> of the initial sound wave (Nouvion, 1981).

178. For a long time, the electronic components available on the market were inadequate for processing the voice in such a way as to code in binary digits and then transmit it like any type of computer data. It was thus the arrival of microelectronics and in particular the integrated circuit that made it possible to develop digitization.

179. Once digital transmission had arrived, there was fairly rapid progress to digital switching. This, also known as time switching, is carried out entirely electronically, unlike space switching which works on electro-mechanical principles. The method consists of taking a flow of mixed digital signals created according to the pulse code modulation technique described above, then restoring these signals in a different order and routing them to their divese destinations. This method of switching is thus indissolubly linked with pulse code modulation and forms the rational extension of it. For this reason, it is hoped that the networks of the future will be installed in this form (pulse code modulation plus time switching), which is suited equally well to voice and data transmission.

180. This convergence of switching and transmission techniques based on using a digital and no longer analogue signal, favours the integration of switching and tramission operations and thus reduces cost, with the supression of analogue/numeric interfaces, which are in any event often unreliable. It also makes possible the integration of services within a universal network that can be used for different services. As already stressed, digital links can very easily carry other services than the telephone service (data transmission, telex, facisimile, videophone, etc.) since they are by their very nature transparent to the signals they carry.

3. The emergence of optoelectronics

181. In the words of Nouvion, "the convergence of telecommunications techniques, developed on the basis of signal digitization, had hardly come about when there arrived other techniques bringing a new disequilibrium. As before, the transmission component was in the vanguard". There is now in fact a trend to a more systematic use of guided transmission (by wire, cable or waveguide) by contrast with radioelectric transmission with no material support. It will be recalled that radioelectric transmission systems (radio beams, satellites) had themselves gradually substituted (though without ever totally replacing them) for coaxial metal cables carrying elctric signals. This return to a transmission system using a material medium is due in part to the huge volume of traffic in radio communications which is the cause of interference, and also to the arrival of opto-electronics as a new base technology in the telecommunications industry.

182. The introduction of optics into information and communications technologies, i.e. the replacement of the electron by the photon as the information carrier, has so far been in two important stages (Gille, 1987):

- The first was the laser;
- The second is the production of very low attenuation optical conductors (optical fibres).

OPTICAL FIBRES

The main advantages of optical fibres are as follows:

-- Small size (60 fibres can be fitted into a cable of less than 20 mm);

-- The band width used, in other words the potential capacity in terms of telephone channels (1GHz for 1 mm). This allows the multiplexing of very many television channels on a single support and also very high transmission rates. Thus, for the same price, optical fibres can transmit a thousand times more data than copper cable;

-- Low attenuation: at one and the same time optical fibres can transmit ever greater flows with ever smaller signal regeneration requirements. Thus the regeneration systems, which generally account for over 30 per cent of the cost of a transmission link, can be separated by ever greater distances, thus significantly reducing the overall cost of the transmission system;

-- Insensitivity to electromagnetic parasites;

-- Abundance of the raw materials required (glass or silicon).

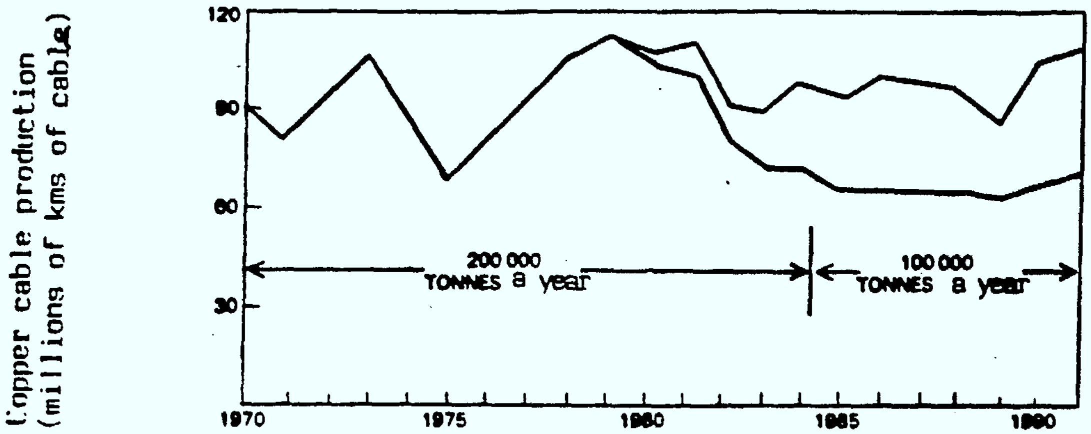
183. The spread of optical transmission techniques has been rapid. Virtually all new telephone cables for long distance communications are of optical fibre and, in the United States, one-third of the lines linking exchanges to the different groups of users are no longer copper cables, but optical fibres.

184. The first optical fibre transatlantic telephone cable, planned for 1988, will be able to transmit some 40 000 simultaneous conversations, or four times as many as the last coaxial cable, laid about 1975.

185. The gap between the actual level of production of copper cables and what it would have been without the arrival of optical fibres which is illustrated in Graph 8, shows the increasing importance of this latter technology in the field of communications:

Graph 8

TRENDS IN COPPER CABLE PRODUCTION



Source: Mayo, 1986.

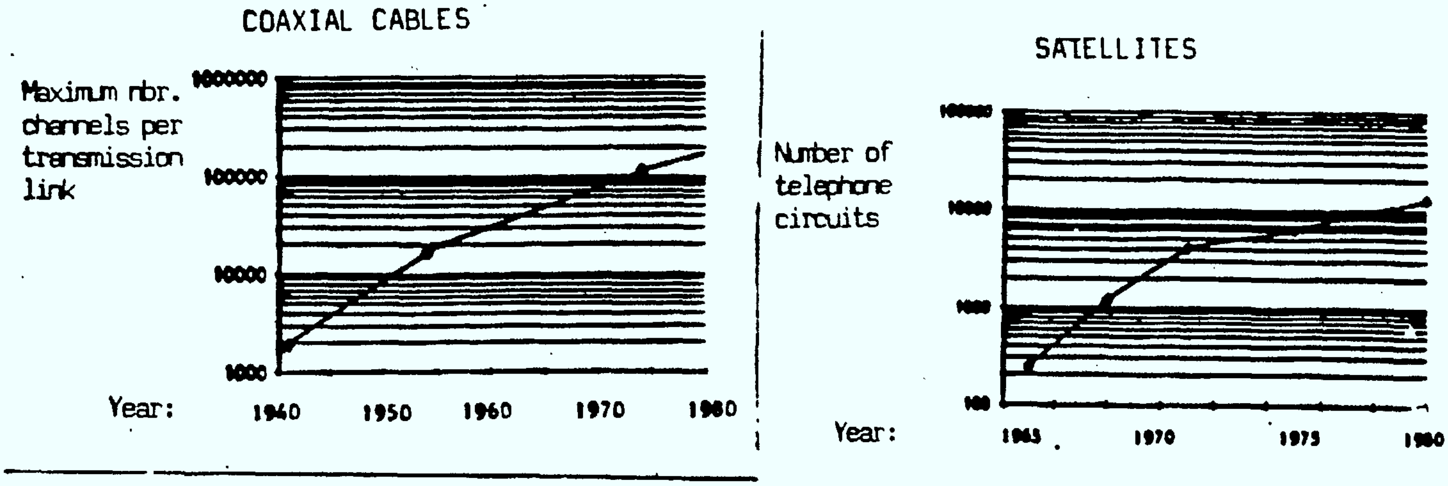
186. The fact nevertheless remains that a certain number of factors are still limiting the spread of optical fibres.

187. First, there are technical obstacles: opto-electronics is at present existent only in the communications sector: signals are produced and transmitted, but they are virtually not processed at all. However, an optical computers would have a processing capacity far greater than that of traditional computer: the optical equivalents of electronic transistors would be faster and, above all, they would be able to treat several signals at once. Any progress made in optical switching will therefore be vital for the evolution of networks. Efforts so far have have mainly come up against problems of materials and the integration of components. For this reason, they join and are sometimes merged with other fields of research, in particular optical computing.

188. The second series of factors limiting the extension of optical fibre use concerns not the limitations of opto-electronics but the progress of competing technologies: coaxial cables and satellites in particular.

Graph 9

TRENDS IN COAXIAL CABLES AND SATELLITES



Source: Mizrahi, 1986.

4. Convergence between computers and communications

189. We have already stressed the contribution made by electronics in the appearance of digital transmission systems. Similarly, progress in optical telecommunications will depend very much on progress in electronics, since lasers cannot emit pulses more rapidly than the circuits that control them. The fastest integrated circuits on the market have a switching speed of about 3 billion per second. This frequency would be higher if the materials used had faster electron transfer rates than silicon. The best choice would be gallium arsenide.

190. The progress achieved in microelectronics thus influences the way in which telecommunications technologies develop by providing new opportunities for innovation (digitization, laser transmission). Microelectronics also has a decisive influence on price, reliability and the size and weight of telecommunications systems. These advances also increase the variety of services offered in this field.

5. Integration of services

191. Table 7 gives an overall view of the considerable increase in the range of services provided.

Table 7

THE DIVERSIFICATION OF SERVICES

1847	1877	1930	1970	1980	1990
Telegraphy	Telegraphy	Telegraphy	Telegraphy	Telegraphy	Telegraphy
	Telephony	Telephony	Telephony	Telephony	Telephony
		Telex	Telex	Telex	Telex
		Telefax	Telefax	Telefax	Telefax
			Datex	Datex	Datex
			Radiotelephony	Radiotelephony	Radiotelephony
			Wideband data transmission	Wideband data transmission	Wideband data transmission
			Cable television	Cable television	Cable television
				Teletex	Teletex
				Interactive videotex	Interactive videotex
				Broadcast videotex	Broadcast videotex
				Radio call	Radio call
				Remote monitoring	Remote monitoring
				Remote control	Remote control
				Videotelephony	Videotelephony
				Video-conference	Video-conference
					Text facsimile
					Voice facsimile
					Electronic mail
					High-speed facsimile
					Electronic newspaper
					Color facsimile

Time ⟶

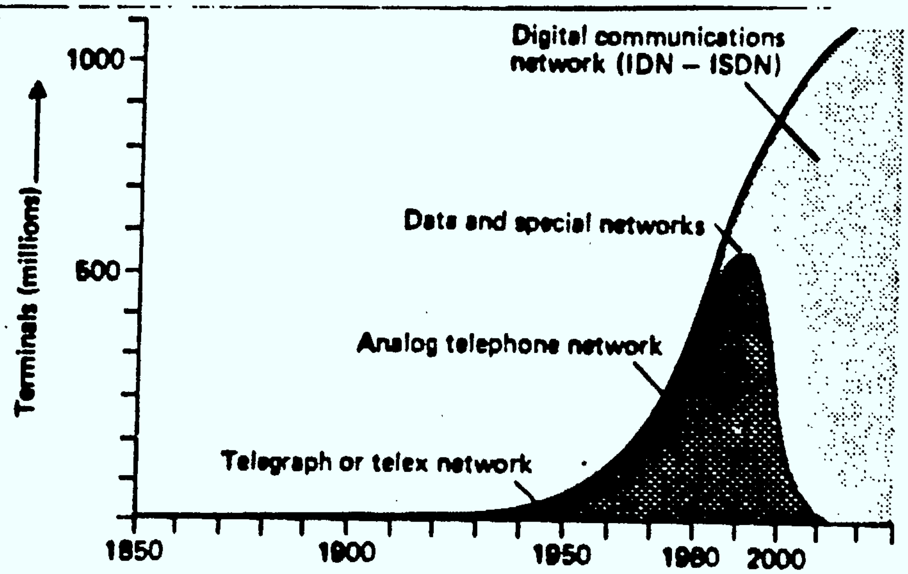
Source: Adapted from Ohman, 1982.

192. This increase in variety is essentially due to two major factors: digitization, since digital systems are by their very nature transparent to the signals they carry, unlike analogue systems, and the effects of microelectronics, in terms of the price, reliability and size of the available hardware.

193. This variety is gradually converging towards the establishment of integrated services digital networks (ISDN) that will carry sound, images, data, etc. Graph 10 suggests that this era has already begun.

Graph 10

THE EVOLUTION OF NETWORKS



Source: Ohman, 1982.

6. The telecommunications economy

194. Instability is certainly the striking characteristic of the telecommunications economy. While there is at present a certain equilibrium between transmission and switching techniques, thanks to the domination of digital signals, competition between the different transmission modes is a factor for further instability -- the gradual extension of optical techniques to switching and computing is in this respect a major source of uncertainty. The fact remains, however, that it is possible to identify the main trends: The networks of tomorrow will be digital -- this is the inexorable law of the progressive subsitution of digital circuits for analogue circuits -- and integrated -- just as generally there is just one path home whatever the mode of transport, a common access point will integrate the different modes of communication with a single simple dialogue. Networks will continue for a long time to benefit from progress in microelectronics (price, reliability, size and weight, power consumption, capacity) while conceding an ever larger place to optical techniques. However, the real age of optics will not begin, as long as these techniques remain limited to the field of transmission and not that of switching.

195. Lastly, there are two essential features that should be recalled and that are both due to the very nature of technologies organised in networks:

- First, the coexistence of old and new equipment causes problems of interfacing, which are all the greater because the equipment has a long lifetime. The changeover to time switching will thus be extremely slow, and it is estimated that in the year 2000, 50 per cent of exchanges will still be of the electronic type;

-- Second, as for all communications technologies there is a great need for standardization, but there is no worldwide standard so that there is considerable fragmentation of the international market for telecommunications equipment. This fragmentation is particularly costly in Europe because of the heavy research and development investment involved in contrast with the small size of national markets even in the biggest countries.

7. The technological choices

196. The establishment of integrated service digital networks, as defined by the International Telegraph and Telephone Consultative Commitee (the ISDN concept) seems to be the major objective of the special programmes. This is the aim of the INS programme in Japan and the RACE programme in the EEC. These different programmes include in particular the digitisation of circuits and the large scale use of opto-electronics. The RACE programme also imposes on Member countries an unprecedented standardization effort, since it is a European network that is to be installed.

UNITED STATES

Fiber optics

The National Science Foundation supports university research in the field of fiber optics. Although the global budget was only US$1.75 million in 1983, 18 to 20 projects were supported in a dozen universities. A further US$300 000 was provided for university laboratory equipment. The NSF also endeavours to promote industry-university co-operative action in this field:

-- Optical Sciences Center established at the University of Arizona;

-- Co-operation projects between Bell laboratories and the University of Arizona ($100 000 a year for two or three years);

The Department of Defense devotes large sums to promoting research in this field (US$ 32.4 million), with the largest share (95 per cent) going to enterprises.

JAPAN

The integrated network system (INS)

INS can be considered as the telecommunications equivalent of the Fifth Generation computer programme. Like the latter, the INS programme was launched in 1982 and makes massive use of the results and experience of the VLSI programme. INS is aimed at establishing an integrated services digital network. Three objectives should be mentioned: integration of a great number of services, digitisation of the whole of the network, massive use of optical fibres.

Unlike the European countries and the United States, whose strategies are constrained by the need to use existing networks, INS is developing a totally new base technology, without attempting to make the old and the new coexist. For this reason the cost of the project is extremely high and it is estimated that the total cost will be between US$80 and 120 billion over the next 15 years.

EC

Research in Advanced Communications Technology (RACE)

The objective of RACE is to define a European broadband network simultaneously carrying voice, image and data. As compared with the Japanese programme there is an additional problem for in addition to the technological effort (digitisation, opto electronics), there has to be a standardization effort between the different countries: the industry choses the technologies and terminals and the PTT administrations define the systems, the entire network having to be fully compatible. The scope of the programme has made it necessary to articulate it in three stages.

The predefinition stage has just been completed. A total of 40 million Ecus were spent for this purpose. The next phase (1987-1992) will develop the pre-competitive elements and define the standards (32 projects have been selected). The last phase (1992-1997) will witness the implementation of an operating network. The overall research budget is estimated at 1.6 billion Ecus.

GERMANY

The BMFT and DBP programmes

R&D support in the field of communications technologies comes under two federal institutions: the Ministry for Research and Technology (BMFT) and the Post Office (DBP). The BMFT funds are allocated to the four following fields:

-- Optical communications techniques;
-- Integrated optics;
-- Systems technology, ISDN and HDTV project (new television standard);
-- Data transmission: DFN project (German research network).

The DBP participates in technological development projects (ISDN and HDTV) and experimentation projects concerned with communications in society (e.g. BIGFON, experimenting with an optical fibre digital communications service). The ISDN (Broadband ISDN and optical information technology) project stands out from all these activities. This project is for four years (1984-88) and has four main lines:

-- Components for optical communications;
-- Electronic components for future networks;
-- Technologies for optical communications;
-- Development of equipment to enable services to be consumed (telephone, videotex, teletex, facsimile and multifunction terminals).

B. Automation and Industrial Computing

197. The development of information technologies has considerably modified industrial production methods, on the one hand by permitting the adoption of new types of equipment capable of considerably increasing the performance of manufacturing processes, and on the other hand by offering the possibility of reconciling varied production and high productivity in a context of tight markets and the segmentation of demand.

198. We shall first examine new generations of industrial equipment: numerical control machines, industrial robots, computer assisted design and manufacturing systems, visual and tactile recognition devices, which all contribute to increased technical efficiency and comprise the technological base for the integrated automation of production (computer-integrated manufacturing -- CIM).

199. This constantly progressing supply of complex manufacturing equipment has made it possible in recent years to reconcile for the first time two traditionally conflicting objectives: that of variety and that of productivity. The introduction of flexible manufacturing systems will therefore be discussed as a vital stage in the evolution of production methods.

200. Lastly, the conclusion will present some examples of national strategies which, through special programmes, are attempting to accelerate the development and spread of information technologies in industry.

1. Numerical control machine tools

201. A machine tool is called a numerical control machine when it functions automatically or semi-automatically according to instructions transmitted to it in a coded form. The evolution of this new generation of machines can be divided into four major stages:

The History of NC-CNC

The generic configuration appeared at the end of the 50s. These first automatic numerical control (NC) machines were controlled by a logically organised series of coded instructions stored on punched tape. Each machine had its own paper tape reader and the control gear necessary to execute the instructions received. NC machines are particularly suitable for workshop type production (short runs);

The next stage was marked by the appearance of machining centres (MC), better suited to long production runs, and whose configuration is essentially based on grouping together several machining stations with automatic tool changing and transfer of work pieces, with transfer machines automatically passing pieces from one machining station to another. Although this type of installation is mechanically extremely complex, the machining centre remains essentially non-flexible;

Subsequently, in the period 1972-74, computer numerical control (CNC), i.e. systems directly controlled by computer, began to appear as the result of the use of microprocessors. Each machine is controlled by a microcomputer and the disadvantages of storing information on paper tape are eliminated;

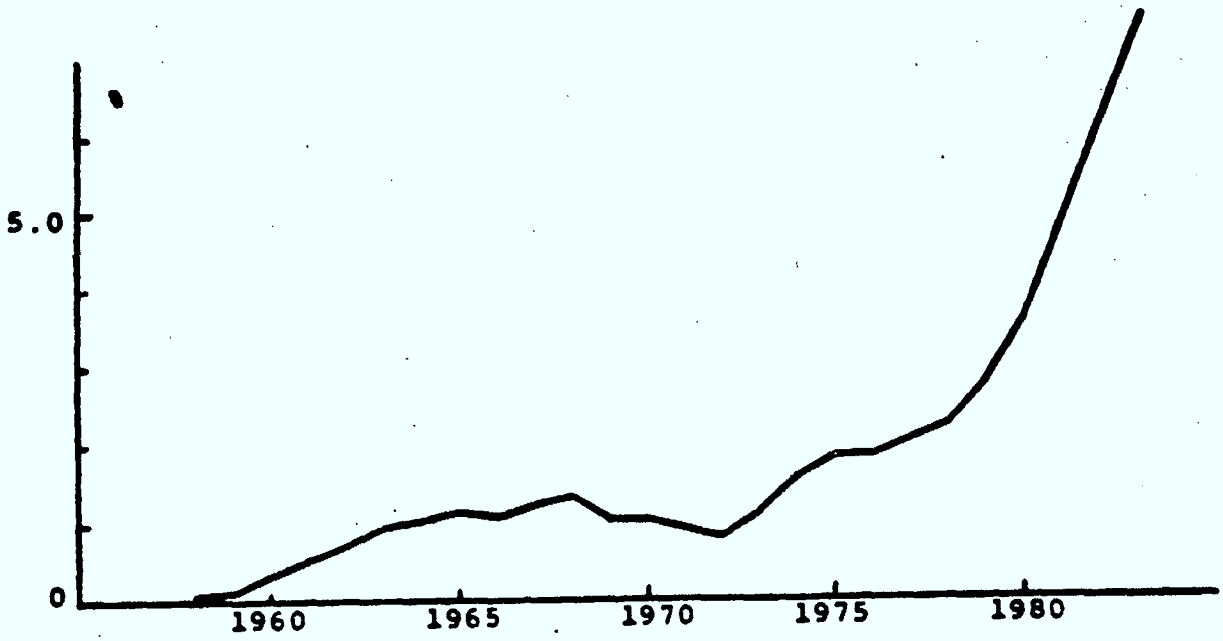
The arrival of CNC also made new developments possible: the simultaneous control of several machines by a central computer: direct numerical control (DNC). This latest stage is characterised in particular by the appearance of manufacturing cells that integrate a sequence of specific forming operations and a sequence of handling and palletisation operations. According to R. Ayres (1987), the high cost of the initial electronic control units in the 60s was a major obstacle to the adoption of NC: in

1958, a transistorised control unit cost between US$70 000 and 80 000; by 1968 the cost had fallen to US$30 000, while in 1974 with the appearance of the first integrated circuit control units (CNC) the average cost was US$15 000.

202. It is from 1968 that the spread of numerical control really took off, particularly in the United States (Graph 11).

Graph 11

THE NC SHARE IN TOTAL METAL CUTTING MACHINE TOOLS IN THE UNITED STATES

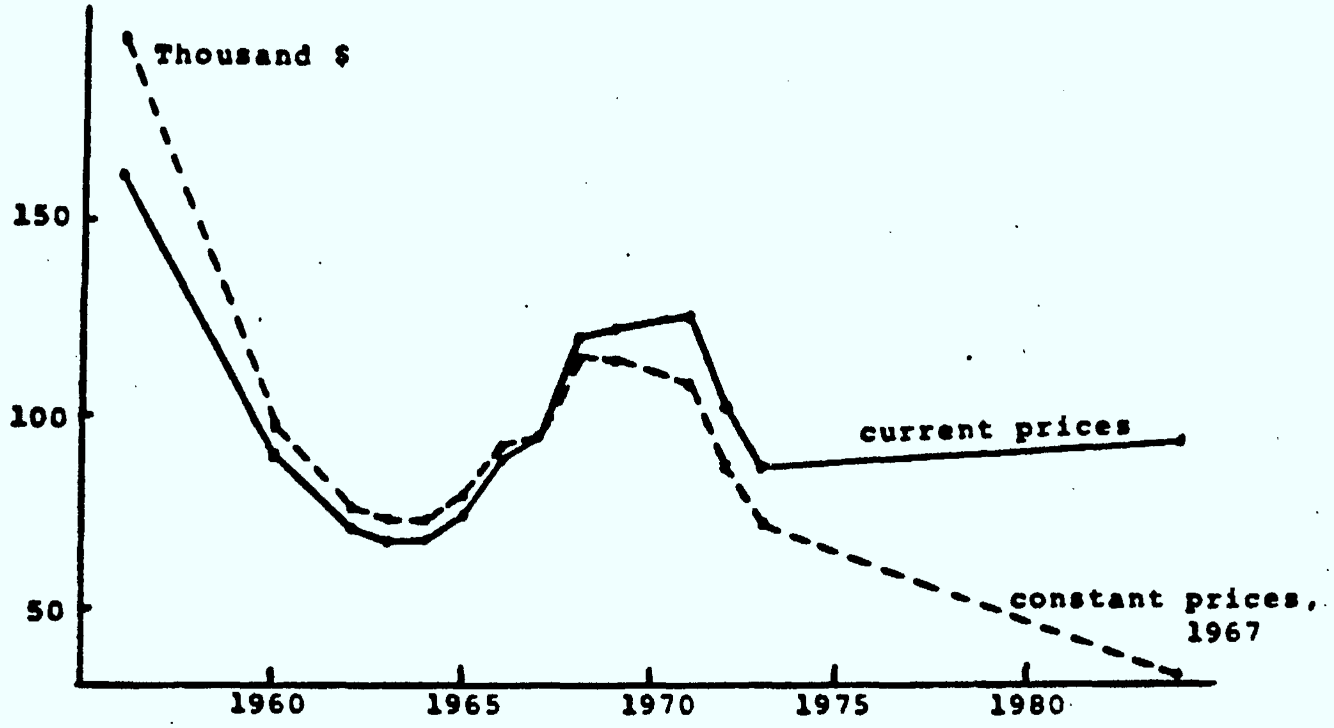


Source: R. Ayres, 1987.

203. The reduction in the cost of numerical control systems seems to have levelled out as from 1975, however, as shown in Graph 12. This stabilisation is due, still according to Ayres, to the constant increase in the capacity of the machines and the increased importance of machining centres as opposed to single machines in the annual sales of numeric control systems.

Graph 12

UNIT PRICE OF NC MACHINES IN THE UNITED STATES



Source: Ayres, 1987.

204. In 1980, one-third of the total number of machine tools bought in the United States were NC machines and over 103 000 NC and CNC machines were then in service. While this figure represents only 5 per cent of the total number of machine tools in operation in the United States it represents very much more in terms of output in view of the vastly superior capacities of NC and CNC as compared with conventional machine tools. Thus 50 per cent of the value-added produced by the metal cutting industries in the United States is earned by numerical control equipment. Taking account of a certain number of limits on the possibilities for application, it would appear that the number of NC/CNC machines in service today is about one-quarter of the number actually possible in the United States (Ayres, 1987).

2. Industrial robotics

205. Our perception of the extent of the spread of industrial robots and of the technological improvements brought about in them depends essentially on the adopted definition of the term robot itself. The definition generally

accepted in Europe and the United States evokes the idea of universal manipulation systems, used in industry, having at least three axes, whose movements can be programmed and capable of being fitted with devices to pick up and handle work pieces and/or tools (Lay, 1987).

206. With these narrow definitions, the diffusion curve is less advantageous than would result from a broader understanding of the term "robot" (Graph 13). First appearing in the 60s, the industrial robot spread only slowly at first. In 1970, there were only 200 industrial robots in service in the United States, while the 1 000 barrier was not passed until 1974. The real take off did not occur until 1983 with about 24 000 robots at that date. The OTA estimates (Graph 28) indicate that 50 000 robots could be in service in the United States by 1990 but the estimated sales for 1984 and 1985 have already been exceeded. More than any other automated equipment, the robot has had a "sectorally differentiated" rate of spread. The main fields of application remain the machine tool and in particular welding (60 per cent of cases in Germany), the manipulation of pieces and in particular the loading and unloading of machines remaining little robotised.

