Fermilab

TM-811
0102.00
August 16, 1978

TOWARD A WORLD ACCELERATOR LABORATORY*

R. R. Wilson

Introduction

As scientific projects have become more complex and more expensive, there has been a growing tendency for world-wide cooperations between nations. Thus the International Geophysical Year of 1957-58 saw a major coordinated effort of nearly 30,000 scientists in sixty-seven nations to explore the characteristics and resources of planet earth, with dramatic emphasis on Antarctica.** The Atoms for Peace conference of 1955 in Geneva represented the opening of a new era in scientific communication after years of extreme secrecy that had been imposed by WWII and the Cold War. The success of that conference has eventually led to collaborations between nations in the development of nuclear reactors and in the exploration of controlled thermonuclear power. The most spectacular joint effort and the one which captured the greatest popular attention was the Apollo-Soyuz project, at the climax of which Russians and Americans met together high above the earth to conduct their research about outer space.

My own specialty of physics is the study of inner space, that is, the study of the fundamental particles and of the forces between them, a study characterized by huge and expensive instruments which are required to study matter in its smallest aspects.

---

* A revision of a paper given before the Chicago Council on Foreign Relations on April 26, 1978

** Walter Sullivan, Assault on the Unknown: The International Geophysical Year (New York: McGraw-Hill Book Co., 1961).

There has always been a strong tradition of internationalism in this field of study, a tradition which may eventually lead to the formation of a World Laboratory at which a very large accelerator, one beyond the capability of any single nation or regional group of nations, might be built. One reason that the arcane subject of accelerators and elementary particles might be of general interest is that there are implicit in it features that transcend physics, that have to do with cooperation and understanding between peoples, between nations.

The Tradition of Internationalism in Physics

Even in its origins in classical times physics has had a strong flavor of internationalism. Greek natural philosophers came to Athens from all over the western world; and the innovations of Greek, Chinese, and Indian natural philosophers were known to one another. Since then, the whole field of physics has advanced as one huge international collaboration. Physics has been and is the same in every country of the world. Thus there is no French electricity, nor German mechanics, nor British theory of heat. Even in the early days of modern science the scholars of each country were in good communication by letter, by heresay, by travel, and by direct word of mouth with one another - even in time of war. The peripatetic 18th century American physicist, Benjamin Thompson (Count Rumford) was able to contribute his seminal ideas about the nature of energy whether he resided in Bavaria, in France or England, despite (or because of) his active involvement in revolution and war.

But it is atomic physics in this century that I wish to discuss, or more specifically, the study of the constituent particles of the atom. Early in this century, in the experiments of Ernest Rutherford and the theory of Niels Bohr the structure of the atom was dramatically delineated. Both men established great international centers. Thus Rutherford, born in New Zealand, worked first in Canada, then eventually at the famous Cavendish Laboratory of Cambridge University. The Cavendish already had a long tradition of welcoming foreign visitors, and under Rutherford's direction physicists from Russia, France, Germany, Japan, Denmark, India, and the United States constituted a substantial part of the staff. It was in Bohr's Institute in Copenhagen (financed by Carlsberg beer!) that the quantum theory of the atom was largely elucidated, and nearly all theoretical physicists who contributed to the development of quantum mechanics, fundamental to understanding the atom, have participated in the work of that Institute at one time or another. Most physicists in this country, indeed in the world at large, can trace their academic lineage directly to one of these two institutes.

A little later, in the thirties, as the attention of physicists turned to the nucleus of the atom, Ernest Lawrence invented the cyclotron at the University of California at Berkeley and founded the Radiation Laboratory there.* The cyclotron became one of the principal instruments used in the study of the nucleus, and

---

* Now the Lawrence Berkeley Laboratory

scholars came from all over the world at Lawrence's invitation to learn about it and to help develop the technique. They then returned to their own country to construct similar research devices there; something like a dozen cyclotrons were constructed in nearly as many different countries. I can remember as a student in the Radiation Laboratory being particularly impressed by its strongly international flavor, and later in my travels, I was to be welcomed as an old acquaintance in cyclotron laboratories all over the world.

