Chapter 6

Exploiting Other Management Approaches

CONTENTS

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OVERVIEW

As the U.S. Department of Defense (DoD) and Congress look for ways to solve problems associated with managing technology programs and research facilities, they will find that they are not alone in this concern. Other organizations—large corporations, foreign governments, and international groups—face similar challenges, and have taken a number of approaches with varying success.

For two reasons, the experiences of these other organizations warrant attention. First, they form part of the backdrop against which DoD will operate —the corporate structures and the foreign governments with which DoD will cooperate to implement its research and technology programs. Second, these organizations exemplify other approaches to accomplishing related tasks and addressing similar management problems. They offer models that might be adapted for DoD's purposes.

This chapter concentrates on organizational and management techniques, but along the way it addresses the emerging international defense-industrial environment within which DoD will operate in the next decade.

The Changing Environment

Research managers—both in government and industry-must find ways to keep up with the rapid pace of science and technology. In industry, timely applications of technology are essential to remain competitive. In the case of defense programs, the West must maintain a credible deterrent in a period of political change and uncertainty, Rapidly increasing research costs and diminishing financial resources are also causing U.S. Government officials and their industrial counterparts to rethink their research programs. The overall structure of research programs has been under scrutiny, especially the mix between long-term research and near-term applications. The use of new approaches to research and technology development—such as university-based or industrial centers of excellence—to direct interdisciplinary resources toward key research goals has grown in popularity. Policies governing intramural v. extramural research—the industrial research equivalent of make-or-buy-are being debated. On this point, the U.S. Government is unique with its large and wholly owned laboratory structure. At the opposite extreme, some governments and companies maintain no internal research capabilities at all, depending entirely on technology developed by others. Research management methods are also under review, with particular emphasis on the question of whether centralized management should replace independence at the researcher level.

Whether to collaborate or "go it alone" is becoming a major issue. In general, full-spectrum laboratories (i.e., those capable of conducting basic research, advanced development, and engineering) appear at odds with those offering specialized capabilities (e.g., centers of excellence) and focusing on selected research topics. The disparity arises because full-spectrum laboratories are often oriented along mission lines and, for reasons of efficiency or security, prefer to work alone; whereas specialized laboratories must interact with other organizations to get the job done. There is a growing attitude in governments and the private sector that collaboration, with all its inherent difficulties, is perhaps the only practical way to finance basic and applied research on contemporary topics in science and technology. Independence, whether for individual laboratories, companies, or countries, is becoming financially prohibitive, and those who insist on going it alone are increasingly at a competitive disadvantage relative to those who collaborate.

Finally, incorporating laboratory technology in products carries a high priority for companies and government officials alike. While different approaches have been taken to encourage better technology transfer, they all involve giving someone the responsibility and the authority to ensure that the process occurs. While this is simple in concept, making it happen is not easy, and few organizations do this job satisfactorily.

Other Experiences and Concepts—How Applicable?

In this chapter, approaches to technology base management employed by other Western governments[1] and by the private sector are examined to see if the successes-or failures-of others can serve as models for DoD. Japan, major European governments (those with significant military technology bases), and U.S. and European defense companies are the primary subjects. The defense sector of private industry was selected because its research methods and objectives are viewed as being more consistent with DoD's than, say, pharmaceuticals or consumer products. The specific approaches vary according to the nature of each national or industrial research program, the level of financing, and the availability of skilled researchers to do the work. In Europe, some interesting trends are developing, with governments adjusting their research programs and priorities to changes in world markets, the post-INF East-West political environment, and the advent of European economic integration in 1992.[2] A few major themes emerged from OTA's review:

- Most governments and companies have some form of "research policy," which is approved at the top and promulgated throughout the organization. While some latitude is still allowed and innovation encouraged at the research level, projects must be justified on the basis of their contribution to achieving either science and technology policy objectives or business objectives.
- There is a trend toward centralized management of research programs, with an increasing emphasis on periodic, and relatively frequent, reviews to assess actual v. planned progress. Managers appear to be more willing to cut their losses when projects continue to miss milestones, and to look outside to acquire technology developed by others.
- Private and public organizations see collaboration as a means of affording research programs that are of significant magnitude and have promise of meeting overall policy or business objectives.

It is tempting to suggest outright that DoD should embrace these themes; indeed, DoD has already begun to in some respects. However, their applicability to the Department's overall missions and responsibilities may not be entirely clearcut. Further, making sweeping changes to DoD's structure requires great caution; it may result in severe disruptions instead of the promised improvements. The magnitude and scope of DoD's technology base activities dwarf those of nearly every other organization in the world. DoD's annual Science and Technology (S&T) Program (i.e., budget categories 6.1, 6.2 and 6.3A) is approximately $10 billion, whereas the United Kingdom's (U. K.) Ministry of Defence (MoD) equivalent is less than $1 billion and, in West Germany, military S&T is just slightly more than $500 million. The U.S. Army, Navy, and Air Force each spend more on defense technology base activities than these other nations.

It may be that DoD's S&T Program is too large and diversified to employ effectively the management techniques of smaller, more manageable organizations. Nevertheless, there do appear to be methods that could be applied at least in part to DoD. This chapter highlights some promising approaches to the three broad issues that appear to be occupying the minds of U.S. Government officials and corporate executives: 1) planning and priorities; 2) management and control; and 3) getting results.

PLANNING AND PRIORITIES

Top-Down v. Bottom-Up

DoD employs a highly decentralized approach to science and technology planning. (See chapter 4.) The three Services define their research needs with only minimal direction from the Office of the Secretary of Defense (OSD), and individual researchers exert substantial influence over program content and priorities, By contrast, most other Western governments are involved directly at the highest levels in setting national research objectives—

[1] In this chapter, "Western governments" includes Japan.

[2] The "Single European Act," passed by the European Parliament in 1985 and ratified by European Community (EC) member nations in 1986, has put in motion a set of measures that will lead to a standardized and largely integrated financial and trade system in Europe in 1992. This should, in turn, result in stronger and more competitive European industries operating m world markets.

in some cases addressing both defense and civil research with a ministry review committee. Through the use of centralized research committees or advisory panels, cabinet-level officials set priorities and take steps to ensure that the government's wishes are translated into specific programs conducted by their laboratories or by the private sector. These priorities strongly influence the content of research programs at all levels. The Japanese Government skillfully ''influences" civil research activities, and the same trend is seen in several European governments. The European Community (EC) is exerting top-down influence over the scope and content of the member countries' research programs. This influence is sure to grow as the Community works toward its 1992 economic integration.

Japanese Government

The Science and Technology Agency (STA), Ministry of International Trade and Industry (MITI), and Ministry of Education constitute the three largest players in Japan's Government-directed research and development enterprise. Much of the size and influence of the Ministry of Education is attributable to its responsibility for managing educational research facilities. The other two institutions are deeply involved in planning and priorities. There exists in Japan a broad consensus on the value of research and development (R&D) efforts that provides a stable political and economic environment for the pursuit of long-term goals. Bureaucratic organizations and more politically oriented groups help ensure the preservation and continual assessment of that consensus. STA, for example, is organized under the office of the Prime Minister, while MITI's research programs report directly to the head of the ministry. Scientific research trends are monitored and influenced by advisory councils associated with the office of the Prime Minister. These councils fulfill multiple roles, including facilitating a cabinet-wide consensus on government research policies, allocating resources, and legitimizing initiatives developed in the private or public sector by publicly endorsing them. Council reports can have a considerable impact on progress in specific research fields. Space exploration, for example, has become a national priority, in part because of the role played by these advisory councils in articulating the government's objectives and gaining national support for them.

