SCIENCE, TECHNOLOGY AND INTERNATIONAL SECURITY: A SYNTHESIS

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C/81-6

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Prepared for the Five Year Outlook project of the American Association for the Advancement of Science and to be published in Science, Technology, and the Issues of the 80's, edited by the AAAS, Boulder, Colorado: Westview Press, 1982 (forthcoming).

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September 1981

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INTRODUCTION

In a world substantially altered in this century as a result of the products of research and development, and with the elements of security of most nations directly affected, government institutions and policy processes in the United States remain heavily domestic in orientation. Contrary to common assumption, this is at least as true for the scientific and technological enterprise as it is for any other.

Some of the most important issues and needs relevant to science, technology, and international security, are presented in the following pages and in the accompanying papers. The parochial nature of U.S. national institutions, however, makes it peculiarly difficult to come to grips with some of these needs, or to anticipate them in any orderly way. For many years this problem has plagued U.S. government attempts to deal with the international implications of research and development (R&D), and international science and technology. The problems and the dangers now become more pressing as scientific and technological competence

in other nations becomes more formidable. New measures are needed, yet the issue of excessive domestic orientation is only rarely identified or directly confronted. Without some attempt to understand this issue, actions that focus on the specific needs discussed below are likely always to remain ad hoc, and seldom equal to their tasks.

BACKGROUND

The results of science and technology have had dramatic effects on the restructuring of nations and of international affairs, particularly in the 35 years since the Second World War. Aircraft, satellite communications, health and sanitation measures, missiles, nuclear weapons, automated production, radio and television, agricultural mechanization, and new crop strains all bear witness to the productivity of R&D and, in their effects, to the profound revolution in human affairs they have brought about or made possible. The pace of change, furthermore, shows no sign of slackening.

International affairs have been heavily influenced by the differential ability of nations to carry out and capitalize on the results of R&D. Two nations have emerged with military power and influence far greater than others largely as a result of natural endowments and resource bases that have allowed massive exploitation of science and technology. The gradual decay of that dominance, especially in its economic dimension, is already a source of new international relationships and problems. The disparity among nations of the North and South in ability to acquire and exploit technology is also a major factor in their

relative economic status, and in their increasingly acerbic political relations.

Concurrently, the pace of industrialization of technological societies has greatly intensified the dependency relations among states, so that even the most advanced societies find themselves critically dependent on others for resouces, information, capital, markets, food, and even technology.

Traditional geopolitical factors have been altered or expanded by advances in science and technology to include, inter alia, size and number of long-range nuclear missiles, satellite communications and surveillance capability, competence of the educational system, fundamental change in the very significance of major conflict, and critically, R&D capacity.

The results of R&D have also given rise to new technologies of global scale, creating wholly new issues in international affairs, notably atomic energy and space exploration. Also a matter of worldwide concern are the side effects of technological development. The resultant changes have altered traditional international issues and created major new ones, such as transborder environmental concerns, stratospheric modification, and ocean exploitation.

Not all of these changes in international affairs directly bear on security, but the web of interactions in a technological world makes it difficult, even misleading, to exclude, say, economic concerns of developing countries from the concept of international security. In fact, the broad issues of food, health, resources, energy, and population are aspects as legitimately a part of security as are military issues.

Given these effects of science and technology on the international security of states, it is ironic that the support for science and technology is primarily a national endeavor, particularly in the United States. Policies for R&D are seen in a national perspective, and come primarily from national governments. This means, however, that international or global needs are not likely to be adequately taken into consideration in a national decision process.

A natural result of the nation/state system is that decisions in all policy areas are usually made unilaterally within one nation. Moreover, the apparent worldwide intensification of nationalism in the face of economic difficulty, not least in the United States, further encourages unilateral decision making. The parochial nature of decisions concerning R&D, however, goes beyond normal constraints of nation-based decision making and funding. The decentralized nature of public funding for research means that it is predominantly considered within the context of mission agency budgets. Even for those agencies whose rationale has a basic foreign policy motivation (DOD, DOE), the actual decisions and choices are heavily influenced by domestic pressures and inputs. Some departments or agencies are in fact precluded by their legislative charter from committing resources for anything other than domestic problems. All are faced with a budget process, in both the Executive and Legislative branches, that discourages (or often denies) all departments except foreign policy agencies the right to allocate their own R&D funds for other than U.S.-defined problems.

In the private sector as well, research decisions are heavily

conditioned by the U.S. market, with American industry still primarily concerned with U.S. sales, and only gradually adjusting to the growing share of exports in the economy.

The implications of this situation are evident throughout the discussion of specific issues below, and deserve subsequent elaboration to suggest possible policy or institutional departures that could be undertaken.

Of course, not all issues are handicapped by this particular institutional limitation. What follows is a broader discussion of the issues in the interaction of science, technology, and international security that are likely to be central questions over the next five years. Though the focus is on a five-year period, policies cannot sensibly be seen in that short time frame without taking into account long-term objectives. Where relevant, what are in effect assumptions about desirable futures will be spelled out. The final section will be concerned with some of the institutional and policy process questions raised by the specific issues.

KEY ISSUE AREAS

It is tempting to start with national security issues, which appear to be most directly related to the subject. But, economic issues will probably receive policy priority in the next few years, with important consequences for international security. In addition, as significant as defense issues are, they tend to receive more concentrated attention. Hence, defense issues will be addressed later in this paper, without in any way denying the fundamental significance of science

and technology to security issues and, particularly, to international stability.

Economic Issues

Competition and Cooperation Among Advanced Industrial Countries

It is not a novel observation that the most serious short-term problem of the United States and of other Western industrialized nations is and will continue to be coping with inflation in a largely stagnating economic situation. Unemployment rates are high in many countries (over 9 percent in the United Kingdom at the end of 1980), with inflation at the double-digit level for several. The relatively bleak economic outlook has many causes; analysis of them within the context of this paper would be inappropriate. However, not only do economic problems affect the international role of science and technology, but some measures individual countries may take for economic purposes will affect the course of science and technology or limit the international flow of scientific and technological information.

