Appendix G

European Organizations and Policies for Research and Technology

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Appendix G
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INTRODUCTION

This appendix focuses on the approaches European government and multilateral groups employ in sponsoring research and technology. Among the countries reviewed are the United Kingdom, France, West Germany, Italy, Sweden, the Independent European Program Group (IEPG) and the European Community (EC) have been studied. The following country summaries and concluding review of collaboration contain some "themes" that may apply to the U.S. Department of Defense's Science and Technology operating concepts.

Overall Findings

1. There appears to be a trend for governments to reduce funding for defense research and technology (R&T) and to place more emphasis on broadly based (civil) research. Industry, in turn, is expected to introduce new technology into defense products and systems at the "applications" stages.
2. Civil research programs are increasingly established as "national (or strategic) goals." Although specific projects retain some latitude, the trend is toward more central direction and control. Financial control from the top is becoming the norm.
3. Although there is a widespread demand that governments receive "value-for-money" in research, "peer review" remains the standard method of assessing results. Several nations are examining more elaborate schemes,
4. Research costs are prompting nations toward both rationalization and collaboration. In the case of rationalization, separate research activities are being merged, with "centers of excellence" becoming a common means to assemble sufficient scarce resources to make headway in selected (strategic) technology areas. Collaboration has also become a way of life for governments, companies, and academia. The Single European Act, creating a single economic entity in 1992, is giving this trend an added push.
5. Universities appear to play a major role in both formulating and executing national research policies. A significant percentage of national R&T budgets goes into academia, with strong links encouraged between universities and industry to effect "technology transfer."
6. There has been some backlash, especially among those European industrialists who question the wisdom of emphasizing technology-based industrial growth. Their dominant concern is that Europe take care to invest in technologies that are new and unique, rather that continue to "chase" the United States and Japan for a share of today's markets.
7. Most countries view space research as a major area for R&T funding. It appears that this area has replaced defense as a "locomotive" for research, providing potentially lucrative spin-offs for commercial market exploitation. In the view of industry, however, these expectations have not materialized.

1992 and the Single European Act

Overview

Europe's potential can be summed up by the date 1992, when Europe is to become a true common market. A campaign that began with the original commitment establishing the European Economic Community aims to propel its 12 nations[1] toward a common market in which goods, people, services, and capital could move unrestricted among member nations.

1 Ireland, Britain, Portugal, Spain, France, West Germany, Belgium, Luxembourg, Holland, Denmark, Italy, and Greece.

Background-In the early 1980s Europe, with decreasing revenues and high employment, found itself lagging in comparison with America's and Japan's strong economic positions. In 1985 the new EC President, Jacques Delors, a former French finance minister, toured the member states and found growing support for a renewed campaign for a true European market. Lord Cockfield, a British Conservative ex-businessman, was the EC Commissioner charged with drafting a White Paper on the subject. He drafted a list of 300 initiatives that would be needed to produce a wholly unified European market.[2] Cockfield laid out an accompanying timetable to accomplish these initiatives over the next two EC Commissions' 4-year terms (1985-88; 1989-92). The target completion date was the end of the second term—December 31, 1992.

Although 20 or more of the original 300 initiatives have since been dropped or replaced, the magic round number represented all that European governments wanted. They accepted the challenge and passed the Single European Act, which became effective on July 1, 1987. This Act states:

> The Community shall adopt measures with the aim of progressively establishing the internal market over a period expiring on 31 December 1992 . . . The internal market shall comprise an area without internal frontiers in which the free movement of goods, persons and capital is ensured in accordance with the provision of the Treaty.

Member Nations Support-Of the 12 member nations, France embraces 1992 with the most passion, with polls showing that more than 70 percent of French companies regard "quatre-vingt-douze" as a golden opportunity. This attitude was promoted by a new French Government that despises old French habits of "dirigisme." West Germany's industrial giants are also eagerly awaiting 1992. The large chemical companies-Bayer, Hoechst, and BASF—are confident that no one can beat them in a free market. Italy's industries, such as Olivetti, are leading their government in supporting 1992 concepts. Some say this is a timely accompaniment to an Italian industrial trend to create Europe-wide business empires. Some of the medium-sized companies are less optimistic, and smaller nations are resigned to accept what they cannot control.

The biggest surprise is the United Kingdom, which could benefit the most from a free market (especially in the areas of finance and insurance). A 1988 survey by the accounting firm of Ernst & Whinney found that fewer than 40 percent of British company directors were aware of 1992 plans in the EC. In financial services, an area where Britain should dominate, fewer than 30 percent of companies had planned for the 1992 goals. However, British businessmen have launched a Club 1992 to discuss the implications of a single market, and the government is promoting a publicity campaign in support of 1992. Prime Minister Thatcher now insists, "It is not a dream. . . it is for real, and it is only five years away."[3]

Other European Nations-Outside the EC, the six countries of the European-Free Trade Association (ElTA),[4] fear that they are going to lose their "good deal.'* Each has a free-trade agreement with the EC, permitting duty-flee access to EC markets and vice versa, without having to share in the cost of supporting the EC's farm policy. They fear that once 1992 arrives, they will become outsiders; to prepare themselves, they are now modifying their relations with the Community. Although the neutrality issue keeps Sweden and Switzerland from joining the EC, Austria may apply for Community membership sometime in the 1990s. Unencumbered by neutrality, Norway may ask to join after its 1990 elections. But the EFTA ministers have already called for a proper system of consultation between the two groups, and are ready to cooperate with the community in new fields of industrial research, the environment, and education. They hope to create a "single European economic space" (without agriculture, of course) that would encompass a Western Europe of 18, not 12, members.

Japanese Actions-Scores of Japanese corporate planners are visiting Europe to analyze the 1992 phenomenon. It appears that Japan, viewing the EC as "safer" than the protection-prone American market, is turning its export focus towards Europe. Japanese firms such as Nissan, NEC, Fujitsu, and

[2] Commission of the European Communities, "Completing the Internal Market," A White Paper prepared for the European Council, COM (85) 310 Final, Brussels, June 14, 1985.

[3] M. Thatcher to British businessmen, reported in *Christian Science Monitor,* June 27, 1988, p. 111.

[4] Switzerland, Austria, Sweden, Norway, Finland, and Iceland.

Toshiba are targeting direct investments to two or three EC countries, building factories from which they aim to serve the whole Community. They are watching the European market closely, ready to grab any opportunities as frontiers come down.

Fearing the economic strength of a Washington-Tokyo connection, many EC members believe direct Japanese investment in the EC could enliven the European economy-as American multinationals did when they set up European plants in the 1950s and 1960s. To do this, however, Japanese firms in the Community would have to become part of the local economy; they would have to transfer technology from Japan to Europe and buy more components from European suppliers. They would have to abandon their current practice of setting up "screw-driver plants," in which the final product is largely made up of parts imported from Japan.

EC and the COMECON-The EC and the Soviet-led economic bloc COMECON (Council for Mutual Economic Assistance) signed a joint declaration of mutual recognition on June 25, 1988. This will boost trade and economic ties with COMECON and enable the EC to open diplomatic relations with individual COMECON members.

With a potential market of more than 400 million consumers, COMECON traded a total of just under $50 billion with the EC in 1987. EC officials view the East Bloc as a highly underdeveloped market for exports. They are watching closely to see if *glasnost* will succeed, and whether that will open the way for increased trade opportunities with the East Bloc.

Analysis

Economic 1rnplications-Dissolving the frontiers of the European Community means that all 12 countries will be using just one passport, stamped EC, with the EC symbol (a circle of 12 gold stars on a blue background) on the front. Individual country citizens will now be EC citizens-able to live anywhere in the EC they want, able to practice their profession in any of the 12 countries, able to retire to any EC area they desire.

However, the true impact of the Single European Act will be economic. A recent study, "The Cost of Non-Europe,"[5] estimated that the customs costs attributed to border delays and trade barriers might run as high as 8 billion ECUs[6] to firms and 1 billion ECUs to governments. This study supports the long-held belief of many European industrialists that the governments' nationalistic policies have retarded the growth of strong, world-class companies in Europe.

Given such savings, calculation indicate that 1992 lifting of frontiers could result in an increase of up to 7 percent in gross domestic product (GDP) and 5 million new jobs.[7]

The Market

Selling to a Single Market—For business, the single market is welcome. The EC estimates there are more than 100,000 technical regulations and standards (most often in high-tech sectors) where market fragmentation places Europe at a major competitive disadvantage vis-a-vis American and Japanese competitors. In electronics and engineering, the different requirements will be reduced or eliminated. For the Netherlands-based electronics giant Philips, it means making one kind of television set instead of 12. For the transportation companies, who face appalling obstacles of frontier documentation and corruption, it means cutting delivery time and costs in half.

What it does not mean is marketing a product in the same way. If the companies are to be competitive, they will have to shift their emphasis to an expanded market outside their national boundaries. In this respect, the larger EC companies already have an edge. Accustomed to different marketing strategies for different areas, the larger conglomerates show no fear in the face of 1992; they have subsidiaries in many countries. It is the smaller and middle-sized companies of the EC member nations that are going to have to play "catch-up" in marketing strategies in general (with a "pan-European" flavor specifically)-an area where they may lack experience.

[5] Commission of the European Communities, "The Cost of Non-Europe: Basic Studies" (vol. I), 1988.

[6] The European Currency Unit (ECU) is the unit of accounting used by the EC. Its value is set by a basket of European currencies. 1 ECU= US $1.23. (November 1987 ratio).

[7] Commission of the European Community, "'he Economics of1992," No. 35, March 1988.

European Industrial Mergers—The problems that small and medium-sized European firms anticipate have generated several hundred industrial mergers since 1985. These mergers are especially significant in the software industries. The CAP group, a British software and services company, has announced a merger with France's Sema-Metra to form Semacap. There was a similar deal between two British companies, Systems Designers and Scicon, the latter of which also has interests in France, West Germany, and America. *These mergers create companies that can sell in the American market and compete with American companies in the emerging pan-European software business. The two* new companies, Semacap and SD-Scicon, are now rated second and third, behind Europe's premier software firm, Cap Gemini Sogeti of France. The thinking is that pan-European software companies stand the best chance of winning contracts from European giants in retailing, communications, and financial services.

With estimates that the European software and services market will grow from under $50 billion today to about $250 billion by 1996, competition between American and European companies is now likely. In the past, Europe's software market has been fragmented by language and culture; now, more companies are becoming international. And as information technology becomes more complex, customers are turning to "one-stop shopping," rather than assembling a different package themselves. Although vendors are now adopting international standards that make it easier for computers to talk to each other, the large American computer firms should continue to hold the edge in Europe for a while-unless they fail to adapt.

A hostile takeover bid for the Belgian conglomerate Société Générale de Belgique in early 1988 represented, for some, the downside of 1992 economics. The Italian financier Carlo de Benedetti, who finally settled for a minority interest in Générale (plus a stake in the French financial group Suez and a $1 billion profit), works as if 1992 already exists. One of his aides explained it: "He says if he is really a European there is no reason, for instance, [not] to meddle in French politics. We are all part of the same country."[8] The recent GEC/Siemens bid to take over Plessey and Plessey's countermove with Thomson-CSF and possibly AT&T are other examples of how the "takeover game" is heating up. The effect on Europe's defense technology base will be profound, but is yet uncertain.

Public Procurement-The buying of goods and services by national and local governments and public and private utilities amounts to about one-sixth of the EC's GDP. Strong nationalist interests have resulted in an abundance of duplicative production: 11 EC telephone exchange manufacture, 10 turbogenerator manufacturers, etc. Although the EC has been compelled to put large construction contracts (anything over 1 million ECUs) out to Europe-wide tender since 1971, and to do the same with other large purchasing orders (above 200,000 ECUs) since 1977, just 2 percent of orders in each category go to other European countries.

There are four main aims of the procurement part of 1992:

1. to broaden the scope of, and block loopholes in, existing obligations;
2. to give the EC greater police powers over regulations;
3. to improve redress procedures for disappointed offerors; and
4. to extend open procurement to businesses that have remained exempt until now (energy, transport, water, and telecommunications).

Impact on NATO and European Defense— Members of the EC include all European NATO members except Iceland, Norway, and Turkey. Only one EC country, Ireland, is not a member of NATO. Although the EC charter maintains that the Community is an economic body uninvolved in defense matters, anticipated changes are so broad that almost all aspects of European defense operations will feel their impact.

Like most EC officials, European defense ministers resist the 1992 changes out of a reluctance to surrender the political power they now hold. However, European economic unity may require the establishment of central procurement agencies, such as those the Independent European Program Group is now studying for defense purposes. More centralized research and development will be necessary to avoid duplication and cut costs. A European R&D agency like the U.S. Department of Defense's

[8] "Businessmen: They Grow Than Bigger Now in Europe," *The Christian Science Monitor,* June 28, 1988, p. 118.

Defense Advanced Research Projects Agency (already recommended by the 1986 IEPG report, “Towards a Stronger Europe"[9]) could assist in expanding a European technology base. Multilateral European projects like the European Fighter Aircraft, will have to change their form to accommodate the economic realities of a single European market. International consortia will compete for European defense contracts without the added burdens of different national policies (e.g., financial, industrial, etc.)—and the implications for U.S. defense/aerospace firms will be significant.

Impact of Advanced Technology-Accompanying Europe’s concern about its economic position in world trade is a heightened sense of concern about its technological future. Many papers have focused on this issue, with some suggesting that Europe’s problems lie in the failure to organize properly for exploiting innovations with commercial potential.[10] Many European companies still rely on home markets or operations dedicated to each national market. Breaking down the barriers that have isolated European companies from each other, as well as from other European national markets, is an explicit objective of the collaborative high-technology initiatives now being pursued. Breaking down these same barriers is also a goal of the Single European Act.

In pursuit of technological achievements, the EC has agreed to spend 5.2 billion ECU on R&D collaborative programs over the next 5 years. Within that framework are several individual spending lines, including information technology, advanced telecommunications, biotechnology, alternate energy sources, environmental research, and nuclear safety. These subjects have their own specific research programs such as ESPRIT, RACE, and BRITE. In principle, the EC supports, but does not fund, EUREKA, a separate program approaching $5 billion in value. All of these advanced research programs support Europe’s 1992 goals.[11] European advanced-technology collaborative efforts are bound to help Europe succeed in meeting the challenge of the single market-and to compete in world markets.

Problem Issues

Trade Barriers and National Subsidies-Article 115 of the White Paper[12] allows governments to bar imports of non-EC goods “entering” in indirectly through another member country. If Article 115 were abolished, France and Italy, for example, would want higher trade barriers against imports from outside. Otherwise, they argue, non-Europeans will be the main beneficiaries of a single market. The West Germans and the British point out that, for maximum benefits, external trade policy should produce a lower rather than higher level of overall protection.

The EC has to come to terms, not only with trade barriers, but with the issue of national subsidies, which are quite high in some countries. Stiff rules against subsidies must accompany the removal of trade barriers, if the full benefits of a single market are to be realized.

A Central Bank—The financial community will gain from the completion of the internal market in 1992. Peter Sutherland, the Commissioner responsible for competition policy in the European Community, believes that the financial sector will benefit more than others, with gains exceeding $30 billion annually .13 Presently, there is a wide variety of service charges levied by banks and insurance companies. These charges will probably be reduced and brought into line with one another, so that consumers can make payments anywhere, thanks to truly European credit cards.

Changes in the European Monetary System are being made, and there are already discussions on establishing a new central bank for Europe. Yet plans for this “Bank of Europe” must go hand in hand with a common currency; more and more businessmen are now using the “ECU” as a unit of accounting in their European operations. A central bank with a common currency would bring about monetary stability in Europe, as it merges EC

[9] Independent European Program Group, "Towards a Stronger Europe," vols. I and II (Brussels, Belgium: NATO Headquarters, 1987).

[10] See for example, Commission of the European Communities, op. cit., footnote 5.

[11] See Commission of the European Communities, op. cit., footnote 7.

[12] Commission of the European Communities, op. cit., footnote 2.

[13] "Window on the European Community," in "A Letter From Europe: A Monthly Update on the European Community From Its Delegation in Washington," No. 51, June 14, 1988, p. 4.

members into one economic unit. The microeconomic benefits that would result from a single market-no border delays, greater efficiency thanks to larger markets, and more effective competition-would be multiplied by a single currency. A macroeconomic gain could also be achieved. With monetary policy no longer under national political influence, reckless spending would give way to financial stability and lower inflation.

The EC summit meeting in Madrid in June 1989 will review the report and recommendations of EC committees studying monetary policy. Since the committee is headed by France's former Finance Minister Jacques Delors, who has just been reappointed to the EC Presidency for another 2 years and is the prime driver in the movement toward 1992 goals, it is anticipated that the meeting will recommend a central bank and a common currency.

Value-Added Tax-One of the biggest problems the EC will have to overcome is the wide variance in member nations' value-added tax (VAT) (similar to a sales tax). Current variations range from O to 33 percent. In a frontier-free economy, this variation would allow citizens to go shopping across the border where prices were cheaper. The EC has proposed two bands of VAT: a standard rate of 14 to 19 percent and a rate of 4 to 9 percent for "necessities."

Conclusion

"Fortress Europe''—Many Americans fear that 1992 will mean a "Fortress Europe''-impenetrable to outside competitors. Europeans officials loudly proclaim "No!" "If Europe is strengthened internally," says Lord Cockfield, "there will be less fear, less need for trade protection, not more."[14] "We are each other's biggest and best customers," says EC Commissioner de Clercq. However, accompanying those reassuring words is an underlying message that Americans should heed—because the Commissioner goes on to say: "The Community . . . will actively share (benefits) with *those who are willing to cooperate with us."*[15] *The* downside of 1992 is that Europe intends to be stronger, more competitive— a potent rival in world trade and a hard negotiator in trade talks. Reciprocity will be a key to dealing with the Europe of 1992.

The United States is currently the EC's largest trading partner-about $133 billion in 1986, $53 billion of which consisted of American exports to the EC (double the value of American goods sold to Japan). However, Americans are still wary of potential European protectionism. Alfred Kingon, U.S. Ambassador to the Community cautions: "When I speak to EC leaders, I receive reassurances that the Community will not become 'Fortress Europe'. But when I hear talk of 'nurturing' industries, I become concerned."[16]

U.S. Industry-Segments of U.S. industry are gearing up for 1992. Giants like IBM, Ford, and AT&T have set up planning groups to develop strategy. As things stand, both their subsidiaries in EC countries and teaming efforts with European companies place them in a strong position-IBM has subsidiaries in every EC country; Ford operates assembly plants in six European nations; and AT&T is in partnership with Olivetti of Italy, Philips in the Netherlands, and Telefonica in Spain. *Inside-Europe sales by U.S. subsidiaries dwarf U.S. exports to* ***Europe: $500 billion*** *in 1987 compared to $75 billion in U.S. exports to Europe. They are* ready to seize the opportunity to sell to this unified market of 320 million people. On the other hand, the "smaller" American companies will feel the competition, as the European companies grow larger and stronger through mergers and acquisitions and expand their "target" areas, venturing into countries previously closed to their sales.

U.S. companies' ability to compete with a unified Europe-and Japan-in global markets will require new attitudes and strategies. In an intense international economic competition, technological isolationism is not an option. Markets are becoming increasingly international and information flows worldwide despite restrictions imposed by government or industrial organizations. A recent study by the National Academy of Engineering (NAE)[17] suggested that better focused efforts are needed for

[14]"Setting Sights Boldly on *Unity," Christian Science Monitor,* June 27, 1988, p. 10.

[15]"U.S. Begins Assessing Impact of 1992 Deadline," *Europe, May* 1988, p. 15.

[16]"Toward Real Community," *Time,* Apr. 18, 1988, p. 55.

[17]National Academy of Engineering and Office of International Affairs, "Strengthening U.S. Engineering ~ @ International Cooperation: Some Recommendations for Action. " (Washington, DC: National Research Council, 1987).

the United States to remain a leader in world markets. There needs to be a new level of international collaboration on technological issues and an increasingly international outlook of major corporations. Once again, it is the small and medium-sized companies that are at a disadvantage. Most of them lack the resources of large companies for accessing international markets and technical developments. "Banding together" must become commonplace-and government policies must be set to encourage this process.

U.S. Government-Industry alone cannot be responsible for U.S. international competitiveness. In a 1988 report, an NAE committee on technology issues that affect international competitiveness[18] outlined several areas in which U.S. Government policies must respond to the global challenge. There must be, the committee said, a reassessment of the Federal Government's role to support and enhance U.S. competitiveness. There must be government policies that stimulate industry to create new products and improve productivity. A climate must be created for the early development of innovative technologies, as well as for promoting industry consortia and joint government/industry/academia cooperation. In a 1992 environment, U.S. protectionist policies will only hamper U.S. efforts in an increasingly competitive global market.

U.K. POLICY FOR RESEARCH AND TECHNOLOGY

Background

Civil v. Defense R&D Trends

Throughout 1986 and 1987, the U.K. *S policies for R&D were subjected to intense scrutiny by the British Govemment, Parliament, industry, and the scientific community. In mid-1987 the government published its plans for sweeping changes in the management and funding of R&D in the United Kingdom, including a restructuring of university science programs.[19] The proposal, which p1aced a strong emphasis on exploiting the economic potential of research, were drawn up after sharp criticism earlier that year from a House of Lords Select Committee of the Government's $9 billion annual R&D effort.[20] (Note: Funding levels are given in US$ with an exchange rate of US$l.89/l pound sterling.) The Lords said that the R&D strategy lacked coordination, particularly in the way research was applied to industry. If the advance of science and technology were to restore and sustain economic growth and prosperity, they said, its promotion should be a central objective of government policy, with the impetus coming from the Prime Minister.

As reported in the 1987 Annual Review of Government Funded R&D issued by the Cabinet Office,[21] the Ministry of Defence spent 52 percent of total government R&D in the year 1985/86. This high proportion of total R&D dedicated to defense has generated widespread concern among economists and industrialists of all parties that *defense may be crowding out valuable investment in the civil sector.* In its 1987 Defence White Paper** the government noted this concern and announced that it would, over the next few years, take a closer look at defense programs with a large R&D element to ensure that government funding was essential. Significant reductions in funding could, therefore, be expected in 2 to 3 years as defense R&D became more efficient and competitive-and as Britain reduced its duplication of Allies' research efforts through greater collaboration. The aim would be to release more government money to support the civil sector, in both industry and academia.

