PREFACE

INTERNATIONAL COLLABORATION IN FUSION ENERGY DEVELOPMENT

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The Environment, Energy and Resources Group in the National Science Foundation's Division of Policy Research and Analysis has conducted a series of policy workshops in response to interests expressed by the Executive Office of the President. These workshops have assessed federal policy options relating to commercialization of selected energy technologies viewed as alternatives to oil-based fuels.

Four policy workshops relating to fusion energy have been conducted: "Alternate Fusion Concepts and Their Utilization," "Mobilization of the Private Sector in Effective Development of Fusion Energy," "International Collaboration in Fusion Energy Development," and "End-Use Products of Fusion Energy." Each workshop was structured to allow intensive discussion of identified policy issues and various federal policy options. Initially four to seven discussion papers were commissioned in each major policy area with experts having a variety of background and experience. The prepared papers were then discussed at a two-day workshop attended by the selected reviewers, authors, and concerned federal policymakers. Authors revised their papers after the workshop to incorporate reviewer comments and the workshop discussion. The five papers presented in this special issue are the finalized versions of the papers presented at the policy workshop entitled "International Collaboration in Fusion Energy Development."

In his paper, Professor David J. Rose of the Massachusetts Institute of Technology reviews international collaboration in fusion research from a historical viewpoint. He points out that extensive international cooperation has been necessary for fusion research and development (R&D) to get to where it is today, and emphasizes the desirability of increased cooperation in the coming decade. He describes international collaboration not as a zero-sum game but as a positive-sum game in which all participants benefit.

The paper by Drs. Peter J. Kortman and Stephen O. Dean of Fusion Power Associates gives a detailed analysis and evaluation of various international and bilateral programs. Their paper focuses on the characteristics of the U.S. and foreign fusion programs and examines potential direct and indirect interfaces between them.

One of the major cooperative programs has been the ongoing International Tokamak Reactor (INTOR) project. Professor Weston M. Stacey, Jr. of the Georgia Institute of Technology, who is a leader of the U.S. INTOR team, presents in his paper an analysis of technological and scientific issues related to international programs. Professor Stacey describes the potential opportunities for international technological collaboration in fusion research.

The success or failure of international or bilateral programs depends not only on the technical competence of collaborating scientists and engineers but also on institutional and other nontechnological issues. Professor Lawrence Scheinman of Cornell University, a political scientist and an expert on international nuclear matters, addresses these issues with an overall analysis of the U.S. experience in science and technology cooperation from the political, economic, managerial, and organizational points of view.

Complementing Professor Scheinman's paper, Mr. John Metzler of the Office of International Affairs of the U.S. Department of Energy gives an assessment of organizational and administrative approaches toward international cooperation in fusion energy.

Although these papers and discussion at the workshop covered a wide range of issues, the following issues served as the central questions.

1. What scientific and technological benefits or accomplishments can be attributed to bilateral or international cooperative programs in fusion research and development activities?

2. What lessons can be drawn from these past experiences in designing, negotiating, and implementing bilateral or international cooperative programs in fusion energy development? Is there any specific mechanism that has proven to be more productive?

3. Are there some clear advantages in establishing exchange or cooperative relationships with certain countries or programs based on the existing and planned fusion activities of other countries?

4. What proposals are active and what ideas are being discussed in connection with bilateral or international cooperation at this time?

BENEFITS AND ACCOMPLISHMENTS

Fusion research has traditionally enjoyed open international technical exchange and cooperation. In fact, fusion research has been conducted with a higher degree of international collaboration than any other large research activity. This collaboration started in 1958, the date of declassification, and has continued ever since. Formal agreements between the United States and the Soviet Union and between the United States and Great Britain have been in effect since that time. In 1978, a formal agreement between the United States and Japan was signed. Other western European countries and China are now participants in international collaboration in fusion research.