207. To the extent that robot applications in welding and painting are virtually at saturation point, the potential for further applications are on the one hand in assembly and on the other in handling, but the actual realisation of this potential requires the solution of a certain number of technical problems, specific to each sector of utilisation. In other words, the existence of a need is not enough to cause the rapid spread of robotics. R. Ayres (1987) has identified three main factors hampering the penetration of robotics in the production system:

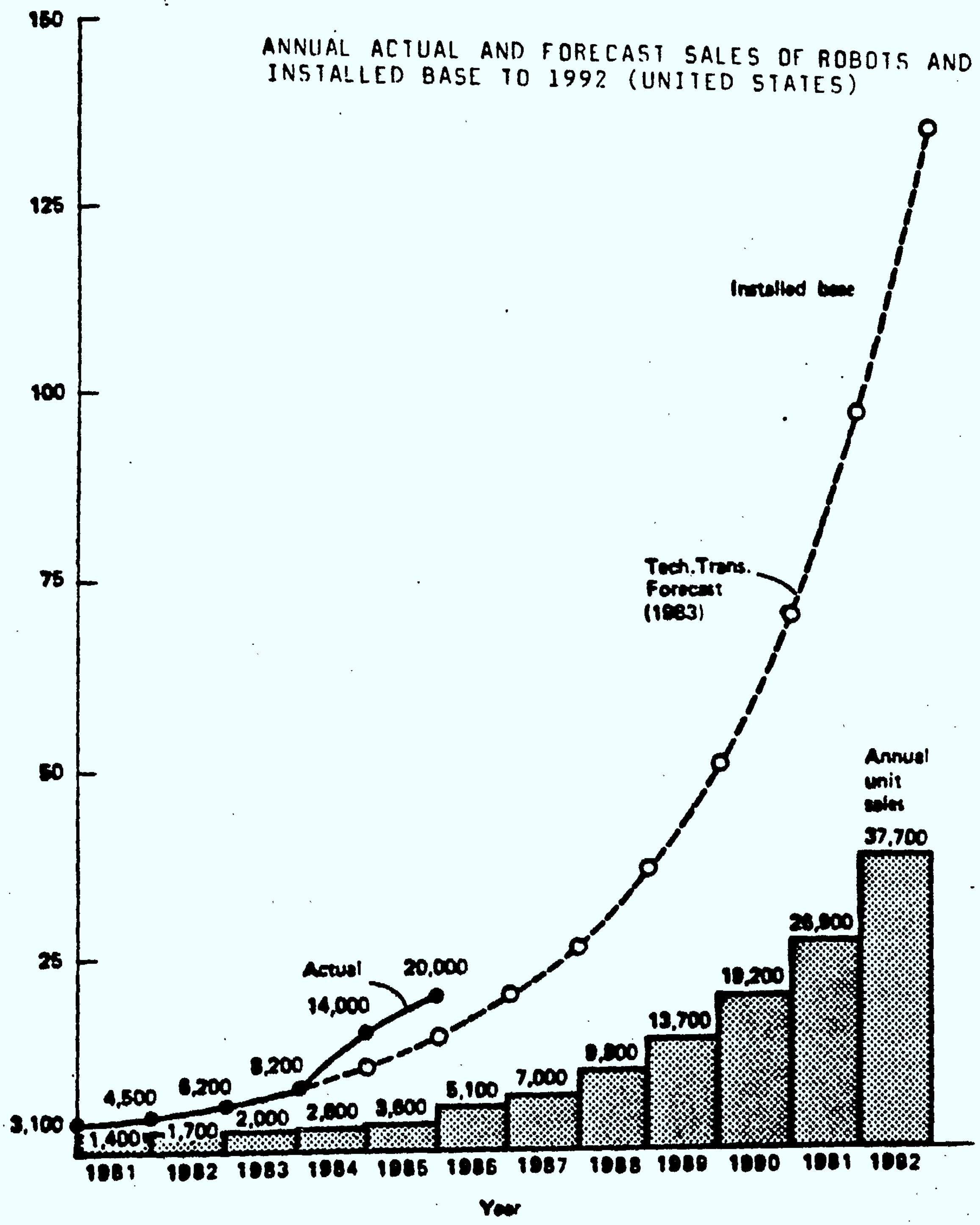
- First, the "primitive" nature of the technology. The first assembly robot appeared only in 1980 and the inadequate development of sensor technology was for a long time an obstacle to robotisation;

- Second, the framework in which the industrial robot is inserted: in an old plant the difficulty of introducing robots is much greater than in a new one. The development of integrated manufacturing cells (CNC + robots) constitutes the best vector for the spread of robotics. According to D. Mowery (1986), 90 per cent of the robotics systems sold today have to be associated with existing equipment that is often between 10 and 20 years old;

- Third, the programming languages are cumbersome, so that costs for new applications tend to amount to twice the cost of the robot itself, which constitutes a major obstacle for small firms.

208. Ayres nevertheless concludes that these difficulties are gradually being overcome with the accumulation of production experience. Lastly, it should be noted that the capacities of robots have increased substantially thanks to improvements in the controls and better programmability. Recent progress in gripper design will make it possible to reduce the amount of specialised engineering needed for each application. Electric motor drives are replacing pneumatic and hydraulic systems for robots requiring great precision. The speed of operations in increasing, but the major technical breakthrough of the 80s has been the development of vision and/or tactile sensors and feedback control giving robots the capacity to react to modifications in the environment.

Graph 13



Adapted from OTA (84)

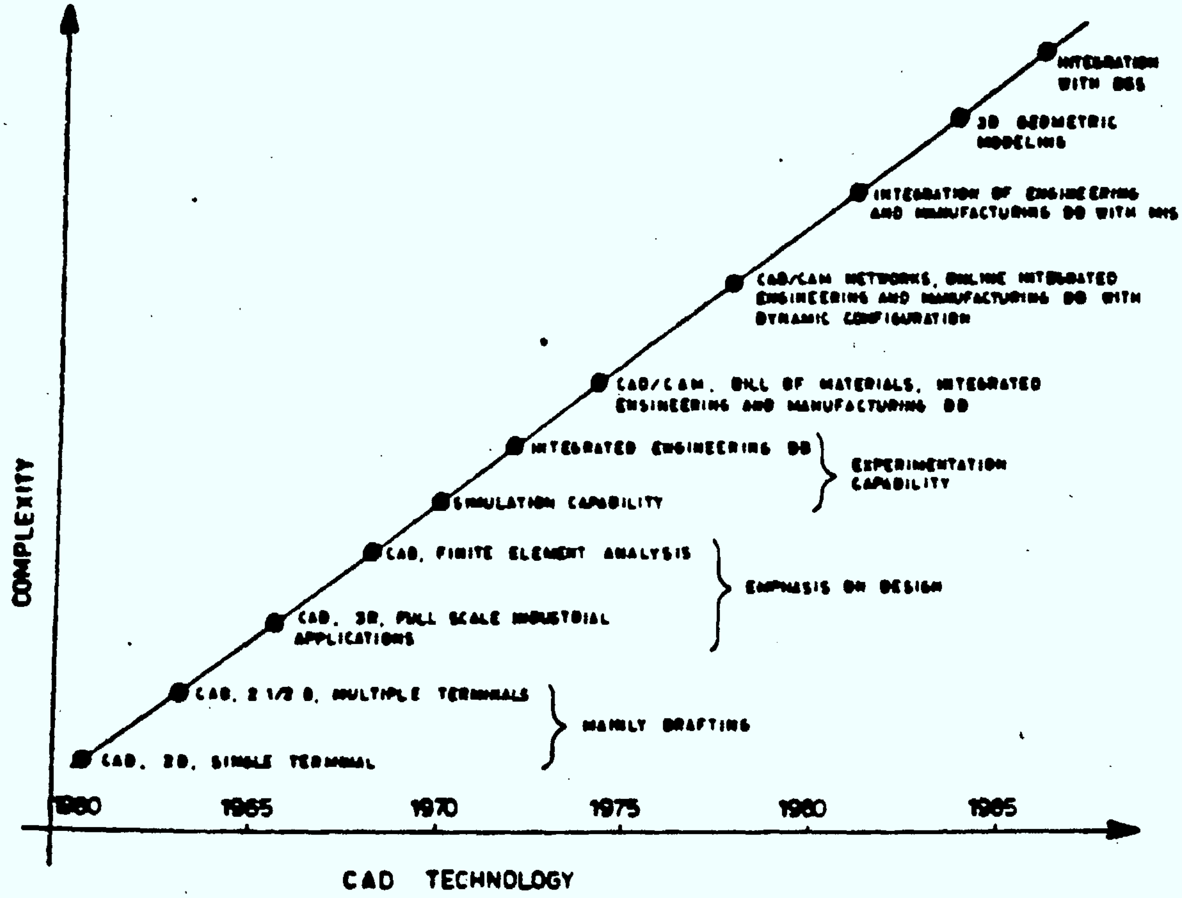
Source: Ayres, 1987.

3. CAD/CAM

209. Computer aided design (CAD) systems are characterised by computer assistance in the design and graphic representation processes and also includes calculation and simulation tasks. A CAD system comprises a central computer, peripheral computers, an operating system and applications software. Graph 14 illustrates the increasing complexity of CAD systems.

Graph 14

THE INCREASING COMPLEXITY OF CAD SYSTEMS



There has been an increasing amount of complexity, over 25 years of CAD implementation. In the future, complexity will be even greater and hence, the wisdom of using expert systems

Source: Chorafas, 1987.

210. The initial development of CAD systems took place within large firms like McDonnel-Douglas and Boeing. As from 1970, the spread of these systems became very rapid. The market amounted to US$25 billion in 1977 and was already US$350 million in 1979. At this time all producers without exception

were in the United States. World demand has continued to rise, reaching US$592 million in 1980, 2.9 billion in 1982 and 3.5 billion in 1985 (US$2.9 billion of which produced in the United States).

211. Unit prices have fallen spectacularly, from US$500 000 in 1980 to 400 000 in 1985. Most of these systems used 32-bit mini-computers. In 1985, 25 000 systems were in service, 18 000 of them in the United States.

212. The increasing use of CAD systems adapted to run on 16-bit personal computers (PCs) is likely to bring the price down further, while reducing the average performance of this type of system. It is expected that by the beginning of the 90s, 90 per cent of CAD systems will be on 16-bit PCs.

213. An analysis of the sectoral spread of CAD systems carried out in Germany indicated that mechanical engineering dominated (with 52 per cent) followed closely by electronics engineering (integrated circuit design).

214. Computer aided manufacturing (CAM) systems are operations management devices, planning operations within a unit of production and creating programmes for the individual machines. There is much less information available about the CAM systems market, no doubt due to the amount of in-house software development for specific applications. The fact remains that expansion of CAM applications depends very much on the spread of CAD systems, for as R. Ayres points out, as long as CAD and CAM are not integrated into a single system the dream of "industrial boutiques" producing parts on demand will not be realised.

4. Towards the integrated automation of production: the search for flexibility

215. The integrated automation of production includes systems whose prime characteristic is to integrate different types of automated equipment. Although the idea of computer integrated manufacture (CIM) has advanced considerably in recent years, it is still difficult today to identify any marketed systems that really do constitute integrated automation. To date, the use of CAD systems and computer numerical control machines is the most widespread form of partial integration. It is clear that problems of the interface between hardware and software constitute serious obstacles in the transition from the partial integration stage to that of computer-integrated manufacture.

216. "The production technologies used up to now have tended to favour either productivity or flexibility, but have never made it possible to achieve these two objectives simultaneously. New technologies were thus essential to improve the flexibility of mass production systems without reducing their productivity and, conversely, for improving the productivity of multipurpose shops without impairing their essential quality: flexibility.

217. 1967 saw the advent of the first flexible manufacturing system (FMS), combining different NC machines with an automated handling system under computer control. The basic principle of the FMS is that work-pieces of different types and machined by different programmes pass from one machine to another. FMS integrate virtually all the technological devices described above: CNC machines as the basis of the manufacturing process, robots to

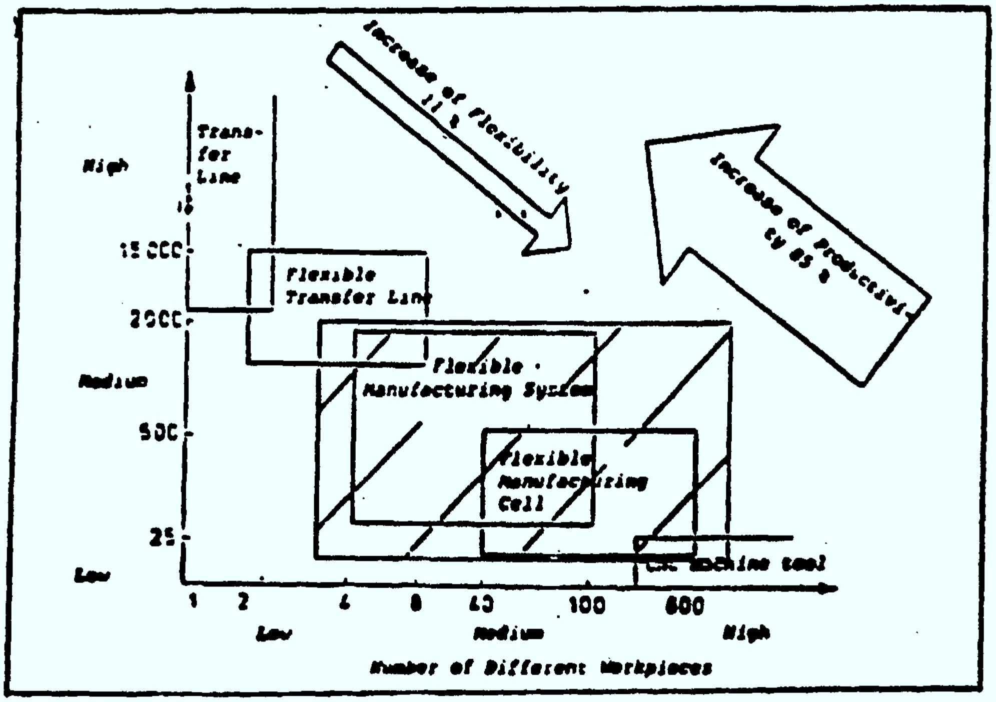
automate the handling of work pieces, CAM systems to automate the control and supervision of the entire process. Only CAD systems are not concerned in the design of an FMS.

218. An FMS, like a machining centre, requires machine tools and systems for handling work-pieces and tools. But the requirement of flexibility, which means varying cycles and speeds, requires the introduction of additional numerical control devices and a supervising computer to co-ordinate the different cells. There are thus additional hardware costs on top of the normal extra cost of producing special software.

219. It is nevertheless clear that hardware costs could fall significantly with the use of standardized equipment modules that could themselves be produced in greater volume (the rapid Japanese penetration on the US market seems to be based on this strategy). As shown in Graph 15, the typical field of application of FMS is situated between very high productivity but highly inflexible manufacturing systems and flexible but somewhat inefficient manufacturing systems. This graph brings to light the fact that the implementation of an FMS would be rather geared to an increase in the productivity of a flexible system (85 per cent of cases) rather than to achieve greater flexibility for a transfer line with high productivity (11 per cent).

Graph 15

FMS AND THE PRODUCTIVITY/FLEXIBILITY DILEMMA



Source: Fix-Sterz, Lay

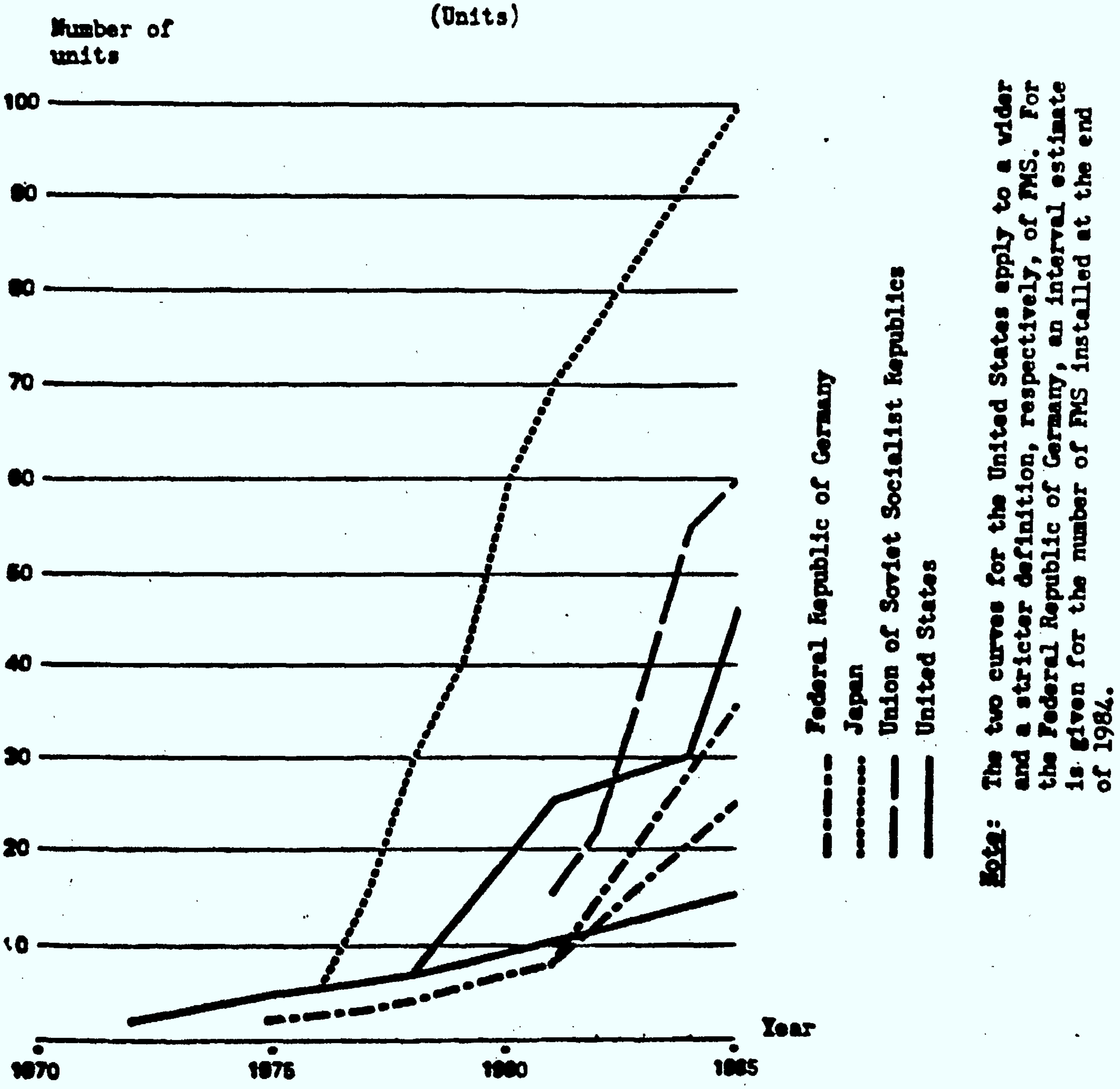
220. Since 1975, FMS have spread relatively rapidly. At the beginning of 1985, there were 46 in the United States, as against 4 in 1975. As suggested by Graph 16, the rate of growth appears to be accelerating. There could be 280 FMS installed in the United States by 1990.

Graph 16

DEVELOPMENT OF FMS

Growth of FMS in the Federal Republic of Germany, Japan, the USSR and the United States

(Units)



Source: Ayres, 1987

5. National automation strategies

221. Virtually all industrialised countries are engaged, in different ways, in the integrated and flexible automation competition. It is therefore necessary to evaluate their automation strategies. "Some, particularly those of Japan and the United States, make it possible to identify new forms of technological and economic superiority and the conditions for its durability, while others, in particular those of European countries, provide an occasion to estimate the efforts and alliances necessary to make up lost ground and reduce the risk of technological and economic dependence" (Lafaille, 1983). The special programmes of the United States, Germany and Japan and the co-operative actions developed under the Eureka, Brite and Esprit programmes provide concrete examples.

JAPAN

The JUPITER programme

Starting with the observation that the technologies required for the second and third generation of robots are still far from being mastered, MITI in 1983 launched a new 8-year national programme called JUPITER (Juvenescent Pioneering Technology for Robots). The ARTRA (Advanced Robot Technology Research Association) is conducting the programme in collaboration with about ten private firms. The overall budget of the programme amounts to about 18 billion yen for the eight years. This programme in a way took over from the Flexible Workshop project, using lasers, which was completed in 1983.

UNITED STATES

From ICAM to SDI: Military programmes

Among the multitude of actions undertaken, directly or indirectly, by the US State in the field of industrial automation, one of the them stands out from the others by virtue of the sums involved. This is the Integrated Computer-Aided Manufacturing (ICAM) programme of the Department of Defense. The aim of ICAM is to improve techniques and productivity in the aerospace industry. The funds allocated for this work for the period 1977-85 amounted to US$250 million. Under the ICAM programme more than 65 contracts were concluded with about 50 companies.

Another military programme is the Strategic Defense Initiative (SDI), which is particularly concerned with robotics. Applications in special environments and improvement in the capacities of the robots (utilisation of laser weapons, radar, vision sensors) are sought in particular. It should be noted that several of these technologies (laser, sensor, improved real time control) are likely to be applied on a large scale in industry even though the cost/efficiency ratios acceptable in weapons systèms are not well-suited to commercial applications.

UNITED STATES

The MAP project

Resulting in particular from a private initiative of General Motors, the aim of the MAP Project is to persuade automation equipment manufacturers to work on the definition of standards to permit the use of common flows of data and instructions for all the hardware concerned (robots, computers and other terminals). This is a harmonization and standardization policy whose originality lies in the nature of the initiator: a very large firm, General Motors, which can exert enough leverage on its suppliers.

GERMANY

The "Fertigungstechnik" programme
(1984-87)

The Fertigungstechnik 2 (PFT2) programme, launched in January 1984 constitutes the logical successor to PFT1 (1980-83). This programme, endowed with an overall budget of DM 530 million, comprises the three following components:

-- First, indirect specific aid, whose aim is on the one hand to encourage the use of CAD/CAM systems in enterprises in the capital goods sector, and on the other to promote the supply of industrial robots. The greater share of the resources, DM 530 million, is concentrated on this specific indirect aid;

-- Second, direct aid to collective research projects in the field of computer integrated manufacturing (DM 148 million);

-- Third, indirect aid to technology transfer, which is in part devoted to the functioning of the Karlsruhe CAD/CAM demonstration laboratory.

In the area of direct aid to collective research projects, work carried out in international co-operation (with Norway, France the United Kingdom) also benefit from a BMFT subsidy.

EUROPE

Eureka, Brite, Esprit 1

The promotion of collective European research in the field of robotics and automation is pursued under three programmes:

Eureka: this is an incentive for targeted research aimed at the development or marketing of products in 13 major sectors, including robotics and computer integrated manufacture. For example, the Mithra programme (on advanced intertechnology robotic hardware) involves French, Italian and Swiss partners and has an overall budget of FF 230 million.

Brite: (Basic research in industrial technologies for Europe) is designed to encouraged precompetitive research in all industrial technologies.

Esprit 1: Under Esprit 1, the computer integrated manufacturing (CIM) sub-programme had two objectives: developing architectures and criteria for the integrated control of work stations. In the pursuit of these two objectives, priority is given to the creation of pilot systems.

*

* *

222. The establishment of integrated services digital networks on the one hand and computer integrated manufacture on the other constitute the two main objectives of the special programmes devoted respectively to telecommunications and manufacturing production. In the same way as was demonstrated in the preceding chapter, here again there are obligatory technological points of passage, which explains why there is a certain uniformity in national choices: the targets are identical and the special programmes of the different countries have a common technological content. They are also confronted, in both sectors, with the problem of old equipment and structures hampering the spread of the new technologies. Thus, in the communications sector, the coexistence of old and new equipment causes interfacing problems which are all the more acute because the equipment concerned has a long life. It is therefore estimated that in the year 2000, 50 per cent of the exchanges will still be of the electro-mechanical type. Similarly, in the manufacturing sector, 90 per cent of the systems sold today have to be associated with existing equipment that is often between 10 and 20 years old.

223. Like network technology, the economics of information technologies in both these sectors depends on an active standardization policy which alone can enable the potential for economies of scale to be realised and attenuate the virtually irreversible nature of the choices.

Chapter IV

THE R&D EFFORTS: THE LIMITS OF INTERNATIONAL COMPARISONS

224. The difficulty of analysing national R&D efforts in information technologies and making international comparisons is due to the fact that we know very little about the scale of the various government actions in this area. An ignorance which is all the more awkward and surprising in view of the fact that the outcomes of the government programmes in question will certainly have profound political, economic, social and cultural implications, and even ultimately affect the very roots of our civilisation! We know that major research programmes have been launched by the governments of Member countries, we know their names and their major objectives, we know that there are many other more scattered R&D activities which are highly relevant. But we find it extremely difficult to obtain data which will allow international comparisons of the efforts in question, in terms of human and financial resources invested, or in terms of research strategies, or in terms of procedures and mechanisms. Yet, such comparisons are required to clarify the policy options open to Member countries in this area, in order to assess the effectiveness of ongoing programmes so that future ones benefit from past experiences and draw the lessons which will assist government decision-makers in the design of new major R&D programmes in information technology, as well as in other high-technology areas.

A. The Main Technological Axes

225. In the light of the preceding analyses, it is now possible to formulate three major remarks with a view to describing in general terms the nature of the strategic choices made by different countries in the field of information technology.

* There are compulsory technological points of passage that have to be traversed, which means a certain uniformity in the choices:

-- The tendency to miniaturisation and integration, new MOS, GaAs and Josephson junction technologies, new methods of manufacturing circuits, are compulsory points of passage in the field of microelectronics;

-- New architectures (parallel, data flow), high level languages, new methods of producing software are the compulsory points of passage in the field of software;

-- The change to digitization for transmission and switching functions, the introduction of opto-electronics, the integration of services, are the compulsory points of passage in the field of telecommunications;

-- The development of numerical control, robots and computer aided manufacturing systems are the compulsory points of passage in the field of automation and computer integrated manufacture.

The existence of these compulsory points of passage explains why R&D promotion policies do not differ significantly from one country to another: the targets are identical and the special programmes of the different countries have a common technological content.

* The study has nevertheless revealed the existence of a certain liberty of choice as regards products to manufacture and market segments to conquer.