Beside the need to transfer R&D funds from defense to the civil sector, there was also a clear desire both in government and industry for greater civil spin-off from R&D carried out by the government's Defence Establishments. Several initiatives have been introduced, both to exploit technologies within the Establishments for the benefit of the civil sector, and to offer selected facilities for use by industry.

In implementing its new R&D policy, the British Government sees two challenges: 1) to target

[18] National Academy of Engineering, "The Technological Dimensions of International Competitiveness" (Washington, DC: 1987).

[19] "Civil Research and Development," Cmnd 185 (London: Her Majesty's Stationery Office, July 1987).

[20] "Civil Research and Development: Report of the Select Committee on Science and Technology," vol. I (HL 20-1), British parliament, House Of Lords, November 1986.

[21] "1987 Annual Review of Government Funded R&D," Government Statistical Service, United Kingdom, 1987.

[22] "Statement of the Defence Estimates 1987," CM 101-1 and 11 (London: Her Majesty's Stationery Office, 1987).

scientific and technological resources without constraining individual creativity; and 2) to coordinate parallel R&D programs without divorcing them from the individual objectives they are meant to serve. The new policy has been given an impetus by the government's acceptance of two principles: 1) the collective ministerial consideration, under the Prime Minister's leadership, of science and technology priorities; and 2) the creation of an independent advisory body to comment, not only on British scientific and technological endeavor, but on international efforts as well. The government's aim is to harness Britain's total R&D resources, both civil and military, in a science and technology program that will enhance both the U.K. economic growth and its defense capability. To assure value for money, a government committee will coordinate and oversee the more-or-less independent civil and military programs.

The 1987 Annual Review of Government Funded R&D reflects the status of departmental plans as of July 1987. It does not take into account the changes agreed during the Public Expenditure Survey held in fall 1987; these changes will be reflected in the forthcoming Public Expenditure White Paper.

Total spending in 1985/86 was $8.5 billion, of which 52 percent was spent by the Ministry of Defence (MoD). Civil spending was $4.1 billion, over half of which was in the Research Councils and universities. Civil Departments, such as the Ministry of Agriculture, Fisheries and Food, the Department of Energy (including the U.K. Atomic Energy Authority), and the Department of Trade and Industry (DTI) accounted for less than 22 percent of spending on R&D. Government R&D expenditure was 2.9 percent of total Government expenditures in 1985/86. Compared with 1984/85, the final figure for 1985/86 was 6 percent higher in current prices; spending on defense R&D was 7.5 percent greater, compared with a rise of 4.4 percent in civil R&D.

The $8.5 billion government expenditure on R&D in 1985/86 is expected to increase to $9.2 billion in cash terms by 1989/90. Total civil spending is expected to increase by 12.8 percent to $4.65 billion, and defense by 2.9 percent to $4.55 billion. However, these are net reductions in real terms, with defense R&D spending programmed to fail by 10 percent and civil by 5 percent in constant value. In the 1988 Defence White Paper[23] the total defense R&D expenditure for 1987/88 was given as $4.43 billion, with the following breakdown:

	Research	Development
In-house	$0.48B	SO.89B
Contracted out	$0.28B	$2.79B
Total	SO.76B	$3.68B

The "push" in government for a more even distribution of government R&D funds between military and civil sectors has come from Mr. John Fairclough, Chief Scientific Adviser to the Cabinet, with support from DTI. But in recent years a widespread view among economists, industrialists, and politicians has been that, compared with many other countries, Britain directs too large a share of the R&D funds to a relatively small sector, defense. Their main arguments are that those countries spending least on defense R&D have prospered most—Japan, West Germany and, to some extent, Italy. Although France and the United States direct a high share of government R&D into defense, they are seen as richer countries anyway, also spending more on civil R&D. The second concern, as the 1987 Defence White Paper puts it, is that Britain's pool of scientists and engineers is " . . . not inexhaustible. . . ," and". . . it would be regrettable if defence work became such a magnet for the manpower available that industry's ability to compete in the international market for civil high-technology products became seriously impaired. " Some believe that has already happened.

The Levitt Report in 1985[24] found a perverse correlation between defense procurement and productivity: in the electronics components sector, which in the United Kingdom depends very little on military sales, productivity was rising quickly, while in the radio, radar, and electronics capital goods sector, which does depend on military sales, productivity growth was negative. It also found that the inflation rate for defense procurement was significantly higher than the national rate of inflation—even for dual-purpose products like oil and nonmilitary vehicles. Other analyses of the benefits (or lack thereof) to the British economy from expenditures on defense R&D reached broadly similar

[23] "Statement of the Defence Estimates *1988*" (London: Her Majesty's Stationery Office, 1988).

[24] M. S. Levitt, "The Economics of Defence Spending," National Institute for Economic and Social Research, London, 1985.

conclusions. The essential point is that, of the $4.55 billion spent on defense R&D, only $0.75 billion was spent on research as opposed to development—and much of defense R&D was thought inherently unsuitable for civilian use. Most defense R&D led to product innovation, while much of the innovation on which civilian industry depended was in improvements to manufacturing processes; it was mainly through process improvements that companies competed to achieve price and/or quality advantages.

House of Lords Select Committee Report

The comprehensive report by the Select Committee on Science and Technology of the House of Lords focused on civil R&D. Specifically, a subcommittee was set up to consider "the policy and practice of public support for civil science and technology in the United Kingdom," with four main areas of inquiry:

1. the organization of civil R&D;
2. sources of funds for basic, strategic and applied R&D;
3. the working of the customer/contractor principle; and
4. the civil implications of defense research.

Although it had no charge to analyze the management of defense R&D except for spin-off, the Select Committee Report embraced the "annual" or "whole" national R&D effort, which must include the defense element.

The report described *the central weakness of Britain's annual R&D effort as its fragmentation and lack of coordination,* with flagging morale among scientists and a low level of public interest in R&D-particularly in the City (London's "Wail Street"). The committee called for companies to disclose their R&D investments to encourage "financial interests to take R&D strength more into account when weighing a company's future prospects." The report recommended that a Cabinet Minister should take responsibility for the national R&D, with a central body to coordinate the whole effort and that a new source for public funding of R&D should be introduced to supplement present mechanisms. The new source would finance "strategic" research, which was defined as that undertaken with eventual applications in mind-even when these could not be clearly specified. Only in the 1980s had such research been identified as a distinct category, funded as if it were basic research, with no specific application in mind, through a dual-support system involving the science budget of the Department of Education and Science and the University Grants Committee. -

The Lords urged a third route "for funding that strategic research which is of most significance to the United Kingdom's economic future." But they also saw the Research Councils and Government Departments, as proxy customers in non-commercial fields, retaining responsibility for some strategic research. They also criticized the research community's own efforts to evaluate the performance of research, finding its approach "less scientific than the science and technology it is designed to assess." The Committee suggested that about 1 percent of all government R&D funds should be spent on evaluation, which must be approached as a discipline, and not as a threat.

Among the 39 conclusions and recommendations of the Lords' report were the following:

- The advance of science and technology, which is essential to the economic recovery of the country, must be a central objective of government policy.
- Anew impetus is needed to raise the morale and focus the effort of the scientific community and industry. This requires action at the highest levels of government.
- Neither government nor industry is spending enough on R&D to restore Britain's industrial position in world markets.
- Departmental policies and spending on R&D must be looked at horizontally across the whole of government, in addition to the traditional vertical look by individual Departments.
- A Cabinet Minister should be designated to be responsible, under the Prime Minister, for the science and technology dimension of governmental policy and the promotion of national effort in R&D.
- A Council on Science and Technology (chaired by the Prime Minister) should be established, with the designated Minister as deputy. Its Secretariat should be located in the Cabinet Office under the Chief Scientific Adviser. It would oversee the whole of scientific and technological endeavor.
- The five Research Councils should as far as practicable harmonize their administrative procedures, criteria, and approaches and work

more closely on corporate planning, marketing of results, and external relations.

- Strong management and clear decisions about priorities between Research Councils are essential in present circumstances.
- The customer/contractor principle for R&D funded by government departments is endorsed.
- Beside the dual-support system and the customer/contractor principle, a third method of public funding of R&D is required. To this end, a process should set in motion to fund that strategic research of most significance to the United Kingdom's economic future.
- The government should assist in funding the process for generating strategic research in exploitable areas of science, and should make new pump-priming funds available for research generated by the process.
- Any other initiative to ensure that the government's R&D funding makes a greater contribution to the economic well-being of the country is to be welcomed, but it must be adequately funded and its relationship with exploitable areas of science must be clarified.
- The Science and Technology Assessment Office (STAO) is welcome to carry out its assessment function, as well as to evaluate the operation of the exploitable areas of science. Approximately 1 percent of all government R&D expenditure should be devoted to evaluation.
- Closer links between government Research Establishments and Research Council Institutes, adjacent universities, and polytechnics are desirable.
- Civil and defense R&D budgets should normally be recorded separately. The size of each should be determined by the civil and defense programs which it supports. A thorough examination of defense R&D expenditure should be an early task of STAO and the proposed Council for Science and Technology.
- The Committee welcomed recent initiatives to improve the effectiveness of defense procurement, reduce R&D costs, and increase spinoff, and recommended that further efforts be made to pursue the industrial opportunities for obtaining more civil benefit from defense R&D.
- The security classification of the results of defense R&D should again be examined with a view to introducing a more liberal policy. Further, a more detailed annual report on the results of defense R&D should be published.
- The committee recommended a high profile for science and technology, dynamic leadership at the center, and a new approach to funding R&D.

The Lords' report has been covered at length because the British Government has incorporated much of it in its new science and technology policy. Some actions were taken before the committee had finished its inquiry, causing the committee to report that it had "sometimes felt they have been operating on a moving staircase."

U.K. R&D Program Overview

The Politics of Research and Development

The Government's Response—The government published its interim response to the report of the House of Lords Select Committee in July 1987.[25] The 1987 Conservative election manifesto had given an early indication of the government's intended policy with the following:

> Government support for R&D amounts to more than 4500 million pounds sterling [$8.5 billion] per year. It is larger as a share of our national income than that of the United States, Japan, or West Germany. A country of our size cannot afford to do everything. These resources need to be better targeted. The task of Government is to support basic research and to contribute where business cannot realistically be expected to can-y all the risks. We will ensure that Government spending is firmly directed towards areas of high national priority by extending the role of the Advisory Council on Applied Research and Development, drawing on the full range of advice from the academic community and business.

All that was missing in the manifesto statement, from what was eventually to become the new policy, was the commitment to fund it and the establishment of new centers of excellence independent of the universities.

[25] "Civil Research and Development, Government Response to the First Report of the House of Lords Select Committee on Science and Technology, 1986-87 Session" (London: Her Majesty's Stationery Office).

These components were still missing when the government published its initial response to the Lords' report. However, it did accept the two principles mentioned earlier: collective ministerial consideration, under the Prime Minister, of science and technology Priorities; and advice by an independent body, which will comment not only on the whole of British scientific and technological endeavor, but on international efforts as well. The first of these two principles was decoded by the press and others[26] to signify the establishment of a Cabinet-level Committee on science and technology, chaired by the Prime Minister. Although the existence of this committee and its work are probably shrouded in the Official Secrets Act, it appears from leaks and government briefings that the committee will have four main tasks:

- considering important ad *hoc* issues, e.g., U.K. involvement in space and nuclear research;
- considering major policy developments in science, e.g., the government's response to the Lords' report;
- overseeing reviews of particular parts of government-funded R&D in relation to general policy considerations; and
- undertaking an annual review of science funding priorities as a major input to the Public Expenditure Survey process, beginning in 1988.

This last task is thought to be particularly important as, for the first time, it appears that government will scrutinize the level and distribution of its R&D expenditure across all departments. The new advisory body will be known as the Advisory Council on Science and Technology (ACOST), with an independent chairman reporting directly to the Prime Minister.

Soon after his appointment as Chief Scientific Adviser in 1986, John Fairclough established the Science and Technology Assessment Office within the secretariat of the Cabinet Office. Its terms of reference were, broadly:

- to establish a central body that will analyze the contribution made by each component of government-funded R&D to the efficiency and competitiveness of the economy,
- to advise ministers and officials on the shape, content and conduct of the national program, and
- to advise on priorities in spending.

The STAO will complement the activities of ACOST by analyzing data gathered by it. The Lords' Report welcomed the STAO in its own right-and hoped that it would "help evaluate the operation of the exploitable areas of science process." As noted earlier, the Lords had recommended that approximately 1 percent of all government R&D expenditure should be devoted to evaluation, having found that the research community's own efforts to evaluate the performance of research are inadequate. Throughout all documents consulted in this study, no measure of research quality has been mentioned other than a count of patents or published scientific papers; in all cases, evaluation of research has been by subjective peer review.

The ABRC's Strategy for the Science Base—Published together with the Government's response to the Lords' report was a discussion document prepared for the Secretary of State for Education and Science by the Advisory Board for the Research Councils (ABRC), and called "A Strategy for the Science Base."[27] The ABRC includes the Government's main scientific advisers, as well as representatives from industry and the universities. Although the document did not have unanimous ABRC support, there was consensus that British science was underfunded and underdirected, and that research was too widely spread. It was also agreed that universities and other institutions in all fields of experimental science lacked staff and resources with which to compete in the international arena, and that some rationalization was needed. Earth sciences research, for example, was distributed over 54 departments in 41 university institutions.

The ABRC suggested that the provision for science in the universities would have to be fundamentally reordered, and proposed the following re-categorization:

[26] Sir David Phillips, "A Strategy for Science in the U.K.," The International Science Policy Foundation's 1987 (23rd) A. Mild Lecture, Science and Public Policy, February 1988.

[27] Advisory Board for the Research Councils, "A Strategy for the science Base" (London: Her Majesty's Stationery Office, May 1987).

- Type R: Institutions offering undergraduate and postgraduate teaching and substantial research activity across a range of fields.
- Type T: Institutions highly competent in undergraduate and MSc teaching, with staff engaged in the scholarship and research necessary to support and develop that teaching, but without provision of advanced research facilities.
- Type X: Institutions providing teaching across abroad range of fields and engaged in substantial, world-class research in particular fields where they are already preeminent or could achieve eminence in collaboration with other institutions.

The ABRC did not recommend that such differentiation be imposed from above but that, as Sir David Phillips, the ABRC Chairman, emphasized:

> **Significant** responsibility will rest on the institutions themselves in identifyng their main strengths and future roles, in developing collaborative arrangements, and in pursuit of the necessary restructuring. We recommend that the Research Councils should collaborate with and, where appropriate, prompt institutions to bring about appropriate concentration of research activity."[28]

The ABRC also called for interdisciplinary research centers associated with Type R institutions, and with the Type X institutions which can make a good case collaboratively. It wanted much of the research councils' support for universities channeled through such multidisciplinary centers, which "would each have a positively managed coherent programme of work undertaken by a small number of core staff and visiting teams of researchers." It wanted to see Type R and X institutions bidding to host such centers, and for all additional equipment, materials, technical and support costs to be transferred from the universities to the research council concerned.[29]

These proposals challenge the universities as now run; since the Robbins Report of the 1960s they have been seen as equals. Acceptance of the proposals would mean that Britain could not remain at the forefront of all the sciences. There might be some areas from which the country would have to withdraw altogether at the advanced level—and someone would have to decide which these were. Until now, priorities for research have been made on a somewhat ad hoc basis; while budgets have been reasonably constant under the Conservative government, salaries and the cost of equipment have risen. At the same time, because industry expected a growing science base to help it compete internationally, it had to set some priorities. The ABRC proposed that they and the research councils should *adopt new common criteria for gauging priorities in science, taking account of timeliness, pervasiveness, excellence, exploitability, applicability, and significance for education and training.* It also urged the research councils to give higher priority to programs of research and research training undertaken collaboratively with users, to increase the chance of exploitation and reduce the information gap between business and science.

The ABRC document went further. Not only did it call for a wholesale reorganization of British science, it wanted it immediately. "Additional funds will be necessary to facilitate the necessary transition from a widely distributed university research base to a system in which fewer centers are equipped to world class standards, including funds for the establishment of university research centers and for further re-structuring of Research Council institutes. The Government should adopt a business-like approach to this essential investment in restructuring . . . .If our centers of excellence are to be equipped to compete internationally and to provide U.K. with the support it needs, the centers must be adequately resourced now. They cannot wait for the gradual release of funds from elsewhere in the system, as and when commitments can be run down within the constrained recurrent budgets."

In its turn, the government consulted universities, industry, and the various parties involved before taking any decisions on the somewhat controversial changes advocated. The government had always side-stepped policies based on "picking winners" as being too risky politically; in this case, the international scientific community at least appeared to agree on the three broadly-based "winners" of enabling technology: microelectronics, materials, and information technology.

[28] Ibid.

[29] The United Kingdom has five Research councils: science and Engineering (SERC), Materials (MRC), Agriculture and Fisheries (AFRC), Natural Environment (NERC), and Economic and Social (ESRC).

Organizational Aspects of Government R&D Policy

Beside the Cabinet Committee on Science and Technology described earlier, the government has made other changes in the course of implementing its plan for national R&D.

Advisory Council on Science and Technology-As mentioned earlier, in mid-1987 the British Government established, as the closest advisers to the Cabinet Committee on Science and Technology, the Advisory Council on Science and Technology to help it shape the national research and development program. ACOST, which absorbed and replaced the Advisory Council for Applied Research and Development (ACARD), has an expanded charter to cover the whole of national science and technology, particularly those areas previously regarded as academic science, including the life sciences. Its principal roles are to identify areas of science and technology that British industry can exploit, and to identify areas where the government might realize substantial savings. It will also advise the government on the nature and extent of U.K. participation in international science and technology collaborations. ACOST inherited ACARD projects already begun, including a 2-year study of the efficiency of defense research under the chairmanship of Dr. Charles Reece, and a study, headed by Prof. Stan Metcalf, of factors that hinder the growth of small British companies. ACOST's terms of reference are broad and should allow advice to be offered to the government in a much more comprehensive and coherent reamer than has been possible before.

Following the various debates and studies mentioned earlier, the government made two further announcements in late 1987 as part of its plans for reshaping British science: the creation of a Centre for the Exploitation of Science and Technology (CEST) and the choice of Cambridge University to host the first of the government's University Research Centres (URC). Although just a beginning, each illustrated British Government thinking about R&D-and each was undergirded by a novel collaboration among academics.

CEST-First came the establishment of CEST, based at Manchester University. Envisaged as a think-tank, along the lines of the Brookings or Hudson Institutes in the United States, and with a Steering Committee headed by Sir Robin Nicholson,[30] CEST's role is to help improve Britain's ability to exploit R&D, imported as well as home-grown. Above all, it will back-up the ACOST, which in turn reports to the CSA, John Fairclough. CEST was conceived two years ago to bridge the gap between industry and the scientific community; over 80 percent of its finding will come from major science-based companies (18 contributed from 40 invited) and the rest from the government. Its task will be to encourage research in promising aspects of technology where there are commercial opportunities to be exploited for the national benefit. CEST will not be an agency of either the government or its university hosts, but will interact directly with industry and the research community.

The idea has always been that CEST would be hosted by a university, but would operate as an independent center under a strong executive-preferably someone with both academic and industrial experience. The successful bidders were a consortium of seven universities and polytechnics based in northwest England, which pooled talents to make their case; their proposal showed the clearest understanding of the purpose of CEST and its objectives, and it had strong industrial backing in the northwest, CEST's first Chief Executive is Dr. Robert Whelan, former Marketing Director of PA Technology (and ex-Lucas and Monsanto).

University Research Centres—As "agents of change," the new URCs have a vital role in the government's plan. Similar in concept to the Engineering Research Centers set up in some U.S. universities, they will be laboratories devoted to a specific scientific opportunity believed to be exploitable within a decade. The idea is to establish and manage a directed research program in a center of excellence, concentrating resources and expertise in order to create a "world research force. " It is thought that the Chief Scientific Adviser considers that Britain must speedily establish 30 to 40 URCs to bring about the changes he seeks in British science. Those changes can be summed up simply as a science base more responsive to society's needs and wishes.

The disciplines from which the first URCs will be chosen include:

[30] As John Fairclough 'S predecessor as government CSA, Nicholson laid the foundations for the government's new plans for R&D.

- high temperature superconductivity (including power engineering);
- surface science;
- synthesis and characteristics of semiconductors and novel materials;
- molecular sciences;
- lasers in manufacturing;
- engineering design; and
- process simulation, integration, and control.

The National Committee for Superconductivity (a joint DTI/SERC committee headed by Sir Sam Edwards) chose Cambridge University to host the first URC because it could demonstrate that no fewer than five different departments (physics, chemistry, materials science and metallurgy, engineering, and earth sciences) were already collaborating informally on the newly discovered possibilities of high-temperature ceramic superconductors. Although CEST played no part in the Cambridge decision, it is expected to have a vital role in the grand plan and to help identify the most suitable topics for other URCs. Fairclough himself was reported to have believed that the first URC should focus on high-temperature superconductors, seeing it as a good test of academic readiness to break down traditional barriers and embark on truly multidisciplinary research programs. According to SERC, Cambridge also won because of its program of industrial liaison in the technology, including finding, equipment sharing, and staff exchanges with GEC, Oxford Instruments, PA Technology, and the Central Electricity Generating Board's research facility.

Based in the University's Cavendish Laboratory, the Cambridge URC will receive $10 million in SERC funding over 6 years and be the lead laboratory in a three-tier program of government support, The second tier will include such schemes as the Harwell-based club of companies and Oxford University departments, together with the runner-up for the first URC. (In early 1988 the government followed up by announcing a $30 million national program of research into high-temperature superconductivity, and sought proposals involving the collaboration of British industry in "clubs" (or consortia) to pursue a common objective, with which it would match investments.) The third tier will be smaller university and polytechnic efforts also funded by SERC.

