

Seventh US-Japan Joint Science Policy Seminar

Appendix F: Reflections on the Issues

Jennifer Sue Bond, National Science Foundation	pg. 73
Robert Eisenstein, National Science Foundation	75
Teruo Kishi, National Institute for Advanced Interdisciplinary Research	78
Tsuneyuki Morita, National Institute for Environmental Studies	80
Tsuneo Nakahara, Sumitomo, Ltd.	82
Paul Vanden Bout, National Radio Astronomy Laboratory	86

Multilateral Cooperation on Science and Technology Indicators

Jennifer Sue Bond

Summary of Statement

Science and technology are increasingly global in nature. In order to understand better the new global economy, and the changing issues, structure, priorities, and opportunities for science and engineering resources, decisionmakers need to have national science and technology (S&T) capabilities placed in a global context. From a data and indicators perspective, this means that assessing national S&T strengths and systems in isolation is no longer terribly meaningful—even for a large economy such as that of the United States. International comparisons are essential and they increasingly need to be done, not just in a national or bilateral mode, but in multilateral fora. Indicators of the globalization process itself are required and can best be constructed internationally. In particular, the analysis of human resources—the most mobile and the most important resource in a knowledge-based, information rich society—can only be done in a collaborative fashion. Indeed the construction of internationally comparable S&T indicators—including indicators of globalization—could be considered as an international distributed megaproject. I am interested in pursuing these themes during the workshop.

Two major and interrelated trends are occurring which are relevant for this discussion:

1. Science, technology and national economies are becoming increasingly interconnected. Many countries in addition to the United States and Japan are investing in financial and human resources for science and technology, recognizing that such investments are essential underpinnings for social and economic well being in the global economy. Individual scientists and engineers, industrial firms, and academic institutions are taking advantage of the increasingly international character of science and technology, as witnessed by enhanced international mobility of the science and technology workforce, international co-authorship of scientific publications, the development of international industrial alliances, and the global flow of technological know-how.

2. Nations are placing greater emphasis on science and engineering education and training. Countries all over the world recognize the importance of providing an excellent education to their population in a global, knowledge-based economy. At the professional level, universities in the United States, Japan, Europe and elsewhere face the challenge of introducing greater flexibility and breadth into their curricula in order to improve the employment prospects of their students at both the undergraduate and graduate levels. Universities also are examining their future roles, beginning to exploit information technologies, and are exploring the possibilities of becoming virtual universities. More broadly, nations face the challenge of assuring that their workforces will possess sufficient technological literacy, and their citizenry

sufficient knowledge and understanding of science and technology and their socio-economic impacts, to address the requirements of the new century. They also face the challenge of educating, attracting, keeping, sending, re-attracting, and integrating an increasingly mobile population of scientists and engineers.

International Aspects of *Science and Engineering Indicators*

In the *Science and Engineering Indicators* report of the National Science Board of the United States, coverage of international topics has been enhanced with each succeeding edition of the report, as has its international readership. Noting the increase in the globalization of science and technology and the increased interdependence of the world's economies, the Board decided to make international comparisons and global trends a major theme of the *Science and Engineering Indicators--1998* report. The growth in availability of internationally comparable data is in large measure the result of close working relations over many years between NSF's staff and their counterparts in other countries who are also engaged in the collection and analysis of indicators data. The United States and Japan have had a long and fruitful bilateral relationship in science policy and in S&T indicators projects. Several multinational organizations contribute substantially to constructing and exchanging internationally comparable data. These include (but are not limited to) the Organisation of the Economic Cooperation and Development (OECD), the United Nations Economic, Scientific, and Cultural Organization (UNESCO), the European Union (EU), the Pacific Economic Cooperation Council (PECC), Asian Pacific Economic Cooperation (APEC), the InterAmerican InterIberian Science and Technology Network (RICYT), and the Organization of American States (OAS). The United States and Japan can work together in these and other new fora as well, such as the World Bank. The Middle East and Africa remain regions that need to begin to develop better S&T indicators data and information and require assistance from countries and organizations that have more experience in these areas.

