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SCIENTIFIC AND TECHNOLOGICAL COOPERATION AMONG INDUSTRIALIZED COUNTRIES

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The Role of the United States

Mitchel B. Wallerstein
Editor

Office of International Affairs

National Research Council

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Foreword

It is somewhat paradoxical that in a period of human history when scientific progress proceeds at an accelerated pace, there is also growing concern regarding the health and effectiveness of international cooperation in science and technology (S&T). Even though science is by its very nature international, its increasing importance in the life of nations and in the international relations between them has given rise—especially in the economic and political climate of the early 1980s—to frictions and difficulties. These circumstances led the National Research Council in 1983 to examine the state of S&T cooperation among selected industrialized countries, mainly members of the Organisation for Economic Co-operation and Development.*

It was recognized from the outset that focusing on this group of nations would exclude from consideration other important international relationships (e.g., East-West or North-South cooperation). But time and resource constraints did not permit the adoption of the more rational and desirable comprehensive approach. Instead, this project was viewed as merely the first, preliminary step in a continuing effort to examine and make more widely known the characteristics of and constraints on the entire *global* system of S&T relationships.

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*Member countries of the OECD are Australia, Austria, Belgium, Canada, Denmark, Finland, France, West Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, United States, and Yugoslavia.

Basic questions are being raised in both the United States and abroad regarding the continued effectiveness and appropriateness of the existing infrastructure for international scientific cooperation and of the benefits that such an involvement confers. To be responsive to these concerns, we felt it necessary to consider the historical bases of international cooperation and target some case histories of success and failure. But we also looked at future needs to the extent that they could be anticipated and considered whether institutional machinery existed (or could be developed) to satisfy them.

Staff members of the Office of International Affairs organized a working conference of scientists, engineers, and S&T administrators, drawn from academia, professional societies, industry, foundations, and government, whose purpose was to consider specifically how the international role of the United States in science and technology had changed in recent decades. We were fortunate to have on hand a group of experienced and enthusiastic participants. The topic seemed indeed timely and significant.

Commissioned papers, which were prepared by authors with intimate experience in a wide array of activities in the realm of international cooperation, provided a solid base for the discussions. The roundtables proved stimulating; they contributed to the mutual education of those present and emphasized the need for the education of broader relevant publics.

This workshop and its proceedings are only a start. There are many important pieces of the mosaic of international S&T cooperation that have yet to be examined, and there is much that yet remains to be done to arrive at a commonly accepted rationale for international cooperation in science. But a rationale alone will not suffice; we must learn to evaluate cooperative arrangements—both multilateral and bilateral—for their mutual benefits and maintain them in a flexible and healthy condition.

WALTER A. ROSENBLITH
Foreign Secretary, National Academy of Sciences

Chairman, Office of International Affairs
National Research Council

Contents

Scientific and Technological Cooperation Among Industrialized Countries

Introduction

A distinctive feature of U.S. participation in international science and technology (S&T) is its diversity. Individual scientists and engineers, universities, private corporations, and governments all are involved, along with the National Academy of Sciences and the National Academy of Engineering, professional societies, and private foundations. Such cooperation is arranged and conducted by individuals and managed largely by governments through both bilateral and multilateral channels, although international organizations and private nongovernmental organizations also play an important role. These arrangements cut across a broad spectrum of scientific and technological research activities.

Despite the fact that the strength of U.S. participation in international S&T cooperation derives from its complexity and variety (and, of course, its quality), relatively little attention has been devoted to understanding the strengths and weaknesses of this largely ad hoc network. The paucity of systematic attention to the subject is particularly regrettable in the present climate, given the increasing cost of high-quality research projects (particularly in Big Science), the fiscal constraints operative in both the public and private sectors, and the various political exigencies that often make cooperation difficult. This research project was initiated in January 1983 by the Office of International Affairs (OIA) of the National Research Council (NRC) in recognition of the need to identify existing gaps in knowledge and to focus attention squarely on the changing conditions of the international research system.

Accordingly, OIA undertook a year-long project designed to identify and describe the major institutions, modes, and specific research and development (R&D) activities through which the United States participates in international cooperative science and technology projects with other Western industrialized countries. It was recognized from the outset that this focus excludes a substantial amount of cooperation that occurs through East-West and North-South channels, but such a limitation was necessitated by the time and resource constraints under which the study was implemented. It was also acknowledged early on that these same constraints would not permit a detailed consideration of the principal mode for cooperation on the development of technology—namely, the industrial research sector—although the volume does include a paper on this subject. These issues presumably will be addressed in a subsequent phase of the study.

The project was implemented by OIA staff through six separate activities, many of which were undertaken in parallel. These included (1) a comprehensive review of existing literature on U.S. participation in international S&T cooperation and the development of an annotated bibliography; (2) the identification and commissioning of case studies of successful U.S. bilateral and multilateral S&T cooperation; (3) the design and implementation of a survey and selected personal interviews with more than 125 individuals in the U.S. government, academia, private industry, and elsewhere on present conditions and future needs in international S&T cooperation; (4) the development of staff background papers describing the framework of U.S. international S&T cooperation with selected industrialized countries and cataloguing the views expressed in the survey of the science and engineering communities; (5) organization of a 2-day workshop involving more than 70 invited participants and observers; and (6) the preparation of the present volume.

The workshop, which was held in September 1983, opened with introductory remarks by Dr. Frank Press, president of the National Academy of Sciences (NAS), who noted that involvement in international scientific cooperation had had a profound effect on the development of his own career. Press recalled his early days as a student and junior research scientist, when he saw the value of exposure to the textbooks and literature emanating from the great European scientific centers. Later, as science adviser to President Carter, he remembered seeing firsthand the importance of scientific relations with both industrialized and developing countries. He also cited his frustration during this period over the fact that the United States seemed incapable of organizing its own procedures and bureaucracy to take full advantage of its great strength in science and technology in its relations with other countries.

Press expressed the belief that there would be increasing emphasis on science and technology in U.S. international relations during the next 10–15 years. The new force driving this change will be an acceleration in the progress of science in many different fields and a growing awareness of the central importance of science in the advancement of the human condition. Thus, the question of scientific and technological relations between nations becomes especially timely.

The scope and specific objectives of the meeting were then set forth by Professor Walter A. Rosenblith, foreign secretary of the National Academy of Sciences, who began by noting that the history of U.S. involvement with international science dates back to Benjamin Franklin and Thomas Jefferson. One hundred years ago, thousands of scientists were mobilized in approximately 50 observations stations for the International Polar Year. More recently, of course, the International Geophysical Year (IGY) saw an even larger mobilization of international science involving scientists from 67 countries. Countless other examples of bilateral and multilateral cooperation undertaken both through governmental and nongovernmental channels come easily to mind.

Rosenblith suggested that we are presently at a particularly interesting point in history, given the progress of science over the past 50 years. For example, there have been great unheavals in the physical sciences, in the ocean and space sciences, and in the health and life sciences, to name just a few. While the size of the scientific community has exploded, so too has the size of the higher education establishment. There are about 350,000 foreign students in the United States today, and foreign nationals now play increasingly important roles in teaching and research in our institutions of higher learning, especially in engineering. We are faced with a major intellectual migration—perhaps a million people on a global scale— which will influence international cooperation for years to come.

Rosenblith pointed to the Great Depression as the beginning of the period of accelerated growth in the size of the scientific community. During this time, national and international nongovernmental organizations (NGOs) came into being to satisfy the need for coordination and facilitation of cooperative international scientific efforts. The International Council of Scientific Unions (ICSU) was created in 1931, and its first president was the American astronomer George Ellery Hale. Hale was both president and foreign secretary of the NAS.

Since then the context of international science has evolved and become more complex. Discussions of international cooperation in the 1980s need to consider the level of interest and character of the interaction, the extent (if any) of governmental involvement, be it in the framework of bilateral or multilateral agreements. Because nongovernmental organizations depend very substantially on governments for their operating resources, the mix or relation between them and governments is a critical dimension of international cooperation. The scope and dynamics of cooperative ventures will depend on the scientific and technical fields involved, the time scale of the efforts, and the ability to mobilize the required expertise and human resources. Clearly the outlook will differ for multiyear programs on a global scale compared to short-term laboratory experimentation involving special facilities.

If we want to look toward the future, Rosenblith said, it is indispensable to examine the "ecology" of international cooperation in science and technology. It is necessary to depict the complex array of institutions, cooperative agreements, cooperative programs, etc., that has evolved and to see how political, economic, and other considerations influenced that ecology. The U.S. scientific and technological establishment has been aware that it must be accountable within the larger national political process; international S&T projects must find their own mode of accountability. But the time constants for payoffs in science and in politics often are quite different. Thus, Rosenblith argued, if the budget process is to recognize a commitment to long-range, higher-risk international cooperation—something which is clearly problematic from a political point of view—then the scientific community must make a special effort to be more communicative to the relative publics. It must recognize that international cooperation is becoming "encrusted" with a great number of exogenous political constraints, including limitations on technology transfers for foreign policy and national security reasons.

The present volume begins with a general framework under which the motivations for and the objectives of U.S. international S&T cooperation with selected industrialized countries may be analyzed and understood. This is followed by groups of workshop papers organized by the substantive topics to which they bear relevance.

The first section considers the *domestic* basis for U.S. S&T cooperation, including an overview analysis by Eugene B. Skolnikoff of the problems in the U.S. government organization and policy process for international S&T matters. Herbert I. Fusfeld similarly examines the role and contribution of private industry.

This is followed by a series of case studies of successful cooperative research projects. Attention is focused first on *bilateral* modalities, including papers by John M. Logsdon on U.S.-European cooperation in space science, Justin L. Bloom on U.S.-Japan bilateral S&T relationships, and Max Hellmann on the U.S.-Israel Binational Science Foundation. Additional case studies are then offered that examine *multilateral* modalities, including papers by Clemens A. Heusch on U.S. participation at CERN, John S. Perry on the Global Atmospheric Research Project, G. Ross Heath on the International Phase of Deep Sea Drilling, and William J. Gartland, Jr., on the development of safety guidelines for recombinant DNA research.

The next section focuses on the competing objectives and pressures that impact upon U.S. S&T policy. Included here is an analysis by Philip W. Hemily of recent trends in the mobility of young scientists and engineers into and out of the U.S. research system.

The final section of the volume concerns future international S&T cooperation. The concluding thoughts of the workshop participants are presented, along with an afterword by Victor Rabinowitch, Executive Director of the NRC Office of International Affairs. A series of appendixes then follows, summarizing the results of an OIA staff opinion survey and presenting brief biographies of paper authors, a workshop agenda, a list of workshop participants, and an annotated bibliography of relevant literature.

The contribution of OIA staff members Carol Picard and Mary Lee Schneiders to the production of this volume is gratefully acknowledged. Special thanks are also extended to Mary Martha Treichel, for her management of the opinion survey and assistance with the workshop, and to Wendy White, for her bibliographic research.

U.S. Participation in International S&T Cooperation

A Framework for Analysis

Mitchel B. Wallerstein

The decade of the 1980s has witnessed a renewed interest in international scientific cooperation and the forces that shape U.S. participation. Enhanced appreciation of science as a national resource, of the value of cost/task sharing in large or expensive projects, of technological advances in telecommunications and travel, and of constrained opportunities for younger scientists are some of the factors that have become central topics of international science and technology (S&T) policy discussions. At the same time, science and technology have become increasingly important as instruments of foreign policy.

U.S. policy on international S&T cooperation must take account of opposing and, often, irreconcilable pressures. On the one hand, the constraints on domestic resources and growing scientific excellence abroad suggest strongly the need for the U.S. to enter into cooperative arrangements with other technically advanced nations. Yet, on the other, foreign policy imperatives and concerns about the loss of proprietary information to potential competitors or security-sensitive information to potential adversaries have created new impetus in the United States for greater vigilance in the open interchange that characterizes the international S&T community.

THE SETTING AND OBJECTIVES OF S&T COOPERATION

International cooperation in science and technology encompasses a broad spectrum of activities ranging from informal exchanges or visits arranged privately by individuals to large multinational projects or programs funded and arranged either directly by governments or through international organizations on their behalf.

The form of cooperation best suited for any particular S&T initiative is determined by a wide range of factors, often varying according to the nature and historical traditions of the scientific field, prevailing economic and/or political constraints, and other factors. Among the considerations that are involved are the following: (1) the nature and frequency of the information to be exchanged, (2) the length of time for which cooperating scientific personnel must interact, (3) the extent to which the problem lends itself to a division of labor and the relative scientific strength of the cooperating partners, (4) the relative economic strength of the cooperating partners, (5) the type and cost of facilities involved, (6) the degree to which global coordination is required (e.g., the model of the International Geophysical Year), and (7) the extent to which national security or proprietary concerns or other sovereign prerogatives are involved.[1] The form of a particular cooperative activity evolves as the result of discussion, consultation, and the historical pattern of collaboration among interested parties.

The type of international cooperation favored in one discipline may be quite different from that favored by another. A survey of National Science Foundation (NSF) program managers found, for example, that certain modes of cooperation were cited with greater frequency in some disciplines than in others. The results of the survey are summarized in Table 1.

Scheinman[2] has noted that the overall record of international cooperation among technologically advanced countries appears to favor bilateral channels, especially when something more than the exchange of personnel and information is involved. On the other hand, multilateral channels seem to be favored for agreements emphasizing information exchange. This latter category also includes nongovernmental contacts such as those initiated through the International Council of Scientific Unions (ICSU) and its disciplinary member unions.

The motivations for intergovernmental cooperation are extremely diverse. On the most general level of national policy, international S&T cooperation is supported in pursuit of both symbolic and utilitarian goals. Symbolic goals are essentially political, involving considerations of prestige, political influence, propaganda, and national security, while utilitarian goals are usually focused on economic and/or technological objectives.[3] At a more functional policy level, international S&T cooperation in a particular field may be attractive for some or all of the following reasons:[4,5]

TABLE 1 Frequency With Which Modes of Cooperation With Western European Nations Are Cited by Various NSF Programs

	International Conferences	Focused Seminars	Short-Term Exchanges	Sabbaticals	Fellowships—Postdocs	Bilateral Research	Multinational—Continuing	Multinational—Temporary
Astronomical, atmospheric, earth, and ocean sciences	16	15	9	18	8	17	13	13
Applied sciences and research applications	20	12	12	4	11	25	5	2
Biological and behavioral sciences	11	10	10	13	10	11	5	6
Social sciences	0	12	10	6	0	10	8	7
Physics	12	12	11	14	7	6	6	6
Engineering	8	15	13	13	15	11	7	6
Materials research	3	5	10	11	8	8	3	3
Mathematics and computer science	10	10	7	10	9	6	5	2
Chemistry	4	6	8	10	9	7	4	2

SOURCE: NSF Professional Staff Questionnaire.

1. *Cost Sharing*—avoid unnecessary duplication of effort particularly in the case of research facilities or instrumentation requiring substantial amounts of capital.
2. *Concept Development*—formal cooperation can build on the invisible colleges of science to speed the identification and exploitation of new research approaches.
3. *Acceleration of New Technologies.*
4. *Enhancement of Scientific and Engineering Competence*—a particular concern at the end of World War II.
5. *Political Considerations*—S&T cooperation may provide an attractive means of projecting national influence or of encouraging other forms of contact between nations (e.g., the United States–People's Republic of China bilateral S&T agreements, Antarctica).

Clearly, U.S. policy has encompassed all of these objectives at various times, although the emphasis accorded to each has shifted over the years.

In the period immediately following World War II, a chief U.S. concern was the rebuilding of the European science apparatus which had been largely disrupted or destroyed. U.S. assistance was particularly important in some of the faster moving disciplines such as molecular biology and high energy physics. During the 1950s, the United States supported a number of initiatives to promote international S&T cooperation, some of which were intended further to promote the redevelopment of European scientific infrastructure and some to benefit the United States itself. These included U.S. support for the creation of the specialized technical agencies of the UN, such as the World Health Organization (WHO) and the UN Educational, Scientific, and Cultural Organization (UNESCO). Later in the decade, the United States was instrumental in an effort, launched through the NATO Science Committee, to establish an International Institute of Science and Technology.[6]

Perhaps the most enduring example of U.S. involvement in international S&T cooperation during this period was the organization in 1957–1958 of the ICSU-sponsored International Geophysical Year (IGY), involving representatives of 67 countries with worldwide networks or surveys in 14 scientific disciplines in all aspects of the earth's environment. The IGY opened up the Antarctic and initiated the space age. The organization of the IGY itself spawned new ways of conducting science for large-scale problem solving that had profound effects on the disciplines involved (e.g., oceanography) and on the manner in which individual scientists approached their fields. It introduced mechanisms for the orderly sharing of detailed observational data as a new dimension to the traditional sharing of scientific results through publication. It also generated new intellectual capital which, in turn, gave rise to additional cooperative research efforts (e.g., the Global Atmospheric Research Program, or GARP).

By the 1960s, European science had become largely self-sufficient, and the United States was experiencing a retrenchment in its own R&D budget. The result was that, for the first time, a substantial number of young American scientists were receiving *European* support for their work in European labs. With the dawning of the era of East-West detente in the late 1960s and early 1970s science and technology agreements became favored instruments of both symbolic and instrumental diplomacy. Conversely, the end of the detente era during the Ford administration witnessed the curtailment or cancellation of many of these same bilateral S&T arrangements.

The post-oil crisis (1973) "stagflation" that has afflicted the entire Organisation for Economic Co-operation and Development (OECD) community since the early 1970s has had a dampening effect on the willingness and capacity of the United States and other technically advanced countries to undertake new international S&T activities. One manifestation has been a changing demography in the academic job market, which has created a reluctance on the part of young American researchers to leave the country for extended periods to participate in scientific exchanges. The decline in the number of Ph.D.s undertaking foreign postdoctoral study in the period since 1971 is apparent in the data presented in Table 2.

U.S. policy since the mid-1970s regarding international S&T cooperation has remained at cross purposes. Europe and Japan are no longer "weak sisters" requiring U.S. capital and technical infusions; they are strong and sophisticated economic competitors. At the same time, growing alarm has been expressed regarding the potential loss of militarily sensitive scientific and technological information as a result of various international S&T contacts.[7] In many fields, this concern also involves the potential loss of proprietary data, due to the reduced time delay between basic research and commercial application.

Yet, there are also trends toward *increased* levels of cooperation. These have been particularly in evidence since the 1982 economic summit at Versailles, France, at which the heads of state agreed to study the most fruitful areas for collaboration in various scientific and technological areas. The subsequent report, produced under the direction of Jacques Attali of France, identified 17 specific cooperative projects involving various combinations of OECD countries; it re-

TABLE 2 Ph.D.s With Firm Commitment for Foreign Postdoctoral Study at Time of Degree Award, 1967 to 1979

	Total Number	Percent of All Ph.D.s	Number to Western Europe	Percent of All Ph.D.s
1967	249	1.4	191	1.0
1968	226	1.1	161	0.8
1969	271	1.2	174	0.8
1970	325	1.2	204	0.8
1971	430	1.5	267	1.0
1972	368	1.2	227	0.7
1973	255	0.9	145	0.5
1974	228	0.8	129	0.5
1975	250	0.9	150	0.5
1976	239	0.8	136	0.4
1977	201	0.7	119	0.4
1978	195	0.6	113	0.4
1979	236	0.8	139	0.4
TOTAL	3,473		2,155	

SOURCE: Office of Scientific and Engineering Personnel, National Research Council.

ceived formal approval at the 1983 economic summit at Williamsburg, Virginia. Since that time, multi-national working groups in each of the 17 areas have been functioning with varying degrees of success. Despite the lack of major accomplishments to announce at the most recent summit in London, England, all seven governments (plus the Commission of the European Economic Community) formally endorsed continuation of the exercise. There was even discussion of assigning the projects' steering committee, which consists of top level science advisors, a more prominent role in international affairs. This could involve a range of activities from giving collective advice to heads of government to becoming a channel for negotiating international agreements on major scientific facilities. If such a role were to materialize, the steering committee could well supplant the OECD as the principal international channel for science policy discussions.[8]

CURRENT FORMS OF U.S. INTERNATIONAL PARTICIPATION

To the extent that the Reagan administration has articulated an international S&T policy, it has attempted, where possible, to deemphasize the role of the federal government while placing increased reliance on private contacts through university and/or industrial firms. As the

1982 annual report of the Office of Science and Technology Policy stated,

> . . . international cooperation is not synonymous with Federally sponsored cooperation. American scientists and engineers cooperate in a great many international ventures—often through the universities or the industrial firms that employ them—in which the Federal Government acts, at most, as a facilitator.[9]

Other evidence suggests, however, that the U.S. government continues to maintain interest in cooperative activities (witness, for example, the recent U.S.-India bilateral S&T agreement). This is further demonstrated in the NSF FY 1984 budget for international cooperative scientific activities ($12.9 million), which represents a 30.3 percent increase over the FY 1983 budget for this category ($9.9 million).[10]

Intergovernmental Organizations

Many pressing global problems can be handled only by organizations with *global* representation. The United States and other nations that contribute substantial resources to international organizations such as UNESCO, WHO, or the International Oceanographic Commission (IOC) have found multinational channels useful as a means of promoting international cost burden sharing and of facilitating activities, individual scientific contacts, and access to research localities that, for political reasons, would not be feasible on a bilateral basis.[11] On the other hand, supranational organizations—UNESCO chief among them—have become increasingly politicized in recent years, often on issues having little to do with their stated mission and in a manner that is inimical both to U.S. interests and the general health of international science. Moreover, many of these organizations are characterized by large bureaucracies where progress occurs slowly and where resources may be used inefficiently.

Growing dissatisfaction with the operation of UNESCO was brought sharply into focus on December 28, 1983, when Secretary of State George P. Shultz informed the organization's director-general, Amadou Mahtar M'Bow, of the intention of the United States to withdraw effective at the end of 1984. In his letter, Secretary Shultz stated:

> For a number of years, as you know from statements we have made at the Executive Board and elsewhere, we [i.e., the United States] have been concerned that trends in the policy, ideological emphasis, budget, and management of UNESCO were detracting from the Organization's effectiveness. We believe these trends have led UNESCO away from the original principles of its constitution. We feel

that they have served the political purposes of member states, rather than the international vocation of UNESCO.[12]

Both the Shultz letter and subsequent public statements by senior administration officials—including the President himself—left open the possibility that the United States would reverse its decision if certain changes were made in the tone and substance of UNESCO's work, and if the budgetary and management shortcomings were resolved.

Leaders of the U.S. science community met during the months following the announcement to consider what, if anything, could be done to encourage the administration not to implement its announced decision. While it was generally agreed that the science-related activities of UNESCO are *not* the primary source of the difficulties within the organization, it was also recognized that those supporting continued multilateral scientific cooperation have only limited influence on the larger political process and must therefore wait for the right target of opportunity before acting.

Whatever the ultimate outcome of the U.S. policy regarding UNESCO, it would appear unlikely for the foreseeable future that the United States will further expand the level of its multinational S&T participation, since it continues to maintain serious political reservations about the effective use of such resources. On the other hand, given the global, interconnected nature of many current S&T problems, the United States is equally unlikely to disengage further from the world research system.

Regional multilateral arrangements are another common channel for promoting S&T cooperation. The United States has been a strong supporter of the NATO Science Committee, which has promoted the advance of basic science through the mobility of scientific personnel, and of the Committee for Scientific and Technological Policy of the Organisation for Economic Co-operation and Development (OECD). In both cases, the principal functions are education and information exchange, which were the principal emphasis of U.S. multilateral S&T cooperation before 1973.[13,14] Also, in both cases U.S. participation contributes to its broader foreign policy agenda (national security in the former case and economic development in the latter).

The United States has, in addition, supported other types of multilateral cooperative arrangements that have circumvented some of the political, economic, and organizational problems on which multinational programs have often foundered. There is, for example, the unique joint sponsorship arrangement of the Global Atmospheric Research Program (GARP), supported both by the World Meteorological Organization (WMO) and by the International Council of Scientific Unions (ICSU). In this case, ICSU involvement provided scientific leadership, while the involvement of WMO offered some assurance of steady funding and global access. A similar arrangement exists today in the cooperative arrangement between ICSU and WHO for the World Climate Research Program. U.S. scientists have figured prominently in the development and implementation of both programs.

Bilateral Agreements

In 1982, the United States had approximately three dozen formal bilateral S&T agreements in force.[15] When these formal arrangements are combined with other bilateral mechanisms such as interacademy exchanges, joint commissions, and informal (National Science Foundation- or Agency for International Development-sponsored) arrangements and interagency memoranda of understanding, total U.S. bilateral S&T relationships number many hundreds. Certainly no form of cooperation is more explicitly political; agreements have sometimes been developed primarily in order to give visiting heads of state something to sign at the conclusion of a visit. On the other hand, some bilateral agreements tend to continue in effect long after the conditions that created the need for them have changed, because termination may be politically difficult. For example, the United States maintains a bilateral arrangement with Japan based largely on the technical and economic circumstances which existed at the end of World War II.

In most cases, the central function of bilateral arrangements is to serve as a symbolic means of winning or maintaining support with friendly governments. Moreover, the U.S. decision in the wake of the Soviet invasion of Afghanistan to scale back U.S.-Soviet bilateral S&T relations demonstrates that other types of symbolic messages also can be sent in this fashion.

Nongovernmental Organizations

Given the predominant values of science that transcend national identity—i.e., objectivity, neutrality, replicability, generation of new knowledge, etc.—it is not surprising that some of the more successful examples of international cooperation are nongovernmental in nature. The principal venue for nongovernmental S&T arrangements is ICSU, an autonomous federation consisting of 20 disciplinary scientific unions and 70 national member organizations (mostly academies of sciences and like institutions). ICSU was created in 1931 out of the International Research Council to reflect the growing importance of the scientific unions. Its dual national and scientific membership is unique within the international field. In addition, ICSU has provided an important infrastructure over the ensuing years for nongovernmental scientific cooperation, including organization of the aforementioned International Geophysical Year (IGY) and its successor programs: in space, Committee on Space Research (COSPAR); the oceans, Scientific Committee on Oceanic Research (SCOR); Antarctica, Scientific Committee on Antarctic Research (SCAR); and the biosphere, International Biological Program (IBP), to name a few.

The ICSU family of activities represents an important infrastructure for cooperation initiated and conducted directly by the scientific community. The U.S. membership in ICSU is exercised by the National Academy of Sciences (NAS) via a network of U.S. national committees (USNCs) located within the disciplinary units of the NRC and drawing on the participation and cooperation of a wide range of professional societies. Support for annual membership dues is sought from the federal government, and many of the U.S. contributions to international collaborative research programs occur with government support. ICSU is constrained both by administrative and funding limitations and is currently in the process of reexamining its role and functions. Nevertheless, its existence serves as an extremely important scientific counterbalance to the explicitly political types of bilateral cooperation.

Besides serving as the host institution for the USNCs of ICSU, the NAS—and its research arm, the National Research Council—also participate directly in international cooperative S&T activities through agreements with counterpart organizations in other countries. Among the types of agreements that the NAS may initiate are the following: (1) informal agreements with counterpart institutions aimed generally at fostering friendly relations and greater scientific interaction, (2) formal exchange agreements with counterpart institutions which are usually negotiated with or through government organizations, (3) agreements aimed at strengthening the capabilities of scientific organizations in developing countries, and (4) arrangements in which the Academy complex plays a role in government-to-government agreements. There are currently academies of science (or corresponding organizations) in over 70 countries, of which 20 are located in industrialized nations.

Mention also must be made in this context of the International Institute for Applied Systems Analysis (IIASA), which was created in 1972 (out of discussion initiated at the request of President Lyndon B. Johnson), as a new prototype for international cooperation on pressing global problems. Because the charter dictates that a *nongovernmental* organization must represent each member nation, the institute is ostensibly nonpolitical in nature. Nevertheless, due to a combination of internal and external factors, the U.S. government withdrew NSF funding in 1981. In the absence of U.S. financial support for its involvement, the National Academy of Sciences, which was the U.S. national member organization, resigned its membership. Subsequently, the American Academy of Arts and Sciences established a mechanism to support U.S. membership in IIASA, seeking funds from nongovernmental agencies in the United States. The decision to withdraw NSF support also has had negative ramifications beyond the context of IIASA. It has raised serious questions about the viability of nongovernmental organizations involved in international S&T cooperation that must depend, even indirectly, on government funding.

Industrial Cooperation

Another promising channel for future nongovernmental S&T cooperation is direct contacts between two or more industrial firms. While most arrangements of this sort focus on applied research and joint development, some basic scientific research also is supported. Among the major objectives of and motivations for industrial S&T cooperation are: (1) exchange of information to promote modernization and/or new product development, (2) pooling of technical talent and/or financial resources across national boundaries to facilitate projects that otherwise would be prohibitive, (3) conservation of resources to avoid unnecessary duplication and provide economies of scale, and (4) preservation of market share.[16]

The frequency of private-sector technical cooperation, while still relatively low, is increasing. A survey of announced private technical cooperation agreements conducted in 1980 found that at least 78 such contacts were made in that year, involving either research and development or collaboration on the development of new products or processes. The survey also revealed, however, that two-thirds of the agreements were in just two industries—electronics and aircraft. Cooperation agreements in other manufacturing technologies remain relatively rare.[17]

In a world inhabited increasingly by *transnational* private companies, cooperative S&T arrangements that benefit a private firm may not necessarily be viewed as advantageous by the host government.

The United States, for example, may intervene actively in private international agreements in cases involving (1) national security considerations, (2) antitrust considerations, or (3) questions of national industrial policy (e.g., protection or promotion of a failing industry).[18] Yet, despite the problems of control inherent in such private cooperation, a future increase in industrial contacts may reduce the need to build additional international S&T infrastructure at public expense.

Individual Cooperation

In the final analysis, the most basic and enduring channel of international S&T cooperation remains at the level of the individual scientist or engineer. There is a rich sociological literature on the so-called "invisible colleges" of science[19] that function informally through correspondence, telecommunications, and personal contacts and visits. Most would agree that this is the very lifeblood of scientific progress. On a more formal level, individual S&T cooperation takes place chiefly through short- or long-term academic exchanges and fellowships, student-teacher relationships, attendance at international conferences and meetings, joint authorship of scientific literature, and collaborative research projects. Data monitored by the NSF indicate a decline since the mid-1970s in U.S. foreign participation in international meetings and U.S. postdoctoral study abroad, and only very modest increases in the authorship levels of U.S. international cooperative research in the period between 1973 and 1980. (In fact, the United States and Japan continue to maintain the lowest levels of cooperative international authorship among the major OECD countries.)[20]

These trends may be explained in part by the increased costs of foreign travel at a time when travel budgets are no longer growing. For example, due to inflation and rising costs, most of the Fulbright awards made to U.S. scholars working in Western Europe in recent years have been only partial grants for periods of less than 9 months. In academic year 1982–1983, only 38 percent of the awards were for the full academic year; of this group, only 38 percent were fully funded. However, Fulbright scholars in *scientific* disciplines, who received 34 percent of the research awards made from 1978 to 1982, have been somewhat more successful than those in the humanities or social sciences in identifying supplemental sources of support.[21]

U.S. postdoctoral fellows cite a number of additional factors for not considering further study outside the United States; these are listed in Table 3. Among the most frequently mentioned are the inadequacy of funding, poor support by the hosts, and language problems. The lack

TABLE 3 Factors Inhibiting Effective Foreign Scientific Interchange by U.S. Postdoctoral Students[a]

Inadequate funding	27%
Poor administration or staff support by hosts	25%
Language problems	23%
Quality of foreign scholars	16%
Inadequate scholarly/scientific facilities	14%
Nationalism	9%
Inadequate personal facilities	9%

[a]Duplicate answers included in tabulation.
SOURCE: Ladd-Lipset (1977) data on foreign travel of scientific personnel.

of career advancement rewards also continues to be a factor in such decisions. Moreover, there has been mounting pressure on scientists and engineers working in research areas with potential national security or proprietary applications to be more circumspect in the open and immediate dissemination of state-of-the-art information.[22] Despite these pressures, the consensus—both within and outside of the government—is that individual scientific contacts and the dissemination of ideas and research results, all of which occur primarily within the academic context, must continue unimpeded if scientific and technological progress is to be maintained.[23]

ASSESSMENT OF COSTS, BENEFITS, AND EFFECTIVENESS

The historical record of U.S. participation in various forms of international cooperation in S&T reveals, in the aggregate, a pattern of steady and rather impressive expansion through the decades of the 1950s and 1960s with interruptions only in the 1930s and 1940s. The 1970s witnessed slowing growth and near-equilibrium, and the 1980s so far have seen somewhat erratic expansion and contraction. Certainly this pattern does not hold true to the same extent in all scientific fields. It is reflective, however, of the fact that, since the successful rebuilding of S&T infrastructure in Europe and Japan, U.S. international S&T policy has become much more complex and unpredictable, meaning that international cooperative agreements are now pursued as much for diplomatic, strategic, and economic reasons as for reasons of scientific priority. In fact, some argue that, particularly in the bilateral context, sound scientific design is sometimes sacrificed in the interests of political expediency.

One particular manifestation of this changed policy environment is the extent to which the proffering or withdrawal of S&T cooperative agreements is employed by the United States as a direct instrument of diplomacy. Examples abound of the use of science and technology as positive or negative reinforcement for the policies of another nation. What is new about this situation is the increasing frequency with which the realm of science has come to be viewed as a fundamental component of U.S. foreign policy. This may be explained, in part, by the fact that access to frontier S&T is greatly desired worldwide. Greater use of S&T as instruments of foreign policy may also be understood, however, to reflect the simple fact that there are often constraints on other traditional sources of foreign policy leverage (e.g., capital, food, or military assistance).

This emerging pattern of increased use of S&T as elements of foreign policy raises two important and interrelated questions: (1) are S&T effective as instruments of policy?, and (2) is involvement in the political arena good for the health of science and technology? Clearly, as a symbolic action, the development of a new cooperative initiative is highly effective for public relations purposes. Witness, for example, the high degree of publicity that surrounded the United States-People's Republic of China S&T agreement during the Carter years. But have such arrangements succeeded in influencing the foreign (or domestic) policies of other nations? While there is little doubt that S&T agreements have helped on some occasions to move relations onto a more positive basis, and on others to signal U.S. displeasure regarding certain behavior, there would appear to be little conclusive evidence that the signing or termination of an agreement has been very influential in persuading another nation to pursue or desist from a particular policy position.

With regard to the health of S&T, we have already made note of the fact that cooperative S&T projects are sometimes designed more according to the availability of funding and political support than on the basis of scientific priority. Mention also has been made of the growing preoccupation with national security and proprietary considerations, resulting in some efforts to "close down" international scientific communications. But, besides the problem of maintaining free and open channels of communication among scientists, there is also the problem of the apparent mismatch between the requirements of diplomacy and the process of scientific inquiry. Sound cooperative projects do not always materialize at politically opportune moments. Moreover, because the pace of scientific research must, of necessity, be slow and methodical, results cannot always be provided within a short-term time frame. In fact, high-quality S&T cooperation frequently requires sustained multiyear funding in order to achieve anticipated outcomes.

Thus, it must be recognized that certain tensions or mismatches do exist between the needs of science and the exigencies of foreign policy. While these conflicts are probably inevitable and not altogether counterproductive, they do raise profound questions about the future scope and direction of S&T cooperation.

There are, in addition, other types of pressures or conflicts extant within the U.S. S&T policy environment. For example, many analysts[24] have noted the imbalances that exist between the priorities of the mission-oriented agencies (e.g., the National Aeronautics and Space Administration, the Department of Energy, etc.) and the objectives and competencies of the Department of State. While the State Department maintains a comprehensive view of the U.S. role and interests in the international context, it is poorly equipped to provide the same high level of staff competence and mission focus on S&T fields as other line agencies. This problem is mitigated to some extent by the existence of the Office of Science and Technology Policy within the White House. But, in some respects, the lack of effective State Department involvement relegates the formulation of international S&T policy to an ad hoc "turf battle" between the mission agencies.

Less significant but nevertheless important are pressures that emanate from within the scientific community itself. Given both their access to the highest levels of government decision making and their need for government funding, scientists often function as formal or informal pressure groups for particular projects. On some occasions, groups of scientists within a discipline are able to bring pressure on intergovernmental or nongovernmental organizations to support a certain type of cooperation for which they themselves may be among the beneficiaries. Governments besieged by multiple competing demands for scarce resources have sometimes viewed the impassioned exhortations of the scientific community for additional research support not so much as "common good" but as a form of "special pleading" from yet one more interest group.

Costs and Benefits[25]

The importance of achieving "critical mass"—as measured in terms of capital, human expertise, and facilities—in an area of scientific endeavor stands out as a major benefit of cooperation. The synergistic economic effect of multiple funding for a particular line of research is obvious, but collaboration in fields such as environmental science or geophysics also can facilitate the coordination of numerous modest projects into a major global program of lasting significance. By the same token, agreement on cooperative research permits the pooling of research talent and/or facilities to produce results beyond the capabilities of any one country or university and avoids needless duplication of effort. The sharing of costs for construction of facilities becomes especially critical for "Big Science" projects. Significant cooperation often brings with it, too, a higher level of visibility to areas of scientific inquiry that may lead to improved future funding prospects. (There is a danger, however, that the greater visibility and appeal of "Big Science" projects may have a deleterious effect on the health of smaller-scale scientific cooperation.) Finally, higher levels of activity in a given field also increase the chances of "spin-off" research initiatives' yielding unexpected breakthroughs.

The opportunity to interact and exchange ideas is in itself a benefit of international science, because it expands the familiarity of U.S. personnel with the work of foreign colleagues (and, of course, vice versa). This, in turn, increases the likelihood of future cooperative relationships. The sharing of new or modified approaches is the foundation of scientific intercourse, and the awareness that other groups in other countries are working on the same or similar approaches can also prove to be a powerful motivating factor governing the pace of research. Finally, the knowledge that a particular approach is being pursued with success elsewhere may lend legitimacy and influence to project proposals. Witness, for example, the redirection of the U.S. fusion program towards the Tokamak concept after the exchange of information with Soviet scientists.

Many of the costs of cooperation are mirror images of the benefits. For example, there are opportunity costs involved in committing personnel and equipment to a joint research project when these resources might have been assigned to other tasks. Similarly, there are what might be called "development" costs associated with sharing information and/or ideas produced previously under other auspices and, presumably, other financing. In fact, part of the motivation for the recent attempts to stem the flow of unwanted technology transfer in the United States has been the concern over the lack of compensation for the sizable capital and time investment involved in developing the S&T information supposedly being "lost."

Little need be said about the direct costs of participating in international S&T projects, which involve primarily personnel, facilities, and equipment. It should be noted, however, that it is often not so much the capital outlay itself which is viewed as a liability as it is the loss of *control* over R&D resources. Such concern becomes paramount in cases where resources are channeled through or controlled by an intergovernmental or nongovernmental organization. Recently, the control issue has been exacerbated by the increasing politicization of many intergovernmental organizations dealing with science and technology (e.g., UNESCO). The United States, like many other countries, has little desire to make large contributions for dues or for special projects only to see the organization engage in activities or rhetorical debates inimical to U.S. interests.

The problems of dealing through intergovernmental organizations raise yet another type of cost, the principle of "juste retour,"[26] referring to the expectation that each participating nation will get a share of the research, engineering, and equipment supply contracts in proportion to its financial contribution. As a result, the efficiency of sound management practices often must be sacrificed in favor of greater equity of distribution. Euratom, ELDO, and INTELSAT all have been affected to varying degrees by this problem.

Finally, there are the inevitable internal bureaucratic costs of undertaking cooperative projects. Unless such collaboration is kept very narrowly focused, it tends almost inevitably to overlap agency jurisdictions. In those cases where an agency's participation in a cooperative venture requires that it transfer budgetary authority or personnel to an international organization or to another agency of the U.S. government, the inherent tendency to guard bureaucratic "turf" may have negative ramifications for the project.[27]

There are, of course, no universally applicable guidelines for successful international S&T cooperation. Much depends on the specific circumstances (and previous history) of the initiative and, frequently, on the presence or absence of a few charismatic individuals who can provide initial and continuing leadership. Some of the more significant background conditions likely to increase the chances of successful cooperation were set forth in a 1981 study by the OECD.[28] These are summarized below.

- Intergovernmental cooperation must be based upon an awareness of the political context, and the further the program moves toward applied research, the more precise the political implications must be.
- It is important that there should be similarity between partners, both in terms of scientific and technical development, and economic development.
- Aims of the joint action must be defined clearly at the outset.
- A general preparatory mechanism for contact and discussion is necessary to launch, define, and mount the joint effort.
- A detailed cost-benefit analysis of various potential institutional frameworks should be conducted.

- Direct cooperation between national establishments—or use of existing international organizations—is generally preferable to the creation of a new international body.
- A balance between equity (returns in relation to investment) and efficiency (entrusting work to those more competent to perform it) must be reached.
- Adequate mechanisms for supervision and responsibility in monitoring and management must be provided.
- The international program should not compete with national programs—it should complement them.
- Red tape must be minimized and the delegation of responsibilities maximized.
- Budgets should extend over a number of years to ensure financial stability.

It is significant that these OECD guidelines fail to address directly what many would consider the most essential criteria for effective cooperation: namely, the need to take account of that which promotes the health and advancement of science in terms of the allocation of limited resources and the design of cooperative arrangements. As suggested in the preceding analysis, this prescription represents a not insignificant task. Yet, given the changing conditions and new challenges facing the global community, the search for new, more effective modes of international cooperation must become a matter of high priority for the science and engineering establishment both in the United States and worldwide.

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The Domestic Basis for U.S. Participation

Problems in the U.S. Government Organization and Policy Process for International Cooperation in Science and Technology

Eugene B. Skolnikoff

The U.S. government supports international cooperation in science and technology through a number of different mechanisms and to serve a variety of national goals. Almost every agency of the federal government is involved to some extent, and cooperation takes place through bilateral, multilateral, and private-sector channels. No precise measure of the funding dedicated to international cooperation is available, but most of the relevant programs are described in an annual report to the Congress colloquially known as the Title V report.[1]

It is not an overly impressive document, notwithstanding its bulk; the list of activities appears substantial only until one recollects that this represents the international dimension of a federal research and development (R&D) budget of well over $40 billion. Then, it seems minor indeed, to which most of those who have been engaged in attempting to promote international cooperation in science and technology from inside the government can quickly attest. In the abstract, one would assume that the shared interest in R&D progress among friendly and even not so friendly countries, the global nature of many problems, the wide diffusion of technological competence, the importance of building science and technology in developing countries, the budgetary pressures all are experiencing, let alone the political interests that can be served, would all lead to substantial pressure for increased cooperation. In practice, of course, other pressures—economic nationalism, domestic institutional interests, concern over technological leakage, bureaucratic difficulties, ignorance of developments overseas, a commitment to leave R&D to the private sector and the general domestic orientation of the U.S. government (of which more below)—conspire to keep the number and scale of government-supported international programs a quite minor proportion of total R&D support.

It was not always so. Even though international cooperation was always a relatively small part of the budget, the present situation is in fact poorer than in earlier postwar years. Following World War II, and particularly after the Marshall Plan and the onset of the Cold War, there was a substantial U.S. interest in science and technology cooperation with Western industrial countries. Research was supported directly by U.S. agencies in Europe, and the climate was generally supportive for expansion of cooperation wherever possible. A major program of cooperation was begun informally with Japan in the late 1950s, and formally in 1961. The National Aeronautics and Space Administration (NASA) legislation, passed in 1958, explicitly called for an international approach, as had the National Science Foundation (NSF) legislation in 1950. Early objectives in NATO included major interest in joint research and production, and the NATO Science Committee was started in 1957 with grand ideas of spurring cooperative R&D. Even the Organisation for Economic Co-operation and Development (OECD), when it was reconstituted out of the former Marshall Plan, included science policy cooperation among member countries as an important segment.

But the climate substantially changed. Absolute resources going for international cooperation in science and technology may be larger today, but relative to national budgets, the relative amount is surely much lower. Certainly, the atmosphere in which cooperation must be developed and funded is less supportive, notwithstanding the discussion at the last three summits about international cooperation. (Perhaps the formal agreement at the Williamsburg summit will spur a change in attitude, but it is too early to tell.)

From economic, budgetary, political, and scientific perspectives, this is unfortunate. Public-sector goals in science and technology could benefit from a different climate of receptivity toward international cooperation, and certainly this nation's objectives in foreign affairs and in technical assistance would benefit from much greater ability to tap American scientific and technological resources.

Among the several reasons for the relative lack of support for international cooperation is one "family" of reasons that has received relatively little attention or analysis. That is the organization of the U.S. government for policymaking and funding of international cooperation in science and technology. In fact, the particular structure of the U.S. government and the government's budgetary process have a great deal to do with the difficulty of expanding such programs even under supportive administrations and much to do with the ease of cutting them back in antagonistic or disinterested administrations. The lack of clear understanding of this aspect of the subject, though by no means the only critical element, nevertheless can frustrate efforts to build international cooperation even when the political will exists to do so. And it certainly goes a long way to explain why more projects and possibilities for international cooperation do not arise spontaneously, whatever the interest of a particular administration.

Astonishing as it may be, the U.S. government has no clear governmental instrument for international cooperation, and in fact some agencies are legally barred from using appropriated funds for other than "domestic" R&D objectives. Individual departments and agencies must carry out their own programs of cooperation as part of regular budgets, with little or no recognition of the problems and disincentives thus created. Difficult as it is for cooperation on projects of clear scientific merit and interest, proposals with mixed scientific and political objectives have no natural home or funding resource. We will attempt to explore and explain this situation.

THE ISSUE

The U.S. government's purpose in supporting international cooperation in science and technology is exactly the same as that for supporting science and technology more generally (or of any other federal activity, for that matter): to contribute to the nation's domestic and international goals. These goals have to be translated into specific policies, of course, and, in practice, into concrete programs and budgets. From the perspective of the government bureaucracy, this process now becomes a policy management issue: how best to formulate programs, compare them with each other in relation to the national purposes they are to serve, budget for them appropriately, and ensure effective implementation and evaluation. These necessary management objectives turn out, given present structure and practices, to discourage proposals for international cooperation, or to bias the system against them once proposed. Ironically, we are denying ourselves substantial use of science and technology in the service of national interests in the international arena, in the laudable effort to maintain detailed policy and management control.

To examine this in greater detail, it is best to first separate international science and technology activities into three rough categories, recognizing inevitable overlap, for the issues are somewhat different for each.

International Cooperation Directly Supporting U.S. "Domestic" R&D Objectives

In this category are those programs or activities that arise directly from the R&D goals of the U.S. government. Examples are:

- cooperation with, and occasional support of, foreign scientists or institutions in pursuit of common scientific objectives when justified on competitive assessments of scientific quality
- programs carried out internationally because of the requirements of the subject, such as in oceanography, geophysics, or global climate;
- participation in internationally organized research endeavors, such as the International Geophysical Year or the Global Atmospheric Research Project; and
- comparative studies or conferences intended to improve U.S. efforts by examination of policies or programs of other countries (e.g., environmental standards, use of health care technology).

International Cooperation Carried Out for Mixed Foreign Policy and Scientific Purposes

In this category are those programs or activities that have an important foreign policy component as part of their motivation.[2] Examples are:

- dedicated programs of bilateral cooperation with other countries that are established to serve one or several foreign policy objectives with those countries (i.e., the programs with the USSR, Poland, China, and France are illustrations; the Chinese program overlaps with the development assistance category as well);
- activities with, or in, other countries that may not be part of a dedicated program with that country, but are at least partially justified by foreign policy interests (e.g., possible desalination projects in

the Middle East, involvement of local oceanographic institutions in U.S. expeditions);

• application of U.S. science and technology capabilities for U.S. policy purposes (such as foreign participation in Landsat, use of U.S. technology abroad for mapping and oil exploration, or commitment of domestic R&D resources to tackle a problem of particular interest to another country);

• programs to encourage expansion of foreign R&D, or refocusing of foreign R&D on objectives the United States sees as priority problems (e.g., efforts to stimulate energy-related R&D through the International Energy Agency (IEA), or some aspects of the Japanese cooperative program).

Science and Technology Cooperation Designed to Serve International Development Objectives

This category, closely related to the previous ones, involves those activities particularly geared to the development assistance objectives of the United States and to the problems of developing countries across the range from the poorest to those now considered "middle income." The justification for separation from other foreign policy interests is simply the present magnitude and likely future significance of this category to the United States. In addition, the different policy and funding structure in the development assistance area makes the issues to be dealt with substantially distinct. Examples are:

• programs of cooperation between U.S. agencies, or U.S.-funded institutions and those in less-developed countries (LDCs) on development problems, sometimes in the context of dedicated bilateral agreements, other times on an individual project basis;

• support of R&D in institutions outside the United States on development problems;

• commitment of R&D resources in the United States to work on development problems, varying from full commitment of some resources to partial modification of domestically oriented programs to make them more relevant to development applications;

• application of U.S. science and technology capabilities to development needs abroad, such as resource exploration, Landsat imagery, communications technology; and

• participation in international science and technology programs (United Nations and others) concerned with development.

This category will not be considered in detail in this paper as it is largely outside the focus of cooperation among OECD countries.

POLICY MANAGEMENT ISSUES

A number of policy management issues arise in the government's sponsorship of international cooperative activities in the first two categories that have become serious disincentives to elective program development. We can take up the categories in turn.

International Cooperation Directly Supporting U.S. "Domestic" R&D Objectives

This category of activities poses the least difficult conceptual management issues within the government, since the programs presumably must and in principle can compete for funds within agency budgets and objectives. Criteria are clear, or at least no less clear than for R&D in general, and it is evident what programs new proposals are to be compared against.

But there are important policy process issues here that serve to create major barriers to active development of international cooperation. These have to do with the detailed processes by which projects are proposed and funded, and the general encouragement (or lack of it) of an international perspective in government R&D programs. The two are related.

The dominant domestic orientation of the American R&D enterprise is often a surprise not only to scientists in other countries, but also to Americans used to the view that science is basically an international enterprise. Though science is nonnational in its substance, nations do support science and technology for national purposes, and the institutions of government providing support are necessarily oriented to national goals. In the United States, the development of governmental institutions has historical, cultural, geographic, and political roots that result in a policy process that weights domestic interests and concerns to a much greater extent than is prevalent in most other countries. The separation of powers between the executive branch and the Congress is a major factor in continuing this dominance of domestic interests. Moreover, the very scale of science and technology in the United States, coupled with the geographic isolation of the country, has tended to make scientists and engineers as a whole less knowledgeable about and less interested in what is happening outside the country.

The result is a policy and budget process geared so automatically to domestic use of funds that necessary adjustments for international projects, e.g., extra initial costs or funds for needed travel, are almost always ad hoc and usually viewed with skepticism. Nor is there a general climate in the government that recognizes the value to the United States of international cooperation, nor widespread interest and pressure from the scientific community at large advocating more international cooperation as a major policy need. It is anomalous in an era in which high-quality R&D capability exists (and is growing) in many countries that share U.S. interests, in which the problems facing these societies are increasingly common and intertwined with those of the United States, and in which the costs of R&D increase so as to limit the ability of any one country, even the United States, to seek answers entirely on its own, that so little of an international perspective is in evidence.

To develop that perspective, to take more advantage of the R&D benefits of international cooperation, and to realize the potential value to the United States of an international approach to the problems that loom so large in all societies will require more than a simple policy decision. Agencies, and particularly the lower levels of R&D management, would have to be sure not only that there is high-level executive branch and congressional interest in developing international activities that support the agencies' R&D objectives, but also that international programs, if competitive, would be welcomed in their overall program and that the likely greater uncertainties encountered in evaluation of new proposals would be sympathetically taken into account.

There would also have to follow some changes in the funding process that recognized that international projects cannot be treated simply as any typical proposal that is wholly domestic. Up-front funding may be necessary to explore opportunities and to allow initial development of proposals that may be harder to formulate because of differing research styles or institutional practices. Some risks may have to be taken for situations in which there could be serious costs if a jointly developed proposal is ultimately rejected. Recognition of the importance of being a reliable partner may also sometimes lead to longer commitment of funds than is typical for an agency. In some cases, funding may be necessary for higher infrastructure and travel costs.