Coordination of Research Into Information Technology-In May 1988 another part of the government's plan was launched, aimed at improving coordination of government-funded research projects into information technology (IT). All research onto IT, whether sponsored by the DTI or SERC, will now be done under an "umbrella" advisory organization with an overview of the entire sector, thereby strengthening links between industrial and academic researchers. This restructuring is seen as placing further emphasis on industry's responsibility for investing in product development, while the government itself is adopting a stronger role in disseminating the results of basic research, and encouraging companies to adopt a more adventurous approach to high technology.

In addition, the DTI has redirected its support for high-technology research towards collaborative European projects, particularly the ESPRIT program for information technology run by the European Community. As a result, it decided late in 1987 not to repeat the ambitious Alvey research project (see later Section, "The Alvey Program"), which pioneered joint research by industry and the universities and which still has some on-going projects. Partly as a result of the experience with Alvey, the DTI believed there was an even greater need for coordinating the government's approach to high-technology research. Several committees in DTI and SERC, under which electronics research had hitherto been organized, will now be made redundant under the new structure. Resource allocation will be directed by a top-level advisory committee drawn equally from industry and the universities.

Ministry of Defence—A section on the organizational aspects of government-funded R&D would be incomplete without reference to the largest consumer, the Ministry of Defence. As the 1987 Annual Review of Government Funded R&D puts it:

> The R&D work of the MoD has the overall objective of meeting the needs of the Armed Services for equipment and weapons in a timely and cost-effective reamer. There is a major distinction between the objectives of research and development however. The research programme is aimed at sustaining an underlying basis of scientific and technological expertise on the basis of which support can be given to the selection, development, production and operation of weapon systems and equip ment, and assessments can be made of the likely future evolution of the threat and options for

countering it. It contains no element of basic, curiosity-driven research. In contrast, development is directly related, item by item, to the procurement of specific military equipment and is the essential forerunner to the production of such equipment.[31]

With regard to defense research, the Review continues:

The research program is undertaken both in MoD establishments and as funded research in industry, research institutes, the universities and other institutions of higher education. The contributions of these separate sources are brought together into a coherent programme through an integrated management within which responsibility for specific major fields is delegated to the relevant Research Establishments. Overall the research programme may be characterized as follows:

1. Strategic Research. [A]imed at strengthening and extending the scientific and technological base for future exploitation, which is broadly aimed at known military needs. This is maintained at a level equal to at least 5 percent of the Defence scientific effort available to them.
2. Applied Research. This is work which is directed primarily towards equipment projects in 5 to 10 years' time and absorbs the largest part of the Research Establishment effort . . . .

The Review goes on:

The research programme covers a wide range of scientific disciplines and technologies. Priorities within it are reviewed annually having regard for the largest assessment of Service needs, the timescales of application opportunities, and the varying prospects of making significant technological progress in different fields. . . It is the Ministry's longer term objective, however, to reduce its involvement in well-established technologies where there is a substantial capability in the private sector.

The major fields of research referred to above are listed in the Review as follows:

- Air Vehicles, Aerodynamics, Structures and Materials;
- Gas Turbines;
- Navigation and Avionics;
- Space;
- Ships and Submarines, Signature Reduction, Human Factors;
- Ships Systems;
- Undersea Warfare and Countermeasure Systems;
- Rocket Propulsion, Explosives and Weapons Materials;
- Conventional Weapons, Armaments and Command and Control;
- Military Vehicles and Army Engineering Equipment;
- Chemical and Biological Defence;
- Guided and Air-launched Weapons;
- Tri-Service Electronic Systems;
- Electronic Components; and
- Electronic Technology.

The reduction in defense R&D for which the government and others are pressing is likely to arise from:

- increased collaboration, in R&D as well as production, with European allies and the united states;
- increased competition in British procurement—new MoD contracts are now being awarded on the basis of either competitive fixed-price bids or a maximum-price arrangement; and
- more R&D being contracted out to the private sector, and possibly carried out at private industry's expense, i.e., getting industry to increase its contribution to the cost of R&D.

The MoD Research Establishments have been reduced in number from 22 to 7, with a workforce of about 22,000 compared with more than 30,000 ten years ago. One third of their total research in now extramural (contracted out to industry), and that trend will accelerate. In return, British industry is looking for tax incentives.

Military/Civil Trade-Off

Several of the documents referred to in this section have stressed the need to redress the balance of government funding between civil and military R&D, and secure greater benefits for the civil sector from technology developed under defense R&D programs. Several initiatives have been taken by the British Government in pursuit of that objective, including a study into the role and status of the Research Establishments.

[31] British Parliament, House of hinds, op. Cit., footnote 20.

Technological advances initiated for defense purposes have been exploited successfully by civil industry in fields ranging from new materials and electronic devices to advanced aerodynamics with application to civil aircraft and jet engines. The MoD Research Establishments interact with industry and the civil sector in four main ways, as described by the 1987 Annual Review of Government Funded R&D:[32]

- Some $285 million of research work is carried out under contract to industry and the academic sector, with the MoD joining with the Research Councils to make grants to institutions of higher education for work of high scientific merit that is relevant to defense.
- The Defence Research Establishments carry out some $83 million of work a year funded by other government departments for civil purposes. Much of this is complementary to defense work and uses the same staff and facilities. A further $43 million of work is done for other paying customers, including the use of facilities by industrial firms for both defense and civil work.
- Much of the work carried out in the Defence Research Establishments is relevant to civil as well as defense technology. The Alvey programme and the British National Space Centre, in both of which the MoD is a major participant, spearhead work across the civil/military divide in their respective areas. The MoD consults with industry and with other government departments on the scope for collaborative research programmed (e.g., the research initiatives in electronics at RSRE Malvern). The MoD will be a major participant in the LINK program announced by the Prime Minister in December 1986 to "pull through" innovative work into industry.
- Defense-related work may have commercial applications. To further such work, the MoD has assisted in establishing Defence Technology Enterprises (DTE) Ltd; a privately owned, profit-motivated company, established specifically to assist industry in identifying, developing and exploiting work carried out at the major Research Establishments, to which the company has access under suitable safeguards. Where ideas are not immediately transferable to civil applications, DTE may arrange further development. It operates at four Establishments-RAE, RSRE, ARE, and RARDE.[33] There are now some 500 items on the DTE database judged to have potential for exploitation, and DTE has recruited some 180 companies as associate members. Fifteen licenses for exploitating innovative technology have been negotiated, or are in the final stages of negotiation. As a further initiative directed to enhancing spinoff, work has been done on the idea of establishing a "science park" adjacent to one of the Research Establishments. This idea is currently at the feasibility stage.

A different kind of collaboration is the joint venture between an Establishment and a private company, as epitomized by the July 1986 agreement between Cummins International and RARDE. Cummins manufactures diesel engines, and wanted to enter the international tank market; RARDE has first-class facilities for testing tanks. Under the agreement, Cummins will provide engines valued at about $470,000 in return for a RARDE test program of similar worth.

Another initiative recently publicized is the Civil Industry Access Scheme, whereby MoD will allow companies to use its research equipment and for a fee consult experts at four of its major centers. The centers are RAE, RSRE, ARE, and RARDE. The new scheme, to be operated jointly by both MoD and DTI, is aimed at British companies, but applications from foreign firms will also be considered.

Perhaps the most controversial option in the government's review of the future of the Defence Research Establishments is to privatize them. Six non-nuclear Establishments are being studied for possible change to commercial status: ARE, RARDE, RAE, RSRE, A&AEE,[34] the Chemical Defence Establishment, and (possibly) the Meteorological Office. The options appear to range from simply putting an "agency" label on the Establishments to full privatization. The MoD team conduct-

32Ibid.

33RAE—Royal Aircraft Establishment; RSRE—Royal Signals and Radar Establishment; ARE-Admiralty Research Establishment: RARDE—Royal Armament Research and Development Establishment.

34A&AEE—Aeroplane and Armament Experimental Establishment.

ing the study on behalf of the Controller Establishments, Research and Nuclear (CERN) is due to report to the government in June 1989. Privatizing any of the Establishments should immediately reduce the cost of defense R&D, at least until the proper "commercial" rate is applied. Full privatization that entailed outright purchase would immediately raise questions about the Establishment's ability to act as a neutral technical adviser in assessing competitive proposals, as well as its willingness to sponsor fundamental and intermediate research where the returns are too distant to be commercially attractive.

Collaborative R&Din the United Kingdom

DTI's Role

A White Paper (Cm 278) described the role of DTI in encouraging enterprise, one of the major economic goals of the government.[35] It set out the main policies of the DTI and announced changes both in those policies and in the organization of DTI. On collaborative research the DTI "will encourage the participation of U.K. companies in technological collaboration with other European firms and research communities, including programs such as ESPRIT and RACE." (The DTI uses "collaboration" in a national context to include intercompany and industry-university ventures.)

The White Paper continued: "There are four main ways in which DTI, with other government departments in some cases, will encourage and finance collaborative research:

- LINK encourages companies to undertake joint research with Higher Education Institutions (HEI) and Research Councils. The research will be precompetitive but industrially relevant. Programs currently under preparation include new technologies such as nanotechnology and industrial measurement systems.
- National collaborative research programs promote longer-term, industrially led collaborative projects between U.K. companies in advanced technologies. DTI's role is to help establish the collaborative links both between firms and between firms and the research community at the precompetitive research stage. Once those links are established, decisions on further collaboration and commercial exploitation should be taken by industry itself. DTI, with advice from its Technology Requirements Board, is currently running collaborative programs in such advanced technologies as robotics and gallium arsenide. A new program on superconductivity is now being launched, linked with initiatives by the Science and Engineering Research Council,
- General industrial collaborative projects encourage collaboration through a variety of projects. Some foster R&D serving the interests of fragmented industries where small firms typically do not have the resources for advanced technological projects; Research Associations that pool resources can meet those needs. Some encourage the adoption of technology originating in the science base, particularly in the government's research establishments. Some are collaborative projects involving only industrial participants in joint research for companies with similar interests, especially small and medium-sized companies.

According to the White Paper: "In the future DTI will only contribute funds to research which would not and could not go ahead without some support from the taxpayer. It will normally be DTI's policy to fund any particular project or area of work only over a specific time period and where appropriate to reduce the rate of funding over time. Companies themselves are expected to become aware of the benefits which collaborative arrangements can bring and to undertake collaborative research without Government tiding."

On Information Technology, the White Paper stated that: "Within the context of the policies outlined above, the Government have considered whether the proposals in the report of the IT86 Committee should be included amongst the national collaborative programs. The Government have already agreed to support ESPRIT H, for which there will be a U.K. contribution through the Community budget of the order of [$380M]. The Government also recognize that the Alvey Programme has provided a good focus for the IT research community, which has helped to bring together different parts of industry as well as industry and the HEIs.

[35] Department of Trade and Industry, "DTI—The Department for Enterprises," White Paper Cm 278 (London: Her Majesty's Stationery office, January 1988).

The involvement of secondees from industry, academia and the Government departments involved has also proved successful and has assisted U.K. organizations to participate fully in ESPRIT. The Government nevertheless accept that some resources should be devoted to a national initiative complementary to ESPRIT, within the framework of the national collaborative research programme. . . "

From 1988 the Directorate will be known as the Information Technology Directorate, not Alvey, and its program reoriented towards precompetitive research. The DTI has earmarked $55 million over the next 3 years (1988-90) for IT programs, and SERC has plans to devote $104 million over 5 years to related academic research, mainly in partnership with companies. As mentioned earlier, all IT research will now be done under a joint DTI/SERC umbrella advisory organization with an overview of the entire sector.

The Alvey Program

The Alvey program was Britain's response to the national program that Japan launched in 1981, aimed at developing a so-called fifth generation of computing systems. The Alvey Report of 1982, which persuaded the U.K. Government to launch the program, assumed it would take at least a decade to meet the program's objectives. Launched in 1983, the Alvey Program focused on four "enabling technologies" thought to be crucial: very large scale integration (VLSI); software; man-machine interface; and intelligent knowledge-based systems. Three government departments-MoD, DTI, and SERC (for the Department of Education and Science)-jointly sponsored a common $375 million, 5-year program under its own directorate, with industry contributing another $285 million.

The 5-year program in Information Technology is now coming to a close. All the funds have been committed to over 200 industry-led projects, typically with two or three firms and one or two academic teams working together on each project. Over 110 firms have been involved in the actual research projects, and another 200 on the "awareness" side. The academic world was broadly represented with 56 universities and 12 polytechnics, together with 24 U.K. Research Associations or Government Research Laboratories.

Alvey-generated VLSI technology is being applied to fabricating integrated circuits, as well as memory chips offering switching speeds comparable to U.S. and Japanese products. A major achievement of the Alvey Software Engineering Program is the success with which "Formal Methods" from the academic world are being applied to industrial products. Widespread use of these Formal Methods may revolutionize software writing, with considerable economic benefit. Projects for artificial inteilligence/knowledge-based systems, systems architectures, and man/machine interfaces have led to significant advances, owing to collaboration between industry and academia. Plans for commercial exploitation exist for about half the projects; for the others, it is still too early to judge. Beside the four enabling technological areas already mentioned, the Alvey Program supported four large scale demonstrators, with the aims of stimulating enabling technologies for practical applications, and visibly demonstrating the exploitable results of the program.

Having generated a research strategy based on multi-departmental funding, the government will continue to fund IT research based on the same principles for which Alvey was the model. As was mentioned above, the Directorate has been renamed and the name Alvey has been dropped.

Lessons from the Alvey Program and its relationship with ESPRIT have been documented in detail in an Interim Report of the Evaluation of the Alvey Programme *by a joint team from Sussex and* Manchester Universities.[36]

U.K. Collaboration on Advanced Research

The U.K. 'S policy to support fully European collaboration, both in civil R&D and major military projects is well documented. The U.K. Government, and industry in general, are firm supporters of collaboration among European high-technology companies, academia and research institutes. The heightened sense of concern in Europe about its technological future is attributable to three factors: the sheer breadth and scale of the impact of information technology; the growing perception of

[36] K. Guy, M. Hoboday, R. Duncombe, H. Cameron, T. Ray, and L. Geoghiou, "Interim Report Of the Evaulation of the Alvey Programme" (London: Defense Technical Institute, October 19S7).

advanced technology in strategic terms and the need for self-sufficiency; and the severe "structural" handicaps to Europe's international competitiveness. Collaboration has become an accepted way of life among the high-technology community within the United Kingdom and the other European industrial countries. Put simply, no country can now afford to go it alone on all scientific fronts; it must collaborate or retreat from some or all of the world technological state. That point is well accepted in the United Kingdom.

FRENCH POLICY FOR RESEARCH AND TECHNOLOGY

Background

The administration of government funding for French R&D is highly centralized, though civil and defense R&D are budgeted and administered separately. Innovation and exploitation are encouraged by an elaborate system of aids and incentives; economic growth is sought through market-driven technology; and officials affirm that defense R&D should enrich the overall economy with scientific and technical progress for non-defense. Policies for nationalized firms and the government-supported research system are incorporated in long-term plans for R&D and innovation, with relatively specific priorities and goals. *Science and technology policies (especially technology) are also integrated wherever possible with the government's industrial and broader economic policies.*

The Law of 15 July 1982 established guidelines and a system of planning for French research and technological development; it also legislated the introduction of the High-Level Research and Technology Council (CSRT) to advise the Minister of Research and Higher Education (responsible to the Minister for Education) about the government's major scientific and technological policy options.[37] The Law on R&D[38] stipulated that the Minister should present to Parliament each year "a report on research activities and technological development which outlines the strategic choices for national policy and illustrates the progress made towards achieving the objectives fixed by the Law . . . " (Article 16). The Law also stipulated that "[t]he High-Level Research and Technology Council shall deliver an opinion each on the evaluation of research and technological development policy. The opinion shall be published. It shall be attached to the report on research and technological development specified by Article 16 of this Law" (Article 18).

The basic aim for French Government R&D policy is to stimulate rapid science-based economic growth, with key, technologies assigned priority in either national or collaborative programs. In the Preface to the first Annual Report (pursuant to the above Article 18), the Minister saw the draft 1987 R&D Budget Plan as an essential element in relaunching and reviving the French economy. "The field of research and technological development is a fundamental component of that policy, because research and technological development are seen by everyone as being a powerful factor for the long-term development of our economics and providing a decisive advantage in present-day economic competition worldwide. The policy I am pursuing in the research sector is based on one absolute principle and requirement-evaluation. In my view, it is impossible to define and implement a research policy with relying on means of evaluation. It would bean illusory and irrational misuse of public money if a number of ambitious, not to say over-ambitious quantitative objectives were fixed in advance without providing for a critical analysis of the substance and repercussions of the measures envisaged."[39]

The Minister also promised to review the central administrative structure of the Ministry for Research and Higher Education, and to review the activities of the government research organizations. He reported that, despite budget stringency in 1987, major scientific investment projects had been maintained and their funding assured, allowing basic research to develop within "a modernized technical framework." At the same time, the Minister noted "the need to develop industrial research in France" and "to make a very serious evaluation and re-evaluation of the relevance and cost of projects conducted by

[37] No. 85-1376, Dec. 23, 1985.

[38] No. 85-1376, Dec. 23, 1985.

[39] "Annual Report on the Evaluation of the National Policy Concerning Research and Technological Development," Ministry of Research and Higher Education, October 1986.

the many different intermediaries, whether research agencies or particular research organizations."[40]

R&D Budget Structure

Funding Levels and Priorities

The French Government issues 5-year national plans. Its policies become laws when the particular plans are approved by Parliament. The annual budget law is programmed for Parliamentary approval in January when "credits" or outlays are voted for the spending departments.

When the 1985 5-year plan was being prepared, the CSRT stressed the importance of regular evaluation of research activities; it also specified the principles and criteria of evacuation, particularly the independence and transparency of evaluation results. The law gives the CSRT the power, to consider how well the evaluation process has been conducted and to draw appropriate conclusions. Because there is no precise, operational evaluation system, CSRT confined the scope of its first annual report to selected areas outlined by the Research Committee for the 9th Plan, namely: industry research; scientific posts; research and the universities; the role of the regions; evaluation and forecasting.

Although a budget analysis[41] shows civil R&D to be decreasing as a percentage of government-funded R&D [Effort Budgetaire de Recherche et Developpement (EBRD)], actual expenditures have been fairly constant since 1985. There is, however, an apparent budgetary shift from civil to defense R&D expenditures in the 1988 R&D Budget. Compared with other sectors of government expenditure, R&D funding has actually fared well in the 1988 budget, with an increase of 8.3 percent (+10 percent for defense and +7.2 percent for civil), compared to an average of +3 percent for all ministries. Government-funded defense and civil R&D was split 39/61 percent in 1988, compared with 33/67 percent in 1985. Defense R&D, at about 26 percent of the defense equipment budget, has risen to support the programmed increase in defense equipment expenditure for 1987 to 1991. About 50 percent of defense R&D funding is spent with industry, accounting for about 70 percent of total state R&D funding for industry.

The civil component of the EBRD, the Budget Civil de Recherche et Developement (BCRD), (i.e., the civil element of the EBRD less telecommunications and university staff costs generally attributable to research) shows an increase of 7.2 percent for 1988, owing to the inclusion of expenditure on European collaboration and the loss of income due to the research tax credit system. As part of total government spending on R&D, European collaboration naturally belongs in the EBRD, but the program costs are not attributable to specific ministries' budgets. The civil R&D budget, for 1988 was FF39.3 billion, an increase of 2.3 percent over 1987. Of this, approximately 70 percent was to be spent on the following organizations and programs:

- Centre National de la Recherche Scientifique —FF8.96 billion on general research. Many laboratories are located on university campuses.
- Centre de la Energy Atomique (CEA)-FF6.65 billion on atomic energy research.
- Centre Nationale pour l'Exploration de la Space (CNES)-FF5.43 billion on space-related research, including finding the European Space Agency.
- Aeronautics Program-FF2.49 billion.
- Filière Electronique (electronic components) —FF1.99 billion
- INSERM (medical, health, biology)--FFl.92 billion.

This heavy commitment to Government Research Establishments makes it difficult for the French Government to effect changes of policy or to redirect research rapidly. The influence of the civil servants appears to militate against a cohesive strategy for the Research Establishments, but the Research Ministry is moving them towards a concept of strategic planning. However, the 1988 R&D budget has been heralded as one to "encourage industrial R&D," to get industry to do more R&D, and to make up for the decline in such finding prior to the 1986 changes.

In June 1988 the French Government approved an FF830 million increase for research that will augment, by 2 percent, the FF39.3 billion currently spent. The first priority will be to spend approximately FF90 million recruiting more young researchers to redress existing shortages. There are

[40] Ibid.

[41] Unpublished French Government budget analysis.

currently mom than 300 frozen vacancies for technicians in public research agencies. The remainder of the money will fund 150 new research posts in public research agencies. Of these, 100 jobs will be in biotechnology research at INSERM, the national agency for medical research, and at the national institutes for agronomy, cancer, epidemiology, and immunology. Fifty more jobs will appear at the French national space agency, CNES. Not all the new researchers will be French; some of the money will pay for 200 foreign scientists to work in French laboratories.

In addition to this new money for personnel increases, FF700 million will go to French industry to encourage greater involvement in basic research. Priority will be given to joint projects between industry and research agencies and to the "national priorities," notably research on new materials, set by the government last year. To remedy deficiencies in research in French universities, FF50 million has been earmarked to help universities develop their own research policies, particularly in conjunction with industry. ANVAR,[42] the agency that supports the development of promising *new* technologies, will receive another FF1OO million, and is slated for further funding later from the new industry minister.

This increase in funding results from a long battle by the new French research minister Curien, who held that post until 1986 and resumed it in early 1988 after Mitterrand's triumph in the presidential election. During his 1981-86 tenure, Curien planned to increase the science budget by 4.4 percent per year. But the Chirac Government cut the science budget by 6.6 percent during its 2 years in power (1986-88).

Despite the FF830 million additional allocation, Curien says that he will be unable to realize his original plans, set in 1985, to spend 3 percent of France's total revenues on research by 1990. However, the infusion of new money will allow some research institutions to survive the year.