226. While Japan has opted for the production and marketing of standardized, mass produced components, aimed mainly at the consumer goods industry, the United States has opted for sophisticated components for specific applications.

227. Similarly, while certain countries are able to reconcile the two major objectives of the Fifth Generation (supercomputer and KIPS), in particular the United States, Japan and to a lesser extent France and the United Kingdom, others will have to choose one or other of these options.

228. In other words, some choice is possible. The main considerations here are what others are doing and the time factor. For example, the implementation of the Fifth Generation programme was based on essentially strategic considerations, i.e. the symbolic programming sector was the only field open to Japan to succeed the policy which generated hardware systems entering IBM's market.

* Three major features of information technologies make state intervention particularly important in this field:

-- First, the existence within the technological system itself, of ordered relationships. In other words, the apparent disorder of the information technologies field hides a necessary order for the freeing of technical bottlenecks in the different branches, such that an advance in one area brings advances that follow in terms of this order. This study does not attempt to define a strict order between the different technological fields, but it does reveal some clues: for example, advances in integrated circuit technology are essential for progress in other fields such as supercomputers, digital transmission and switching, industrial robotics. Many other examples could be cited, thus suggesting the existence of a network of technological interdependence and of a necessary order of succession in technical advances relative to different technological fields;

-- Second, the role of "the old" as a factor hampering the spread of the new. Thus, in telecommunications, the coexistence of old and new equipment causes interfacing problems that are all the more acute because such equipment has a long lifetime. It is thus estimated that in the year 2000, 50 per cent of telephone exchanges will still be of the electro-mechanical type. As regards software, insufficient compatibility between systems of different generations give the architectures of the 60s and 70s great importance still today and hampers the spread of new architectures. In robotics, 90 per cent of the systems sold today have to be associated with existing equipment that is often between 10 and 20 years old.

Thus we constantly encounter in different forms the problem of the coexistence of the old and the new. Rare are the countries who try to build their new information processing and transmission systems ex nihilo.

-- Lastly, like the network technology, the economics of information technologies depends on an active standardization policy, which alone can enable the potential economies of scale to be realised and attenuate today's virtually irreversible nature of choices.

229. In the final analysis, it would appear that the clearing of technological bottlenecks in different fields, the management of radical change and the active pursuit of a standardization policy constitute the three nodal points of state action in the field of information technologies.

230. This being said, the major problem that arises from the standpoint of the international analysis of information technology R&D efforts in Member countries is linked with the fact that there is a serious lack of data. There is at present no statistical base that coherently throws light on the paths chosen by the different countries to reach the compulsory points of passage or the order of technological choices highlighted above, or that would make it possible to assess the manner in which countries take advantage of the margin of freedom open them to them in the technological terrain to be explored.

231. The analysis of this technological terrain which has been attempted above provides an indication of the path that could be taken towards new definitions and a new approach to the collection of data on research and development in the field of information technologies. In the meantime, the available data do not allow us to answer these questions and are presented in an aggregate form which serves a quite different purpose, and even then their reliability is such that they must be used with extreme caution.

B. The Lack of Reliable Data

232. A major -- if not the major -- difficulty stems from the fact that the available data which is presented below consists of institutional data, rather than groups of products; the industrial affiliation of the R&D performer rather than the technological field to which the research resources are allocated has determined the categorisation of R&D projects. Furthermore, the institutional affiliations in question originate from classifications which were established in the late 1960s and no longer reflect todays' industrial

reality -- the more so in a sector like information technology related products where structural changes have been extraordinarily profound over the last decade. For example, computers (or, rather, computer manufacturers) are included, as office equipment, in a group called "mechanical construction and machinery". Many countries still collect data which amalgamate "computers" and "other machines". A few collect data for "Electronic Equipment and Components". Fewer still identify communications research as a discreet category -- at a time when it becomes a crucial factor in the advances of information technologies.

233. The result is extreme uncertainty regarding any assessment of public and private R&D expenditures in information technology.

234. These are only examples, and there are many other considerations which at present affect the availability and reliability of R&D data in information technology. Various estimates have been made by various bodies, but the methodologies which have been made are not open to scrutiny and the wide range of such data indicates that there is as yet no reliable body of statistics in this area. Some efforts are under way to overcome these difficulties, but they will not come to fruition in the near future unless a major commitment is made on the part of Member countries to reach an understanding on new common definitions, and collect the corresponding data.

235. So we have to make do with what we have. A set of available data concerning the R&D efforts of Member countries in information technology is presented in Annex I, based on information available from the Organisation's data bank and verified by national authorities in Member countries. These statistics are discussed below, knowing that:

- They are already relatively old since extensive international comparisons are only possible for 1981 or -- at best -- for 1983;
- The data is patchy and does not satisfactorily cover the range of Member countries;
- They do not provide a fully reliable picture of the distribution of efforts between government, industrial and university laboratories;
- They provide no indication on the share of basic research, applied research, and development;
- They do not cover consistently the areas of industrial activity it is supposed to cover;
- Much of them are "estimated";
- Uncertainties about definitions and categories make comparisons between the scales of the various efforts extremely hazardous.

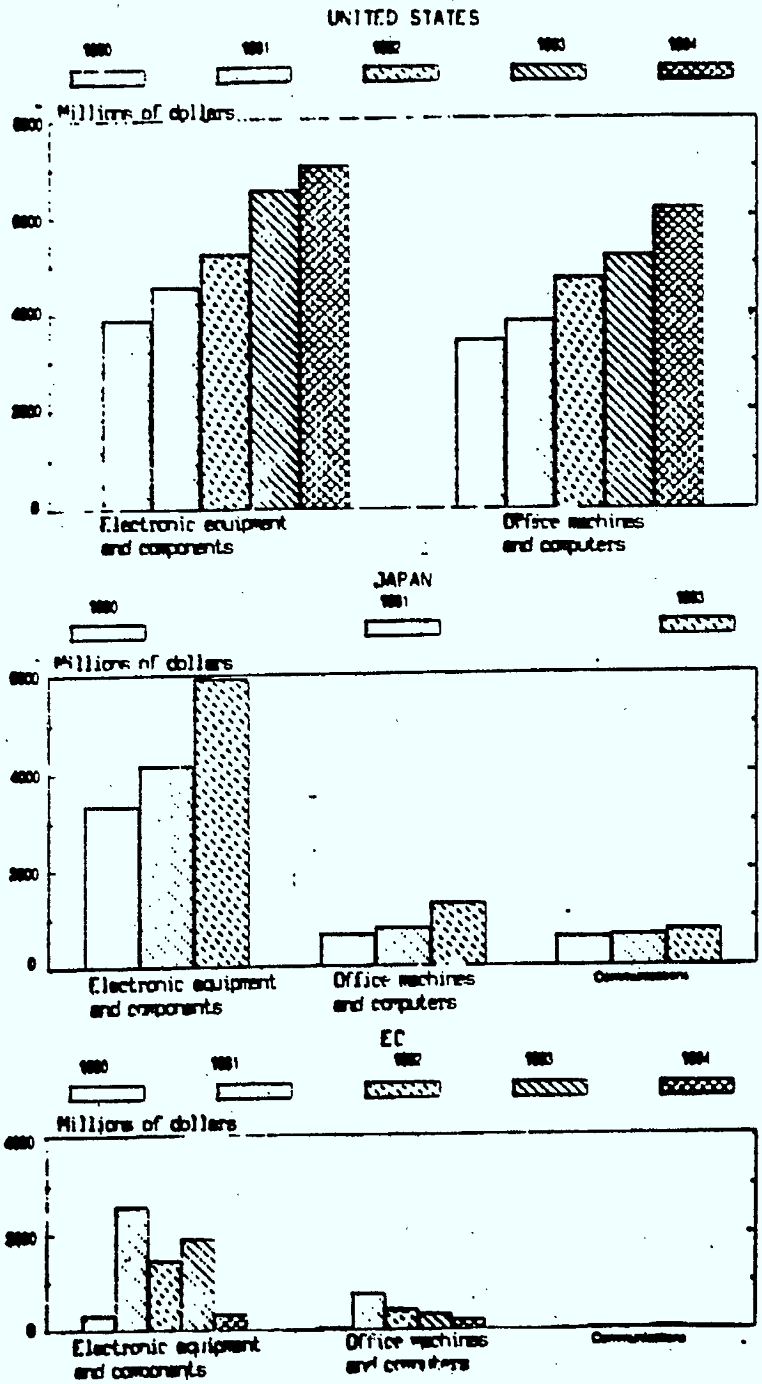
C. Some National Trends in Information Technology R&D Resources

236. The trend of enterprises' R&D expenditure in "electronic equipment and components", "office machinery and computers" and "communications" is shown in Graph 17 for the EC, United States and Japan.

Graph 17

TREND IN INDUSTRIAL R&D EXPENDITURE

EC, UNITED STATES, JAPAN



237. In the case of "communications", the lack of data for the United States and doubt as to the accuracy of the extremely low EEC figures for this field, do not allow us to go very far in the comparison. However, a steady progression in this field in Japanese enterprises can be observed.

238. In the two other fields, the clear and continuous progression of US and Japanese firms contrasts with the irregularity of the trend in EEC countries. In "electronic equipment and components", the industrial R&D effort in these countries increased from 1980 to 1983 (with a sharp rise in 1981) and fell back in 1984 to approximately the 1980 level. As regards "office machinery and computers", there has been a continuous fall since 1981. Here again, we may question the real significance of these figures.

239. A comparison of total R&D personnel in Germany and France in these two same fields is shown in Graph 18. This highlights in particular the relatively slight increase in the effort of both countries, with Germany having a significant lead in electronic equipment and components.

D. The International Distribution of the R&D Efforts

240. Looking at the distribution of the R&D personnel illustrated in Graph 19 and 20, it is possible to assess the relative emphasis of each national effort in the two main research fields.

1. Electronic equipment and components

241. In 1981, according to Graph 19, the United States implemented the largest share, in fact slightly more than a quarter of the whole R&D effort of Member countries, but three countries (United States, Japan and the United Kingdom) were in fact devoting resources of the same order of magnitude to this area -- from 20 to 25.6 per cent. Altogether, these countries were responsible for almost 70 per cent of the whole effort.

242. With the addition of the smaller efforts of Germany and France (respectively 13.9 and 8.8 per cent), it turns out that five countries were responsible for more than 92 per cent of the whole.

243. Unfortunately, the figures available for 1983 do not include the United Kingdom, and this is why Graph 19 also presents the 1981 situation without this country, so that comparisons can be made with respect to the subsequent evolution of the others.

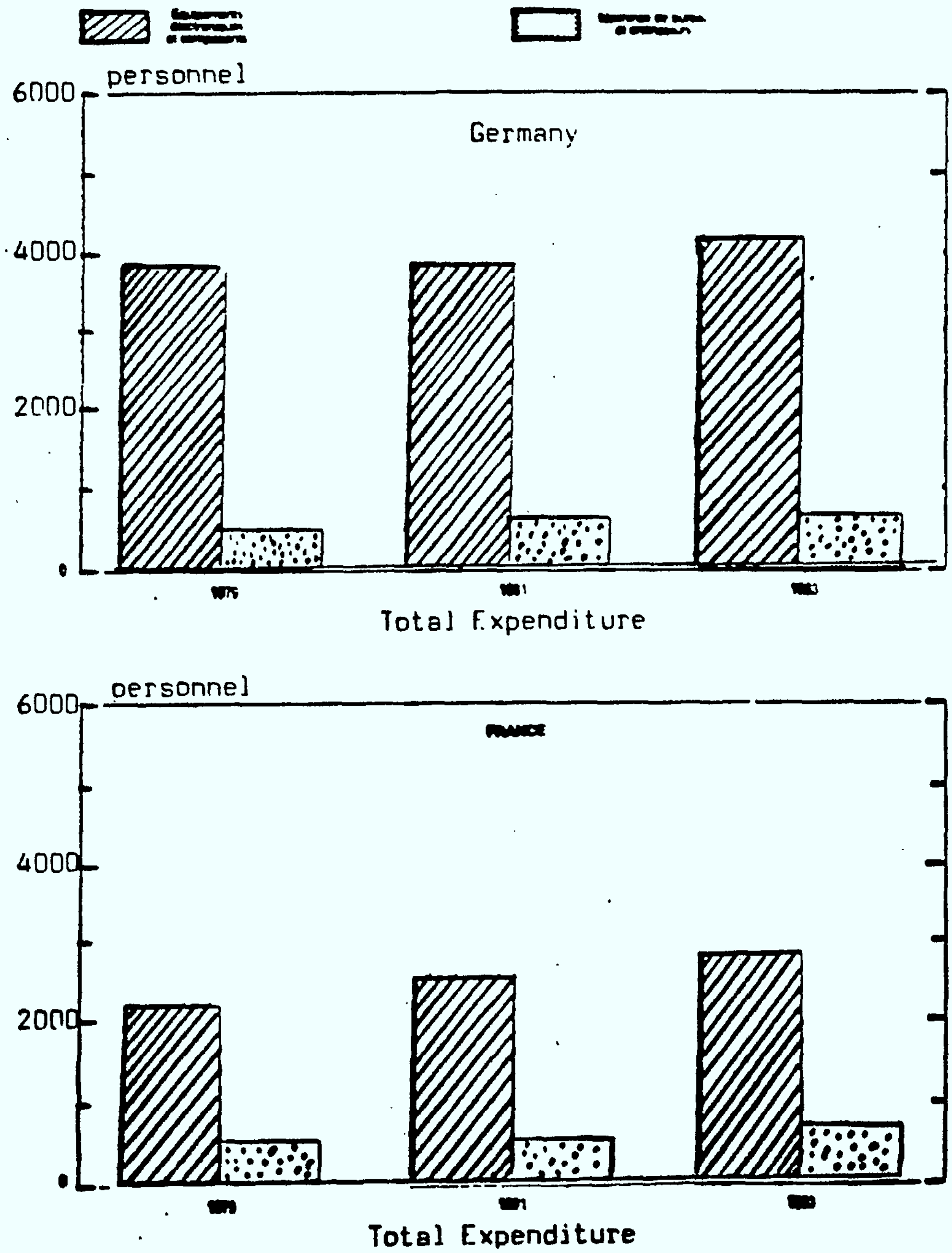
244. Between 1981 and 1983, Japan took the lead, moving from 28.9 to 32.3 per cent of the whole, followed by the United States with 31.4 per cent, (down from 32.6 per cent) and -- at a much lower level, also reduced in comparison with the 1981 situation -- by Germany (16.8 per cent) and France (10.9 per cent). These four countries accounted for more than 91 per cent of the whole, as against 90.5 per cent in 1981. Among other countries, significant increases were achieved by Italy, Canada and, to a lesser extent, by Sweden.

Graph 18

TREND IN TOTAL R&D EXPENDITURE

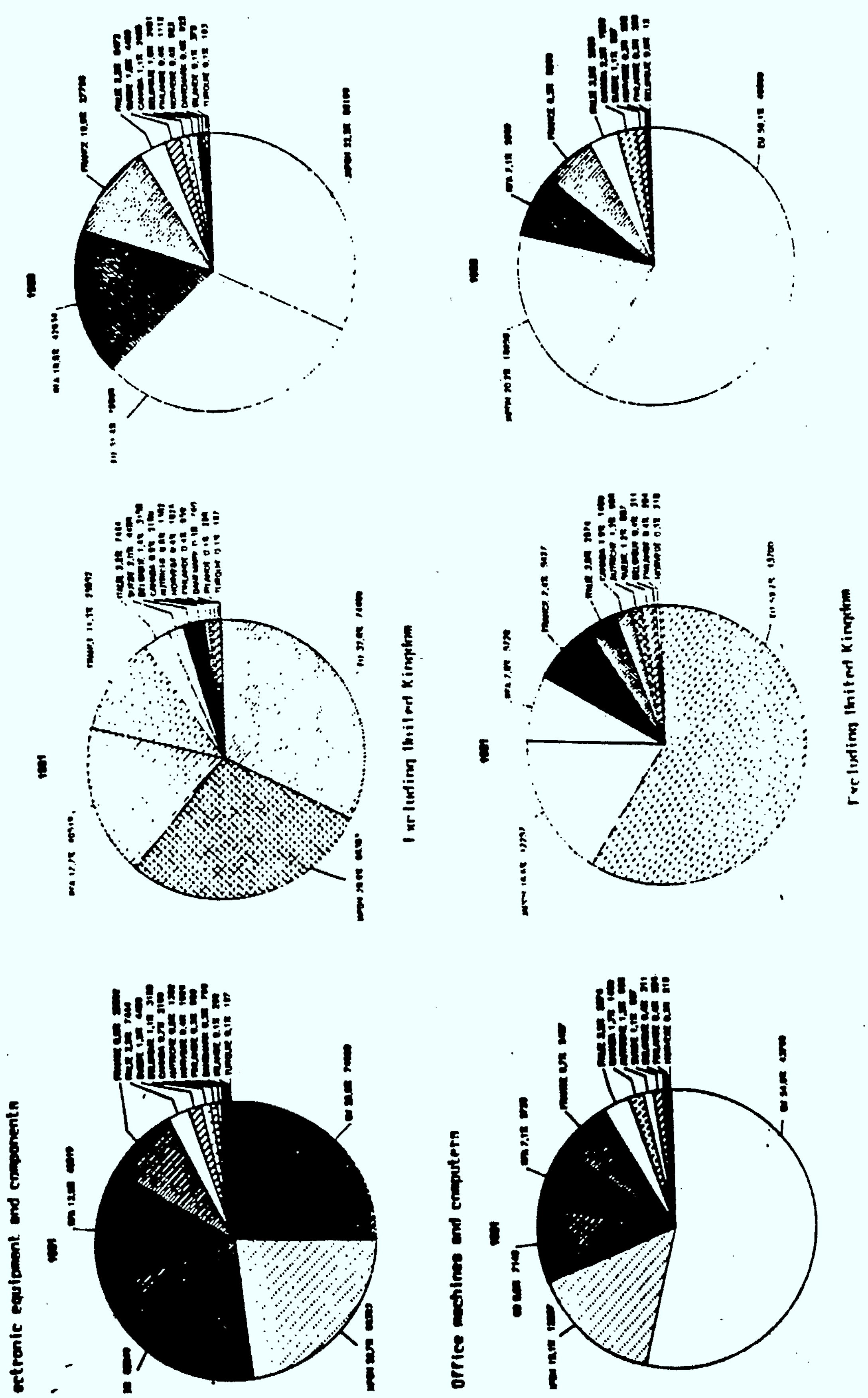
FRANCE, GERMANY

(total personnel)



Graph 19

INTERNATIONAL DISTRIBUTION OF R&D EFFORTS



245. Comparisons are also presented here in terms of major economic groupings, namely the EC and Nordic countries, whose aggregate efforts are compared with those of the United States and Japan in Graph 20. While Nordic countries remained stable at a 2.1-2.2 per cent level, the share of the EC has grown from 41 to 46.4 per cent.

246. The picture, in this area, is thus one of extreme concentration with striking changes in the distribution of the international effort.

2. Office machinery and computers

247. The same remark applies to the second research area, with significant differences, however, in the relative strengths of the Member countries.

248. According to Graph 19, the United States lead is much more striking, and amounted to 54.0 per cent in 1981. As above, comparisons over time do not take the United Kingdom into account and, in this case, the US effort remained stable at close to 60 per cent between 1981 and 1983.

249. After the US, but at a much lower level, the Japanese effort was the most significant in 1981, with 15.1 per cent, and outdistanced the United Kingdom (8.8 per cent), Germany (7.1 per cent) and France (6.7 per cent). These five countries accounted for almost 92 per cent of the whole (United Kingdom included) and four countries (United Kingdom excluded) for 91 per cent of the whole.

250. By 1983, in the analysis which omits the United Kingdom, the Japanese effort had increased from 16.6 to 20.2 per cent. Germany had declined from 7.8 to 7.1 per cent and France from 7.4 to 6.3 per cent. The four countries accounted for ahout almost 93 per cent of the whole. Among other countries, Canada and Italy had achieved significant progress.

251. Similar comparisons can also be made here with a regrouping of the R&D activities of the EC and Nordic countries (Graph 20). Both shares declined, when compared with those of the United States and Japan, from 26 to 24 per cent in the case of the EC, and from 1.8 to 1.6 per cent for Nordic countries.

252. In this area, the international concentration is thus even higher than in the previous case.

E. The Distribution of the R&D Effort by Areas

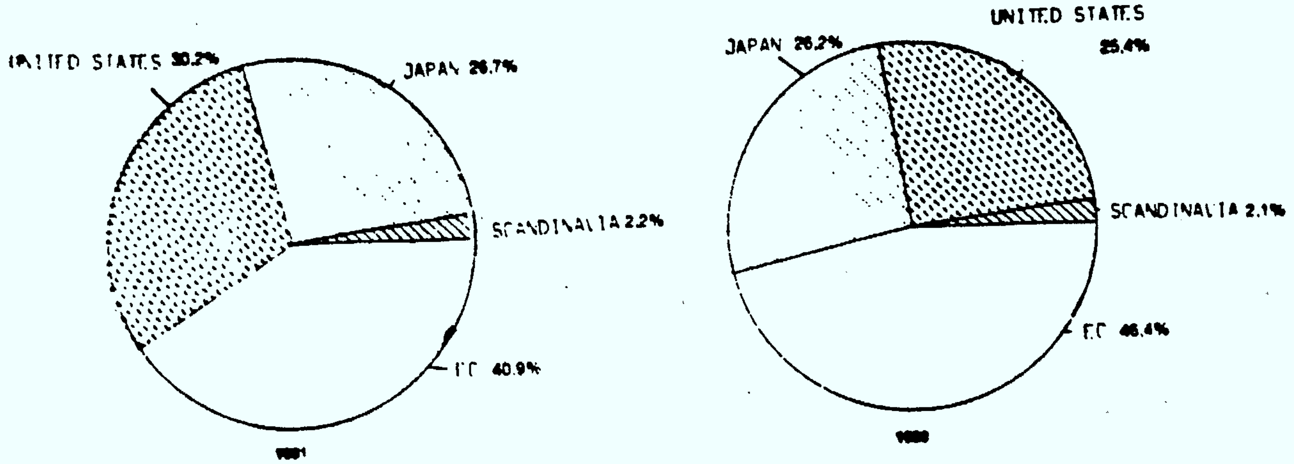
253. The pattern of distribution of the national R&D efforts between Electronic Equipment and Components, Office Machinery and Computers, and Communications is presented on Graphs 21 and 22. It is quite obvious that statistics regarding Communications R&D are very scarce, with only Canada, Denmark, Japan, Norway and Finland reported as having launched significant efforts in this area.

254. The major focus on "electronic equipment and components" is striking in almost all Member countries. Only in the United States is the effort in this area somewhat balanced by the resources devoted to "office machinery and

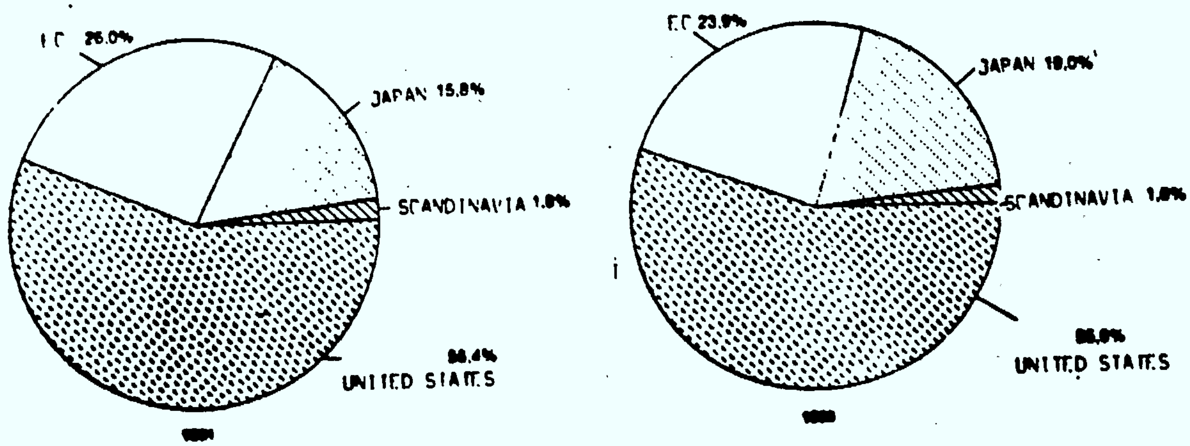
Graph 20

INTERNATIONAL DISTRIBUTION OF R&D EFFORTS, BY MAJOR ECONOMIC GROUPINGS (1981 - 1983)

ELECTRONIC EQUIPMENT AND COMPONENTS
(R&D personnel)



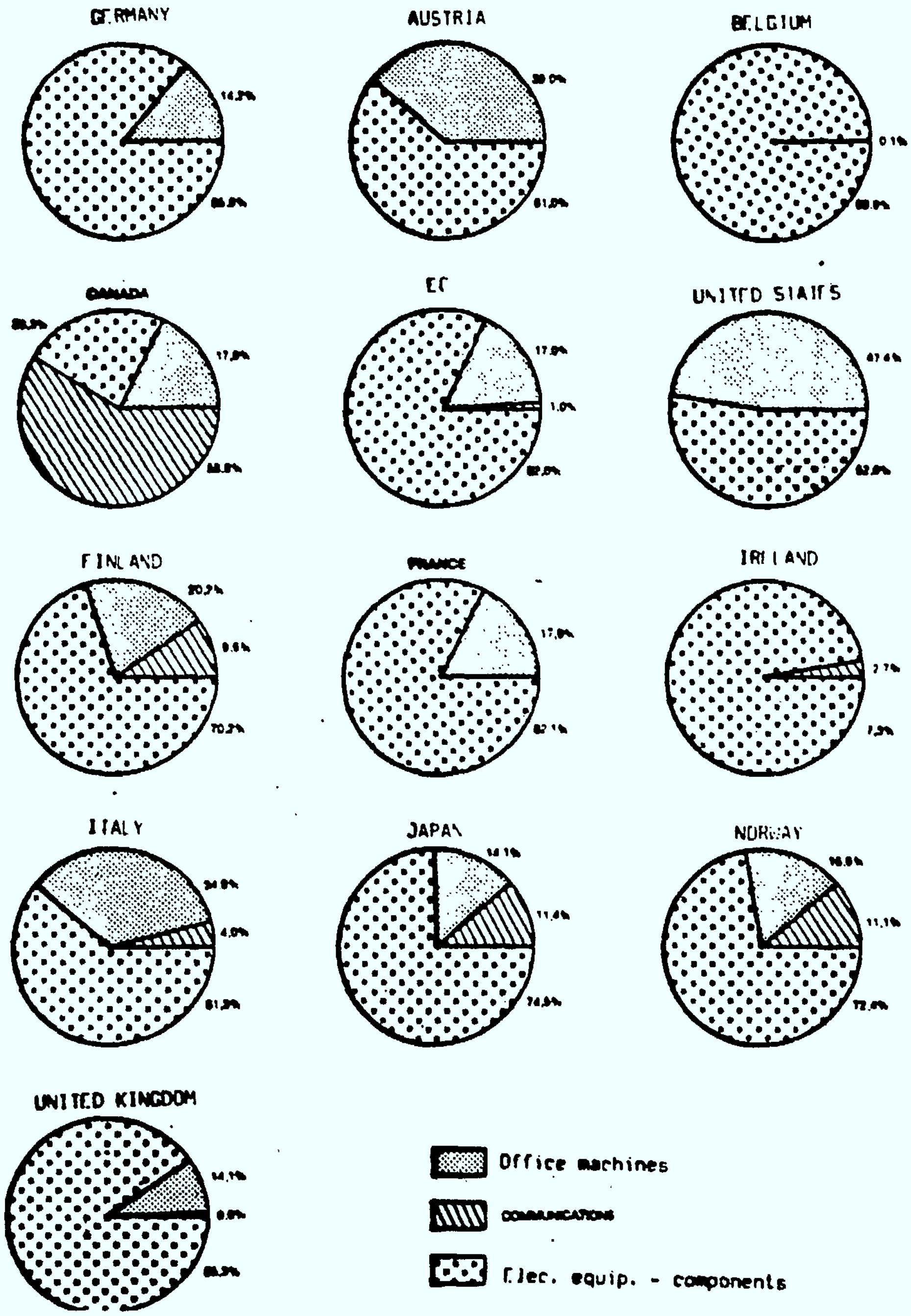
OFFICE MACHINES AND COMPUTERS
(R&D personnel)