World War II had a strongly polarizing effect on internationalism in physics, in good part stopping it but, again, partly enhancing it. The rise of the Nazis in Germany led to a new notion that the acceptance of some kinds of physics depended upon whether it had originated from the "right" kind of people. This, together with other forms of racial persecution, was a catastrophe for German physics. Many, most of the best, of the German physicists were driven out or left Germany in disgust. As the inevitable confrontation of the Nazis with the Free World led to WWII, many of those refugee physicists, after a certain stay in European scientific centers such as in Copenhagen and Cambridge, came together on a "Magic Mountain" in New Mexico - the Los Alamos Laboratory - to help build the first nuclear bomb. However grim the task, Los Alamos was the largest collaboration of such a group of famous international scientists up to that time. The British contingent was there as formal members of a British-American collaboration. It was a tragic mistake to my thinking that Soviet scientists were not invited on the same basis. In

retrospect I believe that such a formal collaboration might have forstalled the paranoia, the "spying", and the competition that led to the nuclear arms race. On the other hand, that the collaboration of a few scientists in the development of nuclear energy could have prevented the Cold War, which was based on deep sociological and political differences, seems also realistically improbable.

In any case Los Alamos was a remarkable experience, partly because there was such a confluence of the international stars of physics. After the war, when the scientists had returned to their own laboratories, they represented a powerful network of friends who were determined to keep the flame of internationalism alive. In addition to Los Alamos there were similar international projects at the Chalk River Laboratory near Toronto, and at the University of Chicago Metallurgical Project where the first nuclear reaction was realized. That the scientists at these laboratories participated in the formation of political organizations dedicated to the prevention of nuclear war, such as the Federation of American Scientists in this country, or the Atomic Scientists Association in England, implied a strong commitment of that international group for peace.

The International Union of Pure and Applied Physics

Of a number of internationally oriented organizations one might have expected UNESCO to have been most important. Disappointingly, it was not, at least not in the field of High Energy Physics. Instead a recondite organization, the International Union of Pure and Applied Physics (IUPAP) established in

1922, has played an important role. IUPAP represents 38 countries, all over the world, where physicists have formed a national committee, usually associated with their national academy, and have requested admission to the Union. In general, IUPAP sponsors the organization of international meetings, encourages travel, visits and talks, and coordinates study in various fields of physics with emphasis on international aspects. Once every three years there is a General Assembly. IUPAP is a member of the International Commission of Scientific Unions, ICSU, which provides a weak link to UNESCO.

IUPAP has been especially successful for high energy physics by sponsoring through its Commission on Particles and Fields the significant international conferences of the field. It has also had as an important aim, in close concert with ICSU, the free movement of scientists. Thus with regard to its sponsored meetings, IUPAP policy has been that "while one might not always expect a host country to declare in advance that any scientists will be admitted ... it does seem reasonable to ask as a minimum commitment that the host country declare in advance that individuals will not be excluded solely on grounds of national origin." As an example, it is interesting that problems of attendance by scientists from Israel to meetings in the USSR have been satisfactorily solved by this policy. On the other hand, because Taiwan is a member, the Republic of China had at first refused to participate with anything sponsored by IUPAP. Nevertheless, because of the spirit of detente, or perhaps because of the end of the Cultural Revolution, the Chinese are moving rapidly to

catch up in the field of high energy physics and are vigorously receiving and sending scientific delegations. They are also now participating in almost all international scientific events.

CERN, A Successful Model for a World Laboratory

One of the most important steps in showing that physicists from many nations can successfully collaborate on a large project has been the formation of the Centre Europeénne pour la Reserche Nucleare, CERN, near Geneva, Switzerland. This was organized in about 1952 partly, at least, at the suggestion of Professor I. I. Rabi who was then the American delegate to UNESCO. Rabi could not see how any single one of the Western European nations, then just emerging from the destruction of WWII, could successfully compete with the large governmental laboratories established in the USA or in the USSR. However, he saw that united they could do very well. I attended one of the early organizing sessions, and can vividly remember the general skepticism that England and France or Germany or Italy could ever work out the intricate political, monetary, industrial and linguistic problems that required solution for such a laboratory to be a success. Yet, those problems were all solved. CERN, partly in Switzerland, partly in France, has become a great center of high energy physics; it has about 5000 workers and it spends more for its research than all the laboratories in the United States in the same field. It is a truly international effort which now includes visitors from the USSR, the USA, as well as from China and Japan; indeed because of this remarkable success, it can serve as a paradigm par excellence for an even more broadly based international effort.