Beside allocating more money, *the new proresearch government will reaffirm its original goals of streamlining the national research councils and agencies, to promote liaison among these agencies, industry, and the universities.* In support of this goal, the principal data networks used by researchers in France are being unified to permit intercommunications and file transfers. The new national research data communications network is seen as a "federation" of data networks already used by the major French research establishments. The new network will encompass those of the CEA, the electric power agency, the institute of computer science and automation research, and the research center for telecommunications. The network will interface to the "Reunir" network developed by the association of universities that links centers of higher education. INSERM, the center for agricultural research, the research center for cooperation with Third World countries, and the research center for agronomic in developing counties.

Government-Funded Civil R&D

Civil R&D funding is managed by the two Departments of Industry and Education (through the Ministry of Research and Higher Education). The several government Research Establishments (or Organizations) receive the majority of the funding, with about 70 percent of the EBRD going to the six organizations and programs listed earlier. The research budget for Higher Education was FF1.65 billion in 1988, (staff costs of FF7.44 billion are included in the EBRD but excluded from the BCRD).

The Industry Department disburses funds to industry for innovation, or the exploitation of research, through ANVAR. The Ministry of Research and Technology disburses funds for downstream R&D through the Fends de la Recherche et de la Technologie[43](FRT). As noted, the CSRT is a High-Level Research and Technology Council, whose role is to advise the Minister of Research and Higher Education on scientific and technological policy options. Scientific committees act as steering and advisory bodies on programs and objectives for each spending department and are answerable to the Minister for Research an Higher Education.

The FRT is the Research Ministry's principal mechanism to support R&D of downstream projects, usually involving at least one industrial partner. The 1988 R&D budget (BCRD) of FF39.3 billion included programs for electronics and information technology (formerly in the Postes and Télécommu-

[42] Agence Nationale pour la Valorization de la Recherche (Agency for Research Evaluation).

[43] Foundation for Research and Technology.

nications budget), of which the FRT budget was FF930 million (+8.8 percent) for 1988, plus about FF63 million unspent from 1987. Over 40 percent of planned FPT expenditure was allocated to the "National Programs" with 11 priority sectors: biotechnology, foodstuffs, medical research, life and social sciences; technology and production; electronics and information technology; transport; natural resources; new materials; new chemistry; and research for developing countries. On average, the FRT funds about 33 percent of these programs, with priority areas (besides AIDS) in superconductors and mechanical engineering (including optics).

In recent years, the FRT has acted as a transfer mechanism between the government Research Establishments and industry; however, little real technology transfer has occurred. In addition, the spending departments concerned received little "impartial" guidance on which programs to support. The Research Minister has now changed the system and (reintroduced scientific committees to act as steering and advisory bodies to each of the departments.

The FRT also funds about 50 percent of the French Government's involvement in EUREKA (21.5 percent of the FRT budget), and training (17.2 percent of the budget). The rest of EUREKA finding comes from the Industry Ministry's Information Technology and Electronics budget. Increasing the number of researchers in industry remains a high priority, and training initiatives include:

- technology transfer schemes (Centres de Recherche, d'Innovation, et de Transfert de Technologies and technology counselors, aimed at giving low-technology companies an entry into the Research Establishments;
- Poles Firtech[44] - centers of expertise that group industries, research facilities and educational establishments by geography and discipline;
- Conventions Cifre - placing doctoral students with companies to encourage industry research.

Manned by career civil servants, the Research Establishments are involved in these initiatives; together with short-term secondments to industry, trial loans, and incentives to public sector workers to transfer to industry, do contract work, or set up their own companies, they improve the transfer of technology into industry.

As noted, the Industry Ministry funding for the exploitation of research is effected through ANVAR. This funding has been increased to FF784 million ***(+8*** percent) for 1988. (With repayment of loans the budget rises to about FF1 billion). ANVAR offers grants for pre-project studies and interest-h loans to convert the results of such studies into a marketable products. For 1988, about FF200 million will be spent on information services to help small companies to collaborate with public sector researchers and professional technology centers. It is also proposed that ANVAR fund the costs of insuring risk capital. (It appears that the Industry Minister has also proposed risk insurance as a funding mechanism for EUREKA projects.)

Most of the Industry Ministry funding for industrial R&D (about FF2 billion) is for the favored areas of IT, electronics, manufacturing technologies, and the space sector, and is administered through SERICS. SERICS also funds about 50 percent of the Government's contribution to the EUREKA program, worth FF200 million for 1988 (the other 50 percent comes from the FRT). Funding for electronic components of FF1.99 billion is thought to come jointly from both the ANVAR and FRT budgets.

As already noted, most of the BCRD funding is spent with the Research Establishments. CNRS, the largest, accounts for about 10 percent of total government-funded R&D expenditures and 42 percent of the Research Establishments' budget. The Establishments employ over 25,000 persons, of whom nearly 11,000 are researchers; staff costs absorb 63 percent of their total budget of FF9.1 billion.

Government-Funded Defense R&D

The 1988 defense budget for both research and development was FF3.2 billion, an increase of 10 percent over 1987. Fundamental to French procurement strategy is the need to maintain an industrial base that ensures independence in armaments and preserves France's freedom of action. The "strategy of means" involves comprehensive planning, programming, and budgeting, with the results embodied in legislation. There must also be a parallel industrial policy to guarantee the development and procurement of the equipment the Armed Forces require; and this industrial policy must be integrated into the

[44]Formation des Ingeniurs pour le Recherche sur les Technologies.

government's other industrial, economic, and social policies.

The organization for defense R&D should be seen against this clearly stated policy background.

Délégation Générale pour l'Armement-The central institution in the French procurement organization is the Délégation Générale pour l'Armement (DGA). It has a dual responsibility:

- to organize the implementation of all of the Ministry's armament programs; and
- to ensure that the country has an up-to-date and effective armaments manufacturing capability.

In short, the DGA is the agency to which implementation of the "strategy of means" has been entrusted. It has both government and industrial tasks.

Its government tasks include:

- determining the Services' armaments requirements in consultation with them;
- supervising the State establishments and the (wholly or partly) publicly owned companies engaged in armaments research, development, and production; and
- developing a long-term program to ensure that France can be assured of the "means" to fulfill its armaments requirements.

The DGA's industrial tasks include:

- acquiring weaponss systems and materiel for the Services; i.e., acting as the government's buyer in the market;
- actually producing these equipments in the arsenals and other establishments it runs; and
- responsibility for bringing the State's interests to the attention of industry, and vice-versa.

The DGA is the institutional expression of the "strategy of means" in that *it is the link between the high command and the defense industrial base.*

The Delegué General pour l'Armement.-At the head of the DGA is the De1egue General Armement, who is directly responsible to the Defense Minister and normally acts as the vice-chairman of research, development, and equipment programs, He is assisted by a "cabinet" of scientific, technical, and military advisers, including a head of research. His entire area of responsibility includes over 75,000 personnel thoughtout France, many of whom are staff military engineers who are graduates of l'Ecole Polytechnique. *These* civil *servants have a full career structure with ranks analogous to military ones,* and often use their ranks as a *mode of address.*

DGA Functional Directorates—The task of the DGA's functional Directorates and one technical service is to provide coordination among the four Technical Directorates and Departments. The Direction des Programmes et Affaires Industrielles is the functional directorate that translates the requirements of the Services into research, development, and production programs (in line with program laws and the annual budget), while the Direction des Recherche, Etudes, et Technique D'Armement coordinates the basic defense research effort, disseminates results, and sets priorities for exploratory development; several study centers and services come under its aegis.

Each of the four Technical Directorates is responsible for both government and industrial tasks. Each is both a "puissance publique''—(public authority) undertaking research for, and exercising direction over, the armaments programs within its area of interest-and a "fournisseur" (provider), itself conceiving, developing, producing, and repairing weapon systems. In other words *the four technical directorates within the DGA are responsible for research, development, production, test, and evaluation of the equipment for which they are also responsible as customers.* Although procurement procedures are similar to those of other major Western nations, the French process is probably more flexible and pragmatic. It has also been observed-specifically in relation to procurement of aircraft for l'Armee de l'Air-that a stress on initial prototype production, and an aversion to the use of projects to "prove" several new technologies at the same time, are distinctive and successful characteristics of the French way of doing things. The four Technical Directorates are:

- Direction Technique des Armements Terrestres for ground defense equipment, technical assistance, and after-sales service of equipments;
- Direction Technique des Constructions Navales for naval ships, equipment, and weapons;
- Direction Technique des Constructions Aeronautiques (DTCA) for the whole range of military aviation engineering, including aircraft design, development, and production; its responsibility also extends to all aspects of civil aviation. The DTCA is organized to deal

separately with the supervision and control of development and manufacturing programs, and test and trials; and

- Direction Techniques des Engins for all aspects of ballistic and tactical missiles.

Policies for Collaborative R&D

Collaboration in Civil R&D

The French Government which initiated EUREKA, is firmly committed to the collaborative programs established under the aegis of the European Commission. The concluding section of this appendix describes some of these programs. Together with West Germany, France is a major partner and contributor to the European Space Agency (ESA) program, with each providing a quarter of its annual budget of about $1.7 billion. The French SNES has a budget of about FF5.43 billion ($1.1 billion), of which 40 percent is spent through ESA. Two of its major projects are the French designed and led Ariane-5 launch vehicle and Hermes, a manned orbiter now in development.

Collaboration in Defense R&D

What the French Government sees as the benefits of collaborative arrangements in defense R&D and procurement is rarely stated explicitly and authoritatively. Formally, France supports the Independent European Programme Group initiatives for coordinating and integrating armament procurements, and is an active partner with Alliance members in several projects such as sonars, army weapons, missiles, aircraft, and ships. It is also involved in the early stages or development of other collaborative projects across the whole range of defense equipment. But it is significant that the country's Loi de Programmation for 1984-88 mandates that French defense industries give France almost complete independence in armament production. The inference is that, for France, collaboration is seriously considered only when there is no alternative. A March 1987 agreement to cooperate with the United Kingdom on arms purchases (and nuclear issues), discussions in 1988 with the United States and United Kingdom on mutual requirements for a stand-off missile, and an accord with West Germany on operational issues, appear to have consolidated that position for the French. With an indigenous capability in most areas of defense technology, the main motivation for collaboration can only be economic. It is difficult to see France collaborating with other nations if the costs of such ventures would exceed those of a nationally produced product. Pragmatism prevails.

Research and Technology Evaluation

There is a Center for Evaluation and Prospective Development (CPE) which has created an intelligence nework that collects scientific, technological, industrial, economic, and social data worldwide—especially from the United States, Japan, the Scandinavian countries, and Germany—and makes them available through publications. CPE also acts for the EC as the French coordinator of data collections in the EUROT'ECH program, which aims at providing information on technological innovation in the EC. CPE was instrumental in providing French data to the Organization for Economic Cooperation and Development (OECD) for its 1986 report and is now working on models dealing with the influence of technical advances on production, on new ways of international technological cooperation, and on problems in creating a potential for intellectual investment. By virtue of its quasi-independent status, CPE hopes to establish itself as a center for evaluation of the major scientific *organizations* and to apply its studies of evaluation procedures to the technologies of artificial intelligence. It will act also as consultant in evaluations required by the EC and OECD.

The concept of "valorization," that is, assessing research in terms of transfer to definite applications, was one that the previous government hoped to address by creating the CPE and new advisory councils such as the CSRT. Recommendations had already been implemented concerning this area. especially by giving the Ministry for Research and Higher Education a central role in overseeing science and technology. However, the new advisory council CSRT, has recently called for another general review and recommendations for increased effectiveness in this area. It has been suggested that establishing technology transfer techniques alone does not automatically generate acceptable policies, and that advisory councils adequate for administrative purposes are insufficient to devise policy. Parallel experience in the United Kingdom shows that advisory bodies do not arrive at acceptable recommendations unless they have available the findings of policy research groups on which to base decisions. The data assembled by the CPE in science and technology will be at the disposal of a new assessment unit *(observatoire)* intended to lay the ground for wide-ranging research on which policy decisions in science and technology can be based.

France now seems to possess adequate machinery for the design of science policy. While value for money is a criterion for evaluation, the decision process in France is easier because there is a more general consensus on encouraging promising new projects-particularly international ones. On the national scene, while France is hoping to persuade industry to make a larger contribution to R&D, it is nevertheless encouraging industrial R&D with grants and tax concessions. The Government is not coercing industry with threats to withdraw support, for fear of undermining the very position in high technology that the French Government is supporting.

WEST GERMAN POLICY FOR RESEARCH AND TECHNOLOGY

Background

Although no country in Europe matches the total spending on research and technology of the West German Government and industry, the proportion devoted to defense R&D is small. The country is also one of the world's leading exporters, but its industry has been less dynamic than that of the United States or Japan in shifting emphasis to growth sectors such as electronics. This is true for R&D as well as production. Overall, the country's competitive position in advanced technologies has not suffered noticeably in the 1980's, but neither has it improved despite a period of weakness for the deutsche mark. West German officials realize they cannot alone match the spending of the United States and Japan, and that the scale of today's research and technology requires cooperation between countries and companies in areas such as aviation, space, and nuclear power. Even then the investment pays off only if a sufficiently large market is available. West Germany is therefore committed to collaboration.

Despite its support for international cooperation, West Germany joined with the United Kingdom in 1987 to oppose an increase in funding for European Community-wide research programs for 1987-91. German officials first wanted to see other governments, particularly those in southern Europe, strive to boost national R&D spending. Germany and the United Kingdom shared the view that the EC is not a replacement for a minimal national R&D policy; EC money should be seen as a stimulus for cooperation, to bring partners together-but not to finance projects, None the less, Germany strongly supports programs such as ESPRIT which have led to the formation of several hundred European research groupings, and believes that, during the next 5-year period, there should be more of them.

Because the EC's existence helps account for the success of Germany's export-oriented economy, very few Germans would want to cast doubt on their support for the EC. Membership has involved a price in that West Germany is, and will continue to be, the EC's biggest contributor; but the political and economic benefits of belonging to a united Europe have always been thought adequate compensation. Now, however, there is less certainty. The view appears to be growing that the country stands to lose more than it gains from the southward shift in the Community's center of gravity, the Commission's bid to reform its agricultural policy, and its plan to harmonize competition rules throughout the EC. Relations are also improving with East Germany—visibly so since the East German President visited the country in September 1987 and pledged scientific cooperation on projects ranging from physics to production technology.

With 1992 and the single European market approaching, a powerful coalition of West German industrial and trade-union interests is opposed to opening borders to genuine EC competition in such areas as insurance and telecommunications services, electricity supplies, and road haulage. The West German Government, like the Italian, sees the need for a closer coordination of European monetary policies and increased cross-border cooperation, to underpin the planned single market.

West German R&D Program Overview

Budgetary Aspects and Statistics

Total spending on R&D in 1987 was expected to be about DM48 billion (2.9 percent of GDP), of which approximately 75 percent was to be privately funded by industry and other sources, and the rest provided by the government (federal and state). The government's share was divided between the Ministry for R&T (60 percent) and the Defense, Education, and Environment Ministries (40 percent). The Government's share of total R&D has steadily decreased from 41 percent in 1983; to some extent, this reflects the administration's efforts to improve the investment climate by using indirect mechanisms rather than direct funding of R&D.

A 1988 report,[45] indicates a 5-percent increase over the initial estimate of DM 48 billion spent on research and development. When adjusted for inflation, this represents a real 2.5 percent growth over 1986. Privately funded research in 1987 was also slightly higher than expected, with 83.6 percent of all research being privately funded, as compared with the approximately 75 percent anticipated. This means that government funding of private research was actually only about 15 percent of the total.

Of government funds appropriated for research and development, most of the federal funds come from four ministries: the Ministry for Research and Technology (more than 50 percent), the Ministry of Defense (approximately 20 percent), the Ministry of Economics (about 10 percent), and the Ministry of Education and Science (which together with the other federal ministries, makes another 8 percent).

A high proportion of West German spending on R&D is for basic research, approximately 70 percent of which is performed in the higher education sector, with about 25 percent in the public sector, and industry spending nearly 20 percent of total basic research funds. Applied research is embedded in "development" figures and is difficult to identify separately; but together these categories constitute almost four-fifths of total R&D expenditure.

The Ministry of Defense accounts for about 15 percent of federal R&D finding, compared to about 50 percent for the United Kingdom. Put another way, in 1986, government-funded *R&D for defense as a percentage of GDP was only 0.11 percent in West Germany, compared with 0.68 percent in the United Kingdom and 0.81 percent in the United States.*

West German Government R&D expenditures consist of both federal and state funds. In 1983 the federal government was responsible for 60 percent of the total government funds. By law, the states fund almost all of the research and half of the capital expenditures of the universities. For the most part funds awarded to universities for general research are not allocated to specific categories-various independent specialist organizations set priorities. Nevertheless, the volume of funds is large enough to distort any breakdown of government R&D objectives by fund category. Funding for the Max-Planck Society, the German Research Society, and the Fraunhofer Society, as well as funding for basic research in the natural sciences, constituted more than 14 percent of the federal R&D budget in 1983 (compared to 20 percent for energy and 15 percent for defense).

Policy Aspects

Basic Pillars of Research Policy-"Art and science, research and teaching shall be free. Freedom of teaching shall not absolve from loyalty to the constitution." These words from the Basic Law of the Federal Republic of Germany echo similar words found in the constitutional legislation of the 11 federal states. While the federal and state governments are authorized to create a climate conducive to research, the researchers themselves are free in the choice of their subjects. Furthermore, the scientists are free to accept third-source funding if money from their own institution is insufficient.

An R&T Ministry director once described the constitutionally guaranteed freedom of scientific research policy in the Federal Republic. The second of these four pillars can be seen as West Germany's federal structure, where the 11 federal states assume independent responsibility in education and science. (The states are thus solely responsible for their colleges and universities, and it is only the area of expansion of the university system that federal and state governments share tasks.) The third pillar is the declared intention of the federal and state governments to interfere as little as possible with the research systems. The fourth pillar is symbolized by the intention that German research be integrated closely and effectively in international—specifically, in European-research cooperation, with a corresponding effort to design generally accepted regulations and standards for innovation and market expansion within Europe.

The significance of this freedom of research is two-fold. One point is that this freedom is never questioned. One institution, the German Research Society (Association), DFG, is an autonomous organization that wields great influence within the scientific community. The DFG's influence manifests itself in key research programs, whether in

[45] "Research Policy for the Federal Republic of Germany," The German Research service, Special science Reports, Special Issue, January 1988.

helping set the direction of research or in generating ideas for research policy itself. Although the federal and state governments currently allocate DM1 billion to the DFG, it is not subject to direct government influence.

It *merely shares the government's goal to build upon a high standard of achievement in basic research in West Germany. The* DFG's independent experts evaluate research grant proposals submitted by researchers of all disciplines. If their decision is affirmative, approval of payment of the grant money is almost a matter of course. The Max Planck Society and the Fraunhofer Society, both currently funded largely by federal and state governments, are also independent establishments that exert great influence in formulating research policies. The Max Planck Society is able to determine what research projects are needed at any given time, while the Fraunhofer Society series as a catalyst for technology transfer between the scientific and business communities.

The second point that bears upon freedom of research is that it is accomplished in an atmosphere of trust and cooperation. These research establishments discussed above build a network that is both multifaceted and an integral part of the federal structure of the Federal Republic of Germany. Their cooperative attitude is almost always harmonious with respect to the federal and state administrations, and conversely, the federated structure appears always to support the scientific community's work. This cooperation between the government and the scientific community extends to the private sector as well. Decisions by the Ministry of R&T consider the likely impact of a project on the national economy, and whether the nation as a whole will profit. Government funds are available, should the company responsible for a project incur technical or economic risks. This freedom of research is fundamental to Germany's success in research and development

Trends-h June 1983, the Ministry of R&T published a long-term financial plan that detailed Federal R&D spending plans through 1987. The plan showed government promotion of R&D to be slowing, with growth rates dropping to 2.4 percent by 1987. While the government remains concerned about the competitiveness of its industries, it has moved away from concentrated direct funding of product development, as illustrated by developments in the Information Technology sector. Instead, the government announced a more comprehensive plan to promote the development of microelectronics and information and communications technology, one that required overlapping ministerial responsibilities in a variety of areas. This initiative began at about the same time as the U.K. Alvey program, with which it has much in common. As with Alvey, this program was a point of departure for German participation in ESPRIT and other European collaborative programs.

The 1983 reorientation of government policy on research and technology called for increased reliance on private initiative and entrepreneurial responsibility, and restraint by the government in supporting R&D in industry, particularly in advanced development projects. Public funds were to be targeted at those areas where the government had its own responsibilities, or where overriding social or macro-economic concerns warranted government support of R&D. This was not unlike similar philosophies underlying the U.K. science and technology policies.

In 1987 the Ministry of R&T presented a "Comprehensive Program" explaining in detail the basic concept underlying its research promotion policies. This program suggests that there a reorientation in several is underway areas. The program emphasized five central tasks involved in research promotion:

1. to promote basic research (Max Planck Society), support large-scale projects, and further research in the arts and humanities and social sciences;
2. to promote government-run long-term programs (space, polar, nuclear fusion research);
3. to promote research in the area of prophylactic care (health, humanization of job life, environmental protection, climate);
4. to support market-oriented technologies (gene technology, molecular biology, materials research, information research and processing, and energy technologies); and
5. to improve the existing framework conditions and prerequisites for economic innovation.

There are specific programs for each of the first four tasks. The final task is more general, but its importance should not be discounted.

It is the Ministry of R&T's policy to emphasize new technology innovation by small and mediumsize businesses. The allocation of funds to benefit large businesses is being reduced, with smaller companies being strongly encouraged to involve themselves in new developments. Tax reforms will also provide a better environment for innovative developments.

The continued goal for research policies in Germany is to intensify cooperation between research, academia and business. Collaborative projects will be emphasized and personnel exchanges between government and privately run research institutions will be encouraged. Accompanying this goal is the expansion of the Fraunhofer Society in its role as "mediator for technology transfer between the science and business communities."