Industrial Policy. It has become almost a fad to speak of the need in the United States for an industrial policy or for reindustrialization. Several aspects of reindustrialization are particularly relevant to R&D. One is the ability (legal, political, and psychological) of the United States government to work cooperatively with individual companies or a consortium to support research designed to improve the international competitive position of U.S. industry. Antitrust considerations, among others, have deterred such joint activity in the past.

Two initiatives in the Carter administration have shown that at least some of the barriers can be overcome. The joint research programs on automobile engines, with a consortium of auto companies (Cooperative Automotive Research Program), and the cooperative program for ocean margin drilling, with a group of oil companies, have received the advance blessing of the Department of Justice. These initiatives are now in jeopardy or cancelled. The international economic payoffs of cooperation of this kind (and the costs of not easing the way) may justify reconsideration of this policy in the next several years. Whether or not the government is involved, the advantage to international competitiveness of allowing research cooperation among companies in the same industry may create new support for antitrust policy legislation. Clearly, such legislation would provoke major political controversy.

A related aspect of industrial policy is the tendency of the United States to apply to U.S. companies operating abroad the same rules and constraints that apply inside the country.[1] The essentially adversarial relation between government and industry in the United States, whatever its historical justification or merits in spurring competition, often serves to put American companies abroad at a disadvantage in competing with companies directly supported and often subsidized by other governments. This is particularly relevant in high-technology industries, as companies in other countries are now able to compete as technological equals for the major new markets that will determine future economic strength. Obviously many complex and contentious

factors will arise as this issue is addressed, but they must be discussed. The economic stakes are high.

The key determinant of America's competitive technological position is, of course, the strength and innovativeness of its high technology industries. Domestic science policy, including support for research, tax incentives, regulations, quality and adequacy of education, and other elements will crucially affect the economic scene in years to come. In addition, specific tax and other policies that bear directly on industry's decisions to carry out R&D either abroad or in the United States will require examination, though it should not be an automatic conclusion that overseas research by American firms is necessarily against U.S. interest. Overseas research can contribute directly to American R&D objectives, enhance the possibilities for large-scale cooperation (more on this below), and contribute to knowledge generally.

One of the greatest dangers of the current economic malaise in Western countries, coincident with serious competition from third world countries and from industrialized countries (especially Japan), is the possibility of a rise in protectionism--to preserve dying or inefficient industries. These industries may be failing for any number of reasons: increased labor costs relative to other countries; changes in cost of other factors of production, particularly for energy and resources; lower productivity; lagging innovation; inadequate industrial organization and others. The temptation to respond politically to worsening domestic unemployment and its ancillary effects by preserving and protecting

inefficient industries is very great, especially when a certain amount of implicit or informal protectionism is practiced by most countries in one way or another (hidden subsidies and biased regulations, for example).

The economic costs of a protectionist spiral among industrialized countries, and the consequent loss of incentives for innovation and support of R&D could be very great. In effect, protectionist measures are an alternative to R&D investment, at relatively low short-term cost and very high long-term cost: a poor bargain, but one likely to be proposed and actively sought by powerful forces in the near future.

One specific protection issue has emerged in recent years over the export of new technology which, it is argued, is tantamount to the export of American jobs as that technology becomes the basis of new competing industries. The argument is that technology developed in the United States is sold to others at a price that does not adequately reflect the true costs, or the broader effects on the United States of that sale. It is a disputed issue, not only with regard to the facts, but also whether this is a case in which the possible cure might be worse than the disease. For example, is the current government pressure to exclude foreign students and faculty from advanced integrated circuit research facilities at universities a wise policy? This is an issue likely to be more visible in the future.

Finally, under the heading of industrial policy the relationship between domestic regulatory policy to protect health and safety, and a nation's international economic position must be included. Already under intense scrutiny, this subject is certain

to be the focus of important debate in the next five years. The basic concern is that unequal regulations from country to country can result in substantially different costs of production, thereby changing each nation's competitive position. That claim is made now with regard to American environmental and safety regulations that are presumed to have important effects on U.S. export potential. Equalizing regulations worldwide would be one way to manage the problem when it exists, but that would not always reflect different conditions in countries, different factors of production, or different values. Regulations can sometimes improve competitive position if the costs of compliance are higher in other countries competing in the same market. At times, regulations are simply a disguised trade barrier. Once again, the complexity of the situation does not allow simple judgments or generalizations. The positive current account balance of the United States in the last months of 1980, in the face of high energy costs and an improving U.S. dollar value would seem to belie the negative effects argument, but it is not known what the balance would have been in the absence of regulation. Moreover, the issue is usually cast not only in specific cost terms, but also with regard to the delays, uncertainties, and bureaucratic constraints imposed on industry by what is seen as a burgeoning regulatory environment.

The Reagan administration has indicated its intention to address this issue directly. It is hoped that sound data and analysis will support any actions taken.

Cooperation. Scientific and technological cooperation among Western technologically advanced countries is not rare. When compared with the scale of investments in R&D and the common goals of Western countries, however, the number of cooperative projects, especially in technological development, is rather small. The explanations are obvious: difficulties encountered in organizing cooperation; concern over losing a competitive position; and, most important, the basically domestic orientation of most governments. Meshing of programs, objectives, budgets, and people is much more complex than when carried out within one country.

Current economic needs and constraints may now put co-operation, especially technological cooperation, much higher on the agenda. Industrial countries are all in need of technological progress to meet their social, political, and economic requirements, at the very time when the economic situation that created these requirements also serves to place severe budgetary constraints on national R&D expenditures.

Today's nearly equal competence in science and technology among countries also means that a given project is likely to benefit from larger application of resources. In some cases, participation by more than one country may be necessary to attain a critical size. The massive investments required in many fields of central and growing importance, especially energy, also make the possibilities of cooperation to reduce the drain on national budgets particularly attractive.

The difficulties and costs of cooperation cannot be ignored:

- inherent difficulties of meshing disparate bureaucracies;
- delays in reaching decisions among differing political and legal systems;
- complications of varying decision processes, priorities, and competencies;
- cost of international bureaucracy;
- the danger of political inertia, which makes projects hard to start, but even harder to stop;
- the possibility of drains on research budgets because of international commitments;
- the tendency to undertake internationally only low priority projects;
- the apparent conflict between cooperation and improving a nation's competitive position.

