6 July 1973, Volume 181, Number 4094 SCIENCE

Science, Technology, and Development: A New World Outlook

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There is a singular significance to this inter-American meeting in the interest of advancing science. This hemisphere was long known as the New World. It was considered the new frontier where freedom—physical, spiritual, and mental—would allow new opportunities to be envisioned, grasped, and developed. Many of those opportunities were realized. Many are in the process of being fulfilled. And hopefully this conference will contribute to that fulfillment.

But much as we believed—and still believe—in the opportunities that exist in this hemisphere, I think we must redefine our concept of the New World. Today we must think of the New World in terms of the entire world, as a community of mankind whose future lies in pursuing the belief that knowledge—universally obtained, widely shared, and wisely applied—is the key to the viability of the human race and the earth that supports it.

We at this conference are advocates of that belief. We are interested in the advancement of science because we know that it will result in the advancement of man. What I want to discuss now are some of our reasons for this belief and a rationale for putting science and technology to work more constructively and humanely on an international scale. This has become truly the main scale on which we can now measure the success of science. Nations may advance their national scientific progress. Temporary power and prestige may flow from such progress. But we now see the world evolving into an ecologic, economic, and ethical whole. Science and technology have created the conditions leading to this viewpoint, and they have created the instruments to observe it; and if they have fostered many of the problems related to it, they are also capable of giving us the knowledge and tools to solve these problems. My convictions about such an international humane role for science have been reinforced by my visits to more than 60 countries during my tenure as chairman of the U.S. Atomic Energy Commission.

This conference on Science and Man in the Americas is built around ten central themes, and of these perhaps the most basic is "science, development, and human values," for this deals most broadly with the human condition.

Call to Action

There has been a commendable move by scientists and engineers in the last few years toward a greater concern about the social impact of their work, accompanied by a redirection of their efforts into areas more directly applicable to practical contemporary problems and the promotion of human welfare. But this effort has been largely confined to the domestic scene. That there has as yet been no concurrent widespread activity on such problems on an international scale is somewhat surprising in view of our traditional interest in this arena. The theme of this talk is a call to my colleagues in science and engineering to expand their action to the international scene. If we want to see our children live in a world of peace based on the fulfillment of human needs and the recognition of human dignity, we must over the coming years make every effort to narrow the gap between the developing and the developed countries through the achievement of a worldwide unified economy. This goal should be among our highest priorities. I shall conclude my remarks with a few suggestions of how we scientists and engineers might improve our means for helping to achieve this goal.

Unifying Force

Why are science and technology the leading forces in an evolutionary unification of man? One reason is simply the universality of a scientific truth once it has been accepted as such by the science community. We may compete as well as cooperate in search of a scientific discovery; but once that discovery has been made, revealed, and confirmed it belongs to all mankind.

The sharing of such knowledge today is an enormous international enterprise. Each year now there are held more than 100 major international scientific congresses, and several hundred smaller ones. Some 60 intergovernmental organizations and more than 250 international nongovernment organizations deal with science and coordinate global scientific activities. The world shares its scientific and technical information in some 100,000 journals printed each year in about 60 languages, and the number of such publications continues to grow. Even more important is the increase in the numbers of those educated and trained to use them and to apply the knowledge they bring. Together with our colleagues in the arts and humanities, we in the scientific and engineering communities are in the forefront of forging a global civilization.

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A second unifying element of science and technology lies in the demands of the earth itself and in our need to work together to understand it and its life-giving resources more fully. This is one of the central themes at this meeting. We now recognize that the earth—its oceans, its atmosphere, its polar lands—forms a most magnificent laboratory in which we must work together to understand the complex dynamic system of forces that create our weather, supply our food and water, and provide us with resources to improve our lives. These forces recognize no political boundaries, and we must explore them together and share our knowledge of them. We have been doing this in a number of ways, through many international organizations and programs. They are too numerous to even list, but perhaps a few examples are in order.

