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ABSTRACT

In this third annual report from the National Research Council (NRC), articles are presented on national issues by officers of the assemblies of behavioral and social sciences, engineering, life sciences, mathematical and physical sciences, human resources, international relations, natural resources, sociotechnical systems, and medicine. Topics addressed include: what determines whether social programs succeed or fail?, industrial research and development, doctoral unemployment and underemployment, the administration of public facilities, environmental problems, management of large institutions, and the role of the NRC in solving these problems. In addition, reports are given by each of the assemblies on study projects in progress. (Author/BB)

The National Research Council in 1978

Current Issues and Studies

NATIONAL ACADEMY OF SCIENCES
NATIONAL ACADEMY OF ENGINEERING
INSTITUTE OF MEDICINE

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National Academy of Sciences
WASHINGTON, D.C. 1978

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Preface

What determines whether social programs succeed or fail? What of the state of industrial research and development? How can we mitigate the personal anguish and societal losses due to doctoral unemployment and underemployment? What are the external and internal forces that guide public facilities, such as electrical utilities or public school systems? Can we find ways to deal more synoptically with environmental problems? How can we improve the management of large institutions, be they organizations such as the Veterans Administration or programs such as the federal government's efforts to knit together the disparate elements of climate research? What is the role of the National Research Council in answering these puzzles? Are its reports listened to? What effects do its reports have?

These are some of the issues treated in this third annual report from the National Research Council.

Contents

I

NATIONAL RESEARCH COUNCIL

On Reports

PHILIP HANDLER

American society and the government of the United States have voracious appetites for "reports." Reports are engendered by every agency of the executive branch of government, by the congressional hearing process, by the Congressional Research Service of the Library of Congress, the General Accounting Office, the Office of Technology Assessment, and by innumerable entities within the private sector of American society. So numerous are reports and so tortuous is the course of policy formation that rarely is it possible to establish a direct cause and effect relationship between a given report and subsequent public policy; those responsible for policy formation must integrate numerous inputs and relevant experiences as they arrive at decisions. Yet, some reports do elicit an early, positive response, while others seem to go almost ignored.

It is sometimes difficult to ascertain which aspect of a given report accounts for the warmth of its reception. Clarity of language, sharpness of analysis, and the logical force of conclusions and recommendations are 3

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certainly important, sometimes critical. The reputations of the authors can give a report additional force. And we would like to believe that the reputation of the National Research Council for objectivity, absence of bias, analytical depth, and adherence to established institutional procedures provides a special cachet. A report addressed to a technical subject, no matter how well drawn, can be implemented only if the receiving agency has a staff that is able to appreciate the analysis offered and is prepared to act accordingly. But perhaps the cardinal attribute of the "successful" report is felicitous timing. Even a relatively poorly prepared report that is placed in the public domain at the right historic moment, when, in some sense, the stage has already been set, can occasionally find immediate acceptance and initiate events of historic importance. Conversely, an excellent report released into an unprepared environment, when the times are not propitious, is unlikely to alter the course of human affairs. Regardless of how compelling its case, if too far in advance of its time, it may seem to have no impact. Only later will the report be recognized to have been part of the stage-setting process.

The National Research Council, which issues about one report per working day, is a principal contributor to the stream of reports directed at the myriad aspects of public policy and program formulation. An NRC report may take the form of the proceedings of a symposium, a letter to a sponsoring agency, or a formal report by the project committee, often accompanied by supporting documents submitted to that committee by its resource groups. Each report summarizes the relevant data that have been analyzed by the committee and presents the committee's findings and conclusions.

Much of the work of the NRC consists of the preparation of authoritative treatises on technical subjects, documents that eschew recommendations for public policy or programs. They include, for example, the periodic summaries of recommended daily nutritional allowances, a series on the nutritional requirements of domestic animals, critical documentation of the medical and biological effects of environmental pollutants, reports of the Committee on Line Spectra, an exhaustive treatment of the inflammability of polymeric materials, and a veritable library concerned with all aspects of highway construction. All become part of the technical literature and find appropriate use. Such reports, lacking policy recommendations and confined to summaries and analyses of scientific data may, nevertheless, inform current debate and illuminate controversial issues. But tracing their contribution to national policy formation is a difficult and complex task.