A Proposal

Japan and the United States and our sister countries could examine ways to join together in such multinational organizations to work with those countries who are beginning to construct their S&T resources and S&T indicators in order to construct a truly global S&T indicators system. An essential aspect of this is personal interaction. People are the best and most effective technology transfer agents. JSPS already has an effective fellowship program, but perhaps this could be one vehicle to stimulate cooperation and increase capabilities in this area. The National Science Foundation has hosted short-term visiting researchers interested in indicators. Another possibility is to jointly sponsor workshops such as this wonderful seminar. After all, in the new information age we can exchange views over email, but it is much easier to be cooperative and to be frank once we have met face to face, and realize we have common goals--and that we like each other.

International Cooperation in Big Science

Robert A. Eisenstein

It goes almost without saying that cooperation (and collaboration) has been an essential hallmark of science since the dawn of the scientific method. It makes its appearance in many ways: from the early exchange of ideas and results and simple apparatus to today's enormous multinational laboratories which host projects costing hundreds of millions, to billions, of dollars. Indeed, these large organizations and projects are often the subject of major international "understandings" or treaties, and it has been the case more often than not that the birthing of these agreements is an arduous, multi-year effort, sometimes involving hundreds or even thousands of scientists and more than a few politicians. And in at least one prominent recent example, the failure to achieve such agreement led ultimately (at least in part) to the demise of an important scientific effort.

It is very clear that the need for effective international partnership is no longer restricted to high energy physics or the space program. Today, such collaborations include use of synchrotron light sources, neutron facilities, fusion reactors, ocean-going research vessels, cosmic ray detectors, participation in the human genome project, and the creation of large-scale databases and networks. It is also clear that information technology and fast global networking are having a dramatic impact on the ability to conduct collaborative research of all kinds, generally much for the better.

An important - perhaps essential - point for our meeting is that there are many efficient ways to establish productive and cost-effective collaborations in both large-scale and small-scale projects.

At the risk of stating the obvious, it is generally true that such arrangements work best when there is no need to exchange funds, or ship equipment, across international borders. Examples of this kind of collaborative include the kind of unwritten understanding that occurs when scientists can freely make use of each other's facilities, each built with the host nation's own resources. Happily, this mode of operation still exists in several science areas.

However, economics—or other social necessity—sometimes dictates otherwise. In the aftermath of World War II, twelve European nations gave birth to the first large-scale truly collaborative international laboratory, CERN, in Geneva, Switzerland. This regional facility, now more than 40 years in existence, is the outstanding example of a successful international (regional) partnership.

Until the mid-1980's there was rough parity of facilities between Europe and the United States in high energy and nuclear physics, so there was felt no need to create specialized understandings or financial arrangements (apart from CERN) to enjoy very fruitful world-wide

collaboration. Scientists made use of these facilities based only on good ideas for science, and a willingness to pay the costs of their own equipment, travel, salaries for students, and so on.

But the decision to construct the SSC, and later the LHC, changed the landscape of high energy physics—probably forever. Certainly this was due mostly to the costs involved. Failure to achieve a suitable international partnership was an important factor in the demise of the SSC in the United States, and the final agreement between CERN and the United States over US participation in the LHC received serious Congressional scrutiny. That agreement (achieved in 1997) in the end involved the 19 CERN member states, Japan, the United States, and a number of other international partners—all working together in the construction of a \$6 billion truly world-wide enterprise.

Earlier, in the beginning of the 1990's it proved not possible to create an international agreement regarding the so-called “B-factory” (an asymmetric electron-positron collider), so that two are being built—one in Japan and one in the United States. In fairness, it is pretty clear that no one tried very hard to achieve agreement, because the cost of these devices is probably not large enough (at about \$300 million each) to warrant the effort and the perceived sacrifice of national prestige in high energy physics. Time will tell whether there is sufficient international will to achieve a meaningful collaboration on other large HEP projects, such as the Next Linear Collider or the Muon Collider.