At this moment scientists from several nations are aboard the deep-sea drilling ship *Glomar Challenger* taking cores of the earth's crust from beneath the ocean floor, examining them for clues to the earth's climate, life, and movement of past ages. More than 50 scientists from 17 countries have participated in this work. More than 6000 samples of deep-sea sediment cores have been taken in 25 voyages. Already this research and evidence from other international geophysical programs has radically revised our theories about the surface of the earth and the formation of the continents.

Under the title of the Global Atmospheric Research Program a vast armada of ships and aircraft of nine nations will take to the tropical zone of the Atlantic Ocean next year in the first of a series of research projects to gain vital information on the conditions that generate the weather over much of our inhabited land areas. This first experiment will employ 25 research ships, 12 instrumented aircraft, 9 geostationary and polar-orbiting satellites, special balloon and buoy systems, and the World Weather Watch network of land stations in some 30 countries. It will be one of the largest international research experiments ever conducted, with its huge amount of data to be managed and collected by a global telecommunications system.

Another example of international cooperation in science takes place on the frozen waste of Antarctica where there have been developed over the years more than 60 research stations to gather data on fields ranging from astrophysics to glaciology to marine biology.

International Cooperation in Science and Technology

I could go on to give numerous other examples of international scientific programs in which scientists from many nations are working together—sharing resources, facilities, and information—to enlarge our understanding of the planet and its resources. But I want to turn to the kind of international cooperation in science and technology that I believe may be most significant in the years ahead, namely, the work that will determine the course of national development.

Science and technology, wisely directed and strongly supported, must assume a more central role in the development of individual nations and in advancing our international systems of exchanging resources, products, and services. It becomes more obvious every day that from an environmental, economic, and ethical viewpoint we cannot afford merely to drift into future development, nor can we let the state of the economy and "the invisible hand" of the international market alone determine the fate of man and the earth. Science and technology can reveal a more rational course for planning our future and give us the means to provide for all men without plundering the planet. It should be possible for the developing nations, without significantly restricting their aspirations, to avoid the environmental blunders that are now plaguing the developed countries and to bypass some of the economic and social problems that have accompanied the development process in the past.

Much of that course has been, or is being, charted by scientific organizations that are already well established or are in the process of being formed. Foremost among these, of course, are the organizations of the United Nations—UNESCO, the Food and Agriculture Organization (FAO), the World Health Organization (WHO), the World Meteorological Organization (WMO), the U.N. Industrial Development Organization, the International Atomic Energy Agency, the International Labor Organization (ILO), the new U.N. Environmental Program to be headquartered in Nairobi, and several other U.N. groups. It is to be hoped that the governments of an even wider range of countries will bring their scientists into these activities. Of great importance, also, is the support being given to the planning and implementation of technological development by the Organization for Economic Cooperation and Development (OECD) and by the international monetary organizations—the International Bank for Reconstruction and Development (the World Bank), the Inter-American Development Bank, and the newer Asian Bank.

The newest addition to the bodies of experts that are concerned with worldwide development, and one which should someday make a major contribution to the course of development, as I am advocating it here today, is the International Institute for Applied Systems Analysis, which will be located in Vienna. This institute, a nongovernmental organization founded by the scientific academies of 12 nations, will support about 100 research scientists who will come to grips with the major interrelated problems of our times. They will investigate urbanization, transportation, communications, energy sources, environmental problems, allocation of natural resources, and several other problems, using the methodologies of systems analysis and operations research, advanced management techniques, and computer technology. They will work not only toward a solution of the problems gripping the developed nations, but in anticipation of those that could befall the developing countries. Hopefully their analyses, models, and warnings will be effectively brought to the attention of the world's political leaders and their significance will be understood, heeded, and acted upon.

The conference here in Mexico, though it purports to deal with the problems of this hemisphere, nevertheless encompasses the subjects with which all the international organizations I have mentioned must become involved. It is to the credit of those in the Consejo Nacional de Ciencia y Tecnologia (CONACYT) and the American Association for the Advancement of Science (AAAS), who jointly planned this conference, that these subjects have been so well covered. Special recognition should go to President Echeverría, the Mexican host government, and the Mexican science community, all of whom are making, through the vehicle of CONACYT, a notable effort to link local science to local development.