Those extra funds have always been difficult to appropriate, and in particularly tight budgets they appear as direct reductions in domestic research funds, and thus inevitably contentious. The effect of the recent distribution of the NSF's international budget among research divisions will for that reason certainly have a chilling effect on international cooperation, even when international projects could in principle be fully competitive scientifically.

It is also worthwhile noting not only the difficulty but also the importance of making the "domestic" agencies of the U.S. government conscious of the international framework in which R&D is actually embedded. The potential practical payoffs are obvious: U.S. R&D can benefit from work in other countries, much more of which is now equal to U.S. R&D in quality, and more frequently there will be parallel work of direct relevance to U.S. R&D objectives and increasing opportunities for cost sharing or for faster progress toward R&D goals.

There is another, perhaps more important but unfortunately only philosophical, reason: the fact that the results of American R&D directly and indirectly affect people in all countries. They have no voice in setting R&D objectives in the United States even though they have an interest in the outcomes of the world's largest R&D enterprise, nor can any process be imagined in the near future (at least) that could provide such a voice. But that only emphasizes the desirability of developing over time much greater sensitivity in the United States to the international nature of the R&D enterprise and to the societal effects, not limited by national borders, it engenders. Rarely is any thought given, and certainly only rarely in an organized, conscious way in the government, to the international effects of the R&D being supported. The conscious encouragement of greater involvement in international programs and cooperation by U.S. domestically oriented agencies can, in the long run, serve to increase understanding of the international dimensions of everything the United States does in science and technology.

Of course, all the obstacles do not reside within the government, though the process difficulties within government do have their resonance in the scientific community. Realization of the difficulties in funding international cooperation or experience in trying to satisfy the difficulties is often an effective disincentive for scientists to invest the time required to bring cooperative projects to the point at which they could be considered in the research competition. In many cases, of course, the opportunities and appropriateness, because of special equipment, skills, or the nature of the subject, make the effort to overcome the difficulties worth the candle. But, in marginal or less clear cases, the disincentives loom large.

Aside from the difficulties inherent in obtaining funding, other factors serve as disincentives. The time delays necessarily involved; the extra travel, language, and cultural obstacles to intimate interaction; and the different national patterns of allocation of research funds (which can result, for example, in disparities of funding and uncertainties of the results of priority ranking) also are important. Moreover, scientists are not immune from national biases, notwithstanding the nonnational basis of scientific knowledge. Particularly in the United States, many scientists think little and know less about the details of work in other countries and have little interest in international cooperation. Others view international cooperation as inimical to the competitive race for national prestige and preeminence and are little inclined to collaborate unless absolutely necessary.

And, of course, the growing national concern with the possible economic and security costs of transfer of technology has served to put a further damper on official interest in international cooperation. Though that does not affect many scientific fields, it certainly is relevant to those, such as electronics and biotechnology, in which the distance between the laboratory and production is shrinking. The concern, still largely focused on security, will almost certainly turn increasingly to economic issues. Growing pressures for "technological protectionism" cannot help but prove to be a deterrent to international scientific cooperation.

Thus, impediments and disincentives, even for projects entirely justified scientifically, can be substantial. These arise from the general domestic orientation of the U.S. government and a policy and funding process that provides little recognition of the special requirements for organizing and implementing international cooperative projects. Not all possible international projects *should* be supported, of course, but the growing importance of such cooperation to the United States, as well as to others, dictates greater efforts to modify the existing climate, and to make the governmental process more flexible and responsive.

International Science and Technology Cooperation Carried Out for Mixed Foreign Policy and Scientific Purposes

Though seemingly less relevant to cooperation among OECD countries, it is nevertheless true that some cooperative programs do (and should) have motivations that go beyond purely scientific purposes. The United States has umbrella agreements for cooperation with Japan and France and other nonspecific agreements in various delineated fields, for example, or those with particular departments in other

OECD countries. Some OECD countries, in addition, are not in the front rank scientifically, so that cooperation with them must be justified, if at all, on foreign policy as well as scientific grounds.

The question here is not *whether*, but *how* to use science and technology in support of international goals. Clearly, international activities in science and technology can serve a variety of objectives in addition to R&D goals, including contributing to U.S. political and economic interests with other countries, attracting high-level attention to particular issues, creating advantages for American industry in foreign countries, gaining knowledge of scientific and technological progress in other countries, and stimulating work on common or global problems. Presidents, secretaries of state, and others have capitalized on the nation's strength in science and technology for cooperation designed to achieve more than scientific purposes and will continue to want to do so. That is appropriate, for national goals can be served by sensible use of all resources, as long as it is done responsibly and without damage to the primary mission of those resources.

The most difficult of the issues raised in these cases in the policy process, and the ones that are at the heart of the problems of management of international science and technology activities, are those associated with funding. They are central to the goal of responsible management and deployment of public funds, and central to the ability of the government to use its scientific and technological resources effectively for a variety of national objectives.

The major problem is that the international programs referred to here cannot be fully competitive on scientific grounds with alternative domestic programs (if they were they would raise no special conceptual problems, as programs in the first category), and even when they may eventually be able to be competitive, the advance planning and commitment process required to initiate a formal international or bilateral agreement is not compatible with the normal competitive budget process. Alternative budgetary processes and in some cases segregated funding are thus unavoidable.

There are several alternative budgetary mechanisms possible, none of them fully satisfactory nor mutually exclusive. They include: funding of international activities from regular appropriated R&D funds; developing line items within domestic agencies administered either by a technical division or by an international programs office; seeking dedicated funds in the Department of State to be transferred to the operating agencies to fund these activities; seeking dedicated funds in another agency, such as the NSF, for transfer as appropriate; or creating a new agency expressly for this task. A different technique of oneshot endowment for a "binational foundation" is also possible and has been employed in the past, notably in the case of Israel. Each has its advantages and disadvantages.

Relying on appropriated agency R&D funds when mixed foreign policy and scientific goals are involved has several problems: establishing objective criteria for comparing the foreign policy interest of alternative proposals, determining the weight that should be given to those interests in comparison with scientific goals, providing adequate means for representing those interests in the budget process, and absorbing the implicit reduction in funds available for the domestic objectives of the agency (especially acute if funds must be segregated in advance to protect against later rejection). The programs, however, are more likely, by comparison with processes that involve nontechnical offices, to be of high quality since the technical people most knowledgeable are those most heavily involved, and the scientific aspects would be evaluated by the normal process.

Developing a separate line-item budget within agencies administered by the technical divisions or the international office (or both) avoids the problem of reducing funds for "domestic" R&D objectives (assuming no larger trade-off in the agencies' overall budgets), but raises more starkly the problem of justification of funds and effective program evaluation. This technique can lead to unjustified continuation of funding once started simply from the normal inertia of budgets, and can reduce the pressure for scientific justification since the funds are not subject to as rigorous scientific competition. In addition, the international offices, if they administer the funds, may develop a vested interest in the programs which may not adequately reflect either overall U.S. foreign policy interests or the scientific opportunities. Line items for programs intended to serve, in part, foreign policy interests raise directly the problem of how funds and programs are compared across agency lines, especially since the normal budget process within agencies and with the Congress involves many other considerations.

On the other hand, both line items and use of regular R&D funds within agency budgets give the agencies a stake in international activities; force them to have to evaluate, advocate, and defend the programs as their own; require commitment to use of resources for international purposes; and allow the development of permanent staff assignments as opposed simply to carrying out programs as a "service" to other agencies.

The alternative of establishing funds in the Department of State to support international scientific and technological activities of the agencies has several serious barriers, though it appears attractive in the abstract as a way of forcing projects to compete within a defined budget. One barrier is simply the political reality of expecting the Department of State to be able to obtain funds of any scale for this purpose (opposition would be substantial in both the executive branch and the Congress). Another is the separation of the source of funds from the scientific and technological resources, coupled with the Department of State's inherent difficulty in identifying adequately the opportunities in science and technology across the government and in developing internal competence in science and technology. In addition, many activities should not be discrete separate programs, but part of larger efforts. If most international funds had to come from the Department of State, the bureaucratic burden for allocation and implementation would be enormous and probably intolerable. Moreover, this route is not likely to develop the desired commitment and competence in the agencies.

Establishment of dedicated funds in another agency, such as the NSF, has some of the same problems as a State Department fund, except that it has proven more feasible to appropriate money to the NSF for international programs, and NSF's internal competence in science and technology could make it easier to work with the technical programs of other agencies. As is evident from past use of NSF in this way, however, an agency finds it difficult to accommodate substantial funds that, as a matter of course, are only to be justified and spent by others. There has always been difficulty even in NSF funding of National Academy of Sciences international programs over which NSF has had little detailed control. It also puts NSF in the middle between domestic and international agencies with little stake of its own.

A separate agency created expressly for international cooperation in science and technology would be a most interesting innovation, but has little political reality in the near future. Though it would have some of the same problems enumerated above, its dedicated mission would minimize them. Moreover, it would have the capability of overseeing a "cross-agency" budget that would make possible responsible comparison of projects and budget management. And, it would provide a focused instrument for international cooperation now lacking in the U.S. government. Such an agency was proposed (Institute for Scientific and Technological Cooperation, or ISTC) as part of a foreign aid reorganization in the last administration and was authorized but not funded by the Congress. It is unlikely to reappear again for some time.

The binational foundation approach has considerable appeal for a limited number of countries as a result of its permanent basis that does not require annual appropriations or detailed oversight. By definition, it is not available for short-term foreign policy purposes though its existence and successful operation can obviously contribute to relationships. Its independence is an asset, but by the same token, it is external to U.S. departments and agencies and not likely over time to stimulate international interests within those agencies, or see its mission as integration of U.S. scientific and technological capacity with U.S. international interests. Finally, its independent status makes program review or modification difficult once a direction is set.

Though all of the alternatives have their strengths and weaknesses, it seems inescapable for now that for the *bulk* of international science and technology activities justified in part on foreign policy grounds, it is the resources of the agencies themselves, whether in an "international" budget or as part of regular programs, that will have to be relied upon. The other choices are simply not commensurate with the nature and scale of the overall objective though all mechanisms are, and ought to be, used to some extent.

This conclusion that the bulk of the resources must come from the agencies, however, requires coming to grips with the difficulties associated with that route. Primarily, those difficulties have to do with evaluation and choice when a foreign policy motivation is involved. Who is responsible for representing and/or qualified to represent the foreign policy interest? How much should it weigh against scientific evaluation? How can activities with different countries, different fields, and different agencies be compared? What can provide the discipline that is required to force hard choices? How objective can foreign policy criteria be in any case?

An argument can be made that almost any science and technology interaction with a country of interest is "good." Traditionally, the Department of State has tended to be rather uncritical in its support of international science and technology activities of other agencies within broad foreign policy constraints. But that is inadequate, if it ever was otherwise, in a period of growing interest in more effective use of U.S. science and technology capacity internationally. Even if funding constraints were not as serious as they are today, responsible use of public funds and resources would require more appropriate discipline.

In thinking about various alternative mechanisms, it is important to realize that the international activities that are actually relevant to this analysis are only those that fall marginally below the cutoff point on an agency's scientific quality ranking of research projects (leaving aside, for the moment, the question of how international projects can be developed to the point of being competitively ranked). That is, proposals above the cutoff can be funded whatever the foreign policy interest because of their inherent scientific interest to the agency. Proposals that fall near the bottom of the ranking are of little scientific interest to an agency and should proceed *only* if there is a special foreign policy interest in having them implemented. In that case, external (to the agency) funding is clearly appropriate and, in fact, essential. Only those that are marginal in an agency ranking—below but near the cutoff—are of interest, for they have reasonable scientific merit and agency engagement.

This logic leads to the suggestion that it should be possible to rank international science and technology programs across departments and agencies according to foreign policy interest. Such a ranking would be compared with the independent ranking within departments and agencies based on agency criteria. Projects that are marginal on an agency ranking, but high on foreign policy ranking, would be given an extra boost. Those marginal within the agency but low on the foreign policy ranking would be dropped, while those low in agency ranking, but high on foreign policy, would proceed only with funding provided by the Department of State or other external source. Those marginal on both scales might deserve further examination.

Such a cross-department ranking makes sense in theory, but in practice how can it be done with competence and credibility? A separate agency for international science and technology cooperation mentioned earlier could have been the chosen instrument, but the attempt to create that agency did not succeed. The State Department is unlikely to be able to carry out such a ranking with sufficient support from technical agencies, or with adequate authority to implement the results. A possibility is an interagency working group, chaired by the Department of State, that could provide the locus for a governmentwide ranking. Or, the Office of Management and Budget (OMB) or the Office of Science and Technology Policy (OSTP) could chair the group to provide more objective leadership.

Whatever mechanism is used for "managing" agency budgets for international cooperation, that will not be enough. The need for planning flexibility, especially for broad programs of cooperation of high political value and White House interest, such as with China and the Soviet Union, and the need for initial funds to define and develop projects dictate a requirement for some segregated (noncompetitive) funds able to be used for new international initiatives. The amounts can be reasonably limited on the assumption that programs once established should move into a competitive process of some kind as rapidly as possible. Under that assumption, the Department of State could be the logical repository of such segregated funds; more realistically, they should be line items in the appropriate domestic agency budgets and/or dedicated international funds in the NSF.

CODA

The analysis of the problem seems clear, but an effective institutional mechanism and appropriate policies are not easy to formulate within the U.S. government structure. Something must be done. The U.S. government is simply poorly positioned to use science and technology in support of its international objectives, especially when an unambiguous scientific justification is not possible. Even when it is, the United States is often muscle-bound in its structure and process in providing incentives or support for international cooperation that is in the national interest. Though there are many explanations for this situation, the fact of the matter is that the changing nature of the problems the nation and the world face, the diffusion of scientific competence, and the economic pressures on Western societies make it essential that ways be found to spur rather than discourage international cooperation in science and technology.

REFERENCES AND NOTES

1. Science, Technology and American Diplomacy. 1982. Third Annual Report Submitted to the Congress by the President Pursuant to Sect. 503(b) of Title V of P.L. 95-426. Washington, D.C.: U.S. Government Printing Office.
2. Development purposes—related to developing country problems—are considered separately from foreign policy purposes for reasons of clarity though the separation is somewhat artificial.

The Role of Industry in International Technical Cooperation

Herbert I. Fusfeld

OBJECTIVE

This paper is intended to offer some perspective on the relationships between the objectives of the private sector and the use of international cooperation as a mechanism for pursuing these objectives. These comments should provide a basis for developing constructive participation by private companies in such actions and identify opportunities for government policymakers to attract private-sector participation when this will promote a broad national or international purpose.

INTRODUCTION

The increasing attention to cooperation in international science and technology normally omits, or minimizes, the role of private industry. This is a reasonable state of affairs, since there are obvious constraints on the value to a competitive industrial organization within the Organisation for Economic Co-operation and Development (OECD) countries of cooperative activities in general.

Nevertheless, several observations should be stated about the subject:

1. There are a number of activities that involve a role for private industry in cooperative international science and technology, and

many of these have existed for a considerable period of time, e.g., bodies to set standards.

2. Rapid and far-reaching technical advances can break down traditional industrial approaches to cooperative actions, e.g., the development of the European Strategic Program for Research in Information Technology (ESPRIT) program in the European Communities (EC) to develop a stronger European base in microelectronics initiated by the major electronic companies within EC countries.

3. It has become increasingly clear to government policymakers responsible for international cooperative agreements that a great many bilateral and multilateral technical agreements among governments can be strengthened greatly by active involvement of the private sector and may not be effective without such cooperation, e.g., technical exchanges in food science or metallurgical processing.[1]

This paper will expand upon these three observations to develop a practical framework for relating industrial activity to international cooperation in the near future. To establish a basis for understanding what is both realistic and desirable, let us consider first the issues involved, then the nature of industrial research.

STATEMENT OF ISSUES

To state the issues most simply, two questions must be answered from the viewpoint of industry:

1. Why should a company participate in a cooperative technical activity?
2. When such cooperative activity is desirable, what added criteria justify or require international cooperation?

There is an additional issue that is of interest to the current concern with international technical cooperation generally, and to this paper in particular. This is the matter of timeliness, namely:

3. What pressures exist today that encourage increased industrial participation in international technical cooperative activities?

Since our concern is more with future actions than with past experiences, the last issue is perhaps of greatest intellectual interest.

One important change, at least in public perception of the subject under discussion, is implicit in the title of this group of papers. The discussion is of "international science and technology," whereas the traditional emphasis of cooperative activities in the past has been on "international science." Since "technology" refers to applications, to practice, to products and processes, there would seem to be a greater opportunity for an industry role in these broader areas of international cooperation.

Nevertheless, the increased opportunity alone is not sufficient to obtain private-sector participation, since the questions of benefit and compatibility with competitive objectives must still be answered. There may be a greater likelihood of industrial interest in scientific cooperation than technological cooperation. What does seem to be emerging is that any international cooperative activity in technology that does *not* include industrial participation will very likely omit important inputs and be less effective in its impact.

These are general statements made primarily to introduce the issues. The most important generalization is that the circumstances are different for each industry and, to some extent, for each company. To permit a more constructive discussion, we should review briefly some of the characteristics of industry and industrial research.

NATURE OF RELEVANT INDUSTRY CHARACTERISTICS

The following comments are greatly oversimplified and are intended to point out certain industrial aspects related to international technical cooperation.

All major corporations think and operate internationally, at least with regard to markets and competitive pressures, very likely with regard to components and raw materials, and in most cases with regard to some form of operating arrangement in other countries. These interests all require technical exchanges across national boundaries. Thus, there exists in every large corporation some mechanism, some network, possibly a substantial structure, for maintaining contact with international science and technology. This can take the simple form of an individual responsible for licensing, who draws on technical personnel within the corporation for support. It may consist of the sum of individual contacts that corporate scientists and engineers maintain with colleagues in other countries. For the larger corporations, it is made up of operating subsidiaries in other countries with associated technical organizations and occasionally separate laboratories not affiliated directly with an operating facility.

There is, in short, a very great deal of international technical activity within each major corporation. How much of this can be categorized as "international cooperation" and, perhaps more to the point, what opportunities exist for future cooperation based upon this range of activities?

It is unlikely that those who organized this collection of papers meant to include under the subject "international cooperation" the arrangements by two or more private companies to work together towards a profit-making objective. Nevertheless, this form of international cooperation has two important characteristics. First, it is very probably the most effective form of international technology transfer. Second, it can provide an important justification for participation by those companies in the forms of international technical cooperation more traditional to the world technical community, particularly as viewed by those responsible for government policies.

As the above paragraph implies, there is an increasing network of joint ventures between independent companies in two or more countries that involve technical cooperation. The program, the results, and the immediate benefits reside within these companies. Nevertheless, the transfer of technology among the technical personnel represents a genuine increase in the technical reservoir available to the countries involved. It therefore accomplishes one of the principal objectives of any international technical cooperation agreement.

To digress slightly, some years ago the author, while director of research for a major U.S. corporation, had the responsibility for establishing a laboratory in England. Several individuals were approached to obtain the reaction of the host country to a U.S. laboratory. The senior technical officer within the British government sent a letter indicating that any laboratory of a U.S. corporation would inevitably benefit the host country in view of the diffusion of science and technology that would occur, despite the proprietary objectives of the work to be conducted.

The business interests of large corporations that lead logically to international activity thus provide a potential for international cooperation. The nature of such cooperation will depend very much on the nature of the technical structure within the corporation in question. We should therefore consider briefly certain characteristics of industrial research.

Industrial research is primarily mission-oriented, interdisciplinary, and relatively self-sufficient. This calls for some explanation.

The bulk of research and development (R&D) in any company is devoted to support of present businesses and to provide for possible expansion of these businesses. Some small percentage of effort may be allocated to exploratory R&D that could offer a basis for new business development.

The amount of basic research performed within industry is less than 4 percent of the R&D funded by industry. This figure varies sharply by industry sector, from a high of 10 percent in chemistry to less than

3 percent in such industries as machinery.[2] Still, these efforts are substantial in total dollars ($1.6 billion in 1981) and account for about 18 percent of all the basic research conducted in the United States.

The planning and funding of industrial research are related to particular product lines, processes, or business plans. They are not based upon scientific disciplines such as physics or chemistry, and they do not usually start with a breakdown by function, such as development or basic research. In practice, of course, the central corporate laboratory of a multibillion dollar corporation will contain most of the basic research activity of that corporation, while the technical groups within operating divisions or subsidiaries emphasize product or process development. Nevertheless, from an overall corporate view, the technical programs are planned to support a business or product line (mission-oriented), and it is left to the judgment of the research manager to organize whatever scientific and engineering talents are necessary to pursue this mission (interdisciplinary). In general, basic research within a corporation is part of this mission-orientation, in the sense that particular areas of basic research will be identified as most relevant to strengthening the broad technical effort.

The characteristic of being "relatively self-sufficient" must be examined more carefully, since it is the critical factor in the attractiveness of cooperative agreements to a company. The statement is based on a simple fact. The resources of major industrial corporations are such that, when there is agreement on a specific technical objective or when there is a corporate decision to pursue a business plan calling for a specific product or process development, all necessary technical inputs are made available within the corporate R&D organization. This is almost true by definition, since, if a necessary input were not available to the corporation, the decision to proceed with a development or a business plan would very likely not be made.

Thus, technical support for current products and businesses does not normally require a major corporation to go beyond its internal structure. The clue to justifying cooperation with the world outside the corporation lies in the two words "relatively" and "normally."

Being relatively self-sufficient refers to having an adequate technical capacity, including basic research when appropriate, to support current businesses and business plans. However, several conditions can exist that lead to interactions with science and technology outside the corporation:

1. Additional technical inputs may permit the pursuit of current objectives more quickly or at lower cost or both, i.e., increase R&D productivity.

2. A broader base of external contacts can increase the probability for new business opportunities in the future.

3. Any technical activity that can be left to, or shared with, other organizations can permit more resources to be allocated for internal activities.

The above items provide the principal basis for industry participation in cooperative activities, both past and future. More detailed breakdown will be discussed in the next section.

Finally, while a corporation does not "normally" rely on outside technical resources for its current business plans, there can be circumstances where a particular business development can only be pursued through some form of cooperation with other organizations. Among these circumstances are:

1. A new industry arising from a major technical advance may need to develop a common base of technical data, develop common instrumentation, or become familiar with new and expensive equipment. One example of this was industry cooperation in the initial National Advisory Committee for Aeronautics (NACA) during the early growth of the aircraft industry.

2. There may be developments so tinged with public interest, or calling for such considerable capital investment, that cooperative efforts involving the government and private companies are necessary. This occurred during the early development of peaceful use of atomic energy and included different programs at Oak Ridge and Argonne concerning materials development, reactor design, and safety standards.

3. The scale of investment for a particular industrial advance may be too burdensome for even our largest corporations. This was the case for different industrial consortia concerned with ocean mining. It is occurring today in the microelectronics industry with the Semiconductor Research Cooperative (SRC) and the Microelectronics and Computer Corporation (MCC) in the United States, and the European Strategic Program for Research in Information Technology (ESPRIT) within the European Communities. These are not all public cooperative activities in the traditional sense, but they go well beyond the "normal" technical activities of an individual corporation.

INDUSTRY ACTIVITY IN TECHNICAL COOPERATION

The preceding sections were an overly long commentary on the motivations and needs of industry and industrial research with regard to science and technology external to the corporation. Let us examine briefly what forms of technical cooperation have taken place, then look specifically at the international aspect of such cooperation.

There are several different ways to categorize the forms of technical cooperation, such as:

- by objective, e.g., cost sharing
- by activity, e.g., basic research
- by sponsorship, e.g., bilateral government agreements

Obviously, there is an overlap among the categories. Whichever we choose to emphasize, there has been a growth in this activity, and several summaries are available. The author chaired a conference in Paris in November 1980 focused on the subject. The published proceedings[3] contained a number of introductory papers that reviewed the categories of agreement. The usefulness of cooperative agreements to industry was summarized by Jacques Desazars de Montgailhard, President of Pechiney Ugine Kuhlmann (pp. 11–16 in the proceedings). Economic benefits, obstacles, and their removal are discussed by Robert G. Hawkins, Vice Dean, Graduate School of Business Administration, New York University (pp. 17–26). A detailed review of past and present international agreements (pp. 26–50), with emphasis on the sponsoring international organizations, is contained in a paper by Klaus-Heinrich Standke, then a Principal Director of UNESCO. Finally, there is a more thorough listing and categorizing of international technical agreements in a recent book by Daniel D. Roman of George Washington University and Joseph F. Puett, Jr., of Alfred University and the McGraw-Edison Co.[4]

Without attempting to summarize these reviews, there is some value for this discussion in setting down briefly the principal objectives of traditional international technical agreements discussed in these reference materials. These are:

- cost sharing
- standardization
- strengthening basic science
- improving international political and economic relations
- solving specific international technical problems (e.g., acid rain)

These categories give us a way to think about international agreements generally. However, in order to spell out the present and potential industry role, we must look at the topic from the industry viewpoint, which follows from the preceding discussion of industry characteristics.

For this purpose, it may be helpful to devise a matrix made up of two sets of categories that are more in line with the factors involved in the decision-making processes of industry cooperative agreements. These categories are:

1. Nature of Agreement
   - Public
   - Private
2. Nature of Company Participation
   - Money
   - People
   - Joint conduct of research

That is, the various cooperative agreements that companies join can be listed as shown in Table 1, with one example in each.

These categories are not, of course, restricted to private companies, but they are useful in discussing and understanding the actions of these companies. Let us consider the growth and trends in industrial cooperative agreements. The hypothesis presented is that this growth, with some exceptions but in general, has spread out from the top-left corner, i.e., public cooperation involving just money, to activities that are private agreements that involve joint activities among corporations.

To expand upon this somewhat, the traditional interest of the technical community—particularly those in government and universities—is with "public" cooperative agreements. The results of these ac-

TABLE 1 Factors Influencing Industry Cooperative Agreements

	Nature of Agreement	
Nature of Participation	Public	Private
Money	Any trade association (e.g., International Copper Research Association)	Microelectronics and Computer Corporation (MCC)
People	Experimental Safety Vehicle (ESV) Program (Europe, U.S., and Japanese auto companies)	Any joint venture (e.g., Alsthom—Exxon Fuel Cells Development)
Joint research	Cooperation in Scientific and Technical Research (COST) (European Communities)	Large complex program (e.g., Concorde)

tivities are readily available for public information with, at most, mandatory and reasonable licenses. Yet the interests of industry emphasize primarily "private" cooperative agreements, wherein the benefits reside largely within the sponsoring corporations, and these arrangements are intensifying. Further, a simple agreement to support common interests could be accomplished by financial contributions, administered through a small third-party organization. The more complex, more immediate, and more important the nature of these common problems, then the more likely the need to involve personnel from the sponsoring companies and, for the broadest problems, to coordinate research efforts conducted within those companies. Let us consider a few examples of how these interests develop.

The common form of industry cooperation, and very likely the oldest, is the trade association. This is a form of public action, since the results are generally publishable and available to the public and the objectives do not affect competition within the industry. Trade associations in the United States do not normally operate laboratories. They are funded by corporate contributions, and the money earmarked for R&D is allocated to projects at universities, research institutes, and companies. This is done with a modest staff, but involves corporate representation on appropriate committees to provide member judgments. Such associations in Europe are more likely to operate a research laboratory, e.g., Iron and Steel Research (IRSID) in France and the British Non-Ferrous Metals Research Association.

These associations emphasize technical subjects common to all member companies. Basic research is an obvious area. Another is the development of new uses for products in the materials industries, or safety questions such as toxicology evaluation for the chemical industry. The programs are very carefully selected to serve common interests and avoid anticompetitive actions. This is due not only to observance of antitrust laws, but also to the fact that each company is sensitive to its own competitive position.

Thus, there is a long history of industry participation in collective actions related to subjects normally of interest to trade associations. These clearly form the principal basis for the role of industry in public technical cooperation, both domestic and international. In the United States, trade associations are useful adjuncts to the R&D within the companies, but constitute a relatively minor effort in comparison. In Europe, it appears that the research of trade associations, particularly in view of the laboratories they manage, plays a more important role. On this basis, one might expect that U.S. firms will look less to collective action than do the Europeans, but this may well be an unwarranted conclusion, as no studies of this sort appear to have been published. In any event, this possibility would have to be examined for each industry sector.

The trade association sets the pattern for industry's technical cooperation of a public nature. However, the growth in formal linkages that include cooperation between a company's internal technical activities and those activities external to the company has taken place largely through private cooperative agreements. This occurs as an integral component in a joint venture.

In an earlier section, we pointed out the international character of every large corporation. This is very often implemented by a joint venture between a U.S. and foreign company, which has become a common mechanism for new business development that combines specific and well-defined assets of each company (there can be more than two) to pursue an agreed-upon business plan. While new technology is not necessarily involved, the joint venture is very often based upon a technical advance by one partner. Thus, technical cooperation involving people and, quite likely, technical groups from each company is a frequent feature of such ventures. There is either adaptation of new technology or a common development effort. When we consider the extent to which joint ventures involving two or more countries have multiplied in use throughout all industry sectors, this mechanism probably constitutes the most significant and effective form of technology transfer within the OECD countries.

Several instances have arisen for private technical cooperation among a number of companies that involve the internal technical groups within the companies to a considerable extent. These have been necessitated by the complexity of the undertaking, the need for different technical contributions, or the sheer cost of the effort. One obvious example is the Concorde, involving Aerospatiale and British Aircraft, Ltd. Another is the establishing of major consortia to develop ocean mining systems, production, and sales, which involve giant U.S., European, Canadian, and Japanese companies. The recent intensity in microelectronics developments has led to the establishment of MCC, consisting of a substantial R&D effort funded by such major U.S. firms as Control Data Corporation (CDC), Honeywell, and Sperry (but not IBM), as a private effort to create major technical advances. Six European auto companies initiated an agreement in 1980 to conduct cooperative R&D in areas of common interests (British Leyland, Peugeot, Fiat, Volkswagen, Renault, and Volvo).

Beyond these private efforts, as well as the "public" cooperation of the trade associations, there have been a number of major attempts to involve industry in technical cooperation agreements under the sponsorship, or at least the initiation, of a nonprivate organization. These are, almost by definition, public in nature.

For example, we have referred previously to the 1983 program, ESPRIT. It has objectives in Europe similar to those of the private MCC in the United States. However, ESPRIT is structured as a program within the EC. Companies such as Thomson, Philips and Siemens will work on defined problems of common interest, funded partly by the participants and partly by the EC.

There was an earlier program set up in 1970 by the EC called COST (Cooperation in Scientific and Technical Research). This facilitated R&D cooperation among members and covered a broad range of subjects such as optical fiber communication, advanced materials, and measurement of pollutants. Industry participation took place where the required skills and private benefits were compatible and agreements arranged with the countries involved.

SIGNIFICANCE FOR INDUSTRY ROLE IN FUTURE INTERNATIONAL TECHNICAL AGREEMENTS

Given industry characteristics and the rather considerable range of industry involvement in technical cooperation activities, what can we conclude as to the trends and possibilities for future participation in international technical agreements?

The discussion to this point has deliberately mixed together both public and private agreements, both domestic and international. The principal intent was to focus on the conditions surrounding *any* cooperative technical arrangement entered into by a private company. While this paper is not by any means complete in treating the subject, enough discussion of industry objectives, procedures, and involvement in cooperation has been presented to permit some appraisal of future actions on an international scale.

In certain respects, industry today should be more receptive to international technical cooperation, provided such agreements are structured to take into account industry needs. There are several reasons for this.

First, there is great pressure within industry to increase R&D productivity, i.e., to derive the maximum benefit from the technical resources available to the corporation. Thus, any use of outside resources, such as a cooperative agreement, can free corporate resources to focus on those activities that can have a critical impact on the competitive status of the company. The challenge is to identify areas for cooperation that are less critical to its competitive status.

Second, there is an increasing sensitivity to the limitations of any single corporation, both of technical capabilities and of finances, to carry through major technical advances alone in a number of fields. This has already led to industry initiatives in taking collective action in microelectronics (MCC, ESPRIT), energy (Electric Power Research Institute, or EPRI), chemistry (Chemical Research Council, or CRC), and others.

Third, the growth of international joint ventures and the resulting increased private technical cooperation provide industry greater familiarity with relevant technical activities throughout the world, and an appreciation of desired sources for cooperative action.

The key criterion in the attractiveness of an international technical cooperative agreement is the extent to which it supports the activities and plans of the company. The simple fact is that the more international joint ventures proliferate and the more consortia are assembled to pursue large and complex programs, the greater is the need for the type of technical support offered by technical cooperation.

For example, a large U.S. company that enters into an international joint venture accepts the fact that it is not self-sufficient technically to carry out the complete business plan alone. It is, therefore, a much more logical candidate, actually and psychologically, to participate in an international technical cooperative agreement of a public nature than a U.S. company with more limited objectives, which makes use only of its internal technical resources.

There are, however, some observations as to the optimum role of industry in public international technical cooperation which follow from the preceding remarks:

1. Industry benefits correlate better with mission-oriented programs, e.g., energy conservation or microprocessor development, than with discipline-oriented ones, e.g., materials research or biochemistry. As mentioned earlier, much basic research is conducted within industry, but each company emphasizes those areas of basic science and engineering wherein advances in knowledge will have a high probability of supporting the company's present business and future plans.

2. There are different inputs that should be expected and requested of industry representatives in mission-oriented cooperative agreements than from industry representatives in discipline-oriented ones. An industry representative in a basic research agreement is primarily a

competent scientist or engineer who happens to work in industry. His inputs are based on technical knowledge and judgments about the subject, similar to his colleagues from government and university. In mission-oriented technical cooperation, the industry representative brings pragmatic judgments affecting the process for converting technical advances to use—problems in ultimate design and manufacture, market requirements, financial capabilities. These affect selection of projects and their conduct, and these are precisely why industry is both interested in these types of agreements and has a critical contribution to make.

3. Despite what has just been said, it is easier for industry to take part in broad agreements dealing with basic research, health, and safety since they offer less probability of conflict with proprietary programs and the competitive positions of the separate companies.

These comments apply to any cooperative agreements. What particular criteria might apply to international cooperation?

It would seem that some clues to answering this question lie in the growth of private international agreements plus the involvement of corporate personnel and the conduct of research within each corporation as a component in cooperation. This combination of expanded international activity and active involvement of corporate people and facilities creates new potential for industry involvement in more public forms of international cooperation.

First, this activity serves to identify subjects that are directly related to, or in support of, programs already being conducted by industry internationally. Second, the private international technical cooperation taking place among operating units of a multinational or among the partners of a joint venture brings to all parties an increased awareness of related R&D activities within the government and academic sectors of other countries. Thus, the ability to derive benefits from joining public cooperative agreements may be more easily seen, and the willingness to work with colleagues from other organizations is more likely to be present.

Third, once an individual company has been able to separate its own competitive interests from those of a private international joint venture, it is a simpler step to separate still further those technical activities that appear critical to the interests of the joint venture from those that, while helpful, might well be pursued more effectively and at lower cost as part of public international technical cooperation.

Industry today has such considerable technical resources internally that cooperative activities are rarely critical to its business plans.

When external resources appear advantageous, industry can develop relationships with universities to provide linkages in particular areas of basic research or it can establish joint ventures with other companies to provide appropriate technical cooperation internationally in private agreements.

Nevertheless, the opportunities and benefits of well-planned public agreements in international technical cooperation should be of increasing value to industry. In turn, this should produce highly valuable technology transfer from industry to the public sectors. Such participation should increase greatly if each party takes into account the interests of the others.

This paper has not been in any way intended to be complete or definitive. The purpose has been to stimulate discussion on the subject. Since this subject is one to which little attention has been given, the paper should at least achieve that limited goal.

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Discussion

An entire afternoon of the workshop was devoted to a discussion of the roles, responsibilities, and contributions of U.S. governmental and nongovernmental organizations. Among the matters addressed was the federal government's role in promoting and facilitating international cooperation from a policy, programmatic, and budgetary standpoint. Discussion also focused on the role of nongovernmental organizations such as the universities, professional societies, the Academy complex, and private industry as alternative modes for international cooperation.

The discussion began with a consideration of the situation with respect to *support from and involvement of the federal government*. It was pointed out that, despite growing budgetary pressures and the increased importance of science and technology (S&T) in foreign policy, the government is now devoting a smaller percentage of its total R&D investment to international cooperative activities than it did 25 years ago. Part of the problem is that the United States does not have a permanent organizational focus for international S&T cooperation; it is all carried out through a very decentralized process of budgetary allocations. Thus, it is useful to distinguish between those activities undertaken in support of U.S. "domestic" R&D interests and those undertaken for a mix of foreign policy and scientific interests.

A variety of considerations arise with regard to the first category. First, in order for the government to support this type of cooperation it must be judged compatible with and contributory to specific U.S.

R&D objectives. Beyond this, however, is the question of how the leadership of the particular agency views the matter of cooperative activities, that is, whether the extra costs involved in travel and so forth are viewed as legitimate and worthwhile. Second, there is the matter of the budget cycle and the process through which projects are peer reviewed. In some cases, even if a project is determined to be compatible with a domestic goal, it may fail to coalesce due to the different approval processes involved in the cooperating countries. Similarly, there may be a problem with unparallel funding renewal procedures. On the other hand, once projects are approved and funded, it may sometimes prove difficult to "turn them off" once they have outlived their functional lifetime.

Regarding the second category of projects, the question is not really whether cooperative S&T projects should serve mixed scientific and foreign policy objectives, but how such objectives can be served without doing damage to the scientific and technological components. Since by definition these projects are not competitive with domestic R&D budget objectives, there are major questions as to how they should be funded. For example, should they come out of domestic R&D budgets? Can separate budgets for international cooperation be defended in the budgetary process? The NSF currently uses both approaches. In the future, there may need to be additional consideration given to increased use of segregated funds in line-item budget allocations. The problem with this approach, however, is that segregated funds require little or no quality control, which often results in lower-quality work. Another approach discussed was that of giving the State Department access to "seed money" that it could make available to other agencies to develop cooperative projects that could not be justified solely on the basis of domestic priorities or scientific merit.

It was noted that the lack of a "central instrument" for long-term strategic planning in science and technology—including the identification of problems and opportunities—is a continuing liability for the United States. There is a growing capability in Western Europe and elsewhere, and there is a need for qualified individuals in government who understand how the world research system operates and who have the freedom to adopt a longer-term view. On the face of it, the President's Office of Science and Technology Policy (OSTP) should play this role, but it is of necessity concerned with the day-to-day needs of the President and "quick reaction, short-term policy." At the same time, the climate in many of the federal agencies dealing with S&T is generally uncongenial to cooperative activities that do not relate to their specific missions. Yet, it is also important for the U.S.

government to originate long-range assessments of international S&T cooperation, because ideas that come solely from the scientific and technological communities often are discounted as self-serving.

The National Science Foundation has played an important role in funding, implementing, and managing some of the major bilateral S&T agreements in which the United States is involved. But this is not a pattern that can be "expanded indefinitely," given the continuing trend toward signing bilateral S&T agreements as part of presidential visits without a concomitant increase in NSF funds. Some participants termed bilateral S&T agreements as "a mechanism in search of a program."

It was indicated that "a whole new conceptualization of multinational science" may be required to convince U.S. policymakers of the domestic benefits that can be derived from international cooperation. While the international culture of science would tend to urge greater collaboration, there are powerful nationalistic forces working in the opposite direction. The result is that international science tends to devolve back into unilateral actions. This is exacerbated by the view of some American scientists that international S&T cooperation represents a "zero sum game" in which funding for international projects reduces the resources available for U.S.-based research projects.

Formal U.S. international cooperation through multilateral channels is increasingly problematic. (This discussion took place before the announcement of the U.S. intention to withdraw from UNESCO.) Although it is the government that contributes the dues to international organizations, it is the scientific community that is responsible for the content of the programs and the participation in the activities. There continues to be a real problem with getting the "right" people to attend international meetings and with designing and directing programs along scientifically valid lines. This is not as much of a problem with international organizations that have a narrow technical focus, but, for those with broad mandates, U.S. representation has often been at the political (rather than the technical) level.

One participant raised the point that the "lumping together" of basic science, applied science, and technological development makes it difficult to articulate and defend their value before the Congress and the general public. Yet such justifications become critical if support is to be maintained, much less expanded. Thus, it may become necessary to develop "proximate models that illustrate the continuum from basic science to high technology."

A second focus of discussion concerning the domestic basis for U.S. international S&T cooperation was *the role of the private sector*. It was pointed out that industry is responsible for an enormous amount of cooperation and is extremely effective as an agent of technology transfer. However, because it ultimately must base such activities on profit and loss considerations, industry "picks and chooses" the situations where it finds it worthwhile to become involved in international cooperation. There also are some new factors affecting the extent of industry involvement, including: (1) increased use of "collective" industry research efforts (e.g., ESPRIT in Europe or the Gas Research Institute in the United States), (2) increased government interest in specific technological fields, and (3) recognition that international technical agreements are generally less effective without industry participation.

Private companies cooperate for a variety of reasons. First, there is cost-effectiveness, i.e., avoiding expensive duplication of effort. Second, there are certain types of research activities, e.g., assessing the need for or cost of environmental regulations, that are not competitive activities and can be accomplished more expeditiously in a joint manner. Third, there are certain types of R&D investments, e.g., ocean mining, that require such enormous levels of capital that joint ventures are a necessity. Industry tends to be most interested and most effective in cooperating in mission-oriented areas. In order to get private industry even more involved in cooperative activities, it must be presented with a convincing case for doing so.

One participant from private industry stated that the private sector accounts for more than 75 percent of all U.S. R&D, and perhaps 18 percent of all basic research. He indicated that transborder collaboration is implemented through technology licensing, joint ventures, blanket information exchange agreements, training programs, and some cooperative R&D programs. Industry requires a much more favorable "cost-benefit ratio" than currently exists to justify the sharing of information and resources. Bilateral agreements are considered generally to be too vague and unspecific, and so arrangements must be built "from the ground up" around the research of a particular individual or laboratory.

There are some types of R&D that industry engages in that do not have a strong competitive factor. These include, for example, public health, civil engineering, and environmental protection. These areas have heavy implications for business, for professional groups, and for society in general. Enhanced international cooperation may benefit all concerned.

There is a need to develop a "web of relations" in the United States between government and industry—and between industries themselves—similar to that which exists in Japan. Few mechanisms are extant in this country to foster such cooperation, and often the tax and antitrust laws do not favor collaborative arrangements. At the same time, however, some of the large multinational corporations are already functioning as S&T transfer mechanisms through the transborder movement of people and ideas among their subsidiary laboratories. There are also cases, such as the large coal gasification plant now operating in California, where private industry from a number of different countries has invested jointly in the necessary R&D.

Another participant pointed to the existence of the Pacific Council for Energy and Mineral Resources, which consists of 19 members from around the Pacific basin who are drawn equally from industry and governments. The council receives both public and private monies, and it sponsors a variety of activities including conferences and workshops, exchange of data on geology and geophysics, and a geological/geophysical mapping project. It is a highly successful example of regional cooperation in a specific field that also transcends the public/private sector boundary.

A third focus of the discussion on the domestic basis for U.S. international S&T cooperation was *the role of nongovernmental organizations* (NGOs). The first institution discussed among this group was the science and engineering academy as a cooperative modality. It was pointed out that, although it is not a major part of its function, there are formal agreements between the National Academy of Sciences and other counterpart academies, particularly in centrally planned societies. Communications between science academies serve as a basis for discussion of issues of concern to members of the international scientific community. The academies also provide a substantial amount of the infrastructure for the work of the International Council of Scientific Unions (ICSU) and related bodies. The academies, through the National Research Council Board on Science and Technology for International Development, support a range of activities and relationships with and for developing countries.

Historically, the major U.S. private foundations have played a significant role in promoting international cooperation in science and technology—particularly in the area of agricultural research—but much of that support is now in the past. Though there are some exceptions, those foundations that earlier were involved in international activities have increasingly turned their attention to local and national problems, often at the expense of international programs.

Scientific professional societies, it was suggested, facilitate cooperation at the grassroots level. These NGOs could play an even greater role, but there are obstacles. For one thing, much international cooperation is interdisciplinary, which creates a potential problem for societies that are exclusively disciplinary in their orientation. There is now some movement, however, toward international cooperation between professional societies. One participant suggested that the international activities of professional societies could be classified in four functional areas: pageantry, fraternity, vocational enhancement, and charity.

Pageantry involves such activities as periodic international meetings of society presidents. In terms of fraternity, societies may send delegates to the meetings of sister societies in other countries, and they may sponsor very specialized exchanges and publish notices in each other's journals. Vocational enhancement is carried out through important topical issues in international conferences. The charitable function is undertaken through the contribution without compensation of time and talent in educational activities and participation in international committee meetings, etc.

The American Association for the Advancement of Science (AAAS) maintains a consortium of affiliates for international programs which is composed of approximately 70 scientific and engineering societies. Similar linkages exist for engineering, including the World Federation of Engineering Organizations, and, in the western hemisphere, the Pan-American Organization of Engineering Societies. On the other hand, it was also mentioned that there is sometimes a difficulty in establishing international programs where an appropriate counterpart society does not exist in other countries.

Bilateral Cooperative Modalities

U.S.-European Cooperation in Space Science

A 25-Year Perspective

John M. Logsdon

In the 25 years that the United States has had a government space program, international cooperation has been one of its major themes; an objective of the National Aeronautics and Space Act of 1958, which was the charter for the civilian space program and which established the National Aeronautics and Space Administration (NASA), was "cooperation by the United States with other nations and groups of nations in work done pursuant to the Act and in the peaceful applications thereof."[1] Armed with this legislative mandate, with presidential and congressional support for a U.S. civilian space program that emphasized openness and scientific objectives, and with already existing patterns of cooperation in space science, NASA has since its inception conducted an active program of international partnership.

In space perhaps more than in most areas of international science, it has been the policies and initiatives of a government agency and its top officials, rather than those of the scientific and technical community, which have established the U.S. attitude toward cooperative undertakings. Although NASA's international programs have involved the Soviet Union, Canada, Japan, and various developing countries, its primary cooperative partner has been Europe—both individual European countries and the various European space organizations that have existed over the past two decades. Table 1 suggests the dominance of U.S.-European interactions in the overall record of NASA's most important cooperative programs.

TABLE 1 Patterns of International Cooperation, 1958–1983[a]

	Cooperative Spacecraft Projects	Experiments With Foreign Principal Investigators
Total, Europe	33	52
European Space Agency	8	1
France	2	17
Federal Republic of Germany	7	11
United Kingdom	7	18
Italy	6	1
Netherlands	2	3
Other	1	1
TOTAL, All countries	38	73

[a]Includes past and currently approved cooperative projects.
SOURCE: NASA, *25 Years of NASA International Programs*, January 1983.

The U.S.-European partnership in space science has been on the whole remarkably successful, both in terms of cooperation between the United States and individual European countries and between the United States and Europe's multilateral space science agencies, the European Space Research Organization (ESRO) and its successor, the European Space Agency (ESA). Projects such as Ariel (United States-United Kingdom), Helios (United States-Federal Republic of Germany), Infra-Red Astronomy Satellite (United States-United Kingdom-the Netherlands), International Ultraviolet Explorer (United States-United Kingdom-European Space Agency), and International Sun-Earth Explorer (United States-European Space Agency) are just a few of the major scientific undertakings which have benefited from U.S.-European collaboration. This record of success must be kept in mind in evaluating any past and current stresses in the cooperative relationship.

As the U.S. space program enters its second quarter century, there are significant changes in U.S.-European cooperation; the major reasons for these changes include: the increased maturity and level of space capability that Europe is bringing to the partnership; the consequent addition of a competitive dimension, both in scientific and economic terms, to the relationship; the increasing cost of space science missions; and the relative scarcity of financial resources available on both sides of the Atlantic for space science.

Last fall saw the first flight of Spacelab, an orbital facility for manned scientific experimentation that was developed by Europe at a cost of approximately $1 billion; Spacelab is designed for use with only the U.S. space shuttle and reflects the intimate character of continuing U.S.-

European collaboration. At the same time, Europe has developed its own launch capability in the Ariane series of expendable boosters and is using that autonomous capability not only to launch its own spacecraft but also to compete with the space shuttle for other launch contracts. European countries are also developing satellites for earth observation and communications and exploring the potential of space manufacturing, with the objective of competing with the United States for economic payoffs from space.

Further scientific cooperation in space between the United States and Europe will occur in this mixed context of collaboration and competition. The state of that cooperation is vigorous, as both the United States and Europe continue the fascinating adventure of exploring the nature of the solar system and the cosmos that is made possible by space technology.

ORIGINS OF U.S. COOPERATIVE PROGRAMS

As the late Homer Newell, one of the U.S. pioneers in space science and an early and strong advocate of international cooperation in space, has noted, "With roots in the International Geophysical Year, which had already generated a lively interest in the potential of satellites for scientific research, one might argue that the appearance of an international component in the NASA space science program was inevitable."[2] The International Geophysical Year (IGY), organized under the sponsorship of the International Council of Scientific Unions (ICSU), was an 18-month (July 1957–December 1958) effort involving 66 countries, some 60,000 scientists, and the expenditure of hundreds of millions of dollars; both the Soviet Union and the United States agreed in 1955 to launch scientific satellites as part of IGY activities.

There was in place at the very start of the space age, therefore, a nascent international community of scientists who saw space technology as providing exciting opportunities for extending and expanding their investigations. This community was quick to press NASA to keep its program open to international involvement. This pressure was congenial, since one reason that the United States had decided to house its major space activities in a separate, civilian government agency was to present to the world an image of peaceful intent and open style; this was in deliberate contrast to Soviet space activities, which were controlled by the military services and conducted with great secrecy.

There were those in 1958 who argued that the U.S. space program should be under military control and not opened to international cooperation because "the tools of space research—rockets, radio, radar, guidance, stabilization—were all common to both the military and to science. Even the scientific objectives . . . were of interest and possible value to the military."[3] Added to this "dual use" character of space technology and some areas of space science was the role of space achievement as an area for superpower political competition, particularly after the United States launched the Apollo program in 1961.

The scientific activity involving the use of space systems took place in a highly charged political and military environment. By carefully defining the conditions under which cooperative activities would be initiated and carried out, NASA was able to conduct an international program that has been relatively free from distortion for political purposes and from limitations because of military sensitivities. Even so, with respect to space cooperation "a clear duality dogs both the history and the prospects of international partnerships."[4]

NASA GUIDELINES AND OBJECTIVES FOR INTERNATIONAL COOPERATION

When NASA announced to the ICSU's Committee on Space Research (COSPAR) in March 1959 that it would assist COSPAR members in launching scientific experiments and satellites, the agency had already under development a set of policy guidelines for such cooperation. Those guidelines have survived periodic reexamination and remain in force today. They reflect "conservative values"[5] with respect to the conditions under which cooperation is desirable; shaping those values were both the recognition of the political significance of space activities and the strong personalities of such individuals as Newell and Arnold Frutkin, who directed NASA's international program from the agency's earliest months until the mid-1970s.

The essential features of NASA guidelines are:

- Cooperation is on a project-by-project basis, not on a program or other open-ended arrangement.
- Each project must be of mutual interest and have clear scientific value.
- Technical agreement is necessary before political commitment.
- Each side bears full financial responsibility for its share of the project.
- Each side must have the technical and managerial capabilities to carry out its share of the project; NASA does not provide substantial technical assistance to its partners, and little or no U.S. technology is transferred.
- Scientific results are made publicly available.[6]

A key feature of NASA's cooperative efforts is that "while NASA has international programs, it does not fund *an* international program." Rather, "funding for international projects must come out of the NASA program offices," and "for an international approach to a project to be undertaken it must not only contribute to achieving the goals of the interested program office, but it must be considered to be among the best approaches to achieving those goals."[7] This emphasis on technical soundness and scientific merit has been a consistent feature of the U.S.-European cooperation over the past 25 years, whatever other objectives are sought through such cooperation. As one perceptive analysis notes, "although NASA recognizes possible political benefits from achieving utilitarian goals, NASA's cooperative programs are justified almost entirely on technical and scientific grounds, both within and outside" the agency.[8]

The objectives of NASA's international programs can be grouped as follows.