However, other reports of the NRC do contain explicit recommendations affecting public policies and programs. For these, it is readily feasible to ascertain whether specific recommendations have been accepted and implemented.

Inasmuch as the principal contribution to the work of the NRC is the voluntary effort of the thousands of public spirited individuals who serve on NRC committees, it seems appropriate occasionally to appraise the extent to which recommendations embodied in NRC reports have found acceptance. In preparation for this Annual Report, such an appraisal was attempted with respect to those recommendations deemed by the executive directors of the commissions and assemblies of the NRC and the executive officer of the Institute of Medicine to have been among the most important embodied in reports issued during 1976 and early 1977. Not unexpectedly, perhaps, the appraisal has yielded all possible outcomes. Some recommendations found immediate acceptance and are now visible in programs conducted by federal agencies. A few reports and recommendations have been misinterpreted or misused. Others are still in flux or contention. It is hoped that the latter analyses and recommendations are finding their way into the thinking processes of those encharged with the formation of public policy. As the summary below will indicate, remarkably few NRC reports have simply been ignored.

Reports from the NRC fall within five broad albeit overlapping categories: the strength and progress of the American scientific endeavor; appraisal of new technologies; the scientific basis for the regulatory functions of government; organization and management of technically oriented government agencies; and broad aspects of general public policy. Quite frequently, studies in the first category are initiated within the National Research Council. Studies undertaken in the next three categories are usually responsive to requests from government, while studies in the final category have arisen by both modes. Recommendations addressed to public policy, to the conduct of specific programs, or to the need for specific decisions may be found in reports in all five categories. However, the frequency of "success," here measured only in terms of explicit acceptance of formally stated recommendations, is not the same in all categories. The purpose of what follows is to gain some sense of the "success" rate and some appreciation of the factors that appear to have made for acceptance or rejection of recommendations in NRC reports. This appraisal, therefore, is not only a report to our readers, committees, and staff; it is also a self-examination. Although the summaries presented may seem to be merely the raw data for calculating our "batting average," they should also enable us better to understand what the NRC mechanism does well or badly and the degree to which NRC provides national leadership. They may also enable one to gather a sense of the extent to which the NRC is sensitive and has given adequate consideration to the specific problems and internal constraints of the individual federal agencies.

SOME RECENT RECOMMENDATIONS THAT HAVE FOUND ACCEPTANCE

Concerning the Strength of Science

A panel of the Solid State Sciences Committee, noting particularly promising applications of synchrotron radiation to X-ray diffraction, photoelectron spectroscopy, and photo absorption studies in the wavelength range from ultraviolet to X-rays, urged commitment of new dedicated facilities for the production of synchrotron radiation. In direct response, government funding was provided to substantially upgrade the synchrotron facilities at Stanford University and the University of Wisconsin, and funds were allocated by the Department of Energy for the construction of a new Synchrotron Radiation Center at the Brookhaven National Laboratory.

Successive reports by the Space Science Board gave high priority to the construction of a large space telescope, a 2.4-meter optical instrument to be erected by the use of the Space Shuttle in 1983–84. Initial funding for this instrument was provided by Congress in the FY 1978 budget. Thereafter, NASA requested the NRC, through the Space Science Board, to recommend appropriate institutional arrangements to assure optimum scientific use of this telescope. An *ad hoc* panel of that board recommended an institute to be operated by a consortium of universities and nonprofit institutions and offered details of the operation of such an arrangement. Presumably, implementation or rejection of this proposal will be made known well before the telescope is operational.

The Planning Committee for a National Resource for Computation in Chemistry identified major computational problems in such fields as chemical kinetics, quantum chemistry, and statistical mechanics. An institutional arrangement was proposed whereby a significant fraction of the time of an already available, large computer might be dedicated to such efforts, along with expert staff to assist chemists with their computational needs. In their FY 1978 budgets, the National Science Foundation and the Department of Energy provided for joint support of the National Resource for Computation in Chemistry. It has now been established at the Lawrence Berkeley Laboratory of the University of California.