Population and Food Supply

Let me turn to some brief discussions of these critical subjects and their relation to each other, as well as to the role of science in development. Of first priority are the problems of population and food supply and those of health and medical services. In the limited time at my disposal I have chosen to focus on the former, which should not be taken as any indication that I regard the latter as less important. A number of the technical symposiums at this conference are devoted to a discussion of health, illness, and disease.

Central to any discussion of development is always the dual matter of population and food supply, and these are considered in two of the central themes of this conference. In some respects it can be pointed out that almost all other human and environmental problems spring from this crucial relationship. The problems of urbanization and the urban-rural balance, together with their effects on labor and employment, hinge on this. The problems of land use, land distribution, and the development of arid lands and tropical forests are related to the same matter. And the problems of the depletion of resources and the deterioration of the environment can be shown to be strongly tied to the issue of population and food supply.

Fortunately, in recent years, great strides have been made throughout the world in recognizing and acting upon the problems of population. We now have a far better grasp of the demographic, social, and economic aspects of population growth as well as better physiological means to deal with that growth. In many areas of the world there are indications that populations are being stabilized and that with a well-organized and sustained program of family planning the birth rate of a country can be regulated according to its best interests.

But neither these hopeful signs, related to some successful population programs, nor the reduced concern over food supply due to the success of higher yield corps should make us overconfident that we are solving the population or hunger problem. Much more needs to be done to turn some hopeful signs and some temporary victories into a more sustained success—one based upon recognition that we are dealing with a series of dynamic processes and relationships and not a group of simple problems that can be solved for now and all times.

If we turn to the matter of food supply, with all of its ramifications, we can readily see why this is true. The first aspect to consider is the viability of the high-yield crops produced by the "Green Revolution." We recognize now that such plants, though they are currently a great boon to mankind, are, like all plant strains, subject to new diseases and pests that are continually evolving. We must therefore be constantly vigilant and active in developing and banking new genetic strains that have the desired characteristics, yields, and food qualities and could be resistant to new strains of diseases and pests that might evolve to destroy them. The Food and Agriculture Organization is, of course, aware of this and is encouraging the establishment of national and regional "gene banks" to maintain seed and plant collections so that the characteristics of the various strains can be preserved.

The "Green Revolution" must become, in a sense, the "Green Evolution," with new research and development always under way. In addition, we must conduct an international effort to spread to many more areas of the earth the benefits of this type of agricultural research and development. Much more research will be required to breed strains that will thrive in a variety of conditions, particularly the cereal grasses which, directly and indirectly, supply three-fourths of all of man's food. The FAO estimates that, with continual introduction of locally adapted new varieties, the high-yield technology so successful today can be applied to one-third of the cereal acreage of the developing countries by 1985. However, to achieve this goal will require great commitment on the part of governments, scientists, and farmers throughout the world. Much credit is due, and continued support should be given, to the FAO for its work under the International Plant Protection Convention in setting up a network of regional plant protection organizations to strengthen cooperation in controlling destructive pests and disease. They are also developing a computerized data system to match fertilizer and herbicide application to soil properties, for rational use and the prevention of pollution.

It is an appalling fact that, at this time of increasing food production, as much as a quarter of the world's food never reaches the consumer because it is destroyed in storage, in transit, or in the market by insect pests, rodents, bacteria, and mold. In some areas the loss runs as high as 80 percent of the supply produced. We must develop and promote ways to avoid these tragic losses. We must create and apply technologies, particularly in the developing nations, to preserve and store grains and other produce efficiently and economically for longer periods of time, so that in bountiful times surpluses can be saved for periods of poorer yield due to unforeseen circumstances. Development of methods for the preservation of food, together with the provision of means for transportation and distribution will help correct its maldistribution—a plethora of one kind of food at one spot with a dearth in another place not too far away.

Nutrition is another aspect of the food problem that demands more attention. It is estimated that today there are more than 300 million children who, for lack of sufficient protein, suffer retarded physical development and who may well, also, be impaired in mental and behavioral development. The health and productivity of a large segment of the world's adult population may be similarly afflicted.