Scientific/Technical

- "Increasing brainpower working on significant problems and expanding scientific horizons by making space an attractive field for research."[9]
- Shaping the development of foreign space programs to be compatible with the U.S. effort "by offering attractive opportunities to 'do it our way'."[10]
- Through such influence, limiting funds available in other countries for space activities that are competitive or less compatible with U.S. interests.
- Obtaining unique or superior experiments from non-U.S. investigators.
- Obtaining coordinated or simultaneous observations from multiple investigators.
- Increasingly making available opportunities for U.S. scientists to participate in the space science missions of other countries or regions.

Economic

- "By sharing leadership for exploring the heavens with other qualified space-faring nations, NASA stretches its own resources and is free to pursue projects which, in the absence of such sharing and cooperation, might not be initiated"[11]; NASA estimates getting over $2 billion in cost savings and contributions from its cooperative programs over the past 25 years.[12]

- "Improving the balance of trade through creating new markets for U.S. aerospace products."[13]

Political

- Creating a positive image of the United States; "the U.S. program of cooperation in space reaches a scientific, technical, and official elite in the struggle for minds."[14]
- Encouraging European unity; the U.S. space program "lends itself admirably to cooperation with multilateral institutions in Europe."[15]
- Reinforcing the image of U.S. openness in contrast to the secrecy of the Soviet space program; "when NASA was organized . . . the keystone of Government space policy was to give dramatic substance to the claim of openness—and, at the same time, to seek credibility for the nation's assertion that it entered space for peaceful, scientific purposes. This was done . . . most importantly, by inviting foreign scientists to participate extensively and substantively in space projects themselves."[16]
- Using space technology as a tool of diplomacy to serve broader foreign policy objectives.

While the priority given to these various objectives has varied over time and mission opportunity, at the core has been a policy that permitted this country's closest allies to become involved in the U.S. space effort. Indeed, some have criticized NASA for making possible such participation, at minimal cost, in an effort paid for almost entirely by U.S. taxpayers; "benefit, know how and opportunity were shared to an extent that was entirely unprecedented where an advanced technology was involved, particularly one with such strong national security implications."[17]

EVOLUTION OF U.S.-EUROPEAN COOPERATION IN SPACE SCIENCE

During the "golden age" of the U.S. space program, from the beginning of the Apollo buildup in 1961 through its peak in the 1965–1966 period, NASA's international activities grew rapidly along with the rest of the agency's efforts. Before the first Apollo 11 moon landing in July 1969, nine European spacecraft had been launched by the United States, and substantial momentum had built behind European involvement with the United States in space experimentation. This momentum has carried through to the current day, but, as one top-level participant has commented, "when resources abound and opportunities are plentiful, a cooperative attitude abounds. . . . When the resources and opportunities shrink, . . . altruism takes a back seat and . . . scientists take a more selfish view of cooperation."[18]

Several factors have influenced the evolution of U.S.-European space cooperation in the 1970–1983 period. In no particular order of importance they are:

1. A shrinkage in the NASA budget overall in the post-Apollo era; the space science budget came under particular pressure as the share of overall resources going to shuttle development increased. This meant fewer science missions and more competition among U.S. scientists to get their experiments on the missions which were approved.
2. A broadening of NASA's international program to encourage European participation, not only in science missions, but also in developing large space systems including manned space flight elements.
3. The evolution of the 11-member European Space Agency (ESA), founded in 1975, into an effective entity that has carried out a successful science program of its own and has managed several space applications projects and two major hardware development programs, Spacelab and Ariane. The national space programs of France, Germany, Italy, the Netherlands, and the United Kingdom, each with differing emphases, are also vigorous.
4. More recently, growing concern in the United States that cooperative undertakings in space, including space science, could serve as vehicles for unwanted transfer of militarily or economically sensitive U.S. technology to other countries.

While Europe has continued to cooperate with the United States, it has also become a formidable competitor in various categories of space applications and in some fields of space science. Europe is now a very capable actor in space, and it could become more difficult for the United States to develop cooperative projects on its preferred terms. While the United States remains the partner of choice for ESA and individual European countries, existing and potential cooperation with the Soviet Union and Japan provides an alternative. There is now the possibility of a global division of labor and cost in space science, and this makes the task of planning and getting agreement for major space science projects both challenging and full of opportunities.

There has been over time an undercurrent of ambivalence among U.S. space scientists and NASA managers about European involvement in NASA missions, whatever the stated policy. For one thing, "always the U.S. side was slightly constrained by fear that foreign collaborators

. . . might not fulfill their commitments." This concern has diminished over time; "in the few cases where serious delays occurred, as in the Solar Polar project, it was more often the United States that was responsible. . . . Had NASA personnel not been susceptible to the then universal belief that other nations necessarily lagged behind the United States in technological capability, the policy of collaboration in space matters could almost certainly have been even more rewarding."[19] For another, when foreign experiments have been selected by NASA, some U.S. scientists have raised the question of whether the foreign experiment was really selected over a competing U.S. experiment based on merit or whether it was selected because it would be provided to NASA free of charge.[20] Another reservation with respect to foreign participation has been that "by selecting a high-technology experiment, the United States encourages development of the industrial base in the foreign country which will contribute to a decreased United States competitive position in world trade."[21] Yet another concern is that management of a U.S. space science project is greatly complicated by the need to integrate the experiments or other contributions from a foreign partner.

While growing European capability has muted concern about the first of these factors, it has also created a healthy competition among all space scientists for access to orbit and beyond for their experiments. While European scientists have always been able to propose experiments on U.S. missions, U.S. scientists are only now gaining a reciprocal opportunity to serve as principal investigators for experiments on ESA missions.

A major attempt to engage Europe with NASA's technology development efforts took place in the 1969–1973 period, as NASA itself sought to gain presidential and congressional approval of an ambitious post-Apollo program of manned space flight. The negotiations on European participation in the post-Apollo manned program were much more political in character than prior (and subsequent) negotiations on cooperative undertakings in space science. This post-Apollo experience, perhaps justifiably, has left a lingering "bad taste" in Europe. NASA's objective was "to stimulate Europeans to rethink their present limited space objectives, to help them avoid wasting resources on obsolescent developments (this was a reference to European plans to develop an independent launch capability) and eventually to establish more considerable prospects for future international collaboration on major space projects."[22]

A basic problem in this case was that NASA could not deliver on what it was promoting in Europe. NASA's post-Apollo ambitions included a space station and a fully reusable space shuttle and the agency continued to solicit European involvement in these programs even when their approval by the President was very uncertain. Indeed, within the United States NASA tried to use the prospect of cost sharing with Europe as a selling point for approval of these programs. When only the space shuttle remained as a potential program, NASA encouraged Europe to consider developing both components of the shuttle orbiter and a separate major project, a reusable orbital transfer vehicle called a "space tug." However, NASA was forced to withdraw these offers at the last minute when the Air Force, whose support was needed for shuttle approval, objected to European development of essential elements of the Space Transportation System; when concerns regarding excessive transfer of propulsion technology were raised; and when some in NASA became concerned about the safety implications of placing a cryogenically fueled tug in the shuttle payload bay. Finally, NASA offered Europe the comparatively simple and less expensive task of developing a "research and applications module" to fit into the shuttle payload bay; this is what became the Spacelab project.

By this time, Europeans were rather skeptical with respect to NASA overtures, but they (particularly Germany) had also become so eager to embark on manned flight activities that they agreed to develop the Spacelab system under what in hindsight have been seen as unfavorable terms; the first set of flight hardware, developed with European funds, was to be transferred to NASA, and after an initial joint NASA-ESA mission that included flying a European payload specialist, Europe was to pay for future shuttle-Spacelab flights. NASA agreed to buy a second set of flight hardware from Europe, but "a significant segment of the European space community believes that the United States is getting the lion's share of the benefits from Spacelab."[23]

European space officials have described themselves as "stupid" in accepting the U.S. terms for involvement in its post-Apollo program and believe that such acceptance stemmed from lack of confidence in European capabilities and from a belief that only through cooperation with the United States could those capabilities be improved. Now, having brought both Spacelab and Ariane to success, Europe has much more confidence in its ability to chart its own future in space and it will be a more demanding participant in negotiations with the United States over cooperative ventures.[24]

European confidence in the United States as a cooperative partner was shaken in the spring of 1981 when the United States announced, without prior consultation with its European partners, that it was canceling a U.S. spacecraft that was part of a two-spacecraft International Solar Polar Mission (ISPM). This withdrawal caused vigorous protests from not only European space officials but also representatives of foreign ministries.[25] In this case, "NASA's success in international participation became a political liability"[26]; NASA was forced to reduce funding in a major space science mission, and all three existing large missions—the Space Telescope, the Galileo mission to Jupiter, and the Solar Polar mission—had major European involvement.

There is general agreement that the ISPM affair was handled clumsily, and both the United States and Europe have moved beyond it, although European officials are not beyond using U.S. guilt over the incident as a bargaining chip in U.S.-European negotiations on future collaboration.

In summary, U.S.-European cooperation in space has become a much more complex enterprise in the last 10 years as both U.S. and European space efforts matured. While the balance sheet in that enterprise remains strongly on the positive side for all participants, competition and conflict have joined collaboration as hallmarks.

CURRENT ISSUES IN U.S.-EUROPEAN COOPERATION

The major U.S. science missions now approaching launch, the Space Telescope and the Galileo spacecraft to Jupiter, have major participation by Europeans, and there is every anticipation that there will be continuing cooperation as both the United States and Europe begin new missions. The following are some of the issues which will influence the development of that cooperation.

Closer Coordination and Collaboration in Planning and Conducting Space Science Efforts

The task of maximizing the scientific payoff from the resources available in the United States and Europe (and other countries) for space research is perhaps the key continuing issue in this area. The United States, ESA, and various European countries are all fully capable of undertaking major space science missions on their own, but with limited funds available on both sides of the Atlantic, there is a need to develop a coordinated approach to space science that recognizes the benefits of cooperation and the realities of competition. To date, it has primarily been government agency-to-government agency negotiations that have attempted to do this. There are regularly scheduled meetings between the heads of NASA and ESA and between the space science directors of those two agencies.

One of these NASA/ESA space science planning meetings occurred in June 1983, and the issues addressed exemplify the problems and potential of a coordinated approach to future space science undertakings.[27] Three areas of cooperation were discussed:

- infrared astronomy
- solar terrestrial research
- planetary exploration

In the first of these areas, in essence the United States and ESA "agreed to disagree." The issue under discussion was the next step beyond the highly successful U.S.-Dutch-British Infrared Astronomical Satellite (IRAS) launched in early 1983. Both the United States and ESA have developed future mission concepts, and the two approaches are not compatible. The meeting noted both "NASA's strong interest in collaborating to develop a single major international infrared space telescope facility" (presumably based on the U.S. mission concept) and "the firm commitment of ESA" to its mission. Recognizing that "the differences in orbit and launch vehicle restrict any major hardware collaboration," NASA and ESA agreed to coordinate the planning for the separate missions to maximize their complementarity and overall scientific return, but also for the time being abandoned any hope of a joint mission.

By contrast, an examination of the large number of missions under study in the United States, Europe, and Japan in the area of solar terrestrial physics identified "considerable merit in considering a joint . . . mission"; NASA and ESA established a working group, which will also include Japan, to "look for joint missions which can satisfy the main scientific requirements in a cost-effective way." Similarly, NASA and ESA agreed in the planetary exploration area "to identify mutually beneficial opportunities for cooperative missions." In particular, the two agencies are to study a joint Saturn-Titan probe mission for a 1992 launch. Planetary exploration is one of the areas of international scientific cooperation agreed on at the recent series of summit meetings and is also the focus of attention of a National Academy of Sciences/European Science Foundation working group. A cooperative Saturn-Titan mission, if feasible, would thus be politically as well as technically significant.

Another example of the benefits of a coordinated approach to mission planning in a particular area of science is found in U.S.-German interaction in x-ray astronomy. A large community of investigators has developed to use the data produced by NASA's High Energy

Astronomical Observatory. However, there would be a data gap of a number of years before the next mission in x-ray astronomy, were it not for the existence of a German project called *Roentgensatellit* (ROSAT). The United States and Germany in 1982 signed a Memorandum of Understanding for close collaboration in this mission, thus ensuring continuity in the field for U.S. as well as European scientists.[28]

There is a growing need for the United States, Europe, Japan, Canada, and perhaps eventually the Soviet Union and other space-capable states to work together in space science, from the early stages of developing a mission concept to the joint funding and conduct of various missions. Because of its dominant position in free-world space activities, the United States in the past has been largely able to shape such collaboration to its own objectives. This situation no longer obtains, and there could be a difficult period of adjustment for this country as the new reality of partnership among relative equals becomes the standard pattern. It may prove advantageous for NASA to engage the U.S. scientific community more intimately in developing its international programs; this could minimize international misunderstandings and perhaps blunt nonproductive and expensive competition. In space science, as in many other areas, the United States is adjusting to the recognition that it cannot be first in everything.

Involvement of Non-NASA Scientists in Shaping International Cooperation

"At present, ideas for joint international endeavors are primarily developed at formal meetings between representatives of the various governments. . . . There is a need for a more effective forum which would enable space scientists and managers to exchange ideas informally."[29] While NASA plans its science programs in close consultation with the external science community, including the Space Science Board (SSB) of the National Academy of Sciences, there is little tradition of SSB involvement in international space science matters. The National Academy of Sciences is the U.S. member in COSPAR, but that forum has little apparent influence on national space programs. Of course, informal interaction among space scientists in various countries interested in similar scientific problems is a major source of project proposals both in the United States and within Europe.

The nearest European equivalent to the SSB is the Space Science Committee (SSC) of the European Science Foundation. This committee has a small budget and has not developed close ties with the ESA. Nevertheless, the SSB and SSC have held joint workshops in 1976, 1978, and 1983, and there is some consideration being given to establishing standing SSB-SSC working groups in selected areas of space science.

In a separate development, at the initiative of the heads of the European Science Foundation and the National Academy of Sciences a joint SSB-SSC working group on planetary exploration has been established. The U.S. side of this group is composed mainly of individual scientists who are closely related to NASA's Solar System Exploration Committee.

All of these developments may represent initial steps in opening up the process of planning U.S.-European cooperation in space science to more structured participation of nongovernment scientists. As scientific competition among those working in space becomes increasingly international, such involvement may be required to reach agreement on how to coordinate or cooperate in research on major scientific problems.

Access for U.S. Experimenters to European Science Missions

If Europe is to approach parity in influencing the direction of progress in various areas of space science, there must also be a mutuality of opportunity for U.S. and European scientists to participate in the resulting activities. NASA has from the start opened its "Announcements of Opportunity" to all free-world scientists, but ESA and individual European countries have limited access to their scientific missions to European scientists, at least as principal investigators. This policy may have been defensible as a means of developing a European space science community, but NASA is now demanding reciprocity of access. Germany has already indicated its willingness to comply. For the ESA mission to Halley's Comet, *Giotto*, 9 of the 10 experiments have U.S. coinvestigators (a total of 33 individuals); ESA has agreed in principle to open up its future missions to U.S. principal investigators, and a NASA/ESA committee is now studying how best to implement that agreement.

Increasing Militarization of Space Activities

Space technology had its origin in military missile and satellite programs, and there has been continuing attention to ensuring that the international programs of NASA do not provide access to militarily sensitive technology. Now the major U.S. launch system is the space shuttle, which is a national capability used for NASA, DOD, and non-U.S. missions. In this context, "classified operations will be a necessity and are bound to lead to a more restrictive atmosphere, less conducive to international cooperation; tending to lead in the same direction . . . are developments in detector technology and in active atmospheric-magnetospheric experimentation."[30]

It is well beyond the scope of this paper to discuss the increasing military interest in various uses of space technology, but if the DOD budget for space, which is already larger than NASA's, continues to grow, there is likely to be an impact on international space activity. One possibility is increased international cooperation on defense applications of space among the United States and its NATO allies. Other areas of scientific collaboration have been able to coexist with military interest in the same scientific area and its underpinning technologies, and this duality has been present in space from the beginning; nevertheless, the changing context of space activity must be of concern to those interested in promoting open international cooperation in space science. In particular, several members of ESA are neutral states that could object to being involved in cooperative activities with the United States which had any hint of military overtones.

Impact of Space Shuttle on Scientific Cooperation

The space shuttle is an extremely capable launch system and short-term orbital platform. It offers scientists a much different environment than previously available in which to design and operate their experiments; there is even the chance to accompany them into orbit. Europe has recognized the shuttle's potential and is designing systems for its own and cooperative space activities which can only be used with the shuttle. These include Spacelab, of course, and an ESA-developed unmanned free-flying platform called *Eureca*, scheduled for a 1987 launch. As the shuttle, Spacelab, and other systems become more familiar to scientists, there will emerge innovative ways to take advantage of these new capabilities.

However, U.S. and European scientists will also share a common problem as they plan their missions for the Space Transportation System; because it is a manned system, the requirements for qualifying payloads to go aboard it and for supporting those payloads with documentation are both demanding and expensive, especially in comparison to similar requirements for unmanned launches. When European scientists began to plan for the use of Spacelab, for example, they "were really shocked by the requirements for testing and documentation and the associated cost of those requirements."[31] Europe is continuing to find it difficult to afford to use elements of the Spacelab system for its experiments; the result is that "continuous use of Spacelab by those who built and financed it is not likely."[32] Whether the shuttle will prove to be a crucial asset for those planning future science missions or a source of costs which limit the number of missions that are affordable is yet to be determined, but the impact of the shuttle is of crucial importance to U.S. and European space scientists alike.

Possible U.S.-European Collaboration on Space Station

Just as U.S.-European interaction over a European role in NASA's major post-Apollo programs has colored the whole of trans-Atlantic cooperation in space over the past decade, so may the outcome of the initial interactions over European participation in NASA's proposed space station program affect the overall prospects for European-U.S. collaboration over the next decade or more. This impact could have several dimensions. Europe has been following NASA's planning for the space station quite closely and has carried out parallel studies of options for European participation; in essence, NASA and ESA are already travelling together down a path that could lead to a major European role in an evolving station effort. This early and close involvement is quite different from what occurred in the post-Apollo period and signifies how closely the U.S. and European outlooks on space have become interwoven.

If, after this start, something intervened to make large-scale collaboration on station development impossible, there would certainly be a ripple effect on other areas of cooperation. On the other hand, a joint decision to move ahead with significant collaboration on the space station would cement the increasingly intimate relationship between the planning and conduct of U.S. and European space activities. While there would still be both economic competition and rivalry over scientific achievement, they would occur within a broader cooperative framework.

One rationale for developing a space station and associated infrastructure is to create a research facility in earth orbit. Just as the existence of the space shuttle and Spacelab will define the conditions for many space science missions in the coming decade, so would the availability of permanent orbital facilities condition the conduct of space science in the 1990s. Thus it is important to the space science community that any space station that is developed be a congenial base for its experiments, and pressure from U.S. and European space scientists will be important in ensuring that such is the case.

CONCLUSION

Kenneth Pedersen, current NASA Director of International Affairs, has commented that "international space cooperation is not a charitable enterprise; countries cooperate because they judge it in their interest to do so."[33] This observation can be extended to the level of individual space scientists; in the 25 years since scientific experiments in outer space became feasible, U.S. and European scientists have found it increasingly in their individual and mutual self-interests to carry out much of their activity on a cooperative basis. NASA's policies have encouraged and facilitated such cooperation; one result has been the nurturing of a vigorous space science community in Europe as well as in the United States.

That community today recognizes the high stakes involved in maintaining effective communication and cooperation across national borders; this appears the only way for space science to thrive. The simple missions have already been flown, resources for space science are scarce, and a coordinated approach to the planning, funding, and conduct of complex science missions makes eminent sense. New ways to allow space scientists to join with the government organizations through which they function in a collaborative enterprise of cosmic discovery may be needed, but in general the outlook for international space science in the coming decades is one of great promise and excitement.

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The U.S.-Japan Bilateral Science and Technology Relationship

A Personal Evaluation

Justin L. Bloom

THE QUESTION

Scientific and technological cooperation between the United States and Japan at the governmental level is probably more intensive and extensive than any other such relationship that the United States enjoys. It predates by several decades the present period of economic contention between the two nations and therefore cannot be attributed to some recently discovered perception of Japanese technical capability—assuming momentarily that the impetus for establishing cooperative agreements and programs has come primarily or exclusively from the American side. Now that Japan has achieved eminence as a leading purveyor of sophisticated consumer products in international markets, the question arises often at the political level as to whether governmental technical cooperation is needed any longer, or to cast the question in more negative terms, whether further cooperation is detrimental to American economic interests.

Similar questions have been raised repeatedly in years past concerning U.S. technical relationships with Communist nations, but with a strong undercurrent of strategic or military implications that is comprehensible even if not universally acceptable. Such considerations are not pertinent to the U.S.-Japan relationship and need not be considered here.

Also to be put aside is the kind of technical cooperation that is viewed correctly as more or less unilateral technical assistance to the less-developed nations. We then find that the U.S.-Japan bilateral relationship should be considered as being of the greatest importance of all to the United States if the principal criterion for international technical cooperation is that there is the prospect that the United States will receive roughly as much technical benefit as it provides. With this being said, an agreed means for determining the extent of reciprocity remains to be found. It is extremely doubtful that a comprehensive, objective formula for this purpose exists now or will be created in the future and therefore any evaluation of the U.S.-Japan relationship will be considered subjective or biased, depending on the degree of knowledge or experience—or upon the prejudices—of the observer.

My own involvement with affairs Japanese goes back to the mid-1960s, when as an official of the now-defunct Atomic Energy Commission I established contacts with Japanese scientists and engineers in the field of radioisotope applications. This resulted in a trip to Japan in 1966 and a determination to keep up with Japanese science and technology. During the 1973–1974 period, I represented the Department of State in negotiating a bilateral agreement with Japan on energy research and development, which culminated in another visit to Japan following the signing of the agreement by Secretary of State Kissinger and the Japanese Ambassador in Washington. Early in 1975 I was sent again to Japan as a member of a delegation conducting a "blue ribbon" review of the science and technology relationship under the direction of Ambassador T. Keith Glennan. Later that year, I was posted to Tokyo as the Counselor for Scientific and Technological Affairs in the American Embassy, where I served until the summer of 1981. While these credentials may appear fairly impressive, they are not by themselves sufficient, for two reasons. First, as is customary in State Department operations, Embassy officials were not routinely consulted in the development of policies toward the host country and I was not always privy to the formulation of U.S. science and technology policies or to the internal Washington debate about them. Second, during the 6 years that I spent in Japan, I was never afforded the opportunity to participate in or to observe any of the counterpart meetings or technical visitations that took place in the United States under the various cooperative agreements, so my observations are limited to a considerable extent to what took place in Japan.

With these general caveats in mind, let me examine the U.S.-Japan relationship in some depth, develop a number of impressions or conclusions, and let the chips fall where they may.

BIRTH OF THE BILATERAL TECHNICAL RELATIONSHIP

The use of formal governmental agreements to facilitate technical exchanges between the United States and other countries appears to be largely a post-World War II phenomenon. Certainly this is true as far as Japan is concerned. With the conclusion of the war, technical assistance to Japan began almost immediately as part of the reconstruction efforts of the U.S. occupation forces. Perhaps partly as a consequence of this, Japanese scientists and engineers who might formerly have turned to Europe to reestablish their international technical relationships began to interact more and more with Americans and to follow American rather than European developments. Furthermore, Europeans logically were more concerned with their own reconstruction than with what was happening in Japan. It is not necessary to elaborate on American assistance to the Japanese in such fields as public health, transportation, basic industry, and education, except to note that this took place and that a lasting and favorable impression was made on the Japanese.

However, there was one highly technical mode of cooperation that began immediately after the war that could have been the progenitor for all that followed. The creation of the Atomic Bomb Casualty Commission (ABCC) by executive order of the President in the fall of 1946 actually followed by about a year the formation of a joint commission (on October 12, 1945) to investigate the medical effects of the bombings of Hiroshima and Nagasaki. The joint commission was composed of American military scientists, who "had the willing and active assistance of Japanese scientists." In fact, Dr. Masao Tsuzuki of Tokyo Imperial University was designated one of the four chief scientists or medical officers of the commission, and dozens of Japanese physicians, medical students, pathologists, and other professionals provided their full cooperation. Thus, in the most traumatic period of Japan's history the victors and the vanquished were able to establish immediate and full collaboration in what was a grim but necessary task—one that both sides hoped would never be repeated.

The ABCC, a civilian organization funded by the Atomic Energy Commission, continued the vital work of documenting the effects of the nuclear explosions. It also was composed of both Japanese and American scientists, with as many as 50 American scientists being in residence in Japan at one time. By official agreement between the two countries, the ABCC was abolished in 1974 and was replaced by a binational organization, the Radiation Effects Research Foundation (RERF). The cost of operating the foundation, about $15 million per year, is shared equally by the two countries. Management is furnished by the National Academy of Sciences for the United States and by the Ministry of Health and Welfare for Japan.

ABCC and RERF form an interesting early case history, if not a model, of bilateral technical agreements between the United States and Japan. The research conducted has been exemplary in quality and objectivity, but organizational and administrative problems have plagued the program on occasion, and it has not been free of political issues either:

- Different management styles have had to be reconciled.
- Problems of obtaining funds on each side have caused some rancor.
- Antinuclear movements in Japan and in the United States have attacked the credibility of the research performed when the demonstrable effects of lower levels of radiation on humans have proven to be less than those postulated by some scientists outside the program.
- In one instance, the Japanese government insisted that a large computer needed for the Hiroshima laboratory be purchased from a Japanese concern, although the Japanese staff of the laboratory had concurred in the selection of an American computer.
- The Japanese populations at risk in Hiroshima and Nagasaki and cohorts of unexposed people (the controls) in the two cities reacted adversely when it was decided that free medical treatment and examinations would no longer be provided by ABCC (or RERF) clinics and the clinics were closed, although free medical care was continued in other nearby Japanese hospitals.

Notwithstanding the turmoil and the difficulties, RERF continues in operation, producing invaluable data. It is strange to me that this oldest and largest of all U.S.-Japan bilateral scientific programs, which was born out of war and has continued for almost 40 years in peace, is almost unknown outside of Japan. I do not even find this program listed in tabulations of agreements published by the Department of State, the Congress, or Japanese organizations. The reasons may be psychological, sociological, or political, although I cannot discount pure oversight or a simple matter of definition.

SOME OTHER TRIED AND TRUE AGREEMENTS

Atomic Energy

By my reckoning the next oldest bilateral agreement with heavy technological content is the *Agreement for Cooperation in the Civil Uses of Nuclear Energy*. This complicated document, which was first signed in 1958 and has been amended several times since, serves many purposes. By law, the United States must enter into such agreements with nations or groups of nations wishing to receive fissionable materials, nuclear reactors, and other nuclear materials and technology. Until 1954, transactions of this kind were prohibited, but the Atomic Energy Act of 1954 authorized international cooperation by the United States for the first time and specified in considerable detail how agreements for cooperation were to be the vehicles for such cooperation. Japan was the first individual nation to enter into an agreement with the United States, thereby setting a course in which it would rely almost completely on the transfer of American equipment, materials, and technology to establish one of the world's largest nuclear power programs. Except for one small nuclear power plant purchased from the United Kingdom and several research, test, or prototype power reactors built completely by indigenous means, all of Japan's 20-odd nuclear power plants are of American origin.

It can be argued that in this sense the nuclear agreement is not truly a scientific or technical one but rather a business arrangement. Perhaps this is true to some extent, since it authorizes only the transfer of technical information that is unclassified and hence in the public domain and actually is a restrictive document that heavily constrains certain aspects of Japanese nuclear development by unilateral U.S. rights of approval for prescribed undertakings. Nonetheless, Japan agreed to this course and was able to develop a nuclear power capability that places it among the world's leaders. The United States, on the other hand, obtained substantial economic and political benefits. Japan has paid hundreds of millions of dollars in license fees and procurement awards to American reactor manufacturers and equally large sums of money to the Atomic Energy Commission and its successor agencies for the purchase of nuclear fuel services (primarily the isotopic enrichment of uranium).

Within this mutually favorable business environment, Japan has been able to develop its own nuclear fuel cycle capability to the point where it could be independent of American sources of materials and technology if it wished. This often unstated objective is important to Japan—a country without sufficient natural resources to survive if it were to be cut off from other parts of the world by political or economic adversity. Contrary to the common view of Japan in the United States, Japan has made no effort to exploit its capacity for building nuclear power plants by seeking international markets in competition with the United States. While I have no evidence to support my view, I believe that a political decision at the highest levels in Tokyo decreed that this was not a field where Japan should take external economic advantage from the bilateral relationship. Of course this reticence could change in the future, and in fact there are signs that this is beginning to happen. However, the international market for nuclear power plants is not exactly thriving and competition is already severe.

The umbrella of cooperation afforded by the nuclear agreement has led in due course to major collaborative efforts between the two countries in nuclear research and development. In the fast breeder reactor field, an initial agreement was concluded in 1969 involving exchanges of scientists and engineers and joint funding of specific projects. The agreement was expanded and renewed for another 10-year period in 1979. Japan modeled its nuclear regulatory framework after that of the United States, and the two countries have conducted cooperative activities in nuclear safety work since 1973. With the formation of the Nuclear Regulatory Commission, separate agreements with that agency have formalized the cooperation, and Japan has invested heavily in the operation of American nuclear safety facilities such as the Power Burst Facility and the Loss of Fluid Test Facility. Many other business arrangements exist between the two nations at the commercial level in peripheral but important areas like the medical uses of radioisotopes, leading to useful interchanges of data and new products.

The restrictive aspects of the nuclear agreement, however, have been the cause of considerable political tension between the countries. These have to do with the application of U.S. policies designed to deter the proliferation of nuclear weapons. Although successive administrations in Washington have taken the uniform view that Japan is not a proliferation risk, there have been fears that if Japan were to be given favorable or special treatment, an unfortunate or even disastrous example would be set for other countries with less impeccable nonproliferation credentials. In the late 1960s, for example, the United States refused to permit the transfer of American technology to Japan for the reprocessing of spent fuel from nuclear power plants. Japan, in its perpetual search for independent capability, turned to France for the technology, and a reprocessing pilot plant was subsequently built by a French company at the Japanese nuclear complex near Tokai Mura. When the plant was ready to operate in 1977, the U.S. government refused to permit spent fuel from reactors of U.S. origin to be reprocessed in it, on the grounds—as stipulated in the bilateral agreement—that Japan could not demonstrate that safeguards to prevent the diversion of plutonium from the plant could be applied effectively. The ensuing political fracas caused a major strain in relations between the two nations. The strain still exists, albeit in diminished form.

From the American government's point of view at the time, reprocessing was unnecessary technically, was uneconomical, and—most of all—should be abandoned in the nonproliferation context. The American nuclear industry already had been enjoined from the use of reprocessing in the nuclear fuel cycle to set an example for the rest of the world. Japan should do likewise, it was postulated. The Japanese obviously held a different view. They pointed to their constitutional abandonment of acquiring a capability to manufacture nuclear weapons and to the fact that other American allies, i.e., France and the United Kingdom, were engaged in the reprocessing of spent fuel. They also mentioned that several hundred million dollars had been invested in the pilot plant and that the United States had not given early warning of its intentions. The issue was resolved more or less to the satisfaction of the parties by diplomatic compromise: the plant was permitted to operate for a limited duration and with a limited amount of spent fuel to permit the French company to demonstrate that its warrantee obligations had been discharged. In subsequent years the reprocessing of additional quantities of spent fuel has been agreed to, but Japan still does not have unencumbered use of its own plant.

As part of the Tokai Mura compromise, Japan agreed to two other conditions, one of which proved to be relatively salutary and the other contentious. It entered into a new agreement, given the acronym "TASTEX," to develop new safeguards techniques for reprocessing plants in a joint effort with the United States. Each side has been spending about $1 million per year on the program, which has been eminently successful. France and the International Atomic Energy Agency have been involved in this research as well. The other condition was that Japan not proceed with the construction of a full-scale commercial reprocessing plant without U.S. approval. That approval has not been given yet and is the subject of continuing negotiations.

Another example taken from the nuclear relationship demonstrates the conundrum facing the potential supplier of technology when the recipient is an advanced nation. The United States was in no position to offer uranium enrichment technology to Japan because this technology is classified and not available under the agreement for cooperation. Japan proceeded to develop an indigenous uranium enrichment capability without any assistance from foreign nations, thereby demonstrating that withholding the technology (on the grounds of national security or nonproliferation considerations) did little or nothing to impede progress. The same conundrum may well appear in matters involving purely industrial property with no national security implications.

My purpose in describing in relatively great detail the bilateral nuclear cooperation relationship is that it vividly portrays both the benefits and pitfalls of intergovernmental technical agreements. Both countries have received economic gains. Japan more than the United States has been the beneficiary of technical expertise and information, but the flow has not been unilateral. Politically, the United States may have shown itself to be strong to its own domestic constituency, but it has appeared to be overbearing in Japanese eyes and in the eyes of several other important countries. What is probably worse in political terms is that the United States has not been consistent in its nuclear policies; changes in administration can lead to fluctuations in the interpretation of technical agreements just as they do in political, military, or economic treaties, and other countries may develop worries about the need for or the value of formal technical agreements with us. This is especially true in the case of agreements that have real substance to them and have not been entered into for temporal political expediency or window-dressing. This point will become apparent again in the evaluation of other bilateral agreements with Japan.

Basic Science

Much has been said and written in the West about the inability of the Japanese to perform basic research. Many Japanese believe this as well. Some critics point to the relatively small number of Japanese scientists (four at this writing) who have been awarded the Nobel Prize. Others describe how fundamental discoveries in the United States or Europe have been exploited by Japanese industry without significant contributions to basic research. It may therefore come as something of a surprise to these critics to find that the first formal U.S. governmental agreement for cooperation in basic scientific research was executed with Japan more than 20 years ago—in December 1961. It was the result of a decision reached by President John F. Kennedy and Prime Minister Hayato Ikeda during their meetings held in Washington in June of that year. The joint communique that was issued on that occasion stated,

> The President and the Prime Minister also recognized the importance of broadening educational, cultural, and scientific exchanges between the two countries. They therefore agreed to form two United States-Japan committees, one to study expanded cultural and educational cooperation between the two countries, and the other to seek ways to strengthen scientific cooperation.

Responsibility for this charge soon passed from the committee of high-level scientists from each country that was formed initially to government science agencies—the National Science Foundation (NSF) for the United States and the Japan Society for the Promotion of Science (JSPS), an arm of the Ministry of Education, Science, and Culture.

As the scientific programs of both countries evolved and expanded in the succeeding years, a formal mechanism was established to carry out the seminars, joint research efforts, and information exchanges that both sides believed were important and mutually useful. Scientists in either country could suggest a cooperative venture to their counterparts in the other country, whom they usually knew through personal associations or by consultation of the technical literature. A joint proposal was then submitted to each governmental body for review. If mutually agreed, financial support to carry out the project was provided by each country. The volume of activity increased to such an extent that the NSF found it necessary to open an office in the American Embassy in Tokyo to administer its side of the arrangement. By 1982, about 1,250 American and Japanese scientists and engineers were part of the cooperative program, with the NSF and other participating U.S. government agencies spending almost $5 million per year to support the participation of the Americans. JSPS and its sister agencies were spending about half this amount. (The numbers cannot be compared directly for magnitude because of different accounting systems, labor costs, etc.) Obviously, these funds do not pay for all of the related research going on in each country.

The program is no longer limited solely to academic research and neither is it limited only to basic research. In fact, it is not even exclusively bilateral any longer; scientists and engineers from other advanced countries have been brought in on occasion when their expertise could contribute to a seminar or project.

With a firm base of cooperation established, it has been possible to expand the technical relationship into larger-scale projects, some of which bear mention here. As part of the International Phase of Ocean Drilling (IPOD), the NSF opened its ocean-bottom exploration program to international participation by permitting foreign scientists to join in the research conducted by use of the *Glomar Challenger*. Japan is one of four other nations to share in this unique project, and it contributes $1 million per year towards the cost of operating the ship.

Another joint project, also unique in its field, is going on at Japan's Tsukuba Science City. Under a separate agreement between the Ministries of Education and Construction and NSF, the largest facility in the world for subjecting structures to simulated ground motion due to earthquakes is in operation. Since full-size buildings, e.g., five-story reinforced concrete structures, are tested to ultimate destruction, the so-called "shake table" cannot be used for delivering stresses; instead, hydraulic rams apply loads at various points to the heavily instrumented building in a carefully prescribed manner. This facility is part of the Ministry of Construction's Building Research Institute complex at Tsukuba. NSF contributes about $2 million per year to the project and is permitted to have American engineers in residence. Just as the *Glomar Challenger* is unmatched among oceanographic vessels, the Tsukuba seismic testing laboratory has no equals, either in the United States or elsewhere. It is clear that the United States will gain invaluable data on the design of earthquake-resistant structures from its participation in the Japanese program. Incidentally, since this program does not directly involve JSPS, it is carried out under the aegis of another agreement for cooperation in the applied sciences and engineering described in the next section.

As I try to evaluate the importance and the efficacy of the cooperative science program, I recall the many scientists I have met who have participated directly in the program, the administrators with whom I have worked on a daily basis over several years, and the biennial conferences that set the future course of the program. I have never heard anyone question the program's validity. From the American side, the large majority of scientists have said that their contacts with Japanese counterparts had led to new knowledge and insights and that they considered themselves to be dealing with equals. Taking into account the breadth of the program—encompassing almost every aspect of the physical and biological sciences—this has to be an exceptional endorsement for an effort that is not free of encumbrances. Both verbal and written communications are difficult and time-consuming. The cost of cooperation is high because of the distance between the two countries. One side or the other occasionally gets snarled in bureaucratic red tape, and there is never enough money to do everything that is desired. Yet the program remains at the highest level of priority among those who are responsible for it in Tokyo and Washington.

As I pointed out at the very beginning, there are imponderables that should be assessed in addition to making judgments about the quality of the science. The establishment of social and cultural rapport among the intellectuals of the two countries is not to be sneered at, considering world tensions today. Americans are not famous for their understanding of other cultures, and this is especially true when it comes to Japan. The long-standing relationships that have developed through scientific cooperation have been particularly valuable in increasing awareness of the Japanese way of doing things and of Japanese sensitivities to American views of Japan. This kind of rationale is often employed to justify international cooperation. I am not doing so here, even though this may have been uppermost in the minds of those who formulated the agreement in the first instance. Rather, I am saying that it is a valuable benefit that has been derived from what is fundamentally a good technical program of roughly equal value to each of the participating countries, and a program that has withstood the test of time better than most.

Natural Resources Development

Another of the older but less well-known technical agreements between the United States and Japan has the formal title of United States-Japan Conference on the Development and Utilization of Natural Resources, or UJNR for short. It was born in 1964 as the offshoot of a standing bilateral cabinet-level committee on trade and economic affairs and was designed to augment the existing science agreement by studying more applied fields. The Department of State at the time did not wish to see the UJNR agreement take on the character of a major, continuing intergovernmental relationship such as already existed in the scientific, cultural, and economic areas, but with the passage of time the UJNR agreement acquired both the superficial and the substantive qualities of the other bilateral agreements. However, it did so almost in spite of an extraordinarily complex management scheme on both sides, since the nature of the program required that several government agencies or ministries be involved. Overall coordination for the United States was placed in the hands of the Department of the Interior, although I recall that at that time Interior had no congressional mandate to engage in international activities. The counterpart body in Japan was the Science and Technology Agency, which on paper is part of the Prime Minister's office.

The modus operandi agreed to was to create binational panels of experts to cover fields of study that were of mutual interest. Over the years the number of panels and their missions have changed, and Interior no longer plays an active management role. Coordination responsibility currently is split between the National Oceanic and Atmospheric Administration of the Department of Commerce (for activities connected with marine science and technology) and the Department of Agriculture (for all other fields). The Department of State has an ill-defined oversight responsibility that varies in its intensity and effectiveness. Seventeen panels are currently in existence, of which seven are in the marine area. The limitations of space preclude any comprehensive description of the various panels and their accomplishments, but in general it can be said that they have been devoted to subjects of a noncompetitive nature which contribute to the common good, with long-standing panels on the following subjects in the marine area:

- aquaculture
- diving physiology and technology
- electronics and communications
- facilities
- geology
- mining
- seabottom surveys

Outside the marine area, panels on the following subjects are in operation:

- earthquake prediction
- fire research
- forage germplasm exchange and evaluation
- forestry
- mycoplasmosis
- protein resources
- toxic microorganisms
- water research and technology
- wind and seismic effects
- conservation, recreation, and parks

The Japanese tend to take the UJNR program more seriously than we do. For example, a line-item budget for it exists in Tokyo, whereas the Americans search for funds from other programs to carry out their obligations. The panels usually meet once a year, alternatively in each country, to deliver papers and to make site visits. Each 5 years, the results of the UJNR collaboration are published in a comprehensive report, but interim reports are also disseminated to provide more timely information.

Having attended many UJNR panel meetings and administrative conferences in Japan, I have been struck by the enthusiasm displayed by the participants, many of whom have been involved in UJNR activities for a decade or more. This is not to say that the program is free of problems. New panels are difficult to create because of funding limitations. Old panels that have outlived their optimum usefulness are difficult to abandon, for fear that they will be considered unsuccessful by outsiders and therefore will reflect adversely on the participants. With so many disparate panels in operation, they cannot all be of equal quality or return equal benefits to either side, so in Washington, particularly, officials who monitor the UJNR program but who are not part of it are continually looking for ways to reduce its extent. The United States far more than Japan has sought to bring in panel members from industry and the academic world. The Japanese prefer to limit participation to representatives of those government ministries responsible for the various UJNR programs. Even with these strains, the program has survived and thrived to a reasonable degree.

My own evaluation of the UJNR program is favorable. It operates at minimum cost to the United States and is carried along by the enthusiasm of its participants. The transfer of proprietary industrial technology is not involved. In several of the panels, we have gained far more from the Japanese experience than we gave up, and the information we obtained is of great value in terms of public benefit. In contrast to any number of other international or bilateral technical programs, documentation of the results of the cooperation is extensive and available to anyone who asks. As in so many international technical programs, more fault can be found in the failure of the technical community at large to keep abreast of and to apply the accomplishments made than in the nature of the programs themselves.

The Various Medical Science Agreements

Early in this paper I described how the United States and Japan formed an important—perhaps vital—initial link in scientific cooperation through the medical evaluation of survivors of the wartime nuclear explosions over Japan. In subsequent years, cooperation in the medical sciences was extended much further. The basic science agreement provided a vehicle for collaborative biomedical research at low cost to the parties, and the National Institutes of Health (NIH) began to support worthy research projects in Japanese academic institutions that were selected competitively for their quality. Also, NIH awarded research and training fellowships to competent Japanese scientists for study within its various institutes. I believe that the number of Japanese participating in this program exceeds that from any other foreign country. Apparently this is a sore point with some in Washington who either believe that the Japanese can pay their own way or who consider the international collaboration as permitting Japan to acquire advanced medical technology without adequate compensation to the United States. The argument is raised that few if any American medical scientists study or perform research in Japan. This is undoubtedly true (outside of the RERF), but it fails to recognize that there is no significant number of American scientists competent in the Japanese language and willing to live in Japan under the same conditions as the Japanese.

The largest new effort began in 1965, as called for in a joint communique issued by President Johnson and Prime Minister Sato. In typical fashion, prominent medical scientists from the two countries met later that year to plan a comprehensive program, and panels were established to exchange information and scientists in fields covering diseases endemic to Asia. Structurally, the new venture—called the Cooperative Medical Sciences Program—was similar to the UJNR program, but it differed in one major respect: Significant amounts of money were committed by each side from the very beginning, and the commitment has continued ever since. Today about $12 million per year is invested by NIH for the United States and an equal sum by the Ministry of Health and Welfare for Japan. Originally, the panels studied specific diseases or medical problems:

- cholera
- leprosy
- malnutrition
- parasitic diseases (schistosomiasis and filariasis)
- tuberculosis
- viral diseases (rabies, dengue fever, and other arboviral diseases)
- environmental mutagenesis and carcinogenesis
- viral hepatitis

Significant advances have been made in the joint program on each of these subjects, and the results have been communicated to the World Health Organization, regional health organizations, and individual countries throughout the world. Recently, the program has been reoriented to study the various medical disciplines associated with infectious diseases, such as microbiology, immunology, and bacteriology, primarily because of the success achieved in alleviation of the diseases on the original list. It should be noted that there was little if any "selfish" motivation on the part of either the United States or Japan in the conduct of this program. Initially, its greatest impact was felt largely elsewhere: in Africa, Southeast Asia, and parts of Latin America, where some of the diseases that have been studied are truly epidemic. Today, the program's results are applicable to the developed world as well.

For what I assume were probably organizational reasons, a separate bilateral agreement, in the form of a Memorandum of Understanding between the National Cancer Institute of NIH and JSPS, was signed in

1974 to cover cooperation on cancer research. The significance of this in a bureaucratic sense was that most cancer research in Japan was being carried out in academic institutions under the purview of the Ministry of Education (and thus of JSPS), although Japan's National Cancer Center is part of the Ministry of Health and Welfare. Likewise, on the American side, most of NIH's involvement in the medical science agreement had been through the National Institute of Allergy and Infectious Diseases. It was probably easier on both sides to create a new vehicle for cancer research than to sort a tangle of interagency or interinstitute responsibilities. Japanese ministries and agencies are particularly susceptible to this syndrome, being very jealous of their prerogatives, responsibilities, and funds. In fact, a general observation can be made in this respect: while the skirts of the U.S. government are not immaculately clean regarding interagency cooperation, the situation is much worse in Japan. It sometimes takes heroic measures to involve more than one Japanese ministry in a cooperative program. Using the cancer research agreement as an example, the American side had to apply considerable pressure to ensure involvement of scientists from the Ministry of Health and Welfare. At least this was accomplished. In other agreements lateral cooperation was difficult or unattainable.

While the cooperative cancer program is less than 10 years old, it also has been making first-class contributions to this most difficult of medical research fields. Japanese oncologists are excellent; most of them have trained abroad and speak fluent English, making cooperation that much easier. An additional driving force for cooperation comes from the fact that the epidemiology of certain forms of cancer, such as stomach or breast cancer, is different in Japan than in the United States. Whether the difference is racial, environmental, or due to unknown causal factors such as dietary peculiarities could lead to a better understanding of the disease and to its ultimate cure. I should note almost parenthetically that in my personal observation of panel meetings held under the cancer agreement, I found that the interaction of the scientists was the best for all the agreements: vigorous technical debates entirely in English, close personal associations that had developed through mutual professional respect, and a degree of informality that accelerated the interchange. The two countries each invest about $300,000 per year in cooperative activities concerning chemical carcinogenesis, cancer therapy, cancer virology, cancer immunology, lung cancer, breast cancer, bladder cancer, high-LET (linear energy transfer) radiation treatment, cytology, and metastasis. It's money well spent.

Separate and smaller programs also exist in the medical field covering vision research and shellfish sanitation, the latter being under the jurisdiction of the U.S. Food and Drug Administration (FDA). FDA also maintains continuous liaison with its counterparts in the Ministry of Health and Welfare on the regulation of food products, pharmaceuticals, biologicals, and medical devices.

Environmental Protection

Japan largely ignored the protection of its environment during its early postwar reindustrialization period and suffered the consequences accordingly. By the late 1960s, its largest cities were blanketed in almost intolerable smog, there had been serious outbreaks of mercury poisoning (given the name Minamata Disease for the city where the largest number of cases occurred), cadmium poisoning, widespread dispersal of polychlorinated biphenyls (PCBs), and many other environmental insults. Roughly in parallel with the growth of the environmental movement in the United States, Japan set about to correct its course with characteristic determination, establishing an independent Environment Agency in 1971. By 1975 it was clear that the United States and Japan among the large countries of the world were committing the most in terms of both financial and intellectual investment to environmental protection.

In that year still another agreement was entered into between the two countries to formalize cooperation in the environmental field that was already taking place, although one could argue that the existing UJNR agreement might have served the same purpose—including as it did already some environment-related panels. Nonetheless, the new agreement was immediately put into effect and it has proved to be one of the most productive in terms of facilitating the transfer of useful technology, environmental statistics, and analytical techniques. It also makes use of panels of specialists to carry out its work. Panels on the following subjects are now in operation:

- sewage treatment technology
- solid waste management
- management of contained bottom sediments
- air pollution-related meteorology
- photochemical air pollution
- stationary source pollution control technology
- automobile pollution control
- environmental impact assessment

- technology for closed systemization of industrial waste liquid treatment
- identification and control of toxic substances
- environmental economics and incentives for pollution control
- water conservation and flow reduction
- controls in water quality
- food additives

Of course the respective environmental protection agencies of the two countries provide the overall coordination and most of the activity under the agreement, but also a relatively large number of other governmental bodies are involved from each side. The reason why this is possible here and not in other agreements seems to be that the Environment Agency in Japan is a policymaking body and does not have the large operational and research role of the Environmental Protection Agency (EPA). Also, it is far smaller, both in manpower and in financial resources, and therefore must rely on other ministries to carry out Japan's environmental mission.

Not all of the environmental panels are equally effective. Efforts by the United States to raise environment-connected trade issues in the context of panel deliberations have been rejected by the Japanese as being outside the scope of the agreement. The Japanese have had difficulty in adopting either the principle or the practice of environmental impact assessment, even though the Environment Agency in Tokyo wants very much to use the American approach. The management problems endured by EPA during the first part of the current administration and that administration's policy of reducing government regulation of environmental protection have interfered with EPA's international affairs program and specifically with the execution of the agreement with Japan. Still, most of the panels have been able to continue their work.

According to the U.S. program managers, the agreement has enabled the United States to acquire a great amount of Japan's sophisticated technology for sewage treatment, solid waste management, and stationary source pollution control. To give only one example, Japanese steel plants have the best environmental controls in the world, particularly for air pollution. It was possible to arrange through the auspices of the agreement for experts from the U.S. steel industry to make exhaustive surveys of steel plant operations in Japan to facilitate acquisition of the technology by American companies. My recollection is that the American companies were not very willing to use the technology, but at least it was available.

My guess is that with the advent of a new administrator at EPA who has a more positive attitude toward governmental intervention to protect the environment, new life will be breathed into the U.S.-Japan agreement.

Miscellany: Transportation, Space, Building Technology, and Urban Affairs

There are three more agreements that have been effective to varying degrees. In fact, two of them are of significant financial importance. I need not dwell on each of them at length, but there are lessons to be learned from them.

As in the case of the UJNR agreement, a periodic meeting of the standing U.S.-Japan Committee on Trade and Economic Affairs held in 1969 concluded that a bilateral technical relationship in the field of transportation was needed and a Transportation Research Panel was established promptly. The U.S. Department of Transportation and the Japanese Ministry of Transport manage and administer this relationship in an informal but productive manner, eliciting almost no public attention. Yearly (sometimes longer if travel funds are limited) visitations of a delegation of experts from one country to the other are made, with the host country alternating each time. A large number of technical subjects concerning surface transportation problems have been studied. Since Japan is the leading country of the world in marine transport technology and relies much more heavily than the United States on public ground transportation, the relationship has tended to benefit the United States more than Japan.

One driving force on the Japanese side for maintaining the exchange has been a feeling of obligation to the United States because we expended considerable efforts after the end of World War II to restore the almost totally destroyed Japanese railway system. One particular manifestation of this feeling was the offer made by Japan National Railways to give its most advanced railway technology to the United States free of charge. The Northeast Corridor Project of the Federal Railroad Administration has been the beneficiary of this offer; it has been given the equivalent of tens of millions of dollars of high-speed train technology. The offer grew out of the excellent technical relationships that had developed through the Transportation Research Panel. While no Shinkansen ("Bullet Train") will actually run along the Northeast Corridor route, substantial improvements in signals, dispatching, roadbed maintenance, and similar technical aspects have been incorporated. Likewise, the high-speed train project being planned as a private venture for passengers carried between Los Angeles and San Diego is an outgrowth of this long-standing technical cooperation. I should note, however, that there were officials in the Department of Transportation who viewed the Japanese offer with suspicion, and who finally agreed to accept the offer only with great reluctance. The NIH Syndrome is not dead.