In earlier years, the most important collaboration was with the Soviet fusion program. In particular, the Russian capability in theoretical fusion research made a major contribution. During the 1960s, perhaps one-third of fusion theory came from the Soviet Union, including the concepts of minimum-B magnetic mirrors and tokamaks (Rose). Also, through collaborative activities with the Soviet Union, U.S. fusion researchers have been able to monitor developments in stellerators, electromagnetic confinement, and imploding liners, all of which receive little or no support in the U.S. program (Kortman & Dean). The Russian experimental results on tokamaks completely changed the nature of the U.S. fusion program. In addition, the Russian demonstration of the minimum-B mirror was the basis of the successful mirror program at Lawrence Livermore National Laboratory.

The U.S.-European Community (EC) collaboration in fusion research has been strong and made major contributions to both programs. For example, exchange of technical information on reversed-field pinch, radio-frequency heating, plasma-wall interaction, and large superconducting coils has proven to be beneficial to the U.S. fusion program. Technical staffs of the U.S. Tokamak Fusion Test Reactor (TFTR) and the EC Joint European Torus (JET) benefited scientifically and technologically from frequent visits and exchange of detailed technical data.

The Japanese fusion program has been making significant progress lately, and is in many respects complementary to the U.S. technical program. The most noticeable collaboration between the United States and Japan is the Japanese contribution to the Doublet experimental program.

Besides these bilateral programs, the U.S. fusion program has definitely benefited from the multinational cooperative projects. The INTOR project, which was initiated by the International Atomic Energy Agency (IAEA) in 1978 and conducted by fusion researchers from the United States, the Soviet Union, Euratom, and Japan, studied the objectives and physical characteristics of the next major experimental device (after TFTR, JET, and the like) in the worldwide tokamak program and assessed the technical feasibility of such a device. Through the INTOR studies, specific R&D requirements for the next stage of magnetic fusion research were identified. New data were provided by participants from other countries, and the U.S. perception of several important technical issues changed as a result of the critical evaluation of these issues (Stacey). The Large Coil Project (LCP), sponsored by International Energy Agency (IEA), has already given U.S. researchers important engineering data for magnet design and fabrication techniques.

In addition to these specific benefits, international collaboration has resulted in the enrichment of the fusion research activities through enhancement of technical information and enlarging the available technical talent. It should also be noted that international fusion collaboration has strengthened U.S. diplomatic relations with other nations and broadened U.S. industry's market abroad.

LESSONS LEARNED

The review of historical benefits of international collaboration at this workshop convinced the participants that there exist strong synergisms between national programs and that they have been very valuable to the U.S. fusion program. These accounts demonstrated that international collaboration in fusion research has not been a zero-sum game (Rose). These benefits from international fusion collaboration will most likely continue until commercial feasibility is demonstrated.

Past experience, however, has demonstrated the following four major requirements for success in international technological collaboration (Metzler).

1. No international project should be a part of the "critical path" of the main U.S. fusion program.
2. Participating parties in international collaboration must have some explicit need(s).
3. Each participating nation must have a significant domestic fusion program.
4. There should be a binding guarantee among participating nations.

The previous success of international collaboration in fusion can be attributed to the fact that the above requirements have been fully met. So far, fusion has involved basic research, and the goal of international collaboration has been scientific achievement. International projects have been conducted among nations with serious fusion programs and no significant economic stakes were associated with the research. Difficulty may arise, however, when fusion research becomes more expensive and technology-oriented. Where the program objective is scientific development and the process is still remote from commercialization, international cooperation tends to be easier. The closer the projects are to development and commercialization, the more difficult it becomes to achieve successful cooperation among competing nations (Scheinman). Thus, the future negotiation for international collaboration in fusion will become more difficult.

To overcome potential difficulties in future international collaboration, past experience shows that a strong political will and an acknowledged leader are essential. There has as yet emerged no acknowledged leader in fusion research who can muster enough support among many nations and overcome administrative and bureaucratic obstacles.