Other Regional Laboratories

During the Cold War between East and West, the Joint Institute for Nuclear Research was established in the USSR about 40 miles north of Moscow, at Dubna near the confluence of the Dubna and Volga rivers. In a sense it was an eastern reflection in the Iron Curtain of the western CERN; it did for all the socialist nations within the Russian sphere of influence what CERN was doing for the western european nations. For the past twenty years the Iron Curtain has been slowly rising; there have been many east-west conferences at Dubna and elsewhere in the USSR under IUPAP auspices, and there have been numerous exchanges of scholars on scientific projects not only with Dubna but also with the large Soviet laboratory at Serpukhov some 40 miles west of Moscow. This of course is not to say that the same rules and customs of freedom and rights prevail in the USSR as in the western world, (the news stories in our papers remind us all too often to the contrary), but at least we are all vigorously interacting about those problems, and with a truly international clamour.

The Fermi National Accelerator Laboratory, Fermilab, near Chicago, although a national laboratory, also has a strongly international flavor. In 1972, just as the accelerator came into its first operation, a team of six USSR physicists and their wives arrived at Fermilab to collaborate with an American group in a series of important experiments with our accelerator. Within months of their taking up residence on the site of the laboratory in the old farm houses, their dress changed, their english improved - soon it was difficult to recognize that in fact they were exotic

visitors. After a few years, a new group replaced the first one, this time accompanied by wives and children. By now, wave on wave of physicists from the USSR and its associated nations have appeared. There have been some 80 Soviet scientists who have worked on 20 different experiments at Fermilab. The collaborations are generally arranged directly between the scientists concerned and are put through the usual review procedures that insure the scientific integrity and value of any experiment undertaken at the laboratory. However, the details, living and travel come under a chain of developing formal agreements that started with Eisenhower's Atoms for Peace Program; from the Emelyonov-McCone Agreement to the Nixon-Brezhnev Accord. There can be no question but that a tremendous number of people-to-people exchanges have occurred in the six years of the Soviet-U.S. collaboration. Will it be an important ingredient in our political relationship? Well, in the adventitious relationships that scientists occasionally are thrown into with people in powerful positions, both in the USSR and the USA, ... who is to say?

The collaboration with the Soviet physicists at Fermilab is small compared to that which goes on as standard procedure with scientists from other nations. Nearly 300 foreign scientists have participated in 120 different experiments at Fermilab, over half of the total number of experiments as yet made there.

Chinese physicists in the Peoples Republic are also becoming active in high-energy physics. An Institute of High Energy Physics was organized a few years ago in Peking, and they will

build a 50 GeV* proton synchrotron during the next five years, romantically enough, in the vicinity of the Ming Tombs just north of Peking. The 50 GeV accelerator will be useful in itself, but it is really just the first phase of a much larger project, for the Chinese plan eventually to build a 5000 GeV synchrotron, greater than anything definitely planned anywhere in the world. The 50 GeV accelerator will then be used as an injector of protons into the larger machine.

During the past several years numerous groups of foreign physicists have been invited to Peking to give advice about the new program. A group of ten Chinese scientists has just spent several months at Fermilab refining their designs, and at the same time smaller groups of physicists are participating in the most modern particle experiments at Hamburg and at CERN. The group of ten at Fermilab has returned to China, but are now replaced by a group of five who studies actual construction rather than design, and who will stay at Fermilab for about a year. Meanwhile, scientists at Fermilab are invited to Peking. Succeeding waves of visiting physicists will follow, and in a few years we can anticipate that the Chinese will contribute equally to collaborations with laboratories all over the world.

Somehow, from the point of view of peace in the world, I cannot but view this development as being an improvement on the earlier more closed situation.

---

* GeV is short for Giga-electron-volts, a precise unit of energy. It is permitted (and encouraged) (and deplored!) for the layman to think that a GeV is a "billion volts".

And For the Future?

The preceding description has been made to demonstrate a vigorous international activity, both formally and informally, in the pursuit of basic knowledge about the structure of matter. Several thousand scholars from all parts of the world are involved in the specialized work which is going on in about a dozen large laboratories. However, these cooperations are either in national laboratories, or in laboratories of a regional character, between which the scientists travel from nation to nation to pursue their own particular specialities, of course, working as close to home as possible.