The pattern of industrial R&D which results from a policy of encouraging industry to shoulder more of the national R&D effort will inevitably be dedicated by the strategic needs of companies as they strive to be competitive in world markets. The balance between civil and military R&D must, however, be influenced by the budgetary policies of governments. *The most prosperous countries appear to be the ones which spend least on defense R&D*, attracting scarce scientific manpower into industries capable of competing in the international civil market for high-technology products, and depleting resources available for defense R&D. As one such prosperous country, with only a small allocation of government funds for defense R&D, it is not surprising that in West Germany both the government and the defense industry strongly favor collaboration.

Referring to civil R&D, the Director of International Cooperation in the Ministry for R&T said that "... the scale of today's research and technology requires cooperation between companies and countries for areas such as aviation, space and nuclear power." Even then, the resulting end-product "... only pays off if you have a large market. So the push for cooperation is stronger for Europeans than for America or Japan." This "push for cooperation" is evident in several major European projects, civil and military, in which West Germany is involved, such as the Eurofighter, Airbus, the France-German helicopter and, of course, the European Space Agency—to which it and France are the major contributors.

European Space Program-In 1987 the federal government made a strategic decision to bolster its aerospace industry. This included a plan to increase government spending on space by 10 percent in 1988, to DM1.2 billion, one-sixth of the total budget for the Ministry of R&T. In addition to the extra money, the space program would also require extra scientists and researchers, perhaps limiting research in other fields. The Research Minister has also suggested that 20 to 25 percent of his ministry's budget could eventually go for space research programs. That idea does not appeal to West Germany's industrialists, who question the wisdom of committing so much money to one sector. The Confederation of Industrial Research Associations (AIF) has warned against this emphasis on space if it means limiting research funds for small- and medium-sized companies, arguing that such a policy is too roundabout away to benefit German industry. The government's reasoning that space-based research findings have other applications does not convince everyone. However, the Columbus, Hermes, and Ariane 5 projects are ambitious and will in time inevitably produce spin-offs for all partners. Also under study, in collaboration with the U.K. (through British Aerospace and HOTOL) is the Saenger rocket-plane concept as the next, and possibly more economical, step into space.

EEC *Budget for* R&D-Realizing the limits to national funding for R&D, West Germany adamantly opposed a major increase in EC funding for 1987-91 Community-wide research programs. Officials first wanted to see more effort from such countries as Greece, Portugal Spain, and Ireland—each of which spend much less than 1 percent of GDP on private and public research-before the EC provides more of its own funds. None the less, West German is firmly committed to collaboration in both civil and military fields, with an estimated 70 to 80 percent of its researchers involved in international cooperation of one form or another, according to the Ministry for R&T

The Role of Science and Technology-The West German Government also uses science and technology *to shape international politics, as* in greater cooperation with East Germany, the Soviet Union, and other Eastern Bloc counties.

The goal of West German industry-staying competitive through high-quality products produced by high-productivity factories-has led the country to create R&D teams in several areas. Government policy now is to use these groups to strengthen

European R&D efforts to produce a stronger European Community while, at the same time, looking eastwards to new markets-and using science and technology agreements to exploit them.

Not all senior researchers agree with the government's research and aid-to-industry programs. The head of Bochum University's Institute for Applied Innovation Research, Professor Erich Staudt, was reported as saying that" . . . state subsidies for high technology lead to peaks, but then there is no connection. The Ministry talks only of *more* high technology, but that doesn't pay off. There's no economic context any more if you're far ahead."[46] He felt it was better to ignore high-technology trends and concentrate instead *on* new untapped areas. Staudt criticized the Ministry for R&T for "pushing" research into technologies where the United States and Japan already had an advantage. The result, he chimed, was the march of national research institutes into saturated market areas, producing new over-capacity already evident for such products as steel and personal computers. West Germany needed to innovate, not copy the world's latest high technology.

Whether by government or not, there is now a virtual hiring freeze at the 13 National Research Centers, 52 Max-Planck Society Institutes, and 34 Fraunhofer Society Institutes, together accounting for 25,000 staff jobs. Having filled these government and big-industry sponsored research centers, there is now thought to be a latent technological potential developing, with job pressure forcing young researchers into small to medium-sized firms where innovation and market-oriented effort should pay off in increased sales.

Evaluation of R&D-In a recent survey of the world's influential S&T journals, German scientists and engineers were found to have authored 6.5 percent of the articles, twice Germany's share of the world's researchers. In some subfields, German articles represented up to 15 percent of the articles. Patent applications, another research quality indicator, increased 9 percent in Germany in the period 1981-83, compared with a 1 percent decline in the United States. The number of U.S. patents granted to West German investors rose more than 40 percent between 1970 and 1984, with over 60 percent in machinery, and chemical and allied product technologies. The main evaluation method for R&D is the expert peer review.

Organizational Aspects

Overall Structure-The West German Government *achieves a degree of coordination of basic research without direct government control, largely due to the efforts of autonomous associations in its science system, e.g., the* DFG, which provides academic project support and scientific advice, and the Max-Planck Society (MPG), which conducts in-house research and operates over 50 research institutes. The Federal science and mission agencies take a more aggressive stance for applied research and work in the national laboratories, but the Association of National Research Centers (for the 13 "large-scale" centers) participates in setting research directions. A Science Council advises the government, DFG, and MPG.

Although no formal government-to-industry coordinating body exists, the Ministry for Research and Technology is the major source of federal funds and plays a coordinating role. Federal, state and industrial funds support the Fraunhofer Society, whose work reflects both government and industry needs. There is industry-government collaboration in the work of the national laboratories.

The system for funding and coordinating science and technology activities in West Germany thus relies on *certain special* organizations in executing the government's research and technology policy. Although many of these are considered to be nonprofit institutions, OECD guidelines state that the sector which largely controls a nonprofit organization, or is served by a non-profit organization, is the one to which the organizations performance and funding should be assigned. If the organization mainly serves or is financed by government, the guidelines consider the work as having been performed in the public sector. If the organization renders services primarily to industry, it is considered private sector work. As a matter of budgeting, however, government funds allocated to the organization are credited to public sector accounts.

The Science Council-The main coordinating body among the federal government, state governments, and the scientific community is the Science Council (WR), founded in 1957 by an administrative

[46] *Financial Times*, London, May 18, 1988, p. 20.

agreement between federal and state governments. It provides advice and recommendations on science policy matters, especially those concerning the higher education sector. Without executive powers, its recommendations carry weight because they constitute the consensus of the Council, whose members represent a variety of sectors and disciplines. An example of its recommendations was the establishment of the special collaborative programs that the German Research Society now sponsors (see below).

The WR is not a funding or granting organization. Nonetheless, it is mandated to review annually planned expenditures of the federal and state governments for higher education, including university proposals for new laboratories, scientific equipment, etc. The Council is thereby able to reduce duplication of major scientific equipment and facilities.

The Council recently reviewed the health of West German universities, especially as they pertained to the age structure of university staff. Most of the university positions were filled by tenured professors hired during the expansion period of the 1960s and 1970s. Since most would not be eligible to retire for another 20 years, there was little room for bright young researchers to enter academia. Moreover, many of the faculty positions had to be filled rapidly during the earlier expansion, and some of the staff were now less qualified than the younger researchers. To create and justify new positions, universities introduced new specializations. This led to the problem of overloading of the university curricula. The academic requirements in individual disciplines became so cumbersome that it was virtually impossible for students to complete their studies in 4 years.

The Science Council considered restructuring the higher educational training system to shorten the length of the first degree programs, and to strengthen graduate education, including the role of R&D.

Other issues with which the Science Council is concerned include the importance of outside funding for universities and research institutions, mobility of researchers, increased competition among states for R&D facilities, employment problems, and evaluating the quality of education and R&D.

Mux-Planck Society— The Max-Planck Society is an important performer of basic research. It is financed largely (94 percent) by public funds from both federal and state governments. Although its budget represents only about 2 percent of total national R&D expenditure, its influence on the national R&D effort is considerable. The MPG consists of 52 institutes, three clerical units, and two independent research groups. Independent research groups are a means through which new research efforts are promoted for a limited time and working relations between MPG and universities are increased. The institutes are not expected to perform basic research in all fields. The Society supplements research in universities and is charged by the Science Council to carry out research that requires large or specialized facilities; to supply adequate human and financial resources to areas of particular scientific importance and promise; and to conduct research in emerging and interdisciplinary fields. Over 60 percent of the MPG's research funds are in natural sciences, and most of the rest are in biomedical fields.

The importance of increased cooperation between the Institutes and universities is being emphasized, with most Institute Directors and senior scientists teaching at universities. The Institutes also offer research facilities to doctoral students. Despite an increase in research projects conducted jointly by the Institutes and universities, competition remains, with scientists preferring the research environment at the Institutes.

Fraunhofer Society - The Fraunhofer Society is to applied research what the MPG is to basic. It is a nonprofit society that sponsors and performs applied R&D through contract research, defense research, and services. The Society's main clients are industry and the federal and state governments. More than half of its 3,700 staff (in 1985) were in natural sciences (40 percent of funding) and one-third in engineering (50 percent of funding).

The Society performs a mix of its own research projects and contract research. Twenty-two Institutes are engaged in contractor project research with government and industry. Six institutes are dedicated to defense research and are supported by the Ministry of Defense. The Society also provides technical information; technical evaluations; economic studies; and assistance in obtaining, maintaining, and exploiting patents. There are four Institutes responsible for such services. The Institutes conduct applied R&D in specific areas:

- microelectronics and sensor technology,

- information technology and production automation,
- material and building component behavior,
- production technologies,
- process engineering,
- energy and construction technology,
- environmental research, and
- technical economic studies and technical information.

The federal and state governments provide subsidies through the Society to assist small and medium-sized companies for R&D projects leading to new or substantially improved products or processes, as well as for technical assistance. The Society has excellent links with industry; in addition to contract work and technical assistance, many of the heads of Institutes are on the boards of directors, or are R&D directors at some of the larger companies. The Society also has close links with the universities, with Institutes usually located near research universities, and more than half of the heads of Institutes university professors.

In 1985, less than half of the Society's funding came from federal and state government's in the form of institutional funding, and about 60 percent from contract research. The importance of contract research is expected to increase still further, thereby reducing reliance on government funding.

The Society performs research for the Ministry for Research and Technology in such areas as electronics, automation, and production technology (CAD/CAM and robotics); materials development (ceramics); and biotechnology and gene technology.

"Large-Scale" National Laboratories-In addition to the MPG and Fraunhofer Society, there are 13 "large-scale" national laboratories. funded by both federal and state governments but primarily supported by the Ministry for Research and Technology. They were established to supplement the efforts of the universities by conducting research requiring large-scale instrumentation and large-scale investment. The first centers began in the 1960s in nuclear research, while others now include space research, mathematics and data-processing, cancer research, biomedics, environmental protection, marine, and polar research. The full list is as follows:

- Alfred Wegener Institute for Polar Research,
- German Electron-Synchroton,
- German Aerospace Research & Testing Institute,
- German Cancer Research Center,
- Society for Biotechnological Research,
- Research Center Geestact Ltd.,
- Society for Mathematics & Data Processing,
- Society for Radiation & Environmental Research,
- Society for Heavy Ion Research Ltd.,
- Hahn-Meitner Institute for Nuclear Research,
- Max-Planck Institute for Plasma Physics Ltd.,
- Nuclear Research Plant Juelich Ltd., and
- Nuclear Research Center Karlsruhe Ltd.

Although supported almost completely by public funds through the Ministry of R&T, these laboratories are legally independent. Each has a supervisory board that establishes research priorities, and all are linked by an Association of National Research Centers that coordinates their activities and represents their interests with the federal government. The Ministry for R&T provides about 90 percent of the financial support for the centers, by "influencing" their research priorities. The laboratories conduct research in areas of technology of interest to the government; when investment in a particular area is reduced, there is a "domino" effect in the laboratories which leads to diversification into other priority areas.

Federal and State Research Establishments-h addition to the research laboratories already mentioned, the federal government maintains 40 research establishments that perform mission-related research for their respective ministries. The various states also own and support 50 of their own laboratories, which conduct applied R&D important to their particular region and economy. There are also 48 research institutions that are funded about equally by federal and state governments, and which are usually referred to as the "Blue List" institutes. They perform research that is usually more basic than that performed by the other federal and state research enterprises; a general requirement is that they conduct research of multiregional or national importance.

The *German Research Society-The* German Research Society (DFG), an autonomous organization somewhat similar to the U.S. National Science Foundation, finances R&D on a proposal review basis, relying on expert peer review. Besides funding research proposals, the DFG supports the training of young scientists, fosters cooperation between researchers, including international cooperation, and provides advice on scientific matters to policymakers. The Society does not have its own research institutes or perform research; it distributes R&D funds, mainly to the higher-education sector.

The DFG receives most of its funding from government sources; in 1984, 58 percent of its budget was provided by the federal government and 41 percent from the state governments. About one-third of its funds were allocated to life sciences, an area for which funding appears to be increasing. Other fields include physical sciences and mathematics (25 percent), engineering (23 percent) and social sciences and humanities (15 percent). The largest proportion (45 percent in 1984) of the Society budget goes to support its normal or core program, in which individual researchers initiate their own proposals and select their own topics. The Society also spends about 13 percent of its funds on proposals under a priority program; for a limited time the priority program supports research in those fields determined by the Senate of the Society to be priority areas, and for which it seeks to improve West German capabilities in order to match international standards.

A special collaborative program, that not only fosters cooperation but also promotes interdisciplinary research, was established in 1968 on the Science Council's recommendation. Under this program the Society provides long-term, but not permanent, funding that was about 30 percent of its budget in 1984. An institution or university, rather than a group of individuals, develops a proposal to demonstrate its commitment to long-term support of the research. Such a proposal must be examined and agreed by peer review. Unlike the other programs, this one is financed primarily (75 percent) by the federal government. A university must identify an area in which it excels, with the university or state government committing itself to continue funding the area after the Society support ends. The sites at which special collaborative programs are developed could be looked on as "centers of excellence," although they may not be the only centers of excellence in that particular field. One of the first special programs was so successful that it has now become a Max-Planck Institute for Mathematics. These programs are able to attract international scientists and engineers and even pay their expenses. In fact, one of the criteria by which a program is reinstated every 3 years is its international standing, calculated in part by the identities of the scientists, engineers, and publishers who have agreed to associate themselves with the program.

The Society is also responsible for administering special fellowship programs to enable young scientists with insecure positions to remain active in research.

Confederation of Industrial Research Associations-The Confederation of Industrial Research Associations is an autonomous organization that finances and coordinates cooperative industrial research-generally applied research and development. This organization is particularly important to the small and medium-sized industrial firms who find it difficult to support their own R&D. It was founded in 1954 and is now an umbrella organization encompassing 92 member associations, many of which have their own research institutes; the AIF even has 63 of its own. Industry supports most of the AIF's activities, but funds are also received from the federal government, particularly the Ministry for R&T and the Ministry of Economics.

If a problem common to member associations exists, a research proposal can be made to the AIF, which relies on a group of 120 experts from various fields to evaluate them. About half of the experts are from industry and half from the research institutes and universities. Reviewers must decide if the proposed project is technically sound and of scientific interest; whether the project is of economic interest to small or medium-sized fires; and whether sufficient resources are devoted to the projects. If the project application is approved, it will be supported with funds from the Ministry of Economics on condition that individual associations demonstrate that they are spending their own R&D funds in cooperative work.

The AIF also administers a federal government R&D support project for small and medium-sized firms that began several years ago. The exact terms have changed over the years; but essentially, they permit the Ministry of Economics to subsidize 40 percent of the labor costs for scientists, engineers and technicians engaged in R&D for those firms with annual sales of DM50 million and not more than 500 employees (1984 figures). It will also pay 55 percent of the labor costs for new R&D personnel if the firm can show that it has increased its R&D effort. In 1985, the program was expanded to include payment for 45 percent of labor costs associated with new R&D personnel in those firms with annual sales of DM200 million and 1,000 employees. Also in 1985, the EC decided that the plan was allowable under Community rules, and it is now scheduled to continue until 1989.

The AIF also administers the Ministry of R&T program that encourages small and medium-sized companies to contract for R&D work. The program subsidizes the costs of an R&D project contracted out with external research bodies (including universities and even foreign institutes). The Ministry subsidizes up to 40 percent of the costs of extramural R&D projects for those companies that have up to DM50 million in annual sales, and up to 30 percent of the costs for those that have annual sales of up to DM500 million.

Defense R&D—The Bundeswehr Plan, harmonized between all three Services, forms the basis for the Defence Ministry's annual contribution to the Federal Government's budget estimate. The military staff implement the equipment aspects of the plan through annual programs of research, development and procurement.

Within the Ministry of Defense there are two agencies concerned with procurement but not part of the military departments. The Armaments Department is specifically concerned with procurement plans, focusing on technological problem areas "project-free." Within the Armaments Department, and reporting to its head, is the Commissioner for Defense Research, who collates the research requirements from all three Services, including international aspects. The Federal Office for Military Technology and Procurement (BWB) is the principal body responsible for carrying our procurement plans. These two agencies administer research, development and procurement for virtually all West German military equipment acquisitions.

As mentioned earlier, West Germany commits only 0.11 percent of its GDP to defense-related R&D, or about 15 percent of government-funded R&D. This is spent within the defense-related industries, with the national laboratories, and with the Fraunhofer Society, which has six of its Institutes devoted to defense research funded by the Ministry of Defense. The defense R&D program is coordinated by the Commissioner for Defense Research in the Armaments Department, but procured through the BWB.

ITALIAN POLICY FOR RESEARCH AND TECHNOLOGY

Background

In recent years, Italy has enjoyed one of the fastest GDP growth rates in Western Europe. The huge state industrial concerns brought their losses under control and last year even turned in small profits, while private-sector industrial concerns have been reaping the profits of major restructurings and cost reductions. During the 42 months of the Craxi government, Italy experienced political stability; however, in the last 7 months, proposals for major changes in Italian Government policies indicate a period of significant turbulence ahead for industry as the government tries to control the country's economy.

In October 1987, the Senate budget committee suspended work on the 1988 budget and told the Italian Government to rewrite it. In the Senate's view, the assumptions on which it was based were just not credible. Since then the fragile, five-party coalition government has proposed the following:

1. *A plan to reconsider the use of large sums of public money to bail out struggling private-sector companies.*

- While not proposing to withdraw all state aid for companies in crisis, the Senate thought it was time to put an end to a policy of rescue tied to exceptional events, and to create instead a system of intervention in crisis situations with well-defined aims, instruments, and a period of implementation. The politics of modernization now have to prevail because European Community rules on industrial aid are becoming more restrictive as the 1992 deadline for a free internal market approaches. A consensus has grown on the need to reduce government intervention in industry in all forms. Previous "rescues" too often saddled the government with an expensive "flock of lame ducks," a welfare activity that protected jobs without specifying a time limit to government aid. Since EEC law will prohibit this, a new approach is essential to ensure competitiveness.

2. *A rnultiyear procurement plan to boost spending on defense equipment by 60 percent over 10 years.*

. This would be the first attempt in 13 years to take a comprehensive view of defense procurement related to Italy's changing strategic requirements. The Defense Minister's political aim is to secure parliamentary endorsement for his planning approach, serving both to establish a consensus and to strengthen the ministry's bargaining position with the Treasury over budgetary entitlements. The plan represents an agreed approach among the three Services, and should reduce the crude lobbying that traditionally has prevailed at the expense of coherently balanced demands.

3. In May, the government sought to end a decade of rising budget deficits and public debt by *adopting a 5-year strategy for boosting taxes and cutting spending.*

. *This* is the first time an Italian Government has committed itself to medium-term budgetary reform; but there are still a great many details to be worked out if the policy is to succeed. The motivation has come from EC's push to free all capital movements beginning about 1990; without a credible budget control program, a debt financing crisis would risk a return to capital controls. An essential complement to the government's approach is closer coordination of monetary policies at a European level_.

With the approach of 1992 and the single European market, the Italian Government will be expected to conduct its policies—whether on science and technology, industrial assistance, or whatever—according to the rules of the European Commission. In that respect, therefore, Italian policies will be similar to the policies of other EEC members.

Compared to the complexity of the country's domestic politics, Italy's approach to the European Community and collaboration has been straightforward. It is: an active participant in the various European collaborative framework programs for research, a strong supporter of the European Space Agency, a member of a European five-nation R&D and design program in nuclear reactors, and a partner in the quadri-national Eurofighter program. In aerospace, as in other sectors of advanced technology (e.g., telecommunications or semiconductor manufacturing), Italy has had to look abroad for (mainly European) collaboration to deliver the "spearhead" technological know-how, markets, and "niche" activities. Nonetheless, its *research activities and development efforts still lag behind the European average, which is in turn, behind that of the United States. This relative under-commitment to R&D is causing concern within Italian industry,* which believes that current levels of technology, though significant, provide no guarantee of being able to maintain present achievements in the future without an increase in government funding of R&D.

Italian R&D Program Overview

Structural Problems With Industry

Any review of the Italian defense industry (and other sectors) must note the excessive number of relatively small companies. This causes many resource problems-including those related to R&D, where the long "gestation" periods of projects absorbs resources. The disadvantages of this structural arrangement were identified in a Parliamentary committee report (unpublished), finally adopted in mid-1987; the report observed that there is a limit to the amount of public money available to finance projects (referring to aerospace, but applicable generally), and deplored dividing it among competitive enterprises. Keeping public companies which offered similar products under separate banners also militates against the economies of scale in manufacturing that can only be achieved by creating companies closed in size to the European average. Industrial "rationalization" seemed necessary; the criterion governing which state holding company an operating enterprise should belong to should be the degree of support and synergy that other companies within the state group can provide.

Proposed alternatives to rationalization included the formation of consortia, and cross-border mergers such as that between SGS-Ates (Italy's main microchip manufacturer), owned by Stet and the nonmilitary semiconductor interests of Thomson in France, spawned by the ESPRIT program. In the telecommunications sector, however, the collapse in late 1987 of Italy's attempt to bring together its two main indigenous equipment manufacturers-Italtel (owned by IRI Stet) and Telettra (owned by Fiat)-epitomized the pitfalls of pursuing a national rationalization policy in Italy. The more aggressive companies have taken the initiative without waiting for the government to act. Olivetti, for example, has embarked on a particularly ambitious program of marketing and licensing deals to increase its access to world markets, while also embarking on an equally ambitious program of acquisitions.