For bilateral programs, there are other lessons. Countries have different negotiating styles, sets of internal procedures, and varying R&D programs. For example, Japanese go through a tedious, laborious, and time-consuming process of building an internal consensus. Russian decision-making is quite susceptible to disruptions of political events. West European nations have options of representation, either as individual nations or as a region through Euratom. In conducting negotiation with these parties, the United States must appreciate the styles and approaches of the negotiating parties.

The U.S.-Soviet exchange will be primarily of value to the United States in the area of confinement physics rather than technology development. On the other hand, the Japanese policy of developing fusion technology in industry will enhance the position of Japanese industry in fusion commercialization. The U.S. fusion program may benefit from joint technology development projects with the Japanese. The U.S.-European nations continue high performance in mission-oriented projects such as JET and LCP. Continuation of collaboration with EC in these major projects should include the interests of the U.S. program (Kortman and Dean).

The INTOR study has shown that a significant commitment of national resources and excellent cooperation can be obtained for an international fusion project. The IAEA has proven to be a useful and functional vehicle for international collaborative efforts, and its role in the future projects now seems much more optimistic. However, agreements for substantive international collaboration are difficult to arrange and require adequate lead time to prepare. History shows that painstaking preparation is justified to avoid complications during implementation.

PREFERRED MECHANISMS

There are a number of mechanisms for international collaboration. These mechanisms can generally be divided into two types: general scientific mechanisms and mission-oriented mechanisms. Presumably general scientific mechanisms go on without specific governmental planning and initiatives.

Professional societies are in charge of these activities and the outcome of this type of collaboration will enhance the progress of fusion science. The mission-oriented mechanisms are specifically designed and have well-defined objectives. The federal roles in mission-oriented collaboration are clearly visible.

Informal visits by professionals, professional conferences, publications, and procurement of equipment facilitate scientific collaborations among fusion researchers. The level and intensity of this type of international collaboration reflect the vigor of scientific activities in fusion research. Among mission-oriented collaborations mechanisms are joint design effort, long-term personnel exchanges, and coordination meetings. Most of these mission-oriented collaborative efforts require international agreement and budgetary provisions. Obviously, the most expensive and ambitious mechanism is an international joint project, e.g., construction of a major experimental device through an international agreement.

The idea of true international cost sharing on a major experimental (and even demonstration) device is enticing, but should be regarded cautiously as a mechanism for future collaboration among nations with substantial fusion programs. This idea is closely related to the idea of an international R&D center for the world (Rose). If an INTOR-type device is ever built through international collaboration, an international R&D center is the logical place to do it. However, no consensus exists yet whether the time has come to do such a project. Many argue that it is too soon to build such a large and expensive device.

Another observation coming from this study is the need for stronger institutional arrangements. The record of international cooperation in scientific and technological R&D is mixed (Scheinman). The most practical mechanism for international collaboration in fusion would be strongly dependent on the development of fusion research toward commercialization and the size of the effort required.

Assuming that collaborative construction of a major device is premature, mission-oriented facility-sharing, joint design studies, and long-term project-oriented personnel exchanges are cost-effective and would yield substantive results. These mechanisms permit the planners and decision makers to emphasize project-oriented programs to supplement the domestic fusion research programs. In selecting mission-oriented mechanisms, specific strategies should be designed to reflect unique characteristics of the chosen R&D topics (Stacey).

PROPOSED PROGRAMS

There are a number of specific opportunities for collaboration in plasma physics and fusion technology. First of all, the physics of tokamaks is under intense investigation by most major fusion research teams. International collaboration in the planning of research programs on the mainline tokamak experiments could be used to assure development of a complete data bank on tokamak plasma physics (Stacey). In alternate magnetic confinement concepts (tandem mirror, bumpy torus, stellerator, reversed-field devices), the United States should take a primary role in the development of some of these alternate concepts and encourage other countries to take a primary role in the development of others (Stacey).