The result is affecting present and future generations. It is trapping them in a form of self-perpetuating poverty. The nutritional well-being of its people is essential to a nation's economic development, not to mention its social and human development. In the years ahead the world's scientific community must intensify its efforts to improve nutrition and public understanding of what is now known. Indications that this can be done are encouraging. Several nations and international organizations have placed nutrition on their development agenda. Three countries in particular—Colombia, India, and Tunisia—are to be commended for their pioneering efforts to establish a national nutrition program. Their work should be studied and, wherever applicable, their methods emulated.

With greater confidence that total food demands can be met through the Green Revolution, more attention should be turned to the breeding of more high-protein crops, to the production of meat, dairy products, and fish. Two agricultural research centers in Latin America that are making major contributions in developing better sources of protein are the International Maize and Wheat Improvement Center

(CIMMYT) here in Mexico, and the International Center for Tropical Agriculture (CIAT) in Colombia. The important work of the Institute of Nutrition of Central America and Panama (INCAP) and its collaboration with U.S. universities and private food industries should not be overlooked. INCAP research emphasizes the interrelationship between malnutrition and childhood disease. It is an outstanding regional program.

Food technology research is making significant strides in the enrichment of foods and in the creation of new foods and food supplements, but the problems of transferring their success to the poor, rural areas of the world remain.

One source of protein that should be given more attention is inland fish farming. There are indications that this may be the most efficient way to produce the highest yield of protein per pound of feed. Some research projects in fish culture are reporting remarkable results with protein yields far greater than poultry farming. This is particularly significant at a time when there has been a decrease in fish catches at sea in certain parts of the world. We now recognize that we have a greater international responsibility to protect the world's oceans from pollution and to use their resources far more wisely. It is encouraging that a U.N. Conference on the Law of the Sea is being held this year in Santiago, here in the Western Hemisphere.

Numerous new ways of approaching the food situation could be considered more seriously in the coming years. For example, the history of agriculture indicates that of the approximately 350,000 plant species described by botanists only some 3000 have been tried as a source of food. Today only a dozen or so of these provide, directly or indirectly, 90 percent of the world's food supply. We need to know much more about the potential for developing other varieties of foods and for producing more food in both arid and tropical lands. Most of the accumulated knowledge in agriculture has been gained in temperate zone countries and is not applicable to other lands. We particularly need to support more research in tropical agriculture, in areas and under conditions where, ironically, man has great difficulty producing food while nature sustains life so abundantly. Have we been taking the wrong approach in the tropics? I was intrigued a few years ago to hear a Latin American scientist suggest this when he stated (*1*):

> We must study wildlife in our Amazon Basin, where trees play a principal role. . . . We must compare tree-eating animals with those that eat grasses. It is fascinating to speculate on what will be found out about the giant leguminous trees so abundant in our jungles, for these are capable of association with a multitude of terrestrial and air-borne organisms for the better utilization of nutrients from the soil and air. They also utilize multiple layers of the soil, and create microclimates more tolerable to animals. Above all, they are extremely efficient in photosynthesis. Perhaps we should try to perfect what nature is already doing so successfully instead of trying to make her do things for which she is not prepared. Perhaps we should develop a technique for efficient animal nourishment from trees. Also promising are the possibilities of our use of the tremendous quantity of solar energy available in the tropics.

In repeating this statement I am not recommending that we abandon research on the more conventional approach to tropical agriculture (and neither was the scientist who made the statement). But perhaps we can pursue more than one approach in developing tropical agriculture in some areas of the world.

The same holds true in our development of the arid and semiarid lands, another central theme of this meeting; such lands represent almost a third of all the world's habitable land. At present arid lands support about 150 million people. Much more could be done to develop these areas and make them more productive and capable of sustaining a larger proportion of the world's people under better living conditions. A principal problem is, of course, insufficient fresh water. Some 60 developing nations must look forward to increasing difficulty in meeting water needs. Many of these countries border on the world's oceans and could benefit by the development of an economic desalting technology. It is unfortunate that much more support is not being given to this promising technology.