Whatever the pitfalls, there is consensus in support of further rationalization within the defense industries, provided a coherent plan for developing industrial capacity exists. However, there is no sign yet that this is about to happen or, with the vested interests of politicians, is even possible. The situation is further complicated by the complex network of shareholdings, linking companies in which shareholders from other parent groups are still represented.

Financing of Research

With over 1500 amendments to be discussed, the finance bill for the 1988 budget was hotly debated. The comments in this appendix refer, therefore, only to proposed policies and priorities; these are subject to change until passed by Parliament.

Total research funding in 1987 was estimated at 1.45 percent of GDP, an increase of 22.3 percent over the previous year. Although funding is lower than for other industrialized countries, the gap has closed significantly in the last decade in spite of devaluations of the lire. The figure is also lower than the 3 percent recommended by the Dadda Report on the future of science and technology in Italy; but at least the government has recognized that increasing the research effort is the key to improving economic conditions.

Overall public sector spending on R&D accounts for 46.4 percent of total R&D. University research expenditure continued to increase in real terms (+24.3 percent), and in 1987 represented 16.4 percent of public sector spending on R&D—higher than for the research organizations.

In 1987, industrial R&D accounted for the other 53.6 percent of total R&D spending, with private sector companies registering a 25.3 percent increase. Public sector companies registered an increase of 22.2 percent further underlining the growth of R&D outlays since the early 1980s. Figures vary with companies, but one public company, Italtel, spent 12.4 percent of group revenues on research in 1987. This increase in R&D expenditure since 1980 compared with growth in GDP in the same period underlines the effort Italy has made to develop a broadly based R&D system.

In 1985, public agencies performed 43.1 percent of the country's R&D, but financed 51.8 percent; whereas companies performed 56.9 percent and financed 44.7 percent. The government shows its commitment to research by supporting the universities and large research organizations, but spends only modest amounts in its own laboratories. Company effort in research and innovation is sustained by public funding (17 percent of total public sector funding in 1985) and from foreign sources (3.6 percent of the total in 1985). The external funding that companies receive represents about 25 percent of their total R&D expenditure.

Trends-In October 1987, amid political and financial uncertainty, the National Research Council (Consiglio Nazionale delle Richerche, or (CNR) submitted its report on the state of Italian science and technology to the Plenary Assembly of the National Consultative Committees prior to submission to the Inter-ministerial Committee for Economic Planning (CIPE). Although presented publicly, the report had still not been passed for publication by the Camera dei Deputati several months later. This review refers to statistics presented in the CNR report.

Italy has a Minister of Scientific and Technological Research (MRST) who coordinates *national* policy on civil R&D. Defense R&D is the responsibility of the Minister of Defense. The major scientific institutions that advise the MRST on his S&T options for basic or long-term research are the CNR, the National Committee for Research & Development of Nuclear Energy and Alternative Energy (ENEA), the National Institute of Nuclear Physics (INFN), and the Higher Institute of Health (ISS). The National Space Plan (PSN) is managed by CNR.

The CNR reported that technological developments were making it difficult to demarcate between basic and applied research. The change in government priorities, combined with increases in the costs of basic research (growing complexity of instrumentation, use of databases and need for more efficient security systems, etc.) created problems for institutes in general and universities in particular. While university research expenditure had decreased significantly in most other Western countries between 1971-83, in Italy it had been maintained at around 15 percent of total public R&D expenditure.

The public research sector favors disciplines with potential economic or social impact; thus, one finds significant support for engineering and technology

(18 percent of 1988 public sector R&D budget), space research (11.4 percent), physical sciences (11.9 percent), and biological and medical sciences (14.4 percent). Net funding has decreased for nuclear research and, strangely, for interdisciplinary research.

A major principle of the Italian Government's S&T policy for supporting companies is that publicly funded R&D tends to contribute to increased industrial competitiveness; as a result, CNR aggressively funds high-technology areas such as aerospace vehicles and materials (28.4 percent of public finding), other vehicle and transport materials (11.2 percent), telecommunications (15.7 percent), and information technology (8.7 percent). The IMI Fund favored telecommunications (21.6 percent of the year's disbursements) and Information Technology (19.6 percent). The CNR presumably sees these industries as Italy's most competitive-but there could also be a circular argument.

Major S&T program funding is identified by laws when the annual Finance Bill has been passed. For example, the following earlier laws were listed in the bill for the 1988 annual and multi-year national budget:

- Law 651/1983: Triennial funding for special intervention in Southern Italy.
- Law 456/1984: R&D programs, AM-X, EH-101, CATRIN for aeronautical construction and telecommunications (Defense).
- Law 284/1985: National Antarctic Research Program.
- Law 331/1985: Urgent provision of university buildings.
- Law 710/1985: Contributions to encourage industrial production.
- Law 808/1985: Assistance for development and growth of aeronautical sector industries (Industry).
- Legge Finanziaria '87: Special rotating fund for technical innovation. Special fund for applied research, university buildings, etc.

The CNR report refereed to earlier[47] also lists an Institution of Ministry of Universities and Scientific & Technological Research, which has its operating costs paid by a "special fund." This fund also provides for capital expenditure on programs such as:

- CNR for Fellowships for Southern Italian graduates (as part of the Government's regional aid policy).
- Reform of Law 46/1982 and participation in international programs of research and innovation.
- Renewal of the Government's support for the International Center for Theoretical Physics.
- Research and growth of geothermal resources.
- Refinancing Law 30/1982 for renewable energy sources and for energy saving.
- Financing of ENEA.

On-going, multiyear activities requiring budgets to be authorized by law, and renewable annually in the Finance Law include (with anticipated changes for 1988-90):

- European COST program (+11 percent).
- Funding to CNR (+12 percent).
- National space program (-16 percent).
- Central Institute of Statistics (ISTAT) (+8 percent).
- Ratification and execution of agreement with ESA (+28 percent).
- Approval and execution of international agreement on energy (+5 percent).

National Research Council—The CNR currently receives about 20 percent of the total public sector funding. Its budget was increased by 19.2 percent for 1988, and its funds for the National Space Plan were doubled. It was due to receive additional funds for "10 new finalized projects," as well as special programs (Law 46/1986) for Southern Italy.

The initiation of the 10 "new third-generation finalized projects" will involve 1,200 new full-time staff, including 690 in CNR and 500 in companies and other participants. The 10 projects are:

- telecommunications,
- robotics,
- electronic technology,
- new materials,
- superconductivity and cryogenics,
- international collaboration,
- information technology,
- biotechnology,

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- applied chemistry, and
- construction.

These, presumably, are program initiatives coordinated by CNR.

Under triennial Law 46/1986, the growth of laboratories and personnel in Southern Italy should account for 40 percent of CNR's total expenditure in the early 1990s. The first planned agreements for investments in area, made between IRI (public), Olivetti & Fiat (private), and CNR (institutions), are in innovation technology and applied and developmental research.

Excluding university research, to which it contributes, CNR's research gives funding priority to the promotion of industrial activity (13.5 percent), human health (10.4 percent), and basic research (10.6 percent). By comparison, the state administration and public companies' figures for 1986 were: promotion of industrial activity (20.9 percent), defense (12.1 percent), and energy (12 percent).

National Space Plan—The National Space Plan (PSN) was formulated in 1979 to give greater support to this sector and to strengthen Italian participation in ESA, to whose budget it is the third largest contributor after France and Germany. Space activity is managed by CNR, based on a 5-year plan which it updates periodically. The third plan (1987-91) is in progress, with such programs as the telecommunications satellite (ITALSAT) the propulsion system of IRIS, the geodetic satellite (LAGEOS II), the tethered satellite, and the science satellite for SAX astronomy.

Over the 1987-91 period the proposed spending breakdown for both national and international programs is as follows:

- 30.5 percent-telecommunications satellites
- 21.4 percent—space structures & research satellites
- 9.2 percent-earth & environment observations
- 9.1 percent-space station
- 7.8 percent-propulsion
- 6.3 percent—space science
- 3.8 percent-feasibility studies for future projects
- *3.6* percent-Technological research
- 8.3 percent-Other activities

In 1987, space activity increased in importance, receiving 9.9 percent of public sector R&D funding, both through the NSP and the growing financial involvement of publicly owned companies.

National Committee for R&D of Nuclear & Alternative Energy—The activities of ENEA in 1988 fall within the fifth Five Year Plan, and most of its budget is spent in the energy sector. ENEA's budget has been cut by 18 percent, reflecting government indecision on energy policy. While awaiting the government's decisions, ENEA reorganized those parts of the plan concerned with fission. Other areas of activity include collaboration with CNR for the management and funding of the Finalized Project on Energy, the national research project in the Antarctic, and agrobiotechnoiogies.

Defense R&D

The defense budget in 1988 accounts for 2.3 percent of GDP, while defense R&D accounts for 12.1 percent of publicly funded R&D. The position of the Italian defense industry among the Western world's arms manufacturers is now well established, but the effort that brought it such prominence in the late 1970s and early 1980s has ended. Exports have peaked, though in 1986 they still accounted for around 60 percent of the industry's output, compared with roughly 40 percent for both France and Britain. Hopes in the defense industry are now pinned on the recently proposed and coordinated re-equipment program (mentioned earlier) in which defense spending is to increase by 60 percent over 10 years-provided Parliament endorses the plan.

The Defense Technical Scientific Council (DTSC) coordinates and directs research and experimental activities carried out on behalf of or by the three Armed Services. In particular, the DTSC:

- centralizes the direction of research of common interest to more than one Service;
- coordinates research of special interest to each Service;
- identifies research of common interest and provides guidelines for its execution; and
- promotes higher education courses for the three Services.

The Chairman of the DTSC reports to the Defense Chief of Staff. The DTSC has a Standing Committee, consisting of one general from each Service and its own secretariat, to define, plan, and supervise the research programs. A Standing Technical Secretariat is the working **body** that implements the Council's and the Committee's tasks. The DTSC also cooperates with other national research agencies, thereby ensuring cross-fertilization with the appropriate civil science and technology programs. The DTSC maintains three specialized facilities: the Center for Military Applications of Nuclear Energy, The Experimental Missiles Range managed jointly by the Navy and Air Force, and a Center for Technical and Scientific Documentation.

The DTSC is primarily concerned with inter-Service research requirements, and does not deal with development or production. The post of National Armaments Director, responsible to the Minister of Defense, was created to provide "one voice" within NATO and elsewhere, to speak with authority on the coordination and control of all activities within Italy's military procurement programs, including collaboration on research.

Research for military purposes is carried out within each Service by dedicated agencies, or through the auspices of the DTSC when there is a multi-service interest. Civil research agencies are used for the benefits of cross-fertilization and to influence the direction of civil programs which have a military application, as well as to use their resources and research skills.

International Collaboratiot—In the past decade, Italy has been involved in major collaborative military programs for all three Services, both within Europe on projects such as Tornado and Eurofighter, and elsewhere on projects such as AM-X with Brazil. Generally, Italy does not become the major partner unless the project was originally a national one, as with AM-X. Italy has also launched several national projects, such as the A-129 helicopter, and only later looked for partners. Now, however, it is unlikely that major new projects would be launched in isolation from the needs of NATO and members of the Alliance, or without first having been considered by the Independent European Programme Group.

SWEDISH POLICY FOR RESEARCH AND TECHNOLOGY

Background

Sweden accounts for 1 to 2 percent of the world's total resources for R&D, to which it commits about 2.7 percent of GDP. With its limited number of researchers, it is impossible for Sweden to conduct research in all fields of importance to industry and the community at large; flexibility, both in the use and direction of resources, and in the definition of priorities, is therefore crucial. Through regular Research Policy Bills the government gives the Riksdag[48] an overview of research and research training at post-secondary education level, of sectoral research, and of industrial research activities. The bills also guide the planning and development of research activities and general priorities.

The Swedes have a concept of sectoral research in which every government department, regional agency, and administration is responsible for its own future, and must therefore invest in the R&D needed for its future operations. This R&D is normally carried out by external partners; approximately 25 percent of all R&D is performed within the higher education system; the rest is performed by industry, national authorities, public, private, and cooperative research institutes, and independent consultants. The higher education system plays a much more prominent role in the performance of basic and applied research than in experimental development, but in industry the ratio of basic to applied research is put at 12/88. About half of the R&D undertaken by public authorities, institutes, and the like is research and half is experimental development.

The main objectives designated by the Riksdag in science and technology are to support the efforts of Swedish industry in strategic areas, and industry's technical renewal. The government and the Riksdag define broad areas of support and decide the balance between different research fields in a national perspective, leaving researchers to decide on the more detailed definition of priorities and the projects to be funded.

The political system (with only 7 prime ministers in the last 50 years) is noted for its stability and a

[48] Swedish Parliament.

strong social consensus that, together, promote the acceptance of structural change and positive adjustment of national policies. This flexibility is further enhanced by the organization of government into small, efficient departments oriented toward drafting legislation and toward political activities, with administrative work entrusted to autonomous agencies.

Emphasis is put on the search for new knowledge and its application to the benefit of society. A pro-science and technology consensus appears to exist among all political parties and trade unions. The Swedish view of the status of science is exemplified by the fact that the *Prime Minister chairs the Special Research Advisory Board* that serves as a conduit to politicians, eminent scientists, and the community; there is a consensus regarding the importance of science and technology as a strategic factor, rather than simply an enabling one—as an investment rather than a current expense.

Swedish Research and Technology Program Overview

Government Organizations and Coordination

There is no Ministry for Research in Sweden: *As a result of the widely adopted "sectoral research" model, each sector of society takes responsibility for the research required for both short- and long-term creation of knowledge. The* Swedish R&D organization is therefore sectorized, and each ministry has its own R&D organization. Most government departments have allocations for R&D; however, 74 percent of public grants are channeled through the "big three," the Ministry of Education and Cultural Affairs (30 percent), the Ministry of Defense (24 percent), and the Ministry of Industry, including state enterprises (20 percent). An analysis of total public R&D funding by socio-economic objective in 1986/87 showed "general advancement of knowledge" as the largest single objective at 43 percent, with defense the second largest at 26 percent (mainly development), energy and water at 6.2 percent, and the industrial activities at 5.7 percent. In the "general advancement of knowledge" by field of science, the top three were medical sciences, natural sciences, and engineering.

Since 1982 the coordination of R&D policy issues has been the responsibility of the Deputy Prime Minister, assisted by an Undersecretary of State in the Cabinet Office. When the Deputy became Prime Minister in 1986 he retained this role, thereby promoting a useful interchange in basic research between the universities and industry. The government has a Research Advisory Board, chaired by the Prime Minister, which interacts among politicians, researchers, and the community and keeps the government informed on research issues. It includes eminent researched in various fields and convenes larger groups to discuss R&D issues-often at the Prime Minister's summer residence.

The definition of priorities is crucial for smaller countries with limited resources, if they are to stay competitive in a rapidly changing world technological environment. In Sweden the Riksdag defined a number of priority fields in the Research Policy Acts of 1982 and 1984. By voting additional funds for R&D in the social sciences and humanities, the Riksdag noted the importance of R&D in those sectors that, although less immediately useful, are vital to a country's intellectual life.

It is accepted by the government and others that only by innovation can Sweden's economic prosperity be maintained. Other organizations involved in the planning and financing of research include the Research Councils, the Council for Planning and Coordination in Research (FRN), the National Board of Universities and Colleges (UHA), and the National Board for Technical Development (STU).

Research Councils—The Research Councils (RCs) administer flexible grants for basic research, 90 percent of which is conducted within the higher education system.[49] Three of the RCs, together with the FRN, come under the Ministry of Education and Cultural Affairs:

- Medical Research Council (MFR)
- Natural Science Research Council (NFR)
- Council for Research in the Humanities and Social Sciences (HSFR).

The Council for Forestry and Agricultural Research (SJFR) comes under the Ministry of Agriculture.

[49] Annagreta Dyring, "Swedish Research, Policy, Issues, Organization," transition by R. Tanner, Swedish Institute, Stockhold, 1985.

The task of the RCs is to encourage research both in new and established fields. Besides promoting rest arch of scientific importance, the RCs also encourage the dissemination of research that maybe important to the larger society. They allocate funds according to criteria that the researchers themselves define. The 3 RCs under the Ministry of Education and Cultural Affairs each have 11 members; the Chairman and 3 members are appointed by the government, while the other 7 are elected every three years by active researchers in the faculties. Members can serve up to 6 years; thus, except for the FRN, the majority are research representatives.

The RCs occupy a central position; their priorities carry weight, because they ultimately select among, and fund, new research projects. Professional chairs can be affiliated to the RCs, and RCs are also responsible for research appointments, postdoctoral fellowships, and post graduate appointments in subjects with heavy recruitment needs. The RCs also evaluate research.

Much international research cooperation is carried out under the auspices of the RCs. The Board for Space Activities (DFR), for example, funded both by the Ministry for Industry and the Ministry for Education and Cultural Affairs, is independently responsible for various national and international space programs, including Sweden's contribution to ESA. Other RC tasks include special investigatory assignments for the Government.

Council for Planning and Coordination of Research-The FRN's main task is to initiate and support research of great social importance, together with the RCs and sectoral bodies. While the basic RCs are dominated by researchers, the FRN is dominated by community representatives from the four main political parties, trade unions, the Swedish Employers Confederation, municipal authorities, and county councils; the government appoints the FRN chairman. The FRN's structure reflects its role of monitoring community research needs and starting new, probably multidisciplinary, research programs. The FRN's tasks also include distributing state grants for expensive scientific equipment, carrying out studies, and sponsoring the National Understanding of Science program.

*National **Board** for Technical Development—The STU* is the state agency that encourages industrial research and development. It is the only central body that both supports initiatives, and plans and advises on technical research and industrial development. Its contributions vary from long-range, broad-based research to technical development, the allocation of venture capital, advisory services, information distribution, and technology procurement. The predominant forms of support for technical R&D are both general and selective. Support is channeled through the STU (or the Industrial Development Fund for longer-term, high-risk projects) in response to proposals from companies and institutions. The support is general, in that anybody can apply for it, but selective, in the sense that awards are made after an evaluation by the funding agency. The STU cooperates closely with higher education establishments and provides much of their funding. Loan to large companies are restricted to projects where an exchange of knowledge with universities and research institutes is part of the program. The STU also has a program for the "Development of Knowledge" as well as its own Technical Research Council.

National Board for Universities and Colleges—The UHA, a Government agency subordinate to the Ministry of Education and Cultural Affairs, is concerned with coordinating and planning national higher education, research, and research training. It compiles documentation on which the government and the Riksdag base their decisions for developing resources for higher education and research. It submits annual budgetary requests to the government, based on the requests it receives from individual educational units and other authorities within its jurisdiction. Central planning of higher education, research, and research training in various fields is conducted by five sectoral UHA planning committees. In budgets since 1982, most education expenditure items have been cut, but not research and research training. Research and research training funds are distributed by the local higher education establishments, not the UHA.

Sectoral Research—Beside the above organizations, the sectorization of Swedish R&D has spawned special agencies for planning, financing, and sometimes performing R&D in various sectors. In some cases special bodies exist to coordinate research in a particular sector, while in others these activities are coordinated through the ministry concerned. There are some 100 sectoral bodies financing R&D, most of them small. Those with extensive R&D activities include the Council for Building Research (BFR), the National Board of

Education (SO), the National Defence Research Institute (FOA), the National Environment Protection Board (SNV), the Swedish Transport Research Board (TFB), and the Work Environmenrt Fund (ASF). The STU described earlier is an agency of particular importance for technological development, and is also a sectoral agency for industry. In its review the OECD,[50] while recognizing that a reasonable balance had been struck between long-term basic research and short-term sectoral research, advised the government not to establish any more specialized in-house R&D facilities for fear that they will isolate themselves from the university system and from strategic research, and be unable to show a correlation between success and funding.

The National Defense Research Institute is a joint sectoral agency responsible for planning and coordinating defense research and for conducting the bulk of its R&D. Its funding allocation is part of the annual defense budget, although long-term development guidelines are laid down in the defense policy decisions enacted at roughly 5-year intervals. FOA also receives an allocation through the Ministry for Foreign Affairs to finance documentation for arms limitation and control.

The National Board for Space Activities is responsible for state-funded space research. Its duties include initiating space R&D long-range analysis, distributing state grants for space research and space technology development, and supporting industrial development in the space sector, including Sweden's contribution to ESA and other international projects.

Sweden has few governmental R&D laboratories outside the system of higher education.

Industrial and Technical Council—An Industrial and Technical Council (ITC), attached to the Ministry of Industry, was set up in 1981 to represent educational, research, and industrial interests, and is designed to promote contacts between government, industry, and technical research. Other miniseries have similar units attached to them.

R&D Policy Formulation

The Role of Education—Higher education in Sweden is a public research resource, and *university researchers are civil servants.* Most basic research takes place within the higher education system and consists of general scientific development, problem-solving, and goal-oriented research. Most development work is done by industry. In the main, the state finances R&D through:

- permanent resources to the higher education system;
- project funding for the research councils; and
- project funding for the special sectoral agencies.

Decisions by the government and the Riksdag concerning higher education research essentially are based on the annual budget requests submitted by educational establishments and research councils. Although the state exercises no detailed control over basic research, except through the establishment and scope of professorial chairs, it issues directives for major sectoral measures whenever it deems the national coordination of R&D necessary. Loose control is maintained through the size of faculty grants and various funding items within them, and by the balance of funds between faculties.

For applied R&D fincanced by the sectoral agencies, the state sets the basic guidelines, based on social considerations of policy, priorities, and structural matters-after consultation with industry, researchers *and the unions.* Within the government, ministries prepare R&D proposals based on requests from authorities, committees, and their own R&D agencies. The government presents its R&D policies to the Riksdag in periodic research bills.

Research Bills—Generally, there is political unanimity concerning the direction of research policy. Various research policy reform measures were carried out in the 1970s to foster technical renewal in industry, encourage industry to increase its own basic research spending, finance institutional research through 5-year framework programs, and the like. To achieve a coherent research policy, the government's practice since 1982 has been to introduce a comprehensive research bill every 3 years. The first such Bill was introduced by the government in 1982, followed by another in 1984 which represented a broader approach across 10 departments. The third was presented in 1987.