The process is not flawless. Inter-ministry integration and cooperation in Japan are not always as thorough as they could be. There have been instances in which ministries have competed against one another for prominent roles in research initiatives, forcing political compromises and wasteful duplication. And important initiatives can fail, even when there is a clear consensus in the government and industry. However, Japan's track record of successful R&D provides a strong vote of confidence for the top-down approach to planning.

British Government

Perhaps the most visible and dramatic movement away from independence and toward centralized research planning is the one now under way in the U.K. For the past 2½ years, the U.K. 'S policies for R&D have been subjected to intense scrutiny by the British Government, Parliament, industry, and the scientific community. In mid-1987, the government published plans for sweeping changes in the management and funding of R&D in the U.K.[3] The proposals, which emphasized the economic potential of research, were drawn up following sharp criticism of the government's annual R&D effort by a House of Lords Select Committee.[4] The Lords had said that the government's R&D strategy lacked coordination, particularly in the way research was applied to industry. If science and technology were to restore and sustain economic growth and prosperity, the Committee said, its promotion should be a central objective of government policy, with the impetus coming from the Prime Minister.

On a related issue, a 1987 review of government-funded R&D in the U.K.[5] reported that MoD spent 52 percent of all government R&D funds in the year 1985-86. This high proportion of total R&D dedicated to defense generated widespread concern

3 ''Civil Research and Development, " Cmnd 185 (London: Her Majesty's Stationery Office, July 1985).

4 ''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.

5 ''1987 Annual Review of Government Funded R& D," Government Statistical Service, United Kingdom, 1987.

among British economists and industrialists that defense might be crowding out valuable investment in the U.K. civil sector. In its 1987 Defence White Paper,[6] the government noted this concern and promised to take a closer look at defense programs with a large R&D content to ensure that government funding was essential. Significant reductions in funding within 2 to 3 years were predicted as defense R&D became more efficient and competitive, and as Britain reduced its duplication of Allies' research efforts through greater collaboration. The aim was to release more government money to support the civil sector, both in industry and academia. In addition, there was a clear desire (both in the British Government and industry) for enhanced civil spinoffs from the R&D carried out by the government's Defence Research Establishments. Several initiatives were introduced, both to exploit the Establishments' technologies for the benefit of the civil sector, and to offer selected defense facilities for use by industry. In a potentially dramatic move, the Establishments may be combined into an independent Defense Research Agency that must "sell" its research to the Ministry of Defence, industry, and other customers (e.g., universities, European and American industries, and consortia).

In implementing this new R&D policy, the British Government outlined two challenges: 1) to target scientific and technological resources without constraining individual creativity; and 2) to coordinate related parallel R&D programs without divorcing them from their individual objectives.[7] To support this policy there is collective ministerial consideration, under the Prime Minister's leadership, of science and technology priorities. Also, the government is to be advised by an independent body that will comment not only on British scientific and technological endeavors, but on international efforts as well. The government's stated 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. 'S economic growth and its defense capability. The planning and execution of the more-or-less independent civil and military programs are to be coordinated and monitored by a government committee to ensure 'value for money" and objectivity, to avoid duplication, and to maximize cross-fertilization between the two efforts.

French Government

In France, top-down research planning has been the rule, and appears to remain firmly entrenched. The policies for government funding of French R&D are highly centralized, but 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 high technology; and defense R&D is expected to contribute to the overall economy. Policies for nationalized firms and the government-supported research system are framed in the context of long-term plans for R&D and innovation, with relatively specific priorities and goals. Science and technology policies (especially technology) are integrated wherever possible with the government's industrial and broader economic policies.

The stated aim of French R&D policy is to stimulate rapid, science-based economic growth, with a selection of key enabling technologies given priority in either national or collaborative programs. These goals have subsequently been reflected in legislation. The draft 1987 R&D Budget Plan was touted as an essential element in reviving the French economy. In the government's view . . 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 economies and providing a decisive advantage in present day economic competition worldwide. "[8]

West German Government

West Germany presents an interesting contrast. The Federal Government's philosophy for civil research encourages independence. Bonn only promulgates general guidelines while a complex and largely informal network of Federal and State Government organizations, universities, private re-

6 "Statement of the Defence Estimates 1987," Cm 101-I and-n (London: Her Majesty's Stationery office, 1987).

7 "1987 Annual Review of Government Funded R& D," op. cit., footnote 5.

8 Draft 1987 French R&D Budget Plan.

search groups, and industries observes priorities and moves research projects toward applications. In the MoD, however, things are different. The Bundeswehr Plan, coordinated between all three Services, forms the basis for the MoD annual budget estimate. In addition, there are two MoD agencies concerned with procurement, but not part of the military departments. The Federal Office for Military Technology and Procurement (BWB) is the principal body responsible for carrying out procurement plans. The Armaments Division is concerned with procurement planning and the coordination of technological areas that are considered ‘‘project-free” (i.e., basic research not tied to specific applications). Reporting to the Division head is the Commissioner for Defense Research, who collates the research requirements from all three Services-including international aspects—into the overall research program.

In 1986, all responsibilities for Research and Technology (R&T) program formulation and execution were assigned to the Armaments Division. MoD has defined three categories of research: basic technology; future technology; and systems technology, which are roughly equivalent to the U.S. DoD’s 6.1, 6.2, and 6.3A. These have been broken into technology elements (100 in all) with an Armaments Division Technology Coordinator assigned to each. The Coordinator prepares an annual plan that includes overall goals, a survey of the state of the art (in Germany, Europe, and worldwide) and task descriptions (with milestones and a 5-year funding profile). The Coordinator also prepares bid requests, evaluates proposals, makes awards, and monitors contracts, Roughly 25 percent of research contracts are delegated to BWB for placement. However, direct control remains in the hands of the Armaments Division Technology Coordinator.

West Germany commits about 15 percent of government-funded R&D to defense-related R&D. This is spent within the defense-related industries, the national laboratories (not owned by MoD), and the Fraunhofer Society,[9] which has six of its Institutes devoted to defense research funded by the Ministry of Defense. The defense research and technology budget is roughly DMIB (U. S.$550M) annually. For defense research the message is clear that centralized planning and control has become the rule, and that duplication cannot be tolerated. There simply is not enough money for laissez-faire.