In the area of astronomy, the European Southern Observatory (ESO), was created in 1962 to establish and operate an astronomical observatory in the Southern Hemisphere, with the aim of furthering and organizing international collaboration in astronomy. It is supported by eight countries: Belgium, Denmark, France, Germany, Italy, the Netherlands, Sweden and Switzerland. It operates the La Silla observatory in the Atacama Desert, 600 km north of Santiago de Chile, at 2400 meters altitude, where fourteen optical telescopes with diameters up to 3.6 meters and a 15-meter submillimeter radio telescope are now in operation.

The Gemini twin 8-meter telescope project (one in Chile and one on Mauna Kea) is another example of an international effort that has made substantial progress toward completion, and one in which the total cost was conceivably manageable by the United States alone. The success of this project is an important proof of principle for the construction of mid-scale facilities. The instruments will be of very significant value to all of the nations involved. They include the United States, England, Canada, Brazil, Argentina, Chile, and Australia.

A completely different kind of international collaboration is typified by the world-wide network of gravitational-wave detectors that is under construction in several nations. Each of these countries is constructing its own facility, via its own resources, and yet is thoroughly involved in an essential way in the world-wide network. LIGO and VIRGO are the three most sensitive units, and together provide the necessary pointing capability to locate possible sources of gravitational radiation. Other detectors (in Germany, Japan, and possibly in Australia) are also contributing in important ways. All of the partners subscribe voluntarily to collaborative rules regarding standards, data sharing, technical information, and the like. The result has

been very effective so far, and without the political difficulties that a financial partnership would have entailed.

A second important point for our meeting is that whatever partnership mechanism is selected, the process itself will require extraordinary patience, drive, and political skill if it is to be realized. And if this were not enough, the process can be counted on to be lengthy. But there is no question that a success in this area is as dramatic as it is rewarding.

Multilateral Science Programs

Teruo Kishi

Owing to the progress in the globalization of economy, multilateral collaborative efforts are increasingly required in some of “big science” projects. Risks and financial burdens imposed by these projects are often intolerable, and adequate human resources to cope with them are not available in a single country. It is essential, therefore, to organize a scheme under an effective cooperation involving industrial, governmental and academic sectors and encompassing a number of interested nations.

A multilateral collaboration usually takes place through the following steps: (1) a seed is proposed at an international circle, to establish a multilateral collaboration agreement, (2) administrative works for implementing the agreement are commissioned to a multilateral organization, and (3) the organization collects and allocates funds and organizes R&D works.

The Summit Meeting held annually among major industrial nations since 1975, is playing an important role in starting multilateral cooperation projects. For instance, the VAMAS project in materials science originated from the eighth meeting at Versailles, France in 1982.

I would like to elaborate as illustrative examples two multilateral science projects: “Photovoltaic Power Generation” and “Human Frontier Science Program”.

Photovoltaic Power Generation

The so-called “oil shock” in 1973 triggered the multilateral collaboration for taking positive measures to solve the energy problem, in preparation for seemingly imminent exhaustion of fossil fuel. The International Energy Agency (IEA) was created in the framework of OECD, and efforts to develop alternative energy have been augmented under the Committee on Energy Research and Technology (CERT) of IEA. Among various types of renewable energy source, the most promising is photovoltaic (PV) energy.

In Japan, where most energy is derived from imported oil and uranium, the utilization of inexhaustible and clean energy of solar radiation is to be eagerly sought for. Under such a circumstance, AISI/MITI embarked on the Sunshine Project in 1974, which was later reorganized into the New Sunshine Project in 1993. In this project, AIST provides research funds directly to national laboratories under its jurisdiction, and via a non-profit organization, NEDO (New Energy and Industrial Technology Development Organization) to researchers of 30 or so private enterprises, which are coordinated by a technological research association PV1:EC (Photovoltaic Technology Association).

Some of the R&D activities of NEDO/PVTEC are being carried out under the multilateral collaboration in the framework of IEA/CERT. Costs for this international joint venture are shared by participating countries. Currently, the number of member countries of IEA is about 26.