[50] Organization for Economic Cooperation and Development, "Reviews of National Science and Technology Policy: Sweden," ISBN 92-64 (Paris: 1987).

The 1982 bill introduced measures concerned with the dissemination of research information, improving contacts between university and industry, evaluating research by research councils and sectoral agencies and, most importantly, improving research planning and coordination. The 1984 bill presented long-term plans from sectoral bodies, so that university research planning could include the sectoral agencies. The bill provided for strengthening research evaluation and, for the first time, defined priority areas across research fields. Industrial strategic priority areas in technical research had been adopted in an earlier act on industrial policy.

The 1984 Act put less emphasis on planning, but defined a number of main issues such as quality of research, working conditions of researchers, and the balance between resources for the sectoral agencies and resources for basic research. The need to strengthen basic research was given particular attention. Measures to improve recruitment of students to research training were established and a system of student grants introduced. In sectoral research, long-term development of knowledge and competence was given a higher priority. The long-term priorities of the 1982 Act remained unchanged, but special emphasis was put on environmental research, information technology, materials science, and biotechnology.

Civil R&D Activities

Universities and Colleges—Sweden is divided into six higher education planning regions, with the university being the main institution of higher education and research in each region. There are 34 state institutions for higher education in 21 cities and towns. Higher education units with permanent research organizations exist in seven cities: Stockholm, Uppsala, Linkoping, Lund, Goteborg, Umea, and Lulea. Faculty and sub-faculty boards plan the research training within their fields and supply the university senate with documentation on which to base its applications for funds, and decide the distribution and use of university or college resources. Some faculties have only one department, while others may have up to 40. Specialized groups that are more or less permanent conduct the research. There are also multidisciplinary projects.

Within the higher education system there has also been a growth of problem-oriented research involving researchers in several disciplines; the Riksdag specifies these "thematic programs." Several professorial chairs have been established for each theme, and a number of research centers have been formed at the universities and colleges involved, such as the Research Policy Program at Lund and the Interdisciplinary Centre at Goteborg.

As a result of the increase in research and research training resources in the 1980s, the higher education system has taken on a growing number of research assignments from industry and the sectoral agencies.

Institutes—By international standards Sweden does not have many state research institutes. It has been, and remains, a deliberate policy of the government and the Riksdag to gather R&D resources within the higher education systems. Research institutes remain an exception. The government has established a number of independent R&D agencies and institutes in specific fields. Usually these are interdisciplinary to benefit the principal customer, exploit the installation of special equipment, do specialized tasks, or meet the needs of a particular region. One such independent R&D institute is the aforementioned National Defense Research Institute, which conducts defense-related research in the natural sciences, engineering, behavioral sciences, and medicine.

Partly to assure development in certain areas, the government has sponsored special institutes and companies to conduct applied R&D. To avoid scattering R&D resources, the government and the Riksdag have recently been more reluctant to start research institutes outside the universities.

A number of "cooperative" research institutes funded equally by government and industry exist; they form a common platform for industry and the state to develop the competence of various sectors. (Other cooperative research, similarly funded, is carried out in universities without the formation of an institute.)

R&D in Industry—As mentioned earlier, only 12 percent of industrial R&D is estimated to be basic research. With companies funding virtually all of their own R&D, it is understandable that the bulk of it should be "experimental development," *The strict distinction between the R&D roles of industry and the public sector (including academia), necessitates close cooperation and transfer of R&D results. The development of good relations between university and industry is therefore very important to Sweden's technological and economic progress.* For many years, both imports and exports of high-technology products have grown more rapidly than those of other sectors; the success of industry must, therefore, depend on its ability to manage technology-related factors.

While industry does little basic research, the OECD Review[51] gives some significant figures for total R&D:

- it represents 10 percent of value added in industry;
- it is nearing 70 percent of all R&D in Sweden;
- about 95 percent of R&D is in firms with more than 500 employees-the five largest account for 37 percent, and the 10 largest for 55 percent. Some of the large companies have their own research councils;
- while R&D is mostly allocated to developing existing products, innovation is growing;
- in some industries, R&D is hampered by lack of manpower,
- R&D-based high technology firms are on the increase, but do not yet play a major role.

University/Industry Cooperation—Attitudes toward operation in both industry and the universities have changed since the early 1970s. There has been strong industry interest in specific programs launched by public agencies, promoted in part by the predominance of well-trained researchers in the universities, and in part by the need of companies for the continuous generation of knowledge. R&D-intensive industries, such as pharmaceuticals and electronics, are now establishing closer links with the universities.

In 1985, the UHA canvassed major companies to identify their graduate needs by qualification, and their preferences for content, kind, and location of education and research. Industry's suggestions included expanding engineering degree studies, producing more computer specialists and other graduates with computer science qualifications, increasing in-service training, offering better language teaching, increasing the interchange of qualified personnel between academia and industry, providing for better dissemination of R&D results, and encouraging wider sharing of specialized laboratories and expensive equipment.

Adapting the system of higher education to the community's rapidly changing educational needs has high priority in Sweden. The OECD Reviews* quoted the Undersecretary of State in the Ministry for Education and Cultural Affairs as saying, "Due to the size of the country and due to specific traditions in higher education, there are three different oriented-research systems which have to co-exist geographically on seven main campuses: first of all academic research; secondly, politically initiated sectoral or mission-oriented research in areas such as defence, health, environment, housing, etc; and thirdly, commercially initiated contract research towards sophisticated products in, for example, the pharmaceutical industry, metals and pulp, computers, telecommunications, etc. All these kinds of research have to be undertaken in the same physical environment and partly by the same people."

Since the mid- 1970s the trend has been for higher education to be job-oriented and framed in the manner of the technical universities or the business schools. By international standards, Swedish industry employs fewer postgraduates or PhDs than comparable countries, preferring instead to hire graduates and train inhouse. This has no doubt contributed to the paucity of basic research done in industry compared to the universities.

University-to-industry cooperation mainly occurs through government agencies responsible for R&D support of interest to Swedish industry; the most influential are the STU and the BFR. STU, for example, funds about 30 institutes in cooperative programs. Most institutes are-located at or close to a university and collaborate very closely with it. The financing of the institutes is regulated through long-term contracts between STU and an industrial consortium, on a 50/50 basis.

SUT also funds up to 500 researchers and up to 1,000 research students in information technology and other priority areas, thereby complementing the basic resources of the university system.

Other examples of university-industry cooperation include science parks, innovation centers. and foundations, all of which grew rapidly in the 1980s. Special arrangements have been adopted, one of which is an R&D center established within a

[51] Ibid.

[52] Ibid.

university to promote contract research as well as industrial applications of new ideas. There are several such centers, often acting on behalf of the whole faculty, some of whom take the application to the pre-production stage. Another model is that of a transfer center established jointly by industry and the university, perhaps by way of a foundation. The most common arrangement is a foundation jointly created by a municipality or a county council, the county administrative board, a university or college, a chamber of commerce, some companies, and one of the industrial development boards. In the government's 1985-86 Budget Bill, special emphasis was laid on promoting the regional economic role of universities, with funds provided for support and dissemination of the technology and knowledge developed. A particularly novel arrangement is the venture in biotechnology carried out in the laboratories of the University of Uppsala, financed by STU, the university, and Pharmacia (a major pharmaceutical company) whereby Pharmacia employs the researchers but a special steering committee ensures that the results are open to all. Acknowledging that some cooperative arrangements may be more effective than others, the government has assigned to FRN the responsibility for evaluating each model.

Other initiatives to promote university/industry cooperation include:

- Adjunct or part-time professorships filled by scientists working outside the university system.
- A program under the government's Commission on University Cooperation with External Partners to make so-called "liaison researchers" from universities available to small and medium-sized companies. The Ministry of Education funds only the initial phase of a project, with regional organizations and the companies funding it thereafter.
- Contact offices at the technical universities to facilitate liaison with local industry. The Federation of Swedish Industries and some regional chambers of commerce have established their own contact offices at the universities of Stockholm, Uppsala, Lund, Linkoping, Umea, and Lulea.

Evaluation of R&D—Research is evaluated through peer review committees comprised of individuals with international experience and reputation. While such audits can help in assessing the quality of R&D, it may be that unless they knew the quality to be high, these international experts would be reluctant to accept the auditing task, as they would be unlikely to learn anything new. Sweden has some scientists of international repute, working in established centers of excellence; this preferential treatment of places and people of excellence may be considered elitist, but according to the OECD it appears to have served Sweden well. Sweden has been eminent for decades in such fields as ultracentrifuging in biochemistry, electrophoresis, exclusion chromatography, and the separation of large biomolecules, together with the enabling equipments in each field. Such success reflects both the persistence and perception of individuals and government support.

Defense R&D

Long-term direction for the defense program is provided by the Riksdag in 5-year defense resolutions, the last of which passed in June 1987. Annual budgets define priorities and identify changes. In 1986/87, defense programs accounted for 26 percent of government funded R&D of which, as in other industrial countries, the major portion was for product and project development rather than for basic research. Allocations Under ''defense R&D" on industrial development, since research contracts are placed with individual companies. Moreover, "common *defense research" as it is called, is closely connected with several other objectives such as space, energy, transport and communications, nature conservation, and public health and hospitals.* In a statement published by the Ministry of Finance, the civil functions for which the Ministry of Defense is responsible even included ecclesiastical preparedness.[53]

The FOA is the joint sectoral agency responsible for planning and coordinating defense research and conducting most of related R&D activities. In accordance with its policy of neutrality, Sweden retains a comprehensive defense industry capability, and can claim to be among the world leaders in several technologies. When capabilities are not domestically available, the freedom to manufacture imported systems and equipment under license or in joint ventures is inevitably sought.

[53] "The Swedish Budget 1988/89," A summary published by the Ministry of Finance, 1988.

International Collaboration—Swedish industry and its exports are highly specialized. Sweden has limited resources and cannot afford to develop a comprehensive range of complex technologies; therefore, it collaborates at all levels from individual researchers to government. International R&D cooperation includes exchanges of information, cooperation on individual projects and major research programs, coordination of research inputs, cooperation on research training, joint financing of research, and joint research institutions.

It is difficult for a small country to strike a balance in allocating its resources among national and international programs; tradeoffs have to be made among existing R&D programs, or at the expense of other sectors of society. For many years, the Swedish scientific community has been mainly responsible for achieving a sound and balanced international orientation for Swedish R&D; this has been a guiding principle of Swedish research policy. Decisions on participation in international programs hinge mainly on potential scientific returns, with special financial arrangements being made to allow participation in long-term European projects such as CERN, ESA, and cooperative fusion research. Though international research projects are also promoted by other motives such as industrial needs and policies in energy, trade, or development assistance, the importance of scientific value as a determining factor is likely to remain. Initiatives to increase international cooperation in research will largely continue to emanate from the scientists themselves; but the Prime Minister is actively involved in ensuring that costs and benefits are compatible with the government's integrated research policy.

Sweden also participates in international R&D under the aegis of such organizations as the United Nations UNESCO. It is involved in EUREKA and, though not a member of the EEC, is cooperating on ESPRIT, BRITE, and RACE, etc. through an agreement with the European Commission signed in January 1986. Sweden is an active participant in COST (European Cooperation in Scientific and Technical Research).

There is comprehensive R&D cooperation among Nordic countries funded through the budget of the Nordic Council of Ministers, and focusing on industrial technology. Substantial grants are channelled into technical and scientific cooperation by the Scandinavian Council for Applied Research (Nordforsk), the Nordic Industrial Fund, and under such project as Tele-X. Nordic R&D cooperation was strengthened by the establishment, in 1982, of the Nordic Research Council.

Bilateral research associations promoted by STU have been established with several countries, most notably France, Germany, and Japan, with extensive contact between individual researchers in the U.S. and elsewhere. The 1984 Research Act proposed that significant funds be allocated to enable researchers and students to work abroad, as well as to facilitate visits by foreign researchers to Swedish universities.

SUMMARY OF EUROPEAN COLLABORATIVE RESEARCH AND TECHNOLOGY

Background

Military Trends in Collaboration

Two diverse arguments support the current trend toward increased intra-European collaboration: first, the pressing need to improve NATO's military capability through a more efficient use of resources, and second, the political and commercial need to promote a stronger "European defense identity" within the Alliance and to maintain a viable "European armaments base."

Supporters of transatlantic cooperation emphasize the need for more efficient use of resources, while others emphasize the need to maintain a viable European defense industry. The need for Europe to export armaments and high-technology products figures strongly in arguments *for* European and *against* transatlantic cooperation, due in part to restrictive U.S. policies on technology transfer and third country sales.

In fact, both arguments are valid. The issue that brings both sides together is money. Real cost growth for military hardware can be more than 5 percent each year and the trend is expected to continue. Unfortunately, defense budgets are not growing to meet these increased costs. This has become a critical problem for the Alliance, which sees inevitable and unacceptable shortfalls in conventional capability, unless steps are taken to reduce armament costs.

While some rationalization is taking place, today's European defense industry is still fragmented and nationalistic, with manufacturers limited to smaller volume production that results in higher costs. In seeking a more cost-effective industrial policy through collaboration, Europe is trying to "put its house in order" and obtain more capability from its defense investments. A strong European defense industry will be better able to collaborate with the United States on more advanced programs, better placed to introduce European defense products to the U.S. market, and able to satisfy requirements for which European governments have in the part turned to the United States.

All European NATO governments today broadly support armaments collaboration, as the collective Ministerial Declaration and Decision Document, issued after the meeting of the Independent European Programme Group (IEPG) in November 1984, revealed.[54] To increase the benefits from armament collaboration these texts emphasized: 1) the importance of R&D collaboration to provide a basis for future collaboration on development; and 2) the need for staffs to work together from an early stage to see if needs could be harmonized.

The IEPG, whose task is to encourage European collaboration in defense research and procurement in a NATO framework, also called on nations not to launch projects that would duplicate others' efforts, and suggested that European governments be more willing to adopt equipment already in production in other Alliance countries, preferably European. *The commitment to collaboration is now registered strongly in national Defense White Papers,* and the intent of the IEPG Ministerial statements is reflected in national procedural documents that instruct MoD personnel to harmonize requirements, avoid duplication, and enhance coordination with the Allies' research and procurement programs.[55] Despite this commitment to collaborate wherever possible, there remains no directive in the U.K. MoD, for example, that European products be given priority in procurement; the principle of "the best equipment for the price" is still paramount.

The IEPG procurement concept models the U.S. style of competitive, consortium contracting, but on an international scale, not unlike the approach now being taken for "Nunn" programs. *Whether diverse industrial structures in individual European countries will allow such competition remains to be see, but the political will essential to success has been established.*

European Collaboration on Advanced Civil R&D

The growing concern in Europe over its technological future can be attributed to three factors: 1) the enormous impact of information technology; 2) the growing perception of advanced technology in strategic terms and the need for self-sufficiency; and 3) the severe "structural" handicaps to Europe's international competitiveness.

Europe's problem does not seem to lie in any critical shortage of basic technological resources, skills, or funds to support them, but in its failure to organize properly to exploit innovations to maximum commercial advantage. Some analysts suggest that Europe lacks high-technology companies big enough to challenge the largest U.S. or Japanese competitors internationally, but this argument does not stand close scrutiny. More plausible is the argument that the structure of Europe's industries has remained too rigid, with older companies slow to recognize that profitable growth requires worldwide marketing resources and a readiness to innovate. Many larger European companies still rely heavily on home markets that no longer provide economies of scale, or else they have traditionally set up operations dedicated to each national market. This contrasts sharply with the ways in which U.S. companies such as IBM, Hewlett-Packard, and Texas Instruments have organized on an EEC-wide basis to take advantage of the Common Market.

Breaking down the long-standing barriers that have isolated European companies from each other, as well as from other European national markets, is an explicit objective of the significant collaborative high-technology initiatives now being pursued. Industry, however, sees additional reasons for collaborating in research. One is that, as technologies converge, companies that once specialized in a single activity need to draw on a spectrum of

[54] Independent European Program Group, "Ministerial Declaration and Decision Document," reporting on first IEPG Ministerial Meeting, Nov. 22-23, 1984 (published in NATO *Review,* December *1984,* pp. *27-29).*

[55] Symposium *on* "A European Armaments Policy," Brussels, October 1979.

sciences to progress; innovation increasingly demands a multidisciplinary approach. The other is that as product life cycles shrink, the need for more frequent introduction of new ideas increases the costs and risks of research; companies can no longer afford to risk a generation gap in their products because of research failures.

As an inevitable step in the above process, *the Single European Act passed by the European Parliament provides the impetus and means to create an open market among EEC members by 1992. The* pace of European industrial integration is accelerating, driven by high-profile government publicity campaigns that "Europe is open for business" in 1992. Astute companies are preparing for 1992; if the internal barriers fall as planned, Europe will need to have in place an industrial structure that can exploit the increased opportunities.

The Impact of Collaborative Research on Future Defense Equipment

The political trend is for governments to reduce spending on defense R&D in real terms, encourage defense contractors to invest more, and put more emphasis on civil research and commercial applications.

The growing European collaborative civil research programs are explicitly directed towards civil commercial application, with little public recognition of their possible application to defense equipment. The dividing line between defense and civil R&D in the technologies appears to be fading, and only becomes marked when technologies are applied to products; at that stage, the trend is for funding to transition form government support to industry investment. *The European collaborative research civil programs clearly do have defense applications, but it appears to have been left to the industries involved to identify and exploit them; the* programs may not yet be sufficiently mature for such technologies to have been matched with defense equipment requirements.

Collaborative Military Programs

Overall Trends

From all that has been said and published, it is not the intention of the IEPG countries to encourage a form of European protectionism at the expense of U.S. defense companies; rather, a stronger and more coherent European industry is viewed both as insurance against waning U.S. attention to Europe, and as a step towards a stronger, more coherent industrial base throughout all of NATO, including the United States.

In fact, a significant impetus was given to transatlantic NATO collaboration by the Nunn-Roth-Warner Amendment to the fiscal 1986 Defense Authorization Bill. European governments and companies are now responding positively to Nunn program opportunities, and transatlantic consortia are forming at record pace; most major European defense contractors are involved in one or more projects listed as "Nunn Projects."

However, there are major European defense equipment programs provided for by Memoranda of Understanding (MoUs) between participating NATO nations, to which the U.S. Government is not a party-and in which U.S. companies can only hope for a minor or subcontracting role. Funding for such projects will come from the "D" element of government-funded defense R&D budgets, with little or no research directly applicable once the collaborative project stage has been reached. These joint programs are invariably run by companies formed specifically to manage them. Table G-1 presents a listing of the most important ones.

To this list of military projects can be added the civil aerospace Airbus program, managed by Airbus Industries on behalf of the U. K., French, German, and Spanish Governments.

Perhaps the most visible example of collaboration among European companies is the European Fighter Aircraft. This program is experiencing all of the traditional problems surrounding joint R&D and production programs, such as equitable worksharing, cost control, project leadership and control—and overcoming national biases. How *the Europeans address (and overcome) these issues may be a good indicator of how well economic "integration" will work in 1992 and beyond.*

European Fighter Aircraft

Program Structure and Goal—The EFA program is a four-nation collaborative venture involving the United Kingdom, Germany, Italy, and Spain. An October 1986 MoU authorized a four-government management organization, the NATO European Fighter Management Agency (NEFMA), to be set up in Munich under the auspices of NATO. The organization is similar to the NATO Multi-Role

Table G-l--Major European Management Companies

Company	Project	Nations
1. Panavia	Tornado	United Kingdom, West Germany, Italy
2. Eurofighter & Eurojet	European Fighter Aircraft	United Kingdom, West Germany, Italy, Spain
3. E H Industries	E H-101 Helicopter	United Kingdom, Italy
4. Eurocopter	Light Attack Helo	United Kingdom, Italy
5. Joint European Helicopter	A-129 Light Attack Helicopter	Italy, United Kingdom, Netherlands, Spain
6. Euromissile	HOT, Milan, Roland	France, West Germany
7. Euromissile Dynamics Grp	TRIGAT	France, United Kingdom, West Germany
8. BBG	ASRAAM	United Kingdom, West Germany

combat Aircraft Development Agency (NAMMA), the Munich-based tri-government agency that oversees the Panavia Tornado program. Also Munich-based are the EFA manufacturers' consortium, Eurofighter Jagdflugzeug GmbH, consisting of British Aerospace, MBB, Aeritalia, and CASA; and the EJ-200 engine consortium, Eurojet Turbo, consisting of Rolls Royce, Motoren-und-Turbinen Union, Fiat, and Sener. Many leading electronics and equipment companies in the four countries have also either formed, or are forming, international consortia to bid for systems contracts for the project. The master contracts for the program, placed through NEFMA, go to Eurofighter and Eurojet, both of which started work ahead of the recent MoU and financed it themselves to save time.

The Chiefs of Air Staffs of the four countries met in Madrid in September 1987 and reaffirmed their air forces' requirements for a fighter to meet the air threat projected from the mid-1990s. They signed the European Staff Requirement for Development (ESR-D) and forwarded it to their respective governments, with the hope that an early decision would be made to proceed with full development. That commitment has now been made by the U. K., Germany, Italy under an MoU signed in May 1988, with Spain expected to sign later in the year.

The original, tentative national requirements for the EFA were United Kingdom and West Germany, 250 aircraft each, Italy, 165, and Spain, 100; but budget stringency has reduced the West German figure to 200 for planning purposes, and there is some doubt as to the firmness of the U.K. *S 250. The United Kingdom and West Germany each have a 33 percent share in the development program, while Italy and Spain have 21 percent and 13 percent, respectively. The initial commitment is to spend $3.5 billion on the development stage, which should be followed by a further $10 billion. *Each production aircraft is expected to cost* **$52** *million at today's prices,* but the final fixed-price figure will not be agreed until nine prototypes have been built for flight testing; each country will build at least one of the prototypes, with the first scheduled to fly in mid-1991. Production contracts are expected to be awarded in 1992 and 1993 after development has proceeded far enough to confirm that the aircraft meets its performance requirements, with introduction to service in 1996.