Graph 21

DISTRIBUTION OF NATIONAL R&D EFFORTS BY AREAS (1981)

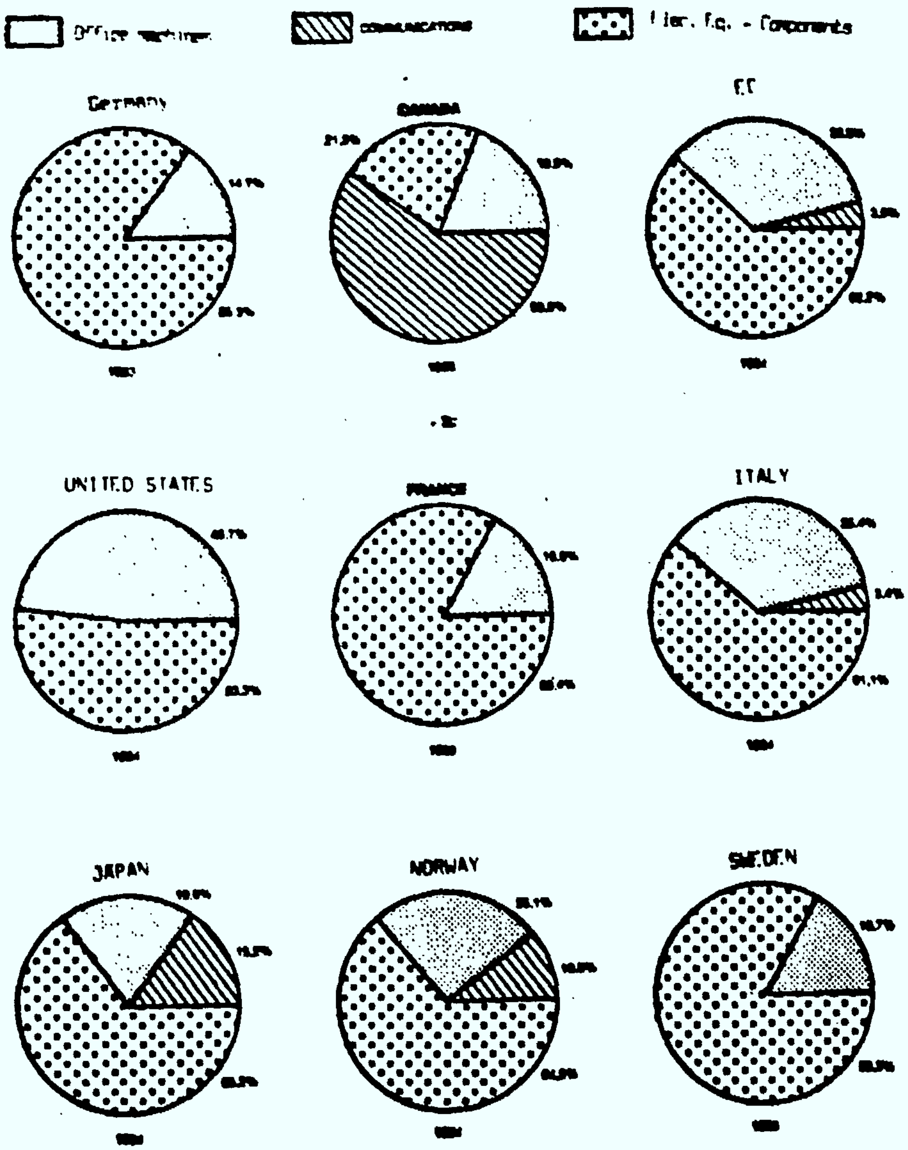
Current Prices



Graph 22

DISTRIBUTION OF NATIONAL R&D EFFORTS BY AREAS

(Current prices)



equipment". The EC allocates about one-third of its resources to the latter area, and countries which have significant efforts in this field include Austria (39 per cent), Italy (appr. 35 per cent), Norway (25.1 per cent) and Finland (20.2 per cent). Member countries such as Canada, Japan, Sweden, Germany, France, and Italy all devote less than 20 per cent to the area in question.

F. Sectoral Distribution of the R&D Efforts

255. The distribution of the national R&D efforts between firms, government, foreign and other sources of funding is shown on Graph 23.

256. The importance of the public sector appears to be enormous (41.4 per cent) in the United Kingdom, out of proportion (which casts a doubt on the accuracy of the data) with its share in other countries. It is only relatively high (above the 20 per cent rate) in a small number of countries: France (25.7 per cent), United States (23.5 per cent), Norway (23.9 per cent) and Ireland (23.0 per cent). It is somewhat lower in the EC as a whole (16.2 per cent), Italy (16.6 per cent), Denmark (10.9 per cent), Sweden (10.6 per cent) and Canada (7.4 per cent). In any case, these differences may seem surprising in view of the existence of major government R&D programmes discussed in this report, but it should be remembered that some of these programmes are essentially co-ordinative in their intent, most provide matching funds which are complemented by firms, and all relate to advanced research which is as a rule much less costly than the development costs which are covered by industry. It is in the context of this discussion that the lack of information on the distribution of efforts between basic research, applied research, and development is most daunting. If it were available, it would probably highlight the importance of government support for basic, long-term research as well as for certain types of "risky" applied research projects.

257. It is also worth noting that, in many countries, the share of the effort which is sponsored by foreign sources is by no means insignificant, and is even as high as 16.5 per cent in Canada and 13.1 per cent in Ireland, with the EEC at 6.6 per cent. These relatively high rates reflect the increasing internationalisation of the information technology sector.

258. Most striking, however, is the importance of the industrial effort. Other technologies which had been the object of special government support in the post- second world war era (such as nuclear energy and space), benefitted from a much higher share of public support. It is a special feature of R&D in information technologies that they draw the bulk of their support from industry -- a characteristic which is both a consequence of, and a factor in, the present intense international competition in this area.

259. Drawn from other sources, a picture of information technology R&D performed by the 100 largest data-processing firms in the world is presented in Annex II and summarised in Table 8. This table brings to light the share of total industrial revenues devoted to R&D by the firms in question. This share is generally high -- as high as 11.3 per cent in Germany -- especially if one takes into account the fact that this information was not available for all the firms included in the list, and that it consists of rough figures

Graph 23

SECTORAL DISTRIBUTION OF THE RESEARCH EFFORT

(Current Prices)

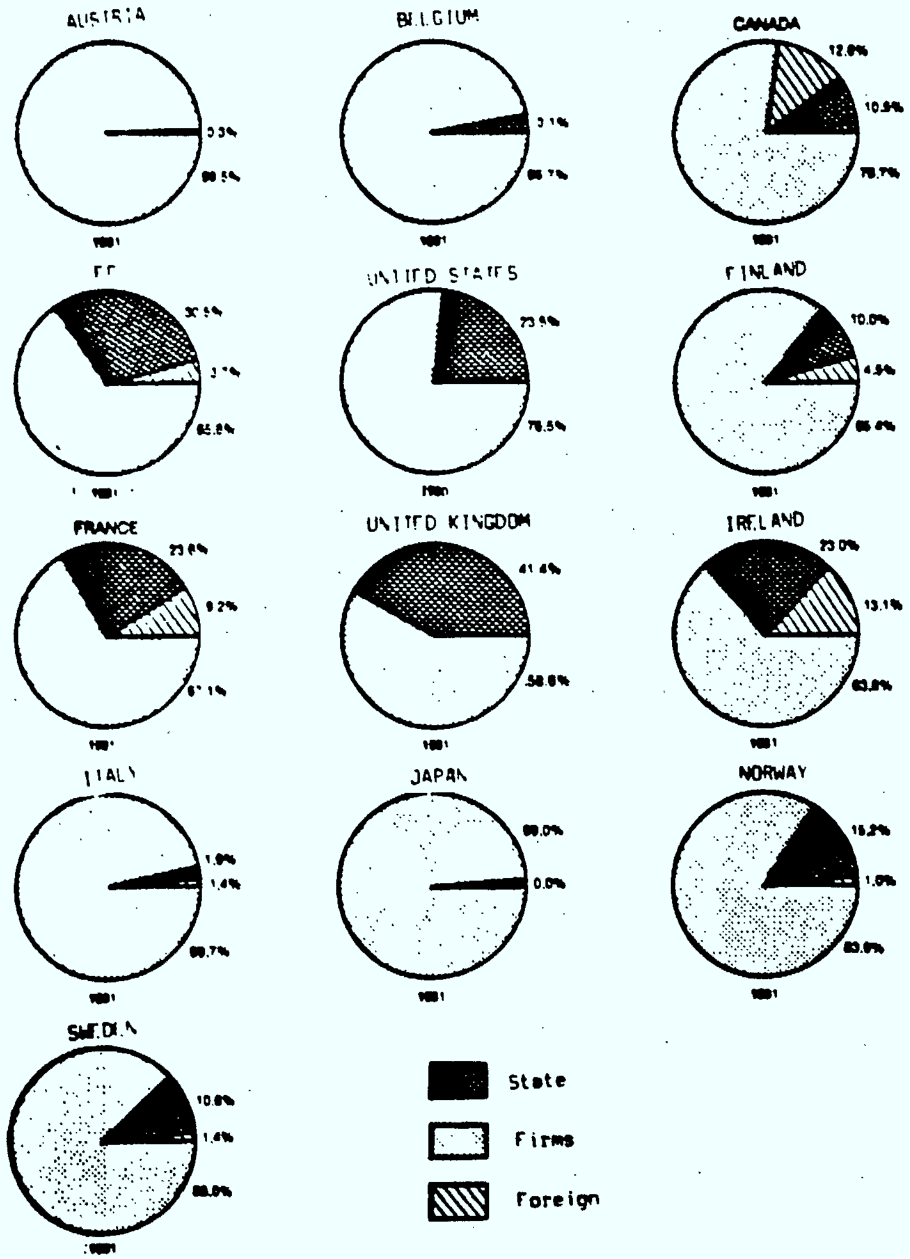


Table 8

THE 100 LEADING DATA-PROCESSING COMPANIES
(1986)

R&D Totals in millions of dollars

Country	Number of Firms	R&D Total	R&D as % of Total Revenue of Firms
United States	55(a)	28 478	7.1
Japan	13(b)	9 587	5.8
Total EEC	9(c)	5 323	7.5
Germany	2(d)	2 685	11.3
France	2(e)	287	9.6
Italy	1	262	5.3
Netherlands	1	1 708	7.6
United Kingdom	3(f)	382	2.3
Canada	1	474	10.8
Finland	1	118	5.0
Norway	1	31	9.0
Sweden	1	400	9.0
South Korea	1	na	na

(a) Data available for only 55 out of 64 firms;
(b) Data available for only 13 out of 15 firms;
(c) Data available for only 9 out of 16 firms;
(d) Data available for only 2 out of 4 firms;
(e) Data available for only 2 out of 3 firms;
(f) Data available for only 3 out of 7 firms.

Source: Data from Datamation, 15th June 1987, pp. 42-43.

which do not disaggregate the R&D efforts which were directly related to the data-processing activities of the firms, which are often very active in many other sectors. The table gives an imperfect indication of the high R&D intensity of the fields in question in industry -- but unfortunately is not sufficiently detailed to allow for international comparisons to be made.

260. On the whole, the above discussion of the distribution of the R&D effort among the various sectors underlines the apparent relative disproportion, in most countries (with the possible exceptions of France, the United Kingdom and the United States) between the public and the private research efforts in this area, showing the latter to be much larger, and intimating that it plays very different roles in the different aggregate national efforts.

G. Some Trends in Scientific Output

261. Scientific publications provide an indicator -- albeit an imperfect one, for many reasons -- of major trends and relative emphasis in research and research production. Some data are available in two subfields relevant to research related to "microelectronics and computers" on the one hand, and "electrical engineering and electronics" on the other -- as displayed in Table 9.

Table 9

PUBLICATIONS IN TWO MICROELECTRONICS RELEVANT SUBFIELDS

	Number of Publications				Percentages of Total			
	Computers & electronics		Electrical engineering		Computers & electronics		Electrical engineering	
	1975	1984	1975	1984	1975	1984	1975	1984
United States	703	643	2570	2752	61.06	57.64	41.1	40.32
Japan	21	46	750	899	1.82	4.15	11.99	13.17
Germany	109	55	383	274	9.43	4.94	6.13	4.01
France	13	23	185	226	1.17	2.08	2.96	3.31
United Kingdom	110	86	1009	756	9.58	7.72	16.13	11.07
Italy	9	17	132	155	0.77	1.52	2.11	2.27
Canada	56	57	319	329	4.83	5.08	5.1	4.82
Spain	0	4	9	38	0	0.36	0.15	0.56
Australia	17	15	84	112	1.48	1.32	1.35	1.64
Netherlands	13	14	72	91	1.09	1.25	1.15	1.33
Turkey	0	0	9	11	0	0	0.15	0.16
Sweden	3	7	45	79	0.26	0.66	0.72	1.16
Belgium	10	10	41	46	0.87	0.86	0.65	0.67
Switzerland	12	9	91	154	1.00	0.85	1.46	2.25
Austria	10	7	11	17	0.91	0.63	0.18	0.25
Yugoslavia	1	5	32	22	0.09	0.43	0.51	0.32
Denmark	6	3	19	22	0.52	0.3	0.3	0.32
Norway	3	0	14	23	0.26	0.04	0.22	0.33
Greece	3	5	13	49	0.22	0.46	0.21	0.72
Finland	4	5	5	16	0.39	0.43	0.08	0.24
Portugal	0	0	1	5	0	0	0.02	0.07
New Zealand	3	1	16	14	0.26	0.09	0.25	0.21
Ireland	0	1	10	6	0	0.09	0.16	0.09
Iceland	0	0	0	0	0	0	0	0

Source: OECD, The Research System in Transition, SPT(87)13 Part II, pp. 63-64

262. The pattern of changes in the two subfields shown here differs considerably among the six largest OECD countries. The United States, Germany and the United Kingdom lost output shares in the two subfields between 1975 and 1984, with Germany and the UK witnessing an actual decline in output in both subfields, and the US a slight gain only in electrical engineering and electronics. On the other hand, Japan, France and Italy gained in both during the same period of time. In Japan, gains involved more than doubling of publications in computers and a significant increase in the share of the two subfields, indicating a greater focussing of efforts in these areas. Similarly, in France, outputs and the shares of the subfields in national outputs rose in both cases. Italy also showed increases in outputs in both subfields, as well as larger shares of national outputs.

263. The comparison among OECD countries made here suggests, according to one interpretation, that some are considerably more successful than others in translating research policy into practice. In some countries, the research output correlates highly with stated national policies and priorities. In others, the correlation is quite low and often strongly negative.

264. Although the data and analyses are limited, they suggest that the countries which have best succeeded in reorienting their research priorities are France and Japan. They have increased substantially their research outputs in accordance with expressed national priorities. In contrast, other countries with the same priorities as France and Japan have been less successful.

265. It may be thought that this reflects the difficulty of achieving, within the scientific community and the research-funding bodies, the realignment of emphasis which would be needed to ensure that stated priorities are in fact implemented. However, one should not forget that the publication counts reflect to a large extent the output of academic research, and thus do not necessarily bear a direct relation to some of the national and international programmes discussed in this report. In this light, the data may indicate a state of disiquilibrium between the major research programmes actively co-ordinated and pursued in Member countries, which may have diverted resources from the more traditional and basic efforts pursued by the scientific community in a "normal" fashion, to launch long-term, basic research programmes in institutional and procedural environments which are less congenial to rapid publication of research results.

266. Needless to say, these interpretations must be made with a great deal of caution, in view of the uncertainty of international comparisons based on publication counts. Many other factors could explain the trends discussed above, such as the growing prevalence of new patterns of behaviour, less favourable to publication, on the part of scientists and their organisations which are increasingly affected by industrial secrecy and national security constraints.

267. Some evidence relating to United States research articles in engineering and technology, shows, for example, that American industrial researchers reduced the volume of their publications between 1973 and 1982,

from 5 130 to 4 356 articles, while academic researchers reduced theirs from 4 715 to 4 039 (1). This may reflect a new reluctance to disclose research results in potentially economically important areas, rather than an actual drop in the productivity of research.

268. In such cases, national research programmes may directly affect rates of publication when they succeed in making university researchers more acutely aware of the stakes of the projects they are involved in -- the more so when the projects in question are linked to defense programmes.

(1) National Science Board -- Science Indicators: the 1985 Report -- USGPO, Washington D.C., 1985, pp. 264 and 289.

Chapter V

THE DEVELOPMENT OF AN EXPLOITATION SYSTEM

269. Thus, the last decade has witnessed in Europe the creation of a significant number of IT programmes each trying in its way to meet the technological and competitive thrust presented by the USA and Japan. Yet, the purpose or objectives of these programmes seem to illustrate a dilemma; a dilemma that is, in part, generated by the complexity of the situation both in terms of the social transformation required for the diffusion and adoption of these new technologies and the shifting meaning of basic and applied research in a regime of rapid technological change.

270. In terms of the IT programmes launched so far, the dilemma can be summarised as follows. Those who have established programmes which have set mainly technological objectives are uneasily aware that these objectives depend upon the successful functioning of a number of research networks and that this in turn depends upon a host of socio-economic factors. Conversely, those programmes which were set up under the threat of competition and which had as their prime aim the re-organisation of the IT research system to make it a more effective policy instrument, are suffering from the difficulty of formulating technical objectives which are sufficiently articulated in relation to national industrial potential.

271. Awareness of the dilemma -- of the need to stimulate both social and technical innovation -- has intensified the search for models which show evidence of being able to bridge the gap between technological opportunity and market, or social, needs. Once again, the temptation to look at the successful has been irresistible, despite the obvious problems and difficulties that would be encountered in trying to transfer solutions from one national industrial culture to another. Here, the Japanese have provided a range of fresh experiences ranging from the role of MITI as a co-ordinator of advanced technological projects to studies of factory level practices such as 'quality circles'. Overall it appears that many have been concerned that the key to keeping in the competitive race for markets in information technology lies in encouraging 'pre-competitive' collaborative research. They have found this operating successfully in Japan but it remains an article of faith as to whether it can be copied elsewhere.

272. Many of the potential difficulties to be faced in collaborative projects were summarised in an earlier section. In this section, major specific issues which have proved to be of major importance in current programmes, are considered in more detail: from the broader socio-economic

question of setting the stage for adequate future applications of IT, to the stimulation of exploitation of research results, and the allocation of intellectual property rights (IPRs).

A. Setting the Stage for Applications

273. Government concerns relating to Research and Development have never been circumscribed to the design of programmes and the production of results. From the beginnings of modern science and technology policy, the exploitation of the results has been a pressing issue which has required new and imaginative forms of institutional and social adjustment.

274. This question of exploitation takes on new meaning, however, when (i) the impetus of technological advance is expected to affect the whole economy and society and can no longer be orchestrated from a central government standpoint; (ii) also when international competition presses on individual countries to adjust quickly and efficiently to the new requirements and ensure that they are well prepared for forthcoming challenges; (iii) finally, when governments are increasingly aware of the potential reward of stimulating demand for new IT applications rather than focussing on the development of a supply which may turn out not to match market requirements.

275. Countries must therefore take steps to accompany their R&D efforts and ensure rapid and extensive applications of results. What is at stake, in fact, is the development of an exploitation system which will set complex requirements for the labour force, industrial management and firms, social organisations and public institutions, as well as for the public at large. To this end, and in order to avoid delays and dislocations which could prove extremely costly, there is an obvious need to anticipate and remove possible bottlenecks which stand in the way of future developments, ranging from education to socio-economic rigidities, and including institutional sluggishness, if not inertia.

276. Some of the national programmes under consideration here include this type of concern.

The concerns about personnel

277. Educational aspects are prominent in many instances, reflecting a basic concern about the adequacy of the national labour force to respond to emerging requirements. In Japan, for example, this preoccupation has already been acted upon since 1969, when MITI started to administer proficiency tests every year to upgrade personnel in industry. In the next ten years, up to 1980, 500 000 people took the test and about 10 per cent qualified as automation processing engineers. In addition, various schemes encourage industrial staff to prepare for a Doctorate, and about half of those granted annually by the higher education system are attributed to this category of candidates. Other actions, such as the Sigma Project, are implemented to anticipate dangerous bottlenecks in the provision of manpower.

JAPAN

The Sigma Project

The Sigma Project started in October 1985 with $164 million worth of backing from industry and the Japanese government, as a result of warnings by MITI that Japan will be short of approximately 600 000 computer programmers by 1990. The five-year project's goal is to create an extensive set of software tools, in order to provide, by the end of the decade, a comprehensive support system for software developers; it follows a three-pronged attack which includes:

-- the creation of a database system with a software library containing programmes, modules and tools available to developers;

-- the provision of sub-systems for developers to handle control of the different versions of software and tools available, as well as demonstrations, including gateways to external national and international systems and data bases;

-- the creation of workstations, each of which will include documentation tools in Japanese language, networking capabilities, file, transfer and remote log-in as well as a virtual terminal. More specialised tools will also be available to answer specific business and professional requirements.

278. Many other countries have also, of course, become sensitive to the threat of shortages of specific categories of personnel required for the exploitation of information technologies. This preoccupies, for example, the Norwegian leaders, who raise the possibility that industry would move development departments abroad and, sooner or later, production plants, because of the lack of skilled personnel: a recent enquiry concluded that the most prominent bottleneck problem facing the country is the lack of skilled personnel, since the number of people educated in information technologies needed by the year 2000 was estimated to range from 17 600 to 34 500 compared with a total of 1 350 graduates in information technology available in Norway at present.

279. Special policies have been proposed to attempt to cope with this threat, including policies for the development of long-term research in the information and communications technology area, which is expected to have a significant impact on the number and quality of graduates in these areas. In Norway, in addition to proposing to increase the number of students studying abroad, it is suggested that universities expand their continuous education programmes (which is, in addition to training as such a good way to open the way for increased industry/university collaboration), and that government research institutes become more active in education.

280. Various national programmes already under way (for example in the Netherlands, or in Sweden) include a range of such measures designed to avoid quantitative and qualitative deficiencies of the pool of available personnel in information technology. There are, however, many uncertainties which make it difficult to reach a reliable forecast of the future needs in this area, or to assess the effectiveness of measures under consideration or already being implemented.

The adaptation of organisations

281. Most experts would agree that one of the most profound challenges facing the industrial societies today as a result of the introduction of new information and communications technologies is the need for organisational adaptation and change, to open the way, in particular, for new modes of decision-making and distribution of responsibilities within service-oriented activities as well as, more generally, within administrations.

282. Little is known, however, about the specific features such transformations could take and the theme, in one way or th other, has become a research subject falling within the scope of special R&D programmes in information technology. Thus, one of the goals set for Nordic co-operation in this area is to promote the efficiency and competitiveness of industry, trade and administration. In Norway, one of the R&D priority areas includes organisational and management problems. Technology assessment, which is one of the sub-programmes of the Danish national technology development plan (and which is also an ongoing responsibility of the Office of Technology Assessment in the United States) also could provide, among other functions, a useful instrument to gather better intelligence on the changes at work.

283. In the meantime, demonstration projects are one of the approaches most consistently promoted in order to facilitate the diffusion of information technology in organisations (for example in Denmark, in Norway, and in the United Kingdom).

Public understanding and social awareness

284. The successful exploitation of information technologies and the diffusion of their applications does not only depend on the availability of trained researchers and engineers, and on the adaptability of organisations. Public understanding of the implications of these technologies, and overall public awareness of what they entail, constitute a necessary condition of their continued development in a balanced social environment.

285. This raises, for example, the question (addressed by Nordic co-operation in this area) of the adequate preparation of individuals so that they are offered better opportunities to exploit new technological advances, and to ensure that they are able to cope with the new problems which may accompany the emergence of these technologies.

286. In Japan, the Information Technology Promotion Agency (IPA) was established in 1970 to ensure that anyone and all should be able to use computers and enjoy the benefits of data processing on a stable long-term basis, and at low cost. In several other Member countries (France, the Netherlands, Sweden, the United Kingdom among others) programmes have been launched to promote public awareness. These programmes usually focus on the

school-age population, and may include special projects geared to the needs of specific industries and professions. In addition, efforts have been made to open access of the general public to information technology.

B. Stimulating the Exploitation of Results

287. To achieve the benefits from collaboration, firms must be able to participate witout fear that they will limit their ability to compete fiercely at the innovation stage. The principal incentive to collaborate is that a firm acquires a greater volume and variety of strategic knowledge more quickly, at a fraction of the resource cost entailed by the programme as a whole. Even so, the firm must expect to obtain a satisfactory rate of return on its investment. This will require it to have an appropriate degree of influence over the context and conduct of the programme, and for adequate provision to the made for the licensing of results and the valuation of intellectual property. To harmonise the views of different firms and to administer the collaboration also absorbs resources and these costs must be added to those arising from the research itself.