The major topics of the "Photovoltaic Power Generations project are as following:

- Improvement of conversion efficiency of solar cells and PV modules.
- Reduction of production and installation costs of PV systems.
- Connection of PV systems to utility grid.
- Development of PV modules integrated with building materials.
- Construction of multi-Mega Watt commercial PV power generation plants.
- Field experiments with large scale, PV-powered agro-industrial complex in desert areas.

Human Frontier Science Program (HFSP)

The last areas to be explored involve the human brain and the life mechanism. An attempt to provide funds to basic research in the brain science and the molecular biology was proposed by Japan for the 13th Summit Meeting at Venice in 1987.

The initiative was welcomed by the summit members and an organization for implementing HFSP was installed at Strasbourg, France in 1989. G7 countries, the EU and Switzerland have joined the program, and Japan contributes about 80 % of annual funding. (\$ 37.4 M for fiscal 1976.)

During the past eight years, 325 international research teams have been awarded with research grants and 1,095 scientists have received long-term fellowships. Applications for research grants and fellowships are accepted by September 1 at the HFSP Secretariat, screened by the Review Committee and the Council of Scientists, and the final decision is given by the Board of Trustees around April next year.

Multilateral collaboration is expected to contribute not only to sharing of cost and risk, and recruiting human resources, but also to formulation of creative concepts through the amalgamation of different cultures.

Expectations for Multilateral Cooperation:

Tsuneyuki Morita

My own experience leads me to believe that there needs to be greater understanding between political and scientific expectations, and a dynamic utilization of both bilateral accords and multilateral frameworks.

Multilateral organizations offer strengths and weaknesses in the context of research. They allow institutional links to be developed, and channels of communication opened, beyond formal political constraints. These channels can often help initiative and support bilateral accords.

However there is a danger, especially in politically contentious areas of research, or economically sensitive areas, that multilateral organizations will not always further the interests of scientific research- accords can be watered down to the lowest common politically acceptable element, imposing artificial or unworkable constraints on research teams.

International Cooperation in Big Science:

Scientific Research has a different modus operandi to the political constraints which are often present in multilateral organizations, and which can heavily shape the distribution of funds and resources.

Scientists work with degrees of uncertainty which are often problematic in terms of their applicability and suitability to political discourse, both at the smaller scale and at larger (holistic, integrative) frameworks.

There is a need for specialists who can communicate directly with both scientists and politicians, allowing greater planning in the establishment of objectives for research frameworks in multilateral organizations, to ensure both the efficient use of funds, and that research teams are set objectives which are obtainable and relevant.

In the context of big science and multilateral cooperation, it may be preferable to have research teams working between nations with mutually compatible research objectives, and then use multilateral organizations and frameworks to work out differences between groups of nations/stakeholders/interests.

This is especially valid when one is considering integrative science, the holistic assembly of many different disciplines into a politically useful framework, a process which is often expected to occur within the institutional structure of multilateral organizations.

My own work using the Asia-Pacific Integrated Model (AIM1), in the field of climate change integrated assessment, is a good example of this point. This work, in the context of the IPCC institutional structure, is discussed during my presentation at the seminar.

Human Resources for Science and Engineering:

Our team has developed links with researchers in developing nations, to allow them to adapt and utilize our model in a fashion which allows them to maximize their human and technical resources.

Climate Change research has been carried out in a multilateral context, involving many bilateral links. However it also serves as an excellent example of some of the problems that can arise, especially in the political context.

Research was primarily conducted by research teams from developed nations, often by the simple transfer of frameworks and theoretical assumptions wholesale to developing nations. Resources were expended in this fashion, which was not acceptable politically to developing nations (the fact that it often was not scientifically rigorous is also pertinent).

As a result developing nations felt that there were many gaps between their socioeconomic realities and political constraints, and the “big science being put forward by uni and bilateral research teams within the multilateral context.