Successful cooperation also requires reliable partners. The record of the United States in modifying or abrogating agreements makes future agreements harder to reach. Most recently, the proposal to cancel the coal liquefaction development project with Japan and Germany, and to withdraw from the International Institute of Applied Systems Analysis have damaged our reputation as reliable partners.

Difficulties are formidable but the potential benefits are also formidable. Successful examples of cooperation

(airbus, International Energy Agency projects, coal liquefaction until this year) demonstrate it can be done. Greater willingness of the U.S. bureaucracy to look outside the United States and recognize the competence and knowledge available elsewhere, and the greater experience the bureaucracy would attain through making the effort, would be substantial additional benefits of accelerating the pace of international cooperation. The forms of cooperation (bilateral, trilateral, Organization for Economic Cooperation and Development--OECD) all need to be examined for each case, though the OECD is the logical organization in which to lay the groundwork and establish a design among Western countries. Increased attention to genuine international technological cooperation ought to be an important task of the 1980s.

North/South Science and Technology Issues

The differential ability to acquire and exploit technology is a major determinant of the strikingly different economic situations and prospects of nations of the North and South, and one of the prime sources of the political disputes among them. Differences in technological capability, however, are potential levers for constructive assistance and cooperation. Can this nation grasp those opportunities, which play to its strongest suit--its technological strength?[2]

The fate of developing countries in economic, political, and military terms in coming years will have a great deal to do with international political stability, and with the security of all nations, not the least the United States. It is reasonable to

forecast that international turbulence will be centered in the developing world. That estimate is reflected in U.S. military and foreign policies. It is much less evident in official economic policies--the U.S. commitment to economic assistance is scandalously low relative to that of other industrialized countries. The various reasons for U.S. indifference and frequent opposition to foreign assistance cannot be usefully probed here. However, the central nature of technology in development does provide a focus for exploring how to maximize the U.S. role, whatever the aggregate scale of assistance, and for highlighting some of the particular issues within specific fields (such as agriculture and population) which need to be confronted.

Economic growth, political stability, and a working economy in a developing country (with important effects on agricultural production, resource availability, reduction in fertility, and markets for American goods) can all be advanced by external assistance from the United States. It is in our national self-interest to provide this assistance. This is not to deny that the more economically advanced a developing country becomes, the more competitive it is with the United States; nor is it to deny that political stability does not automatically follow growth, or that the political objectives of developing countries may differ from our own. But U.S. self-interest is better served by the steady advancement of developing countries than by lack of progress. Whether or not economic assistance to developing countries is high on the U.S. agenda at the moment, there is a substantial probability that it will be forced there through political or economic crises, or national calamities such as widespread drought.

Technology Policy to Developing Countries. It is no longer necessary to justify the importance of technology in development. Technology is essential to management of the problems of agriculture, health, environment, industrialization, population, energy, and most other aspects of a modernizing society, and is recognized (sometimes overemphasized) in most developing countries to be essential. The United States, whatever its relative decline in technological leadership, is still the world's strongest technological nation, with a broad and flexible education and research establishment.

The technological capability of most developing countries is steadily improving. Nevertheless, most research is carried out in the developed countries either for military purposes or for the domestic problems of those countries. Perhaps no more than 5 percent of global R&D can be said to be devoted exclusively to problems of development. In a setting in which industrialized nations have such a stake in economic growth and elimination of poverty in the developing world, it makes little sense to devote so little scientific and technological effort to problems that are peculiarly those of developing countries.

Much of this R&D cannot and should not be done in industrialized countries, for practical as well as philosophical and political reasons. To be effective, to work on the right problems, to be sensitive to local needs and preferences, to produce solutions that fit and are likely to be adopted, to keep up with and adapt technology--all require R&D defined and carried out locally. In turn, this implies attention to the building of the scientific and technological infrastructure in developing countries.

This does not mean, however, that all research relevant to developing countries needs must be carried out locally. Many areas of basic research can more effectively be done in existing laboratories; many problems are generic and can be more quickly investigated in experienced laboratories with resources and skills already deployed; many technological problems require general solutions before locally adapted applications are possible. Perhaps most important is finding ways to elicit commitments from scientists and engineers in industrialized countries to work on problems of development in a sustained way that allows cumulative benefits and continuous attention. Long-term availability of financial resources is essential, not only to make such commitment possible, but also to make it respectable in the eyes of disciplinary peers.

Transfer of existing technology to developing countries is no longer seen as an adequate alternative. Experience shows that such transfer, especially of public technologies of health and agriculture, is inefficient or inappropriate without adequate receptors to choose, adapt, finance, and develop knowledge to fit local environments and needs. Technology requires adaptation to a unique social, economic, and political as well as technical environment. Also, it tends to change that environment, often quite rapidly, so that mutual adaptation of technology and environment is a continuing and dynamic process.

Relations of developing countries with multinational corporations also require local capability. The bulk of industrial technology is transferred to developing countries through private

investment by international firms. To work effectively with technologically advanced companies, without losing control of the resulting development or being exploited economically, presupposes the ability to set realistic objectives, negotiate contracts, weigh often esoteric choices, and in general be fully aware of technological and economic options.

Thus, a significant and growing indigenous capability in developing countries is required. And, it must embrace basic science as well as technology, for without the insight and self-confidence created by an indigenous scientific community, a developing country will lack the ability to control its own development. In short, what is required is greater allocation of research resources to development problems in advanced countries, especially in the United States, and the building and strengthening of indigenous capability in developing countries.

To date, the ability of the United States to help in either of these efforts has been seriously limited, because of the low level of resources allocated, and because of the institutional and policy constraints that deter or prevent effective commitment of scientific and technological resources for other than domestic purposes. At present, essentially all research devoted to problems of developing countries must come from the foreign assistance budget either spent directly by the Agency for International Development (AID), or through transfer to other U.S. government departments and agencies. With minor exceptions, departments and agencies are prohibited by their legislative charters or by the budget process from spending any of their own funds on

objectives other than domestic ones. Thus in an overall federal R&D budget well in excess of $35 billion, the total allocated for objectives directly related to developing countries, is on the order of $100 million, or one-third of 1 percent.[3]

The result is not only very limited in terms of R&D output; it also means that the competence of the U.S. government's technical agencies is barely tapped on issues to which they could significantly contribute. When all funds come by transfer from other agencies, there is no incentive to build staff or agency commitment, to work on these issues with their congressional committees and university or industry constituents, or even to know through experience how they can contribute.