Several favorable opportunities for international collaboration exist in the development of fusion technology. The workshop participants agree in general that the following topics can benefit greatly from international collaboration: superconducting magnet technology, high performance radiation-resistant materials, advanced plasma-heating techniques, blanket and shielding engineering, plasma-wall interactions, tritium-handling technology, and safety and environmental assessment. To facilitate information exchange, an engineering data base is also proposed as a very useful program for international collaboration.

Component development and testing in major fusion devices provide substantial opportunities for international collaboration. The large fusion experimental devices can be used for the integrated testing of many technologies at a level directly relevant to the design of fusion demonstration devices. Formal bilateral or multilateral agreements should facilitate optimized use of the major devices for testing activities.

The IAEA has the longest standing programs for promoting international cooperation in fusion. The IAEA's fusion programs are guided by its International Fusion Research Council, which consists of fusion R&D directors from major member nations. The IAEA will continue sponsoring workshops and conferences, publishing technical journals and reports, and, most importantly, sponsoring the INTOR Workshop. The zero phase of the INTOR Workshop was conducted in 1979 and defined the objectives and physical characteristics of the next major experiment (after TFTR, JET, T-15, JT-60). The phase-1 of the INTOR Workshop was authorized to develop a conceptual design of the experimental device.

Another important series of international programs has been carried out under the auspices of the IEA. The LCP, the coordinated fusion materials research, and the study of plasma-materials interactions using the TEXTOR tokamak are guided by IEA's Fusion Power Coordinating Committee.

The United States has bilateral agreements in magnetic fusion research with the Soviet Union and Japan. In the coming years, the U.S.-Japan program will become more active with short-term personnel exchanges, long-term exchanges, collaboration on Doublet-III experiments, and possibly participation in the proposed Joint Institute for Fusion Theory Center. Japan has agreed to contribute $60 million over a five-year period to upgrade the Doublet-III. Joint planning activities through the U.S.-Japan Coordinating Committee on Fusion Energy are also significant. Proposed cooperation on the Fusion Materials Irradiation Test Facility, Rotating Target Neutron Source, Tokamak Poloidal Field Systems, and the High Field Test Facility will move the U.S.-Japan cooperation into the second tier of technology projects (Kortman and Dean).

CONCLUSION

The commissioned papers and the workshop discussion covered most major dimensions of the strategy for international collaborations in fusion. The discussion also identified important issues relevant to international collaboration, which should be assessed more thoroughly by future studies. It was agreed that the United States should have a clear understanding of benefits and costs before it gets involved in international projects. Fusion is now a serious business and proposed projects must be carefully planned and examined.

A clearly defined and sustainable national commitment will be essential if there is to be a successful international fusion program. The reliability of participants is a key issue. The managerial and financial structure for the collaborative projects is also very important. The probability of success will be much higher if an accepted leader exists, and conditions of cost sharing are well laid out in advance for future international projects. Information control is a major issue. Research findings and technical information will be subject to control since they are directly related to patents, licensing agreements, and other proprietary information. This issue will be raised not only for fusion technology but also for many other potential spin-off technologies.

Of course, there are other important issues not covered adequately by this study. One of them is in connection with small fusion devices such as the "throw-away tokamak."

There appeared to be a consensus among the workshop participants that fusion research is too big for a single country to handle by itself, and that international cooperation is imperative. International cooperation can result in significant benefits to participating nations and the global fusion research. International programs must therefore be regarded as an integral part of the domestic fusion programs. The United States should be more serious in selecting future international programs. There are, however, administrative and managerial problems associated with international programs. The United States should not put itself in the position where the central element of its fusion program is subject to decision-making by other nations. Judicious selection mechanisms and thorough planning will be critical to assure the benefits of international collaboration.

The workshop was moderated by Mr. James Williams of Los Alamos National Laboratory. The list of participants follows the papers in this special issue. The edited proceedings of the workshop is available through National Technical Information Service.

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