By directly involving research teams from developing countries, and helping them formulate their objectives and research strategies in a linguistic framework which is complementary to the paradigms utilized within the multilateral context, we hope to create a research structure which is more compatible to the political needs of both developing and developed countries. This ultimately means it is more likely that the research shall lead to implementable results.

A Note on Illustrative Bilateral Corporation for a Global Borderless Society

Tsuneo Nakahara

Foresight of global environment surrounding science and engineering

With the collapse of the Berlin Wall in 1989, the Cold War that entailed the threat of a nuclear war between the US and USSR came to an abrupt end, followed rapidly by the termination of the antagonism between democracy and communism, and that between free market economy and socialist planned economy. The world has since been increasingly integrated in a borderless economy.

In general, the optimal direction of national and corporate policies is decided by three external factors - politics, economy and science & technology. In this note, I will try to forecast the international environment likely to emerge in the 21st century, focusing on these three factors.

Science and engineering are underlain by universal principles. In this sense, we may say that science & technology embodies the idea of globalization and a borderless world. The rapid development of information technologies foretells the advent of highly advanced information society. Today, the nations around the world are no more dedicated to development of military technologies as they were in the days of the Cold War; instead, they are seeking national development based on advanced science & engineering. In the field of applied development, more efforts will be directed at the enhancement of economic competitiveness, while closer international cooperation will be sought in conducting basic research, especially, in the fields of environment, energy and life science.

Economically, the world is now in the process of shifting to a borderless liberalistic market economy with the encouragement of the WTO, IMP, etc. On the other hand, the expansion of global information networks enables large-scale speculative trading which might result in instantaneous financial panic, while dependence on electronic money makes the society more prone to criminal acts of an international scale. These might create the threat of collapse of global, liberalistic market economy. It is therefore necessary to work out the measures to prevent moral hazard without recourse to an Invisible Hand, and mitigate the issues related to the expanding gap between extremely rich and poor nations. Whether we can make effective use of science and engineering to tackle these problems will largely affect the future relations among the United States, Japan and relevant third countries.

Politically, nation still prevails in today's world. On the momentum of the trend towards globalization, inter-governmental dialogue has just started, which, however, is still at a preliminary stage. Implementation of proposals presented by the United Nations and summit meetings such as the P.K.O. issue is all conditioned on inter-governmental treaties, and it is down to each nation to decide whether to ratify the treaties or not. On the grounds of the

important role intellectual property plays in the furthering development of science & technology and the likelihood of an increase of international-scale criminal acts, it is essential that the international society should set to formulation and execution of international laws and codes of conduct where practical, in order to effect a global shift to democracy. Further involvement of science & technology will be required in addressing a wider range of issues, concerning, for example, environment, energy, population and life science. The question as to what contribution science & technology can make in the political, legal and ethical fields will also take on greater importance.

Action plans to promote the trend toward a borderless economy in terms of science & technology

Companies, if they are to grow to be multinationals, must pursue global business development in manufacturing or provision of services or goods, by means of direct investment in foreign countries, which involves international transfer of technologies and know-how on management. The progress of information and communications networks as well as traffic and transportation technologies has made such global business development possible in economic terms, and is further accelerating the trend towards globalization of business and a borderless economy.

The growth of multinationals as such, however, may possibly give rise to such problems as industrial hollowing, unemployment and financial difficulties in their home countries, while presenting threats to the survival of local competitors and causing serious confusion in the conventional political system and people's life in recipient countries. Considering the above, it is important to examine the pluses and minuses of a borderless economy on a global basis.

From the viewpoint of local governments, invitation of state-of-the-art factories of multinationals, whether domestic or foreign, means creation of jobs and improvement of financial conditions. By vying with other countries in inviting factories, they can also deepen their understanding of the global industrial standards, which, in turn, helps them in promoting global business development. As for consumers, globalization contributes to the improvement of their living standards, because in the world of a borderless economy, superior products and services are readily available to them at lower cost, consequent to intensifying competition among local and foreign suppliers. Local suppliers may lose their business to a certain degree, but a borderless economy will also enable them to make more effective use of human resources by inviting foreign direct investments and introducing advanced know-how on technology and management of multinationals.