The rationale for these legislative restrictions and for budget compartmentalization stems from the early history of the creation of cabinet departments and agencies, and from natural management principles of tying program objectives tightly to appropriate funding sources. The trouble is that as foreign and domestic issues have become more closely intertwined, corresponding reflection in the allocation of resources has not taken place. And the rigid budget compartmentalization does not take into account the often mixed purposes (combining technological and development assistance goals) of many possible programs.

The implications of these institutional restraints go farther. Astonishingly, the United States has no governmental instrument for cooperation with other countries, unless that

cooperation can be defined either as scientifically competitive with domestic research and development, or as foreign aid for the poorest of countries. Thus, the United States cannot respond to those developing countries that have graduated from the poorest status, the very countries with developing science and technology capabilities best able to make use of cooperation with the United States, though not yet able to compete at the scientific frontiers. These countries have the greatest interest in substantive cooperation (often without any transfer of dollars), and are in the best position to begin solving their own problems as well as assisting in attacking global problems.

In fact, in recent years, the United States has undertaken rather substantial efforts at developing bilateral science and technology cooperation with these countries. Those initiatives have had to be taken primarily at the White House level directly, with major problems of planning and implementation. And now, at least some bilateral agreements that already have been negotiated may be abandoned as a result of large, targeted budget reductions.

The opportunities to use America's strength in science and technology in cooperation with other countries to further U.S. objectives (political and economic as well as scientific) are likely to grow in the coming years. The absence of an adequate institution and policy process to plan and fund these programs, and to engage the competence of the American scientific enterprise, both governmental and private, will be an important issue that will have to be confronted. The Institute for Scientific

and Technological Cooperation (ISTC), which was proposed by the administration in 1978 and authorized but not funded by Congress, was designed to correct some of these institutional and process deficiencies.

Food and Agriculture. Some issues within the context of North/South relations stand out in their importance and in the likelihood they will or should be the focus of much greater attention in the next quinquennium in the United States. One of these is food and agriculture, because of its fundamental nature in the development process and the great concern that increases in agricultural productivity will not keep pace with the growth of population that already includes several hundreds of millions chronically malnourished.[4] It is estimated that food production must increase at least 3-4 percent per year if significant imrpovement is to occur by the end of the century.[5]

The United States has a unique role to play because of its unparalleled agricultural production, as well as its R&D capabilities. For the reasons cited earlier, however, much of the necessary R&D and experimentation must be carried out in the countries trying to improve their own agricultural enterprises. This implies building greater indigenous capabilities than now exist, and also strengthening and expanding the enormously successful international agriculture research centers that have been primarily oriented to, and staffed by, developing countries. The recent move to devote more of the resources of these centers to the applied problems of improving agriculture (low-cost technologies, water con-

servation, etc.) are much to be applauded. The international centers must not be seen as alternatives to individual country capacity, but as necessary complements to allow some economies of scale, to focus resources on generic problems, and to provide an essential psychological tie to a world community for a sometimes isolated scientist in a poor country.

The U.S. research community could play a substantial role, larger than is at present likely. One impediment is the budgetary process, cited earlier, that bars the Department of Agriculture from effectively committing its own funds for agricultural problems not seen as domestic.

Another is the organization of agricultural research in the United States that is essentially a state-based structure without the extensive tools for central planning or quality control. That makes it difficult to ensure the essential quality of the entire agricultural R&D effort, to build competence in areas of study not peculiar to the United States, or to enable effective planned connections to be established between developing countries and the United States on agricultural R&D on any satisfactory scale.

It is also important to note that improvement in agricultural productivity is not dependent solely on advances in traditional areas of agriculture. Water conservation, climate, energy, pest control, and low-cost technology, and the social sciences related to agricultural economics, innovation, application and distribution, are, inter alia, of equal importance. The agricultural research agenda must include those areas as well.

Population. Although fertility has declined in recent years, growth projections remain high enough to cause serious problems of starvation, economic stagnation, and political unrest.[6] The international system has only begun to feel the effects of forced or voluntary migration across borders, which is likely to become a major cause of international political instability in the future; in addition, there is the already evident internal instability that arises from urban migration, un- or underemployment, lack of adequate food and sanitation, and serious health problems.

Science and technology cannot solve the population problem, but they can provide the necessary tools for public policy. In particular, more research is needed to provide low-cost contraceptive technologies (especially including male contraceptives), and to increase our understanding of the social determinants of effective family planning policy. Fertility decline is so closely related to other aspects of development, particularly health, food, sanitation, transportation, and communications, that in a sense all technological research can contribute indirectly or directly to the population problem.

In population-related (and health-related) subjects, we find a special variant of the domestic orientation of U.S. institutions. Health and safety regulation of drugs in the United States is based on risk-benefit criteria keyed to the United States. Thus, proposed contraceptive drugs are evaluated for safety based on the risks of health side-effects in the U.S. environment, when the risks and benefits are likely to be quite

different in another country. In some cases, American pharmaceutical companies are deterred from developing a drug at all, since the benefits of protecting against some diseases (schistosomiasis, for example) are so low in the United States that any risk of side-effects would overwhelm potential benefits, while in another country the benefits would greatly outweigh the risks.

The reverse side of the coin is the stringent testing regulations in the United States that have led some companies to test drugs for safety in other countries, in effect using their people as guinea pigs for the U.S. market.

Neither situation is tenable. Some means must be found of internationalizing drug evaluation, as it would not be appropriate to expect the Food and Drug Administration, for example, to institute its own criteria for evaluating drugs for foreign applications that would be different from criteria for U.S. application.

The general problem of encouraging greater commitment of U.S. scientific and technological attention, whether in government, industry, or university, to population- and health-related issues should be an important issue in the near future.