Considerable sensitivity is attached to our cooperation with Japan on space technology. Perhaps the word "cooperation" is wrong to begin with, because the relationship is much more a unilateral transfer of American hardware and know-how to Japan through industrial contractors than it is anything else. Nonetheless, the importance of the relationship cannot be understated. Japan is the only nation in the world that has been authorized to receive American space technology at the level that I shall describe. U.S. law (the Munitions Control Act, in particular) requires government approval for the transfer of hardware and know-how to be used in launch vehicles capable of delivering missiles, and there is no question but that Japan has been given special treatment in this regard. A succession of exchanges of diplomatic notes in 1969, 1976, and 1980 has permitted the Japanese government through its industrial contractors to purchase launch vehicle technology and satellites from counterpart American companies. As might be expected, there are some strings attached:

- Only unclassified information may be transferred.
- The information or hardware received by Japan may be used only for peaceful purposes.
- Equipment and technology transferred to Japan may not be retransferred to a third country without U.S. approval.
- Japan may not launch a satellite for a third country without U.S. approval, if U.S. technology or hardware is employed.
- Launch vehicle technology is limited to the level of the Thor Delta vehicle.
- Communications satellites launched by Japan as the result of U.S. assistance must be employed in a manner compatible with the International Telecommunications Satellite Organization (INTELSAT) international agreement.
- If Japan wishes to launch a satellite that exceeds the capacity of its launch vehicle (currently 550 kilograms into geostationary orbit), Japan will employ the U.S. Space Transportation System (the Space Shuttle), provided that the conditions of launch and costs are reasonable.

It is clear that Japan entered into this arrangement to free itself from being completely dependent upon other nations for launch and satellite services. While this approach cost Japan a great deal of money, it would have been much more expensive and time-consuming to develop a wholly indigenous space capability. On the other hand, some have argued—both in Japan and elsewhere—that the whole effort was unnecessary and that Japan could always have obtained what it needed when it was needed from the United States or another advanced nation.

While the Japanese space program has been controversial, it also has been successful. Communications, direct TV broadcast, and communications satellite technology have been purchased and absorbed from the United States, and Japanese aerospace companies are now able to design and construct these kinds of satellites and others as well with little if any foreign support. The Japanese launch vehicle has progressed through several phases of improvement with a remarkable test history of zero failures, although one or more satellites have been lost for other reasons.

Japan's space applications program continues to receive heavy funding (about $500 million per year) and is second only to the atomic energy program among all scientific and technical ventures. Yet Japan spends only about $50 million per year on space sciences. One reason for this disparity is that the latter program is the responsibility of the Ministry of Education, which considers $50 million to be an extraordinarily large amount of money. The space applications program falls under the Science and Technology Agency, which also manages atomic energy development and is accustomed to large expenditures. To demonstrate once again how vertical integration within Japanese government ministries tends to increase inefficiency, the space sciences program has included the development of its own launch vehicle and dedicated launch site. There is increasing talk in Japan about merging the science and applications programs into one, with consequent monetary savings, but whether this will truly happen is unclear. The current small size of the science effort has inhibited extensive cooperation with the United States in what could otherwise be a natural joining of interests. Another agreement covers cooperation in the space sciences and it will be discussed later.

A 1970 Memorandum of Understanding (MOU) between the U.S. Department of Housing and Urban Development (HUD) and the Japanese Ministry of Construction addresses cooperation in building technology and urban affairs. Sporadic visits and exchanges of documents have taken place under this MOU, but most of the activity concerning building technology occurs within the UJNR agreement. I personally have not participated in or observed the HUD program with Japan and am unable to make any further comment.

RECENT "PROBLEM" AGREEMENTS

The last two agreements that I intend to discuss are related in political terms, are the most recent to be enacted, and are the most difficult to evaluate. One is concerned with energy research and development (R&D) and the other is intended to be a broad-ranging vehicle for cooperation in science and technology. Both have had major problems in negotiation and execution, and they may therefore be unusually valuable in providing guidance for general approaches to technical cooperation.

In the flush of enthusiasm—and funds—for nonnuclear energy R&D that followed the oil shock of 1973, the United States concluded its first international bilateral agreement in this field in 1974. It was with Japan, as had been the case so often previously, but there was a major difference on the Japanese side. The instrumentality chosen by Japan was its Ministry of International Trade and Industry (MITI). Prior to that time, energy R&D had been the province of the Science and Technology Agency, but with the oil shock came the formation of a new agency—the Agency for Natural Resources and Energy—within MITI, and this agency was given responsibility for developing alternative energy sources in conjunction with its sister organization, the Agency of Industrial Science and Technology. I managed the negotiation of the agreement for the United States, and it covered the gamut of new and renewable energy sources: geothermal, solar, synthetic fuels from coal, and so forth. It also covered the development of a variety of energy conservation measures.

The agreement proved to be an absolute failure. Almost nothing was accomplished over the next 5 years, although no subject was more important in the public eyes of both countries. I attribute the failure mostly to a mismatch in the size of the energy R&D programs of Japan and the United States. Most of Japan's funds were going toward nuclear energy, while the United States was turning away from this source and was increasing spending on other sources at a staggering rate. I am still at a loss to explain why Japan did not increase its funding of alternative energy source development, considering that it was and is almost totally dependent on foreign energy supplies. Despite repeated efforts by the United States to get a real program going with Japan, nothing of consequence happened.

In 1978 the most unusual event in the entire history of our bilateral technical relationship took place. Prime Minister Fukuda went to Washington and proposed to President Carter that the two nations embark on a long-range, billion-dollar program to develop controlled thermonuclear fusion and photosynthesis as alternative energy sources. All previous agreements had been at the initiative of the United States, as far as I can ascertain. The "Fukuda Initiative" took Washington more or less unawares. After much internal debate, a counterproposal was made: The United States would enter into cooperation on fusion and photosynthesis if Japan would agree to invest in our rapidly expanding coal conversion program. Now it was the Japanese side that underwent the throes of internal debate, finally acceding to the American approach.

A new energy R&D agreement was signed by Secretary of Energy Schlesinger and Foreign Minister Sonoda in 1979. However, the United States did not offer up its first-line fusion program for cooperation but instead persuaded Japan to invest manpower and money in a smaller fusion system also under development. In due course, Japan (and also the Federal Republic of Germany) entered into a contract to furnish 25 percent of the cost of development of the American SRC II process for converting coal to synthetic crude oil. Photosynthesis was relegated to a minor position in the scheme of things. The new agreement also provided for cooperation in geothermal energy and—strangely—high-energy physics. Every scientist knows that high-energy physics has nothing to do with energy as a resource!

Once it had signed the agreement, the Japanese government set about to honor its commitment and succeeded in persuading its ministries and its energy industry to allocate several hundred million dollars over a 10-year period to the SRC II project. A contract was also executed to provide about $70 million over a 5-year period to the fusion project, and the Japanese ultimately committed themselves to further expenditures of several million dollars per year on other fusion-related projects in the United States.

After the 1980 presidential elections, however, the new administration in Washington canceled the SRC II project and the Japanese were left high and dry. Germany had already signaled its intention of withdrawing from the project. The Japanese should have resigned themselves to this turn of events and should have been thankful that they were thereby spared a potentially risky investment that was surpassed in magnitude only by the atomic energy and space programs. However, the government had lost face and recriminations abounded. The "SRC II Shock" joined the "Tokai Mura Shock" and the "Soybean Shock" as examples of American "untrustworthiness." Investment by Japan of about $6 or $7 million per year in American high-energy physics projects appears to be protected, since high-energy physics enjoys a high priority in the current administration—even if it does not contribute to expansion of our energy resources.

The Carter administration sensed that the Japanese might be amenable to making further investments in U.S. R&D projects, since Japan by this time appeared to be using these investments and other contributions to American academic and cultural institutions as a way of improving Japan's image in the United States. Certainly, the American public's perception of Japan had taken a turn for the worse because of the heavy inroads made by Japanese sales of consumer products and the tirades made by segments of American industry against what appeared to be Japanese reluctance to relax barriers against importation of American products. While the attempt to ameliorate the trade issue by gifts, contributions, and investments was characteristic of Japanese domestic practice, I doubt that it had the desired effect among either high-level officials or the public at large.

In any event, the new S&T agreement was formally proposed by President Carter and ultimately was signed by him and Prime Minister Ohira in May 1980. It was the first of the many bilateral technical agreements to be literally signed by the respective heads of state of the two nations. From the U.S. point of view the agreement was intended to subsume or absorb most of the other existing agreements, but the Japanese resisted this. Such an action would have disrupted all of the administrative arrangements that had been built up over the years and would have made the agreement too cumbersome to manage effectively.

The Office of Science and Technology Policy (OSTP) in the White House is responsible for overall coordination of American involvement in the agreement. The Foreign Ministry has had to assume this responsibility for Japan since there is no bureaucratic equivalent to OSTP there. Initially, almost all of the projects proposed for execution under the agreement came from U.S. agencies, but following the signing, a few counterproposals have been generated by Japanese research entities. To my knowledge there is no intention of spending significant amounts of U.S. funds in Japan, although the Japanese are expected to provide funds for expenditure in the United States. If this unbalanced arrangement persists, those in Washington who believed that Japan "owed" the United States for the free scientific information it received over the years and should provide compensation through support of American research will have found some satisfaction. I personally find this argument highly tenuous. It has not been directed toward other advanced nations counted among our friends and allies. It rejects the more commonly held view that scientific and technical information in the public domain is available to anyone who wishes to make use of it, and it fails to recognize that we ourselves borrowed much of the same kind of information from others as we grew to be the world's leading economic power.

The agreement is now over 3 years old, and all parties would agree, I believe, that not very much has been accomplished beyond the exchange of correspondence and technical delegations and the creation of a number of relatively small joint projects. The language of the agreement hints at the prospect of joint undertakings that would result in the development of proprietary information, but the projects under discussion or in effect seem to be more like those covered in the UJNR, Cooperative Science, Environment, and Medical Sciences agreements.

There are some exceptions to this general conclusion, particularly in the field of space sciences. Prior to the signing of the S&T agreement, negotiations already had been concluded between the National Aeronautics and Space Administration (NASA) and the Institute of Space and Aeronautical Sciences (ISAS) in Tokyo to embark on a new effort in space exploration. Cooperation in this field was already well established with Europe, but the small size of the Japanese program had made it difficult for NASA to expect much from Japan. Further cooperation in the space sciences was subsumed under the new S&T agreement and 17 projects are at various stages of activity, now involving a number of Japanese agencies besides ISAS.

I am not sanguine about prospects for the long-term success of the science and technology agreement. The fact that 3 years have passed without much in the way of accomplishment indicates that the Japanese are giving lip service to it at worst and a low priority at best. Our side may have the same attitude. Ordinarily, the Japanese require about 1 year to prepare for international cooperation, this being the time to make budget proposals and to obtain appropriations from the Ministry of Finance and the Diet. The hiatus does not surprise me. The agreement was not entered into enthusiastically by the Japanese, and there was not even much enthusiasm exhibited by the U.S. agencies when the White House directed that they prepare proposals for technical cooperation. On the U.S. side there is no budget specifically allotted to the agreement, meaning that agencies must take funds from existing programs—an approach sure to meet with resistance. Besides the anomaly of the bias toward conducting joint research only in the United States, there is another peculiarity: the NSF, which after all sponsors most of the advanced research in the United States that is not connected with the military or the energy sectors, has no new programs under the agreement. I suppose this is because the basic science agreement with Japan is considered sufficient for the NSF's purposes. However, that same argument could have been applied to all of the other agencies and their respective agreements as well, with the exception of NASA.

Other external factors have appeared during the past 3 years that do not bode well for the S&T agreement in particular and the gamut of agreements generally. The growth of protectionist sentiments in the United States has cooled the ardor of some Washington agencies and their civilian contractors to participate in cooperative albeit public service relationships with Japanese agencies. At the political level, the motivation for cooperation has changed to some extent from encouraging Japanese investment in U.S. research to trying to learn more about the course of Japanese progress in advanced industrial technology. Thus one of the objectives of a newly formed U.S.-Japan Work Group on High Technology Industries, arranged by the Department of Commerce with MITI, is to conduct joint R&D on semiconductors, computers, telecommunications, and aerospace. There may be a semantic problem here in that R&D in this context may mean something like examination of future markets in the fields cited, but intergovernmental cooperation in highly competitive, commercial technologies is unlikely to be successful.

FURTHER INFERENCES, OBSERVATIONS, AND CONCLUSIONS

The mere complexity of the U.S.-Japan technical interaction indicates that it is not the result of some grand design. While it may have originated in the traditional American desire to help the vanquished or less fortunate, it has grown in many directions and for many different purposes. The Japanese have been willing partners in most instances, once an agreement has been concluded, but more rarely have they been the initiators of cooperation. Japan, on the other hand, takes a more formal view of cooperative relationships once they are in effect, budgeting for them and considering the terms as more or less obligatory.

Much of the success of the various bilateral agreements I have described can be attributed to the enthusiasm and determination of the participants. When there have been strong project leaders on each side, the projects have thrived. We tend to forget that governments can arrange and facilitate international cooperation, but it must be carried out by working scientists and engineers. Likewise, the success or failure of cooperation is best measured by those conducting it, although no rigorous scheme exists for this purpose. If anecdotal information has any value, the U.S.-Japan relation has been phenomenally successful when taken in large segments or as a whole. No one has been able to suggest a better way of accomplishing the same objectives, assuming that restraints on manpower and funds were to continue to be as stringent as they have been.

The disparity in size of some related programs in the two countries has caused difficulties, particularly when the Japanese effort is much smaller than that of the United States. Typically, Japan has been slow to move into new areas of science and technology, but once started progresses at a rapid pace to "catch up."

If research and development related to defense, energy, and space is not included, the Japanese government is a much heavier investor in industrial R&D than is the United States, although this picture probably will change on both sides. That is, I expect that Japanese government investment in defense research will increase and that the U.S. government will follow the lead of Japan and the European countries by increasing its financial support of industrial research. There is no good counterpart in the United States for the many industrial research institutes operated by the Japanese government, with the exception of the National Bureau of Standards (NBS). (By my own definition I do not include the U.S. national laboratories or the NASA research centers as being engaged in industrial research.) Therefore, for the time being I do not see much potential for collaboration at the governmental level in industrial R&D, even when it is conducted in noncompetitive terms. For example, Japan has proposed international cooperation on the development of a "Fifth Generation" computer, but it is not clear which entity in the U.S.—government, industry, or academia—might be a logical participant. In fact, it is uncertain whether any U.S. involvement whatsoever will occur, since there are great pressures here to undertake even the early phases of the development of this computer on a proprietary basis solely within the United States. The British already have made this determination.

I must now reverse my field and contradict myself to an extent by pointing out that NBS has signed an agreement with Nippon Telegraph and Telephone Public Corporation (NTT) to exchange information on computer science and microelectronics. While no joint research is contemplated, the parties seem to be intent on keeping each other up to date on the latest advances in these fields. In this case, there is a heavy disparity in size and mission in favor of the Japanese organization. If this relationship should prove to be successful, it could be the harbinger for other ventures—but limited as I have noted by the lack of counterpart government organizations in the United States.

While Japan is just entering the world of "big science" with first-class basic research facilities in such fields as high-energy physics, space exploration, and radioastronomy, it already has the best facilities in the world for conducting engineering research related to the public sector. For budget and manpower reasons, these facilities are underutilized. It would be quite natural to open them up to international collaboration, but the Japanese do not believe that foreigners would be willing to live in Japan in Japanese housing, to eat Japanese food, and to learn their language. They may be right, but there has not been an adequate test yet.

THE RELATIONSHIP AS A MODEL

While there are many lessons that have been learned and are still to be learned from the elaborate relationship between the United States and Japan that can be applied to other countries, I doubt very much that it can be duplicated. The conditions that led to the current level of cooperation probably were unique, and I see no other country at present that appears to qualify. Superficially, I might be tempted to suggest that the European Community would be a likely target, but the Community is a single entity in name only, and technical cooperation suffers as soon as the number of parties becomes more than two or three. The United States embarked on a huge program of scientific and technical cooperation with the Soviet Union during the period of detente, only to dismantle it when political relations worsened. China is receiving more attention now from us than any other country, but China is also a totalitarian state and has the additional burden of being at least a decade behind the United States in most technical fields. Other members of this workshop, through their more acute insight into the situations obtaining elsewhere, may see something that I am missing, but for the moment the Japan Connection seems to stand by itself.

The U.S.-Israel Binational Science Foundation

Max Hellmann

HISTORY

The U.S.-Israel Binational Science Foundation (BSF) was established in 1972 by a formal treaty between the two governments. The main impetus for its creation was the rapid depletion in Israel of U.S.-owned excess foreign currency generated from the repayment in local currency of U.S. loans for the purchase of agricultural products. As authorized under P.L. 480, these funds had been used by the U.S. government for a variety of local purchases, including the support of scientific research performed in Israel. From 1958 to 1972 the U.S. government, through various scientific and technological agencies, had invested about $70 million in research projects conducted by Israeli scientists at Israeli institutions. A major share of this support went to research projects in agriculture, medicine, and the life sciences.

When it became clear that Israel would soon be removed from the list of "excess currency" countries and thus would no longer be eligible for P.L. 480 funds, the two governments searched for ways to assure the continuation of the very successful scientific cooperation between the two countries. This resulted in the creation of the U.S.-Israel Binational Science Foundation and the establishment of an endowment fund. The U.S. contribution to this fund was the equivalent of $30 million in Israeli currency, which was matched by an equal amount provided by the Israeli government for a total of $60 million (equivalent to 252 million Israeli pounds at that time). Furthermore, the two governments agreed to an annual interest rate of 3.5 percent to be paid on a quarterly basis by the Israeli government and to be adjusted annually for inflation. Subsequently, the interest rate was increased to 4 percent, and the frequency of adjustments for inflation was changed first to a semiannual and later to a quarterly basis. The annual income from the endowment constitutes the operating fund of the foundation.

ORGANIZATION

A Board of Governors was established to set the policies of the foundation and to oversee its operation. This board consists of 10 members, 5 from Israel and 5 from the United States, appointed by the respective governments. Israeli members are usually appointed to represent specific ministries or organizations (e.g., ministries of Finance, Health, Agriculture, Science, and the Israel Academy of Science and Humanities), whereas on the U.S. side only the Department of State retains a permanent membership. Other U.S. board members have come from government as well as academia and the private sector. The National Science Foundation (NSF) has been represented on the board since BSF's establishment. Furthermore, NSF, through its Division of International Programs, disseminates information on BSF in the United States and provides other liaison services.

The functions of the board are to establish policies with regard to the scope and management of the foundation's program, recommend the allocation of funds to various research areas, and approve budgets and annual funding plans. The full board meets once a year in Jerusalem; its Executive Committee meets annually in Washington about 4 months prior to that meeting. The foundation's offices are located in Jerusalem. Its business is conducted by a small staff headed by an executive director. Currently, the permanent staff consists of four senior professionals and five administrative and secretarial employees. This core staff is supplemented by a larger number of part-time advisers and consultants who assist with legal and financial, as well as scientific, aspects of the operation. At the time of the establishment, it was agreed that the executive director should be an Israeli and his deputy an American. Other staff members can be Israelis or Americans.

OPERATION

The BSF conducts a program of awarding research grants similar to those programs conducted by the NSF and the NIH in the United States.

Initially, the research areas supported included agriculture, medical and biological sciences, physical sciences and mathematics, and selected areas of interdisciplinary research, such as energy, environment, oceanography, etc. With the establishment of the U.S.-Israel Binational Agricultural Research and Development (BARD) Foundation in 1978, BSF support for agricultural research was phased out. However, since 1979, social sciences (sociology, anthropology, and psychology) are included among the areas eligible for support. All applications submitted to BSF must involve active collaboration between Israeli and U.S. scientists even though the major part of the research is usually performed in Israel. This collaboration may range from consultation and exchange of data and samples to side-by-side collaboration in the same laboratory.

Selection criteria for awards include:

- scientific merit
- strength of the collaborative arrangements
- interest expressed by both governments in the research topic

The scientific merit of each proposal is determined through the traditional peer review process with the unique feature that this procedure is "binational" as well. Normally, proposals are sent for review to equal numbers of Israeli and U.S. scientists. Since the BSF senior staff is small and has only limited expertise in a few research areas, assistance in the review and evaluation of proposals is rendered by science advisers. These advisers are recruited on a part-time basis from among senior research scientists in Israel. Each of them is assigned a group of proposals in his or her field of specialization with the charge to select suitable referees. BSF maintains a large roster of potential referees, mainly U.S. and Israeli scientists, to assist the advisers in their selections. This roster is continuously revised and updated. When the reviews are returned, the advisers summarize their contents and assign a grade and priority ranking to each proposal. Final recommendations for awards are made by the executive director and his staff and are presented to the Board of Governors for approval.

An added factor in the decision making is the expression of interest in the research topic by both governments. Each year all proposals are sent to cognizant agencies of both governments for an indication of their interest. If either government indicates a negative interest, this constitutes an automatic veto of the application. If, on the other hand, either or both governments express a high-priority interest in a proposal, this may be an important factor in the final decision, provided that the scientific merit is high. The BSF conducts only one competition per year.

Most grants are made for a period of 3 years, but funding is provided for only 1 year at a time. Continuation of a grant depends on the submission of acceptable financial and scientific reports.

In the ten years since BSF started to operate, about 1,000 awards have been made. In any given year, funding is provided for about 250 projects. Distributed among the major scientific disciplines, 40–45 percent of the projects are in the medical and biological sciences, about 35 percent in the physical and mathematical sciences, and the remainder is divided among the other fields, including the social sciences. This distribution approximates the proposal pressure in the different areas. Although the large majority of proposals and awards can be classified as basic research, applied research projects are also eligible for support.

Proposals are submitted by individual scientists through their institutions. Although institutions in both countries are eligible, normally proposals are submitted by Israeli institutions since funding is in Israeli currency and the research is performed primarily in Israel. Most of the applications (about 90 percent) come from the seven academic institutions in Israel. The rest come from government research institutes and hospitals. The U.S. collaborators on these applications also come primarily from the academic sector, but there is a somewhat greater percentage from government laboratories, as well as a small number from nonprofit research institutes and from laboratories in the private sector.

Most of the U.S. collaborating scientists are from the leading U.S. academic and government laboratories. Nevertheless, the involvement of the U.S. scientific community in BSF activities is quite broad. A recent survey of 300 active projects revealed that they involved 383 U.S. cooperating scientists who work at 124 different institutions located in all regions of the United States.

FUNDING

As indicated before, BSF derives its income from the interest on the original endowment. Because of the very high inflation rate in Israel (over 100 percent per year), the current value of the endowment would now be only one-hundredth of the original, except for a system linking interest payments to the cost of living index. As a result, the real annual income has remained fairly constant over the past few years and corresponds to about $4 million. Nevertheless, budgeting is complicated by the inflation and requires estimating the rate of inflation both for the anticipated income and the anticipated research costs. (The budgeting procedures used may be beyond the comprehension of the average

American, who considers a 10 percent inflation rate excessive.) Awards made by BSF are rather small when compared to U.S. ones. The average annual research budget per grant is equivalent to about $20,000. It should be noted, however, that BSF grants do not pay salaries of senior investigators and that Israeli institutions contribute a larger share of research costs than is common in the United States.

One of the problems created by limited funds and by the fact that the income is in Israeli currency is that although BSF insists on the active collaboration of U.S. scientists, it cannot fund any part of the research performed in the United States. At best, the U.S. collaborators receive support for one or two trips to Israel and also occasional visits by the Israeli collaborators. The result is that BSF projects are heavily dependent on the support of U.S. granting agencies and institutions for the American part of the project. On the other hand, it is also true that quite often BSF grants complement work funded by NIH, NSF, or other agencies and thus expands the scope of the research at no additional cost to the U.S. agency.

ACCOMPLISHMENTS AND BENEFITS TO THE UNITED STATES

A research grant program that deals primarily with the support of basic research is difficult to evaluate since most of the projects do not lead immediately to practical and technological applications. Their main contribution is the advancement of science and the contribution to knowledge. However, one measure of the quality of a basic research program is the publication record. The latest survey of completed BSF-funded projects indicates that 85 percent of all projects completed in the first 6 years of BSF operation resulted in publication in internationally recognized journals. Furthermore, the average was about seven scientific papers per project.

In addition, a number of BSF-funded projects resulted in developments with potential applications such as:

- a simplified process for producing thin amorphous silicon for use in solar cells
- development of a computer program to improve the yield of cotton by optimizing the use of insecticides
- a chemical system capable of storing energy without the energy losses that usually occur
- an improved laser system for treating glaucoma
- a compound with anticancer potential derived from an indigenous Israeli shrub

- synthesis of a vitamin proved to aid human bone development
- a process to make hard phosphate soluble for use as a fertilizer at half the high (i.e., expensive) temperature normally required for the purpose
- integrated (combined environmental and chemical) control of certain plant diseases

Benefits from the BSF program are intended to contribute to the scientific and technological development of both countries. The benefits to Israel are obvious, as BSF plays a pivotal role in the support of academic research in Israel and fosters closer links with the U.S. scientific community. However, there are clear benefits to the United States as well.

The professional standard of research in Israel is high and comparable to that in many of the advanced countries. In some areas, Israeli scientists are among the world leaders, e.g., hormone research, solar energy, theoretical physics and chemistry, mathematics, nuclear medicine, and arid zone research. The cost of research in Israel is lower than in the United States. The average annual BSF grant of $20,000 compares to about $40,000–$50,000 in the United States. Thus, with the United States paying only one-half of BSF cost, it can "buy" research at about one-fourth the cost of supporting comparable research at home.

Scientific progress reports and final project reports are provided to interested U.S. agencies as soon as they are received by BSF. This assures a rapid flow of information that benefits U.S. technical agencies. Also, as mentioned before, BSF projects often complement and supplement work funded by U.S. granting agencies or performed in U.S. government laboratories, thus ensuring more rapid progress at no additional cost to the U.S. government.

ANALYSIS OF THE BSF MODEL: ITS SUITABILITY FOR INTERNATIONAL SCIENTIFIC AND TECHNOLOGICAL COOPERATION

Compared to other modes of formal international cooperation, the binational foundation model (as exemplified by BSF) presents many advantages and a few disadvantages. Before describing these, however, it should be noted that certain conditions existing at the time of the creation of BSF made success highly probable. First of all, BSF grew out of the very successful U.S. P.L. 480 program in Israel, which laid the groundwork for close cooperation between U.S. and Israeli scientists and government agencies and which could point to many accomplishments in its completed projects. Secondly, and independently of the P.L. 480 program, there existed close links between the scientific communities of the two countries. Many Israeli scientists had received some or all of their training in the United States. Even those who had not either spent some time on sabbaticals in the United States or worked for several years at U.S. academic institutions or in industrial laboratories. Conversely, a fair number of U.S. scientists spent sabbaticals in Israel working at the major research institutions. Thirdly, the Israeli scientific establishment is recognized as one of the best in the world. On a per capita basis, the number of scientists and engineers in Israel compares favorably with that of many of the most scientifically and technologically advanced countries. With these preconditions, one could feel confident that a reservoir of collaboration already existed that could easily be tapped to generate a large number of good project proposals. There was no need for the foundation to perform the services of a "marriage broker."

Some of the advantages of the "BSF model" are presented in the following paragraphs.

Assured Annual Budget

Since BSF operates on the income from a fixed endowment, it does not need annual appropriations. Neither does it have to depend on the ability and willingness of various government agencies to contribute support for selected activities. Although, due to special circumstances prevailing in Israel, the annual income fluctuates and cannot be predetermined with great accuracy; nevertheless, BSF can count on approximately the same income year after year. If the endowment were in dollars (as is the case with the BARD Foundation) rather than in Israeli shekels, the situation would be even better.

Nonpolitical Character

Even though the BSF Board of Governors represents the two governments, political issues rarely enter its deliberations. Its main function is to set policies and guidelines and to review annually the scientific program of BSF and approve its budget. Both governments also enter the decision-making process by indicating their priority interests in proposals submitted. These indications are based primarily on scientific and technical considerations and, only in very rare instances, on political considerations (e.g., security). Since by its charter BSF is committed to support only unclassified research for peaceful purposes, security considerations hardly ever enter the picture.

Quality Control

By using a "binational" peer review system, BSF is assured of a comparison between the projects submitted and those currently in vogue in the United States and other scientifically advanced countries. Most of the U.S. and many of the Israeli reviewers also review proposals for major U.S. funding agencies (e.g., NSF, NIH, the Department of Energy), and their evaluations reflect their comparative assessment. Even though the peer review system has its shortcomings in reaching final decisions in a very tough competition, it nevertheless provides an excellent indication of the overall quality and relevance of the applications received.

An added element by which BSF tries to assess the quality of its projects is the provision of project reports to cognizant U.S. agencies. Feedback from these agencies is used to evaluate the scientific quality and relevance of its work on a continuing basis.

There are some disadvantages as well. The financial independence, which was previously identified as an advantage, may also become a disadvantage. For several years now BSF has tried to obtain an increase in its endowment, which has been partially eroded by inflation, to be able to fund more projects of excellent scientific quality. Such an increase, however, requires agreement by both governments and also the provision of fairly substantial funds, albeit on a one-time basis. Complex political and budgetary considerations make this a slow and difficult process.

Another disadvantage, previously alluded to, is the lack of dollar funds, which makes it virtually impossible for BSF to support portions of the research conducted in the United States and thus creates a heavy dependency on existing support provided by U.S. funding agencies for the American collaborators. However, this shortcoming was corrected when the BARD Foundation was created. As mentioned earlier, its endowment is entirely in U.S. dollars and funds are available to support the U.S. investigators.

Another possible disadvantage is the broad coverage of research areas by the BSF program. The result is that BSF activities are scattered among many fields of research without making a significant impact in any one field. However, this is a problem that could be resolved by a policy decision of the board.

SUMMARY

Overall, the model of a binational science foundation, as exemplified by BSF, has much to recommend it. However, this model might not be as effective if it involved cooperation between countries of widely different levels of scientific and technological development, or if it existed in a framework where foreign policy considerations outweighed scientific ones. However, even if such conditions prevailed, it would seem to be possible to adapt this model to be more effective than other modes of formal international cooperation currently practiced by the United States. It should also be noted that the success of BSF led to the creation of two more U.S.-Israel binational foundations, the Binational Industrial Research and Development (BIRD) and the BARD foundations. Their operations vary somewhat from those of BSF, both with respect to financial arrangements and objectives, which emphasize applied research and development. The success of their programs proves that the basic concept is a good one that can be adapted to fit different objectives.

Discussion

One focus of discussion in the workshop was the various models of U.S. bilateral S&T cooperation. Among the oldest and most enduring examples of such cooperation is the *U.S.-Israel Binational Foundation.* Financed on the basis of credits to the United States under the P.L. 480 food assistance program, the Binational Science Foundation (BSF) was established in 1972 with a board appointed jointly from both countries and with an emphasis on agricultural and biological research and, to a lesser extent, on the physical and mathematical sciences. Each funded project involves some degree of collaboration, ranging from data exchange and consultation to side-by-side research. Among the major advantages of the BSF model are: (1) operation from an endowment so that it does not require an annual appropriation, (2) operation that is largely nonpolitical, and (3) binational peer review for quality control. Among the disadvantages are the facts that (a) little or no money goes to U.S. investigators (since the work must be carried out in Israel), and (b) the program has overextended the amount of interest income available to it.

A second form of bilateral S&T cooperation discussed at the meeting concerned the various *U.S.-Japan cooperative arrangements*. The relationship is based at the governmental level on more than a dozen major agreements, including most recently the U.S.-Japan Agreement for Cooperation in Research and Development in Science and Technology, signed in 1980. Other agreements cover the basic sciences, medical science, cancer research, natural resources development, transportation research, nuclear energy, environmental protection, and space. It is estimated that, at any given time, there are approximately 1,000 U.S. scientists and engineers engaged in some kind of cooperative activity with Japan through governmental auspices. Most government program managers involved in U.S.-Japan S&T cooperation agree that the relationships are based on equity, with the United States getting at least as much as it is giving, and that the projects themselves are among the best which the United States has developed with other countries.

Japan has now committed itself to an investment of more than $100 million in U.S. R&D programs. There is no other country that even approaches this figure. By contrast, the approximate U.S. investment in R&D programs in Japan amounts to only $4–$5 million. There would appear to be substantial justification for increased U.S. investment in the many unique Japanese research facilities if the financial resources could be identified. The problem is how to determine an appropriate boundary between cooperation and competition.

Although succeeding administrations have recognized the need to protect and promote cooperation with Japan in basic science, there is a growing resistance to expanding cooperation in areas of technological development (e.g., microelectronics or biotechnology) where the United States is being seriously challenged. While the early post-World War II rationale for cooperation with Japan was based explicitly on political criteria (i.e., to bind the rebuilt nation to Western democratic institutions), the political and economic situation today is fundamentally different. U.S. policy must be altered to take account of these changed circumstances.

A third type of bilateral S&T cooperation discussed at the workshop was *U.S.-European space science projects*, which represent a slightly different model in that they have involved both strictly bilateral efforts and consortium arrangements between the United States and the member countries of the European Space Agency (ESA). In this case, there is no transfer of U.S. funds to other countries; each participating nation supports its own activities. As a result, however, there is also little technology transfer, and it is likely that the United States probably would not participate if it were forced to share the critical space technology that it has developed alone at great expense.

On the other hand, the United States no longer controls access to space (i.e., launch capability) as it once did. ESA now has an independent launch capability, and the Japanese also are developing space technology. At the same time, budget resources in both the United States and Europe are severely constrained, thereby creating an impetus to avoid unnecessary duplication of effort by developing a global plan for space science. With the planning effort now under way for the development of a space station, NASA is probably more receptive than at any previous point in its history to expanded international cooperation. Meanwhile, the Europeans have been engaged in a planning process that is to culminate in 1985 in a decision whether to opt for full collaboration with the United States or for the development of parallel autonomous space capability.

Discussion regarding specific space science projects centered on the difficulties caused by the cutbacks and/or cancellation of some recent cooperative efforts. In particular, NASA representatives indicated that the decision to cancel the International Solar Polar Mission (ISPM) was a difficult one and that the agency was fully aware of the consternation that this would cause in Europe. In the end, the lack of an internal NASA science adviser and the realization that cuts *would* have to be absorbed somewhere in the NASA budget forced a decision as to which of the pending international missions could best tolerate the cutback. This was judged to be ISPM. It was noted that experience in space science cooperation indicated that the projects most likely to fail are those in which high-level committees try to lead projects from the top, rather than ones in which mutual interest on the part of scientists on both sides causes an idea to be promoted from the grass roots.

Multilateral Cooperative Modalities

U.S. Participation at CERN

A Model for International Cooperation in Science and Technology

Clemens A. Heusch

INTRODUCTION

On the slightly sloping plains between the southwest end of Lake Geneva and the steep southern flank of the Jura Mountains, a vast complex of architecturally confused and confusing surface structures makes up that part of the European Laboratory for Particle Physics that is visible to the casual visitor. A tightly interlaced network of beam tunnels and accelerating and detection equipment is almost entirely hidden from view, much of it subterranean, all of it fed from one initial source of positively charged hydrogen nuclei ("protons"), all of it masterminded by one precisely linked network of computers. The protons, on their way from initial liberation out of a hydrogen plasma to eventual collision with a stationary target at an energy equivalent to 500 times their mass, or to final annihilation upon encountering head-to-head an antiparticle of equal but opposite momentum, will pass the border between French and Swiss territory some 100,000 times. This is the border across which Voltaire withdrew when his free-thinking ways made him suspect to the rightist French monarchical establishment, the border which has guarded covetously held freedoms and prejudices between different political and economic systems over centuries. For the 10^{11} protons contained in every burst of accelerated beam, and for the 6,000 scientists, engineers, technicians, and support personnel implementing a large number of research projects on this site, the frontier does not exist—even while customs officials ferret through automobile trunks at the official border post of the Route Nationale Lyon-Geneva just outside the laboratory fences.

The vast laboratory that geographically straddles the République de Genève and the French Département d'Ain was formally established by an intergovernmental treaty of 11 European nations in early 1952. Dedicated to the pursuit of fundamental research in particle physics, and financed on a level beyond the means attainable by most individual countries, the organizational entity created at that time was given the name Conseil Européen pour la Recherche Nucléaire (CERN). Although the laboratory's mission is better reflected, in today's context, by the nomenclature the present directorate prefers also for political reasons—European Laboratory for Particle Physics—the acronym of the initial organization, CERN, gives the laboratory its name to this day. More importantly, CERN is the single most successful international organization that has sprung out of the misery of postwar European political, social, and cultural conditions. It may be one of the very few international organizations ever created that have fulfilled their mission, almost invariably high-minded, to the expectation of their initiators.

Geneva is home to a number of organizations whose multifaceted international missions and precariously balanced constitutions permit only limited success; others flounder from crisis to crisis, from bilious infighting to sullen compromise. At CERN, on the other hand, preoccupations and highlights concern the successful operation of a major new accelerator or beamline, a tantalizing new experimental result, or a splendid new discovery. The epochal achievements of two large experimental teams that, this year, discovered field quanta akin to the massless photon, but a hundred times more massive than the hydrogen nucleus, had no national origin and found no nationalistic overtone—it was an achievement of the first order produced by teams of scientists from all across Europe, and the entire laboratory appeared to share in the pride the discovery generated. The author list of the scholarly publications following from this work also contains U.S. scientists, reflecting both institutional participation and individual visitors.

What makes particle physics a field where international cooperation appears to generate success?

HIGH-ENERGY PARTICLE PHYSICS: FEATURES OF A DISCIPLINE

Particle physics is the discipline that deals, by all means accessible, with the physical world at its most fundamental level—that is, with the most elementary constituents of our universe and with the forces that govern their appearance and their interactions. Originally devoid of all practical implications, the philosophical quest for an understanding of these phenomena has occupied fertile minds from antiquity to the present day: diffuse threads link Democritos' postulate of the existence of an *α-τομοσ* (=atomic, i.e., indivisible state of matter) to medieval alchemists and to nineteenth-century chemists, whose observations first indicated a precise number of basic constituents of, say, a liter of water. Their *ατομοι* were water molecules.

The vast explosion of scientific knowledge that has characterized the most recent hundred years has, as its principal landmarks, discoveries that more and more precisely defined notions of what would describe "particle" behavior in successive generations: Maxwell's theory of electromagnetism, Roentgen's discovery of X rays, Einstein's theory of blackbody radiation, Bohr's model of the atom, and finally the tidal wave of quantum mechanics, both classical and relativistic, the emergence of particulate electrons, photons, neutrons, of antimatter, and of massive particles ("pions") that appeared to carry the force between atomic "nuclei," the dense insides of the atoms that make up yesterday's *ατομοι*, the molecules of the chemist.

If there are two discoveries that have set the scene for today's appearance of the discipline of particle physics, they are, first, Einstein's 1905 postulate that energy and mass are equivalent ($E = mc^2$), with its later corollary that a particle of a given energy is describable in terms of a wave characterized by a fixed frequency of oscillation, or a wavelength inversely proportional to that energy; and second, on a different level, Hahn's and Strassmann's 1939 discovery that a heavy atomic nucleus, e.g., certain isotopes of uranium, can be split in such a way that neutrons emerging from the break-up process can initiate further such splittings, leading to a chain reaction. The first of these observations has been leading us to understand that, to study successively smaller substructures of matter, at levels way below the atoms of 1905 or the nuclei of 1938, we have to go to smaller and smaller wavelengths of the "light" that we use to illuminate them, and therefore to higher and higher energies for the particles that make up these beams. The second occurrence has forced us to realize that an illusion held dear by modern-day scientists—the illusion that, unlike the medieval alchemist whose livelihood was provided by some lord who really expected his hired sage to turn tin into gold or carbon into diamonds, our latter-day civilization permits them to pursue knowledge for its own sake in suitably equipped and comfortably soundproofed ivory towers—is at best a dangerous one: a mere 6 years after Hahn's and Strassmann's discovery, a technology based on their laboratory observation put an abrupt end to what remained of World War II and to the cities of Hiroshima and Nagasaki.

Particle physics in its present form is shaped by these two events. How?

The distances over which we observe elementary particle structure and interactions today have decreased from the 10^{-8} cm of typical atomic structure to some 10^{-16} cm. This means that the energies needed for particle beams that will probe subnuclear interactions as we study them today are some 10^{8} times higher than energies typical of atomic phenomena. This translates into a need for great technical efforts. We can illustrate this by a look at particle accelerators at the cutting edge of our science. Take, as examples, the CalTech Electron Synchrotron, which helped accumulate vital data on nucleonic structure between 1955 and 1970: at a final energy of 1.5 GeV,[1] it accelerated electrons so that photons could probe nucleons to distances a few times 10^{-14} cm; it fitted comfortably into a single hall on the small Pasadena campus, and was well supported by a crew of eight operators and technicians, with annual operating costs of about $0.5 million. Between accelerating cycles, its energy was stored in a large steel flywheel. The bill paid to the local power company was negligible.

The synchrotron that will accelerate electrons to an energy of some 50 GeV as a first stage (later to be raised to 100 GeV) and their antiparticles to an equal but opposite momentum,[2] to be built by CERN for initial operation in 1988, needs a subterranean tunnel of roughly circular shape, and of a total length of some 26.7 km. Its building costs will be some $400 million,[3] the permanent support staff will number some 800 people, and the electrical power bill alone will amount to an annual $20 million.[4] This accelerator, suitably called LEP (Large Electron-Positron [collider]), will probe the so-called Weak Nuclear Force (the force responsible for β-radioactivity in nuclei) at distances below 10^{-16} cm, just as the CalTech Synchrotron probed the strong nuclear force at 10^{-13} cm. Just as there were four experimental setups serving four teams of experimental physicists at CalTech, doing different but related experiments, so we expect to have four experimental setups providing four related experimental goals for four teams of scientists at LEP.

This is where the parallel becomes skew: The teams at CalTech consisted of, typically, a faculty member and a couple of graduate students; at LEP, the teams will consist of between 200 and 400 scientists each, with more senior researchers and professors than research fellows or graduate students. At CalTech, the beamtime was casually divided between the people interested, who could be summoned at all hours from their nearby houses for emergency discussions or fixups of apparatus; at

LEP, people will fly in for shifts arranged months ahead of time, from home bases hundreds or thousands of miles away. At CalTech, preparation of an experiment took from 3 months to a year; at LEP, the minimum time deemed reasonable for full preparation of a major experiment is approximately 6 years. At CalTech, funding for the individual experiments was informally arranged within the laboratory and almost automatically subscribed by the U.S. Atomic Energy Commission (which at that time funded about 90 percent of particle physics research in the United States); at LEP it takes deliberations involving representatives of 12 national governments to finance any of the four experiments. Across the changes illustrated by the two examples given, these changing features as well as those that have remained constant make up the very special features of particle physics that make it a natural for international collaboration:

- The problems pursued are of a truly fundamental nature. There is no dissension concerning the basic importance of our understanding of the most elementary constituents and forces of nature. The field is not subject to scientific or cultural or economic "fashion."
- The aims of particle physics are deeply cultural. They are, as of themselves, remote from the interests of military use or economic gain. This is not to say that secondary effects may not be interesting to both of these pursuits, but the second of the shaping events mentioned above has engendered a strong tradition among scientists that keeps them well separated from all military or even traditional commercial interests.
- Fundamentality as well as remoteness from competitive power structures permits and encourages openness. All research done at all high-energy particle accelerators the world over is unclassified, readily published, easily communicated among colleagues, and accessible to all interested.
- Easy communication encourages competitiveness on an international basis: new theories or speculations that suggest novel experiments are immediately known worldwide. Many scientists may wish to pursue an almost identical problem, maybe even with almost identical means.
- Undeniably, there is a prestige or "flagship" aspect to the support of elementary particle physics. All great cultural and economic powers support this field despite its remoteness from practical use and notwithstanding the very considerable economic means needed. Sometimes, this happens in the face of dire demands from other national needs that may appear much more pressing—the recent Chinese efforts to establish a new accelerator laboratory, initiated by Chou En-lai and emphasized by his successors, may serve as an example.

• The ever-increasing size and cost of elementary particle experimentation has forced a sharing of resources and of responsibilities. When CERN was founded, national accelerator laboratories flourished in France, England, and Italy; Germany was starting her own. Today in Western Europe, only Germany maintains a vigorous national facility of her own, and even that is attempting to widen its appeal to all interested parties from Europe, Asia, and the Americas.

• Through all the vagaries of the Cold War and the economic straits of the past 30 years, scientific contacts among particle physicists from all nations involved in this pursuit have been unbroken. This has been true despite the most trying aspects of strategic, economic, and civil rights disputes.

All of these points may indicate why elementary particle physics is a special field that profits from the most unrestricted international collaboration—and has done so traditionally. It may not be a coincidence that, even in a historical context, an arch-internationalist nation like Italy, spreading its people over the globe, has done extremely well in particle physics—*vide* Fermi, Segrè, Amaldi, Piccioni, Wick, Cabibbo, Regge, and many others, disproportionately so when compared with other, more chauvinistic nations that tend to try and go it alone, albeit with much superior means.

It may not be too astonishing then that the team of scientists that discovered the $W^{\pm}$ and the Z^0 bosons at CERN contains 150 scientists from a score of nations, headed by an Italian who also holds a professorship at Harvard, and that the apparatus it used was financed by a dozen European governments.

CERN: FEATURES OF A LABORATORY

CERN owes its origins to a confluence of efforts by various individuals and institutions whose original aim was the establishment of a "Centre Européen de la Culture" including specialized institutes.[5] Formally, it took a UNESCO initiative that encouraged European governments to pool their resources for the purpose of doing nuclear research on a level that would permit smaller, less pecunious nations to participate in these activities. The structure that has grown from the 1952 convocation is a most impressive one, as we will see below. Its true measure of success may be most apparent when compared with the fate of its much more official, much better financed sister organization EURATOM; this latter one, established in parallel with the European Common Market for the purpose of furthering cooperation toward the exploration and realization of economically interesting nuclear physics applications, has had a hard time rising from political and economic, nationalistic and factional controversy, and has since been formally integrated into the European Community.

CERN today has 13 member states who participate in the running and the financing of the laboratory according to a convention and a financial protocol signed in 1953; it has been amended several times since without changing the basic spirit or setup. Article I creates the organization with its seat in Geneva; significantly, Article II immediately states that "the organization shall provide for collaboration among European states in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto. The organization shall have no concern with work for military requirements, and the results of its experimental and theoretical work shall be published or otherwise made generally available."

CERN's mission has been principally the design, building, and operation of particle accelerators capable of realizing these research aims, the execution of major experimental programs on elementary particle research topics, and the assembling of a team of theoretical physicists capable of stimulating and interpreting experimental work. The laboratory today operates a proton synchrotron (PS) with an energy of 26 GeV (since 1959) and a proton synchrotron (SPS) that reaches 450 GeV (1976); these have recently been modified to also accelerate antiprotons in the opposite direction, so as to make collisions of protons and antiprotons traveling at equal but opposite velocities possible ($\bar{p}p$ Collider); it also operates the Intersecting Storage Rings (ISR), which collide protons traveling in two interlaced rings almost head-on. For many years, starting in 1957, there was also a vigorous medium energy program centered on the SC (Synchro-cyclotron), which accelerated protons to 0.6 GeV. Much of the present CERN activity is directed toward the design and operation of the LEP project discussed in the previous section—the first excursion of CERN into the realm of electron machines, hitherto dominated by the Stanford Linear Accelerator Center (SLAC) in California and the German Electron Synchrotron Laboratory (DESY) in Hamburg.[6]

Among these projects, two do not at present have an equivalent in the United States, the ISR and the $\bar{p}p$ Collider. The antiprotons that feed the Collider can also be decelerated to permit low-energy $\bar{p}p$ (proton-antiproton) interactions in the Low Energy Antiproton Ring (LEAR), another unique facility. The huge LEP project, on the other hand, will have a U.S. competitor, the Stanford Linear Collider (SLC), for its first (50 GeV) phase; but machine parameters and readiness of access make for differences that will still attract powerful U.S. interests to LEP; on the whole, SLC and LEP should be seen as complementary facilities.

CERN's organizational structure, owing to the multinational support it enjoys, differs considerably from that of American laboratories: its governing body is the Council. Each member state has two delegates in the Council, usually one scientist and one representative of its government. The Council determines the outlines of the scientific policies and its relations with the member states. It has to pass the CERN budget, supervises all financial, legal, and personnel matters, and appoints the director-general.

The Scientific Policy Committee, consisting of scientists without regard to their national origin, advises the Council on scientific matters and on their importance for the CERN program. Its membership includes the chairmen of the experimental committees that are responsible for the examination of experiment proposals submitted to the laboratory. Experiments are approved or disapproved, upon the recommendation of the appropriate experiment committee (of which there is one for each large accelerator) by the Research Board. This board, chaired by the director-general and also containing CERN's research directors and scientific divisional leaders, carries ultimate responsibility for definition and realization of the experimental program of the laboratory.

The CERN management is headed by the director-general, whose term of office usually extends over 5 years. The director-general is a scientist who has considerable executive privileges, but usually comes from outside the laboratory and usually returns to a position outside the laboratory after his term. There has been only one extension of the term of office of a director-general. The director-general need not come from a member state.

The distribution in national origins of CERN scientific personnel, coming mostly but not exclusively from member states, is not necessarily representative of the importance of their home countries in CERN support. Out of a total of some 6,000 people working at the laboratory, some 3,500 are full-time employees (the top echelons of which enjoy diplomatic status, on a par with the leading employees of other international organizations); the remainder are fellows, visitors, or people working at CERN for outside laboratories.

The financial resources needed for the operation of CERN are determined by a standing committee, the Finance Committee, and then are agreed upon by the Council every year; a 5-year projection of expenditures is passed by the Council, providing for due notice to national governments. The member states contribute to the CERN budget in proportion to their GNP of the past 3 years, with the proviso that no nation shall contribute more than 25 percent of the total budget. At present, the 674 million Swiss francs ($320 million) annual operating budget is subscribed 25 percent by Germany, 21.7 percent by France, etc., down to 0.36 percent by Greece.

Certain decisions, such as the LEP construction, have to be supported and subscribed to by unanimous vote of the CERN Council. This gives unusual weight to the small nations and acts as a safeguard against the domination of the fate of the organization by the large contributors. The recent agreement to establish LEP was preceded by endless negotiations. A special convention saw only two-thirds of the member states in favor of LEP. It took special negotiations by the Council to mute the preoccupations of several countries and reach unanimity.

Given the above organizational features of CERN, what makes it the success it has been? It should first of all be remembered that the discipline itself sets the tone of the activities (see section above). But in practice, here are patterns that have evolved over the years which must be counted important:

- Experimental teams, large or small, very rarely if ever are composed of people from one member state only. Most collaborations have multinational membership.
- CERN management has never been shy about imposing organizational conditions on experiment proponents, including the recommendation that teams from other (usually less well supported) nations be absorbed into a collaboration. This has, notwithstanding its interference in the internal workings of scientific teams, ensured that strong and well-funded nations would not dominate the scene.
- There is no history of national rivalries, of chauvinism among CERN teams; competition for support means, for beamtime, or for approval of an experiment is tough, sometimes even vicious, but always directed at the task at hand.
- In its decision-making process, CERN management has invariably been mindful of the societal impact of the laboratory. This has sometimes led to the support of programs the principal distinction of which appeared to be that they would feed a large number of physicists, rather than maximum scientific merit.
- CERN has consistently opened its door to outsiders: Although scientists from nonmember countries do not share in all the privileges of their European colleagues, U.S. participation has been significant and steady; Russian and Chinese scientists have collaborated directly at CERN or from their home institutions; so have people from many other

nations. There has been a consistent pattern of helpfulness toward countries whose scientists had political or economic problems of collaboration.