Whether or not the above gains can more than offset possible adverse effects of globalization depends on the successful implementation of the following action plans which are conditioned on proper application of science & technology.

1. To realize sustainable economic development by encouraging growth of new high-tech industries, which will contribute to the solution of the problems of unemployment and financial difficulties in developed countries.

2. To create an environment to develop technical skills and human resources locally in order to ensure continued improvement of productivity of the production systems introduced in developing countries.
3. To establish a global legal system to enforce intellectual property to facilitate the above plans, and to create an environment to encourage worldwide application of intellectual property and develop human resources in this regard.

Action plans to promote the trend toward political globalization in terms of science & technology

As the world is shifting to globalization in terms of science & technology and a borderless economy, there has arisen a conflict of interest among academic institutions, multinationals and local governments. Under the circumstances, international activities of governments could only insufficiently promote the trend towards political globalization, and greater involvement of international NGOs and NPOs as well as international academic institutions is required.

A government has a basic role to enact and execute a constitution and laws and spread ethical rules and codes of conduct. Its missions will be providing comprehensive security; securing jobs; preserving the environment; developing infrastructure; investing in education and research & development; and promoting growth of new hi-tech industries.

The worldwide shift to a borderless economy will likely entail various problems stemming from the difference between the newly emerging global political systems and the conventional social systems. These problems require urgent attention, because the current political, legal and ethical systems have been unable to cope with the new situations created by the advance in global information networks, which might result in serious worldwide disorder and collapse of the existing social systems. To be specific, large-scale speculative trading through a global network could cause sharp fluctuation in exchange rates, eventually leading to the death of financial capitalism. When electronic money or electronic trading is launched extensively on an international network, criminal acts such as forgery and money laundering involving an enormous sum of money could instantaneously prevail all over the world, and paralyze corporate activities. Other serious social problems that may arise on an open networking environment include infringement on intellectual property and penetration of undesirable information.

Such unethical acts (moral hazard) could put a brake on the worldwide trend toward democracy and liberalistic market economy. In this connection, science & technology is expected to make somewhat contribution to the settlement of these problems through the following action plans.

1. To create an education system that incorporates a course to study the relations between human depth psychology relative to ethics, religion, culture and society, and science & engineering, in addition to the existing

MBA course that deals solely with science & engineering and economic efficiency.

2. To form an international team of experts in laws, ethics, economics and science & engineering to discuss the establishment of international laws and ethical standards. The fields that require introduction of such laws and standards include environment, energy, population, life science and intellectual property.

Reflections on the Issues

Paul A. Vanden Bout

A personal reflection: The seminar is timely for me and I am happy to be invited to participate. The long-standing cooperation in radio astronomy between the Nobeyama Radio Observatory (Japan) and the National Radio Astronomy Observatory (US) has recently become embedded in a larger context involving Europe, specifically, with the European Southern Observatory, itself a multi-lateral organization. I look forward to the seminar.

With respect to the topic of the first plenary session, "Expectations for Multi-lateral Organizations," one might infer from the suggested questions to be addressed an assumption of continuing existence for multi-lateral organizations: a review of accomplishments and what might be accomplished leads to a call for plans for improvement. Would it not also be appropriate to ask how effective multi-lateral organizations have been in avoiding unsuitable projects and in dropping activities that were unproductive? For that matter, what mechanisms exist for deciding whether a multi-lateral organization itself should continue to operate, and how effective are those mechanisms?

Having stated that, let me say that one of the expectations I have for a specific multilateral organization, the OECD and its Megascience Forum, is increasing the awareness at the highest levels of governments of the harm caused radio astronomy and the threat to its future that is posed by increasing use of the electromagnetic spectrum and the trend to de-regulation and relaxation of the rules governing use of the spectrum. Spectrum management is already done through a multi-lateral organization, the International Telecommunications Union, part of the United Nations, but high level government awareness of the issues that concern science is far less than the awareness of the needs of the telecommunications industry.