Transborder Issues

A series of transborder and global science and technology issues will be important elements of the international security picture in the next five years, though the separation of these from "economic" issues is rather arbitrary. The importance of environmental, ocean, resource, and energy issues will be largely in their economic and ultimately political effects, as is the case for those just discussed.

Resources and Energy

In the short term, the major issues related to security, resources, and energy have to do with supply interruption engendered by political action, and secondarily, the economic terms on which resources are made available to industrialized societies.[7]

A major political phenomenon of recent years is the assertion of the right of absolute sovereignty over natural resources. It is a natural concomitant of a nation state system, but has not before been sanctified as it is today. The growing dependence of industrialized societies on resources under the control of others, particularly developing countries, creates major dependency relations, many fraught with great uncertainty and danger for international stability.

The dangers come not only from the threat of supply disruption, or of sudden dramatic increases in the cost of the resources, but also from the second-order strains created among industrial countries whose disparate dependence on resources from abroad may lead to major and disruptive foreign policy differences. The much greater dependence of Japan and Continental Europe than the U.S. on Middle East oil, or the differential dependence on South African resources could lead to serious conflicts of interest over Middle East, or African, or Soviet policy.

Though the world is painfully conscious of the political restrictions, oil-rich developing countries sometimes place on resources, these countries are not the only ones to do so. Canada and Australia have both restricted export of uranium ore on nonproliferation grounds, and the United States severely

restricts export of enriched uranium on the basis of specific political considerations. Moreover, the United States embargoed soybean export for a short time in 1974 to stabilize domestic prices, and has embargoed the sale of grain and high technology to the Soviet Union in political protest to the Afghanistan invasion. A cabinet member of the Reagan administration in his first public statement spoke of using U.S food exports as a foreign policy "weapon" (later changed to "tool").[8]

These consequences of resource dependency and of unequal distribution are all political and economic in character. The issues arising in the near future will be concerned with distribution and availability, but not with depletion. In the long-term, the adequacy of resources will be determined by economic, not geological, phenomena,[9] and there is no reason to doubt that the industrial system could cope with long-term changes in the price and availability of materials and energy.

Short-term vulnerabilities must be met with measures that are largely outside the realm of science and technology directly: stockpiling, political negotiations, pooling arrangements in time of crisis, and so on. Conceivably, new R&D for resource exploration, or exploitation of deep seabed minerals, could change U.S. dependency on foreign resources, but this is unlikely in a five-year time horizon.

In the longer term, science and technology have major roles to play in the development of substitutes; in expanding knowledge of resource exploration, recovery, processing, and use; and more generally in contributing to innovation and productivity

in the nation's industrial plant (both to improve efficiency of use of materials and fuels, and to generate the export earnings necessary to pay for imports). The long lead times inherent in reaching these objectives mandate early commitment of R&D to these tasks.

The changing price and availability of materials and energy may change critically the comparative advantage of some American industries. The adjustments necessary to allow the orderly decline of those industries will themselves set up serious political and economic strains.

The need for R&D in the resource area is coupled with an inadequate understanding, both in the United States and globally,[10] of certain areas: geological deposition of minerals; the exploration process; and the impact of the changing industrial structure in minerals on the flow of mineral supplies.[11]

These tasks will require reinvigoration of concerned government agencies, especially the Bureau of Mines and Geological Survey, and may also require a new institutional means to develop an objective, credible data base (technical and economic) for resource-related decisions. In addition, coordination of policymaking must be improved to avoid conflicting policies carried out by individual agencies which are not aware of the activities of other agencies.

Environment and Global Commons

Closely related to resource and energy issues are those involving transborder environmental questions, and more general global issues of the environment: atmosphere, oceans, and outer space.

Our national activities have effects beyond borders and, in some cases, on a global scale. Transborder pollution has already become an important issue in many areas of the world, with some progress in the last decade, particularly in melding environmental policies, in reaching international agreements, or dealing with the traditional problem of the global commons. The issues are likely to become more severe, however, and often will take on the cast of zero-sum games.

The worldwide recession and the rise in energy prices raise the indirect costs of coping with environmental degradation, and make it more difficult politically to restrict activities whose harmful effects fall across the border. The standard problem of reflecting full costs in a production process is exacerbated when the externalities are felt outside a national economy. Issues associated with acid rain, water pollution, forest degradation, and others will become more contentious internationally in the next decade.

The depressed economic situation will also lead to greater resistance to domestic environmental regulation if that is assumed to affect adversely the international competitive position of a nation's goods. As noted earlier, it is not always appropriate to call for common environmental standards in all nations, and even when it is, it is not clear they can be successfully negotiated. Thus, the costs and bases for domestic environmental regulations are likely to be difficult issues because of their international implications.

Some long-term issues may become clearer in the next few years as research increases understanding of important global systems. In particular, CO_2 buildup and NO_X in the atmosphere may be better understood along with their global economic implications and potential ways of controlling them. Unprecedented disputes could arise over such issues, with important changes in the status of individual nations, as some benefit--say through improved agricultural conditions--and others are hurt--for example, if the costs of environmental controls fall more heavily on them. It is unlikely that these issues will come to a head in a few years, but the debate could be far advanced.

Exploitation of global commons, especially the oceans and outer space, is likely to proceed during the coming decade. The Law of the Seas negotiation, which proposed a new international institution responsible for overseeing the mining of the resources of the seabed, appeared to be almost completed, though the position of the United States is now in doubt. Many aspects of that institution would be novel, in particular the assigning of some of the benefits of mining to developing countries. The detailed questions of implementation would be left to the interim arrangements following the completion of the treaty and ultimately to the new authority. Some serious disputes are inevitable, with regard to the mining itself, the operation of the authority, and the unprecedented provisions for transfer of technology in the draft treaty.[12] Certainly, if there is no treaty, a variety of ocean issues--navigation, fishing, oil exploration, research,

as well as mining, may become the source of serious dispute.