Civil research presents quite a different picture. The West German Government’s civil R&D budget is nearly seven times that of MoD. It is augmented by a nearly equal sum from State Governments, and is spent largely by universities, the national laboratories, and independent research organizations (i.e., the Max Planck and Fraunhofer Societies). Through this decentralized system, West Germany has been eminently successful in promoting technology-based economic growth, a fact that seems to call into question the wisdom of instituting a national research program based on centralized planning and control as the U.K. ’S appears to be doing. Looking behind the scenes, however, German civil research is anything but laissez-faire. The Max Planck Society exerts a major influence on research priorities and the Fraunhofer Society, in conjunction with financial support from German industry, serves to “‘pull” the products of research out of the laboratories in accordance with identified market priorities. The “system,” although not set down in formal, government-wide procedures, is apparently well orchestrated and effective, as Germany’s record of industrial growth and its world leadership in exports will attest.

Private Industry

Turning to the private sector, in recent years most European and U.S. companies have instituted top-down planning systems—although specific research projects are increasingly set and executed at a division (or operating company) level. In Japan, top-down planning has always been the rule. The commitment of top management in Japanese companies to promoting technological advances within their companies is, perhaps, unparalleled. The participation of high-level managers and corporate officials varies from one firm to the next, but there is corporate-wide awareness of, and support for, research. Funding decisions frequently are made at senior levels, and failing projects are abandoned

[9] The Fraunhofer Society is a nonprofit society that sponsors and performs applied R&D. Its clients are German industry and the Federal and State Governments, and it is influential in setting the direction of German applied research. For basic research, the Max Planck Society performs a similar function.

quickly, usually without their initial supporters suffering adverse consequences.

Most major companies have elaborate procedures for establishing long-range business objectives, including an assessment of the key technologies that are expected to contribute to their achievement. For certain "enabling technologies" (i.e., those technologies with broad, corporate-wide applications), the highest management levels are involved in decisions on projects and funding. Often, corporate-level centers of excellence are established to bring a critical mass of resources to bear on the assigned tasks—a reflection of how capital-intensive research has become. These centers generally involve generic technologies (e.g., advanced materials, artificial intelligence, optoelectronics, and microelectronics), and steps are taken to ensure that the divisions use the results in applied research, design, and development programs,

To bring applied research closer to market, the responsibility for research management no longer rests solely with corporate central research laboratories; rather, the operating divisions or companies (where the profit and loss responsibility lies) are taking charge, The bulk of corporate internal R&D is thus directed toward achieving near- to mid-term business objectives, usually tied directly to identified customer requirements (e.g., DoD and MoD) or to new products. Whether this trend is good or bad with respect to industries' contribution to scientific knowledge and national technology bases, it clearly demands a firm approach, one that focuses on the bottom line and does not accept laissez-faire.

Balancing Near- and Long-Term Research

Defense Research

There is almost universal criticism that defense research programs in the United States and in Europe, both in governments and in the private sector, focus too much on the near term. This is probably a fair criticism. Engineering tasks are often conducted by DoD laboratories under the guise of technology base projects. U.S. companies direct their Independent Research and Development (IR&D) toward modernizing programs or improving current products and systems, rather than basic research.[10] And as DoD's IR&D recovery program has come under increasing pressure from both Congress and the Administration, defense companies have responded by focusing even more of their IR&D investment on those areas of technology likely to provide a near-term commercial payoff. Critics claim that the "R" in IR&D is silent. Without a government IR&D allocation, European companies are even more likely to spend R&D funds on products, rather than research.

This situation has become further entrenched in recent years as governments have reduced the percentage—and in some cases the actual level-of defense expenditures for basic and applied research. In the United States, for example, DoD's research (6.1) budget did not keep pace as defense R&D budgets increased under the Reagan Administration. In France, under Chirac, overall research was cut, with civil research taking the biggest "hit"; in the U. K., defense research is being constrained, ostensibly to prevent the crowding out of civil research. Defense research in West Germany is really too small to make a difference in the ''high-tech" game.

Civilian Research

Overall, it appears that long-term civil research by European governments—and by the EC—is enjoying a resurgence, with both industry and academia benefiting from this trend. This is not an accident. Influential observers argue that **the greater the proportion of a government's research budget spent on civil research, the stronger that country will be in world markets and, therefore, the more prosperous it will become.** Japan and Germany are clear examples of this theory. Defense research is viewed as a drag on the economy, and governments are being urged not to overspend in this area. In curtailing defense research, some governments-notably the U.K.—have put the burden on industry. Companies are being urged to conduct research, either under publicly funded civil programs or with private funds, and to apply the results (in a more mature form) to defense needs.

[10] Some observers believe that decreases in 6.2 funding could be a cause; 6.2 funding has decreased about 15 percent over the past two decades.

Japan

Japan is noted for its long-term outlook on research and technology. Both the public and private sectors adhere to this philosophy, with corporate strategies keyed to the exploitation of future technologies. This is in stark contrast to the situation in the U.S. and European defense sectors.

Several factors contribute to Japan's ability to focus on the long-term. Cultural factors are important, but there are other reasons, many of them financial. For example, in the United States the value of a company's stock influences business decisions. U.S. managers rank profits and increased share price as their primary objectives. Japanese executives also view profits and return on investment as important, but put them below market share. Further, Japanese companies do not need to worry about the price their stock commands. Equity remains less important than debt in corporate financing, and new stock issues are the exception in raising funds. Also, the lower cost of capital in Japan makes long-term projects more attractive.

A definite shift in emphasis is apparent: **While defense R&D was once the "locomotive" for advancing technology, civil research appears to be assuming this role in much of the Western world.** In part, this is because the line between civil and defense technology is fast disappearing; and in part it is because governments are moving to improve their industries' competitiveness in emerging global markets that are technology driven. In developing policies and priorities for defense research, DoD officials are sure to come under increasing pressure to take a wider view of national security. Indeed, maintaining an adequate defense industrial base may only be possible through maintaining competitive U.S. industries in world markets. The Europeans appear to have offset a near-term focus in defense with support for the long term in civil research. Their industries are finding sufficient government- (or EC-) sponsored civil research programs to challenge both existing scientific and technical staffs and available resources.

The Role of Special Initiatives

Historically, the pace of U.S. science and technology has benefitted greatly from a succession of special top-down initiatives, driven either by urgent defense priorities or by political objectives. The World War 11 Manhattan Project resulted not only in the atomic bomb, but also in an array of technologies that served both military and civil purposes for more than a decade. The Apollo Program of the 1960s succeeded in meeting President Kennedy's objective to put a man on the Moon; but it also provided breakthroughs in materials, electronics, data processing, guidance and control, and propulsion. Other past technological initiatives such as Project Sherwood (controlled nuclear fusion), Project Plowshare (peaceful applications of atomic weapons technology), and Vanguard (rocket development) were not successful, but they also provided beneficial spinoffs in other areas. (The Strategic Defense Initiative [SDI] program may also provide spinoffs to conventional defense programs and to some civilian fields, but the returns are not yet in.)

While these initiatives created an environment that encouraged rapid advancements in science and technology, they also disrupted the normal course of research and have, some argue, thereby undermined the Nation's long-term technological health. It is still an open question whether these initiatives have provided a net benefit to science and technology, or if S&T would be better left to follow a more natural course.