The secrets of particle structure have not been easy to fathom but new discoveries and surprises turn up at a rate that indicates much is yet to be discovered. Much larger accelerators and instruments are now being planned for a deeper look into inner space: the 5000 GeV Chinese synchrotron, or the 3000 GeV Soviet synchrotron at Serpukhov, or the 100 GeV electron colliding beam instrument at CERN, or the 2000 GeV center of mass proton antiproton colliding beam device at Fermilab (please excuse and utterly ignore the jargon!). Now these instruments may cost a good fraction of a billion dollars apiece, or even more when the total cost of the experiments is included. Although there is every expectation that a deeper understanding and an enriched knowledge of our world would result from this new round of instruments, there is no confidence that even larger and more expensive machines may be necessary to continue the exploration. If the quest for the ultimate nature of matter is to be pursued, and I believe it is

in the nature of man's curiosity and perseverance to do just that, then a truly world effort may be required - just for reasons of cost, if nothing else.

The Emelyonov-McCone Accord

For over ten years, the desirability and even the necessity of forming a World Laboratory that would do for all the nations of the world what CERN so successfully has done for the Western European nations has been apparent to many physicists in many lands. The first official exploration of such a possibility resulted from Krushchev's visit to the USA in 1959. As a part of the Eisenhower-Krushchev discussions, Professor V. S. Emelyanov, Head of the USSR Administration of Atomic Energy, met with Mr. John McCone, Chairman of the U.S. Atomic Energy Commission. This led to the signing on November 24, 1959 of a Memorandum on Cooperation in the Peaceful Uses of Atomic Energy. The Emelyonov-McCone Agreement provided for the simultaneous short-term exchange on a reciprocal basis for groups of about five scientists in several fields of nuclear physics, high energy physics being one of them. Among other things it also provided specifically for the "examination of the feasibility of engaging in joint projects in various unclassified areas". The author was a member of the five man delegation headed by R. F. Bacher, Provost of Caltech, which visited the USSR May 12-18, 1960. Before leaving, we had been briefed specifically to explore the joint construction of a large accelerator. It was implicit that if the discussions were fruitful then other nations would be asked to join in the project.

China at that time had a large scientific mission at Dubna, so this might well have led to the World Machine.

Unfortunately, immediately prior to our visit, the infamous U-2 spy plane was shot down over Russia, and a terrible bruhaha ensued. Although formally correct to us, the outraged Soviets, especially those in the vicinity of Moscow, were hardly in a frame of mind to discuss a joint project. The opportunity was lost. Somehow though, in a series of impassioned appeals to my Soviet friends to proceed with the project in spite of the U-2, I convinced myself, if not the Soviets, that in building and operating a World Laboratory we would not only be exploring nature, but we also might be exploring some of the ingredients of peace.

My conviction was deep enough so that at the occasion of the next IUPAP International Conference on High Energy Physics held at Rochester, New York in August of 1960, I arbitrarily invited a group of some 30 leading physicists (it included Heisenberg and Oppenheimer) to a completely unofficial meeting given over to intensive discussion of the need and practicality of ultrahigh energy accelerators in a world-wide context.

The conclusion of the group* was that indeed energies up to 1000 GeV and beyond would in all probability be necessary to move forward in our understanding of fundamental particles and forces, that it would be technically and economically feasible to build

---

* R. R. Wilson, Science Vol. 133, 1602 (1961)

such a ultrahigh energy accelerator, and that the cost of such a 1000 GeV project might be about a billion dollars.

Soon thereafter, it became a custom, not necessarily related to the 1960 meeting, for the directors of the major high-energy physics laboratories of the world to get together whenever a IUPAP High Energy Physics Conference was held, in order informally to coordinate their research by knowing what would be done in each of the other laboratories in the near future. Such meetings were held at Vienna, Austria in 1961, Tbilisi, Georgia in 1968, Morges, Switzerland in 1971, and in Abingdon, England in 1973.

A major step was made in the next meeting of the series at New Orleans in March 1975 under the chairmanship of Professor V. F. Weisskopf of M.I.T., a past Director General of CERN, a revered physicist in every land, a dedicated humanitarian. It was given the name "International Topical Seminar on Perspectives in High Energy Physics", and although completely international in attendance, it was planned originally as a part of the Nixon-Brezhnev concordance. The intention of the meeting was primarily to discuss the program of physics at various national and regional accelerator facilities throughout the world with an emphasis on cooperation. A very frank exchange of views and information regarding problems and shortcomings of the current and past collaborations occurred. The discussion was intense because it was directed toward strengthening future interregional cooperation at existing and new facilities.