- CERN's stable finances have permitted it to do things well, i.e., to devote the necessary resources to the building and maintenance of machines, beamlines, and detectors. Few if any scientists there have had to operate under the constraint, only too well known in the United States, to cut corners whenever possible, to take inordinate risks, to compromise quality.
- CERN's facilities have been designed and built by well-paid engineers—more or less like NASA, which cannot afford technical failures. A U.S. tendency to have research physicists act as amateur machine builders has been avoided.
- The ensuing high quality of machine building has paid off handsomely: only by the high standards of magnet and vacuum chamber construction can the success of converting the SPS accelerator into a colliding $\bar{p}p$ machine be explained.
- CERN realized early on that the presence of a strong theory group is of great benefit to a laboratory based on accelerator work. Today, a senior staff position with the CERN Theory Division can compete for talent with a professorship at Europe's most prestigious universities. Temporary positions, too, are made unusually attractive. Visitors come in hordes. As a result, much excellent theoretical work is done at CERN. U.S. accelerator laboratories rarely if ever have been able to compete for theoretical talent on this scale.
- There has been an explicit policy to bring European industry into close contact with the laboratory. Unlike a tendency well entrenched in the United States, there has not been a trend to build magnets more cheaply on site, to build klystrons or power supplies in competition with industry: Orders have been passed out to industry, sometimes along with necessary expertise. This policy, well balanced over the member states, has made powerful friends for CERN.
- The laboratory management has made consistent efforts to make not only governments, but also a wide public understand its efforts. The popular brochures put out by CERN are exemplary in content and presentation.

Clearly, there is a distaff side to the heavily organized, painstakingly defined structure of CERN. On balance, however, the laboratory is liberal in its approach and its practices, elitist in its aims. Therein lies its key to success.

Thus, an elitist institution can also afford to attract some of the most fertile brains in instrumentation and engineering physics. The laboratory has derived immense benefit from the presence on its staff of such inventive people as Simon van der Meer, developer of stochastic cooling and of the neutrino "horn of plenty" (without which high-energy neutrino experimentation would be unthinkable)—whom Victor Weisskopf, director-general during the 1960s, gratefully calls the "Maxwell Daemon of the 20th century"; as Georges Charpak, the yardstick of detector specialists; as Kjell Johnson and Wolfgang Schnell, builders of accelerators that so far surpassed their specifications as to permit their use for projects far beyond their original mission; and many others, whose ingenuity, in the United States, would likely have found proper recognition only in industry.

CERN: A LABORATORY WITH U.S. ROOTS

Historically, Western European and U.S. science are so tightly interwoven that it would be wiser to speak of roots common to all than of specific national godfatherhood to a great scientific enterprise. Still, it is not just for the present argument's sake that we recognize typically American features—features that would not follow from European traditions—in the structure as well as the practices of CERN.

The roots of CERN science may have little that's American in them, but the great exodus of top European scientists during the Nazi and postwar eras exposed these people to a spirit of pioneering attitudes, of speculative approaches to the problems of the classical sciences, of a lack of respect for passed-down structures of academic life that were to be seminal to European science at the postwar stage. In this sense, it was not only the official UNESCO appeal (influenced in no small measure by the insightful suggestions of I. I. Rabi, the noted Columbia University physicist) that led to the original CERN convention and, by shaking European nations out of national patterns of academic activity, brought a transatlantic breeze into action; but also the attitudes acquired by formerly European scientists who now came back to help establish the new research complex that put a decisively American brand onto a wide range of CERN features. The laboratory may, in its infancy, not have had much of a personality of its own, when Felix Bloch—born in Switzerland, later at Stanford—became its first director-general. The truly formative years of CERN were those when the first important experiments were done—and there again American influence is considerable: The Ford Foundation had provided a generous grant to help CERN attract visiting talent, and American researchers were more than happy to respond to the beckoning from the Alps, for sabbaticals or leaves from their normal duties. The justly famed series of experiments that measured, to ever greater precision, the magnetic moment of the muon, and thereby provided an ever more impressive confirmation of the theory of quantum electrodynamics, had people like Garwin, Lederman, and Telegdi among its initial contributors. On a technical basis, too, U.S. influence was seminal: Courant and his colleagues from the Brookhaven National Laboratory (BNL) suggested to the CERN engineers the adoption of the strong-focusing technique for accelerator construction.

Maybe the most formative period was that of Victor Weisskopf's term as director-general (1961–65), during which CERN became a full competitor to its then U.S. equivalent, BNL. Weisskopf brought to his task an inimitable mix of Old Vienna charm, of the prestige associated with his pioneering work on quantum mechanics with Pauli and others, and of the teamwork know-how he had acquired during his service in wartime Los Alamos. A man of deep culture, he personified the best of both the European and the U.S. traditions: The first made him universally accepted among European colleagues as well as government representatives; the second gave him both the confidence and the know-how to assemble and direct a large team of scientists in such a way as to make the physics result the principal issue. He adopted—consciously or subconsciously—the charismatic leadership style that had been so effectively developed at Los Alamos by Oppenheimer. But unlike the latter, he did not have to live to question the fruit of his labors: To this day, Weisskopf is a popular lecturer and valued counsel around CERN, just as his voice was heard and respected for many years as the chairman of the High Energy Physics Advisory Panel (HEPAP), an advisory panel of the U.S. government, upon his return to the United States.

Weisskopf's activities included attracting top U.S. scientists with European backgrounds to CERN; by inviting Giuseppe Cocconi and Jack Steinberger to join the new laboratory, he again imported U.S. know-how and U.S. attitudes, albeit in European skins. Into his period fall two other important developments, one positive and one less successful: On the positive side, CERN developed a neutrino beamline that was to compete with the U.S.'s Brookhaven Alternative Gradient Synchrotron (AGS) neutrino facility head-on, to find out whether speculations for two separate lepton families were correct or not. CERN lost the race, but its resulting commitments to neutrino physics were to lead to the first great CERN discovery: During the subsequent tenure of Bernard Gregory as director-general (1966–1970), the large bubble chamber

GARGAMELLE received the support that was to lead to the identification of weak neutral currents. On the negative side, we must count the invitation to an entire U.S. team of experimenters that attempted to do a major experiment at the CERN PS, using almost exclusively equipment built in the United States and transported to CERN, in a search for the relative parities of the sigma and lambda hyperons through spark chamber techniques. This concerted effort to do an entire project from the outside on a go-it-alone basis did not lead to success and would influence later attitudes toward experimental collaborations with nonmember states.

Also into this period falls the decision by Weisskopf to build the ISR, permitting high-energy protons to interact with others of equal but opposite momentum; parallel initiatives at BNL had been rejected. The technical success and experience thus gained permitted his successors Leon van Hove and John Adams, in 1978, to support the conversion of the SPS into a proton-antiproton collider, whose great later successes would otherwise be unthinkable.

The presence of U.S. physicists at CERN thereafter remained a persistent but ad personam feature for years, until, with the advent of the above-mentioned ISR in 1971, CERN had a unique facility at its disposal that had no equivalent in the United States. At that point, discussions between Bernard Gregory and Rodney Cool of Rockefeller University, who had spent repeated periods at CERN, led to the entry of U.S. teams into joint experimental ventures at the ISR. The pattern informally suggested by Gregory, never elevated into a fixed rule, implied that there should be at most 50-50 participation from the United States and that there should be a proportionate sharing of the costs of experimental equipment, but no charges for services, setup, or beamtime (as has been the case at other laboratories). The ensuing CERN-Columbia-Rockefeller collaboration has, with modifications, existed ever since. It was later joined by a Brookhaven-Yale-Syracuse contingent for another major ISR experiment series, whose head, W. Willis of Yale and Brookhaven, has since become a permanent CERN staff member and by a major search for high-mass states that might decay into $\mu^+\mu^-$ pairs, headed by S. Ting of MIT. In fact, in 1978, about 25 percent of all physicists working on experiments at the ISR came from U.S. laboratories. All of this happened simply by arrangement with the individual U.S. institutions, not by Council negotiations with U.S. government agencies.

The CERN Theory Division has similarly benefited from its frequent U.S. contacts and from the inclusion of European returnees from the United States among its staff. Much of European theory tradition tends to put great emphasis on axiomatic, "high-brow" aspects of the field. The irreverence typical of the American approach, which doesn't mind occasionally adopting a cheerfully "low-brow" stance, has had a salutary effect on particle theory through its influence at CERN.

PATTERNS OF U.S. COLLABORATION AT CERN: PROBLEMS AND BENEFITS

Activities of U.S. scientists at CERN are seen to fall, roughly, into these categories:

- Individuals who have been invited to CERN because of specific promise that their presence at Geneva would be a major asset to the laboratory. This may be on either a temporary or a permanent basis.
- Short-term visitors (usually for 1-year terms) on leave from their home institutions (often sabbatical leave); they may be partially or fully supported by CERN, or merely enjoy the courtesies accorded unpaid visitors. They may come to CERN to participate in a specific experiment or development project, to do theoretical work, or they may decide on-site which activity to join.
- Small (or even larger) groups from one or several U.S. institutions who come to CERN to collaborate on a given experiment they may have co-proposed. Their activities at CERN are supported by the U.S. funding agencies, mostly within the framework of normal university or laboratory funding. CERN may or may not subsidize their presence in Geneva, which is motivated by the availability of an attractive facility (beamline, detector). Such collaborations may last for 2–4 years, the typical duration of an experiment.
- Groups of U.S. scientists—usually entire university groups—who have been attracted to CERN by a unique possibility of experimentation—*vide* the arrival of stable groups from the United States with the advent of the ISR. Such groups have established a long-term presence at CERN; their funding comes from the Department of Energy (DOE) or the National Science Foundation (NSF) and is usually only indirectly helped by CERN. Their size may be small, as the Northwestern University group, or moderate, as the UCLA team at the ISR, or become quite massive (as the MIT team); they will *in praxi* be treated like a team from any member-state institution, as long as they provide their share of equipment and manpower for an enterprise.
- Lastly, there is an interesting and pervasive presence of U.S. scientists at CERN who are usually young, but past their first postdoctoral period. They are usually bright people who came to CERN for a year

(see above) after their Ph.D. completion, liked Europe or CERN or a specific group of congenial colleagues, and therefore decided to stay on. They are often supported on short-term contracts by member state laboratories and will often contrive to remain in Europe as long as possible. They are the wandering minstrels of modern-day physics, and upon returning finally to the United States bring a flair of European attitudes to their U.S. institutions. Some small fraction of these will wind up in permanent (mostly nonuniversity) positions in various European countries, where again their presence tends to add a refreshing note.

Remarkably, while all of these contracts and collaborative arrangements were made after a slowly emerging pattern, never to reach the level of a rigid set of rules, and often changed to suit specific circumstances, relations of the United States with certain other national high-energy physics communities were bound up in government-to-laboratory or government-to-government agreements, respectively. This is true of U.S.-Russian, U.S.-Chinese, and U.S.-Japanese agreements, setting down precise guidelines of collaboration, specifying the projects involved, the support to be granted by each side, etc. Similarly, protocols of cooperation exist between CERN and the Soviet Union and between CERN and China. CERN also formalized its relations with some nonmember states by appropriate exchanges of letters or of agreements of understanding, usually involving the Council.

CERN permits physicists from other East European states collaborative activities under its mantle agreement with the Dubna Laboratory in Russia. The fact that U.S. scientists have been granted access to CERN and—in varying degrees—to its resources, in the absence of any attempt at formalization, must be seen as a recognition not only of the high quality of U.S. high energy physics and of the special "godfather" role the U.S. originally played at CERN, but also as an expression of a special kinship between the communities of high energy physicists in the United States and in Western Europe. These communities are numerically remarkably well matched. Coincidentally, the informality of the process has been invariably useful to both sides.

In 1978, the European Committee for Future Accelerators (ECFA), an advisory body set up in 1963 by the director-general and the president of the SPC, which acts as an informal adviser to all of European high energy physics, and HEPAP asked a small working group of two U.S. and two European physicists to report on recent trends in U.S.-European "interregional activity" in high energy physics. After studying available data on the 5 preceding years, they reported that the use of European facilities by U.S. scientists and of U.S. facilities by their

European colleagues had been fairly well matched (to be specific, in 1978, 70 American physicists were engaged on CERN experiments, about 70 percent of these at the ISR). Contributions and benefits were seen to have been evenly matched.

Let us try to be more specific here, without attempting to become quantitative. What are the benefits accruing to the United States from its CERN connections?

- Providing access to unique facilities. As the demands on energy and intensity of beams rise, it becomes less advisable (or even feasible) to have parallel machine ventures in the U.S. and Europe. At present, the CERN $\bar{p}p$ Collider, ISR, and LEAR are facilities not available in the United States. Ready access to these machines for U.S. physicists is important for a balanced U.S. program in high energy physics. Conversely, Europe foresees no early availability of 1 TeV[7] fixed-target or collider facilities; as a result, CERN's European Muon Collaboration is the first European group that has contracted to take vital parts of their existing equipment to the United States. This will undoubtedly boost the activities of the Fermi National Accelerator Laboratory (FNAL) muon program. The trend will accelerate in the future (see next section).
- Sharing the cost of accelerator physics developments. In a routine way, U.S. laboratories and CERN share technological advances in accelerator physics—frequently aided by exchange visits of U.S. personnel at CERN and that of CERN staff at FNAL, Brookhaven, or SLAC. Developments of superconducting magnets, of beam cooling techniques,[8] of the study of beam instabilities, and of highly focusing particle optics may serve as examples. This practice more than doubles the means effectively available to U.S. accelerator laboratories for much-needed development work.
- Sharing the cost of detector development (and construction). Similarly, access to much European detector development—which is largely directed at, if not locally tied up with, CERN experimentation—is of great value to U.S. scientists. Much of the pervasively important wire chamber and drift chamber technology, to name just one example, came almost "free of charge" from CERN. The same can, to a lesser degree, be said of liquid argon calorimetry, ring-imaging Cherenkov counting, and other techniques. Again, close collaboration more than doubles effective U.S. resources.
- Sharing the cost of entire experimental projects. This is a concept that has been evolving from early ISR activity, where the MIT-led $\mu^+\mu^-$ experiment was actually performed on a shared-cost basis. With

the advent of complete computer links from CERN to U.S. home institutions and the implied possibility that much of the off-line (if not on-line) data analysis can be done in the United States, this mode is expected to evolve more fully.

• Participation of U.S. scientists in parallel or competing experimental projects. It has been a frequent occurrence that individual U.S. scientists on leave from their home institutions participate in CERN experiments that are close competitors of the projects they are involved in at home. This practice provides for a critical look at their own enterprise, a cross-check, and a sharing of experiences and of responses to problems typical of the specific field studied. Sometimes such activities may lead to a repeal rather than a verification of previous results. Both are obviously healthy.

• The spawning and support of industrial development. This is an area more consciously and vigorously pursued by CERN (and, for that matter, by DESY) than by U.S. laboratories: The highly political nature of the CERN Council makes the support of high-technology industries in the member states an important feature of CERN activities. The acceptance of the LEP project, with its $450 million price tag, was a controversial item for some time; remarkably, CERN put out a 33-page list of items expected to be developed and supplied by European industries, from "hi-tech" to civil engineering, complete with name and telephone extension of the CERN project engineer to be contacted for details. Interaction with CERN developments, frequently through U.S. scientists working there, but also by direct contacts, has heavily influenced the development (and sales) success of U.S. manufacturers of electronics and computing equipment.

• Providing a sales outlet and testing ground for U.S. electronics and computing manufacturers. The relatively foreseeable and solid funding of CERN experiments has been of considerable importance to a number of U.S. manufacturers—to name but a few, LeCroy Systems and Edgerton, Germeshausen, and Grier (EGG), in the fast electronics sector; Digital Equipment Corporation and Hewlett-Packard in the computing sector. It is no coincidence that these companies maintain their European headquarters in Geneva. (There is little if any reciprocity in this sector: European hi-tech manufacturers have made negligible inroads in the U.S. market.)

• Access to European scientific documentation and records. Although this may seem a minor point, sharing documentation resources well developed at CERN is an important help to the U.S. high-energy physics community. Europeans, with more of a sense of history than most Americans, tend to record historical events more readily (an exhaustive history of CERN has been commissioned by outside sources).[9]

- Postdoctoral education for young U.S. physicists. Traditionally, CERN has been receptive to a number of the most promising U.S. Ph.D. graduates and has welcomed them as fully paid CERN research associates. Others have spent their initial postdoctoral period in French, English, or German laboratories, which made them, for long stretches, resident at CERN. Their exposure to a top-notch international research establishment has invariably enriched them—not only scientifically. A cultural broadening may be one of the most essential benefits U.S. scientists experience at CERN.
- "Continuing education" of senior scientists. The great frequency of shorter-term (up to 1 year) visits of U.S. physicists at CERN provides a very important outlet to our community: Easy communication on all levels—scientific, cultural, human—with a broad international spectrum of colleagues is a vital resource to many people on leave or on sabbatical from high-pressure laboratory or academic surroundings in the United States.

Maybe the most pervasive benefit of the CERN-U.S. connection, in a more general sense, is the realization by an important component of the academic elite in the United States that sharing on a broad basis without counting up each benefit, without weighing advantages and disadvantages, is both normal and healthy in international relations. Just as it is of lasting benefit for European-educated scientists to spend some time in the United States and acquire some of the disrespectful pioneering spirit that is so often the key to success in our discipline, it is refreshing for U.S. physicists at CERN to be exposed to European traditions and trends. It helps to remove vestiges of cultural isolationism still pervasive in some of our academic life.

Measured against the benefits, problems springing from U.S. involvement have been less prominent, but are changing as the volume grows. They are mostly generated by the operational mode necessitated by the intercontinental nature of collaborative ventures.

University (or national laboratory) groups are most effective when they can act cohesively. In experimental high-energy physics, this means that a group operating at an accelerator within easy driving distance of the home laboratory has a distinct advantage. Group interactions, vertical and horizontal, are a vital feature of a healthy research and teaching environment. Most university groups face the complication of long-distance travel to accelerator sites. Common seminars become hard to organize, student and shop supervision are more problematic, teaching schedules must be carefully arranged against experimental shifts; but still, by and large, the problems are manageable.

For intercontinental collaborations, practical problems of this nature can severely affect the cohesiveness of university or laboratory environments. If a U.S. group has an important involvement at CERN, a senior professor and three or four more junior people may have to spend most of their time in Europe. With this long-term absence of a major fraction of a high-energy physics group, the cohesiveness at the university level may be seriously disrupted. Inside the United States, daily telephone communication on leased lines can make up for some of this; but intercontinental interaction becomes difficult and costly. As a result, important aspects of group activities can seriously suffer: Normal teaching becomes impossible for long stretches; the vital interaction among senior physicists that shape the future program and present quality of the group suffers; graduate student, laboratory, and shop supervision become impossible. If a U.S. group contracts to furnish a certain fraction of equipment for a CERN experiment, it may not be reasonable to build it at the home institution and ship it to CERN. The home shop size may have to be reduced (and thereby suffer in quality and flexibility) to accommodate purchases abroad. Frequently, ISR participants from the United States have hired and fired research fellows (with U.S. funds, obviously) who never came to visit the home institution. Group identity becomes compromised—it might be just as well to directly fund foreign activities without going through a U.S. university (and thereby inflate the cost by the university overhead expenses).

In the same spirit, maintaining a group abroad is disproportionately expensive. Separation payment, travel expenses, and communication costs can eat up large fractions of a group's budget.

There may, on a purely financial level, also be the problem of creating a two-tiered pay scale. People working abroad pay no taxes. Young postdoctoral scientists on tax-free CERN fellowships may be remunerated as well as some U.S. professors after taxes and will therefore be bitterly disappointed when they come home to a meager U.S. postdoc stipend. CERN-based and FNAL-based researchers from the same U.S. institution may feel they belong to different societies.

To revert to the previously cited comparison with CalTech Synchrotron operations in 1965, it was easy to have a healthy, fruitful university atmosphere conducive to the education of young scientists when all were locally present day and night; it is not obvious how much of a university atmosphere and character can remain intact with intercontinental operations. This is the principal price we pay for all accruing benefits.

CHANGING BOUNDARY CONDITIONS: OUTLOOK

At present, we appear to be crossing a dividing line in the operational mode of high-energy physics operations. It may have been marked by the migration, in 1982, of an active major detector from the SPEAR facility at Stanford to the DORIS facility at Hamburg, Germany. Concurrently, the Crystal Ball Collaboration, which had operated this detector at SLAC, doubled in size, swelling its ranks with European collaborators. The detector, after being adapted to its new habitat, has been taking data since early this year.

The trend is motivated by the drying up of more and more beam "spigots" available to experimental groups of moderate size, the emergence of unique facilities abroad, and the determination of the international high-energy physics community to operate as free of national and regional bias as possible. U.S.-CERN relations are realigning themselves to this development.

If we look at the machine facilities presently available, or firmly approved for construction such that experimental planning is already under way, the message becomes clear: A few years from now, initial-state (i.e., machine) parameters for high-energy experimentation will be different in Europe, in the United States, and in Japan. In the United States, there will be 1,000-GeV fixed-target physics as well as 1 × 1-TeV $\bar{p}p$ collisions at the FNAL and 50 × 50-GeV e^+e^- annihilations at SLC, plus the remaining (and possibly upgraded) lower-energy facilities at Stanford, Cornell, Los Alamos, and BNL. CERN will have the $\bar{p}p$ Collider program, probably upgraded in luminosity, LEP, and the remaining SPS fixed-target program. Electron-proton (ep) physics will most probably be available at the HERA facility in Hamburg, Germany, where 30-GeV-electrons will meet head-on with 800-GeV protons; there will be 30 × 30-GeV e^+e^- interactions at the TRISTAN facility (Japan); possibly, the UNK facility (in the Soviet Union) will offer 3-TeV fixed-target physics.

CERN is attracting large contingents of U.S. physicists to its LEP program, since the SLC is slated for only one experimental region. (Also, LEP promises to have higher luminosity and, in its second phase, higher energy than the SLC, and thereby the prospect of investigating a wider variety of processes.) While, typically, DOE support for the CERN operations of U.S. groups has totaled some $0.5 million per year, this will rise to some $7–8 million per year with LEP operations. If we include the total support for U.S. high-energy physics groups operating abroad, this figure will approximately double and make up some 13 percent of the U.S. DOE university support volume by the agency. In fact, projected U.S. expenditures for one of the LEP detectors (L-3) are of the same order as the target cost of both detectors at the U.S. "competitor" installation, the SLC. Clearly, interregional operations in high-energy physics have become more than a fringe phenomenon; U.S. relations with Europe and Japan will have to be defined within our discipline. U.S.-CERN arrangements may have to be modified.

The International Committee on Future Accelerators (ICFA) has defined a set of guidelines for interregional collaboration in particle physics, which attempt to ensure access to all high-energy physics facilities to appropriately staffed and supported groups of scientists irrespective of their national origin. Scientific merit should be the principal criterion for acceptance of an experiment proposal; but local collaboration should be secured for any distant-based originator of a proposal, and ultimate control rests with the host institution.

Given the great success of informal U.S.-CERN exchanges in the past, it must be our goal to keep formal arrangements at a minimum level. Still, the sheer volume of U.S. interest in CERN has led to some unprecedented changes. Frequent contacts between CERN management and the DOE High Energy Physics (HEP) Office culminated in the exchange of formal letters between the present CERN director-general, Herwig Schopper, and the director of the DOE-HEP Office, James Leiss, affirming the ground rules for U.S.-CERN relations; and a U.S. representative was made a member of the selection committee for LEP experiments (R. Taylor of SLAC).

The recent decision not to pursue the construction of a high-luminosity, high-energy (400 + 400-GeV) $\bar{p}p$ Collider in the United States has contributed to the concern that U.S. participation at CERN will be much stronger than CERN member-state participation at U.S. facilities. HERA and TRISTAN construction will add to the trend of U.S. scientists' participating in experiments abroad. The worry that this will lead to a massive spending of U.S. high-energy physics funds abroad, to the detriment of the national laboratories, must be seen in context:

- Insufficient coordination and subcritical funding of U.S. facilities and facility development are largely the basis of this imbalance.
- While reciprocity is a laudable objective in interregional cooperation, it is not at all compelling that such balance would have to be

established over a short period of time; rather, arrangements for U.S. support of, and interest in, CERN facilities might well be coupled with CERN participation in the preparatory work for the very large $\bar{p}p$ Collider recommended by the 1983 HEPAP subpanel.

• Major U.S. use of LEP (as well as HERA and TRISTAN) means that the great investments made by the countries subscribing to their construction and operating costs directly benefit the United States; the arrangement remains economically advantageous.

• Essentially all other benefits of U.S. CERN participation, specifically those to U.S. electronics and computer manufacturers, remain valid.

As we embark on a period where international coordination becomes more prominent, we have to strive for greater continuity in our high-energy physics program. The stable growth of the European program is not in the least due to the long-range planning prevalent in European countries. (In Germany, e.g., even individual university groups are funded for 3-year periods, and long-range projections are written into national budgetary legislation.) Lackadaisical support for our own facilities and abrupt termination of half-finished projects, as well as the unpredictability of the funding for our university program on a yearly basis, put us at a severe disadvantage when it comes to coordination with international research activities. The longer time range over which a major experimental effort will span—say, 8–12 years for an LEP experiment, from proposal to the completion of the initially foreseen program—alone mandates greater long-term stability for our program.

CONCLUSIONS

When the European Laboratory for Particle Physics started operations in the late 1950s, benevolent U.S. assistance helped to set a pattern of successful operation. A tradition of informal U.S. presence at CERN built up over the years, thus opening up the physical and cultural resources of this uniquely successful laboratory to American scientists on a mutually beneficial basis.

As individual machines grew ever more costly to build and operate, CERN facilities started to include some that were otherwise unavailable to U.S. scientists. Still informally arranged, participation by entire U.S. teams became an accepted feature at CERN.

A continuing trend toward contraction to a smaller number of high-powered, high-cost facilities can be partially offset by the practices thus evolved, to permit joint usage of major facilities at CERN and in the

United States (as elsewhere) to scientists from both sides of the Atlantic. It will be desirable to keep U.S.-CERN relations as informal and, therefore, as flexible as possible. This will be helped by better long-range planning and a willingness to assume longer-range commitments by our government. University groups will have to restructure their activities to permit far-off operations without an interruption of their classical mission, the "unity of teaching and research." Funding agencies and parliaments on both sides of the Atlantic will have to show flexibility and imagination; they will have to resist the temptation of trying to write narrow balance sheets.

Properly administered, the U.S. presence at CERN will increasingly mean a vast widening of our technological and scientific horizon; cultural and economic benefits will combine to ensure continued and increasing success of this collaboration.

On a more general level, a broadening of the horizons of U.S. and European scientists may provide for the most lasting advantages to be realized. Just as CERN's impact in Europe has been largely due to its proven history of a most successful enterprise in international relations, U.S. relations with CERN may yet set a pattern for fruitful interactions of American economic and scientific power with other nations.

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NOTES

1. 1 GeV = 10^9 electron volts; the mass of the proton corresponds to approximately 1 GeV.
2. For high energies, we can use momentum and energy as though they were quantitatively the same. But the definition of momentum contains the direction of motion; energy does not.
3. To be precise, 910 million in 1981 Swiss francs, 1,017 in 1983 currency equivalent. Experimental equipment is not included in these figures.
4. This includes the power bill for the preaccelerators feeding particles into LEP.
5. For historical accounts, see: L. Kowarski, An Account of the Origin and Beginning of CERN (CERN 61-10, 1961), and D. Pestre, Eléments sur la Préhistoire du CERN (CHS-2, 1983).

6. DESY is a German national laboratory that is currently attracting a large number of foreign, including U.S., scientists to its program; it operates e^+e^- storage rings roughly equivalent to the PEP and SPEAR positron-electron colliders at SLAC.
7. 1 TeV = 10^{12} electron volts.
8. Cooling here means the compression of phase space, permitting the accumulation and acceleration of large amounts of particles like positrons and antiprotons.
9. Note, however, that the American Institute of Physics (AIP) maintains very useful archives and similarly sponsors historical studies.

The Global Atmospheric Research Program

John S. Perry

INTRODUCTION

In 1979 and 1980, our earth's atmosphere received its first truly complete physical examination. Aircraft cruised over the broad expanses of the Pacific, Atlantic, and Indian oceans, releasing parachute-borne instruments to sense the atmosphere's structure. A fleet of more than 50 ships stationed themselves around the equatorial oceans to release additional instruments and obtain oceanographic observations. Hundreds of drifting buoys were deployed in the vast reaches of the southern oceans. A flock of balloons floated through the lower stratosphere transmitting observations of temperature and wind to orbiting satellites aloft. Commercial aircraft similarly transmitted observations through satellites to a network of ground processing centers. From space, two polar-orbiting and five geostationary satellites kept the globe under surveillance. The routine operational weather services of the world went into high gear, and special care was taken to transmit every possible observation to data-processing centers and archives. Today, some 5 years later, the body of data collected in this Global Weather Experiment—the centerpiece of the Global Atmospheric Research Program (GARP)—has been processed and analyzed through an internationally organized network of centers and is being intensively exploited by the world's research community to unlock the secrets of weather and climate.

The execution of this massive data-gathering program was a remarkable achievement. Moreover, its conception and planning represented an even more remarkable interplay between science and politics on a global scale. To understand how the Global Weather Experiment came to pass, one should consider the development of its parent program—GARP—in the context of the history of international cooperation in the atmospheric sciences.

BACKGROUND

Of all scientific endeavors, those dealing with weather and climate are surely the most international in character. Air flows freely over political boundaries. The same storm may bring rain to London and snow to Stockholm. The hurricane that ravages Cuba today may irrigate Mexico tomorrow. Even the climate of Siberia is moderated by the distant but vast ocean. Thus, exchange of weather information between nations goes back many centuries to the circulation of ships' logs between mariners.[1] However, it was only in 1872 that a formal international system for data exchange was organized with the formation of the International Meteorological Organization (IMO). Following World War I, the International Commission for Air Navigation took an interest in the exchange of aviation weather data, and the International Union of Geodesy and Geophysics, a nongovernmental member of the International Council of Scientific Unions (ICSU), concerned itself with meteorological research. After World War II, the IMO's functions were inherited by the World Meterological Organization (WMO), an intergovernmental specialized agency of the United Nations (UN).

The point of the above chronology is simply to emphasize that an active and effective infrastructure for international activities in the atmospheric sciences has existed for a longer time than have many of the world's nations. While the Global Atmospheric Research Program eventually became grafted onto this infrastructure, its genesis lay in a unique convergence of scientific and political circumstances.[2] In the period around 1960, many circumstances favored major forward steps in meterology. Advances were being made in the design of mathematical models of the atmosphere, and electronic computers were becoming sufficiently powerful to implement these models. The launch of Sputnik in 1957 and its many successors had demonstrated that the earth could be observed in its entirety from space at feasible cost. At the same time, the postwar hopes for a world of peace and universal cooperation were being dashed by the emergence of the Cold War. On assuming the presidency in 1961, John F. Kennedy faced a world rapidly solidifying into two hostile camps—the first brick in the Berlin Wall was laid in August of that year. Moreover, the opposing camp was demonstrating impressive capabilities in the prime technology of the age: The first man in space in April 1961 was a Russian.

In these circumstances, the new President was naturally motivated to open channels of communication in science and technology with other countries, especially the Soviet Union, in the hope that advances in science—particularly in the mastery of space—could be turned to peaceful ends. Explorations were initiated in the U.S. scientific community to uncover areas in which international scientific activities could serve these objectives. As suggested above, it was almost inevitable that meteorology would be seized upon as a most likely candidate because of its long record of success in the international arena and the emergence of exciting scientific opportunities. Complex discussion in the U.S. scientific community and government led to insertion of a single sentence into President Kennedy's September 1961 address to the United Nations on "the peaceful uses of space" appealing for "further cooperative efforts between all nations in weather prediction and eventually in weather control." This impetus, in turn, led to the adoption of UN resolutions in 1961 and 1962 calling on member states, WMO, and ICSO to develop plans for expanded programs in meteorological services and research, with particular emphasis on the peaceful uses of space technology.[3]

PROGRAM DEVELOPMENT

These resolutions set in motion a lengthy period of exploration and planning both within the United States and in the international community. The Panel on International Meteorological Cooperation was formed by the National Research Council's Committee on Atmospheric Sciences (1966), and a similar international group was established under ICSU auspices. In early discussions, a wide variety of topics for international cooperation under the UN's broad charge was discussed.[4] However, attention rapidly focused on a single problem, the large-scale motions of the atmosphere and their relationship to weather and climate.

On this topic, all the streams of motivation that had led to Kennedy's call to action strongly converged. Numerical models of the atmosphere were already being employed in routine weather prediction and were evolving into tools for the study of global climate. Research had shown that, while there existed a clearcut limit to detailed predictability of weather systems, this limit lay well beyond the realized capabilities of the weather services. The primary barrier to extending the range of prediction was the difficulty of determining with sufficient accuracy and detail the initial state of the entire global atmosphere. With an adequate research data set, it would be possible to distinguish between prediction errors induced by scanty data and those arising from imperfections in the models, and meaningful research could be performed. This would pave the way for better operational forecasts employing improved models and an efficient global observing system. Moreover, observations from space provided a new means for obtaining the complete worldwide observations needed to carry out meaningful research in this area. Finally, it was evident that such a global data set could be obtained only through close cooperation among all nations—including the Soviet Union—thus addressing the political goals of the Kennedy initiative.

With the central goal of the program defined, there remained the establishment of an institutional framework to support its implementation. Here, many competing interests and allegiances had to be reconciled. It was clear that a program to observe the entire planet would require significant resources and that these resources could be supplied only by the governments of the world. It was equally clear, however, that a simple hardware-oriented data-gathering exercise would fail to build the intellectual bridges between scientific communities that were so urgently desired. A complex partnership thus evolved, the advantages of which will be discussed more fully later on.

Two major and closely linked programs were developed. The first, the World Weather Watch, was to be organized by the intergovernmental WMO. This promised near-term improvements in the world's operational weather observing and forecasting systems by providing coordination of national efforts and infusions of technology and training from the developed to the developing countries. A parallel Global Atmospheric Research Program held out hope for the future. This program would be organized jointly by both WMO and ICSU in order to draw on both the needed physical resources that governments can provide and the intellectual inputs of the nongovernmental scientific community. For this latter effort, a unique planning and management structure was developed, centered on an independent Joint Organizing Committee (JOC) of distinguished scientists reporting directly to the executive bodies of the sponsor organizations and an equally independent Joint Planning Staff (JPS) reporting only to the JOC. This central structure was provided with significant funds of its own that it could use with minimal bureaucratic inertia and constraint. Supporting national committees were established in many countries, notably the United States, and made important contributions to the program's development.[5] By 1968, this structure was complete, and the detailed planning of GARP began.

IMPLEMENTATION

The remainder of the history of GARP is best told in terms of its achievements.[6–8] In 1974, the GARP Atlantic Tropical Experiment was conducted in the equatorial Atlantic off the coast of Senegal. Scientifically, this experiment addressed the problems of the tropical atmosphere and ocean and their interaction with the global circulation. Politically and organizationally, it served to test the previously untried notion that scientists, technicians, and support personnel of many nations could work intimately and effectively on a common goal in the stressful circumstances of a major field program. Both objectives were achieved with remarkable success. Other preparatory, process-oriented experiments were also launched in the ensuing years, such as the Air Mass Transformation Experiment (AMTEX), organized largely under Japanese leadership in the western Pacific.

Meanwhile, planning for the Global Experiment continued. The details of its observing program are largely irrelevant to the present discussion. In essence, it sought to obtain accurate observations of the atmosphere and the underlying surface with a resolution in space and time that numerical experiments had indicated would be adequate for effective weather prediction research. These stringent requirements demanded not only global satellite data, but also in situ measurements over the tropics and the oceans. Assembly of the many observing systems that might be contributed by many countries was a complex and challenging task. Moreover, regional programs such as the Monsoon Experiment (MONEX) arose to take advantage of the observational network of the Global Experiment. It is not surprising that the Global Experiment, first proposed for 1972, was postponed many times because of problems in one or another observing system.

Throughout, the JOC set scientific objectives and priorities and served both as a court of mediation and as a court of last appeal seeking to maintain a program that would be both scientifically meaningful and operationally achievable. JOC's success in this difficult endeavor is evidenced not only by the execution of the largest international scientific field program to date, but also in the continued vitality of the worldwide research effort based on the GARP experiments.

IMPLICATIONS

What lessons may be drawn for the design of international scientific efforts from the history of GARP, and what guidelines may be deduced for U.S. involvement in such activities? First of all, I believe we must recognize clearly that many aspects of GARP were unique to their time and are unlikely to be repeated. GARP arose in the postwar, post-Sputnik era when a unique convergence of scientific optimism, technological opportunities and Cold War tensions obtained. The linkages between nations, including those in science, had been disrupted by war, and there was a widespread yearning to reestablish them. The desire to penetrate the Iron Curtain led to strong and continuing political support for the program in the United States. This strong political support was reiterated time and time again not only by the nations assembled in the WMO but also by each successive U.S. president. This continued backing, and—even more remarkably—the continuing provision of funds by successive U.S. congresses, may demonstrate a fairly stable constituency for international cooperative scientific activities.

Other factors that contributed to the success of GARP are to some extent unique to the atmospheric sciences. As we have noted above, meteorology has an unequaled history of effective international collaboration. Moreover, most individual meteorologists have at one time or another performed the exercise of plotting data from around the world on a world map in order to develop analyses and forecasts. In this process, they are vividly reminded that none of their work would be possible without the cooperation of thousands of meteorologists and technicians in all countries of the world. Thus, meteorologists are preconditioned to take for granted the necessity of and the feasibility of worldwide cooperation toward common goals. Reflecting the nature of the discipline and the psychology of its practitioners, WMO is generally recognized to be the most efficient and least political of the UN specialized agencies and is served by an exceptionally capable Secretariat. Thus, international activities in the atmosphere can lean upon a unique sociological and institutional infrastructure possessed by no other discipline.[9]

Other factors underlying the success of GARP, however, may be more widely applicable to programs in other fields.

A distinctive feature of GARP was its implementation through a novel partnership between an intergovernmental organization, the WMO, and a nongovernmental organization, ICSU. Each type of international mechanism has distinct assets and liabilities. Governments levy taxes, control access to their territories, protect the security and welfare of their citizens, and—somewhere in the lower reaches of their list of priorities—provide most of the resources to support basic science; it is hard to do anything concrete in the real world of science without bringing in governments. Bringing in governments, however, inescapably brings in foreign ministries, national politics, territorial squabbles, and a host of other issues and institutions extraneous to the scientific tasks at hand. Moreover, governments are by their nature complex and multicellular political-bureaucratic organisms; each of their component agencies has its own political linkages, territorial imperatives, and supporting constituencies. The specialized intergovernmental organizations deal with their national member countries primarily through the specialized governmental agencies of these nations. Thus, the Food and Agriculture Organization's communications channels run primarily through the food and agriculture ministries of governments; the WMO sees the world through the national meteorological services, and so on. A scientific program implemented exclusively through an intergovernmental organization will therefore inevitably be molded by the interests of the organization's constituent national bureaucracies. Moreover, the members of these bureaucracies will usually play a disproportionate personal role in the program. For example, in WMO-organized activities, scientists associated with the meteorological services are notably more numerous than academics.

The nongovernmental organizations are to a great extent mirror images of their intergovernmental colleagues. Typically, they have slender resources and minuscule staffs—indeed little physical existence at all. Their constituencies, however, cross both national and bureaucratic lines. On any particular scientific problem, they can entrain quite directly the worldwide network of interested and expert individual scientists who, in the end, must do the work. For example, the framework of the composite observing system for the Global Weather Experiment was largely designed by ISCU's Committee on Space Research (COSPAR).

It is important to recognize that the WMO-ICSU agreement on GARP that created the JOC and the JPS essentially created a *new international organization* with interesting, and perhaps unique, capabilities that simultaneously combined the assets and minimized the liabilities of the two types of organization. Responsible not directly to individual governments, but to organizations representing global constituencies, the JOC could define GARP's goals with considerable independence, guided primarily by scientific imperatives. Through these scientific plans, it could focus the resources of governments as could no private club of scientists. However, the JOC could also call on individual scientists to participate in its work without much regard for their national or organizational affiliation. The JOC had a staff and resources that were modest on the scale of intergovernmental organizations, but substantially greater than those enjoyed by typical nongovernmental associations. Moreover, the JPS used the efficient infrastructure of the WMO Secretariat, while avoiding many of its administrative constraints. This ad hoc hybrid organization proved immensely effective and served as a model for the current WMO-ICSU World Climate Research Program and its ICSU—UNESCO oceanographic component.

The programmatic setting of GARP was adroitly conceived to pair a scientific program of fundamental research justified by rather esoteric intellectual concepts with an operationally oriented program of services and development assistance that offered short-term practical advantages to all countries. The linkages between the hoped-for results of the research effort and the clearly apparent needs of the operational program were continually made explicit. Indeed, the terminal event of GARP will be a conference in 1985 specifically designed to draw from the research community the conclusions important for the design of future operational weather systems. The linkage between research and operational needs, and the parallel linkage between the scientific community and governmentally provided resources, promoted a widespread perception of mutual benefits in the program. Developing nations, even those with minimal scientific research establishments, could readily perceive the benefits of improved weather services. Moreover, the existence of a world weather program offered a channel for technical assistance and training that was of great appeal. Participating scientists saw a means not only of attaining their individual scientific objectives and of communicating with their colleagues in other countries, but also of legitimizing their own aspirations in the eyes of their nations' research establishments. The GARP label on a scientific proposal may not have been equivalent to a blank check, but it certainly buttressed strongly the efforts of scientists in many countries to obtain resources from their governments.

The most important factor, however, underlying the longevity and achievements of GARP was the steadfast maintenance of its scientific integrity. Although its genesis was largely political, it rapidly acquired a sound scientific basis through the efforts of Jule Charney, Edward Lorenz, and many others. An impeccable and widely accepted body of scientific research demonstrated unequivocally that improved numerical models of the atmosphere and ocean would indeed lead to better weather forecasts and enhanced ability to deal with the problems of natural and manmade climate variations. The innovative institutional arrangements set up under WMO and ICSU permitted the clarity and sharpness of focus on these objectives to be maintained throughout the long life of GARP. The JOC was not only independent in theory, it was provided with the resources in terms of money and staff to exercise effectively that independence. In essence, the nations of the world committed themselves individually and collectively to do something called

"GARP," and delegated to the JOC virtually unlimited authority to define its objectives and to design its execution.

Time and again in GARP's long gestation period, the JOC was faced with temptations to accept convenient shortcuts and compromises that might have undermined the program's integrity. Each time, these temptations were decisively rejected. The JOC decided, for example, that a GARP Atlantic Tropical Experiment (GATE) program without a satellite would not be meaningful, and by a miracle of leadership and improvisation, the United States came up with a satellite in the nick of time. The JOC decided that a global experiment without atmospheric soundings in the tropics would not be meaningful, and a patchwork quilt of aircraft and ship programs was evolved to replace the neat and glamorous technical solution of a carrier balloon system that had failed to materialize. A global experiment with only four geostationary satellites instead of five could have been organized with far less East-West wrangling, but the JOC stuck to its guns and the gap left by delays in a Soviet satellite was eventually filled by a U.S. contribution. GARP demonstrated that an international scientific program can maintain the integrity of its scientific goals over years and decades.

THE U.S. ROLE

As the capsule history above indicates, the U.S. role in the development of GARP was crucial in almost every respect. The original impetus to the program was provided by U.S. leadership from the very top. Our steadfast political support set an example for other countries to keep the program going both through the sponsoring international bodies and through their own programs. Our physical resources in terms of money, technical and logistic capabilities, and scientific talent played a vital role. We contributed large sums to the international planning activities; we provided unique observing systems such as satellites, aircraft, and airborne electronics, and we seconded many scientists to international planning activities and field programs. Most significantly, however, the intellectual contributions of the U.S. community, which through most of the planning period was clearly preeminent in the world, shaped the program and lent it the scientific integrity and authority noted above. The magnitude of the U.S. contribution is difficult to assess quantitatively, in part because of the intermingling of research and operational activities. Over the lifetime of the program, total expenditures by all participating countries were probably on the order of $500 million, with the U.S. providing about $100 million of that sum.

BENEFITS TO THE UNITED STATES

Did the United States accrue benefits commensurate with these outlays? The benefits are even more difficult to assess quantitatively than are the inputs contributed, but the existence of benefits is not in doubt. In common with other nations, we acquired access to unique data sets, including not only complete collections of global observations, but also specialized data on regional phenomena such as the Asian monsoon and the details of air flow over mountain masses. These could have been obtained in no other way than through an international collaborative program, for the real estate of the globe is after all managed by some hundreds of sovereign nations. Access to that real estate, the atmosphere above it, and the ocean bordering it for the purposes of science therefore requires the cooperation of those nations. If our scientists are to address global geophysical problems at all, they must address them in an international context.

We also obtained ideas from afar and thereby enriched our own national scientific life. Although the U.S. scientific community is massive and affluent, it has no monopoly on talent and imagination. Throughout the history of GARP, major intellectual contributions were made by scientists from other countries. Indeed, for most of the program's life, Sweden and Canada provided the leaders of the JOC, and Argentina and Sweden were the chiefs of the multinational JPS. Ideas initiated in the United States time after time migrated into the international planning forums, were reshaped by many hands, and returned in a greatly improved form. The international machinery offers an opportunity for independent review and improved conceptualization of scientific ideas that is often difficult to obtain within the political and institutional framework of an individual country.

One must recognize also that other countries mobilized through GARP contributed very significant resources to the program's implementation that in total outweighed our own. For example, the Soviet Union contributed 10 oceanographic ships to the Global Experiment, and we enjoy access to their results. The Air Mass Transformation Experiment (AMTEX) and the recently concluded Alpine Experiment (ALPEX) were primarily led, funded, and implemented by other countries. The United States played a minor role in the support of these efforts, but was able to draw fully on their observational and scientific results. International programs can provide highly significant leverage for our investments in science.

There are also other intangible benefits accruing to U.S. science from such international activities. GARP drew together the meteorological and oceanographic communities throughout the world, not the least in the United States. This rapprochement not only fostered a wide range of research in ocean physics relevant to atmospheric problems, but also slowly worked a sociological evolution in the oceanographic community. Oceanographers began to think in the larger context long familiar to meterologists and developed an increased appetite for and competence in cooperative programs. For their part, meteorologists began to acquire an understanding of the ocean's challenging complexity. This joint understanding was an essential foundation for the development of meaningful research on the long-term problems of climate, where ocean and atmosphere are inextricably linked. GARP also demonstrated that "Big Science" could not only be good science, but moreover could offer exciting opportunities and rewards for individual scientists. GARP made the organization of subsequent large-scale interdisciplinary programs in the environmental sciences infinitely easier. Thus, not only the end results of international activities, but also their process benefit the participating nations.

The inertia of an international program, once established, tends to lend a highly desirable stability to the contributing programs of individual nations. In the United States, for example, a network of interagency planning offices and agency focal points, each equipped with a budget line, gave an enviable stability to GARP-related research over better than a decade. GARP served as a flywheel on the often erratic engine of government support for atmospheric sciences.

The international process also gives us a better understanding of the real scientific capabilities, limitations, and attitudes of other countries' scientific establishments. The value of this understanding is hard to quantify, but in a world of competing nations, it must have some worth.

Finally, GARP really did achieve its objective, the improvement of weather forecasts. Operational predictions made by the world's weather centers are now genuinely useful out to 5 or 6 days. We—the nations of the globe—took on a job that could only be done in concert, and we did it.

PAST LESSONS AND FUTURE HOPES

In summary, then, it appears that a number of useful lessons may be drawn from the GARP experience. First of all, it demonstrated that science in an international setting can do a number of unique and valuable things not readily achievable through other mechanisms of the human endeavor. It showed that the scientific goals and the political goals of international activities are not necessarily incompatible and, indeed, may be mutually supportive. Not only the concrete outputs of international science, but also the process of international science has benefits to the participating countries.

It seems that three prerequisites must obtain for a successful international scientific program:

1. There must be a strong political support by the participating governments that must legitimize the program and provide its resources. This support can be mobilized only on the basis of a commonality of political objectives and a shared perception of benefits. The objectives and structure of international programs must be carefully tailored to enlist this support.
2. There must be an adequate infrastructure of institutions, communities, networks, and interests that allows access to both the governmental and nongovernmental scientific communities. Such an infrastructure can best be based on existing, successful structures that have well-established constituencies and well-supported ongoing activities. However, specialized ad hoc hybrid arrangements that provide considerable scientific sovereignty have great advantages.
3. Above all, there must be valid scientific goals, recognized and supported by all participating countries and scientific constituencies. A program pursued only for political or institutional ends will in the end achieve no ends at all.

Could a program such as GARP evolve in present circumstances and carry on with comparable success into the twenty-first century? One must admit that many circumstances today are far different from those of the 1960s. International cooperation is no longer a novelty. Indeed, our problem may be to use more effectively the international linkages we have rather than to create new ones. Technology is now all-pervasive, and our greatest problem is the unglamorous maintenance of what we have rather than the launching of daring new ventures. The parameters of our relationships with the Soviet Union and its allies are much better defined now than in the 1960s. Again, the problem is one of prudent management and maintenance rather than trailblazing.

Thus, more than ever before, international programs pursued solely for the purpose of doing something international seem both sterile and redundant. Nevertheless, the potential benefits of international activities to the United States remain great. The challenge for the future, then, is to identify clearly and to define rigorously those scientific problems whose resolution will inescapably depend on organized cooperation between the scientific communities and governments of the world.

As the human race as a whole presses ever more strongly on the resources of our finite globe, more and more such problems will undoubtedly emerge and will not only benefit from, but indeed will demand coordinated attention by the scientific communities of all countries. For the United States, the type of international cooperative activity exemplified by GARP may prove to be an indispensable tool for our own survival.

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Deep Sea Drilling
The International Phase

G. Ross Heath

The International Phase of Ocean Drilling (IPOD) is a cooperative program of the United States, France, the Federal Republic of Germany, Japan, and the United Kingdom to investigate the geology and geophysics of the deep ocean basins by means of advanced drilling technology. The field studies have been carried out from a specially configured drilling ship, the *Glomar Challenger*, owned and operated by Global Marine, Inc., under contract to Scripps Institution of Oceanography of the University of California, San Diego.

This review focuses on the development of the drilling program and its international aspects. The scientific results are well documented in the Initial Reports of the Deep Sea Drilling Project and in the scientific literature.

HISTORY OF THE PROGRAM

Development of a U.S. Drilling Program

Van Andel (1968) has reviewed the history of ocean drilling prior to the launching of *Challenger*. The first part of this section draws heavily on his review.

Project Mohole, proposed in the late 1950s, was the first serious attempt to use advanced drilling technology to penetrate the deep sea floor. This National Science Foundation (NSF)-supported project used the barge CUSS-1, equipped with a large drilling rig, to drill 10 experimental holes in water depths of up to 3,600 m off San Diego and western Mexico. These tests demonstrated the ability to recover sediments and volcanic rock, as well as the feasibility of dynamic positioning of the ship, an essential requirement where the water is too deep for the use of anchors. Project Mohole then foundered as the estimated costs to construct the large, self-propelled platform required to meet the goal of drilling through the earth's crust to sample the mantle rose to unacceptable levels.

At the same time, however, marine geologists interested in sampling only the sediments and the surface of volcanic basement realized that the use of existing drilling equipment and techniques on a relatively mobile ship could meet their needs. Even a relatively modest program was beyond the capability of any one oceanographic institution at that time, however, so some form of multiinstitutional management was required.

The first such organization, created in 1962, was the LOCO ("long core") committee made up of two representatives each from the Institute of Marine Sciences of the University of Miami, Lamont Geological Observatory of Columbia University, Princeton University, Scripps Institution of Oceanography of the University of California, and Woods Hole Oceanographic Institution. This committee could not agree on the charter for a nonprofit corporation to manage a drilling program. Lamont, Woods Hole, and Scripps then formed such a corporation (CORE), which submitted a proposal for a drilling program. LOCO did not endorse their proposal, which was not funded. Both LOCO and CORE then faded away.

In 1964, scientists from Miami, Lamont, Woods Hole, and Scripps signed a formal agreement creating JOIDES (Joint Oceanographic Institutions for Deep Earth Sampling) to plan and propose drilling programs, and to designate one of its members to act as operating institution and to be responsible to the funding agency for management. This structure was tested in 1965 when Lamont successfully managed a drilling program on the Blake Plateau, off the southeastern United States, which made use of the D/V *Caldrill*.