Until recently, the Europeans have made little use of special technology initiatives. Although concentrated efforts have been applied in major development programs [e.g., the Mane spacecraft, the Tornado aircraft, the Airbus, and now the European Fighter Aircraft], national research and technology programs were relatively well-insulated from political pressures. But growing concern that Europe is falling behind the United States and, perhaps more importantly, Japan in world markets has changed this attitude dramatically. Technological initiatives are rapidly becoming the rule in Europe, rather than the exception. These initiatives have been mainly multinational in nature, directed from either the EC or other multinational groups, such as the Independent European Program Group (IEPG).[11] They also appear to have provided a "ramp effect" in several key technology areas, propelling Europe to a level of technology that is close or equal to that of the United States. While the EC research projects are for civil purposes, most involve "dual-use" technologies, and many of the results will no doubt find their way into Europe's military systems. The impact of these initiatives, therefore, will be relevant to future DoD defense technology base programs.

The EC is sponsoring several research and technology initiatives, headed by ESPRIT (European Strategic Program of Research in Information Technology). The loosely defined intergovernmental EUREKA[12] program launched by France in 1985 has attracted support from 19 European countries. After early successes—and a lot of publicity—Europe's governments encountered difficult questions on priorities and funding. The European Commission proposed a substantial research budget increase for the next 5 years. This proposal was supported by the southern-flank European countries but opposed by the major budget contributors (the U. K., France, and West Germany), who urged financial constraint and stringent selection to ensure that funded projects broke new ground. The members finally agreed in September 1987 to spend 5.2 billion ECU (U.S. $6.8 billion)[13] on a "European Framework" for technology collaboration over the next 5 years. Within the Framework are several individual initiatives addressing, for example, information technology, advanced telecommunications, biotechnology, alternative energy sources, environmental research, and nuclear safety. These initiatives have been translated into specific research programs, such as ESPRIT, RACE, and BRITE.[14] Yet, the Commission does not fund EUREKA, which could approach $5 billion in itself.

None of the more than 200 ESPRIT and 165 EUREKA projects have as yet yielded breakthroughs, although progress is claimed in many areas. The most important contribution may be psychological, with the shedding of isolationist attitudes and inhibitions. Reaction by European industry and academia to the EC programs varies from enthusiasm to open skepticism. To some Europeans, subsidized EC research collaboration administered by officials in Brussels is not a cure for Europe's problems. It might, they warn, even impede healthy change by accepting too readily the established industrial order. ESPRIT, for example, is dominated by a dozen big electronics groups. It remains to be seen if these European high-tech companies can actually cooperate in product development and marketing, thus capitalizing on the EC's investment in research.

Technological initiatives of some significance might also evolve from Europe's defense community. Driven by decreasing defense budgets, the member countries of IEPG have, after more than a decade of trying, finally begun to develop a coherent program for cooperation in research, development and acquisition. One of the IEPG's first actions was to establish a set of cooperative research projects. Little has come from this effort to date, but much more visible progress is being seen on joint development and production programs. The 1987 report of an Independent Study Team[15] signaled clearly that the IEPG would henceforth be a primary forum for collaborative defense programs within Europe, and that it would increasingly become the "single voice" on acquisition and cooperative issues involving the United States and Canada.

Centers of Excellence

Special research teams or "centers of excellence" are becoming a favored means to implement research priorities. These groups concentrate on interdisciplinary research relating to technologies that require a critical mass of resources and person-

11 The IEPG is comprised of the 13 European members of NATO: Belgium, Denmark, France, West Germany, Greece, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Turkey, and the U.K.

12 The European Research Coordinating Agency is a European program to strengthen non-military technologies, emphasizing joint industrial and government funding of civil projects that have clear market potential.

13 European budgets for research and technology usually do not include research overhead (e.g., general facilities and administration). Also, other groups (primarily industry) are expected to contribute up to an equal share. Thus, the EC's $6.8 billion 5-year research budget is actually equivalent to a much larger amount in terms of, for example, a DoD budget.

14 RACE: Research and Development in Advanced Communications for Europe. BRITE: Basic Research into Industry Technology for Europe.

15 Independent European Program Group, "Towards a Stronger Europe." Vols. I and II (Belgium: NATO Headquarters, 1987).

nel; these are often corporate-wide activities. In the case of governments, such centers may serve military or civil interests or both at once. Some examples are described below.

European Community

The EC funds four laboratories, 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 collaborative research effort, their direction, objectivity and usefulness have recently been criticized so extensively that the EC is planning to revamp their management. Under proposals adopted by the Commission of the European Community in October 1987, the JRCs are to reduce their dependence on the EC budget by 40 percent by 1991. The proposals envisaged that 15 percent of the JRCs' resources should come from contract research for individual governments and the private sector by 1991, with a larger proportion also coming from other Commission departments. While the plan does not call for cuts in the JRCs' 690 million ECU (roughly $900 million) allocation for the subsequent 5 years, the Commission proposed a sweeping reform of the JRCs' objectives, mode of operation and methods of management.

The nations, however, were unwilling to accept the Commission's proposals; West Germany called for more details on how the JRCs' performance would be monitored; the U.K. called for better control on areas where JRC work duplicates other EC research; and West Germany, the U.K. and the Netherlands thought the 40 percent reduction in dependence on the EC R&D budget by 1991 did not go far enough or fast enough. This debate suggests that the JRCs are suffering from the same malaise and lack of relevance in their research that affected many U.S. corporate research laboratories in the 1960s. In today's environment, research must be responsive to the marketplace or to military needs.

European Nations

On the national scene, the intense and public debate over the "State of Science" in the U.K. resulted in movement toward the centers of excellence concept. In late 1987, two steps were taken for reshaping British science, with emphasis on its exploitation for commercial purposes. First came the establishment of the Centre for the Exploitation of Science and Technology (CEST), based at Manchester University. Envisaged as a "think-tank" with a Steering Committee headed by the Cabinet's Chief Scientific Advisor, CEST's role is to help improve Britain's ability to exploit R&D, imported as well as home grown. CEST is to bridge the gap between industry and the scientific community; over 80 percent of its funding will come from major science-based companies and the rest from the Government.

The second step was to create a number of University Research Centres (URCs). The URCs are expected to have a vital role in the government's plan as "agents of change." Similar in concept to centers of excellence established in U.S. universities, these laboratories will be devoted to studying specific scientific opportunities that hold the promise of being exploitable within a decade. The National Committee for Superconductivity chose Cambridge University to host the first URC. The British Government's Chief Scientific Advisor is thought to believe that Britain must quickly establish 30 to 40 URCs to bring about the changes he seeks in British science.

Industry

Industries on both sides of the Atlantic have been following this trend. In Europe, nearly all major companies and universities have participated in the EC research initiatives or have joined "clubs" (consortia) striving to bring together a critical mass of resources. In the United States, major companies are also beginning to shed their go-it-alone attitudes and are seeking collaboration in key technologies, either with universities or with potential competitors. The newly formed SEMATECH, a DoD and industry consortium created to develop microelectronic manufacturing technologies, is the most recent example. Earlier examples include the Electric Power Research Institute (EPRI), the Semiconductor Research Cooperative, the Council on Chemical Research, the University Steel Resources Center, and the Microelectronics and Computer Corporation (MCC). This trend toward banding together has been encouraged by a more benign U.S. Government attitude toward the antitrust implications of joint ventures in advanced technology and by the obvious success of such ventures in Japan, and now in

Europe. While collaboration in the ‘‘pre-competitive phase” of research can result in a degree of technical leveling and requires a long view of market penetration, this trend holds promise as an affordable means for U.S. industry to keep pace with international competition.