In space applications controversy may arise over geostationary orbit allocations, but more likely will be controversy over the international efforts to manage and control space technology systems such as Landsat. This earth resource surveillance system has been until now an experimental American monopoly, but as it moves to operational status, many questions will become more pressing. Who owns the information in a world in which sovereignty of resources has been zealously asserted? Should the output be available to anyone who asks for it? What rights do nations have for unilateral surveillance of another country's resources? What are the security implications of the high resolution that will now be built into the system? Who should manage the system, and determine its technical characteristics? What are the economic and political implications of greater knowledge of resource endowments, of more accurate annual predictions of agricultural production domestically and internationally? Undoubtedly, these issues will soon become more prominent on the international political agenda.

Interaction of National Technological Systems

Many national systems--aircraft, communications, weather observation, finance, banking, postal--are basically information systems which require interaction with counterparts in other nations. The explosive development of information technology systems has begun to cause serious strains, and is likely to be an even larger cause of strain in the coming years.

Traditional differences between fields break down (for

example, communications versus data flows, postal versus electronic mail, information versus banking), and the economic calculus of benefits and costs changes perceptibly. Controversies arise over privacy of information, access to information within nations, the role of central computer banks, the transnational nature of economies of scale, and related issues. In the face of U.S. dominance of technology, other Western countries are wary of allowing unfettered development that undermines their competitive position; the Soviet Union and its allies worry because control of information is vital to its political system; the developing countries worry that the loss of control over information will threaten their independence.

The dynamic nature of the growth of this technology, and its base in the private sector in the United States, makes this a particularly difficult issue in which to anticipate implications, much less develop clear international policies and conduct negotiations. It is certain to appear significantly on the international agenda in the 1980s.

National Security

Science and technology have been central factors in the evolution of weapons and military systems in this century. They have altered drastically not only the nature and scale of hostilities, but the very meaning of strategic war as an option to achieve national objectives. The strength and productivity of a nation's advanced technological community have become major elements in any geopolitical calculation. Massive support for security-related R&D has, in turn, changed science, technology, and the university.

The application of science to national security shows no sign of abatement. In fact, a new round of major commitments to large-scale strategic systems is in the offing, turning the ratchet one more notch in a search for security that seems steadily receding into the future.

In the context of this paper, only a few general issues in this area can be briefly touched upon; clearly it is an enormous subject that is itself the subject of a large literature.[13]

One controversy concerns whether the constant search for more technologically advanced weapons systems in fact contributes to the nation's (or the world's) security. Whatever the views of the causes of the arms race between the Soviet Union and the United States, or the current state of relations between the super powers, new weapons systems often make the arms balance more precarious, more vulnerable to preemptive action rather than contributing to stability. This may continue, and perhaps worsen, as capabilities are pursued that threaten concealment of weapons systems, give greater premium to surprise, and make it harder to know whether missiles contain one or many independent warheads. Developments in conventional weapons, moving rapidly, may also change the nature of "local" war, leading to greater instability among developing countries as one or another believes it has the capability for rapid strike and victory.

No simple solutions exist. It is easy in rhetoric to call, for example, for more attention to military and related systems that contribute to greater stability and less uncertainty

and threat: adequate conventional ground forces; improved command, control, and communications in a hair-trigger weapons environment; greater commitment to developing arms control agreements, more attention to "hot-line" communication capability; less emphasis on strategic weapons that pose a first-strike threat in favor of those with clear survivability; and others. Each has its ambiguities, however, and there is no agreement on what is required for security, or even for greater stability.

The fact of the matter is that science and technology are most likely to continue to alter military systems. The effects of these changes cannot always be anticipated. One of the objectives of arms control is to bring the situation under greater control; but even if one were optimistic about SALT II, agreements of this sort deal only with existing or planned technology. They do not deal with the possibility of new weapons systems or unanticipated capabilities created by further research.

Our knowledge of "threat systems," the involvement of the scientific and technological community in strategic debates, the public perceptions of military and strategic affairs are all inadequate. The once substantial public role of scientists and engineers in strategic policy deliberations, for example, has been greatly reduced, and the public inputs to arms control and weapons debates have suffered. This is illustrated by the spectacle of the stagnation of the SALT II agreement in the U.S. Senate over essentially extraneous issues.

Some argue that the whole framework of the strategic debate has been rendered inadequate.[14] They call for emergence

of a new paradigm, a new discipline of conflict studies, and assign the scientific community special responsibility in bringing this about. The argument of the inadequate framework of debate is persuasive, although the path for achieving a new paradigm is hard to discern in practical terms.

The scientific and engineering communities have special but more traditional responsibilities within the existing framework particularly because of the esoteric technical aspects of the issues. The relative neglect of these responsibilities in recent years must be reversed. New programs such as arms control fellowships in the National Academy of Sciences and a concomitant program of studies are to be applauded, and similar initiatives in other scientific organizations are to be encouraged. In all these efforts, however, it is important to recognize that the issues themselves are never purely technical. Real participation involves a commitment to master the political, economic, and related aspects, which will eventually determine the outcome.

The quality of debate needs to be improved in the public sector as well as in the scientific communities. Better information, and greater resources, public and private, committed to the analytical area are badly needed. The momentum of a defense budget close to $200 billion requires open debate of the purposes, details, and implications of that budget. In turn, more funding is required to produce information and analysis to make public debate possible. The Congressional Commission to study the establishment of a National Academy of Peace and Conflict Resolution presumably has the same goal.[15]

One aspect of the role of science and technology in weapons

development is peculiarly troubling. Much of the initial development of ideas for new technology--ideas that may later be revolutionary in military terms--occurs in the laboratory at a very early stage, without military applications in mind, and often without military funding. This dynamic of the research process leads to instability, both in weapons development and in the long-term viability of arms control agreements.

Little can be done about this now, although ultimately ways of bringing R&D within the scope of arms control agreements must be considered. One aspect, somewhat farther along the R&D chain, does deserve institutional attention, however.

Proposals for new weapons development are, in their early stages, often made at low levels in the bureaucracy, with relatively little R&D funding required. At these levels, choices tend to be made on strictly technical grounds, with little consideration of their ultimate effect on relevant arms control objectives. The situation is repeated at higher levels as well, so that it is not uncommon for the government to be faced with mature weapons designs creating major new foreign policy problems that might have been avoided or eased if some alternative technical options had been chosen instead.