In a spontaneous but determined manner, the subject of a world laboratory was raised. It was recognized by the participants, after some heated debate, that indeed high energy physics would

"eventually require the construction of an accelerator facility, the scope of which would place it beyond the capabilities of any of the separate regions now active in the field." The participants followed through on this by recommending in their formal report* that a Study Group be established to investigate the scientific, technical, economic and organizational problems connected with a world-wide collaboration in the construction of the accelerator facility, which they referred to simply as "Very Big Accelerator" (VBA), a name given to it by Professor Leon Lederman*, one of the strong proponents of the World Laboratory. They listed the following regions as having been particularly active in high-energy physics and suggested that the Study Group be comprised of the indicated representation: Eastern Europe via JINR (Dubna), 2 members; Japan, 1 member; USA, 4 members; USSR, 2 members and Western Europe via CERN, 4 members.

The next step was getting the "official" report "officially" accepted, but the meaning in this context of what was "official" was not very well determined. Physicists, who are raised on the "principle of indeterminancy", left it up to the regions concerned to decide what was the appropriate official act. In any case, delegates to the Study Group proposed at New Orleans were duly appointed, and, after a preliminary organizational meeting at CERN in October, 1975, they met in Serpukhov and Moscow in June,

---

* Summary of the Chairman, V. V. Weisskopf, International Topical Seminar on Perspectives in High-Energy Physics

* L. M. Lederman, VBA, IEEE Trans. on Nuc. Sci. Vol NS-24 No. 3 June 1977

1976. It was recommended by the Study Group that a continuing committee be set up under the aegis of the IUPAP Division of Particles and Fields, that it be concerned with the coordination and collaborative use of the next generation of regional facilities, and, more importantly, that it continue to explore an international collaboration in building a VBA (defined as an accelerator producing 10,000 GeV protons or higher, or electrons of energy greater than 100 GeV, and of course with appropriate storage rings). A time scale of about ten years within which plans for the facility might be developed was suggested.

At the meeting in Moscow a humanly understandable obstruction to the discussion of a world laboratory reappeared. This had to do with a practical problem of raising funds for a new large national or regional facility. Clearly any such project has to be "sold" to the appropriate governmental agency, which usually displays some reluctance to commit the hundreds of millions of dollars, or rubles, or francs, of public monies required: talk about a collaborative project would be good reason for the statesmen to procrastinate. Thus at the time of the Emelyonov-McCone exchanges in 1960, conditions were ripe for a world collaboration, for no specific national plans for a large accelerator had then been formulated. However, a few years after the failure of the 1960 discussions, firm plans were developed in the U.S. for a 200 GeV facility, and the congressional approval processes were started. As a sociological note, the Joint Committee on Atomic Energy held several days of hearings in the form of a seminar during which the senators and congressmen became preternaturally

sophisticated about accelerators and particle physics.* There was very little discussion about a World Laboratory in the USA until the project had been funded, until Fermilab, the resultant facility, had been largely constructed.

At about that time, an almost identical accelerator, the Super Proton Synchroton, had been initiated at CERN, and again the Western European physicists were reluctant to discuss collaboration with the by-then-enthusiastic Americans and Soviets, for example, at the Morges meeting in 1971. By the time of the Moscow Study Group of 1976, the Soviets had formulated a pretty definite project (the UNK) to upgrade their 80 GeV accelerator at Serpukhov to 2000 GeV. Hence it was hardly a surprise when they demonstrated a certain coolness toward a world laboratory and tended to emphasize cooperation in the construction and use of regional facilities. Nevertheless, to their credit, the Soviet group did go along with the recommendation to explore the construction of a VBA on a world basis.

At the meeting of the IUPAP Commission on Particle and Fields which was held in Tbilisi, Georgia in June, 1976, the Commission agreed to sponsor the new committee suggested by the Study Group at Moscow and officially named it the International Committee on Future Accelerators (ICFA) in analogy with ECFA, a European committee having a similar function for Western Europe. It was particularly appropriate that the late Bernard Gregory, a

---

* Hearings Before the Subcommittee on Research, Development, and Radiation of the Joint Committee in Atomic Energy, Congress of the United States, Eighty-Ninth Congress, March 2-5, 1965.

past Director-General of CERN, and then Chairman of the IUPAP Commission, became a member of ICFA, ex officio, and Chairman, for he, with consummate parlimentary skill and devastating French logic, had played a crucial role in 1975 at New Orleans leading to the realization of ICFA.