Department of Defense

In DoD, the Services, especially the Army with its University Research Initiatives Program, have been instrumental in encouraging the trend toward university centers of excellence. Such centers can and should accelerate the state of the art in technology, However, time and the danger of technical leveling could work against what should be a good idea; clearly such centers need good management. It will be important for DoD to set priorities and foster collaboration with U.S. industry, or perhaps with other governments.

MANAGEMENT AND CONTROL

Which Focus: Technologies or Missions?

Department of Defense

DoD’s laboratory structure is primarily mission-oriented, with most Service laboratories dedicated to a particular warfare specialty. While some conduct (or sponsor) generic research, the vast majority are considered a dedicated asset for accomplishing one of the Service missions (e.g., Wright Aeronautical Laboratories, the Naval Ocean Systems Center, and the Army Missile Command RD&E Center). Although a mission focus provides a closer link between technology and military applications, it also encourages overlap and duplication throughout DoD. At mature R&D stages, a mission orientation may be appropriate; however, in technology base programs, where the key technologies are not yet coupled to military applications, it can be argued that DoD should be organized along more generic technology lines, with Department-wide priorities guiding individual research activities.

European Defense R&D

Recent trends within major European governments, described earlier, reinforce this argument. For France, Germany, and the U. K., defense research activities are being increasingly planned, organized, and managed by central authorities, independently of Service requirements and development activities. Research organizations are being set up to serve as sources of technology that, when mature, can feed into equipment-oriented organizations. This is also becoming the case on a multinational basis. The IEPG is considering forming a European defense research agency. On the civil side, most EC research projects are directed toward a common set of enabling technologies, with applications left to industry to determine. In the U. K., even mature research activities are being consolidated. Under a gradual rationalization policy, MoD’s Defence Research Establishments have been encouraged to adopt a technology, rather than mission, orientation,[16]

Japanese Defense R&D

Japanese defense technology strategies are intertwined with an extensive process of technology management within the government and industry that emphasizes dual-use technologies to assure Japan’s security in the broadest sense into the next century. To understand the direction of defense technology management, one must look beyond narrow definitions of defense and security. One must examine the roles and perceptions of a range of business and government interests in formulating and implementing technology-management policies as part of a larger economic strategy. As evidenced by the priority it places on developing dual-use technologies with multiple applications, Japan’s technology policies are generated and implemented in a manner that merges economic, security, and industrial policy considerations. As a result, government and industry consciously blur the line between purely defense and civilian technologies to ensure maximum use of emerging applications and processes. They encourage a flexible approach to applying commercial technology in military systems, with

[16] If the proposed consolidation of Defence Research Establishments occurs, the U.K. new Defence Research Agency may find-as has U.S. industry with its IR&D program--that research which does not directly satisfy a customer’s identified needs will be difficult to justify at the “bottom line. ”

the aim of making Japan equal or superior to other countries in terms of its defense technology base.

In Japan, there is not necessarily a national or government-wide consensus about the value of defense production and research for the overall economy. Although Japan has embarked on a policy emphasizing domestic weapons research and development, that policy is not universally embraced. The Ministry of Finance argues that virtually any spending on defense comes at the expense of the economy. This attitude is manifested in other ways. A number of major research efforts within civilian ministries and agencies have potential military applications (e.g., artificial intelligence, high-performance plastics, ceramics, advanced alloys, jet-engine research, and deep-sea mining systems). Although both the public and private sectors are examining possible military applications, the projects nevertheless are justified primarily because of their expected beneficial impact on the civilian economy.

European Civilian R&D

In Europe, the bulk of publicly funded civil research is directed toward generic technologies, especially work conducted by universities and by private research organizations. To capitalize on this investment in basic research and technology, governments are also setting up support (or technology transfer) organizations that work closely with researchers and industrialists to move basic research into useful, marketable products.

West Germany presents an interesting case where decentralization, coupled with adherence to broad national research goals, has been successful. While the Federal and State Governments have longstanding policies that nurture civil research, the researchers themselves are free to choose their subjects. This constitutionally guaranteed freedom of scientific research is the first of four basic pillars governing research policy in the Federal Republic. The second can be seen as an outgrowth of West Germany's federal structure, where the 11 federal states assume independent responsibility in the areas of education and science. 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 into international—specifically European-research cooperation.

The German Research Society (DFG), an autonomous organization within the scientific community, has great influence over German research programs and policies. Although DFG is funded by the Federal and State Governments [DM1 billion (approximately $750 million annually)], it is not subject to direct governmental influence. It merely shares the government's goal to seek, realize, and expand upon a high standard of achievement in basic research in West Germany. The DFG's independent staff of experts evaluates research-grant proposals submitted by researchers of all disciplines. If their decision is affirmative, approval of the grant is almost automatic. The Max Planck Society and the Fraunhofer Society, both funded largely by the Federal and State Governments, are also independent establishments that exert great influence in formulating research policies. The Max Planck Society advises on what research projects are needed at any given time, while the Fraunhofer Society serves as a catalyst for technology transfer between the scientific and business communities.

Intertwined with this, one finds German industry working both with the basic research organizations—in search of commercial "nuggets' '-and with the Fraunhofer Society to smooth the way for technology transfer. Thus, while the Federal and State Governments fund basic research with few ''strings" attached, **an infrastructure exists to encourage a natural evolution from basic research into product-related (or mission-specific) research which is much closer to the market.**

Industry

In the U.S. and European industrial sectors, it often appears that internally funded research is largely conducted in operating companies. Closer inspection reveals that most of this so-called research falls into the categories of development or product improvement. The really basic research continues to be conducted in central facilities that concentrate on specific areas of technology. As noted earlier, major corporations have established their own centers around key technologies, which provide a single technology source for the operating companies' use. These centers of excellence are often staffed by a combination of permanent research personnel and personnel assigned from operating divisions—the latter tasked to become skilled in the state of the art and to bring that capability into the division. Also, the trend toward banding together in research consortia further emphasizes a growing private-sector concern for technology-oriented, rather than mission-oriented, research. Both moves respond to the skyrocketing cost of research and technology.

It can be argued that multiple, mission-oriented laboratories working along parallel lines will encourage, or at least create opportunities for, greater innovation. It appears, however, that many companies and governments have concluded that the benefits of duplication are marginal and can even be detrimental if sufficient funds are not available to conduct in-depth research at multiple locations. By merging technical and financial resources, managers hope to gain the benefits of new ideas and innovation, while maintaining a central focus on selected areas of technology.

Central v. Local Program Control

In Germany and Sweden, civil research is built on a foundation of independence; the view is that independence will encourage innovation, and innovation will result in progress. An informal, but influential, infrastructure has evolved to link research to the market, with researchers having only minimal technology -transfer responsibilities. This is fine as long as there is no financial bottom line for the research establishments, or no military capabilities that are needed urgently. In such cases, one could argue that independence may not be wholly appropriate.