288. Provided that obstacles to collaboration can be overcome, the prospects for successful exploitation are likely to be greatly enhanced, and for two reasons. First, the results of the research are disseminated to a wide variety of firms so raising the chances of an effective match between knowledge and ability to exploit. Secondly, the experiences gained during research collaboration are likely to suggest practical joint ventures in exploitation, in which firms pool complementary, marketing production and other skills and assets, so enhancing the national ability to offer internationally competitive products or systems. In both regards the "club" arrangements such as exist within Alvey may be important, since they achieve what optimality requires, namely widespread dissemination of a public good to all who place a positive value on the knowledge generated. Clubs should be viewed as an essential component of any programme to develop enabling technology with public money.

UNITED KINGDOM

ALVEY Clubs

The Alvey Clubs are seen as a key element of the Alvey Programme aimed at speeding up technology transfer in the various research communities. The decision to vest Intellectual Property Rights resulting from Alvey projects with the industrial partners, whilst being a spur to commercial exploitation of these results, could have constrained technology transfer to the wider community. To overcome this potential difficulty the Alvey Letter of Grant requires project participants to make basic progress disclosures to other members of the Alvey Category Club, and also to grant licences for exploitation on "normal commercial terms".

> As the programme has developed the Club structure has taken shape and a wide range of meetings and workshops has taken place. In all areas it has been found desirable for the main activities to be carried out at a more specialised level than the four basic technologies. There are now many sub-clubs and special interest groups. Reports on the organisation and activities of these clubs are given below, together with a contact point for each. Some, as in the VLSI process clubs, have grown out of "consortium" activity started before the Alvey Programme. Others were formed specially and are playing a useful part in bringing the appropriate community together. In all cases the discussions cover the whole range of topics rather than being confined strictly to Alvey matters. This makes it easier to view Alvey projects and their progress in the context of other research in companies and universities both in the UK and as parts of ESPRIT, RACE, Eureka, etc.
>
> Membership of clubs is basically confined to those companies, research establishments and academic teams who have grants under the Alvey Programme, although, with the agreement of the club members the Directorate may invite others who will make a significant contribution to club activities. In some of the Special Interest Groups this is extended to include all interested parties, but in that case, such members are now automatically entitled to the IPR benefits of club membership.

289. In the specific international context of competition in IT, collaboration enables firms to stay closer to the best practice technology frontiers than would otherwise be possible. Indeed, collaboration is perhaps the only effective way in which firms which are small and medium size by international standards, can cope with the systemic complexity of IT, the rapid rate of progress required for competitive success, and the rising real costs of exploiting the time-cost trade-off in research. But access to international programmes is extremely difficult for many of these firms.

290. In any case, it is generally recognised in all Member countries that different policies must be developed to address the different adaptation problems facing different types of industries, such as large science-based firms, large firms in traditional sectors, small high-technology firms, and small traditional firms. In particular, a great deal of importance is generally attached to extending assistance to small and medium-size firms whose contributions are considered to be essential for employment and innovation. In the Danish Technology Development Programme, for example, two distinct funds have been set up to product, process and software development, respectively oriented towards larger and smaller firms.

291. In Japan, although there are some public programmes (in particular those developed on a regional basis) for assistance to smaller firms, much of the impetus and support for their adaptation comes from large corporations with which they are linked by sub-contracts. In Europe, governments have been very much involved and usually set up special policies in this respect. These may include at the very least the provision of information on the new technologies, often organised on a regional basis. Measures are also often

implemented to ensure the availability of venture capital and resources for development (in the Norwegian Microprocessor Programme, small and medium-sized firms received 90 per cent of the total support to industry). Efforts are made, as in Sweden, to give representatives of small and medium-size firms, as potential users, an opportunity to influence technological developments through procurement procedures and participation in experiments. In Germany, comprehensive programmes have been set up.

GERMANY

The Development of Exploitation Systems for Small and Medium-size Firms

The three following programmes have been developed by BMFT and BMW to strengthen the technological level of small and medium-size firms and to improve their ability to exploit the results of research programmes:

-- allocation of bonuses for R&D personnel (BMW). These are yearly bonuses which may reach 55 per cent of the basic salary up to a limit of DM 120 000 per year and per firm. It mainly applies to firms with less than 500 employees and an annual turnover below DM 50 million. About 15 000 firms (more than 60 per cent of which in the information technology area) have benefited from this aid between 1979 and 1985;

-- high technology based industries programme (BMFT) which provides assistance for the creation of firms in new technology areas. One of its sub-programmes focuses on microelectronics. In 1985 the resources allocated to the programme amounted to DM 65 million;

-- support to R&D contracting (BMFT) which intends to facilitate the access of small and medium-size firms to research resources which they could not organise and manage directly. This programme amounted to DM 40 million in 1985.

292. The pattern is much less clear in the United States, where federal actions are complemented by the policies of individual states. In many cases, these state policies explicitly claim to draw some of their inspiration from European models. It is still extremely difficult, however, to assess their actual impacts.

UNITED STATES

Federal and State Programmes for Small and Medium-size Firms

On the federal government side, there are a number of general programmes of aid to small and medium-size industries through loans and research grants systems, as well as regulatory measures such as the PASS and SBIR programmes: the former attributes 20 per cent of public procurements to this type of firm -- amounting to a total of $32 billion in 1986; the latter commits 1.25 per cent of the federal agencies' extra-mural R&D support to small and medium-size firms -- for a total of $1 billion in 1986.

There has undeniably occurred a development of individual states interventions since the end of the last decade. According to one report, 44 states had developed an economic policy by 1986. One or more local agencies for economic development and support of industry had been created by 37 of them. Venture capital had become available from 20 different state sources. Industrial research parks had been created in 20 states. Experimental programmes for the stimulation of innovation and the promotion of technology transfers had been created by 22 states. A number of funding schemes had been set up (see: Ministère de la Recherche et de la Technologie, CPE Bulletin No. 37, Paris). More specifically in connection with information technologies, a number of state programmes have been launched to promote diffusion and applications in various branches.

293. Collaborative research, however, is not a method for picking winners but it is a framework for ensuring that winning products and processes are more likely to emerge through market driven processes. The concentration of collaborative research programmes on developing the enabling technologies is in some cases being superseded by a determination to 'pull-through' results into marketable products. For example, in the UK, the Bide Committee which considered what policy and programme should follow Alvey, concentrated its proposals around a strong applications core, intended to provide new products and systems to the benefit of users and suppliers in the UK. These projects would use existing UK technology, including that developed by Alvey, and also any other technology regardless of origin. Any additional research would be funded. Indeed the research effort would be focussed on perceived future market opportunities. Some longer term work was recommended, but even this was to be "based on an analysis of market trends, user problems, and technical advances of potential significance to the improvement or modification of current products or to the development of new products". ... "The research projects will .... above all else emphasise, and be reactive to, the needs of the market."

294. This preoccupation with market orientation is shared by all Member countries, since technological goals which are formulated as a result of a number of strategic considerations will sooner or later have to submit to the sanction of commercial exploitation. This is, for example, a source of

considerable debate in the United States, where it is not clear to what extent the programmes which are sponsored out of military considerations will actually lead to commercially viable results. The Office of Technology Assessment points out that, while spin-offs from this enormous concentration of research effort can be considerable, there are also costs in terms of "security classifications which tend to slow advancements in technology; rigid technical specifications for military procurements which have limited utility for commercial applications; and the 'consumption' of limited, valuable scientific and engineering resources for military purposes, which may inhibit commercial developments".

295. These questions have also been raised recently in connection with the Strategic Defense Initiative (SDI).

UNITED STATES

The Strategic Defense Initiative

The Strategic Defense Initiative (popularly known as Star Wars) overshadows other IT-related programmes in budgetary terms. Star Wars was announced as a five-year, $26 billion programme of research to develop a space-based system to defend the United States against ICBMs. An amount of $1.62 billion ($1.40 billion -- DoD; $0.2 billion -- DOE) was committed to SDI in fiscal 1985; $3.06 billion in 1986; and $3.53 billion in 1987. The DoD also sought to raise its expenditure to $6.2 billion in 1988; $7.3 billion in 1989; and $8.6 billion in 1990.

The SDI has five broad programmes:

-- Surveillance;
-- Directed Energy Weapons;
-- Kinetic Energy Weapons;
-- Systems Concepts/Battle Management;
-- Survivability, Lethality and Key Technologies

Although the Star Wars Scheme involves an attempt to construct the biggest and most complicated real-time computer and communications system ever built, SDI expenditure is not directly comparable with other IT programme expenditures. The surveillance management aspect will be heavily dependent on very advanced computing, but the battle management programme is the most concerned with IT. Its goals involve new systems analysis techniques, artificial intelligence, novel architectures and techniques for fault-tolerant software and hardware, simulation techniques, communications, network management and real-time resource allocation.

The Council on Economic Priorities published a critique of the SDI in 1985, and pointed out that in contrast with the Apollo programme in the 1960s, which included funding to raise the number of relevantly educates scientists and engineers available through supplying extra funds to universities, Star Wars involves no measures to reduce its (adverse) impact on the pool of available scientific labour. SDI was to use about 4 800 scientists, engineers and technicians in 1984, rising to 18 400 by 1987. This would include the absorption of 4 per cent of all newly trained engineers in that period. (The DoD as a whole would use one-third of all new engineers during that time). The impact on existing American high-technology industry could, however, be disproportional because the skills needed would primarily be electronic and aeronautical engineering.

Two particular characteristics of SDI tend to make it less likely than many other forms of government-sponsored R&D to bring commercial benefits. First, as CEP point out, 'Private uses of high-energy lasers, particle beams, large optics, and infra-red sensors are not immediately obvious'. But, as already argued, it is more likely that the electronics content of SDI will have spill-over effects. Second, 'The cloud of secrecy surrounding SDI ... tends to reduce the possibility of commercial spinoffs ... Given the sensitivity of strategic defense efforts, the security surrounding SDI could be tighter than most projects'.

296. This is, of course, a perennial debate which raged already in the 1960s in connection with the defence and space programmes. The "spin-off" question has no definite answer. Much depends, certainly, on the time-horizon of the observer. It is obvious in many instances that, on a relatively short-term basis, many of the highly sophisticated requirements of defence seem to have no direct relation with identifiable commercial prospects. In a much longer-term perspective, however, spin-offs from such advanced research may prove essential, as they have already done in many cases in the past. This is all the more significant in view of the fact that, at times of budgetary constraints and fluctuations in public research-funding policies, defence-related support has often provided an essential stability and continuity for advanced research. This was the case, for example, with Artificial Intelligence towards the end of the 1970s, and research was then kept afloat by DARPA at a time of general disgruntlement with the field and worldwide cutbacks of its funding.

297. It had long been assumed that military procurements and R&D programmes have at least a positive indirect impact on the overall technological capability of contracting firms. Recent work in the United States, however, challenges at least part of these assumptions and would lead to the conclusion that defence-related programmes may divert resources from civilian-oriented industrial efforts. Procurement procedures (competitive and non-competitive) would in fact play a key role in the determination of impacts. According to F. Lichtenberg:

-- Competitive R&D procurements have a less than proportional positive impact on industrial R&D;

-- Non-competitive R&D procurements have a strong negative impact;

-- Competitive non-R&D procurements have the strongest positive impact on industrial R&D;

-- non-competitive, non-R&D, procurements have a negative impact.

298. Overall, in the case of the United States, the impact would be negative since the effects of non-competitive procurements are reported to outweigh those of competitive procurements.

299. Such conclusions imply that procurement mechanisms and procedures play a much greater role in the transfer of military research results to the civilian sector than had been recognised. This is all the more important at a time when international competition requires that countries attempt to take advantage as quickly and efficiently as possible of available technological capabilities. And measures have been proposed to increase the commercial benefits from defence programmes. In the United Kingdom, emphasis has been set on strengthening the competition in defence procurement to put more pressure onto companies. The Ministry of Defence has also introduced "ferrets", whose job is to identify technologies developed within government defence research laboratories and establishments, and transfer them to commercial firms.

300. Going back to the more general question of the market orientation of IT R&D programmes, another important feature emphasised by the Bide Report in the United Kingdom was the early involvement of end users of IT products, matching the capabilities of technology with the requirements of end users: "... users of IT can ... make general statements about their requirements, and may welcome the opportunity to influence research programmes designed to meet their future needs..." This may be an essential component of any IT research strategy, from a number of prespectives: market-orientation as well as, for example, social appropriateness of new technologies, social receptivity, etc.

301. The problems involved in technology transfer are widely recognised, but there is no agreement on measures to overcome obstacles. There have been suggestions that the R&D programmes should include research directed at facets of exploitation where the country is perceived to be weak, and explore methods of improving the take-up of new ideas, the transfer of technology between suppliers and users, and the identification of key market sectors for IT. "A study of why particular organisations are more successful than others at absorbing IT into their culture, structure and operation would be particularly worthwhile" (Bide Report). Various measures have been recommended, such as use of 'teaching company' schemes, demonstration centres, user clubs, published case histories of IT exploitation, and further education in IT for all levels of management.

302. Many countries are considered to have problems in transferring results of research (from universities and government research units) to industry. The ultimate purposes of the programmes this report is concerned with, are to produce exploitable research which will improve the international competitive performance of the industry. For this exploitation to take place, it is essential that the technology transfer mechanisms function adequately. When a single firm undertakes research, the process by which results are applied to products or processes generally follows well defined procedures determined by

the organisational structure and practices of the firm. When two or more firms are involved, this process inevitably becomes more complex and even where satisfactory IPR arrangements are established, effecting the transfer of knowledge across the firm-firm or firm-university boundary is likely to encounter problems. This is particularly so where the research is pre-competitive, so that the collaboration is terminated at the end of the research phase and exploitation is carried out competitively.

303. Not all countries, however, currently face this kind of difficulty. For example, if a similar problem exists in Japan, it is of less significance given the different context. First, the universities account for a smaller proportion of the national research effort, and are constitutionally prevented from working on contracted work for industry. Industry does not recognise the same division of research and development responsibilities as US and European firms. Longer-term research projects are generally easier to support commercially in Japan.

JAPAN

<u>NEC and "Core Technologies"</u>

In 1985 NEC completed a 2-year exercise which resulted in a list of about 30 core-technologies around which the company's R&D effort was to be based for the next decade. Like other major Japanese firms, NEC conducts its own 'basic' research with 8 laboratories and 1 300 researchers, 70 per cent of which is 'curiosity led', though within company guidelines.

304. A particularly interesting aspect of many Japanese firms is their method of technology transfer. European firms now avoid technology-driven research policies on the grounds that the engineers in charge would lose sight of market needs. Japanese firms overcome this in various ways, all of which try to give researchers experience of the market.

JAPAN

<u>Sony: Marketing Engineers</u>

Sony does not have a marketing department, but all engineers begin their employment by working for several months in retail outlets, giving them a first-hand experience of market needs. Honda does not have a marketing department either; most marketing functions are left to the company's research staff.

305. Yet another aspect of Japanese R&D is the acceptance of a failure rate. The managing director of Honda is quoted as accepting a 40 per cent failure rate of projects, as a by-product of its emphasis on innovation: 20 per cent are cut short because of failure to achieve technical objectives and 20 per cent produce results which are not immediately used.

306. Recent years have, however, witnessed the growth of feeling that Japan must increase its funding of basic research, for the 'psychological' reason that the country should be seen to be contributing to the growth of knowledge and also the practical reason that its past dependence on 'imported' research results cannot continue indefinitely. Other countries will become more secretive about results and there may not be sufficient results generated to sustain past growth rates. As a result of this movement, Japanese universities are receiving increased funding for basic research. It remains to be seen how they will tackle the technology transfer problem in the future.

C. <u>The Allocation of Intellectual Property Rights</u>

307. The phenomenon of large collaborative programmes has generated a whole set of problems concerning the legal basis of projects, including the relationships between participants, and with sponsoring or funding agency.

308. Most programmes differentiate between 'foreground' and 'background' IPRs. 'Foreground' information includes all technical information, inventories, designs and IPR generated in the course of the work of a project. 'Background' includes any inventories, designs, computer software, reports, drawings, etc. made available by a contributor for use in a project but belonging to a participant. Complications ensue with the recognition that these two categories must be treated differently.

UNITED KINGDOM

<u>Alvey Programme: Foreground and Background Information</u>

In the Alvey Programme industrial participants may have a licence to use the background of other contributors to the project to the extent necessary to exploit their own results, and licence to use the results (foreground) of other contributors to the extent necessary to exploit the contributor's own results. Such licensing must be on fair and reasonable commercial terms. However, the problems of asymmetry (where some participants may not have the right to licence other participants' foreground) has resulted in many projects agreeing to simple rights to licence all other participants foreground.

309. A problem common to most programmes has been the delays caused by negotiations and disagreements over collaboration agreements or their equivalents. It is necessary to define in a legally binding document the respective rights and obligations of all parties in carrying out a project and using its results. While IPRs and exploitation are inevitably the key features, a series of other aspects are necessary. Typically clauses will cover confidentiality, publication, reporting and liaison procedures, monitoring arrangements, and provision for arbitration, termination, or change (see Annex).

310. We will concentrate here on the IPR issue, but it should be remembered that there remain a multitude of practical problems which have been encountered. For example, whether sponsoring organisations impose standard agreements upon participants, or whether only a minimum acceptability criterion is imposed and participants left to negotiate the remainder between themselves? Are projects to be managed by prime contractors? On what basis are academics to be funded (in particular, how are overheads to be treated)?

311. In the Alvey Programme, the IPR conditions are embodied in collaboration agreements between partners in projects, and these differ between projects (see Annex). In ESPRIT, the contract with the Commission sets out a standard set of rules, though in practice many consortia have found it necessary to reach separate collaboration agreements covering liability and exploitation, implying that the standard contract terms are insufficient (see Annex). Table 10 gives a brief comparison of Alvey and ESPRIT treatment of important aspects of IPRs. Table 11 shows some of the basic characteristics of MCC and ICOT IPRs. To exemplify the complexity of this issue Table 12 gives the next level of detail involved in ESPRIT agreements, which are often considered to be relatively simple in comparison to others.

312. A wide variety of IPR terms has evolved from the respective collaboration programmes. The MCC owns all rights to results from its projects, and these are obtainable as of right by project participants on a royalty-free basis for an amount up to three times a participant's contribution to funding the project. Licences are restricted to participants for the first three years after completion of a project, and thereafter priority is given to other MCC shareholders.

313. In the case of ICOT, the Japanese government holds all the results and will sell licences to Japanese and foreign firms. In the Alvey Programme, industry owns all the rights and is responsible for their exploitation. Universities may receive a royalty or in return receive a reasonable sum for their contribution of IPR.

314. The question of royalties is another added complication. Different royalties may be expected to be chargeable on the various types of projected results. For example in software, projects can produce at least four different categories of result: software that will be 'sold' (or sub-licenced); software embodied in products, such as telecommunications systems; software tools, used in production of other software or products for sale; and software theory and architecture projects concerned with advanced software. Each of these entails the requirement for different licencing agreements, etc.

Table 10

ALVEY/ESPRIT IPR COMPARISON

ALVEY		ESPRIT
Results vested in non-academic partners in return for royalties	Academics	No separate status for academics
Foreground available to partners (it necessary exploit their results) on 'fair and reasonable' terms	Foreground to partners for exploitation	Foreground available to partners on royalty-free basis
Club members entitled to 'request' licence to use foreground on commercial terms if necessary to exploit own results	Foreground to other participants for exploitation	All participants entitled to license foreground unless conflict with major business interest
Licence to partners if necessary to exploit own results. Club members as above	Background for exploitation	Licence to partners only unless major business interest
Results offered first to partners, then club members, then any participant	Failure to exploit	Results may be offered to any community undertaking unless MBI

Table 11

EXAMPLES OF IPR RULES IN THE UNITED STATES AND JAPAN

USA -- MICROELECTRONICS COMPUTER CORPORATION

1. All participants in a programme pay equal share (except higher for latecomers)

2. Results transferred to participants by licence from MCC

3. Participants receive royalty-free licence for amount -- 3 x contribution

4. Cash royalties divided:

   3% to MCC
   5% to programme researchers
   28% to participants as credit on MCC programme membership
   64% to participants in equal shares

5. Licence restricted to participants for first three years then priority to other MCC shareholders

JAPAN -- ICOT

1. Government owns all results. Will licence to Japanese and foreign firms

2. At start companies deposit sealed envelope with relevant background to be opened in case of subsequent dispute

Table 12

SIMPLIFIED TABULAR REPRESENTATION OF PROPERTY RIGHTS IN ESPRIT

FOREGROUND			
	Communication of Information	Licences to be granted	For the Exploitation
same or complementary contract	royalty-free where and to the extent needed or useful for contract	royalty-free where and to the extent necessary for the work in the contract	unrestricted royalty-free licence and user rights (incl. have-made) (but not for sublicence unless agreed by owner)
other (ESPRIT) contractors	option for access under reasonable conditions to the extent necessary for work under contract	against reasonable conditions where and to the extent needed for the execution of the contract	against reasonable conditions licences and user rights for R&D and exploitation (not to be withheld unreasonably)
eligible			if not exploited and no major business interest withstands, and if products not available: licences to community applicants with legitimate interest, possibly plus additional information under conditions
BACKGROUND			
same or complementary contract	appropriate non-discriminatory conditions if necessary for work in the contract if free (requires agreement of confidentiality)	where and to extent necessary for work under the contract, on appropriate non-discriminatory conditions if free to do so	at appropriate non-discriminatory conditions, if free, unless major business interests oppose, and not if products available for any related background
other contractors		appropriate non-discriminatory conditions if and to the extent needed, if free, unless major business interests	by implication if eligible undertakings exploit foreground of other contractors that do not exploit themselves or do not have it exploited, unless major business interests or product available, if free
OTHER ELIGIBLE	CEE applicants UNDERTAKINGS (not participating) FOR FOREGROUND		
	if R&D work or their exploitation cannot be reasonably executed -- against compensation, not to be withheld unreasonably (reasonable if adequate exploitation is in hand or major business interest opposes)		

315. Other modifications of rights in projects may be encountered where some participants are academics (with differing or non-existent rights to royalties), where software projects are considered (and royalties may be on different percentage rates, and on a base which may be very difficult to define).

316. A major failure of governments and other sponsors has been in not recognising the long-term problems arising from the diversity of IPR rules in the various collaborative programmes. Consider, for example, that a field of research results may be covered by projects within a given national R&D programme as well as by ESPRIT projects (and possibly other European or non-European -- e.g. SDI -- programmes), each with their own standards IPR frameworks, and also with individual project modifications, amongst the (different) project participants. Each of these participants may have brought their own background to projects, and each participant may be involved on a different basis, with different exploitation rights. Types of results (e.g. software, hardware, tools) will require different treatment. In Alvey, members of area clubs have rights to results from other club projects, and also, it is assumed, the participants in Demonstration projects have rights to the use of results from enabling technology areas. Imagine then, that after a time, all these participants enter into new collaborations with different partners, in successor programmes to Alvey and ESPRIT -- not to mention other bilateral arrangements between firms -- presumably intending to use their licences to previous project results. The resulting network of IPRs and licences will probably be unmanageable unless general simplifications are imposed on programmes from their inception.

D. The Nature of New Research Networks

317. Previous Chapters have already given some brief details of five of the most significant collaborative research and/or development programmes in IT: the UK's Alvey Programme; the European Community's ESPRIT Programme; Japan's ICOT; the US MCC; and the IT Component of the wider European EUREKA Programme.

National networks

318. All national programmes for the promotion of R&D in information technologies involve a number of public and private actors. The allocation of financial resources (usually to be matched by industrial contributions to varying extent) may be less important, in this respect, than the institutional and procedural arrangements which bring together participants drawn from various organisations and sectors to advise and monitor the implementation of the programmes in question.

319. The German programme "Informationstechnologie" intends to cover, since 1984, all BMFT policies relating to data processing, communications, electronic components, applications of microelectronics and industrial automation. This programme amounted to an overall budget of DM 583 million in 1984. It is characterised by the heterogeneity of the various forms of government intervention (direct and indirect support, specific indirect support) and of the industrial levels of participation, ranging from 0 to 60 per cent of the amount of a project. The BMFT programme is in particular

complemented by projects under the Federal Post which supports a number of research efforts in the telecommunications area, with a total budget of DM 80 million in 1984.

320. In Japan the Institute for New Generation Computer Technology constitutes the national IT programme. Its objectives are to promote the development of 5th generation (non-von Neumann) computing technologies and technologies of artificial intelligence. The programme is 100 per cent government funded and the work is carried out in a central research institute set up for that purpose. The programme which was launched in October 1981 draws mainly on staff seconded from industry and will run for 10 years. In 1986 the annual budget was Y 5 500 million and the project employed approximately 50 staff plus an estimated 300 ICOT researchers who remained in industry. The programme has evolved in 3 stages: 1981-83 basic technology; 1985-88 sub-system development, and, finally 1989-91, 5G computer working prototype construction. Small firms are not included in the programme. The technologies being developed include parallel processing architectures, and artificial intelligence technologies.

321. The United Kingdom's national programme in Information Technology -- the Alvey Programme -- was started in 1983, its objectives are the promotion of the UK IT industry by encouraging the development of fifth generation computer enabling technologies. Alvey is a distributed programme 50 per cent funded by Government, and has a total budget of £350 million to be spent over a five-year period. The research is conducted by company and university personnel from small and medium sized as well as large firms. The main research covered in the programme includes VLSI, Man-Machine Interface, Software Engineering, and Intelligent Knowledge-Based Systems.

322. Providing a framework for the Programme has been the Alvey Directorate, a body responsible for the detailed formulation of the strategy laid out in the Alvey Report, for project selection and subsequent monitoring and administration. The Directorate itself has been an unusual creation, consisting largely of industrial secondees, together with civil servants from the sponsoring departments. It has been organised according to the technological areas covered, each area having a considerable degree of autonomy. The Directorate has been supported by a network of advisory committees drawn from the IT community. The administration of the Programme has been strongly influenced by the involvement of the three sponsoring government departments, DTI, MoD, and DES through SERC.

323. The Microelectronics and Computer Technology Corporation (MCC) is a prime example of the USA's developing network of IT research programmes. A particularly important feature of the existence of MCC, and other collaborative research ventures in the US, is that they apparently conflict with traditional anti-trust regulations governing US domestic industry. MCC had to delay its start-up to wait for Justice Department approval. The MCC, and other programmes, were a reaction to Japan's Fifth Generation Computing Programme. Changes in the US anti-trust regulations are a recognition that even the US can no longer afford to subordinate external competitiveness to the requirements of internal competitiveness at least in the IT sector. Research networks are an acceptable way of allowing this change to take place.

324. The same potential problem was apparent when the Alvey Programme began. Not only domestic monopoly regulations had to be complied with, but also EC regulations. This uncertain area is even now being clarified. The European Commission is drawing up regulations exempting know-how agreements between companies from Article 85 of the Treaty of Rome. This follows patent regulating agreements adopted three years previously, which allowed individual patent holders and licencers to make agreements enforceable under EC law, not to compete in each others territories. Individual licences were also allowed to make similar market sharing deals with each other. Normally the Commission opposes such agreements, but in this case it wishes to encourage the free movement of technology between member states.