For a number of years I, and many of my colleagues in the nuclear energy field, believed that abundant, economical energy through nuclear power might hold the key to the development of some arid seacoast regions. We envisioned the use of that energy to desalt seawater and to provide power for a highly scientific agriculture and specific industries as a basic means of developing and supporting those regions where certain conditions—such as acceptable soil and temperatures—prevailed. Unfortunately, the economics of nuclear power has not yet reached the point where that concept can be pursued vigorously. We still hope to see the time when the idea of the Nuplex (the nuclear agro-industrial complex) will be successfully developed. In the meantime, other fields of research and development related to arid lands are being explored. Some of these regions lie over large supplies of underground water that could be tapped if energy and the right technologies were made available. Many also receive a small amount of rainfall that could be used more scientifically to better agricultural advantage. Israel has provided the world with an outstanding example of how this can be done. Some of her techniques of irrigation are even being adopted in my own country in order to use water more efficiently and effectively.

Now why have I devoted so many of my remarks to this point on matters of food and agriculture? There are two major reasons. The first is that the physical health of a nation's people is basic to its development—to its economic growth, its social advancement, and even its political stability. Aside from the purely humanitarian aspects of eliminating hunger, a people who are sufficiently fed and properly nourished can better ward off debilitating disease, can be more productive, and will be more likely to make a contribution not only to their own country but to the peace and progress of the world. A second reason has to do with the way in which nations develop and the important matter of how patterns of development will affect the future—particularly the matter of rural-urban balance. This in turn will affect important, related matters such as employment, education, and almost all the economic and environmental aspects of growth. Let me spend a few minutes in trying to relate these various factors.

Problems of Urbanization and Industrialization

It has been estimated that more than two-thirds of the people of the developing nations depend directly on agriculture for employment. Though many of these countries seek to emulate the ways of industrial nations, they are basically agrarian economies. In the past the pattern of progress has usually been associated with a parallel shift of population from rural to urban areas. One of the major questions to be faced in the remainder of this century is whether this pattern will—or can—continue. Certainly it cannot continue

in the way it has. In many of the advanced nations the urban implosion has created serious problems—social, economic, and environmental. Rural areas have decayed and urban areas have undergone cancerous growth with sprawling suburbs surrounding deteriorating inner cities.

But such problems in the advanced nations pale before those that could take place in the developing nations, should their rural-urban shift continue at its present rate. With urban populations in these countries now totaling about 600 million, it is said that they could increase to 3 billion by the end of the century. Such a 400 percent increase within one generation would be disastrous. Consideration of this leads all who think seriously about the future, not just of the developing nations but of the whole world, to wonder whether one of the central questions the scientific and technological community faces in the years ahead is creating ways—perhaps an entire system of development—through which the less developed world can rapidly advance without attempting to repeat the process and pattern of industrialization and urbanization that the developed nations followed. Developing nations must not strive to be carbon copies of developed nations. And to the extent that they seek to industrialize, they should not follow—and do not have to follow—the same route to industrialization.

This is an extremely sensitive and difficult matter. It is sensitive because some developing countries view even its consideration by others as an attempt on the part of the industrial countries to control their status, to restrain them from seeking an advanced and competitive position. It is difficult because, even with their consent and fullest cooperation, to prevent the developing countries from experiencing the urban implosion with all its subsequent explosive problems would require an enormous international effort in rural development, in education, in the creation of new kinds of light industry, and in researching and developing a whole range of technological and social innovations about which we have only begun to think. Should we attempt all this, it would also require a vast change in our global economic and political arrangements, based on a degree of cooperation, integration, and planning that can, at best, be achieved only over a long period.

In the absence of any grand master plan to accomplish this in the near future, it is at least encouraging that some international steps are being taken to prevent many of the harmful conditions associated with industrialization. For example, the U.N. Advisory Committee on the Application of Science and Technology to Development has prepared a report designed to provide developing countries with guidelines for the rational utilization of their resources. The U.N. Industrial Development Organization is providing technical assistance in the analysis of environmental aspects of industrialization. The new Environmental Program of the U.N., organized as a result of the Stockholm Conference, will also be focusing heavily on these problems. And the new International Institute for Applied Systems Analysis, which I mentioned earlier, will no doubt contribute some serious thinking and helpful ideas on these matters.