A joint committee of the Geophysics Research Board and of the Space Science Board assessed past uses and the future potential of balloons for astronomical and geophysical observations. They concluded that, depending on the field, the balloon complements other alternatives, has distinct advantages, or is a unique tool. The report recommended augmentation of the current balloon program and efforts to develop techniques for longer flights. The Advisory Committee of Scientific Users of the Ballooning Facility (at Palestine, Texas) has accepted and is now seeking to implement these recommendations, provided NSF and perhaps NASA augment the budget of this facility.

A panel of the Geophysics Research Board forcefully drew attention to the possible climatic consequences of a build-up of carbon dioxide in the atmosphere, consequent upon continuing combustion of fossil fuels, particularly coal. This report attracted instant worldwide attention; plans are now developing for national and international arrangements to monitor the atmosphere and correlate changes in CO_2 concentration with diverse other aspects of the earth's surface.

A coordinating committee worked with the NASA staff to formulate the specific program elements of the NASA Program of Climate Studies. The committee's report urged the utility of categorizing climatic change by those events that occur within weeks of some stimulus, those that proceed on a time scale best measured in years, and those that occur over many decades; each category involves different physical processes and must be examined by different observational strategies. This formulation was adopted by the NASA staff and has been made explicit in the planning of the NASA climate program.

The limitations of current methodology for earthquake prediction were summarized in a report by the Committee on Seismology, which proposed ways to facilitate progress toward the ultimate goal of routine announcements of reliable predictions. This report, which was summarized before the House Committee on Science and Technology, helped, in significant measure, to set the stage for the "Earthquake Hazards Reduction Act of 1977," which authorized up to $56 million per year for the support of relevant research by the U.S. Geological Survey and the NSF.

The report on world food and nutrition offered a set of recommendations concerning the substance and conduct of research on the most important factors now constraining increased production of world crops. These included the inauguration at the U.S. Department of Agriculture of a competitive research grants program in support of fundamental biological research related to agriculture. These recommendations were warmly accepted by the USDA; the Food and Agriculture Act of 1977 strengthened the mandate of the department for the conduct of research, increased the level of funding for that program, established a competitive research grants program open to all applicants, and established grants and fellowships for education in agricultural science. In addition, that report offered an integrated set of recommendations for significant new nutritional research programs that focus on problems important to the less-developed nations as well as to the United States. The Food and Agriculture Act of 1977 also mandated a much enlarged nutritional research program by the USDA and the conduct of international collaborative research and development directed at the problems of the less-developed nations. The USDA has discussed this report with state agricultural research leaders, who have accepted the research priorities stated in the report, and has created a new organization to manage the competitive research grants program. The Agency for International Development is using the report as the basis for its various activities in support of international nutritional endeavors and the White House has been using the report for planning new initiatives with regard to the nutrition of the American people.

The Ocean Policy Committee presented to the American Ambassador to the U.N. Law of the Sea negotiations a set of recommendations with respect to treaty provisions concerning scientific research in the oceans, which formed the American posture at the Law of the Sea negotiations. Regrettably, the current text of the tentative Law of the Sea Treaty remains far from acceptable to most of the relevant American scientific community. But the situation would have been decidedly worse if American oceanographers had not had the opportunity to make their views known through the NRC channel.

At the request of the President's Science Advisor, an *ad hoc* committee completed, within sixty days, a thorough review of progress under the US–USSR Agreement on Cooperation in Science and Technology. Their report recommended procedures for initiating, evaluating, and terminating joint research projects; approaches to normalizing financial support for projects under the agreement; strengthening of an operating staff for management of the program; and the need for an evaluation of overall US–USSR technical cooperation under all current agreements. These recommendations were essentially accepted *in toto* by the U.S. members of the US–USSR Joint Commission on Cooperation in Science and Technology and guided them in their negotiations with their Soviet counterparts shortly thereafter.

Concerning Technology

An *ad hoc* committee reviewed the testing and evaluation program proposed by the Army Corps of Engineers for a pilot estuary water-treatment plant. The committee concluded that the corps had planned more experiments on various treatment-component configurations than could adequately be conducted during the allotted time and that the test series would therefore not prove successful. It indicated also that insufficient thought had been given to the composition of the raw water to be treated in the experimental plant and that plans were inadequate for testing of the finished product. In response, the corps is revising its testing program and will resubmit new plans to the committee for review.