It is very difficult to deal with this issue in the bureaucracy, since the organization of government serves to create bureaucracies with compartmentalized objectives and few or negative incentives to introduce considerations for which they are not responsible. An attempt to introduce nonproliferation considerations into planning for nuclear reactor R&D, through participation of a State Department representative in the setting of objectives

in the Department of Energy, has apparently had some limited success, and deserves evaluation.

In its most general formulation, this task can be stated as the need to include, in defense R&D planning and management, the evaluation of broader effects of the intended results of research. The objective is an important one and ought to be the focus of further experimentation.

Other aspects of science, technology, and security are also troubling; some because of the effects on nonmilitary areas. The sharp increase in defense spending proposed by the administration will have important effects on the civilian sector, not only in the obvious impact on the budget. Engineers, already in short supply, will be siphoned off in larger numbers to defense industry, exacerbating the shortage in consumer goods industries, and likely worsening the nation's competitive position. It will also tend to stimulate even more the momentum of scientific and technological change applied to military hardware, since the level of R&D, and the ideas for new applications, will be fueled by the larger cadre of scientists and engineers.

The increase in defense spending may also affect the nation's universities, as they become concerned about the almost direct military application of basic research. Signs of that are already evident in cryptological applications of theoretical mathematics, which have led to a kind of voluntary censorship.[16]

Lastly, it must be noted that the Soviet Union has demonstrated its competence to engage the United States in a high-technology arms race. Its technology may not be as refined, but

its greater commitment of resources to defense expenditures is presumed by many to be likely to give the Soviets an edge of some sort over the United States in the latter part of this decade.

Whether this prediction is accurate or not, its anticipation has already fueled a massive new U.S. defense increase. One can only observe that a continued search for strategic superiority over a determined opponent is the search for a chimera that can only distract from the real quest for security.

East/West Transfer of Technology

Another issue which is likely to be of considerable moment in the next five years is the concern over the transfer of technology to the Eastern bloc that could enhange the military capability of the Soviet Union and its allies.[17]

This is an issue with a history stemming from the advent of the cold war, and with recent attention as a result of the embargo on high technology imposed in response to the Soviet invasion of Afghanistan. It is bedeviled by controversy between the United States and its NATO allies over the costs and benefits of the policy, by uncertainty over the military relevance of some "dual use" technologies, by sharp differences of view within the American government, by differences of philosophy over the value of denial in terms of its actual effects, and by differences with industry over enforcement policy.

There is little question about the importance of embargoing specific advanced military technology. Moving from technology

with direct military applications, however, quickly leads to gray areas, with uncertainty over military relevance, over availability from uncontrolled sources, or even of whether denial is in Western interests. Should the West, for example, encourage the Soviet Union to improve its ability to explore and recover its vast oil deposits?

Many more specifically technological questions arise, however: How is technology actually transferred and adopted? What is the real potential of diverting a piece of hardware from a peaceful to a military application? And what actual difference would it make? Is reverse engineering of a piece of equipment possible? At what cost? On what time scale? How long will it take for a particular technology to be developed?

All too often, the debate over technology export controls is characterized not only by political naiveté, as though it is simple to control the movement of technological information, but also by lack of understanding of technological realities. The importance of the issue, and its potential for damaging the West politically and economically, will require effective integration of the scientific and technological aspects in the policy debates.

INSTITUTIONS AND POLICY PROCESS

Several themes run through the issue areas discussed above that bear directly on institutional and process problems of the United States in relation to the international consequences and use of science and technology. The most common theme is that the international dimension of policy is inadequately reflected in government policy making, and that the formal institutions of

government militate against more effective recognition of international issues. Though this observation may be valid for many of the responsibilites of government, it is particularly, and surprisingly, intensive in science and technology matters.

Other themes that emerge relate to the need for more effective integration of scientific and technological aspects in many policy areas, including more mechanisms for effective analysis and anticipation of future implications of science and technology; and the need for new national and international institutions. Some comments on each are in order.

International Dimension in Policy

The history, geography, and rich resources of the United States all led naturally to a system dominated in institutional form and political organization by domestic considerations. Adaptation of the system to its new global role, and to its new dependency on others, has been slow and halting, notwithstanding the enormous sums of public money allocated for this adaptation. At the detailed level of decision making--budget decisions, negotiations with the Congress or with the Office of Management and Budget, setting technical objectives--the traditional pressures dominate.

One of the most significant ways in which this situation affects the involvement of science and technology with international matters has to do with developing countries. The national resources devoted to R&D on development problems is pitifully small, yet the U.S. government lacks an effective instrument for cooperating with that large number of increasingly important nations neither poor enough to be eligible for direct assistance, nor

sufficiently advanced scientifically to be competitive with domestic research. A new institution--the Institute for Scientific and Technological Cooperation--was proposed in 1978, authorized in 1979, and ultimately left unfunded by the Congress. Something to serve the same functions, whatever the form, is required.

But the problem is not simply a new institution. The need is to tap more effectively the scientific and technological resources of the government housed in the functional departments and agencies, and to enlist their R&D clients in the nation at large. A single, new agency cannot accomplish that task alone, though it might provide the leadership for much larger changes. Rather, a means must be found for allowing departments and agencies to allocate resources directly for cooperation with other nations and to carry out R&D on problems that are not "American" problems, when such activities are in the national interest. At present, legal authorization or executive budget policy effectively prevents such allocation except under difficult arrangements, sometimes sub-rosa, and almost always ad hoc.

The problem is not primarily legal, as Congress can change the relevant laws, and has done so for some agencies. The problem is largely one of efficient budgetary management. The Office of Management and Budget argues, with considerable justification, that it is difficult to maintain discipline in a budget if fuzzy arguments of "foreign policy interest" have to be given weight in ranking proposed programs, or if budgets to serve development assistance objectives crop up in a score of federal agencies.

Yet, the answer must surely be more creative than simply to rule out such programs. One possibility, for example, would be to create a development budget that crosses departmental lines and forces a degree of budgetary discipline that cuts across agencies and agency budgets.