But what things can be done to alleviate the human problem associated with the massive migration from rural to urban areas to prevent—as Barbara Ward puts it—the cities fom "silting up with workless multitudes"?

It has been estimated that during this decade the developing nations will face the incredible task of creating productive jobs for more than 300,000 people each week. Whether this can be accomplished remains highly questionable. According to World Bank economists, it would take twice the growth rate of the 1960's—9 to 11 percent annually—to be able to employ in the developing countries those seeking work outside of agriculture. It would also require that agriculture retain about one-third of its own labor force increases.

Energy Supply

This means, in the years ahead, we must see two related massive efforts take place to solve the employment problem per se and to solve it significantly outside of major urban areas. One effort should be in agricultural developments based on methods, technologies, and land use that are perhaps less capital-intensive and more labor-intensive than those in many developed nations, but nonetheless just as highly productive. The other should be an important move toward rural industrialization—small and light industry that will provide high employment and low environmental impact. Much of this industry might be closely related to agricultural and other natural products. These would not be energy-intensive industries; but, nevertheless, power and rural electrification would play a major role in their success, as well as in determining the standard of living of the communities that provide their manpower. It is therefore essential—and urgent—that we move ahead with our energy technologies, nuclear (including fusion) and nonnuclear, to provide sufficient economic power wherever it is needed.

We should make every effort to find ways to use solar and geothermal energy and to search for cleaner and more efficient applications of fossil fuels. Aside from its longer range possibilities of generating economic electricity, solar energy might be used sooner in a variety of ways to meet other energy needs—for heating, cooling, and local industrial and agricultural processing. Nonnuclear energy for development is one of the central themes for this conference.

One of the most difficult things we will have to do, and do soon, is to seek ways to ensure that all the peoples of the world share more equitably the vast human benefits that energy can bring. It is estimated now that less than 50 percent of the world's population uses close to 90 percent of its commercial energy. This fact alone is a major reason for the great chasm between the advanced and the less developed nations of the world. It is no mere coincidence that there is a relationship, when comparing these groups of nations, between the electric power consumed per year per capita and such items as life expectancy and literacy, not to mention the gross national product.

New Frontiers in Human Relationships

We must be just as creative and innovative in our social, political, and economic thinking as we are in our planning and use of science and technology. Furthermore, we cannot deal with human and technological matters in any but the most integrative, interactive way. We may therefore find that in the years ahead we may not be able to make the maximum use of our science and technology in the cause of man unless man, in his various nations and societies, is willing to change many of his tradition-bound ways, free himself of many prejudices and outmoded ideas, and explore new frontiers in human relationships as well as take bold steps forward in his exploration and application of science and technology.

This is not meant to be a rejection

of the past—of all tradition, of national heritages and cultures—but an affirmation for the future, a future in which the best of all traditions and cultural achievements can be carried forward to be enjoyed and treasured and shared by coming generations. A healthy mankind does not have to be a homogenized mankind. A global civilization can contain much diversity and decentralization and still function effectively as a system. In fact such diversity will provide the system with the vigor and strength that is typical of a species that is infused with genetic variety.

Environment and Natural Forces

The kind of human development that I have been discussing can, of course, take place only if man wisely uses science and technology to understand and learn to live with the natural forces of this planet—another central theme of this meeting. The environmental movement we are experiencing signals our recognition of this, and I believe we are responding to the warnings that have been issued on environmental matters. Great challenges have been thrown to the world's scientific and engineering communities. There is the challenge of more fully understanding the effects of man's impact on the biosphere. There is the challenge of developing materials and products that minimize that impact. There is the challenge of creating a civilization bent upon recycling, which will maximize the use of all resources rather than deplete and degrade finite supplies. It is up to the world's scientists and engineers to exercise great leadership, not only in focusing the attention of their communities and countries on these problems but in developing practical solutions that can be rapidly put into effect by industrial and political leaders. The problem of the industrialization of the developing countries in a humane and sensible way provides a great challenge to the world community of scientists and engineers.