In January 1967, Scripps, as the operating institution for JOIDES, signed a contract with NSF to manage the first 18 months of the Deep Sea Drilling Project (DSDP). The D/V *Glomar Challenger* was built especially for this task and began operations in mid-1968. Subsequent extensions and renewals of the Scripps-NSF contract kept *Challenger* at sea until the fall of 1983, when this phase of ocean drilling came to an end.

Although the scientific operation of the drilling ship has changed little over the years, major changes in support and scientific oversight have occurred. From the U.S. side, six additional institutional members have been added to the original JOIDES four: the University of Washington in 1968, the University of Hawaii, Oregon State University, the University of Rhode Island, and Texas A&M University in 1975, and the University of Texas at Austin in 1982. In addition, in 1976, the U.S. institutions formed JOI (Joint Oceanographic Institutions, Inc.), a nonprofit corporation. JOI took over from Scripps the management of the JOIDES scientific advisory structure in 1978 and U.S. site surveys in 1978, thereby resolving a potential conflict of interest between Scripps' role as both the science operator and the contractor responsible for the scientific advice to the operator.

It is clear that the development of the U.S. drilling program was marked by false starts and years of complex negotiations. Even though the scientific goals were widely accepted and the technology was within reach, the self-education of a research community not used to large-scale cooperative research, and the resolution of difficulties introduced by a number of strong personalities at the various institutions took years to achieve. It is doubtful whether the level of cooperation required to launch the DSDP could have been achieved simultaneously at both the national and international levels.

The International Phase of Ocean Drilling

From the very beginning of the DSDP, JOIDES has drawn heavily on the non-U.S. scientific community to participate in the advisory panel discussions that determined the drilling targets. Likewise, non-U.S. participants were prominent in most shipboard scientific parties; for legs 1 through 44 (the U.S.-funded phase of the program) from 1968 to 1975, 141 of 448 shipboard scientists (more than 30 percent) were from other countries.

Thus, by the early 1970s a large community of marine earth scientists from 15 countries outside the United States was well aware of the scientific value of the DSDP, the way it operated and was managed, and the nature of its support.

When it became clear that the United States would have difficulty in providing full funding for the program beyond 1975, these non-U.S. scientists formed a series of knowledgeable pools of expertise able to advise their governments when the United States sought their active participation in the program. As a result, between January 1974 and November 1975, five non-U.S. members joined JOIDES to create the International Phase of Ocean Drilling (IPOD). In each case, negotiations were carried out on a bilateral basis between the NSF and a designated national representative.

USSR. The Soviet participation in JOIDES was formalized by the 1972 U.S.-USSR World Ocean Agreement and Science and Technology Agreement, signed during the Nixon-Kissinger visit to Moscow in 1972. Discussions and letters during the latter part of 1972 and during 1973 led to the signing of a formal Memorandum of Understanding between NSF and the USSR Academy of Sciences in February 1974. The Memorandum, effective January 1, 1974, was for a period of 5 years and was renewed for 9 months (plus close-out costs for FY 1980) in 1979. Subsequent Soviet participation in the program was inhibited by restrictions imposed by the Carter administration following the invasion of Afghanistan and was finally terminated by the Reagan administration's 1982 decision not to renew the U.S.-USSR Science and Technology Agreement.

Federal Republic of Germany (FRG). Negotiations between NSF and its FRG counterpart, the Deutsche Forschungsgemeinschaft (DFG), led to the signing of a 2-year Memorandum of Understanding in July 1974. The Memorandum, effective January 1, 1974, designated the Bundesanstalt fur Geowissenschaften und Rohstoffe (BGR) as the FRG member of JOIDES. The following 3-year Memorandum was signed by the BGR and has been renewed by amendment for three additional 2-year periods.

Japan. In June 1975 NSF signed a Memorandum of Understanding with the Ocean Research Institute (ORI) of the University of Tokyo, by which Japan became a member of JOIDES in August 1975. The initial Memorandum was open ended. A new Memorandum for 1979–1980 was signed when the contribution was increased. This has subsequently been extended by amendment for two additional 2-year periods. Even though ORI is the official Japanese signatory, the funding agency (MONBUSHO) has been an attentive observer during the NSF-ORI negotiations.

United Kingdom. Following the signing of a Memorandum of Understanding between NSF and the Natural Environmental Research Council (NERC) in September 1975, the United Kingdom became a member of JOIDES on October 1, 1975. The initial Memorandum covered 3 years and has been extended to the end of IPOD by three subsequent amendments.

France. France became a member of JOIDES effective November 1, 1975, following the signing of a Memorandum of Understanding between NSF and the Centre National pour l'Exploitation des Oceans (CNEXO). The initial 3-year Memorandum has been extended by three amendments that parallel the FRG and U.K. agreements.

Each of the Memorandums provided the non-U.S. signatory with a number of benefits: membership in the JOIDES Executive and Planning Committees, participation in JOIDES advisory committees, the designation of shipboard scientists, and full access to data and samples. In return, the United States has received annual contributions, initially of $1 million per country per year, increasing to $1.25 million in 1980–1981 and to $2 million per year in 1982–1983.

DISCUSSION

There is virtually unanimous agreement that the DSDP-IPOD drilling program has been an outstanding scientific success. The strong endorsement by the community and National Science Board of a new Ocean Drilling Program, to make use of a larger ship, is a measure of this success. The willingness of non-U.S. JOIDES members to speak in favor of the program and to contribute to IPOD (roughly $50.6 million of $220.6 million through FY 1983) has certainly enhanced the credibility of the scientific arguments.

Benefits

IPOD has allowed the United States access to the best scientists and ideas in the member countries. Background scientific syntheses, site surveys using geophysical techniques not available in U.S. oceanographic institutions, and postcruise analyses of core material, all at no cost to the project, have greatly augmented U.S. contributions and have led to more effective use of the drilling ship. Less tangible, but no less valuable, are the personal relationships developed at sea and ashore between U.S. and non-U.S. scientific participants. These contacts have led to innumerable sabbaticals and study leaves with their inevitable intellectual synergism.

The non-U.S. participants, on the other hand, have gained access to a state-of-the-art scientific tool that they could have afforded with great difficulty, if at all, on their own. They have been able to propose scientific targets and see them drilled as easily as have their U.S. colleagues. The impact of IPOD can be gauged by the number of non-U.S. IPOD scientists participating in *Challenger* cruises. Prior to 1975, 63 scientists from the five partner countries had participated in 44 legs, an average of 1.4 per leg. Subsequently, 272 scientists have participated in legs 45 to 91, for an average of 5.8 per leg. Not only has this created a large pool of earth scientists favorably inclined to international cooperation, but it has also fostered a level of internal cooperation within member countries that did not exist before.

Costs

The formal obligations recognized in the Memorandums of Understanding have resulted in some dampening of the less formal modus operandi of the U.S.-only drilling program. "Targets of opportunity" (often indistinguishable from personal projects of chief scientists or panel chairmen) are drilled much less frequently now than they were early in the program. To some extent, such formalization of the planning process was inevitable as the program matured, but the creation of IPOD accelerated the process. Whether this is good or bad is debatable!

A clear victim of IPOD has been the community of interested scientists whose countries could not afford, or did not choose, to pay the entry price to IPOD. Prior to IPOD (legs 1–44), 78 scientists from such countries sailed on *Challenger* (1.8 per leg). Subsequently, for legs 45 to 91, the number has dropped to 32 (0.7 per leg). One can argue that this is fair—those who pay should benefit. The opposite argument—that a scientific community as small as marine geology and geophysics cannot afford to exclude so many of its peers—has equal merit. The formation of consortia to participate in the new Ocean Drilling Program and the availability of more scientific berths on *Challenger*'s replacement should alleviate this problem in the future.

Why IPOD?

Even though the scientific benefits of international cooperation have been substantial, it is clear that IPOD came into existence primarily because the U.S. program faced serious funding problems. Whether, in the absence of such a need, the program would continue or an analogous one could be created is debatable. Individual U.S. scientists pay a price for IPOD through reduced numbers of berths on the *Challenger* and fewer U.S.-designated drill sites. Whether the intellectual benefits of international cooperation offset or are perceived to offset these costs is unknown and may be unknowable (since the control situation does not exist).

Adequacy of Agreements

The creation of IPOD through a series of bilateral agreements, rather than a multilateral agreement or treaty, has proven to be remarkably successful. For example:

- It has allowed for the Soviet dropout with minimal disadvantage for the other partners.
- It has allowed wording in individual Memorandums to be tailored to home audiences (for improved salability) without compromising the basic scientific and organizational goals.
- It has allowed NSF to deal with an extremely diverse suite of organizations. For comparison, the equivalent diversity within the United States would require an organization to negotiate bilaterals with the National Science Foundation (the analog of DFG and NERC), the National Oceanic and Atmospheric Administration (the analog of CNEXO), the U.S. Geological Survey (the analog of BGR), the National Academy of Sciences (the analog of the USSR Academy), and a research institute at a major university (the analog of ORI, at the University of Tokyo).
- It has allowed NSF to deal with the vicissitudes of each country's national budget cycle on a case-by-case basis.
- And, perhaps most importantly, it has kept active scientists on both sides very close to the negotiations. As a result, virtually all U.S. and non-U.S. scientists perceive that IPOD works for them, rather than the reverse.

There is little doubt that NSF's job would be easier if all bilaterals were identical, particularly with regard to funding cycles. The lack of such uniformity seems a small price to pay for a productive program, however.

Operational and Scientific Interactions

The Memorandums of Understanding created a legal framework for IPOD, but the successful execution of the program has depended largely on JOIDES. Several factors account for JOIDES's remarkable success.

1. The basic structure is sound. The hierarchy of problem-oriented panels reporting to a Planning Committee of experienced scientists who make the operational decisions and who in turn report to an Executive Committee of institutional heads who make policy decisions has proven able to handle almost any scientific, technical, or policy problem.

2. Institutional nominations, particularly to the Planning Committee, have consistently allowed effective, senior, active scientists from each country to make the scientific decisions. These people care about the program and have done the hard work required to make it function and to justify and defend it before their peers and the funding agencies.

3. Both U.S. and non-U.S. members have consistently sent senior scientific administrators to Executive Committee meetings. These individuals have had the authority to make major commitments on behalf of their institutions and countries. They have been able to resolve many policy issues without having to seek approval from their parent organizations. The long tenure of several key Executive Committee members, notably Jacques Debyser from France and Nori Nasu from Japan, have given the committee a corporate memory and developed a level of mutual trust among its members that have allowed it to resolve nationally sensitive issues expeditiously and without rancor. The creative tension between the more conservative Executive Committee and the less inhibited Planning Committee has been particularly useful in exposing all aspects of many thorny problems to vigorous debate.

THE FUTURE

The proposed new Ocean Drilling Program (ODP), a 10-year plan for scientific ocean drilling from a larger and more sophisticated ship, will again require international support for its long-term success. The United States is planning to fund the preparation of the ship over a 1-year hiatus in drilling during FY 1984 and probably can fund the initiation of drilling in FY 1985. During this initial period, NSF will have to move rapidly to negotiate bilaterals, not only with the four currently active IPOD partners, but with one or two new members (perhaps consortia). The long-term U.S. commitment, in principle, to the ODP, which never existed for IPOD, should facilitate international agreements.

CONCLUSION

The creation of IPOD was enormously simplified by the existence of a successful drilling program (DSDP). This allowed non-U.S. members to "buy into" a technically proven and scientifically productive program with minimal risk. The existence of a large community of interested, knowledgeable scientists in each prospective member country provided the funding agencies with a ready source of information on the value of the program. Finally, in the case of the USSR, the existence of very-high-level diplomatic agreements on marine science provided an umbrella for the bilateral negotiations. Subsequent events have shown, however, that the removal of such umbrellas can be as destructive to scientific cooperation at the operational level as their creation is constructive.

The creation of IPOD may have been possible in the absence of either an established U.S. program or strong national scientific lobbies. It would almost certainly have been impossible in the absence of both.

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Cooperative Efforts in Development of Safety Guidelines for Recombinant DNA Research

William J. Gartland, Jr.

GUIDELINES FOR RECOMBINANT DNA RESEARCH

Guidelines of the National Institutes of Health (NIH)

Recombinant DNA is a technique that allows deoxyribonucleic acid (DNA) from different organisms to be joined together in the test tube and subsequently propagated in a living cell.

Participants at a Gordon Conference on Nucleic Acids in July 1973 sent a letter to the U.S. National Academy of Sciences (NAS) asking the academy to establish a study committee to consider the problems posed by recombinant DNA research and to recommend specific actions or guidelines. This letter appeared in *Science* in July 1973.[1]

The NAS formed a Committee on Recombinant DNA Molecules that issued a report that was published in several journals in 1974.[2] The report requested that:

1. *certain* experiments be voluntarily deferred;
2. plans to construct recombinants with animal DNAs be carefully weighed;
3. the Director, NIH, establish a committee (now the Recombinant DNA Advisory Committee to:
   a. oversee a program to evaluate hypothetical risks,

b. develop procedures to minimize the spread of recombinant DNA molecules,

c. recommend guidelines to be followed by investigators; and

4. an international meeting be convened to review progress and discuss ways to deal with potential hazards.

The international conference took place at the Asilomar Conference Center in California in February 1975.[3] The conference concluded that most recombinant DNA experiments should proceed, provided that appropriate biological and physical containment is utilized. The conference report made general recommendations for matching levels of containment with levels of hypothetical hazard for various types of experiments. The NIH was then called upon to translate the broadly based Asilomar recommendations into detailed guidelines for research.

The NIH established the Recombinant DNA Advisory Committee (RAC) in response to the request of the National Academy of Sciences. The committee held its first meeting the day after the Asilomar conference, followed by a series of meetings during 1975 and in early 1976. The original NIH Guidelines were issued on June 23, 1976, and published in the *Federal Register* on July 7, 1976.[4] The guidelines specify safeguards to be utilized in the course of experiments; these safeguards are provided by different levels of physical and biological containment. Physical containment relies upon:

- a set of standard laboratory practices
- special procedures, equipment and laboratory installations that provide physical barriers

Physical containment is divided into four levels, designated P1, P2, P3, and P4, with P1 the lowest level and P4 the highest.

The guidelines specify three levels of biological containment. The goals of biological containment are to:

- minimize the survival of recombinant DNA in the host organism outside the laboratory,
- minimize the transmission of recombinant DNA from the laboratory to other nonlaboratory hosts.

Having described levels of containment, the guidelines then specify different levels of physical and biological containment for different classes of recombinant DNA experiments based on the assessed hypothetical hazard of the experiment. The guidelines also specify certain administrative requirements under the "Roles and Responsibilities" section.

United Kingdom Guidelines

In January 1975 a report entitled "Report of the Working Party on the Experimental Manipulation of the Genetic Composition of Microorganisms" was presented to Parliament in the United Kingdom. The Working Party was charged with making an assessment of the potential benefits and potential hazards of techniques that allow manipulation of the genetic composition of microorganisms. This group was not charged with preparing a code of practice. This report, also known as the Ashby Report, after the group's chairman, Lord Ashby, concluded in part:

"... After careful questioning of experts in the field, we are convinced that the hazards are less serious than some of us first thought, and we are satisfied that there are ways to reduce them to levels far lower than other hazards which the public currently accepts without question.

In August 1976 the "Report of the Working Party on the Practice of Genetic Manipulation," also known as the Williams Report, was presented to Parliament. The Working Party in this instance was appointed to follow up the recommendations of the Ashby Report, and, in particular, to draft a code of practice, and to make recommendations on the establishment of a central advisory body. The report concluded that work in this field should be carried out under appropriate containment conditions, and it categorized experiments.

The Williams Report differed from the NIH Guidelines in several ways. It differed in technical details, such as the description of physical containment levels. The Williams Report placed greater emphasis on physical containment rather than biological containment. It also differed in administrative procedures for implementation.

The Williams Report favored a flexible approach to containment and considered that this could best be provided by requiring investigators to submit experimental protocols to a central advisory group, the Genetic Manipulation Advisory Group (GMAG), for advice on appropriate safety precautions, rather than by imposing rigid guidelines. In other words, the GMAG would decide the precise containment levels for specific experiments, and the categorization of experiments in the Williams Report was intended as a guide to assist the initial deliberations of the GMAG. It was envisioned that the GMAG decisions would quickly build up into a body of case law.

Efforts at Harmonization of Guidelines

European Molecular Biology Organization. The European Molecular Biology Organization (EMBO), which is a scientific organization located in Heidelberg, Federal Republic of Germany, established a Standing Advisory Committee on Recombinant DNA. In September 1976, that committee held its second meeting to consider the NIH Guidelines and the Williams Report, to compare their technical recommendations and to comment on their suitability as a basis for a common policy toward recombinant DNA research in Europe. The EMBO committee noted that the standards of physical containment recommended by the Williams Report were generally more stringent than those recommended by the NIH, while in the NIH Guidelines, systems of biological containment received heavier emphasis.

The EMBO committee recommended the establishment of national advisory groups and that these groups be responsible for specifying containment levels for experiments. The committee recommended that both the NIH Guidelines and the Williams Report offer adequate safeguards against conjectural hazards and that containment procedures for each particular experiment might be those proposed in the NIH Guidelines or those in the Williams Report.

European Science Foundation. The European Science Foundation (ESF) is an international nongovernmental organization, founded in 1974, with its seat in Strasbourg, France. Members are academies and research councils that are responsible for supporting scientific research at a national level and are funded largely from government sources.

In October 1976 an ESF Ad Hoc Committee on Recombinant DNA Research made a series of recommendations. It recommended that, initially, the recommendations and code of practice in the U.K. "Report of the Working Party on the Practice of Genetic Manipulation" be adopted as the guidelines in Europe. It recommended that national advisory bodies with responsibilities for interpreting the recommendations and code of practice should be established in the European countries. Its final recommendation was the establishment of an ESF Liaison Committee for Recombinant DNA Research composed of representatives of the national committees to provide an opportunity for mutual information, consultation, and advice on general policy for recombinant DNA research and for the discussion of decisions on specific experiments. One of the primary purposes of the committee was to attempt to ensure that the same levels of containment were used in the different countries for the same categories of experiments, so that the same experiments were not classified as differing in level of risk, and hence level of containment, in the different countries. One member of the various national committees was invited to serve on the Liaison Committee. The representatives in general had backgrounds in the biological sciences, although a small number of additional experts in law and other disciplines were invited.

Countries with representatives on the committee included: Austria, Belgium, Canada, Denmark, Federal Republic of Germany, France, Greece, Ireland, Italy, the Netherlands, Norway, Portugal, Sweden, Switzerland, the United Kingdom, the United States, and Yugoslavia. Organizations with representatives on the committee were the European Economic Community, the European Medical Research Councils, and the European Molecular Biology Organization.

The ESF Liaison Committee met six times during the period from March 1977 to January 1981. Scientific aspects considered by the committee included host-vector systems authorized for recombinant DNA experiments, availability of physical containment facilities, risk-assessment experiments, and containment levels set for particular experiments. Policy issues considered by the committee included information on national guidelines, the status and terms of reference of national advisory committees, patent law, national legislation, personal responsibility for laboratory safety, and responsibility in case of accidents.

The NIH very much wished to see comparable, although not necessarily identical, guidelines adopted by the major countries conducting recombinant DNA research. This was particularly true because recombinant DNA technology posed conjectured hazards as opposed to known hazards in other fields, such as the handling of pathogenic organisms. Significant differences in the stringency of national guidelines could lead to displacements in which scientists would conduct their work in countries with more lenient guidelines. This would be particularly true if there were cases in which some countries required the use of high-containment laboratories for a particular experiment, while other countries set containment for the same experiment at a lower level. High-containment facilities are scarce. In the United States, there have been only one or two high-containment (P4) laboratories available for the conduct of recombinant DNA experiments.

Although the conclusions and recommendations of the ESF Liaison Committee were not binding on any of its members, the committee greatly facilitated comparability in several areas. One area was in the categorization of experiments. Representatives of the national advisory committees exchanged information on new host-vector systems being approved and on containment levels being assigned for specific experiments. Initially, members were particularly interested in decisions being made by the two major committees, the U.K. GMAG and the NIH RAC. This information influenced decisions that would later be made by the other national committees throughout Europe.

Another area that the committee facilitated was the worldwide revision of guidelines. Approximately 2½ years passed between the issuance of the original NIH Guidelines in June 1976 and their first major revision in December 1978.[5] In 1977, the RAC began the process of revising the original guidelines on the basis of information accumulated on the effectiveness of physical and biological containment and on the biology of the hosts and vectors utilized in the research. During this period, a series of scientific and public meetings demonstrated the existence of a consensus that the NIH Guidelines were overly restrictive. Subsequent major revisions of the guidelines were issued in January and November 1980, July 1981, April and August 1982, and June 1983.[6–11] These revisions resulted in significant reductions in the stringency of required containment levels. The revisions were justified by the results of risk-assessment studies, by reassessment of the conjectured hazards, and by the confidence instilled by the safe conduct of thousands of experiments. As these revisions were under consideration in the United States, detailed information on them and their justification was shared with members of the ESF committee, and this information influenced decisions on revision of national guidelines by the various countries.

The original ESF Ad Hoc Committee on Recombinant DNA Research had recommended that initially the recommendations and code of practice in the U.K. Report of the Working Party on Genetic Manipulation be adopted as the guidelines for recombinant DNA research in Europe. However, as time passed, more and more of the European countries found it more desirable to adopt the evolving NIH Guidelines rather than to rely on a complicated case law approach. Several of the European countries decided to follow directly the NIH Guidelines as published in the *Federal Register*, without translation. Other countries drafted national guidelines modeled on those of the NIH or the United Kingdom. As a result, similar safety standards were in effect in all the countries represented on the ESF Liaison Committee.

The following paragraph appeared in a statement adopted after this committee's fifth meeting:

> Based on its discussions of principles and case decisions taken by national recombinant DNA committees, the Liaison Committee concluded that throughout Europe and in North America national guidelines provide comparable degrees of protection to the public and to laboratory staff from the entirely conjectural hazards of this research, while at the same time progressively facilitating the opportunities for European academic and industrial laboratories to exploit the now evident benefits of this technique.

After its final meeting, the committee issued, in part, the following statement:

> The ESF Liaison Committee on Recombinant DNA, at its meeting on 14–15th January, 1981, unanimously decided that its work of promoting the necessary harmoni-

sation of national recombinant DNA guidelines is now sufficiently complete for the Liaison Committee to be disbanded. Although the national guidelines of some countries are still evolving towards the position already reached by others, the Committee believes that there is no further need for formal and regular liaison at the ESF between representatives of national recombinant DNA committees.

Through participation in the ESF Liaison Committee, the United States was able to play a significant role in promoting comparable safety guidelines for recombinant DNA research. The costs to it were very small, amounting to those of sending a representative of the NIH to six meetings in Strasbourg.

Committee on Genetic Experimentation (COGENE). The Committee on Genetic Experimentation (COGENE) is a scientific committee of the International Council of Scientific Unions (ICSU). ICSU is an international nongovernmental scientific organization of 18 autonomous international scientific unions and more than 60 national members, i.e., academies of science, research councils, or similar scientific institutions. COGENE, formed in 1977, has among its purposes the following:

1. review, evaluate, and make available information on the practical and scientific benefits, safeguards, containment facilities, and other technical matters;
2. consider environmental, health-related, and other consequences of any disposal of biological agents constructed by recombinant DNA techniques;
3. foster opportunities for training and international exchange; and
4. provide a forum through which interested national, regional and other international bodies may communicate.

COGENE initially established three working groups in the areas of guidelines for research on recombinant DNA, risk-assessment experiments, and training and education.

The Working Group on Recombinant DNA Guidelines was established in May 1977. It was charged with the responsibility of: (1) obtaining information about the status and content of recombinant DNA guidelines in different nations, and (2) analyzing, comparing, and evaluating the provisions of the various national guidelines and the premises on which these provisions were based.

The Working Group proceeded by distributing a questionnaire to scientific representatives of each nation in which recombinant DNA research was being conducted and/or guidelines were being considered. By April 1978 it had received completed questionnaires and/or copies of national guidelines from 39 countries having scientific societies affiliated with ICSU. Based on analysis of these documents, it submitted its first report to COGENE in March 1979. Because of changes that had occurred in the status or content of the guidelines of a number of nations, the Working Group issued a draft report rather than a formal document.

The information indicated that at the end of March 1978, approximately 365 recombinant DNA projects were estimated to be under way in 180 laboratories in 20 countries. Twenty nations had drawn up guidelines for recombinant DNA experimentation. Of these, five had developed their own guidelines, while the remainder adopted or modified guidelines of the United States or the United Kingdom. The Working Group issued an updated report in 1980 to take into account revisions of the various national guidelines.

U.S.-JAPAN COOPERATIVE PROGRAM FOR RECOMBINANT DNA RESEARCH

The basis for the U.S.-Japan Cooperative Program for Recombinant DNA Research is the U.S.-Japan Agreement for Cooperation in Research and Development in Science and Technology signed by President Carter and Prime Minister Ohira in May 1980. Recombinant DNA is one of many areas of mutual interest that was included. The first meeting of the program was convened in February 1981 to exchange information on national guidelines, host-vector systems, and risk-assessment considerations. At that meeting, it was agreed that there would be a Japanese liaison representative to the NIH RAC. As a liaison representative, the Japanese representative would receive all materials distributed to voting members of the RAC, as well as minutes of meetings and other mailings.

Guidelines for recombinant DNA research had been developed by the Science Council of the Japanese Ministry of Education in November 1978 and promulgated in March 1979. The first Japanese guidelines were similar to the original 1976 NIH Guidelines. As mentioned earlier, the first revision of the NIH Guidelines, accompanied by some significant changes in containment requirements, was issued in December 1978.[5] The Japanese had adopted as their first guidelines standards that were more stringent than those in effect in the United States. The Japanese government appointed a committee to review the 1979 guidelines in light of developments that were taking place in the United States. As part of this review, the Japanese government in August 1981 invited the director, NIH Office of Recombinant DNA Activities, to present talks on the NIH Guidelines and their history to the Ministry of Education and several other research institutions throughout Japan. These talks provided direct contact between a representative of the NIH and members of the Japanese committee with responsibility for reviewing the guidelines. In August 1982, revised Japanese guidelines, largely comparable to the then current NIH Guidelines, were issued.

ORGANIZATION FOR ECONOMIC COOPERATION AND DEVELOPMENT (OECD)

Following a recommendation in an OECD report, "Biotechnology-International Trends and Perspectives," the OECD Committee for Scientific and Technological Policy requested OECD staff to undertake a study on the problems of safety and regulations in biotechnology. The purpose of the study is to provide governments with an analysis of the safety problems that may arise from the developments of biotechnology, especially in large-scale industrial applications, and of the implications these would have for regulatory and other government policies. As a preliminary step in the preparation of the study, OECD staff prepared a paper that attempted to identify the relevant problems at the different levels of research, of industrial production, and of application in the open environment.

The OECD held a meeting in December 1982 to discuss how such a study should be conducted. A representative of NIH chaired the meeting, the purpose of which was to assist OECD staff to review the main issues related to safety and regulations, to identify particular risks and/or problems related to research and production, and to suggest a priority order of activities OECD should consider.

The Committee for Scientific and Technological Policy in June 1983 agreed to establish a group of government experts on safety and regulations in biotechnology. The group is charged with reviewing country positions as to the safety of genetically engineered organisms at the industrial, agricultural, and environmental levels against the background of existing or planned legislation and regulations for the handling of microorganisms.

In particular, the group is being asked to identify what criteria have been or may be adopted for the monitoring or authorization for production and use of genetically engineered organisms in industry, agriculture, and the environment. It is being asked to explore possible ways and means for monitoring future production and use of genetically engineered organisms in industry, agriculture, and the environment.

The group, which held its first meeting in December 1983, is to complete a report before June 1985. The United States, with the Environmental Protection Agency taking responsibility, has agreed to be responsible for assembling information on guidelines and regulations governing release into the environment of genetically engineered organisms. The Netherlands has agreed to be responsible for reviewing guidelines and regulations for large-scale applications. The OECD views this work as a step toward better international harmonization of guidelines, codes of practice, and/or regulations.

CONCLUSIONS

The United States has had from the beginning the largest number of scientific investigators involved in recombinant DNA technology. U.S. scientists first raised concerns about the hypothetical hazards of the new technology. The NIH adopted a completely open process for the safety guidelines, one that was watched closely by the rest of the world. Because of the openness of this process, as opposed to that of the GMAG, which meets in closed session, the NIH Guidelines were scrutinized carefully by other countries. The NIH felt a responsibility to encourage the adoption of similar, although not necessarily identical, guidelines throughout the world. This would ensure that scientific, and particularly biomedical, research would proceed with minimal constraints consistent with the current assessment of the hazard. One aspect of this is the free exchange of scientific materials among investigators throughout the world.

The costs to the United States for this cooperation have been relatively small. To costs associated with attendance at meetings there should be added the expenses of preparing the public record of NIH decision making, which is documented in a seven-volume series entitled *Recombinant DNA Research*, published by NIH.

As recombinant DNA technology reaches the stage of being applied, second-generation problems will arise, such as the release of genetically engineered organisms into the environment and the ethical and social issues of human gene therapy. The NIH hopes to continue to play a role in the discussion of these new issues. NIH participation in the OECD study on safety and regulations in biotechnology is one such example.

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Discussion

Workshop participants discussed a variety of examples of successful multilateral S&T cooperation. It was pointed out that the *Global Atmospheric Research Project (GARP)* is one of the most successful international programs in geophysics ever undertaken. GARP arose out of unique political and scientific circumstances in the early 1960s, and control of the project was dominated by a small number of developed countries, led by their weather services. It not only demonstrated the possibilities for international cooperation, but it also brought together in new ways the scientific disciplines of oceanography and meteorology. It provided proof that it was possible to conduct practical field programs in special environments with international scientific teams, and this set the stage for further work.

Some of the elements of GARP's success may be transferable to other types of S&T cooperation. First, the program managed to preserve its scientific integrity throughout its lifetime. There was never any question that critical decisions were made primarily on the basis of science, although the political support the project received from successive U.S. presidents also was important. Second, there was a carefully designed institutional arrangement, involving both WMO and ICSU, and an independently funded joint planning staff along with supporting committees in individual countries that provided scientific input and political support. Thus, the most transferable lesson from GARP was the possibility of establishing a long-lasting intergovernmental arrangement that draws on the strengths of all participating nations while minimizing the weaknesses of international organizations and preserving the integrity and efficiency of the project.

A second cooperative multilateral model discussed was the *International Phase of Ocean Drilling (IPOD)*, which grew out of extensive prior international cooperation in oceanography that originated with the International Geophysical Year (IGY). These early activities involved the coordination of activities and some sharing of facilities, but very little exchange or sharing of financial resources. The actual internationalization of the drilling effort occurred when funding problems within the United States caused a reorganization of the project, eventually leading to participation in the form of $1 million contributions by West Germany, Japan, France, and the United Kingdom. Subsequently, the Soviet Union also became a participant as a result of a bilateral S&T agreement signed with the United States in 1972.

Several features facilitated the quick and effective establishment of IPOD. The first was that the non-U.S. members were "buying in" to an extant U.S. program with an established calendar of activities and broad-based advisory structure in place. In addition, a large number of foreign nationals had sailed aboard the drilling vessel during the U.S. phase, so that by the advent of the IPOD, the international oceanographic community was highly knowledgeable. Second, government-to-government discussions were buttressed by an influential scientific lobby who knew that the program worked. Third, NSF was able to deal flexibly in developing the necessary bilateral agreements with both "pure science" and "mission-oriented" agencies and a strong scientific advisory network also was developed independent of the formal bilateral agreements.

Although the structure has worked, there also have been problems. For one thing, Soviet participation in the joint project was terminated in the wake of its invasion of Afghanistan, purely on the basis of political exigencies, without a compensating increase in the contributions of other IPOD participants. Second, the U.S. commitment has been perceived as being of a short-term, political nature, which has caused some irritation in the other countries. Third, U.S. resources have gone disproportionately to the logistical side of the operation (i.e., to keep the ship at sea) as opposed to the science, a situation that was not true of other IPOD members.

The situation at present is that the current international arrangement has now come to an end. However, the National Science Board and the various advisory units of all the joint programs have made a 10-year commitment in principle to the program, which should make it far easier for the other countries participating to approach their governments for long-term funding. Ideally, the non-U.S. contribution should approach 50 percent, but there is presently no legal entity that makes this possible. It may be necessary, therefore, for a new mechanism to be created.

A third type of multilateral cooperative effort discussed in the workshop, *the development of recombinant DNA guidelines*, was of a somewhat different nature; it concerned cooperation for the purposes of regulation rather than to achieve new scientific progress. The issue arose as a result of parallel efforts during 1976 in the United States, the United Kingdom, and elsewhere in Europe to develop safety guidelines for the conduct of rDNA research. Establishment of standards involving public health considerations is a complex and politically charged undertaking under any circumstances, but the effort to develop uniform national policies is even more difficult. In this case, the proposed British guidelines were more flexible than those proposed by the NIH. In October 1976, the European Science Foundation (ESF) convened a workshop on DNA research that recommended that the member countries adopt the British code of practice.

The ESF also recommended that there be established a liaison committee composed of representatives of the different national committees intended to promote the exchange of information and consultation on policies and procedures. Seventeen countries, including the United States and Canada, were represented on this committee which met six times between 1977 and 1981. Partially as a result of the consultation, the U.S. guidelines underwent a process of revision that led to a significant reduction in the stringency of required containment levels. Moreover, as time passed, a number of the European countries found it more desirable to adopt the NIH guidelines rather than those of the British.

Since 1980, there has also been a cooperative U.S.-Japan program on DNA research. The Japanese issued their first DNA research guidelines, which were quite similar to the 1976 NIH guidelines, in 1979. These were revised subsequently and a new set of guidelines issued in August 1982. There also have been a series of four successful U.S.-Japan scientific workshops on DNA research held under the cooperative agreement.

The OECD also has been active in the area of biotechnology and DNA research, recently issuing a report entitled "Biotechnology: International Trends and Perspectives." As a result of this report, the OECD Committee on Science and Technology Policy (COST) requested the OECD staff to undertake a study of the problems of safety and regulation of biotechnology, particularly dealing with large-scale production of genetically engineered organisms released into the environment. In June 1983, the COST approved the establishment of an expert group on safety and regulation in biotechnology, which will likely have representation from both the NIH and the Environmental Protection Agency.

There was further discussion in the workshop of the role of the ICSU committee known as the Committee on Genetic Experimentation (COGENE) in building consensus on guidelines for DNA research. The COGENE activities were undertaken in parallel with the NIH and ESF efforts and involved consultation with UNESCO and the World Health Organization. This has now led to a series of training courses and symposia for developing countries dealing with biotechnology and safeguarding the environment.

Competing Objectives and Pressures on U.S. Science and Technology Policy

Graduate Student and Postdoctoral International Exchanges of U.S. Scientists

Philip W. Hemily

INTRODUCTION

The year is 1927. Picture a recent doctoral graduate arriving in Copenhagen, taking the tram to the Niels Bohr Institute, ringing the bell, announcing "I am Isidor Rabi. I have come here to do research." He was, of course, welcomed to join the bright, exciting group of young scientists working in close collaboration in this world-famous international setting. This was a major benchmark in his emerging illustrious career as a teacher and researcher at the frontiers of physics and as a public servant at the national and international levels—adviser to presidents, governmental agencies, and the Congress, promoter and spirit behind the NATO science program, the Atoms for Peace program, the establishment of the International Atomic Energy Agency (IAEA), and so many other activities of benefit to this nation and the world scientific community.

During the first three decades of this century, it was pretty much taken for granted that bright promising American scientists like young Rabi would seek out and participate in Western European research activities through doctoral and postdoctoral training. This was the time when the Solvay conferences and other colloquia in a broad range of fields were evolving; when the center of the scientific universe was a select group of universities and research institutes in Western Europe; when this network was being extended to a few promising centers in North America. It was a time of ferment, excitement, and evolution within a scientific community without national frontiers. Totalitarian regimes in Europe subsequently led to an influx of scientific leaders to the United States; World War II provided a great impetus for further advances in science and technology. The center of the scientific universe shifted more and more to North America. Still, the traditions and values of the great centers of training and research in Western Europe remained attractive to young American scientists in the postwar years. And U.S. governmental agencies, particularly those concerned with defense and health matters, supported the research and training of European scientists. The International Scientific Unions were strengthened and provided increased leadership in organizing and managing cooperative international research programs. New governmental institutions and associations were established: the Organisation for Economic Co-operation and Development (OECD), the North Atlantic Treaty Organization (NATO), and the European Communities, providing a basis for a broadened international community of scientists that today encompasses the advanced countries of North America, Europe, and the Far East.

For any given country, the interdependence between the domestic elements and particularly the foreign elements of the scientific community is critical. The capacity of its graduate and postdoctoral scientists and engineers to benefit from lively cooperative and competitive cross-country interaction is dependent on the competence of the domestic research and training system that has earlier shaped them. And, at the same time, the dynamism of that system continually draws on feedback from its own scientific "returnees" and on interaction with the foreign fellows in its own laboratories.

Lively reciprocity is a key factor in the exchange. But, over the past quarter century a number of inhibiting factors have appeared on the U.S. scene that discourage international mobility—in contrast to that first half of the century when the United States drew heavily on the Western European scientific community. It is a truism to say that, with the world scientific and technological community based on widespread interactions, we cannot afford to draw away from stimulating and supporting our graduate and postdoctoral scientists to initiate careers abroad. Enhanced by the challenges of working with foreign colleagues, these people are prime candidates for leadership in our academic, governmental, and industrial institutions.

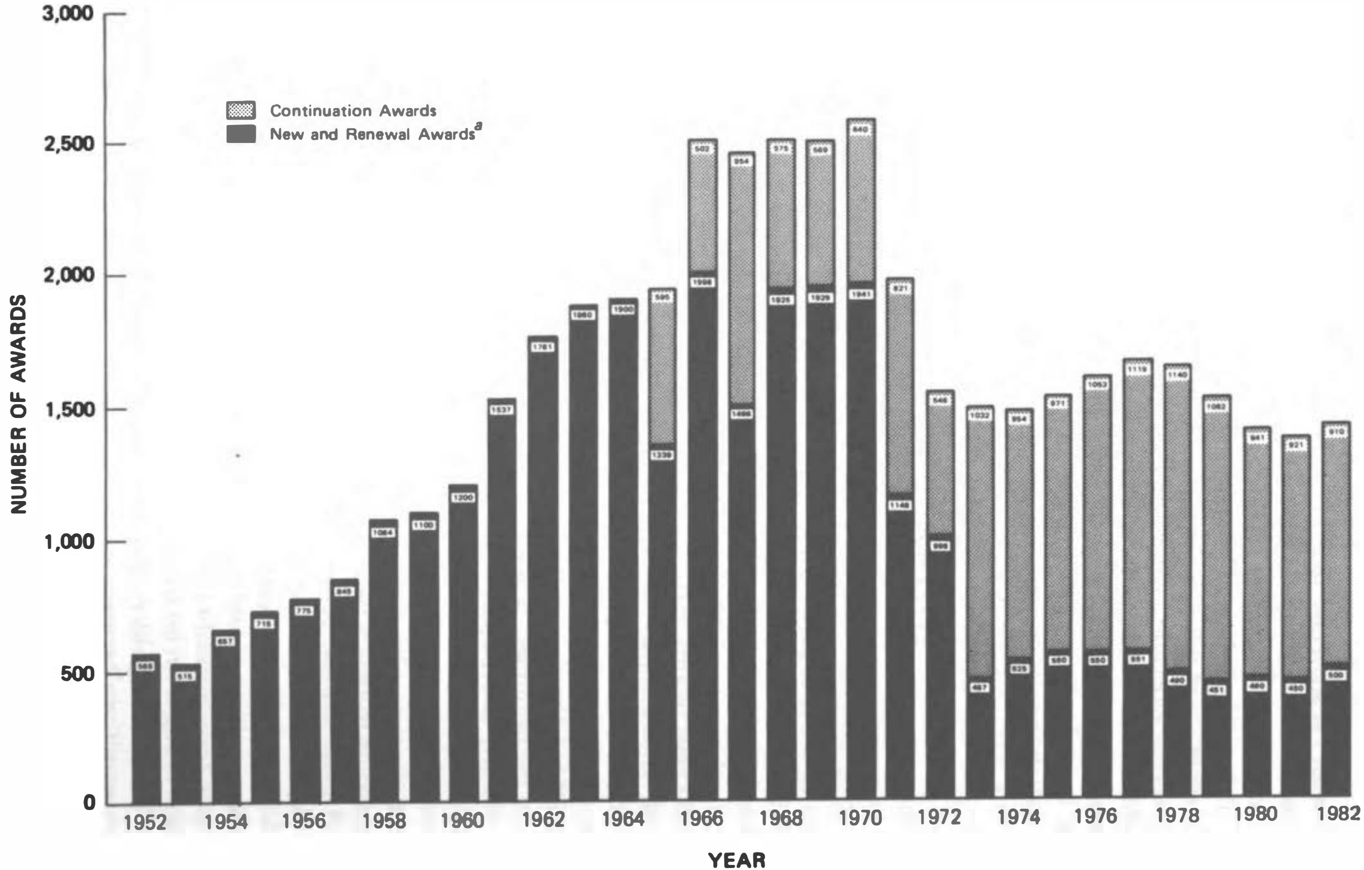
Within this perspective we shall trace through some of the factors influencing U.S. graduate student and postdoctoral exchanges in the natural sciences during the past 30 years. Particular attention will be given to National Science Foundation (NSF) programs and the Fulbright Senior Scholar Program, as well as to activities sponsored by the NATO Science Committee in order to highlight trends, benefits, and needs. We shall examine the international aspects of graduate and postdoctoral fellowship developments as well as short-term tutorial schemes and collaborative research activities involving young scientists. This will be followed by some general considerations on international mobility of young scientists and engineers. The emphasis here, as in preceding decades, will be on the person-to-person contact established in the researcher's early years. The enduring relationships developed by researchers in their early years, moreover, provide the basis for effective participation in all other modes of fruitful international science and technology cooperation during ensuing years.

FELLOWSHIP PROGRAMS

NSF Graduate Fellowships

One of the first major programs implemented by the newly established NSF in 1952 was the graduate fellowship program for predoctoral-level science students. This program experienced a range of pressures in the ensuing 30 years, but has consistently provided some 450–550 new awards each year. A near doubling of these awards (including renewals) was experienced during the 1960–1970 period under the influence of the post-Sputnik increase in foundation budgets. Thus, total annual awards, including continuation awards, grew to the 2,500 level by the year 1970, tapering off to the current 1,400 level.

From the beginning, a small number of NSF graduate fellows chose quite readily to study in centers of excellence abroad, mainly in the United Kingdom, France, Germany, and Canada. Figure 1 and Table 1 show that there were from 20 to 50 such fellows per year in foreign institutions throughout the first 20 years of the graduate fellowship program, or from 1.5 percent to 5 percent of all fellows. Data from NSF Annual Reports present an unexplained aberration in 1956 with 95 (8.4 percent) of fellows going to foreign institutions. The numbers of fellows attending foreign institutions fell off significantly beginning in 1974 to a large extent because of the discouraging restrictive rule requiring special justification for tenure in foreign institutions—a restriction brought on by Congress's concern, at the time, with a weakening dollar and gold outflow. Then, in 1981, this fellowship program, as well as all science education activities of the foundation, was doomed to cancellation through the policy of the administration at that time. The graduate fellowship program was, however, maintained through the concern of the Congress. At the same time, other



[a]Prior to 1973, black represents New and Renewal Awards combined; beginning with 1973, black represents only New Awards (Renewal Awards were made on the basis of NRC recommendation... by the fellowship institution).

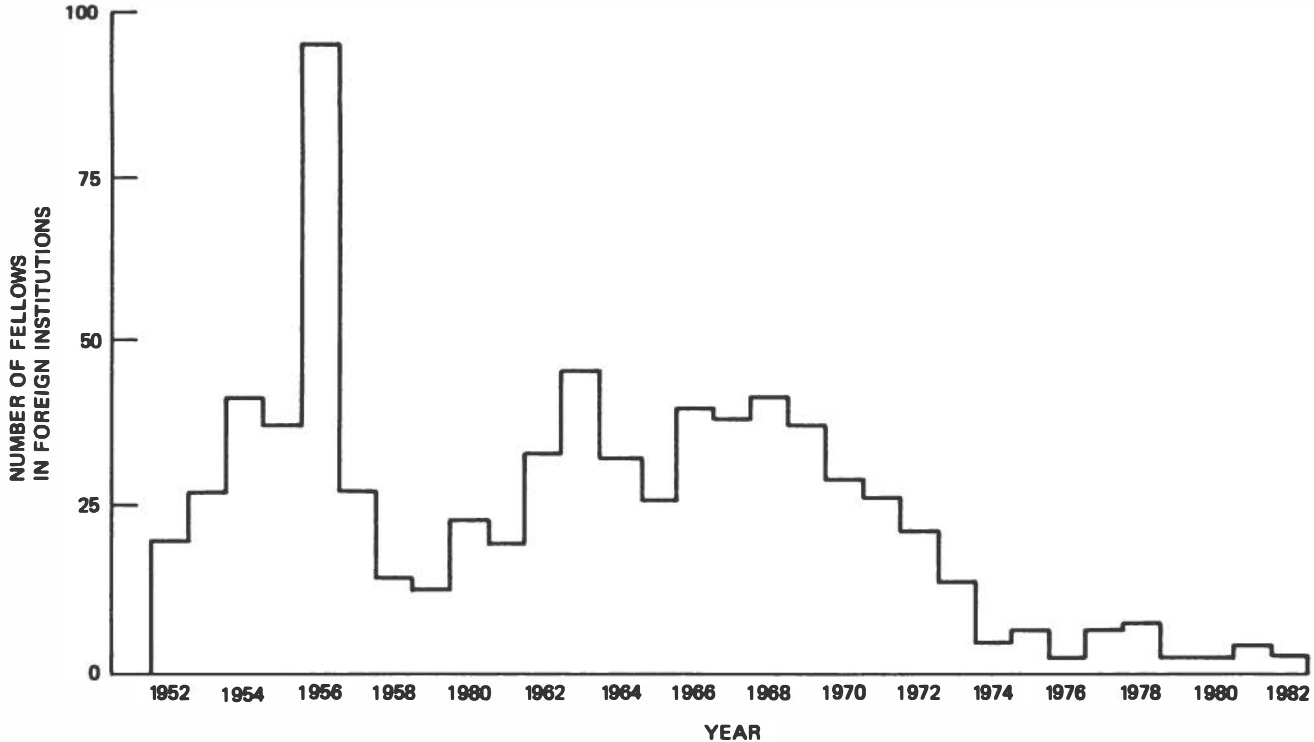


FIGURE 1 NSF Graduate Fellowship Program Awards, 1952–1982, and international participation in the program.

TABLE 1 NSF Graduate Fellowship Program, 1952–1982

Year	Total Awards Offered (No.)[a]	Grad. Fellows in Schools (No.)[b]	Grad. Fellows in Foreign Inst. (No.)[b]	Grad. Fellows in Foreign Inst. (%)
1952	569	575	20	3.5
1953	514	680	26	3.8
1954	657	913	42	4.6
1955	715	914	37	4.1
1956	773	1,133	95	8.4
1957	849	958	27	2.8
1958	1,081	939	15	1.6
1959	1,100	1,100	13	1.2
1960	1,200	1,198	24	2.0
1961	1,537	1,443	20	1.4
1962	1,760	1,761	34	1.9
1963	1,880	1,880	47	2.5
1964	1,900	1,900	33	1.7
1965	1,934	1,934	27	1.4
1966	2,500	2,500	40	1.6
1967	2,450	2,450	39	1.6
1968	2,500	2,500	42	1.7
1969	2,498	2,500	38	1.5
1970	2,581	2,582	30	1.2
1971	1,969	1,972	27	1.4
1972	1,738	1,550	22	1.4
1973	1,489	994	14	1.4
1974	1,479	581	5	0.9
1975	1,521	576	7	1.2
1976	1,603	550	3	0.6
1977	1,670	550	7	1.3
1978	1,630	490	8	1.6
1979	1,513	451	3	0.7
1980	1,401	463	3	0.6
1981	1,371	450	5	1.1
1982	1,410	500	4	0.8
1983		450	4	

[a]NSF Graduate Fellowship Program Table 1: New Applicants, New Awards, Success Rate of New Applicants—Total Awards Offered and Total Obligations by Year, 1952–1982, from NSF staff, June 1983.

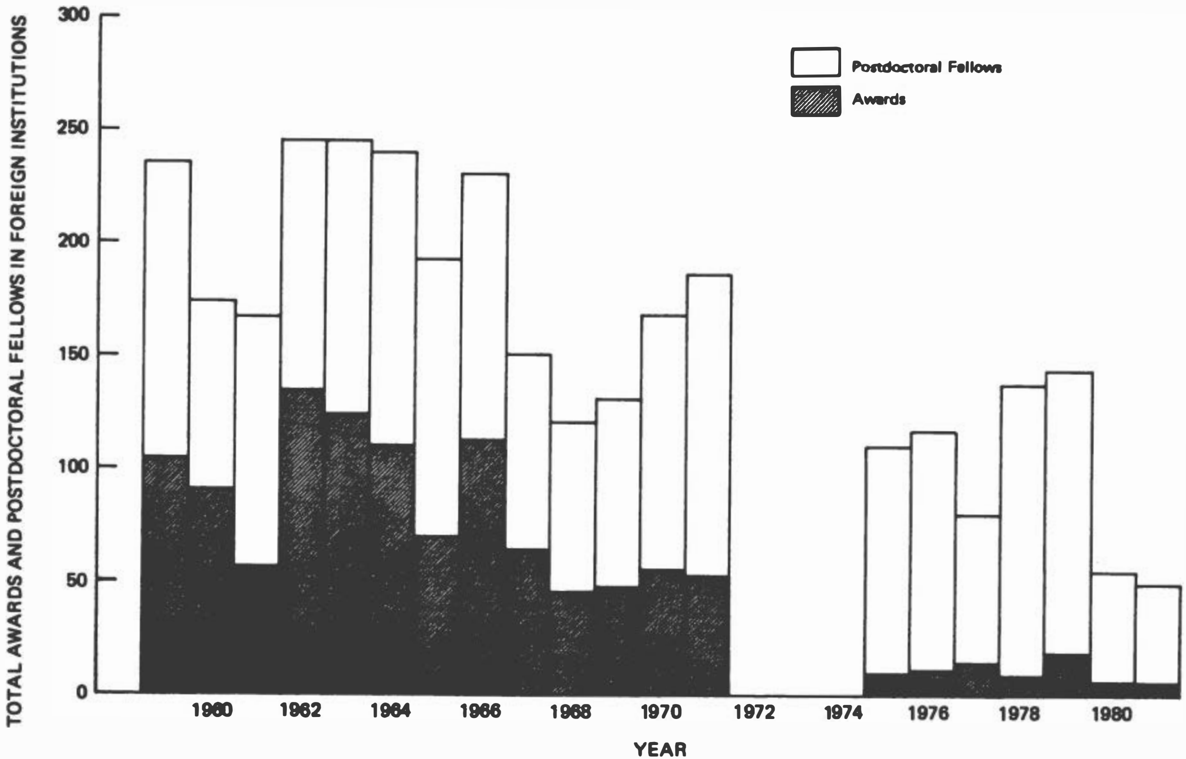
[b]Annual Report Listings: Institutions chosen by Fellowship Awardees. (Related to New Awardees as of 1973; 1983 data from award announcement.)

problems were developing with mobility of scientists and engineers in general. These are noted below under the discussion on international mobility. In any case, the numbers of fellows seeking study in foreign institutions is today at its lowest level in history—far less than 1 percent of awards.