In Japan, government laboratories and research institutes fulfill a variety of roles in the R&D process. It is important to note that they do not serve exclusively as creators of new technologies or initiators of larger research projects. While they often serve these purposes, government facilities have an equally important role as neutral testing grounds to verify results achieved in private-sector laboratories, and to carry research to a point where it becomes more economical to pursue it in private-sector facilities. With such divisions of labor, it is not surprising that much of the interaction between business and government occurs among individual researchers, their supervisors, and the directors of research facilities.

In Japan's private sector, engineers, researchers, and other technical specialists are heavily involved in assigning priorities among potential civil research projects, and are active in the design and development phases of new products. Production and manufacturing considerations are merged with development and design stages virtually from the first consideration of a promising technology all the way through the production phase. These considerations are incorporated into product design, thus necessitating fewer costly and time-consuming modifications later. It is still difficult to determine if the same can be said for defense production in Japan, but similar attitudes and practices probably prevail.

Among Western governments and industry, there is a notable trend away from independent (i.e., "project free") defense research that reflects the need to get near-term results from shrinking budgets, An example described earlier is West Germany's consolidation of its research and technology activities under a single organization within MoD's Armaments Division. Based on priorities set at the Minister level, MoD "Technology Coordinators" develop, organize, and direct the program. These officials are expected to relate research priorities and results to future operational requirements and are often assigned temporarily to concept formulation (or pre-feasibility) study teams to ensure that research results will be used. MoD oversight of research activities is maintained at all times.

U.S. and European defense companies are increasingly holding their researchers accountable for results, especially the ultimate applications of their work to products or business objectives. As with the West German MoD, many companies temporarily assign researchers to project definition studies or long-term product development activities, emphasizing that they have a responsibility for the bottom line. The prevailing attitude in some companies seems to be that 'research is too important to be left to researchers.*' Centralized direction, review, and feedback are the rule, While central control may tend to stifle innovation, it is becoming a financial fact of life that the industrial research community must face.

Balancing Intramural and Extramural Research

U.S. and U.K. R&D

DoD's extensive network of government-owned and government-operated R&D facilities is unique among defense establishments in the Western world. Perhaps its closest counterpart is the U. K., with its Research Establishments organized originally to support specific mission areas (e.g., the Royal Aerospace Establishment and the Admiralty Research Establishment). However, as noted earlier, these activities have been gradually consolidated and rationalized to align them more with areas of technology. Also, if the Research Establishments are separated from MoD and operated as an independent government research agency, MoD will own no research laboratories and will have to contract out all of its basic and applied research. MoD would then mirror the West German MoD, which owns virtually no laboratory facilities.

French Defense R&D

In terms of defense research, France falls somewhere between the United States and West Germany. The Ministry of Defense owns and operates, through the Delegation Generale pour l'Armement (DGA), three research laboratories (one in conjunction with West Germany). France is a special case; the head of DGA, who reports directly to the Minister of Defense, has greater control over research, engineering, and industrial matters than any other European-or American-defense official. In addition to the MoD laboratories, the French Government operates development facilities, and owns and controls a large share of the defense industry. Under these circumstances, the distinction between government and industrial research is blurred, but it seems that because of budget limitations little "project free" research is performed.

Japanese Defense R&D

Japanese intramural defense research is directed by the Technical Research and Development Institute (TRDI). Organized as a division within the Japan Defense Agency (JDA), TRDI is the Agency's primary research organization. It is headed by a civilian who oversees three administrative departments along with four uniformed directors, who supervise research and development in ground, naval, and air systems, as well as precision guided munitions. Conceptualization, design, and prototype responsibilities occur at this level. Research centers carry out projects, including surveys, research, test, and evaluation to enable further development on specific systems. TRDI maintains five research facilities in Japan for testing and evaluating a broad range of weapon systems and technologies. The Institute has no prototype manufacturing capabilities, relying instead on private-sector capacities.

The government established TRDI as an independent center for weapons development, as well as to stimulate the growth of the domestic armaments industry. It began with a philosophy of limiting direct participation in defense-related R&D, partly to minimize government budget outlays; but also because the assumption was (and still is) that defense spending constituted a burden on the civilian sector. To a large degree TRDI has managed defense technology according to its impact on the domestic economic and technological base. The Institute does not necessarily target the development of technologies to field specific weapons systems; a criterion for selecting and nurturing technologies has been the expected impact on the commercial sector. The chance that a given technology will be targeted for development by TRDI is greater if it contributes to the overall industrial base and is likely to provide commercial opportunities.

Reflecting normal practice in the Japanese commercial sector, TRDI maintains close relations between government and business. TRDI works with industry both formally and informally, in many cases simply monitoring research already under way at private companies. It also carries out preliminary research that it hands over to the private sector, once the research reaches the stage where risks have been reduced and the technology is proven. These patterns were reinforced by a reorganization in July 1987 that totally eliminated minor research programs that could be pursued more effectively by private-sector research facilities. **In addition, TRDI's role was defined to include research that lacks an immediately identifiable demand in the commercial sector. This** could mask an important change in TRDI's institutional role, and perhaps represents a JDA judgment that fielding advanced weapons systems will require selective development of specialized technologies with primarily military applications.

Civilian R&D

In European civil research, there appear to be more laboratories that are owned, operated, and supported by governments than in the United States. France maintains an extensive network of government-owned research facilities performing basic research in areas such as atomic energy, space, automation and telecommunications. These laboratories, which are staffed by researchers and administrative personnel, exert a powerful influence over French research policies. Criticisms have been voiced that these civil servants stifle innovation and serve their own purposes, rather than those of the country at large (arguments one often hears regarding U.S. Government labs). Germany, Sweden, and Italy operate a few laboratories, but rely mainly on the private sector, especially universities, to provide most research capabilities.

Industrial R&D

Despite the growing number of industrial research consortia and, in the EC, common-funded research, most industrial R&D is still performed in company-owned facilities by company researchers. This is understandable. Industry's motivations are to gain a competitive edge from research, making collaboration or contracting out risky. However, financial pressures now make research collaboration acceptable to more industrialists. Some companies have taken a different course of action by closing their central research organizations and concentrating solely on applied research. In these cases, the companies sometimes establish small advisory bodies to follow worldwide research and invest modest amounts in promising technologies, often with research institutes or universities. Such companies effectively become "technological parasites, " seeking to acquire technologies from any source to apply them to products and systems to obtain a near-term effect on the bottom line.

Other companies in Europe have established hybrid programs in which some basic research is conducted in central research facilities, some in operating companies (often funded by the central research organization), and a small amount is contracted out. Rotating personnel between the research organizations and the operating companies serves to sensitize researchers and engineers to their responsibility for technology transfer. In this way, the companies hope to keep their basic research organizations as lean as possible, and yet keep ideas flowing into new products.