Living with the forces of the planet means also fostering a better understanding of the destructive capacity of the earth—its ground movement and weather—and designing human habitats to minimize the loss of life and property during nature's rampages. This can be done. For example, earthquake engineering (another central theme here) is becoming successful in designing buildings to withstand sizable tremors. It is important to note that two large buildings that survived the recent Managua earthquake with only interior damage had been designed by experts trained in earthquake engineering. Other buildings surrounding them were reduced to rubble.

We are also making progress in understanding our global weather so that we can make longer range forecasts and give more advanced warnings of storms. More accurate forecasts and longer range forecasts can save millions of dollars annually in property damage and crop losses as well as reduce the loss of life and human misery caused by severe weather. Of greater importance, such forecasts—for example, of the behavior of the monsoon in South Asia—could help farmers plant their crops at the right time to take advantage of the steady rainfall. Without such forecasts, they are liable to plant their seeds at the first rain and then lose them if the monsoon rains stop for several weeks, as they often do. Study and limited experimentation is taking place in weather modification (one particularly successful experiment has helped in preventing local hailstorms), but extensive weather modification involves so many complexities that it is probably many years away.

Education and Research

In conclusion, let me focus briefly on the human force that will be necessary to carry out much, if not all, of the change demanded to create a livable future. That force is organized knowledge; and it is transmitted by education. It is education, perhaps more than any single factor, that will determine how we survive—the way in which developing nations develop, the quality of life in all nations, and the extent that human freedom and dignity flourish in a complex and highly organized world. Our global civilization will be shaped more by the activity and content of its classrooms, books, and television screens than by its forges and factories. One of the central themes at this meeting—opportunities in education—is devoted to this key subject.

While the growth and direction of higher education remains an important matter, it is far overshadowed by the need to combat the illiteracy and ignorance of a large portion of humanity. Are we winning this struggle? We are making progress but the outcome is still in doubt. In the 1960's educational growth rose steeply in the developing countries. It is encouraging that much of this growth took place in Latin America where more than 250,000 primary school classrooms were built and more than 1.3 million teachers were added to the primary and secondary schools. During my own tour of Latin America 6 years ago I witnessed much that attested to the quality and effort of education there.

Throughout the developing world the number of students enrolled in formal schooling rose 6 to 7 percent annually during the previous decade. Yet, by the end of that period, nearly 300 million children between the ages of 5 and 14 were not enrolled in school. Aside from other factors, the cost of education is a major deterrent to its necessary growth in developing nations. It has been estimated that, relative to their incomes, it costs most low-income countries five to ten times as much to provide primary schooling for a given proportion of their population as it costs the high-income nations. This is also true proportionately at secondary and higher levels. Reasons for this include the rate of population growth that has raised the fraction of school-age population, the relatively higher teachers' salaries, and the higher costs of school buildings.

But much can be done by educational research and technology to improve this situation. Attempts are being made to use satellite and television technology to bring basic education to remote and rural areas. These should be supported, and efforts should be made to improve teaching systems and materials and to produce and distribute equipment as economically as possible. Traditional education will have to change and give way to new ideas in order to meet the new needs emerging today. One of these needs is to relate schooling to rural development, to produce local populations and leaders educated to improve conditions in their regions and yet who are willing to work cooperatively and productively with the central government.

At the higher levels of education, much work is being done in the developing nations to focus on the development of scientific capabilities to serve their own unique needs. During my 1970 trip to six African countries I was impressed by the quality of this work in which small but dedicated cadres of men and women in each country were engaged, and I urged, in an article in *Science* (*2*), that more support and cooperation be given by other nations to their efforts in educa-

tion and research. Education to spread developmental knowledge—whether in the form of basic literacy, instruction in sound hygiene and health practices, or the application of new agricultural techniques—has only begun and yet must be advanced rapidly. This represents a major challenge in the years ahead. And efforts to meet it should be strongly supported by the scientific community who, perhaps more clearly than any other group, can see the consequences of failure.

Some of this support will come from a number of recently planned international organizations. In my article in *Science* I urged the creation of an International Science Foundation; this had also been suggested by Roger Revelle and by Robert Marshak and Maurice Levy and, as a result of their efforts and those of others, such an institution (the International Foundation for Science, IFS) for the support of research in developing countries is in the process of being created. The newly formed International Federation of Institutes for Advanced Study (IFIAS) also represents a positive move in this direction and the various moves toward the concept of the World University or various forms of the International University could help fill this need. And the older International Council of Scientific Unions, together with the individual International Scientific Unions, has certainly played an important role for many years in fostering scientific education and research on an international scale.