Departments and agencies would be allowed, with congressional concurrence, to budget some of their own funds for R&D, but those projects would have to be compared not only with proposals within the department, but also with proposals of other agencies. Similarly, for those proposed programs that have mixed foreign policy (other than development) and scientific objectives, a cross-agency evaluation of foreign policy could exert the necessary budget discipline. Although difficult to administer and subject to its own bureaucratic pitfalls (the temptation for playing budgetary games and the difficulty of ranking according to foreign policy criteria), this or something like it requires experimentation.

In another area, ways must be found domestically or internationally to deal with situations in which apparently domestic regulations directly impinge on other countries or significantly affect a country's international trade position. For some situations, the answer may have to be regulatory machinery within existing or new international organizations. With regard to trade regulation, more impetus will have to be given to the move to analyze the broader economic effects of proposed regulations before the regulations are approved.

International cooperation with advanced countries also deserves more emphasis in the changing climate of cost and

relative competence in science and tehcnology. But this change in emphasis will not happen naturally in the American system, again because of the built-in focus on domestic problems and pressures. This problem of focus is exacerbated by the restrictions imposed by the Office of Management and Budget on foreign travel, and the suspicion in Congress that foreign travel by "domestic" agency personnel simply implies junkets.

The blurring of domestic and international affairs is real. Government at all levels must become aware of and adapt to their ineradicable intertwining. It is not a matter of simply creating an international office in an agency. All have such offices, which more often than not are weak and removed from the core of the agency's interests.

Rather, it is a matter of infusing the whole government with policies, institutions, and rhetoric to make possible a gradual change of attitude that conforms to today's and tomorrow's reality. The Congress must also be no small part of that change, and ought to be forcing the Executive Branch to recognize what is needed.

Integration of Science and Technology in Policy

The problems of scientific and technological planning are particularly severe, and pose major problems of governance in a technological age. There are many aspects: how to represent scientific and technological information and uncertainty adequately in the policy process; how to plan for effects of science and technology not only uncertain, but possibly seen too late to alter once the effects are in evidence; how to estimate risks

and benefits which fall unequally within a society or internationally, with interested people and nations often not represented in the policy process; how to deal with issues in which the relevant information is under the monopoly of one segment of society, or of one government; and a host of other issues.

No single solution is adequate. Like all problems of governance, these problems are not solvable--all that is possible is amelioration or improvement. However, these are difficulties that directly involve understanding of science and technology, and thus require not only greater participation of scientists and engineers, but also more means for making credible analyses available to the public, and ways of drawing the public into the debates. Participation alone, of course, is not enough. Scientists and engineers do not have, on the basis of their professional training, superior credentials for making policy decisions. They are no more free of bias than are other segments of society. Participation by the scientific and technological communities and technology and the broader aspects of policy, and a commitment of time that makes such understanding possible. A technocratic approach to the making of policy is not an improvement over the present situation.

One of the effects of science and technology on both national and international affairs is to make the future much more relevant to the present than in earlier periods of human history. To an unprecedented degree, today's policy must be made in the light of future developments, particularly in science and technology themselves, or in the side effects of increasingly technological

societies. The importance of more efforts at credible, objective anticipation of the future is obvious.

International Organizations and Structure

The need for new international instruments, or for modifying existing ones was mentioned briefly in a few subjects--drug regulation, ocean mining, space applications--but was not emphasized. The questions associated with international political machinery, particularly machinery designed to deal with requirements growing out of science and technology, are many and complex.

The products of science and technology increasingly create new issues and force traditional domestic issues into the international environment. Unfortunately, existing international organizations charged with dealing with those issues are often inadequate. Most global organizations are now politicized along North/South lines, and more efficient regional or smaller alternatives do not represent all interested parties. As representation in organizations broadens, technical efficiency tends to decrease.[18]

This situation is unlikely to reach crisis form within a few years, but in it are the seeds of major confrontation. These seeds could mature quickly, if current budgetary reductions drastically reduce U.S. presence in international organizations. The adequacy of international political machinery is likely to be a fundamental question of international security. So many of the functions the world (and the United States) depends on--communications, transport, nuclear materials control, resource information, health, agriculture, ocean minerals, to say nothing of international financing and lending--will fall increasingly

under the auspices of international organizations. Many of the issues involve developing countries, but others involve conflicts of interest among Western industrial countries, or East/West controversies.

It is not a matter of indifference whether the organizations exist or work. The functions they perform must be carried out in some way by an organization, or by a limited number of countries, or by a country acting on its own. The ultimate character of the international system and the place of the United States in it may in large measure be determined by whether these international tasks are carred out through organizations with broad participation, but so designed as to allow reasonable efficiency, or by default are managed by efficient but limited groups of wealthy countries.

CONCLUSION

It may not be too far wrong to characterize this last issue, and all that have been touched on it this paper, as fundamental choices in the international system between efficiency and equity, and between hegemony and consensus. Those are sufficient for any policy agenda.

NOTES

1. Lester Thurow, "Let's Abolish Antitrust Laws," New York Times (18 October 1980).

2. See the paper by Charles Weiss on pp. 257-314 of this volume.

3. "Development Issues," 1981 Annual Report of the Chairman of the Development Coordination Committee, U.S. IDCA.

4. The paper by Sylvan Wittwer in this volume (pp. 315-353) discusses this issue.

5. Ibid., p. 317.

6. The paper by Michael Teitelbaum, pp. 355-385 of this volume, is devoted to the population problem in substantial detail.

7. The paper by William Vogely on pp. 387-420 of this volume deals with resource issues in detail.

8. New York Times (27 December 1980).

9. See p. 406 of the paper by Vogely in this volume.

10. Ibid., p. 417.

11. Ibid.

12. Law of the Sea draft treaty, United States Delegation Report, "Resumed Ninth Session of the Third United Nations Conference on the Law of the Sea" (Geneva: 28 July-29 August 1980).

13. The paper by Kenneth Boulding on pp. 421-452 is devoted to one aspect of the subject.

14. Ibid.

15. Ibid., p. 435.

16. Science, vol. 211 (20 February 1981), p. 797.

17. Office of Technology Assessment, Technology and East-West Trade (Washington, D.C.: U.S. Government Printing Office, 1979).

18. See E.B. Skolnikoff, The International Imperatives of Technology, Research Series No. 16 (Berkeley: University of California, Institute of International Studies, 1972), for a more complete discussion of technology and international organizations.