A separate committee, at the request of the Corps of Engineers, reviewed a study of the water supply to the metropolitan Washington area. The committee concluded that the plan took insufficient account of measures for conservation of water and reduction of demand, of environmental impacts, of water quality characteristics, and of public health implications of the various alternatives that had been considered; moreover, the report had not given adequate consideration to institutions for managing regional water supply. The corps has accepted the committee's conclusions and assured the committee that the deficiencies will be remedied.

To stimulate the development of electric and hybrid motor vehicles, the Congress directed the Energy Research and Development Administration (now absorbed into the Department of Energy) to purchase several thousand "state of the art" vehicles in 1978 and advanced vehicles in 1981. Critical to the performance of such vehicles will be the availability of improved energy storage systems. In a study commissioned by ERDA, a panel of the Committee on Advanced Energy Storage Systems reported that there is no likelihood that this schedule can be met and suggested that readjusting the timing by one or preferably two years would significantly enhance the prospect of meeting the objectives of the Electric and Hybrid Vehicle Research, Development and Demonstration Act of 1976 (Public Law 94-413). The report of a concurrent study at Purdue University, of the entire spectrum of opportunities and risks involved in implementing the program mandated by that act, incorporated in its entirety the set of conclusions of the NRC study. The House of Representatives received these reports at hearings on the act in the fall of 1977; Congress subsequently revised the act and authorized a schedule of demonstrations through 1987, in accord with the recommendation of the NRC committee.

At the request of AID, a panel of the Food and Nutrition Board recommended a simplified methodology for use in developing countries for the determination of the food intake of infants up to thirty months of age. This survey protocol has been tested in Guatemala and Pakistan, and further tests are now planned in Cameroon, Sierra Leone, Haiti, and, perhaps, in Egypt and Mexico.

At the request of the Bureau of Radiological Health of the Food and Drug Administration, an *ad hoc* committee reviewed the use of ionizing radiation for the treatment of diseases other than malignant cancer. The report set out guidelines for employing ionizing radiation with respect to the necessity for such use, the character of the radiation, the total dose, the time over which radiation is administered, the organs underlying the radiated area, and shielding precautions. The Bureau of Radiological Health published this report and distributed it widely among relevant medical specialists, particularly dermatologists and radiologists. The bureau sent copies to the Radiological Health Program Officers in all fifty states and is currently considering using the report as the basis for establishing federal guidelines in these regards.

Two reports have been prepared by NRC committees concerning the potential of the jojoba bean indigenous to the American Southwest. Cultivation of this bean would provide employment and income for the Indians of this region and, by virtue of the remarkable similarity of the oil of this bean to sperm whale oil, will enable it to substitute for whale oil for use as a high-pressure lubricant. This proposal is being adopted and increasingly extensive plantings are now under cultivation. (The article by Roger Revelle has more details on jojoba and other potentially useful plants.)

At the request of the Agency for International Development, a panel of the Committee on International Nutrition Programs of the Food and Nutrition Board studied the occurrence of vitamin A deficiency in developing nations. The panel recommended that, in regions where xerophthalmia itself is known to be endemic, prophylactic administration of vitamin A be initiated upon evidence of low intake and blood levels of vitamin A, independent of clinical symptoms of deficiency. The program should be undertaken with suitable controls so that any benefits can be accurately estimated. AID is currently planning field trials of such a regime in cooperation with the governments of several developing nations.

The Advisory Board on Military Personnel and Supplies, which has done much to upgrade food service for the Army, provided a set of recommendations for studying and improving the feeding system for the crews of aircraft carriers. Under way on the USS *Saratoga* is a large experiment with improved processing equipment for food preparation and expansion of the use of "convenience food commodities" to reduce problems of storage, sorting, measuring, and mixing space. The major novelty is adaptation of the techniques and equipment utilized by commercial "fast-food" establishments. It is expected that this will both improve the morale of the crew and result in much more efficient and expeditious food service.