An official membership of ICFA has been decided upon* and two meetings have already been held; one at Hamburg in August, 1977 and another at CERN in Geneva in January, 1978. At the CERN meeting the idea of coordinating work at national or regional laboratories was down-played, for almost all physicists were wary of it, but it was agreed that a first Workshop on "accelerator and detector possibilities and limitations" would be held at Fermilab in October, 1978, and that a second Workshop on the technique of superconducting magnets and cavities would be held at Serpukhov in the spring of 1979. At this writing the Workshop at Fermilab is about to be held and outstanding scholars in the field are scheduled to come from every region. It will be interesting to see their projection of what can be built and what can be measured. After that a decision must eventually be made about the necessity and desirability of becoming really serious about a world laboratory. In my own view, one of the necessary conditions of such a laboratory is Chinese participation. It augurs well for the future that the Chinese are taking such

---

* The membership as of September 1978 of ICFA is: J. B. Adams, Chairman, CERN; G. H. Stafford, G. B.; M. Vivargent, CERN; L. M. Lederman, USA; B. Richter, USA; R. R. Wilson, USA; E. L. Goldwasser, ex officio as IUPAP Chairman; V. Dzhelepov, USSR; K. Myznikov, USSR; V. A. Yarba, USSR; K. Lanius, USSR; Y. Yamaguchi, Japan.

A detailed account of ICFA is to be given by E. L. Goldwasser at the IUPAP Conference of High Energy Physics, in Tokyo, August 1978.

vigorous strides in the field of high energy physics to become "equal among equals" so that they can participate.

A Few Misgivings

Not all physicists are in agreement on the desirability of a world laboratory, or even of having very much formal structure in internation planning and use of the present and future national facilities. They would point out that the present system is producing great advances in physics and that the collaborations informally arranged between the scholars involved are also very effective. Physicists tend to be individualists who are justifiably frightened by large organizations, which in the hands of skillful bureaucrats can stifle research. Constant travel to a distant center of research makes for a frantically disagreeable mode of life. They also have seen new technological innovations make it possible today to construct on a purely national basis, that which was considered yesterday only to be possible on a world basis. Although personally a strong advocate of a world laboratory, largely for ideological reasons, I am also sympathetic with these considerations, and would feel that a world effort that was not really scientifically valid and necessary on that scale, would likely be doomed to failure; that it might then do more harm than good.

Location of a World Laboratory

If indeed the desirability of proceeding can ever be agreed upon, one of the most difficult problems will be where the world center is to be located. A large site is necessary, one that can contain a magnet-ring 10 miles in diameter or larger plus

miles of experimental beam-lines. I have somewhat capriciously suggested Tahiti as a possible center. The accelerator and experiments would be placed deep in the ocean for appropriate shielding. A Director-Admiral could eventually extend the successive magnet rings out "twenty leagues under the sea" and reach an energy of a million GeV - and think of the life on the beach! This is not all that far fetched, for there is a serious project, DUMAND, to use the ocean as a giant neutrino detector.

If one looks for an appropriate historical center of the world, the desert near Jerusalem suggests itself. There are also no-longer-used caravanserai on the old silk road to China that might be considered. More remote, but fulfilling the criterion of "equal inacessibility for all" would be one of the Poles, Arctic or Antarctic. Fermi suggested back in 1948 that the ultimate accelerator would ring the world and produce an energy of several million GeV. In this day and age, the ring could extend out in space, so even the sky is not the limit! Perhaps, ad astra, we should join the exploration of inner space to that of outer space, for at a very basic level the two studies have been closely interrelated in studying matter in a condition of great stress.

If the physicists do decide that they need to build and operate such a large laboratory as a World Project involving all people, if they can convince their statesmen of the necessity and desirability of that, then I am confident that they will solve the problems of place and construction and use. And if that happens, the individual nations will get more knowledge, more

technology, and more opportunities for science at home, for their money and effort, than if they get mired in a morass of petty national facilities. Even more important to the people of those nations will be the human experience in international cooperation, so necessary for survival in a precarious world.