The topic of the second plenary session is closer to home for me, "International Cooperation in Big Science."

Here a number of issues for discussion come to mind. First, I would hope that recognition would be given to the principle that cooperative activities in science work best when driven and initiated from the bottom, that is, from the working scientists. There is a long tradition in astronomy, as in many scientific disciplines, for such cooperation. The current drive to internationalize "big science" is top-down in nature, springing from the need to balance national budgets and the hope that international partnerships will reduce costs. A policy to encourage or require internationalization of major projects can be effective to the extent that it is applied to projects with science driven requirements that call for facilities beyond the reach of a single nation. Requirements that lead to indiscriminate internationalization of science projects will be counter-productive.

In that context, I would hope that the additional costs that accompany international cooperation are recognized. For a large project, these costs lie in the loss of efficiency in the decision-making process, extra burdens of project oversight due to the multiplicity of institutions and governments involved, the marked increase in systems engineering requirements, to cite a few examples. If the result is something that could not otherwise be accomplished, it is worth the price, but only then.

Equitable cost sharing is a non-trivial consideration in an international project. I favor arrangements under which agreement is obtained at the outset on a set of deliverables, the partners then being left on their own to produce these at whatever it might cost them. This approach recognizes the desire for partner governments to spend their funds in their country. It also provides a mechanism for dealing with the fact that the same item can cost one country two to three times as much as it does another country. (Such price differences can arise in contracting policies, for example, in the distribution of risk between buyer and seller.) This principle can be extended from the construction phase of a project to operations. Purchased materials and services necessarily require division on a cash basis. But personnel can be contributed with no exchange of cash. Indeed, given the deeply embedded differing labor policies of different countries, leaving staff as employees of their home partner institutions is simpler and more effective than creating new policies for a new *international* staff. It is also less expensive.

From a political perspective, the appropriate formula for access to international facilities is on a basis of proportionality — equal access for equal contributions. This does not necessarily produce the best science, however. The only way known to scientists for doing that is to hold a competition for access. Peer review of proposals for access in a single, common process will, in principle, select the best. This has been the standard in US radio astronomy since the founding of the NRAO, where the facilities are open on the basis of merit to any qualified scientist in the world. They are used at a level of 20-30 percent by foreign scientists. One could think of this solely as a benefit to foreign scientists. But, in fact, it is equally true that the US scientists are the beneficiaries: the heightened competition for access that the foreign scientists provide forces a continued improvement in the scientific proposals from the US scientists. However, it is difficult to secure foreign participation in any new project that, under such a policy, would grant access without financial participation. The need to internationalize a project can lead to an abandonment of an open access policy and risk a reduction in the quantity of top-ranked science the facility could produce. I would welcome discussion of this issue.

The proper role for governments and inter-governmental organizations in facilitating multi-lateral cooperation in big science is the minimum involvement that is effective. In that regard, I would note that the US practice of operating many (all NSF) facilities at arm's length from the government through private contractors is very different from the practice of many nations. Most of the world's astronomers, for example, are civil servants, and their observatories and institutions are very often part of government agencies. In an international project, those agencies will wish to work with their government counterparts in the US, encouraging and even requiring an involvement on the part of the government in project management that was

formerly not necessary. This works against the principle that less government involvement is better.

Areas where governments and inter-governmental organizations can be helpful come readily to mind for the topic of the third plenary session, "Human Resources for Science and Engineering." First, it is critically important that the universities continue to produce instrumentally savvy scientists. There is a trend throughout all of US astronomy, for example, to produce PhDs who do all of their research at a computer terminal, using data from space and ground-based observatories. But there is a continuing need for people with the skills required to *design and build* these facilities.

There are real issues to be faced in the area of mobility between countries for students and scientists. International cooperation requires this mobility for success and will naturally foster a desire on the part of participants to visit and work in partner countries and to share students and post-doctoral fellows. This is frequently in conflict with policies for visas and immigration, not to mention legislation restricting the use of government funds to support foreign nationals, or policies that make it next to impossible for foreign nationals to obtain permanent positions.