325. The most significant feature of national collaborative programmes is their pervasiveness. Tables 13 and 14 show for the US and Japan respectively, the membership by companies of the various national collaborative research schemes in IT. The complexity of the emerging national networks is clear and a similar type of network is beginning to emerge on the international scene with initiatives such as ESPRIT and EUREKA.

326. Finally, it must be underlined that networking often includes a technological element. One of the most famous networking programmes in information technology, in this respect, took place in the mid-1980s in the United States with the creation of "ARPANET".

International networks

327. The continued development of international networks in basic science has always been one of the key factors for the effectiveness of the research community. Recent efforts have attempted to strengthen this flow of ideas and results, and extend it to the technological area. These efforts, however, are essentially regional ones which develop within the European framework. On the other hand, competitive and strategic considerations have recently affected international networks with a view to better control some technology transfers in key areas.

328. The international picture in this area is therefore somewhat contradictory. In the past, for example, the United States has often, since the Second World War, sought to extend its technological efforts internationally, through the participation of other countries. The history of nulear, space and military R&D has thus been marked with a series of such initiatives.

329. The latest to date has been in connection with the SDI initiative, where other countries have been invited to participate either through national commitments or through the involvement of individual firms. The governments of France, Canada, the Netherlands, Denmark and Norway all decided not to participate as such -- whilst not forbidding private sector collaborations -- and the governments of Great Britain, Israel, Japan, Italy and West Germany signed formal agreements. By the end of 1986 about $85 million in SDI contracts had been let to allied industry: $34 million in Great Britain; $46 million in West Germany; $2 million in Israel; and $2 million in France. However, in August 1986 the Senate Armed Services Sub-Committee limited funding of foreign SDI research contracts to cases where that work could not be carried out by United States subcontractors.

Table 13 Participants in some American industrial research co-operatives, 1985

Company	RPI1	RPI2	CIS	MCC	SRC
AIR Products		x			
Alcoa	x				
Altech	x				
Allied				x	
AMD				x	x
AMI (Gould)			x	x	
AT&T Technologies					x
Bell Communications				x	
BMC Industries				x	
Boeing	x			x	
BTU Corp		x			
Burroughs					x
CDC				x	x
Cincinnati Milacron	x				
Computervision		x			
DEC	x	x	x	x	x*
du Pont					x
Eaton		x			x
E-systems					x
Fairchild Republic	x				
Fairchild Schlum.	x	x	x		
GCA					x
GE	x	x	x		x
GI*				x	
GM	x				x
Goodyear Aerospace					x
GTE		x	x		x
Harris		x		x	x
Hewlett-Packard		x	x		x
Honeywell			x	x	x
IBM	x	x	x		x
Intel			x		x
ITT		x	x		
Kodak	x	x		x	x
Lockheed				x	
LSI Logic					x
Martin Marietta				x	
Matheson		x			
Monolithic Memories					x
Monsanto			x		x
Mostek				x	
Motorola			x	x	x
NatSemi				x	x
NCR				x	
Northrop			x		
Norton	x				
Perkin-Elmer		x			x
PEW Memorial Trust		x			
Phoenix Data Systems		x			
Polaroid		x			
Raytheon		x			
RCA				x	x
Rockwell			x	x	x
SEMI. Chapter†					x
Signetics (Philips)			x		
Silicon Systems					x
Sperry		x		x	x
Tektronix			x		
Texas Instruments			x		x
3M				x	
Timex	x				
TRW			x		
Union Carbide					x
United Technologies	x		x		
Varian					x
Westinghouse					x
Xerox		x	x		x

Abbreviations:
RPI1 Rensselaer Polytechnic Institute, Manufacturing Productivity programme
RPI2 Rensselaer Polytechnic Institute, Integrated Electronics programme
CIS Center for Integrated Systems, Stanford University
MCC Microelectronics and Computer Technology Corporation
SRC Semiconductor Research Corporation

* General Instrument resigned its SRC membership in April 1985
† SEMI Chapter: Macrion, Micronix, Pacific Western, Probe-Rite, Pure Air

Table 14 Japanese co-operative research in IT: industrial membership

	Den Den	A	B	C	D	E	F	G	H	I	J1	J2	J3	K
Companies with strength in computers														
Fujitsu	•	•	•	•	•	•	•	•	•	•	•			•
Hitachi	•		•	•	•	•	•	•	•	•	•		•	•
Mitsubishi			•	•	•	•	•	•	•	•		•	•	•
Oki	•	•	•	•	•	•			•	•		•		•
NEC	•	•	•	•	•	•	•	•	•	•		•		•
Toshiba			•	•	•	•	•	•	•	•		•	•	•
Companies with strength in consumer electronics														
Sharp				•		•		•				•		•
Matsushita				•		•		•	•			•	•	•
Others														
Sumitomo									•		•			
Furukawa									•					
Koya Glass				•										

Key to Table

Co-operative research projects

A — High-Capacity Computer Development Project, 1962–66
Total cost Y3.5 bn ; Y700m subsidy

B — Super High-Performance Electronic Computer System (AIST), 1966–72
Y12 bn. (subsidy)

C — Pattern Information Processing System (AIST), 1971–80
Y22 bn. (contract research)

D — Mainframe Computer Project, 1972–76
Y8,700 m. (subsidy)

E — Fourth Generation Peripherals, 1972–80
$290 m. (English & Watson-Brown, 1984)

F — VLSI, 1976–79
Y30 bn. (subsidy)

G — Fourth Generation Operating System, 1979–83
Y47 bn. (subsidy)

H — Optical Measurement and Control (Optoelectronics Project) (AIST), 1979–86
Y18 bn (contract research)

Other participants are.
Shimadzu Seisakushu
Nippon Sheet Glass
Fuji Electric Components
Fujikura Cable Works
Yakagawa Electric Works
(According to English and Watson-Brown (1984), these play a subsidiary role.)

I — High Speed Computer for Scientific Use, 1981–8
Y23 bn. (contract research)

J — New Function Elements (AIST under NGBT), 1981–90
J1: Super-lattice elements
J2: Three-dimensional ICs
J3: ICs fortified for extreme conditions
£68 m. (contract research)

K — Fifth Generation Computer, 1982–91
Y100 bn. (research contract)

Software projects

Automatic software, 1976–81
Y6,600 (subsidy)
Participants: over 100 software houses
Interoperable data base (AIST), 1985–90
SIGMA, 1985–90

330. As a result of increasing sensitivity to the economic implications of R&D, there has been an impact, which it is difficult to assess, on the traditional modus operandi of the international research system. Scientists have found themselves barred from certain scientific conferences abroad. Uncertainty has prevailed over many aspects of normal academic publication procedures. For example, in some academic disciplines it has been a technical breach of national controls to submit a paper to journals which have foreign referees.

331. Within Europe, however, networks expand. IT industry is now the subject of several collaborative research programmes. A UK IT company could, for example, be involved in a national programme; Alvey, several EC programmes such as ESPRIT, the wider framework of EUREKA or the more recent one of RACE in connection with telecommunications. Each has a different emphasis in its technological targets, its funding, its closeness to the market, etc. What has emerged in Europe is a network of overlapping and interlocking programmes. A major policy question concerns the extent to which such a network imparts strength to its field, or the alternative possibility that respective programmes contain conflicting objectives, promote duplication of work, and generally cause confusion, especially to smaller commercial entities which do not possess the resources to investigate each one, let alone participate in each one.

332. The major research programmes are ESPRIT and EUREKA, with RACE entering its implementation phase. The European Strategic Programme of Research in Information Technology (ESPRIT) is the IT programme of the European Community. Its objectives are to provide the European IT industry with the technology it needs to become and stay competitive with the USA and Japan within the next decade. As with Alvey, ESPRIT is starting to establish a tradition of collaboration in the respective industries. The programme, which is a distributed one is 50 per cent funded by the Community and involves staff from a range of universities, companies and government laboratories. The first phase of the programme was a pilot phase launched in February 1984 and will run for a period of five years with a possibility of a further five years' extension. The total cost of the programme is expected to be 750 Mecu and to involve about 7 200 man-years of work over the initial five-year period. The programme is intended to focus on 'generic technologies' including advanced microelectronics, CAD, software technology and advanced information processing.

333. Nineteen European countries and the European Commission created the EUREKA initiative, which was launched in July 1985. The original suggestion came from France, as a response to the expected advances in enabling technologies available to US companies as a result of the Strategic Defence Initiative. The present membership comprises the twelve countries of the European Community and Austria, Finland, Iceland, Norway, Sweden, Switzerland and Turkey.

334. It is a framework for international technological co-operation between firms and research institutions, aimed at raising productivity and strengthening competitiveness of their industries, by advancing the technologies important for the future.

EUROPE

EUREKA

EUREKA projects are in the civilian arena and any product, process, or service in the "high-tech" field may be included. A novel aspect of the initiative is the lack of any further strategic targetting of areas of coverage. This internationally open, "bottom-up", approach has resulted in the following broad areas being covered (numbers of projects in parentheses, December 1986):

Technological Areas Covered by EUREKA

Information Technology	(30)
Robotics and Manufacturing (including laser)	(26)
Biotechnology and Medical Technology	(13)
New Materials	(12)
Environment and Transport Technologies	(12)
(Tele) Communications and Audio-visual	(10)
Marine Technology	(2)

335. Two years after its inception, EUREKA had generated 108 projects amounting to a total value of 3.5 billion ecu.

336. The scheme is open to all 'innovating entities' including large, small, and medium sized enterprises, universities, and specialised research institutions, irrespective of their structure or size.

337. Participants fund their own projects from appropriate sources, such as their own resources, financial markets, or any public funds made available by their respective governments. These governments and the European Commission facilitate exchanges of information and provide other services in the project definition phases.

338. The common philosophy behind governmental involvement in EUREKA is the recognition that the establishment of a "large, homogeneous, dynamic and outward-looking European economic area is essential to the success of EUREKA". It should lead in particular to an acceleration of effort in areas such as elaboration of common industrial standards, elimination of technological obstacles to trade, or the opening of the system of public procurement. These considerations have been recognised by the European Commission, which has published a paper setting out the relationships between the European Technology Community (ETC) and EUREKA. This document is worthy of study, but it points out many potential problem areas for the future between parallel collaborative programmes.

339. Areas of similarity between EC programmes and EUREKA are noted: the objectives are convergent, to make Europe, its research scientists, and its manufacturers better able to master and develop the advanced technologies

needed to ensure the present and future competitiveness of Europe as a whole. The programmes tend to converge on key technologies, particularly manufacturing technologies, computing, and communications. In the same way, the methods used to attain these objectives are similar: cross-frontier co-operation between industry and the scientific community by implementing joint projects involving partners from European states. However, EUREKA and the ETC exhibit differences which must be recognised if co-operation is to be established. The ETC is an integral part of the EC itself (analogous to the aim of European market harmonisation) and must therefore be constrained by the usual framework of the EC, for example EUREKA is purely an intergovernmental initiative with projects and financing being entirely decided on a case by case basis. Community activities are essentially intended to be pre-competitive, involving long-lead time research, or pre-standardisation R&D, upstream of market place development. EUREKA is mainly concerned with developing products, processes and services having a market potential.

340. Financing arrangements reflect these differences in nature between the work carried out: the longer term riskier EC work justifies a 50 per cent contribution from public funds, but since EUREKA is closer to the market and involves less risk, a lower proportion of public money is granted (though EUREKA projects vary considerably in their individual financing arrangements).

341. Community programmes have strategic plans into which projects must fit, and proposals for projects must be assessed by a strict selection process. EUREKA projects are proposed by companies without reference to a strategic plan (apart from a very broad reference to the field of 'high technology').

342. EUREKA's participants are primarily European industrialists, with little university or public sector participation, in keeping with its downstream character. Community programmes encourage associations between universities and public sector organisations, in order to break down barriers between university and industrial research, basic and applied. In ESPRIT, for example, universities are involved in 80 per cent of projects.

343. The most fundamental difference between the two types of programmes concerns the economic and legal environment of each. The community approach is part of the general and permanent framework laid down by the European Community, and its objectives, such as market harmonisation, trade relations, competition, etc. Decisions are made collectively and apply to all EC member states. EUREKA operates on an ad hoc, case-by-case, basis: identifying 'additional measures' project by project as and when projects are put forward.

344. The Commission considers that these similarities and differences must be taken advantage of; it should be possible to construct a continuum from upstream pre-competitive research to R&D close to the marketplace. Interfaces should be established which would make possible interaction between the various networks involved in R&D for example the Community programme could have a special role in involving universities. Community programmes may produce results or information which can be used by EUREKA closer to the market. Similarly, EUREKA products may identify requirements for upstream research by EC programmes.

345. Certain dangers may exist, however. In particular the fuzzy distinction between 'pre-competitive' and 'close-to-market' research may lead to duplication or overlaps. The distinct procedures for creating groups of partners may also create problems.

EC

<u>Relationships between EUREKA and EC projects</u>

A detailed case-by-case project analysis in the EC document defines four types of relationships between EUREKA and EC projects:

Category 1: No obvious links
Category 2: Projects are in the same field, but with no overlapping of work on relation between projects. In this case information exchange would be encouraged.
Category 3: Two projects may be linked, for example by an upstream/downstream relationship. A clear working relatinship between projects of this type must be defined.
Category 4: Partial or complete overlaps between projects. Measures must be taken in this case to reduce the risk of duplication, or ensure the best possible interaction.

A preliminary exercise analysed the first 72 EUREKA projects and found that:

9 projects are in category 1
22 projects are in category 2
33 projects are in category 3
8 projects are in category 4

346. Several areas of co-operation between EUREKA and the community are suggested. These concern the establishment of an internal market, which involves technical issues such as standardisation. A potentially troublesome area concerns the Commission's responsibility for eliminating any distortions to competition within the EC. EUREKA projects may be more liable to contravene these rules due to their market orientation.

347. The Commission considers that it can have a valuable function in the provision of research infrastructure, including financing as well as support such as information networks and databases, all of which it considers part of its activities in establishing the ETC. Other measures here include encouraging the mobility of scientists and researchers, and provisions for the optimum use of large scale equipment.

348. In summary, even just considering EUREKA and European Community programmes, it can be seen that the relationship is extremely complex. When national and other international programmes are added, the resulting

complexity is daunting. The initial question may therefore be repeated: will these interlocking networks provide a firm foundation upon which can be built a regenerated European IT industry, or will the result be just an impenetrable bureaucratic tangle which does more to hinder technological advancement than encourage it in this fast-moving field? At present it seems too early to give a definite answer to this.

349. Preliminary indications indicate at least moderate success, however. For example, many firms have begun to look beyond their country for collaborative partners not only to carry out research, but also to bring products to the market. Especially successful have been the 'vertical collaborators' which reduce the risk of encouraging domestic competition for the partners. The ultimate success of the programmes, and the concept of collaborative research must be judged by the success of exploitation of the results; some products are already being marketed. However studies of technological innovation have stressed that the 'success' of innovations cannot be judged purely on the basis of which firm markets its new product first, but on the continuing advancement of the new products' performance parameters, and <u>long-term</u> outdistancing of competitors. Similarly with collaborative programmes, there is no presumption that a 'once-and-for-all' surge of research can result in the establishment of a permanent competitive advantage. The programmes must result in a change in behaviour and structure of an industry resulting in continuing competitiveness.

E. <u>The Role of Evaluations</u>

350. One must be careful to distinguish between the meanings of 'monitoring' and 'evaluation', as some confusion has resulted in the past from alternative interpretations.

351. 'Monitoring' is taken to mean a continuous process of judging the progress of work, particularly of individual projects within a programme, comparing this with workplans and technical milestones, and in some circumstances comparing output with expenditure and budget (financial monitoring). 'Evaluation' is meant to encompass a broader exercise of assessing the progress of programmes as a whole, their objectives, strategy, appropriateness, methods, administration, success against objectives and implementation issues in general. This may entail the study of individual projects, but only insofar as this can identify issues affecting a programme as a whole, such as methods of collaboration, exploitation routes, etc. A further term to be distinguished is 'appraisal' which is taken to mean the initial process of selecting or approving individual projects. (Occasionally, for example in ESPRIT terminology, 'evaluation' refers to this process, and 'monitoring' seems to include some aspects of what is here defined as 'evaluation').

352. The purposes of evaluations vary. Under a narrow definition can come 'value-for-money' reasons, especially where state support is involved. A number of countries conduct "audits" of programmes and research organisations. These are not usually evaluations in the strict sense of the word, but administrative enquiries which do not follow identifiable and explicit scientific methodologies. In addition, as a rule, their results are not made public and open to discussion as well as national or international comparisons.

353. A long-term objective of evaluations may be to analyse factors influencing the success, or otherwise, of programmes, and this points out lessons to be learned which can improve future or successor programmes often in entirely different fields. In Finland, for example, it is intended to evaluate the system of indirect fiscal incentives for industrial R&D. Similar evaluations have been implemented in a number of countries. A more recent innovation, real-time evaluation (discussed below), may assist the administrator of programmes in information gathering and other management tasks, and also provide a check on programmes for their sponsors.

354. In theory, evaluations usually come from 'outside' the programmes under review, including independent consultants, academics or civil servants from other departments who may have a systematic evaluation responsibility. Special institutional arrangements may be implemented for this purpose, as in relation to the SDI programme in the United States.

UNITED STATES

Evaluation of SDI Programmes

In March 1986 the DoD proposed the establishment of the Strategic Defense Initiative Institute (SDII) to perform a technology evaluation and integration role in support of the Strategic Defense Initiative Organization (SDIO):

> "SDII will evaluate SDI-sponsored research and development efforts of other organisations including candidates, national laboratories, university groups, and the armed services. And, SDII will be responsible for integrating concepts and technologies into alternative macro-level system architectures. Results of such work, including the trade-offs associated with each technology or option will be presented to SDIO where all decisions regarding the future course of the SDI R&D programme will be made". Additional SDII functions as described in The Federal Register notice include, but are not limited to: performing test and evaluation planning, integrating offense/defense scenarios and analyses into useful conclusions; framing issues for decision by the SDIO, and developing and maintaining a database on active SDI projects and capabilities, continually analysing same for overlap, duplication, and opportunities for co-ordination."

The SDII started its operations in 1987. It was originally expected that staffing levels would rise to 100-200 people, with funding levels of $20-30 million per annum.

355. In reality it is difficult to ensure independence of evaluations. Programmes should have encompassed all the 'experts' in a field, so finding an independent technical expert would be an admission of failure. Internal evaluation also has advantages: access to privileged information;

person-to-person contact between evaluators and evaluated; greater receptivity of management. A similar consideration applies to industrial representation on evaluations. The mid-term review of ESPRIT was chaired by Dr. Pannenborg, who has had a long association with Philips, which plays the major part in ESPRIT. The evaluation of ICOT is carried out by the services of working groups.

JAPAN

Evaluation of ICOT

MITI presents the budget to the Ministry of Finance annually, after evaluating the proposed programme by ICOT which may be reviewed each year. The MITI evaluation committee includes senior university professors. The programme proposed by ICOT is the responsibility of the Director, who is responsible for executing it, but he is given advice on theoretical or basic technical aspects by a series of working groups. The thirteen working groups consist of experts from the universities, national laboratories and NTT. They are co-ordinated by the Project Promotion Committee. An industrial/commercial input to the strategy is provided by an advisory committee in MITI. The Industry structure Council, chaired by Mr. Y. Inayama, President of the Federation of Economic Organisations has various sub-committees of which one is the Information Industry Committee, consisting of industrial and academic members. This deals with issues concerning an information-oriented society, such as privacy, security of computer systems, and technological development including the 5G Project.

356. It may be feasible to conduct an evaluation of a national programme using foreign experts (as with the German study cited below), but this entails obvious dangers in sensitive areas of work.

357. Sponsors and participants may not wish to have the results of evaluations publicly distributed, so may settle for entirely internal reviews.

358. Evaluations may be either 'ex ante' (involving programme definition and implementation) or 'ex post'. More recently two variants have emerged: the 'interim' evaluation, which takes a snapshot view of programme progress, and 'real-time' evaluation which proceeds in parallel with a programme from its inception to its termination or beyond.

359. An example of ex-post evaluation is that of the German Electronic Data Processing programme of the Ministry of Research and Technology (BMFT) (1967-1979).

360. This was to cover the background, the intentions, the instruments, the framework, and the results of the EDP support programme, which the Federal Government supported with DM 3.5 billion of public funds. The aim of this programme was to create a viable German EDP industry and to further EDP applications in private industry, public administration, and in the sciences.

GERMANY

Some Conclusions of the Evaluation of the Electronic Data Processing Programme

"The evaluation shows that there were substantial positive results: EDP-suppliers with a German base employ a work force of 50 000, reach annual sales of about DM 6 billion and export 45 per cent of their production.

The aims of the EDP support programme were, however, only partially met. German-based EDP suppliers do not yet hold a sufficient position in the international markets and the necessary interaction of EDP and telecommunications systems and strategies has not yet been achieved.

Public support continues to be required if the German-based EDP suppliers are to remain or become internationally competitive since other industrialised nations also support their EDP industry. The support instruments used in the past were not very effective. In addition, the aims of public support of the EDP industry have to be adjusted to changing competitive conditions. Therefore, the German Government should adopt more appropriate instruments of support. In particular, support should be given to business strategies of the companies rather than only to technology development projects."

361. The evaluation was carried out under contract by consultants, (SRI International and Arthur D. Little International) who were deliberately chosen from outside Germany to minimise bias. Only one part of the EDP Programme was evaluated, concerning industrial applied research. The sponsoring ministry was not entirely happy with the report produced in 1982, though the programme level evaluation was seen to be useful.

362. The ESPRIT Programme has been the subject of an interim review, apart from project reviews etc., (monitoring in our terminology). The Council Decision of February 1984 which established the Programme provided that it should be reviewed either after 30 months or as soon as 60 per cent of the funds had been committed. The Pannenborg Review team already mentioned, carried out interviews and discussions with 131 organisations and a structured questionnaire was mailed to all 477 participants in the 1984 programme.

363. The objectives of the review were to assess the extent to which ESPRIT is meeting its objectives and to consider the orientation of ESPRIT in future years.

The ESPRIT Mid-Term Review

The report, submitted in October 1985 reflected the nature of the exercise. Despite the rather low response to a very simple questionnaire (238 replies), the conclusions must be taken as representing the views of the participants. As might have been expected from the beneficiaries there was strong support for the concept of the programme and its continuation. Less obviously predictable was a general approval of the execution of the Programme by the Task Force, though a number of issues were raised, some of which are mentioned in this report. As an opinion survey the Review stands up well but, for lack of a synthesis, analysis or back-up with data, it does not constitute a full-scale interim evaluation.

The Council of Ministers in April 1986 requested the Commission to establish a report on the technical results of ESPRIT achieved so far and to comment on four other issues:

-- size and composition of consortia;
-- cost/benefit as a function of different levels of financial support;
-- comparison of human resources involved in ESPRIT with the general situation in the Community; and
-- issues relating to the participation of multinational enterprises;

The larger part of the report dealing with the economic impact and industrial application of projects, represented a summary of the output of the monitoring process in the form of 200 reports from the reviewers. It is highly problematic to raise the question of whether exploitation is taking place three years into a ten-year programme of pre-competitive research. Indeed if full exploitation of results was taking place it would probably be an indication of poor project selection as it is not the Programme's role to assist in product development. Having said that, the report did identify technological deliverables which were in evidence in practice, strategy or standards. Systematic project by project appraisal would have been useful, but might have led to premature judgements of what was always intended to be longer term work.

It is worth mentioning two other points covered by the report. The size of consortia had been raised in the Mid-Term Review which recommended that the number of partners in most projects was too large and should be smaller except in standards-related projects. Problems of large projects are mainly of co-ordination or of uneven contributions from partners. This is an important empirical question for collaborative research and must depend heavily upon the nature of the technical work, the range of skills required, the geographical situation and the IPR and exploitation environment.

The other issue discussed was that of the 50 per cent funding level. The Commission argued that this was part of a careful balance in the structure of the programme which included IPR arrangements and relations to national programmes. While there was a strong case for raising the proportion to increase the participation of small firms and universities, and probably a case for lowering it in more overtly commercial projects, the main obstacle is one of implementation; if a discretionary element entered the Programme there would be scope for damaging argument as to the level. Size of firm might not be a sufficient criterion to operate automatic discrimination.

364. The Alvey Programme is notable for its real-time evaluation, which has been in progress since Alvey's start-up and will produce a final report about one year after termination of the Programme, though numerous reports on particular issues are being produced on a regular basis.

365. A similar approach is intended in Denmark in connection with the Technology Development Programme: the National Agency of Technology will follow-up the information technology related activities of the TDP. Interviews will be used to find out how well the programme is becoming known in the industrial community. Fact-finding evaluations will be carried out in most of the areas of activity according to a scheduled process. Questionnaires will be sent out regularly. A final report will be prepared by 1990.

366. There are several general reasons for carrying out a real-time evaluation:

-- To allow collection of data and opinions for an eventual _ex post_ assessment as they are generated and so avoid their unavailability or distortion by hindsight;

-- To provide information and analysis sooner than would be obtained from and _ex post_ evaluation. The importance of this lies in the fact that planning for the next programme generally takes place while the current programme is still running. Only a real-time evaluation can offer an input to this planning. This feature is illustrated by the interaction between the Evaluation and the activities of the IT86 Committee which considered the question of successor programmes in Alvey. In particular, the evaluation team submitted a series of reports on various aspects of Alvey's performance to the Committee, and the Alvey Evaluation Mid-Term Review is likely to have some impact on final decisions on the implementation of Alvey II. A continuous series of presentations, for example at the annual Alvey Conferenc, of the results of the evaluation, has served several useful purposes. They have provided a focus and a forum for discussion of important issues in collaborative research. This is especially important in a distributed programme where there is no central research facility. In addition, on certain issues the evaluation can offer feedback applicable to the current programme.

367. In many respects, the second reason for carrying out real-time evaluation is particularly relevant to the process approach. Wider issues such as the impact of the Programme on the IT industry of even the appraisal of technological outputs are very difficult to assess before the Programme has ended, though the data collection argument holds here. There is also the difficulty in obtaining independent advice, mentioned above. Structural features, however, are discernible by participants at an early stage and are more amenable to adjustment.