Postdoctoral Fellowships

NSF Postdoctoral Fellowships. For young scientists primarily motivated toward academic and research careers at the frontiers of knowledge, postdoctoral fellowships and research associations in centers of excellence are a logical next step after completing their doctorates. Such movement to European centers was very much the case for young Americans in the decades prior to World War II, and this lively mobility continued in the 1950s, facilitated by the GI Bill, and Fulbright grants, as well as invaluable support from private foundations. However, it took the Sputnik tremor to move NSF into supporting a significant and highly effective postdoctoral program beginning in the 1958–1959 academic year. Some 120–245 NSF postdoctoral grants were awarded per year in the ensuing 13 years to 1971, with between one-third and three-fifths of these fellows pursuing training and advanced research in foreign institutions, primarily in Western Europe (see Figure 2 and Table 2). These were the halcyon days of U.S. science and technology. Advancements in space, medicine, communications, security, and most fields were increasingly centered around U.S. institutions and the leadership of U.S. engineers and managers of technology. We should recall the so-called "technology gap" of the late 1960s and the concern of our European and Japanese colleagues that they might never catch up. Still, the traditional and newly emerging intellectual centers of scientific excellence in Europe and Japan were readily recognized and sought out by leading American scientists and postdoctoral fellows.

But, for a complex of reasons—perhaps an exaggerated sense of confidence and self-sufficiency as well as serious questioning of the NSF role in supporting science education, and, furthermore, expectations that other sources might fill the gap—the NSF ended its broad postdoctoral fellowship program in 1972. The foundation then went through a mixed period (1975–1981) of supporting much smaller specialized postdoctoral fellowship programs designated as related to "energy," "national needs," or simply as "postdoctoral." The percentage of persons attending foreign institutions was much smaller. Since FY 1982 this program has been at zero level. It should be noted that a modest specialized exchange program of postdoctoral and senior-level scientists (10–15 each way) has been supported since 1970 under a U.S.-France Bilateral Agreement. More recently, even more restricted research (postdoctoral) fellowship programs have been initiated in the fields of plant biology and mathematical sciences, the latter restricted to U.S. institutions. This history certainly raises questions concerning



SOURCE: NSF Annual Reports.

FIGURE 2 Total awards and postdoctoral fellows in foreign institutions for NSF Postdoctoral Fellowship Program, 1959–1982.

TABLE 2 NSF Postdoctoral Fellowship Program, 1959–1982

Year	Postdoctoral Awards (No.)[a]	Postdoctoral Fellows in Foreign Inst. (No.)[a]	Postdoctoral Fellows Foreign Inst. (%)
1959[b]	233	102	44
1960	173	90	52
1961	168	56	53
1962	245	134	55
1963[c]	245	124	51
1964	240	110	46
1965	191	70	37
1966[d]	230	111	48
1967	150	63	42
1968	120	45	38
1969	130	47	36
1970[e]	169	54	32
1971	185	52	28
1972[f]			
1973			
1974[g]			
1975[h]	110	9	8
1976	118	10	8
1977[i]	80	12	15
1978	138	7	5
1979	144	18	13
1980	54	4	7
1981	50	4	8
1982[j]			

[a] Annual Report Listings: chosen by Fellowship Awardees.
[b] Initiation of postdoctoral program as well as cooperative graduate fellowships, senior postdoctoral fellowships, faculty fellowships, summer fellowships.
[c] Initiation of senior foreign scientists program.
[d] Termination of senior foreign scientists program.
[e] Establishment of U.S.-France (NSF-CNRS) Exchange of Scientists Program which has supported 10–15 postdoctoral/senior scientists exchanges (each way) per year.
[f] Termination of postdoctoral fellowships, senior postdoctoral fellowships, science faculty fellowships, summer fellowships.
[g] Faculty science program.
[h] Initiation of energy-related traineeships postdoctoral energy-related fellowships.
[i] Transformation to national needs, postdoctoral. Initiation of minority graduate programs.
[j] Termination of postdoctoral fellowships.

the objectives, continuity, and credibility of policies for the support of American postdoctoral researchers.[1]

Fulbright Senior Scholar Program (1978–1982). The Fulbright program is funded and administered by the U.S. Information Agency (USIA).[2] Most countries of Western Europe, including Germany, France, Italy, the Netherlands, and the United Kingdom, also make substantial contributions to the funding of the program. The number of grants and the fields in which they are offered are determined by the binational Fulbright Commission or U.S. embassy in each participating country. Each spring the Council for International Exchange of Scholars (CIES) announces approximately 650 awards for American scholars to lecture or conduct research in more than 100 countries, including 19 in Western Europe.

Of the 1,170 Fulbright awards made in all fields to American scholars going to Western Europe over the past 5 years, 722 were for lecturing and 448 for research. In the lecturing category, only 82, or 11 percent, were specialists in science and technology. However, in the research category, where awards are usually open to scholars in any field, 164, or 34 percent, of the awards made in the past 5 years were in the sciences. Of the 246 scientists who received lecturing or research awards to Western Europe, the largest cohort was in engineering, which had 53 grantees, followed by chemistry with 45, and physics with 34. The 114 remaining grantees were distributed among the life sciences, astronomy, computer science, food technology, geology, and mathematics. In summary, there have been on the average over

TABLE 3 Distribution of American Scientists and Engineers Under Fulbright Awards in Western Europe, 1978–1982

	1978		1979		1980		1981		1982		Total	
	Lect	Res	Lect	Res	Lect	Res	Lect	Res	Lect	Res	Lect	Res
Astronomy		1								1		2
Chemistry	3	8	2	4	3	6	3	4	3	10	14	32
Computer Science	2			1	1			1	1	1	4	3
Engineering	8	5	7	3	6	3	3	9	2	7	26	27
Food Technology									1		1	
Geology		1					1	5	2	1	3	7
History of Science				1						1		2
Life-Animal	2	2		2	1	6	2		1		6	10
Life-Botany	1	3		2	1	1		1	2	5	4	12
Life-Cell	1	3	1	3	1	2	1	1		6	4	15
Life-Medical	2	2	3	1		5	1	3		6	6	17
Mathematics	3	1	2	2	1	1	1	1	2	3	9	8
Physics	3	3		7		3	1	3	1	13	5	29
Total Science and Engineering	25	29	15	26	14	27	13	28	15	54	82	164
Total Other Fields	119	50	121	50	145	51	148	66	107	67	640	284
Grand Totals	144	79	136	76	159	78	161	94	122	121	722	448

SOURCE: Council for International Exchange of Scholars (1983).

the past 5 years 49 American Fulbright grantees per year to Western Europe: 16 at the lecture level and 33 as researchers. Table 3 portrays the distribution of American scientists and engineers under Fulbright awards in Western Europe by year (1978–1982) and by discipline.

Because of inflation and rising costs, most of the Fulbright awards made to U.S. scholars in all fields to Western Europe in recent years have been partial grants for periods of less than 9 months. In the past, most Fulbright grantees have been able to make up the difference between the amount of the Fulbright award and their expenses abroad through sabbatical leave pay or with support provided by their host institution. However, the uncertain economic climate in the United States has meant that fewer American colleges and universities can supplement Fulbright awards through sabbatical pay. As a consequence, many American scholars are being forced to limit their stays in Western Europe to a few months. It appears, however, that more science than nonscience applicants are able to supplement awards.

Trends in Postdoctoral Appointments Abroad for Doctoral Scientists and Engineers From U.S. Universities. If we wish to assess in more detail the movement of postdoctoral fellows from the United States to other countries, we must distinguish between two classes of postdoctoral foreign research experiences: those of new postdoctoral scientists, and those of a larger, older group extending into sabbatical/senior scientist research-teaching appointments abroad.

With respect to new postdoctoral scientists, we have some quantitative information gathered by the National Research Council (NRC) on those new Ph.D.s from U.S. universities who have indicated firm commitments for postdoctoral study abroad. One should be cautious of using these numbers, which indicate the trends of new postdoctoral scientists' research plans, as indicators of the actual total numbers of postdoctoral scientists. The actual total may be perhaps twice as high during certain earlier periods for three reasons.[3] First, in any given year many prospective Ph.D.s, who have no firm foreign commitment when they receive the NRC questionnaire, secure such appointments later on. (The NRC survey has observed that less than half (46 percent of a sample of 441 individuals who held postdoctoral appointments abroad during the period 1970–1976 had had firm plans for foreign postdoctoral study at the time of the Ph.D. The remaining 54 percent had had other plans at that time.) Second, in any given year, a number of Ph.D.s who were awarded the degree 2 to 5 or more years earlier (and who do not figure in the data) take up postdoctoral positions abroad. Third, the NRC data do not include medical doctorates who in years past (particularly the 1960s) entered into foreign basic

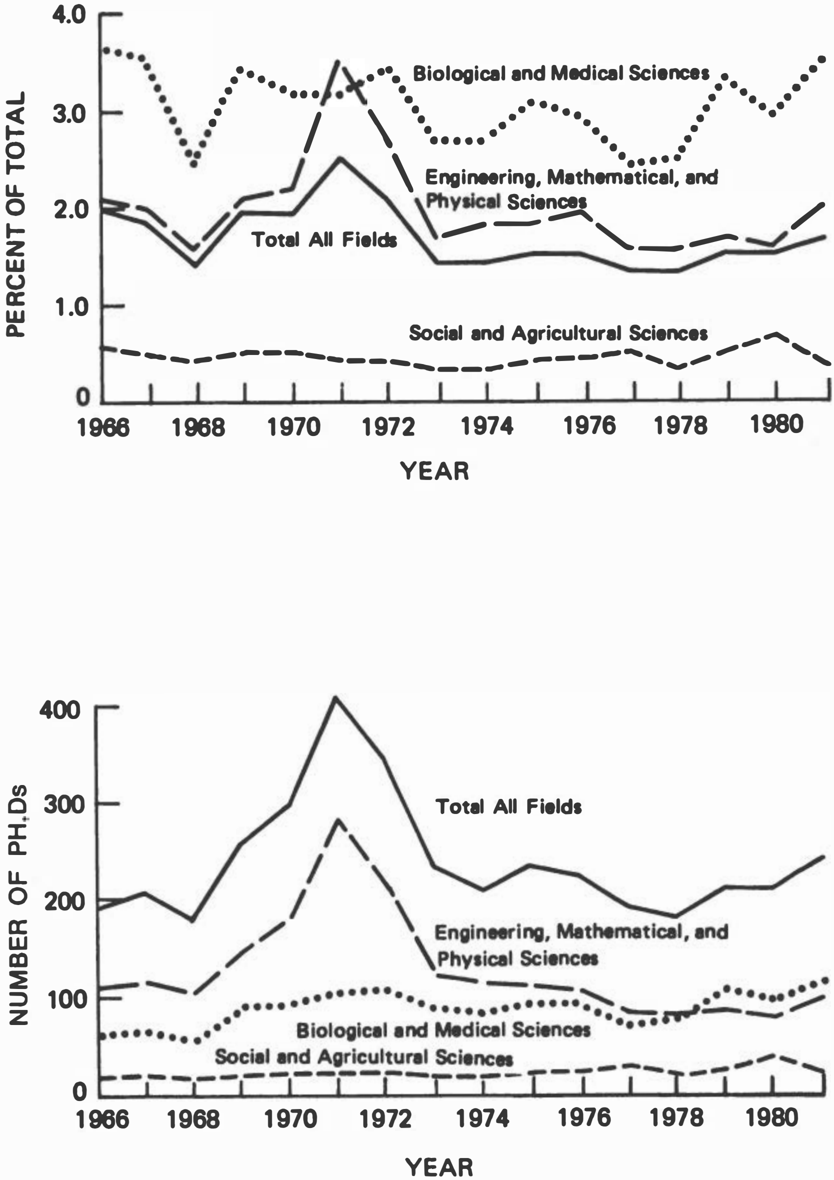


FIGURE 3 Number and percent of U.S. Ph.D.s in science and engineering with firm commitments for postdoctoral study abroad.

research experiences in significant numbers. The data are sketchy, although there appear to have been in the order of 50–100 M.D. basic researchers in the 1960s, tapering off to essentially zero at the present time.

The available data on trends in overseas postdoctoral posts must be scrutinized both for what they show and do not show. Reports and presentations frequently use the peak year of 1971 as a base, implying thus a 50 percent decline in the number of new Ph.D.s accepting foreign posts in ensuing years.[4–6] Using estimates of probable distribution of fellows for 1966, 1967, and 1968, Charles Kidd shows that the number of new science and engineering Ph.D.s with postdoctoral appointments abroad may, with fluctuations, be more or less constant when viewed not from this peak period, but over the longer span of years preceding and following 1970–1972.[7] Trends over the 1966–1981 period are portrayed in Figure 3 and Table 4. More importantly, Kidd points out that this relatively constant level conceals *increases* of about 20 percent in the biological and medical sciences that are offset by *declines* of about 20 percent in the physical sciences and engineering.

In examining possible causes of the 1970–1972 peak, Kidd refers to the motives, perceptions, and aspirations of new Ph.D.s, particularly those in physical science and engineering, when they received their U.S. degrees more than a decade ago. Significant factors turning their plans toward overseas posts were the sharp decline in federal research funds available per full-time equivalent scientist and engineer as well as the growing scarcity of tenured faculty positions. At the same time during the early 1970s, there was a pull from Western European research institutions to invite U.S. physical scientists and engineers to take up postdoctoral research appointments; this situation changed significantly by the end of the 1970s. In contrast to this experience in the physical sciences, Kidd shows that there was virtually no peak in the life sciences during the 1970–1972 period (Figure 3).

As already noted, the number of new Ph.D.s reporting firm commitments for study abroad is an indication of trends, but may be, in fact, about one-half of actual postdoctoral appointments abroad. Figure 4 shows that the percent of prior year's Ph.D.s in science and engineering who actually took up postdoctoral appointments abroad declined from an order of 5 percent in 1972 to around 2.3 percent in 1976.

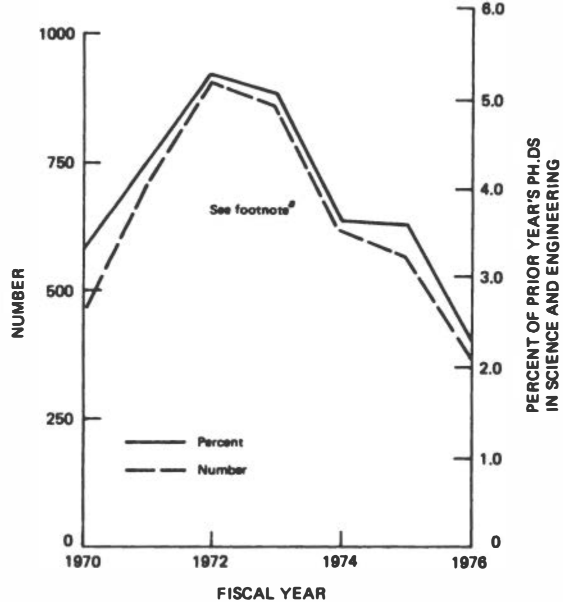
In contrast to this rough picture of trends in new Ph.D.s (and M.D.s) taking up foreign appointments leveling down to an order of 2 percent at the current period, there is certainly a much larger older group (postdoctoral scientists/senior scientists/persons on sabbaticals) that one must consider in assessing trends of postdoctoral inter-

TABLE 4 Ph.D.s in Science and Engineering Awarded to U.S. Citizens and Holders of Permanent Visas by Fields and With Firm Commitments for Postdoctoral Study Abroad, 1966–1981 (Data for Figure 3)

	S&E Total (No.)[a]	S&E Abroad Total (No.)[b]	S&E Abroad (%)	EMS Total (No.)[a]	EMS Abroad Total (No.)[b]	EMS Abroad (%)	BMS Total (No.)[a]	BMS Abroad Total (No.)[b]	BMS Abroad (%)	SO/AG Total (A)	SO/AG Abroad Total (B)	SO/AG Abroad (%)
1966[c]	9,566	192	2.0	5,104	109	2.1	1,792	67	3.7	2,670	16	0.6
1967[c]	11,063	207	1.8	5,888	118	2.0	2,026	72	3.6	3,149	17	0.5
1968[c]	12,397	179	1.4	6,429	102	1.6	2,436	62	2.5	3,532	15	0.4
1969	13,846	261	1.9	7,102	149	2.1	2,712	92	3.4	4,032	20	0.5
1970	15,545	298	1.9	7,927	178	2.2	2,975	96	3.2	4,643	24	0.5
1971	16,588	409	2.5	8,042	281	3.5	3,263	105	3.2	5,283	23	0.4
1972	16,532	347	2.1	7,789	213	2.7	3,216	110	3.4	5,527	24	0.4
1973	16,246	232	1.4	7,233	124	1.7	3,258	88	2.7	5,755	20	0.3
1974	14,840	213	1.4	6,314	115	1.8	2,957	80	2.7	5,569	18	0.3
1975	15,261	232	1.5	6,140	112	1.8	3,100	96	3.1	6,021	24	0.4
1976	14,851	225	1.5	5,682	108	1.9	3,160	92	2.9	6,009	25	0.4
1977	14,387	188	1.3	5,410	84	1.6	3,071	74	2.4	5,906	30	0.5
1978	14,056	177	1.3	5,043	81	1.6	3,134	79	2.5	5,879	17	0.3
1979	14,184	212	1.5	5,164	88	1.7	3,262	108	3.3	5,778	26	0.5
1980	14,241	213	1.5	4,790	77	1.6	3,430	98	2.9	5,804	38	0.7
1981	14,141	242	1.7	4,758	98	2.0	3,416	118	3.5	5,968	26	0.4

[a]Science and Engineering Doctorates 1960–1981, NSF Special Report, NSF 83-309, pp. 28–39. *EMS*: Eng., Math., Earth, Physical. *BMS*: Biological (N.B. NAS/NRC data approx. 10 percent greater than NSF data due to inclusion of Pub. Health, Vet. Med., Nursing, etc.) *SO/AG*: Social, Ag., Psycho.
[b]Summary Report 1979, Doctorate Recipients from U.S. Universities, NAS/NRC 1980, p. 13.
[c]Figures for postdocs abroad by field for 1966, 1967, 1968 estimated by assuming that the percentage distribution by field was the same as 1969 (from C. Kidd, 1983).

Trend in Number[a] of Doctoral Scientists and Engineers with Postdoctoral Appointment Abroad, 1970-1976



[a]The above chart is presented only to show the trend in number of doctoral scientists holding postdoctoral appointments abroad. The actual numerical level is considered to be an underestimate because it is based on a survey question that had 24.3% item non-response, however, this bias is partially offset by the relatively high response rate of Ph.Ds who had firm plans for postdoctoral study abroad at time of Ph.D.

SOURCE: National Research Council (1978).

TRENDS IN POSTDOCTORAL STUDY ABROAD, 1970-1976

(U.S. citizens and foreign citizens with permanent visas)

- The peak year for postdoctoral study abroad was 1972 followed by a continuous drop in number through 1976, a 59% drop in a four year period.
- The peak year for postdoctoral study abroad, 1972, not surprisingly, followed the 1971 peak year in number of Ph.Ds in science and engineering.
- The number of doctoral scientists holding foreign post-doctoral appointments is not a constant proportion of the number of Ph.Ds in the prior year. Trends in number of Ph.Ds awarded are amplified in the following year in number of postdoctoral appointments abroad.

FIGURE 4 Actual postdoctural study abroad.

TABLE 5 NATO Science Fellows, 1963–1982—Number and Percent of Fellows

Sending Country	Belgium		Canada		Denmark		France		Germany		Greece		Iceland	
Receiving Country	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Belgium	2	0.4	23	4.2	5	1.6	11	0.5	4	0.3	21	1.4	1	0.5
Canada	23	4.9	—	—	16	5.2	85	3.8	56	4.7	13	0.9	11	5.1
Denmark	5	1.1	13	2.4	7	2.3	6	0.3	6	0.5	5	0.3	16	7.5
France	24	5.2	49	9.0	10	3.3	1	—	87	7.3	152	10.2	2	0.9
Germany	11	2.4	40	7.3	5	1.6	19	0.9	—	—	107	7.2	7	3.3
Greece	—	—	—	—	1	0.3	—	—	—	—	—	—	—	—
Iceland	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Italy	8	1.7	6	1.1	1	0.3	21	0.9	10	0.8	34	2.3	—	—
Luxemburg	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Netherlands	5	1.1	23	4.2	4	1.3	10	0.4	6	0.5	8	0.5	4	1.9
Norway	1	0.2	12	2.2	—	—	1	—	6	0.5	—	—	14	6.5
Portugal	—	—	1	0.2	—	—	—	—	2	0.2	—	—	—	—
Turkey	1	0.2	—	—	—	—	—	—	6	0.5	—	—	—	—
UK	39	8.3	183	33.6	45	14.6	122	5.5	104	8.8	753	50.5	53	24.8
US	333	71.6	187	34.3	208	67.3	1,870	84.0	877	73.8	361	24.2	85	39.7
(Sweden)	4	0.9	—	—	1	0.3	19	0.9	5	0.4	5	0.3	12	5.6
(Swiss)	4	0.9	7	1.3	1	0.3	28	1.3	8	0.7	9	0.6	3	1.4
(Other)	5	1.1	1	0.2	5	1.6	34	1.5	12	1.0	24	1.6	6	2.8
TOTAL	465	100.0	545	100.0	309	100.0	2,227	100.0	1,189	100.0	1,492	100.0	214	100.0

[a]1963–1981 data only (figures not yet available for 1982).
SOURCE: NATO Science Committee Year Book—1982.

national exchanges. Unfortunately, one must rely on anecdotal evidence available through extensive contacts and interviews with Western European science policy officials and educational authorities. The picture of a dramatic decrease in the U.S. presence at mid-career and senior levels in Western European research institutions was brought out at the June 1981 Lisbon Workshop on International Mobility of Scientists and Engineers discussed below. Similarly, Kidd[7] has underscored this significant decrease through interviews with Western European authorities; there was a unanimous opinion that a serious decline in U.S. senior-level researchers taking up foreign appointments had occurred.

NATO Fellowship Program. The picture of postdoctoral fellowship support available to U.S. Ph.D.s would be incomplete without reference to the invaluable, consistent contribution of the NATO Science Fellowship Program. This broad-based civil science program, established in 1958 also partly in response to Sputnik, offers a flexible mechanism to enhance collaboration among scientists in the 16 Alli-

From Each "Sending" Country Who Go to Each "Receiving" Country

Italy		Luxemburg		Netherlands		Norway		Portugal[a]		Turkey		UK		US		Total
No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.
32	1.7	24	11.3	2	1.0	1	0.3	21	2.8	17	1.0	33	1.4	21	1.8	218
45	2.4	3	1.4	6	3.0	14	4.4	7	0.9	34	1.9	137	5.9	41	3.6	491
9	0.5	—	—	—	—	9	2.9	3	0.4	3	0.2	68	2.9	36	3.1	186
158	8.6	50	23.4	4	2.0	13	4.1	106	13.9	88	4.9	207	9.0	144	12.5	1,095
35	1.9	49	23.0	1	0.5	19	6.0	17	2.2	221	12.4	116	5.0	144	12.5	791
1	0.1	—	—	—	—	—	—	—	—	—	—	3	0.1	1	0.1	6
—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	0.3	4
2	0.1	—	—	3	1.5	1	0.3	9	1.2	8	0.4	33	1.4	34	2.9	170
—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	0.1	1
25	1.4	1	0.5	—	—	4	1.3	17	2.2	10	0.6	112	4.8	50	4.3	279
8	0.4	2	0.9	—	—	—	—	2	0.3	1	0.1	53	2.3	39	3.4	139
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3
—	—	1	0.5	—	—	—	—	—	—	—	—	2	0.1	1	0.1	11
442	24.0	10	4.7	8	4.1	76	24.1	484	63.6	421	23.6	—	—	515	44.6	3,255
1,000	54.4	34	16.0	160	80.8	169	53.5	77	10.1	942	52.9	1,137	49.1	—	—	7,440
22	1.2	—	—	8	4.1	5	1.6	1	0.1	9	0.5	95	4.1	24	2.1	210
35	1.9	38	17.8	2	1.0	3	0.9	9	1.2	9	0.5	140	6.1	56	4.8	352
25	1.4	1	0.5	4	2.0	2	0.6	8	1.1	18	1.0	180	7.8	44	3.8	369
1,839	100.0	213	100.0	198	100.0	316	100.0	761	100.0	1,781	100.0	2,316	100.0	1,155	100.0	15,020

ance nations of North America and Western Europe. The source of support comes from member nations; the U.S. contribution is channeled through State Department appropriations. An estimated 150,000 scientists and engineers of many nationalities have been supported through a range of exchange programs furthering collaboration with colleagues in other Alliance nations during the 25 years of the program. The NATO Fellowship Program provides support for nationally administered exchanges of some 800–900 fellows per year among Alliance nations. Well over one-half of these exchanges involve transatlantic travel.

The United States has concentrated its participation in this program on the support of postdoctoral fellows. (Some other countries give primary attention to NATO-supported predoctoral or senior postdoctoral exchanges.) On this basis about 65 U.S. postdoctoral scientists work each year in other Alliance scientific institutions (new awards plus extensions). About 70 percent of awardees attend institutions in the United Kingdom, France, and Germany. The total over the 25 years of the NATO Fellowship Program has been around 1,200 U.S.

TABLE 6 Trend in Transatlantic and Inter-European Exchanges

	1963–1980		1970		1975		1976		1977		1978		1979		1980	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Trans-Atlantic	8,177	60.1	451	62.3	429	61.7	439	59.1	451	61.6	432	56.4	570	65.6	563	62.9
Inter-European	5,133	38.7	270	37.3	254	36.6	299	40.2	271	37.0	323	42.2	272	31.3	293	32.7
Inter-North American	172	1.2	3	.4	12	1.7	5	0.7	10	1.4	11	1.4	27	3.1	39	4.4
Total	13,310	100.0	724	100.0	695	100.0	743	100.0	732	100.0	766	100.0	869	100.0	895	100.0

SOURCE: The NATO Science Fellowships Programme, Analyses of Trends in Various Aspects of the Programme, 1963–1980.

postdoctoral fellows, which is about the same order as the number of U.S. postdoctoral scientists going abroad under support from various NSF programs during "on-off" periods of activity.

The beneficial cost-benefit ratio to U.S. science of this NATO program is highlighted by the continuing flow of well over 50 percent of the fellows from other NATO nations to advanced studies in the United States, with support by NATO and their own countries. They contribute to the advancement of knowledge in U.S. institutions, as well as furthering long-lasting cooperative relations between their U.S. colleagues and their home institutions throughout the Alliance. The distribution and exchange of NATO Science Fellows over the past 20 years is given in Table 5. An overview of transatlantic and inter-European exchanges supported under the NATO Fellowship Program is given in Table 6.

SHORT-TERM TRAINING INSTITUTES

Next to doctoral fellowship experiences, participation in short-term international advanced-training projects has proven to be of greatest value to young scientists. An example is the NATO Advanced Study Institutes (ASI) Program, which has provided such opportunities over the past 25 years.

The ASI Program focuses directly on the dissemination of knowledge at the frontiers of science and the formation of lasting contacts among participating scientists from different countries. An ASI is primarily a high-level teaching activity at which a carefully defined subject is presented in a coherently structured program by members of the cognizant research community. Since its inception in 1959, the ASI Program has supported over 1,200 institutes in which some 100,000 scientists have participated. The proceedings of most ASIs have been published as advanced texts by world-recognized publishing firms.

Each ASI has a relatively small number of participants (70–100 persons), facilitating informal discussion of presentations directed largely toward a postdoctoral audience. But the participants range from graduate students to highly qualified senior scientists with achievements in the area of the ASI or related fields. A lecturer-to-student ratio of around 1:5 is usual. Furthermore, it is evident that only if the meeting is of sufficient length can an adequate program be presented—experience has shown that a duration of about 2 weeks is preferable, with a minimum of 10 working days. Finally, an ASI is frequently structured as an interdisciplinary meeting, with specialists in one field teaching scientists highly qualified in a different area. The roles of lecturer and student will be interchanged during the meeting as the theme of common interest is developed from the viewpoint of different sciences.

The distribution of ASIs according to fields of research over the 1959–1981 period, presented in Table 7, shows that the physical and mathematical sciences have dominated this program to date. However, increased attention is now being given to research topics of industrial interest. U.S. scientists have actively contributed to and participated in the ASI Program. Some 28 percent of the ASI Directors have come from the United States, and it is estimated that about 15 percent of the student participants (some 15,000) have been American scientists, primarily at the postdoctoral level.

At the time of the Twentieth Anniversary Commemoration Conference of the NATO Science Program (1978), a review was carried out on the various aspects of the program.[8] The answers to a question-

TABLE 7 Distribution of ASIs according to Fields of Research, 1959–1981

Field of Study	1981	Total	Percent
Life sciences			
Agricultural sciences	2	15	1.4
Biochemistry	5	18	1.7
Biology	6	87	8.1
Botany	0	13	1.2
Ecological sciences	1	10	0.9
Medical sciences	6	52	4.8
Zoology	1	16	1.5
Physical and mathematical sciences			
Atmospheric sciences	1	29	2.7
Computer sciences	4	42	3.9
Chemistry	5	81	7.6
Earth sciences	4	35	3.3
Mathematics	3	99	9.2
Oceanography	0	7	0.6
Physics	22	403	37.6
Behavioral and social sciences			
Behavioral sciences	2	42	3.9
Social sciences	0	12	1.1
Diverse applied sciences			
Engineering	7	63	5.9
Materials science	3	11	1.0
Systems science	2	32	3.0
Information science	1	7	0.6
Total	75	1,071	100.0

SOURCE: NATO Science Committee Year Book (1981).

naire completed by ASI participants noted that "the most beneficial and outstanding value of the Institutes was in the new ideas for research they generated and the new professional associations they made possible." This review concluded by noting, "If the ASIs can be assumed to be unique, then their uniqueness derives from their ability to lessen the gaps between scientists that could exist because of their status, physical location, and other deterrents to the activity of science. The suggestion is certainly clear in this assessment that the ASIs are indeed unique—through their format of encouraging extending scientific associations that endure long after the termination of the Institutes." This international collaboration within tutorial schemes at the frontiers of research is of fundamental importance to young American researchers.

INTERNATIONAL COLLABORATION IN RESEARCH

Another mechanism for promoting international exchanges of young scientists is through collaborative research projects. Although the major interactions within such projects are probably between principal investigators, normally senior scientists, these projects provide invaluable opportunities for postdoctoral scientists to engage in and experience important developments abroad. As major examples, the NATO Collaborative Research Grants Program and certain aspects of NSF Research Grants and Travel Grants Programs are briefly discussed below.

NATO Collaborative Research Grants Program

NATO grants specifically assist projects in which the basic costs are met mainly by country funding, but where the international collaboration entails costs that are not met by other sources. Supported projects are carried out as a joint effort of teams in university, government, and other research institutions in at least two member countries, with exchanges of personnel through short visits. NATO support mainly covers travel and living expenses of the investigators while working abroad in each other's institutions. Since its inception in 1960, this NATO program has supported about 2,000 projects (awards were made in 1982 for 270 new grants). American scientists are by far the most active participants in this program with some 65 percent of collaborative-research projects involving exchanges between U.S. research labs and their counterparts in other Alliance nations. It is interesting to note that when Canadian participation is taken into account, three-fourths of the projects involve transatlantic collaboration.

NSF Research and Foreign Travel Grants

Over the years, the NSF staff in the Division of International Programs has not only managed a wide-ranging number of cooperative research and training activities under bilateral programs, but has also periodically attempted to provide analyses of the overall international activities of the foundation. A recent analysis has provided a basis for policy discussions by the National Science Board. A major examination of science in the international setting was prepared for the June 1982 board meeting.[9]

A board statement[10] issued some weeks after the meeting, in September 1982, noted in particular:

> Scientific interaction at the international level is an essential element in the continued vitality of science. Historically, the Nation has profited from its positive stance of encouraging outstanding scientists from throughout the world to be aware of and participate in our scientific activities and encouraging U.S. scientists to travel and interact closely with scientific projects in other nations.
>
> Cooperation with the industrialized democracies, such as OECD members and our NATO allies, is clearly of great value to the economic well-being and industrial capability of our own Nation as well as theirs. These nations enjoy comparable levels of technical sophistication and the potential for sharing advanced, costly facilities. Since opportunities for interaction with these countries are readily available, the greatest latitude should be given to individual cooperation and exchanges independent of formal bilateral programs. However, the NSF should continue to participate in selected intergovernmental agreements that serve identifiable useful functions.
>
> The nature of science requires that its international dimension be considered an organic aspect of the scientific enterprise. This dimension must be actively provided for in all Foundation programs, from education and fellowships to the various disciplinary efforts in the natural sciences, social sciences, and engineering. Planning for new facilities and the setting of priorities for major scientific investigations and programs should be carried out with the full recognition of the priorities of other countries and in an environment which encourages complementarity or planned supplementation, cost sharing, and coherence of the various efforts of cooperating countries. National Science Foundation organization and management procedures should reflect these principles.

The staff's analysis, from which the board worked, was based in part on the recorded and coded information from all foundation awards on specific modes on international "implication," that is, international involvement. Some important findings are:

- Of 28,125 NSF awards of all directorates studied for the period, 26.7 percent had international implications.
- Although large international group efforts use most of the NSF funding that has international implications, the largest number of NSF grants are for research by individuals and nearly 1,000 U.S. scientists annually receive some NSF support for such activities, under bilateral programs alone.
- The figures related to industrial, or scientifically advanced, countries show high values for mathematical and physical sciences, engineering, and biological, behavioral, and social sciences, mainly reflecting cooperation with Western Europe and Japan.
- The "nature of implication" (i.e., international involvement) varied greatly according to program needs of the directorates, as shown in Table 8 below.

In summary, foundation awards do include significant support for international interactions, although the nature of such interactions varies considerably among the discipline programs. One can assume that there is an involvement of young researchers through these support mechanisms, although the amount cannot be determined from current data collection. It is noteworthy that under foreign travel the foundation does give special consideration to supporting participation of postdoctoral and young scientists who wish to attend NATO Advanced Study Institutes.

TABLE 8 Nature of Implication According to Directorate

Percent of Awards With:	AAEO[a]	BBS[b]	ENG[c]	MPS[d]	STIA[e]	Other
Foreign travel	68.2	87.4	91.2	84.2	91.3	66.7
Foreign citizens	9.2	22.2	11.6	19.3	16.5	20.6
Long visit	37.9	55.3	16.2	4.0	62.2	24.8
Coop. proj.	22.1	6.8	19.3	3.4	64.5	17.6
Agreement	49.8	3.3	14.9	2.4	75.4	23.6
Other	5.6	7.9	1.5	0.4	1.3	25.5

[a]AAEO Astronomical, Atmospheric, Earth, and Ocean Sciences.
[b]BBS Biological, Behavioral, and Social Sciences.
[c]ENG Engineering.
[d]MPS Mathematical and Physical Sciences.
[e]STIA Scientific, Technological and International Affairs.

INTERNATIONAL MOBILITY OF YOUNG SCIENTISTS AND ENGINEERS

This discussion has touched on trends and concerns pertaining to some of the most important programs that provide young American scientists with opportunities to profit from advanced research and training experiences abroad. The value and need of such experience is largely supported by anecdotal evidence—we are all familiar with a number of "Rabi" examples of perhaps more modest yet significant contributions to science and world affairs. There are convincing arguments to support increased international interactions as essential elements in the career development of the coming generations of American science and engineering leaders.

Professor Kurt Fleischhauer of the Anatomisches Inst. der Rheinischen Friedrich-Wilhelms-Universitat noted most aptly at the June 1981 Lisbon Workshops on International Mobility of Scientists and Engineers that

> the most important form of establishing effective international collaboration is to provide opportunities for young scientists, preferably still in their twenties or early thirties, to work in a foreign institute of high scientific standard for a period of not less than one year and preferably two years. Any experience gained at this stage of the career is of utmost importance and long-lasting influence because at this stage the scientist still has an open mind and is not only able to gain enormously with respect to his actual scientific achievements but also to form international links that are based on personal understanding and friendship. And since, after all, science is an undertaking of persons with all their likings and dislikings and with all the prejudices every one of us has, links based on personal trust are of particular importance for international exchange.[11]

The Lisbon Workshop dealt with a number of issues relevant to the interests of young researchers. A Working Group on Mobility and the Career Paths of Individuals identified three problems of overwhelming importance:

- the reentry and job security problem
- the dual-career family problem
- lack of obvious reward for taking the adventurous step[12]

The Working Group on Research Systems and International Mobility devoted major attention to the problems of transatlantic mobility, noting the greatly changed environment and two-way movement of young scientists through the 1950s to now when one workshop participant spoke of the "missing partner"—the United States. The group suggested that:

There should be a U.S. effort to assist foreign institutions on a reciprocal basis—not to place researchers in the U.S. (this is still possible since the links established for this in the forties and fifties continue to work successfully)—but to get postdoctoral fellowships and travel grants for the outgoing Americans and postdoctoral foreigners. U.S. Foundation assistance would be warmly welcomed.[13]

Among the conclusions of the workshop, three, in particular, are relevant to providing convincing arguments for encouraging increased international mobility of the young researcher:

International mobility of scientists and engineers is important to the excellence of the scientific enterprise, the health of technologically-based industries, and the intellectual and professional growth of the individual.

For individuals, international mobility constitutes a major vehicle for the development of inventive and innovative ability. Such experience is particularly valuable early in a professional career—for it is at this stage of intellectual and professional growth when one is especially responsive to new ideas and opportunities. At later career stages international mobility may allow a mature investigator to renew his innovative capabilities.

International mobility is a valuable component in the development and renewal of research systems. The mutual confidence that is built between host and guest leads to long-term cooperation, understanding of different concepts and techniques, and adaption of new technologies more quickly and accurately than is possible when working in isolation.[14]

The key point here is national "isolation"—a condition inimical to scientists and the dynamism of the research system. We are proud of our mobility within and among national institutions. For reasons noted above, we found international interactions of critical importance during the first half of this century. Why not now? And to whom should we pose this question?

Recent policy statements portray a curious perspective on the position of the United States in the world research system on the part of important decision makers. The National Science Board document referred to earlier, entitled "Statement on Science in the International Setting," introduces a first idea that "American scientists no longer lead in every field of science. . . ."[13] Similarly, the President's Science Adviser in the President's "Annual Science and Technology Report to the Congress" for 1981 states that "one of the realities of the 1980s is that whereas the United States retains international preeminence in many areas across the spectrum of science and technology, we no longer hold undisputed dominance in virtually all fields."[15]

In addressing these policymakers one could point out that now, with many fields of science and technology advancing rapidly at the world level (not just at the U.S. level), we have the most convincing argument of all for promoting the international mobility of young researchers—to lead, to participate, to keep up, to provide a mature (a world view) perspective as future managers of our research system, be they in industry, university, or government.

This analysis has shown that isolation is an imminent problem that must be faced. The NSF graduate fellowship program currently encourages a trivial level of participation of fellows to attend foreign institutions. This should be much enlarged.

There is no longer a regular NSF postdoctoral fellowship program. Serious and urgent attention should be devoted to devising mechanisms to promote an increase in the overall postdoctoral appointments abroad from something less than 2 percent to the order of 5 percent. In this, it would be particularly important to give special attention to the mathematical, physical, and engineering sciences. Whether the trends in postdoctural study abroad have declined or remained relatively constant is not the point. Specific measures should be established to encourage increases in foreign research appointments in order to ensure our future participation in the advancement of science as well as provide a vital supply of internationally minded research managers.

Coupled with meeting these needs is the enlargement of opportunities for young American scientists to participate in short-term training schemes such as the NATO ASIs as well as collaborative research projects of all kinds, particularly those supported by the National Science Foundation.

The dynamic interaction of young American researchers with their colleagues in the advanced countries of the Western world is fundamental to the health of our research system. The benefits to the United States—its economy, its political system, its position in the world of science and technology—lie in their hands and intellectual leadership.

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13. Ibid., p. 57.
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Discussion

The morning of the second day of the workshop was devoted to two panel discussions, each examining different aspects of U.S. international S&T policy. The first panel focused on *the objectives and benefits of and obstacles to bilateral and multilateral cooperation*. It was suggested at the outset that there is an attitude toward international cooperation, derived from the situation that prevailed in the 1950s and 1960s, that such involvement on the part of the United States was some sort of magnanimous gesture. In reality, this view is now obsolete, given that the United States often benefits at least as much from its cooperative involvements as do other participating nations.

It must be recognized clearly that there are political as well as scientific benefits from cooperation, yet both depend on a project's producing good science. Although it may appear somewhat obvious, money is the key to any kind of effective cooperation, particularly for the laboratory sciences. Cooperation in the laboratory sciences most often involves the exchange of people—in order to learn new techniques or develop new ideas—or the development of standards, terminology, or safeguards. In the case of the field sciences (primarily the earth sciences, ecology, and some aspects of health science), the problems have more to do with developing effective ad hoc specialized mechanisms, which are often multilateral rather than bilateral. All require the infusion of money.

One example of multilateral cooperation discussed in the session was the Committee for Science and Technology (COST) policy of the

Organisation for Economic Co-operation and Development (OECD). It is a place where member states (24 countries, including the United States, Canada, Japan, Australia, New Zealand, all the countries of Western Europe, and special status for Yugoslavia) can be confronted with respect to their policies on scientific and technical cooperation. The OECD-COST serves a number of functions, including that of a forum where governments can discuss (1) recent developments in their science policies, (2) coordination of regulatory policies for S&T, and (3) policy development and evaluation.

There is a lack of coherence in the approach of the OECD member countries; national policies are disparate and difficult to change. The United States in particular has been erratic in both its representation to and participation in the work of the OECD. Some governments prefer to pursue their objectives on a purely bilateral basis. The member governments finally agreed to hold a meeting in Tokyo, Japan, for the explicit purpose of reexamining their cooperative relationships. OECD is a consensus organization; rarely is anything done by vote. Moreover, governments rarely initiate actions within COST; they tend to sit back and wait for the Secretariat to take initiatives. As a result, there remains a substantial unutilized potential for expanded cooperation within this context.

A second multilateral cooperative mechanism discussed in the meeting was the NATO science program, which has existed for more than 25 years. Motivated originally out of explicit foreign policy objectives, the program has promoted the advancement of basic science among the allied countries by facilitating the movement of approximately 150,000 young scientists and engineers (more than half of which involved transatlantic travel). The NATO Science Committee itself has also been an effective multilateral forum. One noteworthy feature is that the special study panels created by the committee contain a "sunset provision" that causes them to go out of existence after 5 years (unless renewed).

The panel discussion concluded with a consideration of the problems with and prescriptions for multilateral S&T cooperation. It was suggested that some of the costs of cooperating across international boundaries include: (1) problems of meshing disparate bureaucracies, (2) delays in decisions due to different political systems, (3) the financial burdens of funding travel to international meetings, (4) inertia that makes programs hard to start and sometimes even harder to stop, (5) drains on domestic budgets in the form of "sunk costs" of programs that continue indefinitely, (6) focus on low-priority subjects due to nationalistic considerations, (7) potential loss of militarily sensitive information, (8) the danger that the scientific enterprise will become increasingly politicized.

Conditions for successful multilateral cooperation involved both scientific-technological and political criteria. They include: (1) mutual interest in a problem on the part of scientists and engineers in different countries, (2) personal involvement of individuals of roughly the same degree of competence, (3) buffering of the project from political pressures once it is under way, (4) adequate funding both for the project and the costs of national participation (e.g., travel), (5) professional peer recognition of the importance of the work, and (6) availability of specialized equipment and/or facilities. It would seem less important on this basis whether a project originates at the grass roots—i.e., between individual scientists—or meets most of the success criteria set forth above.

On the political side, successful projects also must fulfill certain conditions. There must be mutual benefit for the participating governments or organizations. The project must contribute to national objectives (e.g., R&D, foreign aid, intelligence gathering, etc.) and preferably lead to a cooperative approach to international problems or improve the U.S. image abroad. It is also helpful if the project saves money. Cooperation and competition can and probably should coexist. But it is necessary to gain a clearer understanding of which types of activities can (or must) be pursued on a national basis versus those that lend themselves to international participation.

The second panel discussion took up the topic of the *changing conditions of international science cooperation.* The session began on the note that, despite the changes that have occurred in the international S&T system, the role of the United States is still critical. If the United States acts unilaterally and does not consult with its partners—or puts its own interests above the common good—this reduces the incentive for other nations to cooperate. The fact is, however, that circumstances also have changed significantly within the U.S. R&D environment. Within the last decade there have been two major recessions that have limited the resources available for industrial support of R&D. At the same time, inflation and other factors have driven up the cost of conducting R&D while rigorous budgetary constraints were being imposed to limit government spending. Thus, at the very time that the U.S. technology finds itself hard-pressed by the Japanese and increasingly by the Europeans, the level of government-university-industry support research and development and interaction has not kept pace in some fields.

The nature of university research is also changing, with an increasing percentage of work undertaken in applied or so-called "dual use" areas that raise potential national security problems in terms of the loss of militarily sensitive information. This has been a particular problem regarding the participation by U.S. scientists and engineers in international conferences where potentially sensitive S&T topics are to be discussed. There is now a mounting record of conferences, workshops, and symposia where the Defense Department or other federal agencies have forced the withdrawal of papers and/or banned the presence of foreign nationals on grounds of national security. The net result has been an increasing level of uncertainty and unease within the scientific community regarding the publication of papers in certain fields and interactions with foreign nationals.

A similar effect has been experienced within the industrial research context. On the one hand, multinational corporations have come increasingly to assign research to the subsidiary where it can be done most effectively, rather than thinking in national versus international terms. Thus, there often may be substantial intracompany mobility of people and data. Restrictions imposed under the terms of the Export Administration Act can have serious negative consequences on this mobility and, ultimately, on the competitive position of U.S. industry. It also creates serious difficulties for U.S. multinational companies that employ foreign nationals in areas of R&D that may be subject to control.

It was pointed out that restrictions imposed on foreign nationals out of national security concerns about the loss of scientific and technological data also are responsible, in part, for the decline in the movement of junior scientific personnel (i.e., graduate and post graduate students and junior faculty). The reasons U.S. citizens are choosing not to go abroad for additional training or to conduct research are complex. They relate in part to changing career patterns, reduced opportunities for academic advancement, and, in some cases, cultural and language barriers (e.g., Japan).

There are indications that the climate also has deteriorated for foreign students and scholars in the United States, with at least 12 states now attempting to set limits on the number of foreign students in their state-supported institutions of higher learning. This has come about both out of the concern about the loss of militarily sensitive or proprietary data and a general sense that these individuals are somehow not fully paying their own way. If the flow of junior scientific personnel into and out of the United States is reduced, this may have significant negative ramifications for international cooperation.

Another characteristic of the changing conditions of cooperation may be seen in the changing circumstances of international communication. The reduced cost of electronic communications has made it far cheaper for researchers to interact in real time without the need to travel to the same place. It also has made networking possible among individuals at multiple research sites. At the same time, however, the problems of controlling transborder data flow become more complicated. It also calls into question the foreign language training and capability of the U.S. research community.

The discussion turned finally to a consideration of the overall sociopolitical environment in which international S&T cooperation takes place. It was pointed out that many of the federal agencies involved directly in supporting cooperative efforts have extremely limited "institutional memories." That is, the individuals involved at the decision-making level change frequently and often these people have little knowledge of previous international activities or appreciation of their importance. A number of participants reiterated their perception of a growing nationalism—some termed it protectionism—pervading American culture at the present time that is inimical to the interest of expanded international contacts in science and technology. Despite the largely symbolic rhetoric on international S&T cooperation and the activities among the OECD countries flowing out of the Attali Report and the Williamsburg Economic Summit, there appears to be little serious interest in the subject at the present time within the highest policy circles of the U.S. goverment.

International Cooperation to Meet Future Needs

Discussion

The final session of the workshop consisted of an open-ended discussion of modified or new forms of international cooperation to meet future needs. The terms of reference were established at the outset: There is a new political climate today, and the importance of science and technology has increased substantially in the affairs between and within nations. Many of the rationales that have been operative in international activities flow from the Marshall Plan and the historical circumstances that existed at the end of World War II; these are now in need of adjustment. It must be kept in mind that international scientific cooperation involves a broad range of activities from the "grass roots" level of the individual scientist to the largest global project. It is also important to understand that scientific cooperation involves essentially three different types of flows that are subject to constraint: the flow of people, the flow of ideas, and the flow of resources.

Before turning to specific recommendations for follow-on activities to the workshop, the discussion focused more generally on broader needs regarding international cooperation. It was reiterated that the government's institutional memory is relatively limited, and, as a result, it is necessary to make the case anew every 5–10 years. Given the present inward orientation of national politics, the case for international cooperation would be strengthened greatly by recruiting those from industry, academia, and elsewhere who have an interest in foreign science and technology so that policymakers can be made aware of the costs of *not* cooperating. It also might be helpful in this regard to seek the views of people and organizations in the countries with whom the United States might wish to cooperate more widely.

There was an apparent consensus in the meeting that the present concern should not focus so much on creating additional new modes of cooperation, since this may not be feasible from a scientific, economic, or political standpoint. Rather, it should concentrate on arresting the deterioration in the present system. (Although the workshop was held prior to the announced U.S. intention to withdraw from membership in UNESCO, the problems of U.S. participation were discussed.) Participants in the workshop put forward a variety of ideas for new studies, activities, or institutional mechanisms that would help to reach and influence decision making. Among the concepts proposed were the following:

- Make the case for U.S. participation in international S&T cooperation in different forms so that the information will be accessible to a wide range of audiences. This might include developing specialized course materials, briefing materials, etc., of varying degrees of sophistication. Included in this effort should be a reorganization of the Title V report to make it more readable and usable.
- Develop an analysis that places the S&T needs of and constraints on the United States in a better perspective so that they may be understandable to the Europeans, the Japanese, and others who do not fully comprehend the current U.S. climate.
- Undertake a study that will provide definitive evidence on the current pattern of student mobility, both into and out of the United States. Explicate the reasons why U.S. students are no longer choosing to study abroad in as great numbers as before.
- Make an effort to involve more junior members of the scientific and engineering communities who will have to live with the research system in the years to come.
- Develop seminars and other types of presentations on international S&T for national opinion leaders from industry, government, and the foundations. The joint National Academy of Sciences—Council on Foreign Relations seminar on the role of science and technology in foreign policy, which was convened in May 1984, might serve as a model.
- Create other channels of communication on these matters between the various sectors of society. Foundations could be enlisted to support a vigorous program of seminars in Washington and elsewhere. The new Academy-sponsored Government-University-Industry Research Roundtable could play an immediate role. Efforts also might be made to

form university-industry alliances to the extent that the two communities share common concerns.

- Create a follow-on group—presumably within the Academy complex—that can monitor and engage the issue in all its dimensions. This might include the issuance of "white papers" and/or the dissemination of educational messages through a variety of scientific and popular literature, including *Science*, *Science '84*, *Scientific American*, *Foreign Affairs*, etc.

As Walter A. Rosenblith concluded in the final session, "No country can afford to be scientifically autarkic; cooperation and competition must coexist." As a result, it is necessary for the scientific community to make the case for international cooperation along the entire spectrum of S&T activities. Similarly, the constituency also must be very broad, and, in order to reach it, whatever follow-on group is constituted should include individuals drawn from industry, from the science and engineering communities, and from among those who understand the policy process.

Afterword

It has now been more than a year since we first developed plans for a project to assess U.S. participation in international scientific and technical cooperation. Since that time events have demonstrated only too well the validity of our concern for the apparent trend toward decreasing U.S. involvement in and support for international activities. Nowhere is this more clear than in the case of the 1983 announcement by the U.S. government of its intention to withdraw from the UN Educational, Scientific and Cultural Organization (UNESCO) by the end of 1984. Whether or not the withdrawal takes place, the announcement has triggered worldwide concern for the future of international cooperation and raised fundamental questions about the organization, support, and implementation of international programs, the very questions that guided our workshop discussions.

With the commissioned papers and the workshop discussions, we have taken the first steps in the overall assessment. There is much more that should be done, on the one hand, to understand better the complex issues involved, and, on the other, to educate and inform the various institutions and persons whose cooperation is essential to effective international relations in science and technology.

Toward this end, the workshop recommended that various information packets be prepared that could be used to inform and strengthen the constituencies essential to support U.S. involvement in international scientific cooperation. Interestingly enough, the first constituency that the workshop participants felt needed to be addressed was the scientific community itself, a community that has in recent years for a wide range of reasons been less interested in international cooperation than in the past, or perhaps so comfortable with the present system that insufficient attention has been given to its care.