Concerning Governmental Regulatory Activities

A report by the Committee on Impacts of Stratospheric Change concluded that significant deterioration of the ozone layer will eventually occur if halocarbons continue to be released at their present rate, thereby permitting an increased flux of ultraviolet radiation on the earth's surface, which, in turn, would result in an increased incidence of skin cancer and perhaps other biological damage, as well as the possibility of undesirable climatic effects. (The committee has subsequently reported that the magnitude of this effect of halocarbons had probably been underestimated by a factor of two.) The committee noted that "selective regulations of halocarbon use and release is almost certain to be necessary at some time and to some degree of completeness. Neither the timing nor the severity can reasonably be specified today. . . . " Measurement programs now under way promise to reduce the uncertainties in these calculations quite considerably in the near future. Following issuance of this report, the EPA, the FDA, and the Consumer Products Safety Commission enacted labeling regulations and proposed a ban on the use of halocarbons as aerosol propellants. Thereafter, the Congress, in an amendment to the Clean Air Act, called on the Administrator of EPA "to contract with the National Academy of Sciences to study the state of knowledge and the adequacy of research efforts to understand (a) the effects of all substances, practices, processes and activities which may affect the stratosphere, especially ozone in the stratosphere; (b) the health and welfare effects of modifications of the stratosphere; and (c) methods of control of such substances, practices and activities." This effort is under way.

Over the course of a year, a committee of the Assembly of Behavioral and Social Sciences issued several reports offering recommendations designed to improve the quality of the survey of community reactions to the Concorde Supersonic Transport during its trial at Dulles Airport. Almost all of the committee's recommendations were adopted by the Federal Aviation Agency and its survey contractor; the FAA also requested the committee to plan and analyze a similar survey at Kennedy Airport.

A report on the future of the National Highway Safety Program by the Transportation Research Board provided recommendations concerning the need for, and extent of, safety standards, financial incentives and sanctions, and the roles of federal, state, and local authorities in the management of such programs. Many of these recommendations were incorporated in the last annual report to the Congress by the U.S. Department of Transportation.

A ten-year effort under the auspices of the Transportation Research Board developed a design guide for use by engineers in attempting noise reduction under a variety of traffic and environmental conditions. A computer program for use with the guide was also offered as a tool for field evaluation of noise reduction measures. This program has now been used extensively in the United States and has also been adopted for use in Denmark, Switzerland, Canada, and Puerto Rico.

Much of the work of the Commission on Natural Resources for two years was devoted to a series of studies of decision making in the Environmental Protection Agency. From these studies emerged a series of reports with numerous recommendations of varying degrees of significance. Perhaps the most important thrust of the overview report is recognition of the extent to which the efforts of EPA are unduly hampered and complicated by the patchwork of legislation that constitutes its various authorizations. A strong case is made for a comprehensive act empowering the agency to deal with protection of the environment, recognizing the interrelationships among air, water, and land as sinks and transport media for pollutants. The committee emphasized, in varying ways, that EPA's decisions concerning standards and regulations should in all cases be supported by analyses that explicitly state the objectives of the decisions, identify feasible alternatives, evaluate the consequences of alternative decisions, and indicate the degree of uncertainty that attends such decision making. Such analyses should be made available to the public each time a decision is announced. The actual feasibility of such a course will become evident only after it has been attempted. (In fact, at the request of EPA, the commission, through its Environmental Studies Board, is preparing prototype analyses of three pesticides on which reregulatory decisions are to be made, using the principles of explicit analysis.) The report also calls for thorough review of the scientific and technical data used in arriving at each decision. And EPA is urged to avail itself of panels of external experts for the conduct of such reviews. The Administrator of EPA has responded, ". . . I asked my Assistant Administrators to assess the specific recommendations. . . . As a result of this effort I have concluded that the vast majority of the recommendations made by the Academy are within our policy goals. To implement them would improve our decision making. . . . This effort by the Agency to respond to these recommendations is an effort I take very seriously. . . . On the whole I believe your recommendations are constructive and I hope we will be able to implement many of them within the year. . . ."