UNITED KINGDOM

The Evaluation of the Alvey Programme

The evaluation of Alvey is being carried out by two academic groups, each with a different focus. The first group, the Science Policy Research Unit at Sussex University, is concentrating on outputs and impact of the Programme; while PREST at Manchester University is analysing its structure and organisation. SPRU's attention is on broad strategic aspects of the Programme; asking if Alvey is an appropriate strategy for the UK IT industry, and whether it is achieving its goals. Several tasks have been identified in order to analyse these questions. First a set of policy reviews is being completed for each of the enabling technology areas. The second question is to be answered by the long-term assembly of indicator databases covering inputs (manpower, expenditure, etc.), technological outputs (patents, papers in journals, etc.) and economic indicators in Alvey-related areas (trade statistics, profitability, etc.) Information is being collected at organisation, project, programme, national and international industry levels. These will eventually trace Alvey project developments and also the background IT industry environment, throwing some light on the overall contribution of the Alvey Programme to the performance of the UK electronics and IT industries.

The Programme is unique in the UK in its structure, involving collaboration between government departments, industry, and academia, and as collaboration itself is seen as an essential feature of future large R&D programmes, it was felt to be important to evaluate structural features as well as strategy impact and success in meeting objectives in increasing the competitiveness of the UK IT industry.

In carrying out the evaluation, constrained resources result in coverage of issues in series rather than in parallel, but this is reasonable bearing in mind that particular issues usually arise at particular stages of the life cycle of a programme, and can be dealt with at an appropriate stage.

Methods used include structured interviews with appropriate personnel and questionnaires covering either samples of participants, or in some cases entire populations of researchers or administrators. Postal and telephoned questionnaires have been used.

368. It is essential that evaluators have the full co-operation of the highest levels of programme management. This includes, for example, having full access to appropriate data sources. Participants in the Alvey evaluation programme are reported to have been remarkably open and co-operative in their attitudes to evaluation. Assurances were given about confidentiality and minimum disruption or time cost, and individuals almost always welcomed the opportunity to express their views and feelings, knowing that these may have an influence on subsequent programmes. In such a long term exercise the build-up of confidence in evaluation is dependent upon continuing sensitivity of evaluators to the participants, therefore procedures such as internal circulation of draft reports for comment and elimination of errors become essential.

369. Other techniques are also used. Though quantitative techniques are used (especially in the industrial impact part of the evaluation, which includes patent analysis, citation analyses, etc.) and can give useful information, at present these are not fully developed techniques, and must be used with some reservation, such as the question of appropriateness of citation analysis in the field of applied R&D. Comparison is another valuable technique, which can be used in many ways on different issues. For example, administrative procedures, appraisal techniques and time delays can be compared to other, similar government departments or programmes. Structural questions such as the relative merits of centralised and distributed programmes can be investigated by the use of international comparisons with other national (or international) programmes. A fundamental comparison is more difficult to deal with, though. This is the 'null hypothesis', by which the situation subsequent to a programme should be compared to the situation projected to occur in the absence of that programme.

370. Some final points on evaluation are worth noting. One of the most fundamental requirements of an evaluation is that the evaluators are, and are seen to be, independent of the subject of the evaluation. This is not, however, always the case. Evaluations have on occasion been carried out by direct or indirect beneficiaries of programmes. A justification for this is that 'peers' are the only group qualified to judge detailed technical issues. This is a perennial problem of research assessment, but important evaluation reports have been discounted for this reason.

371. A related point is that until evaluations become a standard requirement, programmes exposing themselves to in-depth critical analysis and reporting should not be seen to suffer by comparison with their less open fellows who are able to hide their shortcomings from less formalised probing.

Chapter VI

NEW ORIENTATIONS

372. The broad spread of scientific and technological research programmes relating to information and communications which have been launched in Member countries in recent years reflects the importance and promises of a number of new lines of investigation. The "technological landscape" which has been explored above undergoes, however, continuous evolution. Furthermore, this whole area is highly subject to the turbulence of international competition which will directly affect the specific goals pursued by governments and industry. Finally, the financial implications of some of these programmes are so large that they become a source of concern at a time of acute budgetary constraints.

373. It is not surprising, therefore, that many of the programmes which have been discussed may have an uncertain future and are the object of a great deal of evaluation, assessment and hesitation. In some cases, the overall political context makes it impossible to outline their likely evolution. This is the case, for example, in the United States, where the outcome of ongoing budgetary discussions will no doubt affect many programmes, from the NSF actions to SDI. In the United Kingdom, decisions were still pending at the beginning of 1988 with regard to the new phase of Alvey which might well demonstrate decreasing government involvement in pre-competitive research. In France, the political agenda seemed to preclude any major decisions in this area before the end of 1988.

374. Thus, the "new orientations" which can be outlined at the conclusion of this report remain highly tentative and fragmentary. A first section will present some of the salient features of programmes which have recently been launched (Norway, Sweden) or have undergone more or less extensive reappraisal (Alvey, ESPRIT, EUREKA, Germany). A second section, will attempt to draw out the most significant trends.

A. New Developments in National and International Programmes

1. The Alvey Programme

375. At the present time the Department of Trade and Industry is undergoing a period of redefinition of priorities following the general election of June 1986 and subsequent appointment of two new Ministers of State with new divisions of responsibility. Though the full extent of any changes is not yet announced, the general change of emphasis is clear. In particular there is a concentration of attention on the creation of market opportunites, by privatisation, deregulation, the encouragement of competition, the development of the new European internal market, etc. Companies are to be encouraged to take advantage of these opportunities by improving the flow of information to business about new methods and opportunities, by encouraging technology transfer, etc. There seems therefore to be a continuing, even increasing, importance given to collaboration as a means of achieving these objectives. However, the new emphasis seems likely to reduce specific project funding, especially close-to-market support.

UNITED KINGDOM

Interim Evaluation Report of the Alvey Programme

In September 1987 a draft version of the Interim Evaluation Report was presented to a conference of civil servants, industrial and academic representatives. Though the Programme is just past its halfway stage, the Report was intended to be a contribution to the debate on a possible successor.

The main conclusions of the Report include:

Progress and Impact

-- In VLSI, Alvey has accelerated and expanded research activities and improved links. The main technological projects are on schedule;

-- Software Engineering is apparently behind schedule, however Alvey has succeeded in expanding and accelerating UK work in the area;

-- Man-Machine Interface was slowest to start, and though advances have been made, overall goals are yet to be achieved. There may be problems to be encountered when exploitation is attempted;

-- The Large Scale Demonstrations experienced some initial delays, however all but one are now proceeding well;

-- Academic research has increased its collaboration with industry, however academic teams are particularly vulnerable to funding delays which may cause their break-up;

-- It is too soon for Alvey to have had a significant effect on firm's strategies, though it has had major impacts on the rate and direction of research;

-- In general the Programme has facilitated future collaboration, created awareness of new technologies, unified research communities, and has had beneficial effects on manpower.

Implementation

-- There have been some problems with the directed, distributed structure of the Programme, such as lack of seconded personnel and resulting delays. However the administration of Alvey by a directorate has been beneficial in providing a cohesive programme and a focus for the community. The most serious failing has come in the interface between the government departments with administrative responsibility for contracts. A unified budget for a future programme would avoid repetition of the inevitable problem of the divided system: one of the departments will exhaust its funds first and cause delays to additional project approvals;

-- Most participants reacted favourably to collaboration. Alvey has tended to upgrade existing links more often than forge new areas;

-- Collaboration agreements have been a major source of delay to the Programme. This would be alleviated if basic principles were embodied in the contract (i.e. between each participant and the Directorate) and supplementary items in collaboration agreements (i.e. between partners) left to partners to work out amongst themselves;

-- A problem is forecast to arise when the existing complex set of arrangements between partners concerning intellectual property rights (IPRs) has to be replaced by another, different, complex system associated with a future programme, either domestic or international;

-- Central institutes have a role where closely managed goal-oriented research on issues of wide interest is required, for example in standards research. Separate funding may be required for these, and they should have a limited lifetime. A rolling programme with the possibility of redistributing funds and reallocating priorities would allow better scope for updating strategies as circumstances change.

Appropriateness

-- In general the choie of areas was in line with world thinking. International comparisons suggest that without Alvey, UK industry would have been substantially disadvantaged;

-- It was considered to have been correct to have undertaken a pre-competitive programme in the UK in the early 1980s, but more emphasis needs to be placed on the UK's problem in exploiting research;

-- The uncertainty surrounding the successor programme risks the break-up of research teams, which will prevent the exploitation being fully carried out.

Progress towards an Alvey Successor Programme

376. Details have already been given above of the Bide Committee Report (known as IT86, then IT87) and its recommendations concerning a successor programme to Alvey, which although it was instituted as a five-year programme, was intended to run into a second five-year term.

377. A government decision on the future programme has been successively postponed since early Summer 1986. This is partly explained by the general election in June 1987, but more significantly by the changing emphasis in Department of Trade and Industry support policy towards industry. Though some of the principal issues in this change are known, a comprehensive statement of the new policy and its ramifications is yet to be announced, and is expected in the early part of 1988. This uncertainty is compounded in the context of the Alvey Programme. The recommendations of the Bide Report suggested a smaller, nearer to market programme (known at present as IT92). One of the new policy changes appears to be a movement away from direct project support in this area of work, to be partially substituted by general "market opportunity" work as mentioned above. However the new policy apparently will place greater emphasis on collaborative work.

378. In this context it is perhaps worth remembering that Alvey itself appears in retrospect to have been an unusual departure from the non-interventionist stance of the Government in its previous terms of office.

379. As a postscript to this, one feature of the post-Bide period has been the lack of sustained or effective lobbying by industry in favour of a successor programme. Though expressions of support have been forthcoming, the UK IT industry appears to have looked towards Europe in search of collaboration: ESPRIT II is double the size of ESPRIT I, and may now have become more important to UK industry than an expected successor to Alvey.

2. Germany: Informationstechnik 2000

380. The Report "IT 2000" is not, strictly speaking, a plan of action. It is more like a record of the discussions held by the think tanks involving roughly a hundred experts and organised in 1986 and 1987 at the instigation of

the Federal Ministry for Research and Technology (BMFT). The discussions produced a document that supplements the Queisser Report (on the needs for researchers in each field of science) and can be seen as laying the groundwork for defining the special programmes of the coming ten years. The document presents an overall picture of the competitive positions of the main economic powers (United States, Japan, Europe) in the world market as well as of the political, technological and economic conditions needed for Germany to sharpen its competitiveness in the four areas of microelectronics, data processing, industrial electronics and telecommunications. The document provides evidence of the BMFT's strategic programming approach and its comprehensive, broad-based view of information technologies.

Guiding principles

381. Notwithstanding the particularities of each of the programme's four main areas, a common frame of reference has been applied, with three main sectors for action:

-- Market, applications, production (output targets, growth of new markets, State action, standardization, European co-operation, support for SMEs);

-- Know-how (rise of a new technical culture, inadequate research and teaching capacity);

-- Capital (financing, venture capital market).

Microelectronics

382. European semiconductor makers supply only 40 per cent of the German (and the European) microelectronics market. As shown in Table 15, Japan by comparison imports only 8 per cent of its semiconductor needs. With a microelectronics consumption estimated at DM 60 per head, Germany is ahead of the average for Europe (DM 30), but trails well behind Japan (DM 170). Given these figures, Germany's domestic semiconductor needs are expected to rise from DM 3.7 billion to DM 18 billion, or 6 per cent of the world market, in 2000.

383. The annual turnover of the three leading European firms is still 5-10 per cent lower than that of the top Japanese firms. Not only that, but they still are 90 per cent dependent on Japanese and American suppliers of manufacturing plant.

384. Between 1986 and 2000, R&D expenditure is expected to rise from DM 0.5 billion to DM 3.2 billion. Considering that, owing to the growing complexity of equipment, the cost of a laboratory workshift will rise from DM 250 to DM 500 per day, the estimated number of researchers will grow from 2 000 to 6 500 in industry alone. If Germany (estimated domestic market needs: DM 18 billion) is to become self-sufficient in semiconductors by the year 2000, output volume will have to grow from DM 2.4 billion to DM 18 billion, a rise that will involve production capacity investment of about DM 14 billion over 14 years.

Table 15

Region	Population* (million)*	Semiconductor consumption (DM million)**	Per capita
North America (US & Canada)	262	18 200	69.47 DM
W. Europe	352	11 000	31.25 DM
Germany	61	3 660	60.00 DM
Japan	120	20 600	171.66 DM

Source : UN Stat. Papers - Series A

* 1984 figures
** 1986 figures (DM 1 = US$ 0.50)

385. The Report concludes by urging strengthened co-operation between manufacturers, between manufacturers and consumers, between manufacturers and consumers and government (norms and standards), between industry and university research, and between manufacturers and manufacturing plant suppliers.

Data processing

386. Out of the world's twenty leading computer manufacturers, only three are European (Siemens, Olivetti, Bull). Together the European makers have a market share of only 8 per cent, whereas Europe represents 30 per cent of the world market. In the field of software, the strength of German industry lies mainly in personal software and software technology, but its main weak point is in standard software.

387. On the hardware side, German firms are among the European leaders but their market share is too low. As shown in Table 16, however, German hardware manufacturers can boast of a growth rate higher than the world average. But, despite this performance, Germany (like the European Community as a whole) is a net importer of computer products and components.

388. This being the case, Europe should give top priority to creating its own major market. The Report observes that this objective is not being pursued with sufficient determination by the European Commission, which prefers devoting its energy to the less important goal of promoting R&D. The programme ESPRIT comes in for some criticism here: cumbersome administrative machinery, leading to cost overruns and the exclusion of medium-sized firms from programmes. There are harsh words also for the slow pace of decision-making and action.

Table 16

GROWTH OF COMPUTER MANUFACTURING FIRMS (1980-1985)

	per cent growth
IBM	18
DEC	21
SPERRY	13
BURROUGHS	13
NCR	6.5
CDC	6
HEWLETT-PACKARD	19
HONEYWELL	4
APPLE	60
SIEMENS	20
OLIVETTI	33
BULL	18
ICL	10.5
NIXDORF	22
FUJITSU	17
NEC	22.5
HITACHI	15.6

(Average growth : 18 per cent)

Source: GMD

389. Five principal spheres of action are defined: creation of future strategic markets, boosting R&D potential, translating technology into new products, building up the innovative capacity of medium-size industry, creating conditions conducive to steady development in the computer field.

390. The five spheres of action suggest a whole set of measures, which include:

- -- Focussing R&D on specific areas, notably parallel architecture and artifical intelligence;
- -- Building up research capacity, involving an increased annual outlay of DM 0.5 billion;
- -- Setting up a permanent forum for the exchange of ideas and information, with the aim of identifying and keeping abreast of research topics;
- -- Upholding co-operative research;
- -- Intensifying the use of specific indirect aid.

Telecommunications and communications electronics

391. The investment cycle for telephone, radio and television systems, including transmission by satellite and cable, is now completed. Another investment cycle, based on micro- and opto-electronics, is about to develop. The cycle was initiated in Germany in 1986 by the ISDN network pilot operations in Stuttgart and Mannheim launched by the Federal Post Office. The cycle's goals are the extension of the telephone system and the incorporation of text, image and data flows into the system using analog techniques. Germany occupies an estimated 6-7 per cent of the world telecommunications market, with a volume in 1985 close to DM 190 billion.

392. R&D expenditure by the leaders in the field (government or private enterprises) shows considerable variations, partly owing to the different types of R&D support practised in each country:

British Telecom	DM	480	million
PTT/France	"	430	"
Deutsche Bundespost	"	160	"
NTT/Japan	"	2 130	"
AT&T/USA	"	2 200	"

393. In the telecommunications field, the basic challenge lies in establishing the ISDN system, followed by the B-ISDN (broad band - integrated services digital network) system, while ensuring adequate compatibility between private infrastructure and government services in conformity with OSI norms. The problem of the heavy cost of terminals and the small number of subscribers to the new services must be met by the German Post Office (Deutsche Bundespost), along the lines of what has been succesfully achieved in France and Japan. The DBP's overall task will be to develop ISDN and B-ISDN services while at the same time promoting their acceptance and use.

394. In the sphere of communications electronics, the main target is to improve sound and image quality through new television standards (HDTV, high definition television). With this in view, government-sponsored bodies will have to:

- -- Help develop a domestic European market with increased demand potential and strengthen the industrial base;

- -- Organise methods of protection against foreign competition while the new products are being introduced.

395. At the point where these two major areas converge, the principal undertaking will be to set up the IBFN (international broad frequency network).

396. As for basic research, private industry annually contributes about DM 250 million and the BMFT DM 95 million to its finance. A 10 per cent annual increase in this expenditure is considered necessary.

Industrial electronics

397. Research support must centre on three areas covering the whole of microperipheral and integration technology: sensors, processors and liaison techniques.

398. Support must consist, one, in strengthening research potential (600 scientists between now and 1995) and, two, in encouraging firms to develop new products. This action seems to have got off to a good start with the microperipherals programme "Mikroperipherik" (1985-1989).

3. Norway: The National Action Programme for Information Technology

399. The Norwegian Government launched an Action Programme for Information Technology which includes education, research and development. An extra input of ca. NKr 300 million was proposed for 1987. The new effort is aimed at strengthening support for R&D in IT under the Industrial Development Foundation, and the Norwegian Telecommunications Administration. The total effort for IT amounted to nearly Nkr 1 billion in 1987. Plans have been made for a four-year programme, but appropriations for the years following 1987 will be considered subsequently. It is expected, however, that the effort will require additional resources, going beyond the level of the 1987 programme.

400. In a short-term perspective the programme is expected to attack problems relating to education and research within information technology and electronics, especially the lack of personnel, competence and equipment. The first phase of the programme includes in particular, therefore, efforts for strengthening higher education in the fields of IT-related subjects and for stimulating the readjustment of professional training.

401. In a longer term prespective the Programme aims at strengthening and developing Norwegian IT-related industry, and in general at assisting in achieving the necessary readjustment and efficiency of industry and services, both in the private and the public sectors.

402. The Action Programme presupposes a close collaboration between public authorities and interested firms for the building up of competence and for new establishments.

NORWAY

THE NATIONAL ACTION PROGRAMME FOR 'IT'

The Action Programme consists of the following elements:

-- The strengthening of professorial training, i.e. supply of adequate equipment and facilities, development projects and continuing education of teachers;

-- Increased admission of students at universities and colleges;

-- Increased purchases and facilities for optimal operation of up-to-date equipment in order to improve quality and efficiency in education and research;

-- Development of the knowledge-base both as regards basic research and applied research in IT, with a view to building up competence and reach international standard in key areas, under the direction of the relevant research councils (NTNF and NAVF);

-- Loans and grants for development of IT products such as computers, telecommunications equipment and software systems, by means of extended R&D loans provided by the Industrial Foundation, NTNF's contributions to innovation and government R&D contracts;

-- Various measures for increased utilisation and diffusion of technology.

Increased R&D efforts by the Telecommunications Administration are included in the Action Programme. In the next few years the Telecommunications Administration expects to increase its R&D efforts from one to one-and-a-half per cent of net profit.

The following table shows the distribution of the public contribution to IT in main areas (NKr million):

	1986	1987
Education	117	157
Equipment	66	130
Advancement of knowledge	101	117
Product development	116	154
Utilisation/diffusion	292	434
Total	692	992

403. The regional distribution of the effort will be improved. It is considered of special importance to encourage the co-operation with universities and colleges in the regions outside Oslo and Trondheim. The spreading of efforts is expected to build up competence at regional colleges as well as within local industry and the regional organisation of the Telecommunications Administration.

404. All parts of the country are supposed to participate in the increased efforts of the Action Programme. The building up of competence and the advancement of knowledge in the regions have already been given high priority within the context of the Regional Development policy. By means of the Action Programme a growing emphasis will be laid upon improving the capacity on IT-related subjects at regional colleges and engineering colleges throughout the country, and elementary training in primary schools and secondary schools will be strengthened.

405. The Ministry of Labour and Municipal Affairs will be given additional possibilities to support the building-up of regional centres of competence, and the appropriations for regional development will include special programmes for the transfer of technology to the regions.

406. The Action Programme will be carried out by existing institutions and organisations. The National steering committee for IT, established by NTNF, will be given a co-ordinating function. Appropriations to the different parts of the Programme come under the budgetary responsibility of several ministries. The Action Programme therefore represents an attempt to promote the coherence and effectiveness of a whole range of items in the National Budget related to IT, based upon the appropriations of individual ministries. The Action Programme thus includes no new propositions to be considered by Parliament, in addition to those contained in the individual ministries' proposals.

4. The Swedish National Information Technology Programme

407. The Swedish Government and the Rijksdag have adopted a National Information Technology Programme (IT Programme), aimed at maintaining and strengthening Sweden's information technology capability over the next few years and thereby reducing dependence on other countries in this field, with the additional aim of promoting appropriate use of information technology.

Context

408. The IT Programme should be seen in relation to the National Microelectronics Programme (NMP), launched in 1983-84, which will be largely completed in the year ahead. To a large extent the NMP has been concerned with design and manufacturing technology relating to integrated circuits. The IT Programme, by comparison, relates to systems applications, both hardware and software. More specifically, the development side of the programme has been defined as covering computer, control and communication systems and their base technologies and, in that context, both the development of technologies, methods and resources and specific applications and groundwork for medium-term commercial product development.

Scope

409. The field covered includes industrial applications of advanced IT, e.g. in the engineering and process industries. Basic technologies include circuit development, motivated by new developments and new requirements in such areas as high-speed applications and opto-electronics.

410. The Government has declared its intention to draw up an action programme on research and other activities relating to the interaction between IT use and users -- individuals or organisations. This field covers data security, ergonomics, organisational effects and other concerns. Such matters are not the primary focus of the IT Programme described here. However, this does not mean there are not important areas of common ground, and close contacts should therefore be maintained when the two programmes are implemented.

SWEDEN

The National Information Technology Programme.
Scientific and Technological Goals

The IT Programme has three main thrusts:

-- Increased support for basic research in areas important to information technology and its applications;

-- Increased support for goal-oriented research in the field of information technology. This support is being planned by the National Board for Technical Development and will be implemented as part of framework programmes or in the form of individual research projects at higher education or research establishments;

-- The development of IT systems, methods etc. through projects jointly funded and run by central government agencies and private companies. State funding, totalling SKr 495 million, will provide a foundation for this part of the IT Programme, for which at least an equal amount of development project finance will be provided by the business sector. Planning and implementation of these development projects will be the responsibility of a specially appointed Board for Industrial Development in the Field of Information Technology (the IT Board).

Established in October 1987, this body currently has 10 members, half representing central government, half private industry. Among other bodies, they represent agencies with IT 4 funds at their disposal and companies that have declared a major and lasting commitment to IT 4 project activities. However, participation in projects is open to all companies, provided the general conditions specified are met, and certain arrangements are being made to facilitate an outward flow of information about IT 4 activities and an inward flow of project proposals.

Development projects

411. The development side of the programme (also known as IT 4), is to be made up of a large number of development projects jointly financed by central government and private companies. This means that it will not so much be a matter of applying for project funds from IT 4, as one of looking for other parties interested in participating in a development project.

412. The rule is that state funding can amount to a maximum of half the total cost of a development project. Central government participation is being channelled through one or more of the National Board for Technical

Devlopment, the Telecommunications Administration and the Defence Material Administration, to which the Government has assigned specific functions in the implementation of IT 4.

413. Defining what areas of IT are to be developed through IT 4 support and how it is to be done -- through methods development, applications projects, hardware or software -- is the responsibility of the body responsible for implementation, the IT Board. Initiating development projects is one of its functions, but projects can also be proposed from other quarters. The decisive requirement is that a draft agreement be drawn up which, as well as answering to the interests and IT development needs of those involved, satisfies the conditions for central government IT 4 funding and represents a contribution to building up a capability in strategic areas, as intended by the IT Programme.

414. Project agreements are to be signed on behalf of central government by PRIM, the Programme Council for Industrial Development in Microelectronics. The content of these agreements and implementation of the projects, however, will be the responsibility of the individual agency or agencies concerned -- the Board for Technical Development, the Telecommunications Administration and/or the Defence Material Administration, PRIM will be responsible for ensuring that conditions for state funding are met in each project agreement.

415. Another condition for IT 4 funding is approval of the project agreement by the IT Board. This approval process will take account of whether the project focuses on strategically important areas of knowledge. The IT Board will thus operate both through its own initiatives and by considering agreements for approval in relation to the strategic objectives of the IT Programme.

416. The IT Board has decided to set up a Directorate and a working committee, which should undertake most of the work of preparing the documentation needed by the Board to reach its decisions.

417. An additional arrangement for facilitating the dissemination of information about IT 4 and for maintaining close contact with various centres of development and competence will take the form of reference groups, to be set up in the Autumn of 1987. Representatives will be chosen so as to create a network of contacts offering good coverage in terms of industries, geographical areas and different applications.

5. ESPRIT II

418. ESPRIT, launched in 1984, was planned from the beginning as a ten-year programme, with two five-year phases, the first of which was given a budget of 1.5 billion Ecu. During the period 1986-1987, two main developments have taken place regarding the Programme: the planning and approval of the second phase of the programme (ESPRIT II), and the integration of the Programme into the Framework of European Community activities in the field of research and development.

Framework

419. One of the activities affected by the 1986 Single European Act has been research and development, which has been given a more firm legal basis and closer association with other European Community objectives. Community R&D activities are now gathered together into an overall 'Framework', which is subject to unanimous agreement of member countries in the Research Council. After this approval the various sub-programmes ('action lines') such as ESPRIT are dealt with by majority voting.

420. It is intended that the Framework programme has a strategic function, of defining scientific and technical objectives, setting priorities and budgets, and setting out the main action lines. The budget is proposed by the European Commission.

421. Eight subject areas are covered by Framework; information technologies, quality of life (health and environment), telecommunications, broadcasting and transport, new technologies for industrial modernisation, energy, bio-technology, seabed exploitation, and 'a Europe for research workers'.

422. The ESPRIT Programme is seen as a particularly successful initiative, and under Framework it will broaden its pre-competitive research with a view to attaining the critical mass needed to enable European industry to recover its competitiveness on world mrkets by the 1990s. This will concentrate on three areas:

-- microelectronics and peripheral technologies;

-- data-processing systems;

-- applications technologies.

423. In addition, the Commission recommends that these activities be accompanied by intensified activities in the field of standardisation.

Approval Delays

424. A draft work programme for ESPRIT II was developed by the European Commission. Estimates of community contributions to ESPRIT II, amounting to 50 per cent of the total cost, are shown in Table 17. However, the approval process was delayed for a number of reasons. It is expected that 'a common position' will be adopted on ESPRIT II early in 1988.

Proposals

425. The Second Phase objectives remain similar to those of the first phase. It is proposed that more emphasis be placed on IT application technology and technology transfer, especially with regard to small and medium-sized enterprises.