Despite the progress of these various efforts, science is pursued today primarily in countries that together constitute only a quarter or less of the world's population. Besides the loss of the vast human resources that remain untapped in scientific research, the benefits of research are largely confined to those countries that pursue science. There is thus created great disparities in the human condition and hence a contribution to worldwide political instability. I believe this is an arena which the international scientific community should enter in a more effective and meaningful manner.

Plan for Action

The main requirement is a widespread rededication to this goal of international science by scientists and engineers on a worldwide basis. One method of implementing such an effort is through the many Associations for the Advancement of Science in the countries throughout the world. These are in general noncommercial, nonpolitical associations of scientists and engineers and of other people interested in science and engineering. They are nationwide and include all of the natural and social sciences within their domain. Their membership is in general open to all without restriction as to scientific qualifications and, typically, there are organized affiliations with many other associations and societies. Thus these Associations are, in varying degrees, representative of organized science in the countries in which they operate and can act with the great authority inherent in their membership. There are at present some 40 associations of this type with a wide variation in their names.

My greatest familiarity and influence, and point of contact from this point of view, is with the American Association for the Advancement of Science in the United States, a cosponsor of this meeting in Mexico City. One of my first acts when I was elected to a position of leadership in this organization was to move toward the creation of an Office of International Activities. One of my specific motivations was the large response to my call for increased cooperation between U.S. and African scientists in my article in *Science*. I felt that this favorable reaction indicated a large potential interest. In attempting to respond to these offers to help in the development of African science and these requests for information, I felt a strong need for a nongovernmental international center, in addition to the Foreign Secretary's Office of the National Academy of Sciences, which did its best to try to help. Additional recent steps toward increased international involvement of the AAAS have taken the form of agreements, either in effect or under negotiation, for cooperation with individual associations of other countries.

I believe that the time has come for the American Association for the Advancement of Science to move further into the international field. Perhaps the next step might be to join with our sister national associations of science in Latin America and Canada to create a true American Association for the Advancement of Science—an association in which the term *American* would represent its broader and true meaning. This might be followed in due course by a joining together of the national associations of science in an International Association for the Advancement of Science (or perhaps an International Association for the Advancement of Science and Technology). There are, of course, many degrees of affiliation that can serve as a start and which can develop into closer and closer affiliation with the passage of time.

This is my farewell address, which is given, in the tradition of a long line of predecessors, as past president and present chairman of AAAS. It is difficult, and perhaps not even desirable, for presidents to make any lasting impressions on AAAS. My immediate predecessors have launched the Association in important and exciting new directions—toward broader membership and increased emphasis on the use of science and technology in the promotion of human welfare. Let me dare to hope that I can help us to move more quickly toward broader international involvement. Should this be the case I feel confident that the demonstrated international interests of my successors, Leonard Rieser and Roger Revelle, will ensure the maintenance of any momentum in this new direction.

I have tried to review what I believe are among the most important issues we in the world of science must face if we are to make science work more fully in the best interest of humanity. The task ahead for science and technology is not made easier by the doubts that many have over the aims and accomplishments of these two forces. There are too many who view the objectivism, determinism, and rationalism of science as threats to humanity and who see in technology only a behemoth out of control and destined to destroy its creators. We in science must prove these ideas false, not merely to justify the existence of intelligent human life, but in order to fully enroll science and technology in the effort to preserve and improve all life on earth. Nothing less is at stake in the struggle to make science and technology successful in the cause of mankind. To this end, I hope, and I believe, we are entering the world's greatest era of international science cooperation. Let it be an era of increasing goodwill among all nations and one that will bring peace and contentment to men, women, and children throughout the world.

References

1. A. Bacigalupo, Puerto Rico Nuclear Center Tenth Anniversary Symposium, 30 to 31 October 1967.
2. G. T. Seaborg, *Science* **169**, 154 (1970).