The program is ambitious in technological, economic, and political terms. In the new climate of fixed-price, competitive contracts-and with the specter of the Nimrod cost and schedule overruns to spur them on-the industrial partners are well aware of the challenges they face to keep costs in line and avoid the ever-present "alternative" to buy a U.S. aircraft (e.g., the Hornet 2000). In Britain, more than in the partner nations, the advantages of "going European" tend to be presented in terms of job creation, but the most compelling case for keeping the project "European" was to retain a cutting-edge technological capability. Cost, it seems, was not the over-riding factor in the commitment to EFA over such alternatives as the McDonnell Douglas Hornet 2000, even though the program is disrupting defense budgets in all the participating countries (the U.K. MoD has admitted that its share is only "affordable with difficulty"); and Germany has reportedly canceled nearly 200 defense projects to "make room for EFA" in its budget.

BAe Experimental Aircraft Programme (EAP)- BAe first flew its experimental demonstrator aircm the EAP, in 1986. Originally conceived as a technology demonstrator when U.K. industry's patience ran out after several years of MoD procrastination over the RAF's fighter requirements, it was also something of an "EFA trailblazer." Funded by BAe, Aeritalia, partner companies in the U. K., Germany, and Italy, and eventually by MoD, the EAP was designed and built remarkably quickly; it was developed to demonstrate "fly-by-wire" and other advanced technologies for eventual application on "the U.K. 'S next fighter aircraft." Only one aircraft was built. In June 1987 it was announced, ahead of the recent EFA MoU, that the EAP was to be further funded for use as a flying test-rig for the four-nation EFA development program. Additional funding was also expected to cover flight setting of the EJ 200 engine being developed by the Eurojet consortium.

Commercial Aspect—The original EAP had been funded to a much greater extent by industry than by the U.K. MoD (German and Italian MoDs had declined to contribute), with the participating companies hoping to secure favorable—or even monopolistic-positions once EFA was launched. However, after the U.K. government imposed its considerable political influence on the EFA project, all EFA bidding became competitive, with all bidders having an equal chance regardless of whether they had contributed significantly on EAP. This caused those companies that had contributed to doubt the wisdom of such up-front investments on major projects when governments denied them any competitive advantage for so doing. The companies now have to bid a firm fixed price for development, drawing on hard-won background knowledge, with the prospect of further competition for subsequent production-and no guaranteed share for the developer. There is little doubt that if the companies had not made such investments, but had left it to governments to act, the EFA project would not be as mature as it is.

Other EFA procurement rules include the need for all bids to be collaborative; bids from single companies which, on their own, have all of the necessary skills will be adjudged non-compliant—*even if lower priced. This* ruling has led to ad hoc or "pseudo" teamings, proliferation of so-called "expert' companies, and lengthy bid lists and evaluations. The EFA program is collaborative by government edict, and no country has been prepared to forego involvement in important high-technology areas; this has led to mixed teams, committee or "political" choice of program leadership, as the risk of longer schedules, increased costs, and technological compromise.

The Radar Battle—The EFA program, if seen as the last major European military aerospace program of this century, may also decide the future of some bidders in specific technical fields. The first equipment to be decided will be the radar, and only in the United Kingdom are two companies (Ferranti International and GEC-Marconi) fighting for their country's share of the EFA radar contract. Each of the other three countries has only allowed one of its companies to bid for the contract, under a "chosen instrument" policy. The radar, which is the biggest single item after the engines and airframe, should be worth $2 billion shared among the four nations; this is about the same as for the canceled GEC-Marconi Nimrod AEW aircraft.

Largely as a result of its experiences on Nimrod and the troubled Tornado Exohunder radar programs, GEC has opted for a low-risk solution for EFA, based on the technology of Hughes' APG 65; Ferranti has offered an all-European. European Collaborative Radar (ECR 90) solution based on its own technology. GEC, which believes that the next competition will be between Europe and the United States, apparently sees the competition's outcome as crucial to the structure of European airborne electronics companies. Ferranti, on the other hand, is more concerned with Europe's retention of high technology, and the ability to update it, free from possible U.S. embargoes.

Under its bidding rules, *Eurof`ighter has insisted on freedom to export all components of the aircraft.* Bidders for contracts have been warned that they must guarantee freedom to export the equipment they supply, or list in advance the countries to which it cannot be exported. European companies are bound only by their governments' adherence to the general Western ban on sensitive sales to the communist world. Although not formally directed at the United States, this rule reflects Europe's sensitivity to U.S. technology controls and will affect U.S. companies most. DoD's response to the situation was a draft MoU that called for a phased release of APG-65 technology conforming to EFA development milestones, and assurances of an equitable workshare for U.S. industry. The DoD also indicated its willingness to be flexible in working out its ground rules for export of the radar technology to non-EFA nations. It emphasized that EFA nations should meet their own inventory requirements before trying to export the aircraft-thereby deferring export license requests until around the year 2003.

European Space Program

The European Space Agency is currently considering its long-term objectives for a series of major projects, including: an upgraded version of Europe's launcher, Ariane-5; Columbus, intended to be Europe's contribution to the U.S. space station program; and the French-sponsored Hermes spaceplane. In the face of significant cost growth on existing programs, ESA is under pressure to redefine its long-term program which the U.K. Government has described as "over ambitious and beyond Europe's financial capacity-and has failed to show how private sector funding would be factored in to reduce dependence on government funding. " These concerns are beginning to be shared by others of the 13 ESA member states, and even the most optimistic are concerned that ESA may have proposed more than Europe can achieve. The concerns are two-fold: first, the cost of building the new infrastructure in space may prove to be beyond Europe's means; and second, inevitable cost increases in coming years will limit ESA's capacity to operate and maintain space hardware.

France and Germany are the largest contributors to ESA, with each providing roughly a quarter of the Agency's annual budget of about $1.7 billion. The French national space agency, CNES, has a budget of about $900 million, of which 40 percent is spent through ESA. With cost estimates for Ariane-5 and Columbus having risen by about 50 percent to around $4 billion for each project, and Hermes nearly doubling to about $5 billion since concept launch 3 years ago, agreement on all three projects would require ESA's annual budget to rise to $3 billion by the mid- 1900s, approximately one-quarter of the U.S. budget for civilian space science and technology.

In contrast to France's unwavering political and financial support for the three projects, including Hermes, Germany initially joined with the U.K. in calls for ESA to delay building the manned orbiter and to give more priority to the Columbus orbiting module project, led by Germany. The French position partly reflected anxieties about competition to the Hermes concept from the West German and British designs for spaceplanes known as Saenger and Hotol, especially as these two projects are now merged under an agreement between BAe and MBB. While France was prepared to increase its already significant financial support to ESA, the U.K. initially refused to increase its 10 percent contribution, insisting that the private sector should contribute. This argument was rebutted by the Director-General of ESA, who believed that the funding of pure science and research disciplines, such as telecommunications and Earth observation, was a matter for "society as a whole" and not private industry. Commercial spin offs from space are still relatively rare, the most obvious being launch facilities and telecommunications satellites; returns from investment in space projects over 20 years will not be attractive to industry, even though technologies from space programs are now being applied in such other industries as electronics and materials.

In April 1988 the United Kingdom reversed its earlier decision and agreed to participate in Columbus, although with a much smaller share than either France, Germany, or Italy. ESA assumed that Britain would make a major contribution to a special satellite called the Polar Platform until the U.K. Government switched the direction of its space policy in mid-1987 and then switched back again in 1988. The Polar Platform will carry radar sensors and other instruments for Earth monitoring, with the prospect that such remote sensing vehicles could spawn a new industry, providing oil companies and agricultural organizations with ground images for monitoring mineral deposits and crop growth. While the U.K.'s contribution and commitment to the European space program is smaller than the space community and its partners would have wished, the U.K. Government at least appears convinced that the program's objectives have been defined more realistically, thereby justifying its intransigence during the 1987 budget discussions.

European Advanced Civil Research Programs

Overview

After months of wrangling over the EC's budget for its framework of R&D collaborative programs, the EEC members finally agreed in September 1987 to spend 5.2 billion ECU ($6.8 billion) on technology collaboration over the next 5-years. Within that framework are several individual spending lines that include information technology, advanced telecommunications, biotechnology, alternative energy sources, environmental research, and nuclear safety. These subjects have their own specific research programs-ESPRIT, RACE, and BRITE-which will be defined and described later in this section.

The Commission does not fund EUREKA, which could itself approach $5 billion.

The September accord contained important conditions designed to meet the objections of the United Kingdom, the only member to refuse a scaled-down version of the Commission's original ambitious research budget first proposed 18 months earlier. Even now, there remain doubts as to how strictly one of the U.K. conditions wiIl be enforced, whereby 417 million ECU ($500 million) was held back pending clear evidence of progress on setting up practical spending controls for the entire EEC budget. The U.K. Government remains adamant that "expenditure on research cannot be separated from the overall question of total resources available and the disciplined identification of priorities for their allocation." Collaboration in advanced research is not without its problems, but the Europeans appear to be making good progress.

The Joint Research Centers

The EC funds four laboratories of its own, known as Joint Research Centers (JRCs), at Ispra in Italy, Karlsruhe in West Germany, Petten in the Netherlands and Geel in Belgium. Whereas the JRCs were once the flagships of the EC's research effort, their direction, objectivity, and usefulness have recently been criticized to the extent that the EC is planning to tighten their management. Under proposals adopted by the Commission in October 1987, the JRCs will have to reduce their dependence on the EEC budget by 40 percent by 1991. The proposals envisage that 15 percent of the JRCs' resources should come from contract research for governments and companies by 1991, with a larger proportion coming from other Commission departments. The plan does not, however, envisage any cut in the JRCs' 690 million ECU allocation for the next 5 years under the EC's framework of research programs. The Commission has proposed a sweeping reform of the JRCs' objectives, mode of operation, and method of management Ispra, in particular, is reputed to need "a clean break with the practices of the past."

The 12 research ministers, however, were unable to accept the Commission's proposals; West Germany called for more details on how the JRC's performance would be monitored; the United Kingdom called for better control on areas where JRC work duplicates other EEC research; and West Germany, the United Kingdom, and The Netherlands thought the 40 percent reduction in dependence on the EEC R&D budget by 1991 did not go far or fast enough. Ministers did agree, however, that the JRCs should have more autonomy and less interference from Brussels.

Eureka

Originally conceived by France as a riposte to President Reagan's Strategic Defense Initiative, the European Research C(K)oordinating Agency program was launched in mid-1985 as a joint European program to strengthen non-military technologies, by jointly funded collaboration between European companies on civil projects with clear market applications. As stated by the Declaration of Hanover, the criteria for EUREKA projects are that they "will serve civilian purposes and be directed both at private and public sector markets." The sponsors are the 12 EEC governments, the Brussels Commission, plus Austria, Finland, Norway, Sweden, Switzerland, Turkey, and Iceland. The *aim of the* program is to improve Europe's competitiveness in world markets in civil applications of new technologies by encouraging technical and industrial collaboration.

Projects are underway in information technology, telecommunications, robotics, materials, advanced manufacturing, biotechnology, marine technology, and lasers, as well as in environmental protection and transport technologies. Companies identify topics and market opportunities on which they wish to collaborate, then seek collaborative partners, with governments acting as "barrier-busters" wherever obstacles to collaboration and trade occur. EUREKA status is granted to a project by agreement between governments of all companies involved, and the EUREKA Ministers' Conference is notified. EUREKA has no central fund instead, governments have promised national support for approved projects.

With a further 58 newly-agreed EUREKA projects announced at the September 1987 Ministers' Conference, *the number of agreed projects is* 165, *with a total value of at least $4.8 billion.* A recent survey of the management needs of EUREKA participants showed that some companies were experiencing difficulties, with the underlying factors being company size and collaborative experience. The U.K. Government believes that EUREKA has confirmed both the need for, and the feasibility of, cooperation between business and scientific communities across national frontiers in Europe. EUREKA has given companies the opportunity to request support from governments and the Brussels Commission. These measures should influence the framework for collaboration and thereby accelerate efforts to: establish joint industrial standards at an early stage, eliminate existing technical obstacles to trade (e.g., mutual recognition of inspection procedures and certificates), and open up the system of public procurement.

Esprit

The European Strategic Program for Research in Information Technology (ESPRIT) was launched by the EEC in February 1984 to encourage collaboration among companies, universities, and research institutes in different EEC countries on a wide variety of Information Technology (IT) topics. The program was conceived out of concern over Europe's poor IT competitiveness on the part of the Brussels Commission and the Round Table of 12 leading European IT companies (GEC, ICL, Plessey, Bull, CGE, Thomson, AEG, Nixdorf, Siemens, Olivetti, Stet, and Philips).

ESPRIT involves joint precompetitive research that, while not intended to generate commercial products directly, may lead to further collaboration. The program was initially set to run for 5 years with a budget of 1.5 billion ECU, half of which is provided by the EEC and half by the participating organizations, in support of 227 projects (from over 1,000 proposals). Five areas of IT are covered: microelectronics, software, advanced information processing, office systems and computer integrated manufacture. ESPRIT is a program of directed research based on published work programs, organized on an annual cycle that includes strategy and project reviews. Management involves the Commission, the Round Table, an ESPRIT Advisory Board, and the ESPRIT Management Committee.

The program is open to companies, academia, and research bodies, public or private. Each project must include companies from at least two member states, but there is no formal prohibition of subsidiaries of multinationals, provided the research is carried out within the Community. Intellectual Property Rights (IPR) arrangements provide that "foreground information" is owned by the contractor generating the information; however, *IPR must be made available on a royalty-free basis to others in the consortium and to those doing complementary work. The same* rules apply to background information provided the contractor is free to disclose. There is a general injunction on the owner to exploit results, subject to conditions of disclosure and the owner's commercial interests.

Since most of the first-phase projects last for 5 years, until the end of 1989, it is too early to judge whether the program has met its three objectives: to boost cross-border cooperation, to develop industrially important new technologies, and to create EC-wide standards for IT products. Even so, the Commission feels it is time to start looking for results, and an *independent technology audit will be conducted later in 1988.* According to ESPRIT's annual report, by the end of 1987 and 227 projects had produced 143 results of "industrial significance," 27 had contributed to products on the market, 44 were in products under development, 44 had been transferred outside ESPRIT, and 28 had contributed to an international standard. About 5 percent of the projects had been scrapped or merged. Specific achievements noted were:

- The high-speed chip or transputer, developed by INMOS of the U.K. Thorn EMI (INMOS') parent company) worked with the French electronics group, Telmat, to produce two low-cost supercomputers (the Parsys 1000 and T-Node) incorporating transputers. They provide around half the performance of the fastest computers in the world—made by Cray Research-at a tenth of the price. Although the transputer required only 4 billion ECU from ESPRIT for the precompetitive research, Thorn EMI needed to invest substantially more to bring it to the market.
- As a catalyst for forming standards, ESPRIT has created a type of software, Communications Network for Manufacturing Applications (CNMA), that allows different kinds of robots to work together in an automated factory. It is compatible with, but wider-ranging than, a similar standard developed in the United States by General Motors, and is already used by BAe to build Airbus wings, and by BMW at its Revensberg plant.
- The same kind of strategic value, this time in office systems, lies in a development called office Document Architecture (ODA), a way of formatting documents so that they can pass easily from one kind of desktop computer to another, thereby making it more difficult for a

dominant supplier to comer the European market. Another ODA allows the same flexibility for mixed text, image, and voice data. ODA was accepted by the International Standards Organization in late 1987.

In monetary terms, the package the Commission recommended for ESPRIT II was roughly double the size of ESPRITI. The program, which the Commission adopted in July 1987 and the European Community Research Ministers approved the following April, benefits from a 1.5 billion ECU cash injection that industry will match. This second phase of ESPRIT (1987-1991), the largest single project in the EEC's R&D framework program, will concentrate on the use and integration of IT, computer-integrated manufacturing, and application-specific integrated circuits. Over 1,000 proposals were again received and final decisions on successful bids were to be made in mid-1988. However, the joint bid by Europe's three leading computer groups, Siemens, Bull, and ICL, for an 85 million ECU program focusing on basic designs for the next generation of computers is one of the most ambitious schemes planned under ESPRIT 11 and "will need a lot of discussion," according to the Head of the Commission's IT Directorate; but the timeliness of the bid's objectives is not in doubt if Europe is to be competitive in IT in the next century.

One source of the success of ESPRIT has been the strength of basic IT research knowledge and skills present in European universities and research institutions. There is a clear need to maintain and increase these resources in Europe and, to this end, ESPRIT II will include a new element—the Basic Research Action-to promote collaborative basic research in selected IT areas most likely to create future breakthroughs. Research should be clearly upstream of ESPRIT precompetitive R&D in microelectronics, IT processing systems, and IT applications, and should be potentially relevant to long-term industrial objectives. Some 70 million ECU have been set aside for the basic research actions, which should be aimed at:

- optical computing, electronic properties of organic materials, quantum electronics, low-temperature electronics in superconductivity;
- formal methods in software engineering, computational logic and algebra, functional logic and object-oriented programming languages, distributed algorithms and protocols, dependability, complexity, parallel systems, databases; and
- learning, knowledge representation, non-standard approaches to logic, reasoning, speech and natural language, higher-level vision, multisensory fusion, perceptual-motor coordination, autonomous systems, symbolic and sub-symbolic computation, and human-computer interaction.

The above list is not exhaustive; proposals for research across disciplines, areas, and topics are encouraged. ESPRIT rules require that consortia must consist of at least two organizations from different member countries but, unlike the main program, industry participation in the Basic Research Actions is welcome but not a requirement.

RACE

Research and Development in Advanced Communications for Europe (RACE) is a strategic, market-responsive R&D program intended to lay the groundwork for a new generation of optical-fiber broadband communications systems to come into service throughout Europe during the 1990s. The aim is to achieve common standards and help European manufacturers gain a lead in advanced telecommunications products. An initial 1-year definition phase began in January 1986, with 31 projects costing 50 million ECU split between the Commission, manufacturers, and national telecommunications authorities. The Commission was seeking 800 million ECU in support of a second or main 5-year phase to develop technologies and specifications and test prototype systems. The Community's contribution to this main phase is 550 million ECU, matched by an equal contribution from the industrial participants in the program.

BRITE

Launched in 1985 as a 4-year program to increase the use of advanced technologies in the traditional sectors of industry, the Basic Research into Industry Technology for Europe (BRITE) program has already achieved a climate of cooperation in industrial technology, leading potentially to a new competitiveness for European industries. R&D carried out under BRITE must have a clear industrial potential and be precompetitive. The scope of the program includes:

. reliability, wear and deterioration;

- laser technology and its application, and other new methods of metal shaping and forming;
- joining techniques;
- new testing methods including Ion-destructive testing (NDT), on-line and computer-aided testing;
- CAD/CAM and mathematical models;
- new materials, in particular polymers, composites and others with special properties;
- membrane science and technology, and problems in electrochemistry; and
- catalysis and particle technology.

Precompetitive technical R&D, including pilot and demonstration projects in new production technologies suitable for products made from flexible materials, is sought in three main areas:

- automated handling of flexible materials and articles made from them;
- automated joining of flexible materials and their assembly into finished products; and
- integration of the above technologies together with others leading to flexible sequential automated manufacture, with particular emphasis on the need to accommodate multi-product manufacture and model changes.

The rules for funding and participation in BRITE are similar to those for ESPRIT

In September 1987, the EEC approved 112 new projects for BRITE, selected out of 471 research proposals submitted from more than 2,200 different organizations. The 112 projects will involve 573 participants from the 12 member states, 60 percent of them industrial companies, 25 percent research institutes, and the rest universities. Out of these, 46 projects were to receive Community finding up to a total of 45 million ECU once contracts were signed. The remaining 66 projects were to receive up to 60 million ECU as soon as the member states agreed on the revised BRITE program to be submitted by the Commission.

Among typical cross-border projects is a Dutch chemical manufacturer teamed with laser specialists in the United Kingdom to develop optical recording materials based on polymers. Unlike existing photographic films, these new materials would need no chemical processing and would be erasable. Other projects include the use of CAD/CAM in shipbuilding, and the use of lasers to treat alloys in steam and gas turbines to reduce wear and increase resistance to corrosion.

Some Reactions to the "Technology Push"

Though the United Kingdom was widely criticized in 1987 for single-handedly obstructing the EC's proposed research package, enthusiasm in other governments was reported as "appearing to be slackening" as they reevaluated technology and industry policies. While programs such as ESPRIT, RACE, BRITE, and EUREKA symbolized an almost obsessive drive to strengthen technological performance, complaints were heard that the Commission was interested only in more research spending. The mood today is increasingly typified by that of the U.K. Government, which accords *higher priority to promoting the use of the new technologies than to aiding the companies that supply them.* In West Germany, the change is thought even more pronounced, with Bonn appearing relaxed to the point of indifference—even with an "information technology" trade deficit. A senior Economics Ministry official reportedly believed that West Germany should concentrate on traditional industries where it has proven strengths, rather than pour money into glamorous new technologies where the risks were high and commercial rewards uncertain. Siemens, too, apparently insisted that it was right to be cautious, when "new technologies like robotics were supposed to become big business but never took off." In France, the government appears more concerned to acquire international market share for its high-technology companies, than to promote technological advances for their own sake.

These trends simply reflect the gradual recognition in Europe that *achieving a commanding technological position, on its own, does not guarantee high profits; innovation quickly becomes subject to intense competition in which even the most successful companies can sustain heavy losses.* European participation in the U.S. Strategic Defense Initiative typifies the mood, being described as "at best of dubious commercial value, and at worst as a wasteful diversion of scarce resources. " Even the recent weakness of the U.S. economy was seen as a counter to the theory that a sound economy and commanding technological skills went hand-in-hand. In Europe there has been a general shift towards deregulation, privatization, and other policies geared to enhancing the role of market forces. In the EEC the completion of the Single Market by

1992 now commands a high priority, and industry is being encouraged to put its own house in order, assume more independence from government support, and respond to the influence of market forces.

In reality, today's trend can be seen as a healthy correction to reduce reliance on costly, often ineffective, technology-push policies and given greater scope to the stimulus of market pull.