426. While there is a continuation of the pre-competitive aspect of research and development, these are regarded by the Commission as elements in a demand driven strategy focussing on key market sectors. ESPRIT is seen as providing

Table 17

ESPRIT II COST ESTIMATES

Commitment Credits

M Ecu *

	1984/86	1987	1988	1989	1990	1991	1992	1993+	Total
Activities second phase (1987-1991)	-	-	263.5	465	404	137.5	330	-	1600
Activities first phase (1984-1988)	560	173.5	16.5	-	-	-			750
Grand Total	560	173.5	280	465	404	137.5	330		2350

Distribution of Resources per Sector

Activities second phase (1987-1991)									
1. Microelectronics & Peripheral Technologies	-	-	90	140	120	45	115	-	510
2. Information Processing Systems	-	-	83.5	140	126.5	45	115	-	510
3. IT Applications Technologies	-	-	90	185	157.5	47.5	100	-	580
TOTAL	-	-	263.5	465	404	137.5	330	-	1600

* Calculated on the basis of a 50% contribution to R&D projects. The resources for accompanying measures and personnel are allocated proportionally to the R&D sectors.

the foundation technologies for applications relevant to specific programmes such as RACE and perhaps EUREKA, thus exploiting the ultimate economic value of the research.

427. The three specific technological objectives which result from this strategy are:

- To enhance the capability in advanced components;
- To produce technologies and tools for systems design;
- To enhance the ability to use and integrate IT.

Each of these is reflected in the work areas shown in Table 17:

- Micro-electronics and peripheral technologies;
- Information processing technologies;
- IT applications technologies.

428. In each of these areas, a new feature has been introduced for ESPRIT II. Technology Integration Projects (TIPs) aim to achieve ambitious well-defined industrial targets, the rationale being that these can only be achieved at a multinational level (1). Special efforts will be made to ensure that TIPs remain truly pre-competitive and do not overlap with the activities of EUREKA.

6. EUREKA

429. The EUREKA programme was set up to encourage collaboration on high technology projects between European countries, both within and outside the European Community. As such it is a further layer in the network of collaborative programmes which include information technology among their interests. However, it has no pre-determined strategy to further its aim of strengthening the competitive position of European goods, processes and services in European and world markets. Its approach is basically "bottom-up". It is left to companies, universities, and private or public sector organisations to determine their particular interests and identify topics on which they wish to collaborate and seek prospective partners. They also are responsible for bringing these into effect as EUREKA projects with the assistance, both administrative and financial, of national governments concerned (and the European Commission when appropriate). The

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1) The list of TIPs includes: Integrated design and production systems; High-speed silicon integrated circuits; Non-volatile memory macrocells; Advanced system engineering environment; Parallel architecture for symbolic and declarative systems; Parallel architecture for high performance computers; Industrial automation; Integrated application support system; European OSI network environment.

EUREKA organisation facilitates these collaborations by helping to overcome some of the traditional barriers to trans-national co-operation, but it is up to individual organisations to initiate and pursue contacts with prospective partners as they see fit. EUREKA's function has often been described as one similar to a "marriage bureau". The EUREKA organisation has stressed that it is not intended as a substitute for existing European technological co-operation, such as those within the EC, COST, CERN, or ESA, but is intended to extend or supplement them.

430. The EUREKA Secretariat receives information from governments and circulates project proposals and expressions of interest to relevant national authorities who in turn pass this information on to firms and organisations. The flexibility of EUREKA enables additional partners to enter a project subject to agreement of existing partners. Obligations regarding disclosure of results may be set up to suit individual projects.

431. Procedures for reviewing projects seeking EUREKA support have been reduced to a minimum while criteria have been spelt out in some detail. There is also a provision for participation of entities from non-EUREKA countries in exceptional cases. EUREKA participants must find the funds they require themselves, either by commercial means or from public funds. Information technology, Robotics and manufacturing, and Telecommunications, represented respectively 25.0 per cent, 17.6 per cent and 7.4 per cent of total project numbers, as of July 1987.

EUROPE

EUREKA Criteria

The objective focus and criteria for EUREKA projects as stated in the Declaration of Hanover are as follows:

"EUREKA projects will serve civilian purposes and be directed both at private and public sector markets".

The Declaration continues to state:

1. "EUREKA projects will initially relate primarily to products, processes and services in the following areas of advanced technology: information and telecommunication, robotics, materials, manufacturing, biotechnology, marine technology, lasers, environmental protection and transport technologies.

   EUREKA will also embrace important advanced technology research and development projects aimed at the creation of the technical prerequisites for a modern infrastructure and the solution of transboundary problems.

2. EUREKA is open to all efficient capacities including those existing in small and medium-sized enterprises as well as in smaller research institutes, in which many of the innovative technological products and processes are initiated.

3. The exchange of technologies between European enterprises and institutes is a prerequisite for a high technological standard of European industry. EUREKA projects will encourage and enlarge this exchange.

4. EUREKA projects will satisfy the following criteria:

-- Compliance with the objectives set out above;

-- Co-operation between participants (enterprises, research institutes) in more than one EUREKA country;

-- Some identified expected benefit from pursuing the project on a co-operative basis;

-- The use of advanced technologies;

-- The aim of securing a significant technological advance in the product, process or service concerned;

-- Appropriately qualified participants -- technically and managerially;

-- Adequate financial commitment by participating enterprises".

The competent authorities will also establish that development work is performed in a prevailing amout within EUREKA countries and the results of the project are exploited to the benefit of EUREKA countries.

Recent Developments

432. The Ministerial Council meeting of 15th September 1987 announced 58 new projects, with an investment budget of 709 million Ecu, thus bringing the total to 165 projects and 4 000 million Ecu. More than 600 entities are co-operating within the initiative.

433. The meeting stressed its support for the creation of "a dynamic and homogeneous European economics space thereby favouring Europe's internal cohesion and external competitiveness". In this context they re-affirmed their support for initiatives aimed at attaining this goal, which is contained in the Single European Act adopted by the European Communities, and in the Declaration of Luxembourg, approved in April 1984 by the Ministers of the European Communities and the EFTA countries".

434. Within EUREKA, the Council "stressed the need to continue with (the supportive measures) aimed at removing the technical barriers likely to obstruct greater openness of the European high technology market and they re-affirmed their readiness to give special attention to those measures which are requested by participants in EUREKA projects ..."

435. A high priority has been given to efforts to set up a network for co-operation with financial organisations. Various initiatives have been designed to attract external private capital to EUREKA projects. Declarations of support for EUREKA and readiness to establish links have been made by various financial organisations, including the European Bankers' Round Table, Associated Banks of Europe Corporation, the European Venture Capital Association, and the European Investment Banks.

436. The Council also noted the European Commission's initiative aimed at providing transnational private capital investment in high technology through innovative financial engineering.

437. The EUREKA Database has now been set up within the Secretariat. This is a publicly available computerised database containing information on all EUREKA projects and proposals, provided by the national co-ordinators.

Emerging Issues

438. Several studies have been undertaken by EUREKA member countries:

-- The UK has carried out a pilot study of management development concerning technological change, in the EUREKA context;

-- The importance of collaboration between industry and research organisations has been studied under the chairmanship of Spain. An Italian seminar is to be organised on this subject;

-- Belgium proposed a study on juridical aspects of industrial collaboration in the R&D field, which was welcomed by the Council of Ministers.

439. The September 1987 meeting of the council determined that several features made it appropriate that the next meeting should review the overall progress of EUREKA, and the High Level Group is to prepare a report to the next Council of June 1988 on the achievement of goals so far, and future developments to be followed by EUREKA.

440. In the meantime, there seems to be some concern over the special problems encountered by small and medium-sized enterprises (SMEs) in achieving effective research, technology transfer, and exploitation. There is some scepticism as to whether the financial/funding methods adopted by EUREKA can allow SMEs to take advantage of the opportunities offered by the Programme.

441. The fear of increasing bureaucracy is also often expressed. The European Parliament, with its new expanded role concerning research and development under the Single European Act, now has a role in monitoring Community involvement in EUREKA. The Committee on Energy, Research and Technology has responsibility for this task. Naturally the involvement of the European Parliament has thrust all such programmes further into the political limelight, exposing and emphasising different opinions and approaches to EUREKA and its complementary programmes. There is a danger here that the multiplication of groups having interests in the work may become a bureaucratic (or political) restraint on progress. For example, though EUREKA has received the support of the European Confederation of Trade Unions, the

links between technological development, employment, and working conditions, may cause further European (and possibly national) monitoring, such as within the Economic and Social Committee of the European Parliament, again emphasising possible differences of political approach.

442. Finally, one additional issue relates to the feasibility of achieving an effective scale of collaborative R&D while at the same time maintaining competition. This dilemma is regularly raised with respect to EUREKA, as with other collaborative initiatives.

B. New Trends

443. Overall, the emerging pattern of government priorities and policies in the information and communications R&D area seems to bring to light four major orientations:

- The definition and implementation of new research directions;
- The reinforcement of structures and networks;
- The development of new "comprehensive" programmes;
- The growing importance of exploitation programmes.

444. These four orientations can be illustrated with a number of examples drawn from recent policy developments in a number of Member countries.

1. New research directions

445. New research goals have emerged, in particular, with respect to semi-conductors, artificial intelligence, bioelectronics, and telecommunications. Aside from research on supraconductivity which is expanding almost everywhere, research into these four areas seems to be undergoing the most significant changes.

Semiconductors

446. In the United States, on 30th March 1987, DARPA put out a contract worth nearly US$ 20 million for a test run of gallium arsenide integrated circuits. Meanwhile the DoD announced the launching of a research programme into GaAs MMIMICs (Micro and Millimetric Wave Integrated Circuits). Aid for the programme should amount to US$ 135 million. The areas concerned are:

- High-speed analog circuits;
- Low-noise circuits for communications and radar systems.

447. Also in the United States, the launching of the Terahertz project as part of the SDI demonstrates the renewed interest of the military in Josephson junction devices. The project is designed to study Josephson circuits in radar imaging and military systems, operating in the terahertz range. Placed under the control of the Rome Air Development Center, the Terahertz programme will receive US$ 3 million over three years.

448. The semiconductor targets for ESPRIT II have already been set: production of chips with logic circuits and at least 4 million gates; cutting development costs for certain systems by a factor of ten; integrated circuits (MOS with 0.7 micron line width, development of high-speed circuits containing at least 10 000 gates).

Artificial intelligence

449. MITI is setting up a joint AI machine utilisation centre to act as an "open house" for users and manufacturers. Germany has announced the opening in 1988 of a computer research centre in Kaiserslautern specialising in the design of AI programmes. To begin with and during the first few years, the centre will be financed by the BMFT to the tune of DM 5-10 million.

450. The EC is due to launch this year a programme aimed at developing artificial intelligence: Brain (Basic Research in Adaptive Intelligence and Neurocomputing). Brain appears to be Europe's answer to to the Japanese "Human Frontier" programme, still at the feasibility study stage.

Biocomputing

451. Japan already has a large-scale programme bearing on three areas:

— R&D programme (MITI) into devices of the future; eight Japanese corporations will join in a 10-year programme worth Y 5 billion;

— Brain function research programme under the auspices of the Agency for Science and Technology (AST);

— Programme ERATO (Exploratory Research for Advanced Technologies), also under the aegis of the AST.

Telecommunications

452. The new European satellite and telecommunications programme aims at developing and testing new technologies and telecommunications services. The PSDE (Payload and Spacecraft Development and Experimentation) programme covers the period 1986-1986. The first two stages (up until 1989) of the programme have been approved with a budget of 102 million ECUs.

2. Reinforcement of structures and networks

453. Information and communications technologies increasingly appear as one of the very few research sectors where new institutions are still being created and efforts are especially numerous to stimulate the development of trans-sectoral and trans-national networks.

Creating extra research capacity

454. In the United States, the NSF recently selected six universities, which will receive US$ 56.3 million over five years, to set up five new Engineering Research Centers. At least two out of these five projects deal essentially with information technologies: "Compound Semiconductors" and "Microelectronics".

455. In Japan, the newly formed Key Technology Center (KTC) is concerned with R&D development in the key areas of biotechnology, electronics, new materials and telecommunications. The KTC operates under a unique statute that allows for private management of government R & D money. The Center's major objectives cover start-up aid to R&D firms, the granting of standby loans, and invitations to foreign researchers.

456. In Germany, in the wake of the Queisser Report recommending an increase in the number of scientists from 1 700 to 3 000 in the IT field in order to help bring the country back to world competitive level, the Mathematics and Data Processing Society (GMD) will consolidate and expand its activities: establishment of high-power calculating centres, creation of 850 top-level posts. The cost of the various measures will be DM 170 million.

<u>The Development of Research Networks</u>

457. The long-term development of networks of collaborative R&D programmes in IT is continuing, most apparently in Europe. National networking efforts are being stepped-up in a number of countries, as noted above with respect to the German, the Norwegian, and the Swedish IT programmes. The increasing competitiveness of the world IT market, together with the advantages offered by large scale production, has left the relatively small European companies and countries in a vulnerable position.

458. The creation of a European Community unified market, which is due in 1992, is one approach which should improve the European position, and moves are being initiated to include non-EC European countries in various programmes.

459. The counterpart of this in the IT sector is the unification of EC R&D programmes in the Framework. This has both supply-side and demand-side impacts, increasing the scale of research collaboration and allowing a wider market to be addressed, for example by means of <u>standards</u> projects.

460. Though the general tendency has been for programmes to move their foci nearer the market, there is a limit to the extent that this is possible, because unless overall resources are increased, the marked-led work is at the expense of more basic long-term work. Governments are becoming more critical of the value of research support, and the crucial factor here is increasingly the effectiveness of <u>exploitation</u>. In this context, the approach followed by the Norwegian Action Programme, with its emphasis on regional development, takes on particular significance.

461. The links between the various 'layers' of networks are being improved. Alvey and ESPRIT work is being co-ordinated to prevent duplication, ESPRIT and EUREKA are also subject to scrutiny to avoid the same problem.

462. The result of the Framework will also be an increased level of co-ordination between ESPRIT and non-IT R&D programmes, again increasing the strength and coverage of the evolving network in Europe.

463. The stepping up of research capacity will also entail more extensive co-operation between the United States and Europe. For example, the JESSI Group (Thomson CSF, Siemens and Philips) has asked to take part in SEMATECH (<u>Semiconductor Manufacturing Technology</u>).

3. Development of comprehensive programmes

464. The potential for application of information technology in practically all spheres of activity, coupled with the increasing integration of information and communications technologies, provide a strong rationale for the design of comprehensive programmes which will attempt to take the broadest view in the definition of the research goals we well as in setting the stage for far-ranging applications.

465. The Japanese programme "Human Frontiers", which embraces such ambitious subjects as life control, molecular component devices, electronics and new materials, has taken a first step towards realisation with the Technopole "Kansai Riken" project. The financial needs are estimated at Y 70-80 billion.

466. In the telecommunications area, Japan provides another example, under the Ministry of Posts and Telecommunications, of a broad research programme designed to explore a whole technological frontier.

JAPAN

R&D PROJECTS TO BE PROMOTED THROUGH PUBLIC SUPPORT

1. Broad-Band ISDN and Advanced Service Technology Aiming at Establishing the Communications Infrastructure

-- R&D for optical communications technology;
-- R&D for broad-band exchange and network technoogy;
-- R&D for space communications technology;
-- R&D for mobile communications systems;
-- R&D for high definition television technology;
-- R&D for broadcasting technology;
-- R&D for CATV technology;
-- R&D for software;
-- R&D for frequency resources;
-- Other forms of R&D.

2. "Frontier" Technology Targeting Intelligent Communication

-- R&D for intelligent communications processing technology;
-- R&D for automatic interpreting telephony systems;
-- R&D for stereoscopic images;
-- R&D for application of biomechanism to communication systems;
-- R&D for new materials and functional elements;
-- R&D for future communications media.

3. Universal, Interdisciplinary Technology Targeting the Harmonious Integration of Telecommunications, Society and the Individuals

- R&D for man-machine interface;
- R&D technology for assuring network safety and reliability;
- R&D for electromagnetic environment technologies;
- R&D for the improvement of regional districts.

(Ministry of Posts and Telecommunications, Research and Development Guidelines for Telecommunications Technology, Tokyo, 1987)

467. In Germany the report "Informationstechniks 2000" lays the foundations for BMFT information technology policies in the coming years. The policy should in principle be built around three main themes: market, applications and production; know-how; capital.

4. The growing importance of exploitation programmes

468. The advances of technological research provide new capabilities, but their full potential in many areas can only be realised through the development of exploitation programmes matching requirements which become more and more sophisticated. Thus, the crucial importance of exploitation programmes has already been noted in connection with the SDI in the United States. Similar requirements are increasingly felt to emerge in the civilian sphere.

469. In Europe, there is talk of launching information technology applications programmes to cash in on the achievements of ESPRIT: Delta (education), Drive (road safety), Biceps (biomedecine), and Dime (electronic funds transfer). The Commission attaches great importance to the last of these programmes, which involves a European market worth FF 5.5 billion (80 million cards and 400 000 terminals).

470. It is also evident that the main exploitation programme handling the results of ESPRIT is the programme Race.

BIBLIOGRAPHIE/BIBLIOGRAPHY

Arnold, E., An overview of Policy initiatives in the United States information Technology Sector, SPRU, Sussex, 1987.

Arnold, E., Computer Aided Design in Europe. Sussex European Papers No. 14, Brighton, Sussex European Research Centre.

Arnold, E., and Guy, K., Parallel Convergence : National Strategies in Information Technology, London, Frances Pinter, 1986.

Ayres, R., Future trends in Factory automation, IIASA, Luxembourg, 1987.

Bardon, M., and Curtis, K., A National Computing Environment for Academic Research, prepared under the direction of Marcel Bardon by the NSF Working Group on Computers for Research, Kent K. Curtis, chairman, Washington DC, National Science Foundation, juillet 1983.

Bell, Trudy E., 'The Decision to Divest : Incredible or Inevitable ?', IEE. Spectrum, novembre 1985.

Benchimol, G., "Segmentation du marché des circuits intégrés à la demande" CPE bulletin, n° 38, 1987.

Borrus, M., Bar, F., Cogez, P., Thoresen, A.B., Warde, I., and Yoshikawa, A., Telecommunications Development in Comparative Perspective : The New Telecommunications in Europe, Japan and the US, BRIE Working Paper, University of California, Berkeley, 1985.

Botkin, J.R., Dimanescu, D., Stata, R., with McClellan, J., Global Stakes : The Future of High Technology in America, Cambridge, Mass., Ballinger, 1982.

Braun, E., MacDonald, S., Revolution in Miniature, 2nd ed., Cambridge, Cambridge University Press, 1982.

Brueckner, L., Borrus, M., Assessing the Commercial Impact of the VHSIC (Very High Speed Integrated Circuit Program), BRIE Working Paper, University of California, Berkeley, 1984.

Burger, R. M., Sumney, L. W., 'VLSI Research in the USA', Future Generation Computer Systems, vol. 1, no. 1, pp. 31-38, 1984.

CEP (Council on Economic Priorities), The strategic Defense Initiative : Costs, Contractors and Consequences, New York, CEP, 1985.

Chaudari, P., "Les semiconducteurs et les matériaux magnétiques", Pour la Science, Paris, 1986

Chorafas D., Engineering productivity through Cad/Cam, Butterworths, London, 1987

Cohendet, P., Lebeau, A., Choix stratégiques et grands programmes civils, Economica, Paris, 1987.

Committee on Assessment of the DoD Very-High-Speed-Integrated-Circuit (VHSIC) Program, An Assessment of the Impact of the Department of Defense Very-High-Speed Integrated Circuits Programme, Washington DC, National Materials Advisory Board, Commission on Sociotechnical Systems, National Research Council, Publication MMAB-382, National Academy Press, 1982.

Committee on Computer-Aided Manufacturing in 1979, Annual Report to the Air Force Systems Command, US Air Force, Washington DC, National Academy of Sciences.

D.T., 'Legislation of Cooperative R&D Efforts in the USA', Fifth Generation Computer Systems, 1(1), 1984.

Defense Science Board Task Force on Export of US Trchnology, An Analysis of Export Control of US Technology : A DoD Perspective, Washington DC, Department of Defense, Office of the Director of Defense Research and Engineering, 4 février, 1976.

DiMaggio, C., Davey, M.E., The Strategic Defense Initiative Institute : An Assessment of DoD's Current Proposal, 86.830 SPR, Washington DC, Science Policy Research Division, Congressional Research Service, Library of Congress, 1986.

Eden R.C., Livingston A., Welch B., integrated circuits : the case for gallium arsenide, IEEE Spectrum, Washington D C., 1983

Evanzuk S., Beresford R., Godin R., "VLSI takes over many kinds of fast subsystems", Electronics, 1983.

Fantin M., "Circuits intégrés : les promesses des rayons x, La Recherche, n°190 1987.

Fix-Sterz J., Lay J., The role of FMS in the framework of new developments in production engineering, Convegno CEE, Torino, 1986.

Fleck, J., 'Development and Establishment in Artificial Intelligence', in Norbert Bass, Herminio Martins and Richard Whitley (eds), Scientific Establishments and Hierarchies, Sociology of the Sciences, Vol. VI, 1982, pp. 169-217.

Foray D., Les politiques de soutien au développement et à la diffusion des technologies de l'information. L'exemple de la RFA, document non publié, 1987

Fox, G., Messina P., "L'architecture des futurs ordinateurs", Pour la Science, 1987

Furk J., The potential societal benefits from developing flexible assembly technologies, Caregie Mellon University, 1986

Gold, B., "Perspectives on continuing advances in automation : past limitations and emerging potentials, "Technovation, 4, 1986

Hildreth, S.A., Maroni, A.C., The Strategic Defense Initiative : Programme Facts, Issue Brief No. IB85170, Washington DC, Science Policy Research Division, Congressional Research Service, Library of Congress, 1986.

Horton, R., The US Gouvernment's Role in R&D for the Information Technology Industry, London, Overseas Technical Information Unit, Department of Trade and Industry, 1986.

House of Lords, Department of Trade and Industry (DTI), Memorandum to the House of Lords Select Committee on Overseas Trade: Support for the IT Industry and Priorities in Government Policy, 1985.

ICOT, Report on the vision on AI, AI Center, 1984.

Immonen, P., "Development trends of electronic components", Sahkö, 56, 1983

Irwin, M.R., Telecommunications and Government: The US Experience, paper presented to ESRC Conference on Comparative Government-Industrial Relations, Cambridge, December 1985.

Jacky, I., 'Ada's Troubled Debut', The Sciences, January/February, 1987.

Johnson, T., Durham, T., Parallel Processing : the challenge of new computer architectures, Ovum Ltd, London, 1987

Jowett, P., Rothwell M., The economics of information technology, Macmillan, London, 1986

Lafaille A., Stratégies nationales d'automatisation, CESTA, Paris, 1983

Landes, David, S., The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present Cambridge University Press, 1969.

Lichtenberg, F.R., The Impact of the Strategic Defense Initiative on US Civilian R&D Investment and Industrial Competitiveness, Columbia University, 1988, unpublished manuscript.

Lighthill, (The Lighthill Report), Artificial Intelligence: A Paper Symposium, London, Science Research Council, 1973.

Lyman J., "Scaling the barriers to VLSI's fine lines" Electronics, 1980.

Mackintosh I., 'Micros: The Coming World War' in T. Forrester (ed.), The Microelectronics Revolution, Oxford, Blackwell, 1980, pp.83-102.

Mayo J., "Le rôle de la microélectronique dans les télécommunications". Pour la Science, n° spécial, 1986.

Meindl, J., "Les puces de l'informatique de demain", Pour la Science, 1987

Miller, N.R., Supercomputers and Artificial Intelligence: Federal Initiatives. Issue Brief N° IB 85105, Washington DC, Science Policy Research Division, Congressional Research Service, Library of Congress, 1986.

Minutes of Evidence before the House of Lords Select Committee on Overseas Trade, 27 February 1985.

Mizrahi J., L'échiquier de l'électronique, Hachette, Paris, 1986.

Mowery D., The diffusion of new manufacturing technologies, Carnegie - Mellon University, 1986.

Nelson, R.R., Governmental and Technical Progress: A Cross-Industry Analysis, New York and Oxford, Pergamon Press, 1982.

Noyce, R.N., 'Competition and Cooperation: A Prescription for the Eighties', paper presented to the fall meeting of the Industrial Research Institute, October 1981; reprinted in Research Management, March 1982, pp. 13-17.

Norris, W.C., 'A Blueprint for Technological Cooperation", Economic Impact, No. 51, 1985-6 pp. 74-7 ; reprinted from Issues in Science and Technology.

NRC (National Research Council), Advanced Processing of Electronic Materials in the United States and Japan, Washington DC, National Academy Press, 1986.

OCDE, Les logiciels : l'émergence d'une industrie, Paris, 1985./OECD, Software an Emerging Industry, Paris, 1985

Ohman F., Reliability in electrical and electronic components and systems, Eurocan 82, Copenhague, 1982.

Ohman F., Reliability in electrical and electronic components and systems, Eurocan 82, Copenhague, 1982.

Osborne A., Running wild - the next industrial Revolution, Mc. Graw Hill, 1979

OTA (Office of Technology Assessment), Information Technology R&D: Critical Trends and Issues, OTA-CIT-268 Washington DC, US Government Printing Office, 1985

OTA (Office of Technology Assessment), Microelectronics Research and Development - A Backround Paper, OTA-BP-CIT-40, Washington DC, US Government Printing Office, 1986.

OTA (Office of Technology Assessment), Supercomputers: Government Plans and Policies - A Backround Paper, OTA-BP-CIT-31, Washington DC, US Government Printing Office, 1986.

Ranta , J., Hienonen R., Palmen H., The impact of component technology development on electronic industry, Technical Research Center of Finland 1984

Reppy, Judith, 'Defense Department Payments for "Company-financed" R&D', Research Policy, vol.6, 1977, pp. 396-410.

Rosenberg N., "The economic implications of the VLSI revolutions", Futures.

Schaefer, Eric R., Information Technologies in the United States (mimeo)

SCP (Strategic Computing Program), Second Annual Report, Washington DC, DARPA, 1986.

Spriano G., Esprit : an attempt at policy evaluation, Center For European Policy Studies, Bruxelles, 1987.

SRC (Semiconductor Research Corporation), Annual Report, 1984.

SRC (Semiconductor Research Corporation), Annual Report, 1985.

Steinmueller W., "Revolutions", Futures, 1980.

Stowsky, J., Beating our Plowshares into Double-Edged Swords : The Impact of Pentagon Policies on the Commercialization of Advanced Technologies, BRIE Working Paper, University of California, Berkeley, 1986.

Tchijov A., FMS state of art and development, ASAZ, 1987.

Zysman, John et Tyson, Laura d'Andrea, US and Japanese Trade and Industrial Policies, BRIE Working Paper, Berkeley, Calif., Berkeley Roundtable on the International Economy, 1984.

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