Through programs such as ESPRIT, BRITE, and RACE, the EC hopes to establish Europe as a major center for advanced technology, and to use this technology to establish European industries as leaders in world markets. Except for the Joint Research Centers, the EC itself has no research organizations and relies solely on external resources, e.g., industry, academe, and private research organizations. Experts are retained temporarily to help establish priorities, set research program goals, prepare bid packages, evaluate proposals, and review programs. This raises the inevitable question regarding the competence of EC staff to make informed judgments on advanced technology and to assess which technologies are ready for application. It will be interesting to follow the progress of the EC to see if an organization with such limited internal research capabilities can accomplish its ambitious goals.

Whether or not the EC succeeds, it appears that **the overall trend in Europe is toward fewer nationally owned research facilities—especially on the part of ministries of defense.** To retain technological relevance in this environment, MoDs will have to coordinate closely with national universities and independent laboratories expert in specific areas of technology. It will also require a much closer coupling between civil research and defense needs if MoDs are to maintain a state-of-the-art military force. The research must be conducted somewhere and, if it is not done in government-owned defense research establishments, then other effective mechanisms will have to be found.

GETTING RESULTS—THE "BOTTOM LINE" OF RESEARCH

Applications—Moving Technology From the Laboratory to the Marketplace

For DoD as well as for industry, the payoff from research is its application, whether to a next-generation weapon system for DoD or a successful new product for industry. If the technology is applied too hastily, manufacturing can become a nightmare and expensive redesign is often needed. Many defense acquisition horror stories are the result of attempts at concurrency-entering initial production stages before a design (or technology) is fully developed and thoroughly tested. But, paradoxically, the Department is often sharply criticized for leaving technology in the laboratory too long, thus basing new weapons and systems on yesterday's technology. U.S. industrialists are also under growing pressure because of their apparent inability to offer products that capitalize on new technology in a timely fashion and at competitive prices. **European governments and industries appear to be no better than their American counterparts at effectively transitioning new technology into weapons systems or products.** The European problem may be more the result of a lack of sufficient investment—a shortfall the EC is attempting to correct through collective investment and "trans-national" research priorities. In the United States, it may be that too many technological options have been available, and that the continued promise of the ''next breakthrough" frequently has paralyzed DoD's decision process.

Department of Defense

Perhaps the toughest problem faced by DoD's research managers is technology transfer-how to insert research results successfully into weapons and systems without excessive cost and before the technology becomes obsolete. Acquisition programs are essentially risk reduction programs involving a sequence of research, development, design, and engineering tasks. New technologies must pass through a number of phases during which they will be viewed differently depending on their state of development and the skills (and biases) of the personnel involved. What might be obvious advantages or shortcomings to a researcher might not be appreciated by the development engineer or designer. As a result, the technology might be used improperly or have too much expected of it, so that the insertion effort is deemed a failure. This dilemma needs to be addressed. One ambitious DoD ' 'insertion" effort is the current very high speed integrated circuit (VHSIC) program, where existing avionics and system design programs are converting to VHSIC technology. The VHSIC program brings significant performance enhancements, but also a share of start-up problems. None of the European governments has attempted, or planned, an effort of this magnitude.

Japan

At present, Japan seems to be unique in its industry-wide ability to move advanced technology rapidly and effectively from the laboratory to the market. The current trends in Europe should be examined in light of Japanese successes, since the Europeans appear to be trying to apply Japanese concepts. What appears to work best is the establishment of teams of researchers, engineers, designers, manufacturing specialists, and even marketeers, early in the life of a technology or product. This group is responsible for ensuring the efficient movement of the technology through to manufacturing. These concepts appear to be under consideration in Europe for EUREKA and for some multinational programs sponsored by the EC, such as RACE and BRITE. Within individual European MoDs, the scope of national research may not lend itself to this life-cycle approach to technology transfer, but if research collaboration grows under the auspices of the IEPG, formal technology insertion programs may soon follow.

European Industry

Private industry in Europe is also struggling with the transition problem, as several large European companies are experimenting with new methods of managing R&D. The goal is to concentrate on the most commercially promising areas and to ensure a faster transfer of research results to the market. In pursuing this goal, R&D responsibilities are becoming more closely tied to the marketing and operating divisions— a practice that has become the rule in U.S. industry. Scientists, especially the most senior research people, are expected to support the company's business goals. They attend planning meetings and are considered part of the business team, along with the marketing and production personnel.

Examples of the close relationship that is essential between the research staff and those who develop technical specifications exist in all successful companies. However, in large and complex organizations the necessary interaction and communication can be jeopardized by interdepartmental rivalries and parochialism-problems that only strong management and a clear set of objectives can dispel. Unfortunately, examples of organizational environments conducive to effective technology transfer are few and far between, with ad hoc measures often substituting for strong management and sound policy.

A few specific approaches for assisting the flow of technology can be mentioned. Some companies recognize the need to retain continuity of technical expertise as a research project moves from research through development into production. One major European firm, with both defense and commercial operations, has developed a' 'distributed" technology transfer system involving four types of laboratories:

- A basic research laboratory that concentrates on long-term topics (>10 years), working with universities and tackling problems of fundamental interest.
- Central laboratories that serve major company groupings through research on areas of common interest and on mission- or business-oriented concepts or systems (5 to 10 years before product introduction).
- Site laboratories that work on new products, funded by individual product divisions and by contracts with outside organizations (2 to 5 years before product introduction).
- Product development within product divisions, working on next-generation products, product improvement programs, etc. (1 to 2 years before product introduction).

In this company, technology transfer is effected through a "push-pull" process, with the technology moving from central to site laboratories, and from site laboratories to divisions, in a process that involves the temporary assignment of scientists and engineers to a project for 2 or more years.

In another European example, a corporate research center serving the entire company receives its funding from a variety of sources (i.e., from central headquarters, from product divisions, and from external contracts). A senior scientist within the research center monitors all research programs, relating each to possible and actual division interests. He also reviews programs for combinational possibilities, commercial leverage, etc., and arranges joint technology demonstrations for the business areas (divisions) concerned. The center has also set aside a budget to fund the business areas that will apply new technology, and routinely assigns center scientists temporarily to the business areas to effect technology transfer. While this technique works in many cases, in others it may represent too strong a "technology push," and can encounter resistance at the division level.

Some defense firms have no central research organization at all, with the divisions being solely responsible for internal R&D. While the research focus of the division is inevitably more near term to match the needs of their customers, these companies do recognize the importance of acquiring new technologies. In one example, an off-line technology group in the central headquarters maintains a' 'technology watch" and advises the product groups (or divisions) when key technologies approach the applications stage. The team studies research collaboration possibilities, monitors the introduction of the technology into the division's product line, carries out marketing surveys, etc. The divisions will coordinate the applied R&D on their own behalf, while the central team then moves on to its next problem.

Industry is employing a variety of approaches to encourage the efficient and timely transfer of technology—approaches ranging from secondment or temporary assignment programs to business development teams, to formal programs of "technological parasitism." The one common thread is that someone who has both the responsibility and the authority to make technology transfer work has been put in charge of the process.