It is our hope that this volume will contribute to the process of developing a sounder basis for international scientific and technological cooperation among the western industrialized countries.

Victor Rabinowitch
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June 1984

Appendix A

Summary of the OIA Opinion Survey

BACKGROUND

In the spring of 1983, the Office of International Affairs began a study, supported by the National Science Foundation (NSF), of selected aspects of U.S. participation in various forms of international science cooperation. The analysis was to focus on cooperation among the Organisation for Economic Co-operation and Development (OECD) countries, examining a range of modalities of cooperation, factors that affect U.S. participation, and new instrumentalities or policies needed to meet the challenge of international science cooperation in the future. One feature of the analysis involved soliciting the views of a group of individuals with interest and experience in international cooperation. A series of questions was posed in a "survey guide" distributed to 125 persons, one-third in government agencies and two-thirds in the private sector. Forty substantive, written responses were received. Eight were from government agencies; on the nongovernmental side, the majority of respondents were from academia (27 persons), the others from private firms or associations (5 persons). In addition, about a dozen interviews took place. A listing of those who responded or were interviewed is attached.

The survey questions were intentionally designed to be open-ended and to elicit views based on individual experiences and perceptions regarding international cooperation. The approach did not reflect a scientific sampling methodology. Therefore, the results as presented here are a purely subjective expression of views, and the purpose of this summary is simply to stimulate analysis and discussion.

MODALITIES OF COOPERATION

Instrumentalities of Cooperation

Describe the major instrumentalities related to your field/discipline/area of experience through which U.S. scientists participate in international science, limiting yourself to cooperation among the Western industrialized countries.

The modalities of international cooperation utilized by the scientific community range from individual contacts, including exchange of persons and information, to collaborative research activities, contributing to and utilizing international journals and data bases, and participating in meetings (from small workshops, colloquia, and managerial meetings to large conferences). At the individual level, mechanisms such as exchange programs, fellowships, sabbaticals, lectureships, pre- and postgraduate training opportunities, and memberships in foreign professional societies are all employed. Scientists engage in international ventures through a variety of institutional affiliations ranging from those sponsored through interuniverity or interlaboratory relationships and professional associations, to international science organizations, both governmental and nongovernmental. Participation in international research projects (with their attendant meetings, coordinated observations, and sharing of resulting information and data), as well as work at international research facilities, provides important opportunities for international science collaboration.

The long tradition of international cooperation in science is noted. Interactions by U.S. scientists with the Western scientific communities are similar to those that occur within the domestic community. Exchanges with a minimum of bureaucratic interference are preferred, but as the number of people, institutions, and nationalities increases, administrative support structures necessarily arise.

On the governmental side, the respondents indicate modalities of cooperation ranging from informal, low-level arrangements to formal bilateral agreements with foreign governments or associations, and memberships or participation in intergovernmental, multilateral organizations. In addition to participation in and support for cooperative research projects, there are government-sponsored programs of individual exchange (visiting scientists program, resident research associateships). Of course, government representatives also participate in international meetings of both scientific and administrative character, and contribute to and draw from publications and data bases.

Objectives and Benefits

What are the major objectives/benefits of this cooperation (i.e., why do people/institutions take the time and expend the necessary resources to participate?) Can you identify some of the principal successes/failures?

Among the most commonly cited objectives of international collaboration are:

- advancement of knowledge—enhancement of the quantity and quality of research
- initiation and maintenance of research contacts
- fostering of information/data sharing and access to and dissemination of research results
- establishment of standards for communication and information/data exchange
- access to foreign knowledge, expertise, facilities, and instrumentation
- avoidance of duplication of effort through time- and cost-sharing activities and mechanisms

In addition to discussion of important scientific issues and efforts to seek solutions to particular problems, international contacts provide an opportunity to foster scientific fellowship, to improve understanding of foreign science communities and practices, and to learn new techniques and research procedures. In the earth and atmospheric sciences area, the very nature of the disciplines demands international cooperation. There is a strong feeling that U.S. science should be appropriately represented in international fora. Aside from a desire to enhance U.S. scientific prestige and recognition abroad, there is also a recognized element of personal self-interest stimulating participation in international activities.

Among the most valuable programs and mechanisms are the International Council of Scientific Unions (ICSU) and its member unions. The unions provide an important infrastructure for the convening of major international disciplinary congresses attended by tens of thousands of scientists annually. The work of the unions in promoting communication through publication activities and work on standards for international exchange of information and data are cited as extremely effective, resulting in a high return on a basically small investment. ICSU-sponsored collaborative research programs, such as those that developed from the International Geophysical Year, are also highlighted. Major disciplinary advances have come about because of organized, internationally endorsed research programs, and these efforts have also stimulated enhanced national funding of related research.

The earthquake seminars under the U.S.-Japan Cooperation in Science Program, the U.S.-Japan Conference on Natural Resources (unfortunately limited to government scientists because of Japanese policy), bilateral NSF-sponsored efforts such as project FAMOUS (a study of the mid-Atlantic with the French), and the Deep Sea Drilling Project are also examples of successful international endeavors. The large scope and cost of the Deep Sea Drilling Project invite international cooperation and perhaps the most important ingredient for its success has been that participating countries all contribute to the cost of the program as well as to its scientific management. Also, the dual management system, in which scientific guidance comes via representatives of academic institutions, and funding and other policy matters are handled at the intergovernmental level, has proven successful.

The NATO research grants program, and NATO- and OECD-sponsored conferences are mentioned as contributing to effective international communication and cooperation. NATO and NSF fellowship programs are noted also. In addition, a portion of the Fulbright Senior Scholar Program provides for exchanges in science and technology between Western Europe and the United States. The importance of expert individuals' collaborating on specific problems is frequently cited. Government-sponsored physics facilities that encourage international participation are, for example, essential to disciplinary progress.

Among the factors that cause failures in international cooperation are poor planning, lack of knowledge of languages on either side, and inability to make commitments, particularly within and for reasonable time frames. Politicization of international organizations can also have detrimental effects and inhibit the achievement of technical objectives.

The objectives and benefits cited by the government respondents correspond to those identified by the private sector in terms of advancing knowledge, sharing resources and experiences, avoiding duplication of effort, coordinating research programs, and utilizing foreign knowledge, expertise, and facilities. Naturally, there is also an emphasis on links with mission objectives and an expectation of benefits with domestic implications. There is overt acknowledgment of the foreign policy objectives of international collaboration. Several successful programs are cited, as, for example, the World Health Organization (WHO) Smallpox Eradication Program, and it is noted that failures are most frequently due to economic, political, or organizational factors.

Quality Control

What are the major quality control mechanisms/procedures? What are the mechanisms that facilitate/inhibit actions/results? Are there major policy positions or operational procedures which adversely affect program development or conduct?

The prime factor in quality control is the peer review process which includes review of proposals or project statements, funding, and monitoring of progress, at both the national and international levels, as well as publication of results in review journals, and reactions to papers and presentations at international conferences. International programs that emphasize science and not politics build credibility and permit evaluation and resource allocation on the basis of scientific merit. Of course, individuals' exercising quality control can result in some abuses, but the scientific merit and technical competence of programs are usually easily identifiable.

Among the factors (randomly listed) inhibiting international cooperation are:

- lack of commitment to and appreciation of the value of international cooperation resulting in limited funds, particularly for international travel, and lack of interest among federal administrators, resulting in limited participation by federal employees
- shifting political positions and policies that can affect the desirability and usefulness of international activities (funding for long-term cooperative research can be affected by restrictive, short-sighted policies aimed at problems outside the sphere of science, but nonetheless damaging to international science cooperation)
- finding qualified personnel with the time and interest to participate in international programs and to develop project proposals that will generate funding
- the peer review process when it evaluates international efforts against national ones (international component may be neglected or even eliminated)

- nonadherence to the principle of the free circulation of bona fide scientists (visa problems)
- restrictions on the flow and free exchange of scientific information, including government policy on dissemination prior to publication in the United States
- special restrictions on foreign travel and currency exchange

The mechanisms that facilitate cooperation are a complex mixture of efforts of international groups like ICSU, professional societies, universities, and occasional special projects (funds) for particular areas. Although not many facilitative aspects are identified, generally speaking, the more that is known about science in other countries, the easier it is to initiate and nurture international cooperation.

The effect of domestic policies and priorities on international programs is high. The agency responses indicate that international work flows from the regular, domestically oriented programs. In most cases, there are no special funds for international activities; these activities must, in fact, compete with domestic research budgets and be weighed against domestic priorities. In some instances foreign contracts must be considered on the basis of several criteria including exceptional scientific merit, a unique research opportunity, or inability to perform the work in the United States. Among some of the inhibiting factors are shortage of resources, difficulties of starting new activities, influence of political tensions, delays, cost overruns, limits on international travel, and the fact that redirection or cancellation of research done at the federal level can affect international programs.

U.S. PARTICIPATION

Roles and Relationships of U.S. Government and Private Sector

Briefly characterize the roles and relationships of the U.S. government agencies and private sector groups concerned (e.g., legal responsibilities, degree of interest and commitment, types and amounts of support, channels of information, interactions in general).

From the perspective of the nongovernmental survey participants, government agencies seem both interested and committed and, to the extent that they support international science, play a positive role. Obviously the private-sector role is also critical, especially in establishing scientific credibility and maintaining open channels of communication. While the nongovernmental side appears to have greater flexibility and can move more rapidly, one respondent asks why government seems to have assumed that scientists from Western countries can take care of international cooperation on their own. The communication needs of scientists, essential to maintain interactions, is pretty much left to the private sector and depends on a volunteer investment of time and effort by individual scientists. Another respondent suggests that the government has two principal roles, one facilitative and the other active. The facilitative role is characterized not only by financial support for international travel, fellowships, visits, exchanges, etc., but government can also create a climate that encourages international cooperation, and can handle travel documents in a positive manner. The active government role involves intergovernmental and interdepartmental agreements for cooperation, memberships in international organizations, and the hosting or sponsorship of international meetings. Formal agreements are almost always politically motivated, and, as a technique for doing science, are not efficient or cost-effective; however, they do have value in the sense that they are a source of funds for scientific activity and can convey signals to the national community as a whole. The decline in travel funds and the creation of a climate restricting the flow of scientific communication mar what has been a good record of government involvement.

While acknowledging the responsibilities of the government in formal intergovernmental relationships, several agency responses indicate the importance of relations with the private sector, including universities, professional associations, and industries. Communication channels are diverse and include international program offices, the publication of formal reports, meetings, and journal reporting.

Institutional Anchors

What are the most helpful "institutional anchors" (e.g., universities, foundations, professional societies, etc.) in the United States? How is the United States plugged into the system?

Federal agencies, national and industrial laboratories, universities, foundations, professional societies, and the National Academy of Sciences (NAS)-National Academy of Engineering (NAE)-Institute of Medicine (IOM)-National Research Council (NRC) complex, including the U.S. national committee network, are cited as prominent institutional anchors for international science cooperation. Universities and societies are not subject to influences beyond the world of science as much as governmental and commercial institutions are, but they are underutilized in international collaboration. The importance of individual interest and initiative is frequently noted. Those international activities involving a combination of private-sector participation plus external federal financing are seen as especially effective, but the opportunities for shared private/public-sector responsibility are not fully appreciated or employed.

The comments of those who responded to the query about how well the United States is plugged into the system range from "sloppy" to "well plugged in" (when the United States supplies the major initiatives and inputs); more adequate financing is seen as a prerequisite to being effectively plugged in.

The agency respondents frequently cite their ties to universities and professional communities as well as to the NAS through NRC committees. Also the National Aeronautics and Space Administration, (NASA), for example, has links to the high-technology industries, although the Environmental Protection Agency (EPA) is experiencing declining industry participation in the international environmental areas.

Value of U.S. Participation

Provide an overall assessment of the value of U.S. participation.

All respondents indicate a high regard for active U.S. participation in international cooperation in terms of its value to U.S. science, to disciplinary progress, to the solution of specific problems, and to the individual participants. The political, social, and economic aspects of international science cooperation are also acknowledged. It is commented that all countries are depending more and more on science and technology and that international cooperation is an aspect that "we can't do without." U.S. participation in international activities is no longer simply altruistic, but should be approached with organized self-interest: There are facilities, equipment, experiences, and information available abroad from which the United States can benefit.

The government respondents also note the technical benefits from international cooperation, the importance of establishing good scientific contacts, the contributions to international understanding, goodwill and other foreign policy objectives, and the establishment of good channels of communication. The value is especially high when the agency initiates the activity. Another respondent states that the most interesting projects are large scale and depend for solution on a number of countries' actively participating.

FUTURE NEEDS/ISSUES

Unmet Needs

Are there needs you believe are not being met? What would be required to improve the operation of the system?

In addition to the most frequently cited unmet need—sufficient resources—there is a strong call for widespread and explicit recognition and commitment to international science cooperation. (Is it known how much is being spent on international science cooperation?) The system needs to have more attention paid to it. This could involve recognition of the value of international cooperation, more effective integration of international activities into U.S. foreign policy, and improved mechanisms for scientific communication and utilization of scientific information particularly within federal agencies. Increased opportunities for travel abroad—long- and short-term visits, international meetings, and other opportunities to follow up on potentially valuable foreign contacts, particularly for young scientists—are especially needed. Some specific suggestions for improving the system include:

- stable organizations and stable funding for international cooperation (a clear prerequisite for fruitful action)
- direct, separate funding for international programs and projects
- improved management of international science cooperation, including clear, high-level assignment of responsibility for international efforts
- more regular meetings and contacts between national science funding agencies (e.g., establishment of recognized procedures for submission of international projects)
- recognition of the importance of free circulation of scientists
- establishment of a clearinghouse for information on resources for foreign travel
- better reporting from U.S. embassies and other personnel abroad
- support for a national translation capability
- more vigorous cooperation with large facilities
- more involvement in international activities by U.S. professional societies, especially engineering societies because scientists from industry suffer more from comparative isolation and lack of tradition of international cooperation (competition versus cooperation)

• greater attention to economic factors and industrial participation in general

New Policy or Programmatic Approaches

What new policy or programmatic approaches are being considered, if any. Do you now have, or do you foresee, conflicts between maintaining high-quality contacts and protecting proprietary or security-related information?

Most of the respondents do not see any real conflict with protecting proprietary or security-related cooperation primarily because they are involved with basic research. It is recognized that there may be problems in areas where the line between basic and applied science cannot be easily drawn. If the general atmosphere is restrictive, however, there is less inclination to engage in international types of activities. There is also the potentially damaging effect on morale and on the deflection of people into alternative areas of research. The real danger is an overzealous reaction that could lead to the isolation of U.S. scientists.

Among the suggested new policy or programmatic approaches are:

• closer relationship between national and international science activities

• development of new international approaches to research cooperation, sharing of research facilities, establishment of an international network of research facilities, construction of joint facilities, together with an infrastructure that would offer the opportunity of access for scientists from many countries, based on scientific merit and peer review

• contracting out cooperative efforts initiated for political purposes to one or more university consortia or other private groups (e.g., NAS)

• establishment of the IUPAP International Committee on Future Accelerators (ICFA)

• calling on research institutions to undertake policy-oriented studies with regard to international science cooperation

None of the government agency representatives indicated that new policy or programmatic approaches were under consideration. However, NASA notes that reduced-cost missions are being proposed, and the Public Health Service indicates that it is currently looking at future involvement in international health, out of which some new suggestions could emerge.

Modes of Cooperation as Channels of Communication

Are these "modes of cooperation" also effective "channels of communication"?

Without exception the responses are positive. There is stress on the importance of individual, person-to-person contacts whether in the governmental or private sectors. It is also noted that, where quality research is actively pursued, modes of cooperation and channels of communication take care of themselves. The importance of the "invisible networks" of informal communication (e.g., exchanging reprints, sharing information, telephone contacts, etc.) is emphasized. In the case of large international research projects, a system that entails a high degree of governmental-nongovernmental cooperation is essential.

LIST OF PERSONS WHO RESPONDED TO THE SURVEY GUIDE OR WHO WERE INTERVIEWED

Private Sector

JESSE AUSUBEL, National Research Council
FRED BASOLO, Northwestern University/American Chemical Society
DONALD R. BEEM, American Institute of Biological Sciences
D. ALLAN BROMLEY, Yale University
PETER CANNON, Rockwell International
RITA R. COLWELL, University of Maryland
DORIS M. CURTIS, Geological Consultant
GEORGE K. DAVIS, University of Florida
HERMAN FESHBACH, Massachusetts Institute of Technology
GARY GERARD, Center for Technology/Kaiser
EDWIN L. GOLDWASSER, University of Illinois, Champaign-Urbana
FRANK B. GOLLEY, University of Georgia
GEORGE S. HAMMOND, Allied Corporation
CHARLES C. HANCOCK, American Society of Biological Chemists
N. BRUCE HANNAY, National Academy of Engineering
BENJAMIN HUBERMAN, Consultants International, Inc.
JEROME KARLE, Naval Research Laboratory
JAMES KILLIAN, Massachusetts Institute of Technology
CARL KISSLINGER, University of Colorado
CHARLES F. LARSON, Industrial Research Institutes
LEON M. LEDERMAN, Fermi National Accelerator Laboratory

JOHN M. LOGSDON, George Washington University
FRANKLIN A. LONG, Cornell University
ARTHUR E. MAXWELL, University of Texas at Austin
C. G. OVERBERGER, University of Michigan
V. ADRIAN PARSEGIAN, Biophysical Society
EVERETT PITCHER, American Mathematical Society
HERMAN POLLACK, George Washington University
CYRIL PONNAMPERUMA, University of Maryland
CASSANDRA A. PYLE, Council for International Exchange of Scholars
CHARLES L. RINO, SRI International
BRYANT W. ROSSITER, Eastman Kodak Company
WILLIAM D. SAWYER, Wright State University
KNUT SCHMIDT-NIELSEN, Duke University
FREDERICK SEITZ, The Rockefeller University
A. F. SPILHAUS, JR., American Geophysical Union
A.G. UNKLESBAY, American Geological Institute
VICTOR F. WEISSKOPF, Massachusetts Institute of Technology
ROBERT M. WHITE, National Academy of Engineering
F. KARL WILLENBROCK, Southern Methodist University

U.S. Government

MILDRED S. ALLEN, Department of Transportation
MARK S. BEAUBIEN, Fogarty International Center
DAVID Z. BECKLER, Organisation for Economic Co-operation and Development
WILLIAM C. BREWER, JR., National Oceanic and Atmospheric Administration
FELIX DOROUGH, Bureau of Oceans and International Environmental and Scientific Affairs/Department of State
PEGGY FINARELLI, National Aeronautics and Space Administration
HUGH LOWETH, Office of Management and Budget
JOHN M. MARCUM, Office of Science and Technology Policy
JAMES R. MORRISON, National Aeronautics and Space Administration
JOSEPH F. SAUNDERS, National Cancer Institute
DAVID H. STROTHER, Environmental Protection Agency
LINDA A. VOGEL, Department of Health and Human Services

Appendix B

Biographic Summaries of Authors

JUSTIN L. BLOOM is president of Technology International, Inc., of Potomac, Maryland, a small consulting organization specializing in foreign scientific and technical information and international technology transfer. Mr. Bloom's career has spanned 35 years, encompassing work as a research engineer and program manager in petrochemicals development, nuclear materials production, nuclear weapons development, radioisotopes applications, and development of nuclear auxiliary power systems. During 24 years of service with the U.S. government, he was technical assistant to the chairman of the Atomic Energy Commission and counselor for Scientific and Technological Affairs at the American embassies in Tokyo and London. He retired from the Foreign Service in March 1983 with the rank of minister-counselor and with a Presidential Meritorious Service Award.

HERBERT I. FUSFELD is director of the Center for Science and Technology Policy at New York University and a member of the Board of Directors of Hazeltine Corporation. Dr. Fusfeld has served as director of research for AMF and for Kennecott Copper Corporation (1963–1978). He is a past president of IRI, a member of the Advisory Council for the National Science Foundation, and a member of the U.S.-USSR Joint Commission for Scientific and Technological Cooperation.

WILLIAM J. GARTLAND, JR., is director of the National Institutes of Health, Office of Recombinant DNA Activities. He joined the staff of the NIH in 1970, and he has been executive secretary of the NIH Recombinant DNA Advisory Committee since its inception in 1974. Dr. Gartland was the U.S. representative to the European Science Foundation Liaison Committee on Recombinant DNA Research, which met from 1977 to 1981. He participates in expert groups of the Organisation for Economic Co-operation and Development and the Council of Europe, dealing with issues of biotechnology.

G. ROSS HEATH is professor of marine geology and Dean of the College of Oceanography at Oregon State University. He serves as chairman of the Board of Governors of the Joint Oceanographic Institutions, Inc., and as a member of the Board on Ocean Science and Policy and the Board on Radioactive Waste Management of the National Research Council. Dr. Heath's research interests are in marine geochemistry and related policy issues. His current projects include deep-sea manganese nodules, sub-seabed disposal of high-level nuclear wastes, and ocean disposal of low-level nuclear wastes.

MAX HELLMANN is currently a private consultant. Until his recent retirement, Dr. Hellmann was deputy director of the U.S.-Israel Binational Science Foundation from 1981 to 1983. He previously served as deputy director of the Division of International Programs of the National Science Foundation as part of a 23-year career with the NSF. Dr. Hellmann was also a research chemist with the National Bureau of Standards from 1951 to 1960.

PHILIP W. HEMILY is currently a consultant to the NATO Scientific Affairs Division and the Office of International Affairs of the National Research Council. Until his recent retirement, Dr. Hemily served for over 6 years as deputy assistant secretary general for scientific affairs on the international staff of NATO in Brussels (1976–1982); as science counselor to the U.S. Mission to the Organisation for Economic Co-operation and Development (OECD) in Paris (1965–1974); and in senior-level posts of the National Science Foundation (1957–1965). During this latter period with the NSF, his program responsibilities to advance the quality of science education in the United States led to initiating cooperative science education programs in Central and South America and in Africa.

CLEMENS A. HEUSCH is professor of physics at the University of California, Santa Cruz, and, during 1983–1984, is on a sabbatical leave at the European Laboratory for Particle Physics (CERN) in Geneva, Switzerland. After a brief period of industrial research in semiconductor physics, Dr. Heusch started work on elementary particle physics at the DESY electron accelerator project in Hamburg, Germany. He was involved in teaching and research at the California Institute of Technology from 1963 to 1971. Dr. Heusch started the particle physics program at the University of California's Santa Cruz campus, leading to the establishment of its Institute of Particle Physics in 1980.

JOHN M. LOGSDON is director of the Graduate Program in Science, Technology, and Public Policy of the George Washington University, where he is also professor of political science and public affairs. Dr. Logsdon's research interests include space policy, the history of the U.S. space program, and international science and technology policy. He is author of *The Decision To Go to the Moon: Project Apollo and the National Interest*, and numerous books, articles, and reports on space policy and science and technology policy. Dr. Logsdon has served as a consultant to the UN, the National Science Foundation, the Department of State, the Department of Commerce, and other public and private organizations. He has been a fellow at the Woodrow Wilson International Center for Scholars and was the first holder of the Chair in Space History of the National Air and Space Museum.

JOHN S. PERRY is staff director of the Board on Atmospheric Sciences and Climate of the National Research Council. Dr. Perry joined the NRC in 1974 after retiring with the rank of colonel from a 20-year career as a meteorologist and research manager with the U.S. Air Force. He was recently elected a fellow of the American Meteorological Society. Dr. Perry's interest in international environmental affairs stems from his decade-long association with the Global Atmospheric Research Program, a 2-year tour at the World Meteorological Organization headquarters in Geneva, and participation in U.S. delegations to many international meetings.

EUGENE B. SKOLNIKOFF is director of the Center for International Studies and professor of political science at the Massachusetts Institute of Technology. He served on the White House staff in the Science Adviser's office in the Eisenhower and Kennedy administrations and was a senior consultant to President Carter's science adviser. Dr. Skolnikoff's research and teaching have focused on science and public policy, especially the interaction of science and technology with international affairs, covering a wide range of industrial, military, space, and economic issues. He is also presently chairman of the Board of

Trustees of the German Marshall Fund of the United States and a consultant to several private and government agencies.

MITCHEL B. WALLERSTEIN is special assistant for policy and planning in the Office of International Affairs, National Research Council. He served previously for 5 years on the faculty at MIT, where he was associate director of the International Food and Nutrition Policy Program. Dr. Wallerstein's research interests have included global food and development problems and various issues relating to international technology transfer. He has authored numerous books, articles, and reports on both topics. In 1982, Dr. Wallerstein served as principal staff consultant to the Panel on Scientific Communication and National Security of the Academy complex. He edited the present volume and directed the project on which it is based.

Appendix C

Workshop on U.S. Participation in International S&T Cooperation

SEPTEMBER 28–29, 1983

NAS Lecture Room

Agenda

WEDNESDAY, September 28

9:00 a.m.	I.	Welcome—Frank Press, NAS President
	II.	Meeting objectives and introduction—Walter A. Rosenblith, NAS Foreign Secretary
	III.	Modalities of international S&T cooperation • Presentations (5–10 minutes each) on selected forms of cooperation • Discussion of what has or has not worked, under what circumstances, and why
	Chair:	Walter A. Rosenblith
12:30 p.m.		Luncheon
2:00	IV.	Domestic basis of U.S. participation in international cooperation • Roles, responsibilities, and organization of the U.S. government

		• Roles and contributions of nongovernmental institutions (e.g., universities, professional societies, academies, and private industry)
	Chair:	Richard J. Green
5:30–7:00		Reception, Members' Room

THURSDAY, September 29

9:00 a.m.	V.	Competing objectives and pressures on U.S. policy for international S&T cooperation • Objectives and benefits of and obstacles to bilateral and multilateral cooperation • Changing conditions of international science cooperation
	Chair:	Harvey Brooks
12:30 p.m.		Luncheon, Lecture Room
2:00	VI.	Modified or new forms of cooperation to meet future needs • New policy or programmatic approaches to make international cooperation more effective
	Chair:	Walter A. Rosenblith
4:00		Adjournment

Appendix D

Invited Participants

PHILIP H. ABELSON, Editor, Science Magazine

RICHARD E. ALDERMAN, Staff Assistant to the Director, U.S.-Japan Natural Resources Program, National Oceanic and Atmospheric Administration

JESSE H. AUSUBEL, Board on Atmospheric Sciences and Climate, National Research Council

EDWARD S. AYENSU, Office of Biological Conservation, Smithsonian Institution

BODO BARTOCHA, Director Division of International Programs, Directorate for Scientific, Technological, and International Affairs, National Science Foundation

MARK S. BEAUBIEN, Acting Director, Fogarty International Center, National Institutes of Health

DAVID Z. BECKLER, Director for Science, Technology, and Industry, Organisation for Economic Co-operation and Development

JUSTIN L. BLOOM, President, Technology International, Inc.

ELKAN BLOUT, Harkness Professor, Harvard Medical School; Dean for Academic Affairs, Harvard School of Public Health; Treasurer, National Academy of Sciences

GIORGIO BOGGIO, Directorate-General for Science Research and Development, Commission of the European Communities

EDWARD L. BRADY, Associate Director for International Affairs, National Bureau of Standards

Harvey Brooks, Benjamin Peirce Professor of Technology and Public Policy, Aiken Computation Laboratory, Harvard University

Dale R. Corson, President Emeritus, Cornell University

Arthur B. Corte, International Relations Officer, Bureau of Oceans and International Environmental and Scientific Affairs, Department of State

Edward Deagle, The Rockefeller Foundation

Fred W. Decker, Deputy Assistant Secretary, Education Research and Improvement, Department of Education

James D. Ebert, President, Carnegie Institution of Washington; Vice President, National Academy of Sciences

Donald C. Ferguson, Director, Office of Cooperative Science and Technology Programs, Bureau of Oceans and International Environmental and Scientific Affairs, Department of State

Herbert Friedman, Chairman, Commission on Physical Sciences, Mathematics, and Resources, National Research Council

Herbert I. Fusfeld, Director, Center for Science and Technology Policy, Graduate School for Business Administration, New York University

William J. Gartland, Jr., Director, Office of Recombinant DNA Activities, National Institute of Allergy and Infectious Diseases, National Institutes of Health

Edwin L. Goldwasser, Vice Chancellor for Academic Affairs, University of Illinois, Champaign-Urbana

Fitzhugh Green, Associate Administrator, Office of International Activities, Environmental Protection Agency

Richard J. Green, Assistant Director, Directorate for Scientific, Technological, and International Affairs, National Science Foundation

G. Ross Heath, Dean, School of Oceanography, Oregon State University

Max Hellmann, Deputy Executive Director, U.S.-Israel Binational Science Foundation

Philip W. Hemily, Office of Advanced Technology, Bureau of Oceans and International Environmental and Scientific Affairs, Department of State

Allen Holt, Deputy Director, Division of International Programs, Directorate for Scientific, Technological, and International Affairs, National Science Foundation

Charles M. Huggins, Manager, External Programs Operation, Corporate Research and Development, General Electric Company

Robert Junghans, Chief of International Activities, National Oceanic and Atmospheric Administration

ANNE KEATLEY, Professional Associate, Office of International Affairs, National Research Council

EUGENE KOVACH, Director, Office of Advanced Technology, Bureau of Oceans and International Environmental and Scientific Affairs, Department of State

RICHARD A. LEGATSKI, Future Development Coordinator, Ocean Minerals and Energy Division, National Oceanic and Atmospheric Administration

JOHN M. LOGSDON, Graduate Program in Science, Technology, and Public Policy, The George Washington University

HUGH F. LOWETH, Deputy Associate Director for Energy and Science, Office of Management and Budget, Executive Office of the President

THOMAS F. MALONE, Chairman, Board on Atmospheric Sciences and Climate, National Research Council, (Treasurer, International Council of Scientific Unions)

JOHN M. MARCUM, Assistant Director for Energy and Natural Resources, Office of Science and Technology Policy, Executive Office of the President

ROBERT E. MARSHAK, University Distinguished Professor, Department of Physics, Virginia Polytechnic Institute and State University

ARTHUR E. MAXWELL, Director, Institute for Geophysics, The University of Texas

PAUL C. MAXWELL, Committee on Science and Technology, U.S. House of Representatives

HUGH H. MILLER, Executive Officer, National Academy of Engineering

JAMES R. MORRISON, Deputy Director, International Affairs Division, National Aeronautics and Space Administration

HENRY NAU, Department of Political Science, The George Washington University

HOMER A. NEAL, Provost, State University of New York, Stony Brook

NORMAN NEUREITER, Vice President, Corporate Staff and Manager of Corporate Relations, Texas Instruments

RODNEY W. NICHOLS, Executive Vice President, The Rockefeller University

ARTHUR PARDEE, Consultant, International Affairs, Joint Oceanographic Institutions

SIDNEY PASSMAN, Special Assistant, Division of Planning and Policy Analysis, Office of Planning and Resources Management, National Science Foundation

JOHN S. PERRY, Executive Director, Board on Atmospheric Sciences and Climate, National Research Council

CYRIL PONNAMPERUMA, Director, Laboratory of Chemical Evolution, University of Maryland

CASSANDRA A. PYLE, Director, Council for International Exchange of Scholars

VICTOR RABINOWITCH, Executive Director, Office of International Affairs, National Research Council

J. THOMAS RATCHFORD, Associate Executive Officer, American Association for the Advancement of Science

JOHN A. REINEMUND, Chief, Office of International Geology, U.S. Geological Survey

ROGER REVELLE, Professor of Science and Public Policy, Program in Science, Technology, and Public Policy, University of California, La Jolla

WILLIAM ROBERTSON, The Andrew W. Mellon Foundation

WALTER A. ROSENBLITH, Institute Professor, Massachusetts Institute of Technology, Foreign Secretary, National Academy of Sciences

JEFFREY D. ROSENDHAL, Assistant Associate Administrator (Science), Office of Space Science and Applications, National Aeronautics and Space Administration

BRYANT W. ROSSITER, Director, Chemistry Division, Research Laboratory, Eastman-Kodak Company

WILLIAM C. SALMON, Special Assistant, Office of the Undersecretary for Security Assistance, Science and Technology, Department of State

WILLIAM D. SAWYER, Dean, School of Medicine, Wright State University

EUGENE B. SKOLNIKOFF, Director, Center for International Studies, Massachusetts Institute of Technology

PHILIP M. SMITH, Executive Officer, National Research Council

JOEL A. SNOW, Director, Science and Technology Affairs Staff, Office of Energy Resources, Department of Energy

A. F. SPILHAUS, JR. Executive Director, American Geophysical Union

FRANCIS X. SUTTON, The Ford Foundation

MARY MARTHA TREICHEL, Executive Secretary, Advisory Committee for the International Council of Scientific Unions, Office of International Affairs, National Research Council

TRUELS TRUELSEN, North Atlantic Treaty Organization

MITCHEL B. WALLERSTEIN, Special Assistant for Policy and Planning, Office of International Affairs, National Research Council

JOHN WALSH,. Science Magazine

WILLIAM J. WALSH III, Office of Environment and Health, Bureau of Oceans and International Environmental and Scientific Affairs, Department of State

F. KARL WILLENBROCK, Cecil H. Green Professor of Engineering, School of Engineering and Applied Science, Southern Methodist University

DOROTHY S. ZINBERG, Center for Science and International Affairs, John F. Kennedy School of Government, Harvard University

Appendix E

Annotated Bibliography

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Carey, W.D. 1977. Intergovernmental cooperation in science. Science 198:785.

Corning, Mary E. 1980. A Review of the United States Role in International Biomedical Research and Communications. NIH Publication No. 80–1638. Bethesda, Md.: National Library of Medicine, National Institutes of Health.

Chronicles the development of U.S. involvement in international biomedical research and public health. Discusses the role of international public health as an instrument of foreign policy and the conflict between the two. Looks at various forms of international cooperation, bilateral and multilateral. Considers future needs.

Coward, H. Roberts. 1981. Citation data for planning international scientific cooperation. Paper prepared for the National Science Foundation, Division of International Programs Symposium, December 8–10, 1981. Philadelphia: Institute for Scientific Information.

Reports on an experiment in the application of citation data to certain questions involved in the development, operation, and assessment of international scientific exchange programs, based on data drawn from the Institute for Scientific Information's data base for the Science Citation Index.

Crawford, J.G. 1977. Development of the international agricultural research system. In Thomas H. Arndt et al., eds. Resource Allocation and Productivity in National and International Agricultural Research. Minneapolis: University of Minnesota Press.

Darvas, György. 1983. International Cooperation and Its Effects on Society. Budapest, Hungary: Institute for Research Organization.

Proceedings of a Symposium on International Scientific Cooperation and Its Effects on Society, sponsored by UNESCO, held at Siófok, Hungary, from May 10–14, 1983. A compendium of invited papers on the impact of international cooperation on national and international science policies. Includes case studies of selected examples of international cooperation and methodological approaches to conduct of research.

Deudney, Daniel. 1983. Space: The High Frontier in Perspective. Worldwatch Paper #50. Washington, D.C.: Worldwatch Institute.

Di Castri, F., M. Hadley, and J. Damlamian. 1980. Ecology of an international scientific project. Impact of Science on Society 30(4):247–260.

Stresses the desirability of developing multipurpose, relatively low cost schemes, built on strong local foundations and integrated internationally to share information and experience. The approach is problem oriented; planners and local populations are involved; natural and social sciences are combined; and new criteria are developed for project evaluation.

Dickson, David. 1984. A political first for scientific cooperation. Science 224:1317–1319.

Updates the status of the 17 multinational working groups in different areas of S&T established at the Versailles economic summit in 1982. Discusses the important political role that the project's steering committee is coming to play.

Drake, C.L., and J.C. Maxwell. 1981. Geodynamics—Where are we and what lies ahead? Science 213:15–22.

Discusses the evolution of the plate tectonics theory during the past two decades. In the process, various international research projects are considered, including the recently completed International Geodynamics Project and its successor, the International Lithosphere Project.

Evan, William. 1981. Knowledge and Power in a Global Society. Beverly Hills, Calif.: Sage Publications.

Fatouros, A.A. 1981. International controls of technology transfer. In T. Safafi-rejad et al., eds. Controlling International Technology Transfer. New York: Pergamon Press, pp. 478–505.

Discusses various institutional and legal dimensions inherent in bilateral and multilateral control of technology transfer.

Fusfeld, Herbert I., and Carmela S. Haklisch. 1982. Industrial Productivity and International Technical Cooperation. New York: Pergamon Press.

This volume is based largely on papers presented at a Conference on Industrial Productivity and International Technical Cooperation held in Paris in November 1980. Overview papers address changing trends in international technical cooperation, technological cooperation in the industrial context, and industry's role in cooperating with governments in international technical cooperation. Considerations in strengthening the scientific and technological base in selected specific fields (e.g., materials, chemistry, biology, etc.) are also presented.

Geophysics Research Board, National Research Council. International Geophysical Year and the International Polar Years.

Marks the anniversaries of major international cooperative programs in geophysics and polar research. Examines the outcome of the IGY.

Glennan, T. Keith. 1976. Technology and foreign affairs. A report to the Deputy Secretary of State.

Reports on a study conducted for the Department of State on the interrelationship of science, technology, and foreign affairs. Specific examples of U.S. involvement in international technological issues are examined, including weather modification, U.S./Soviet cooperation, uranium enrichment, and preparations for international conferences on science and technology. The organization and management of the OES Bureau are also considered. A series of recommendations concerning mission, programs, resources, and relationships is presented.

Graham, Loren R. 1978. How valuable are scientific exchanges with the Soviet Union? Science 202. pp. 383–390.

Describes the scope of present cooperative agreements (as of 1978) between the United States and the Soviet Union. The paper then summarizes the results of the most important evaluations of the programs and analyzes some of the principal criticisms of the agreements that have appeared in the press. Finally, it suggests ways in which the programs can be made more effective.

Granger, John V. 1979. Technology and International Relations. San Francisco: W.H. Freeman and Company.

Describes the origins and uses of modern technology, shows how governments individually and collectively seek to regulate its flow, and explores the public policy issues raised in national security, trade and investment, and developmental assistance. Contains a limited section dealing specifically with intergovernmental cooperation in technology.

Hemily, Philip W., and M.N. Ozdas, eds. 1979. Science and Future Choice, Vols. 1 and 2. Oxford: Clarendon Press.

The first volume of this series, which commemorates the twentieth anniversary of the NATO Science Committee, presents a retrospective and prospective appraisal of selected fields of scientific activity by distinguished scientists. The second volume analyzes issues that are of particular concern with regard to the interaction between science and society.

Jordan, Robert S., ed. 1972. Multinational Cooperation: Economic, Social and Scientific Development. Oxford: Oxford University Press.

Kerwin, L. 1981. International science—An overview. Science 213:1069 and 1072.

Killian, J.R., Jr. 1965. An international institute of science and technology. In Norman Kaplan, ed. Science and Society. New York: Rand McNally and Co., pp. 510–518.

Recounts the attempt during the early 1960s to establish an International Institute of Science and Technology under the auspices of the NATO Science Committee.

Kovach, Eugene G. 1978. U.S. Government Participation in the Science and Technology Programs of Selected Multilateral Organizations. Washington, D.C.: Division of Policy Research and Analysis, National Science Foundation.

Analyzes the science and technology programs of four multilateral governmental organizations: the NATO Science Committee; the Economic Commission for Europe; Senior Advisers on Science and Technology; the OECD Committee for Scientific and Technological Policy; and the UNESCO Natural Sciences Program. The study was based on extensive personal interviews and provides insights into the effectiveness of secretariat performance, U.S. representation, backstopping and coordination procedures.

National Academy of Sciences. 1976. Science, Technology and Society—a Prospective Look. Washington, D.C.: National Academy of Sciences.

This paper is the summary and conclusions of the conference organized and convened by the National Academy of Sciences at Bellagio, Italy, in June 1976. The report presents the views of the participants on various pressing world needs that science and technology can address. A series of recommendations is presented, including an appeal for increased cooperation both through governmental and nongovernmental channels.

National Academy of Sciences-National Research Council, Commission on International Relations. 1979. Preliminary report and recommendations on the role and operation of the international scientific unions associated with ICSU. Board on International Organizations and Programs, A.K. Solomon, Chairman, unpublished.

Preliminary report and recommendations on the role and operation of the international scientific unions associated with ICSU. During 1978 data were collected from the U.S. national committees of the member unions of ICSU and a series of meetings of national committee chairmen was organized to assess the present role and effectiveness of the unions and their relationship to ICSU. This report summarizes the results of the inquiry.

National Science Board, National Science Foundation. 1981. Science Indicators—1980. NSB-81-1. Washington, D.C.: U.S. Government Printing Office.

Analyzes U.S. science and technology per se and in relation to the efforts of other major countries performing research and development. It also provides information on public attitudes and expectations concerning science and technology and impact on society. A small section is included on international scientific cooperation.

National Science Foundation. 1982. The international context of U.S. science and technology. In The 5-Year Outlook for Science and Technology, 1981. Washington, D.C.: U.S. Government Printing Office, pp. 18–25.

Considers major trends in the international context relative to U.S. science and technology. The chapter examines the state of U.S. science and technology relative to other industrialized democracies and the USSR. It also takes up transnational problems and opportunities as well as those S&T problems that are truly global in nature.

Nierenberg, William A. 1978. The deep sea drilling project after ten years. American Scientist 66:20–29.

Nye, J., and R.O. Keohane. 1971. Transnational relations and world politics. International Organizations 25:329–349.

Defines the concept of transnational relations between states. Sets forth four major categories of "global interactions" through which transnational relations take place. Identifies some of the more salient effects of transnational relations on interstate politics, including impacts related to science and technology.

Office of Science and Technology Policy in cooperation with the National Science Foundation. 1982. International cooperation in science and technology, pp. 52–58. In Annual Science and Technology Report to the Congress: 1981. Washington, D.C.: U.S. Government Printing Office.

Examines the state of international cooperation in science and technology in the broader context of U.S. and S&T development. This chapter considers the changing characteristics of the policy context for cooperation and, in turn, scientific cooperation with the industrialized democracies, the middle income countries, and the third world.

Organisation for Economic Co-operation and Development. 1979. The Usage of International Data Networks in Europe. Paris: OECD.

Considers the growing importance of international data networks among the European OECD countries, including technical applications, access control and security, and cost. Presents an analysis of the implications of transborder data flows including the impact on international S&T cooperation.

Organisation for Economic Co-operation and Development. 1980. Technical Change and Economic Policy. Paris: OECD

Organisation for Economic Co-operation and Development. 1981. Science and Technology Policy for the 1980s. Paris: OECD.

Contains the four reports discussed at the ministerial-level meeting of the OECD Committee for Scientific and Technological Policy in March 1981. They deal with R&D policy in the member countries; technological innovation and the economy; impacts of science and technology on society in the 1980s; and trends, problems, and prospects for international cooperation among OECD countries.

Organisation for Economic Co-operation and Development, Committee for Scientific and Technological Policy. 1984. Conclusions of the Workshop on Technological Innovation Policy in Less Industrialized Member Countries. Note by the Secretariat. SPT(84)5; TECO(84)2; Scale 2. Paris: OECD.

Summarizes the proceedings of the Workshop on Technological Innovation Policy in Less Industrialized Member Countries, held in Dubrovnik, September 21–23, 1983. Considers the principles of innovation policy as well as the methods and measures for action. Describes various types of international cooperation between the OECD and the less developed countries.

Organisation for Economic Co-operation and Development, Committee for Scientific and Technological Policy. 1984. High Level Conference on International Co-Operation in Science and Technology Among OECD Member Countries. SPT(84)6; Scale 2. Paris: OECD.

Reports on the discussions of the three Working Groups of the High Level Conference on International Co-operation in Science and Technology Among OECD Member Countries.

Ozdas, M.N. 1977. Science, technology and international cooperation. NATO Review 25:20–25.

Identifies new factors which increase the need for international cooperation in S&T. Focuses primarily on the special role of NATO S&T activities.

Pirages, D. 1978. New Context for International Relations: Global Ecopolitics. Boston: Duxbury Press.

President's Commission for a National Agenda for the Eighties, Panel on Science and Technology. 1980. Science and Technology: Promises and Dangers in the Eighties. Washington, D.C.: U.S. Government Printing Office.

Sets forth the views of a special panel established as part of a presidential commission created under the Carter administration. The report first offers a historical perspective on the origin of federal responsibilities in science and technology. It then addresses a variety of new challenges involving science and technology in the 1980s, including changes in the prevailing world order.

Press, F. 1981. Science and technology in the White House, 1977–1980. Science 211:249–256.

The second of two articles examining the role and objectives of the Office of Science and Technology Policy (OSTP) during the Carter administration. This article focuses on OSTP activities related to national security and foreign policy, space, energy and environment, health, and agriculture.

Raiffa, Howard. 1975. Multinational institute explores global problem. Futurist 9:147–149.

Describes the origins and organization of IIASA. Presents the initial research areas selected for study. Written by the former director of IIASA.

Rannestad, A. 1973. Scientific cooperation with NATO. NATO Review 21(3):23–26.
Describes the evolution of efforts within the context of NATO to promote scientific cooperation among the Atlantic allies.

Rotblat, J. 1967. Pugwash—The First Ten Years. New York: The Humanities Press.
Recounts the efforts to develop a private, nongovernmental channel for scientific communication on pressing international issues such as arms control and disarmament.

Ruggie, J.G. 1975. International responses to technology. International Organizations 29(3):557–584.
Presents a framework of analysis for understanding the role of various international organizations in managing S&T-related activities. Examines the range of international regimes and organizations that have developed to meet specific needs.

Rycroft, Robert W. 1982. International Cooperation in Science Policy: The U.S. Role in Megaprojects. Prepared for Office of Special Projects, National Science Foundation. Unpublished.
Examines the U.S. role in Big Science projects in an era in which the United States is no longer dominant to the same degree that it once was. Considers emerging new issues and needs for the 1980s.

Sagafi-rejad, T., and R. Maxon, eds. 1980. Technology Transfer Control Systems. New York: Arts and Sciences Press.

Salomon, Jean-Jacques. 1964. International scientific policy. Minerva, Summer 1964. pp. 411–434.
Discusses the problems of policymaking in international science from both a governmental and nongovernmental perspective.

Schatz, Gerald S., ed. 1974. Science, Technology and Sovereignty in the Polar Regions. Lexington, Mass.: Lexington Books.
Papers from an NAS colloquium that deal with transnational S&T in the polar region and various legal implications.

Scott, John T. 1975. International cooperation in physics. Physics Today 28:69–21.
Discusses the implications of the fact that the United States is no longer preeminent in the field of physics. Presents the views of those from universities, industry, and the government. Considers the value of the national laboratories.

Sewell, James P. 1973. UNESCO: pluralism rampant. In Robert W. Cox and Harold K. Jacobson, eds. The Anatomy of Influence, New Haven: Yale University Press, pp. 138–174.
Examines the functions, structures, and decision-making processes of UNESCO. Analysis of the "actors" who participate in UNESCO, policy decisions, and the sources of influence.

Shaffer, Stephen M., and Lisa Robock Shaffer. 1982. The Politics of International Cooperation: A Comparison of U.S. Experience in Space and Security. Monograph Series in World Affairs, Graduate School of International Studies, Vol. 17, Book 4. Denver, Colo.: University of Denver Press.
Describes and compares U.S. international cooperation in space with similar involvement in the area of defense. Examines the role of international cooperation in U.S. foreign policy and the salient distinctions between the two areas.

Skolnikoff, Eugene B. 1972. The International Imperatives of Technology. Research Series No. 16, Institute of International Studies. Berkeley: University of California Press.
A comprehensive treatment of the various international regimes established to deal both with old and new scientific and technological problems. The functions and effectiveness of various international organizations are analyzed, along with the posture of governments towards participation in and support for multinational cooperative solutions.

Skolnikoff, Eugene B. 1975. History of U.S. Government Organization for Conduct of Foreign Policy in Technology-Related Subjects. C/75-20. Cambridge, Mass.: MIT Center for International Studies.

Paper prepared originally as part of a project for the Commission on the Organization of the Government for the Conduct of Foreign Policy. Provides an illustrative history and analysis of the post-World War II organization of the U.S. government for the conduct of foreign policy involving science and technology. Key factors relevant to the policy process are highlighted.

Skolnikoff, Eugene B. 1975. Policy Process for Space Satellites. C/75-20. Cambridge, Mass.: MIT Center for International Studies.

Paper prepared originally as part of a project for the Commission on the Organization of the Government for the Conduct of Foreign Policy. Considers the nature of the space domain and the need for international cooperation. Assesses the effectiveness of international organizations and the interests of the U.S. government.

Smith, Philip M. 1981. The role of the Dry Valley Drilling Project in Antarctic and international science policy. Antarctic Research Series 33:1-5.

Analyzes the organization, development, and management of the Dry Valley Drilling Project in terms of the lessons they might offer for similar projects in the future. A number of research management principles are identified.

Spiegel-Rosing, Ina, and Derek de Solla Price, eds. 1977. Science, Technology and Society: a Cross-Disciplinary Perspective. Beverly Hills, Calif.: Sage Publications.

This volume contains the work of 17 contributors from nine disciplines and six different countries who address the critical interdisciplinary questions regarding scientific and technological development in the modern world. Of particular interest are chapters by Brigitte Schroeder-Gudehas, "Science, Technology and Foreign Policy," and Eugene Skolnikoff, "Science, Technology and the International System."

Sullivan W.L. 1979. Future of international cooperation in marine science and technology. Marine Technology Society Journal 13(3):24-29.

Traces the history of efforts to reach accommodations—both legal and otherwise—regarding the use of waters lying inside a nation's territorial zone. Considers the problem for excessive politicization of organizations developed to deal with these issues. Examines some of the implications of a breakdown in the Law of the Sea (LOS) process.

Tisdell, C.A. 1981. Science and Technology Policy: Priorities of Governments. London: Chapman and Hall.

Discusses the role of science in international affairs, including the rationale for governments to invest in international research commitments.

Tolley, George S., ed. 1979. International Science and Technology: The Policy Gap. Chicago: Chicago Council on Foreign Relations.

A collection of papers sponsored by the Chicago Council on Foreign Relations in the spring of 1978 on the subject of international science and technology. Of particular interest are papers by Robert R. Wilson, "Toward a World Accelerator Laboratory," and by Thomas Veach Long, "International Cooperation and Efficient Transfer of Technological Information."

U.S. Congress, House Committee on International Relations. 1976. Science, Technology and American Diplomacy. Prepared by the Congressional Research Service. Washington, D.C.: U.S. Government Printing Office.

This volume represents the culmination of 7 years of research undertaken by the Congressional Research Service at the request of the Subcommittee on International Security and Scientific Affairs of the House Committee on International Relations. The study, in two volumes, contains an overall treatment of the relationship between science, technology and diplomacy. It then presents six case studies—among which is an analysis of "The Political Legacy of the International Geophysical Year,"—and six issues—including topics such as "The Evolution of International Technology," "U.S. Scientists Abroad," and "Science and Technology in the Department of State." Principal policy implications derived from this comprehensive treatment are also presented.

Walsh, J. 1977. United States-West European cooperation in science seems to be declining. Science 198:175–177.

Presents the preliminary results of a number of separate analyses that apparently indicate a decline in the frequency of cooperation between U.S. and West European researchers. Some of the most significant implications of the decline are considered.

Webster, J.J. 1977. International cooperation in science and technology. Search 8(4):94–95.

Discusses international cooperative efforts in S&T between Australia and the United States (as well as other states).

White, Robert M. 1982. Science, politics, and international atmospheric and oceanic programs. Bulletin of the American Meteorological Society 63:8.

Paper presented originally as the Fifth Donald L. McKernan Lecture in Marine Affairs analyzes the scientific and political aspects of the World Climate Program (WCP) and its predecessor, the Global Atmospheric Research Program (GARP). Distinctions between the GARP and the WCP are highlighted and future needs are identified.

Yeager, Joseph A. 1981. International Cooperation in Nuclear Energy. Washington, D.C.: Brookings Institute.

Analyzes the international measures that might be taken to reduce incentives to acquire national reprocessing or enrichment facilities. It also considers means of channeling the development of reprocessing capacity, controlling separated plutonium, and achieving a consensus on the terms of trade in sensitive nuclear materials. Possible new international arrangements—including a nuclear fuel bank—are explored in detail.