Collaboration in Research and Technology

International collaboration in research is becoming a way of life for most Western nations. Not only has the cost of research become prohibitive for individual organizations, but worldwide competitive pressures in defense and civil markets are forcing companies and governments to pool their resources simply to stay in the game. These factors have triggered dramatic changes in the operating methods of high-technology organizations, including DoD, During the 1970s and early 1980s, European governments and companies and, to a lesser degree, their U.S. counterparts began to explore ways to cooperate in defense R&D and production programs. This effort spawned a number of European cooperative development projects, such as TRIGAT, Tornado and Airbus, and transatlantic programs, such as the AV-8B (Harrier), the Multiple Launch Rocket System, and the Family of Air-to-Air Weapons. However, little cooperation was achieved in intra-European or transatlantic defense research, even though cooperation was growing in civil and space research activities. In the mid-1980s, this situation began to change. Concerns about European competitiveness in advanced technology triggered initiatives by governments to promote cooperation in both defense R&D and civil research. The European members of NATO (the IEPG countries) now accept the necessity of giving up a degree of sovereignty to make more effective use of the $8 billion that they spend each year on military development, and to receive through collaboration a better value for expenditures on major procurement programs. The European members of NATO, with and without U.S. participation, have been collaborating on defense projects on an ad hoc basis for over 20 years, but the mood now is to establish a more cohesive, systematic program of collaboration in all phases of acquisition, including research.

Steps are also being taken to deregulate the entire European NATO defense industry. The 1987 IEPG Study Team issued its blueprint[17] for a common armaments market, or a military EC, which it believed could be achieved by "giving greater play to competitive market forces. " By opening Up fragmented and highly protected national markets, and developing a pan-European competitive and collaborative environment, the IEPG Study Team said that European NATO members should be able to reduce the costs of designing and building modem weaponry. The argument went that this would yield a more coherent European defense industry, able to **compete and collaborate on more equal terms with a U.S. defense industry that was twice its size. IEPG** ministers endorsed the report and directed their staffs to begin implementing many of the recommendations. While many hurdles remain, the deregulation of Europe's defense industry appears increasingly likely.

It is an open question whether DoD's research and technology community is ready to cooperate fully with its European counterparts. Cooperative development, with the 1985 Nunn Amendment as a catalyst, has gained favor with the Services. Important programs are now under way. For the technology base program, however, a "go-it-alone" attitude seems to prevail, with Data Exchange Agreements dominating government-to-government interactions and industrial cooperation discouraged by the exclusion of foreign firms from many exploratory and advanced technology development (6.2 and 6.3A) programs. The Nunn Amendment succeeded because it gave the Services a financial incentive to cooperate. Some type of Nunn appropriation might be needed to encourage similar collaboration in defense research and technology.

In civil research, the heightened sense of concern in Europe for its technological future is attributable to several factors, especially the scale of modem technology and recognition of the severe structural obstacles to Europe's international competitiveness. Breaking down the long-standing barriers that have isolated European companies from each other is an explicit objective of the Single European Act and the planned 1992 economic integration. The collaborative high-technology initiatives now being pursued are an important element of this strategy. European industry also sees other reasons for cooperation in research, As technologies converge, companies that once were specialists in a single activity now need to draw on a broad spectrum of sciences and technologies. Also, with shrinking product life cycles, there is a need for more frequent introductions of new ideas, thereby increasing the costs and risks of research. Companies can no longer afford to risk a generation gap in their products as the result of a research failure. U.S. industrialists also face these problems.

Other cooperative efforts have grown on a national level. The U.K. Alvey program was directed toward developing a capability in information processing that would help British industry keep pace with some aspects of Japanese and American developments. In Germany, and to a lesser extent in Sweden, a collegial relationship has developed over several decades among government, industry, and

[17] Independent European Program Group, op. cit., footnote 15.

academe in civil research areas. Germany's strong position in world trade is partly a result of these relationships which, without direct government intervention, have produced an extraordinary network for exchanging information in research and encouraging product development based on the latest research results. The German system, in which a key role is played by the independent institutes (e.g., the Max Planck Society for basic research and the Fraunhofer Society for applied research), maybe the best example outside of Japan of collaboration between the public and private sectors. Some argue that the German system is even better than Japan's for stimulating technology-base activities.

Much has been said in this chapter regarding the progress of Europe's industries toward cross-border cooperation. It is certainly true that the national industries have supported their government's collaborative civil research within the EC. They have also accepted the premise that armaments cooperation (under the IEPG) has become an economic necessity. In defense research, however, there has been little industry-to-industry cooperation. This is, in part, a reflection of the meager funding available from Europe's MODs for basic research-with government research funds being increasingly funnelled into cooperative civil projects-and, in part, a reflection of the highly competitive nature of world defense markets. While European defense companies are willing to cooperate in development programs (or at least will cooperate when their governments tell them to), their internally funded research projects, which are mainly applied research or product development, are usually well hidden from public view.

In Japan, selective cooperative research, particularly in the pre-competitive phase, plays an important role in achieving technological gains in the public and private sectors. Collaborative undertakings, though widespread, are not necessarily the rule in Japanese research efforts, and multinational research collaboration is still relatively rare. The nature, timing, and participants of united efforts vary from one field to the next. Informal and formal structures and processes tend to identify promising research fields or trends. Once a consensus has been reached between government and industry on specific avenues of research, a joint government and industry effort or a government-sanctioned research consortium (involving multiple private-sector interests) is established. As research proceeds, greater competition is introduced to hasten the introduction of products to the market.

However, Japanese companies are apparently less committed today to the consortium approach than they might have been in earlier decades. Many argue that important resources are being diverted from corporations to government-sanctioned consortium efforts without a demonstration of sufficient potential for tangible short- or long-term gains. Some firms have suggested that their own resources and decisionmaking processes are sufficient for stimulating technological advances. And, while not resenting the government role, these firms believe that it should be reduced or shifted to other forms of involvement in R&D. These same companies, however, continue to participate in deference to maintaining government relations—and out of a competitive concern that breakthroughs may be achieved by a consortium to which they would not be a party.

Despite Japanese industry's broadening disaffection with the status quo, this situation is not likely to change in the near future. In defense research and technology, for example, there are a large number of industry consortia, including those in composite materials, advanced turboprop research, and fighter aircraft. Certain projects, such as the Fighter Support Experimental (FSX), are seen literally as once-in-a-lifetime opportunities that, if neglected, could lead to the complete loss of important capabilities. Cost is another factor favoring cooperation, especially in large-scale projects originating in, but not necessarily limited to, the defense field.

Many of these same considerations affect U.S. industry as well. Although U.S. companies have recently begun to band together in the pre-competitive phases of selected technologies, they are doing so largely because of their fear of foreign competitors capturing domestic markets in which the company has a stake-not necessarily to boost the Nation's overall defense preparedness or competitiveness in world markets. Because of financial and competitive pressures, and because "1992" is making it a political necessity, one now observes a steady stream of U.S. industrialists traveling to Europe and the Far East seeking to strike deals. While most of these deals are focused on codevelopment or coproduction, American industrialists are coming to realize that Europe's technology is first-rate, and in many areas is on a par with our own. Japan's technological excellence is, of course, no surprise to U.S. executives, and the reasons for it are becoming well known. Research collaboration among U.S. companies (and with foreign companies) may become increasingly attractive if the U.S. Government provides some incentives. A two-way street in technology development might then become a reality for commercial, not just military, purposes.