A report of the Building Research Advisory Board recommended to the Federal Insurance Administration of the Department of Housing and

Urban Development a method for estimating the wave crest elevation associated with storm surges crossing the open coast on shores of bays and estuaries on the Atlantic and Gulf coasts. Preliminary indications suggest that this recommendation will be adopted by the FIA. If so, this calculated elevation will become the elevation stipulated with respect to community building and land use regulations as the minimum elevation of the first habitable floor of new construction. It will profoundly affect the insurance status of those who do not meet this standard, as well as the value of land still available for future construction along the coasts.

As authorized under the provisions of the Federal Environmental Pesticide Control Act of 1972, the Chief Administrative Law Judge of the EPA submitted several questions of scientific fact concerning the possible carcinogenicity of the pesticides chlordane and heptachlor. The Pesticide Information Review and Evaluation Committee reviewed several thousand histopathological slides, as well as all of the available data in the literature concerning the effects of these two compounds in rats and mice. The committee concluded that, at the upper range of experimental dosage that had been studied, both compounds were carcinogenic in several strains of mice, but not in rats. The committee stated that, in the absence of other information, it must be presumed that these compounds may be potential carcinogens in humans. The committee made no quantitative projection of risk. No recommendation was offered concerning the specific decision to be made by the Administrative Law Judge. However, the committee's analysis becomes part of the hearing record and one of the primary bases for his action.

As mandated under the Safe Drinking Water Act of 1974, an *ad hoc* Safe Drinking Water Committee reviewed the biological effects of a very large number of known potential contaminants of drinking water and, where available data permitted, offered safety guidelines for various radioactive, particulate, microbiological, organic, and other contaminants. The EPA is currently using these recommendations as a basis for establishing standards in promulgating regulations concerning permissible levels of diverse substances in drinking water. In turn, this may have substantial financial impact in those cities that will be required to re-engineer their water-treatment plants.

The National Resources Defense Council had petitioned the EPA to increase, markedly, the stringency of regulations with respect to exposure to alpha-emitting particulate matter. At the request of the EPA, a panel of the Advisory Committee on the Biological Effects of Ionizing Radiation reviewed the data relevant to the contention that there is a special "hot particle" effect of alpha-emitters, which significantly increases the carcinogenicity of such materials as compared with previous calculations. The panel concluded that the NRDC had overestimated the risk associated with each particle by at least two orders of magnitude, that the cancer hazard from insoluble particulate plutonium deposited in the lungs is not much greater than would be caused by the same quantity of radioactivity distributed more uniformly, and that the available evidence suggests that the carcinogenic response is a function of the amount of radioactivity in the lung rather than of its distribution. The EPA published this report and rejected the petition of the NRDC, which, in turn, indicated that it would take no further steps to petition for an increase in the stringency of radiation guides for alpha particle emitters.

The Advisory Committee on the Biological Effects of Ionizing Radiation has also reported to the EPA a set of recommendations concerning approaches to the conduct of health benefit–cost analysis with respect to activities involving exposure to ionizing radiation. The EPA published this report and has used it in developing guidelines for the conduct of benefit–cost analyses. The report has also been reviewed in various scientific journals and has widely been considered to be a major contribution to the development of this form of analysis.

Having detected diisopropylmethylphosphonate and dicyclopentadiene in groundwater in the vicinity of the Rocky Mountain arsenal, as a result of the disposal of these compounds in dry unlined basins during the period 1944–55, the Army requested the Committee on Military Environmental Research to consider an appropriate course of action. The committee concurred in temporary guidelines for the permissible concentration of these substances in food and water for human consumption. The guidelines were accepted by the U.S. Army Medical R&D Command and transmitted to the Army Material Development and Readiness Command. The latter now is considering methods of ensuring that off-post concentrations do not exceed those permitted in the guidelines. The guidelines were based on acute and subacute toxicological studies. Chronic toxicological studies, currently under way, may permit the development of permanent standards with respect to these compounds.

Concerning the Management and Programs of Federal Agencies

The Board on Agriculture and Renewable Resources recommended to the Secretary of Agriculture a set of criteria for an advisory committee to provide scientific advice concerning the management of the national forests. The recommendation was accepted by the Secretary, who also appointed to this committee many of those recommended to him by the board.

In the wake of the Teton Dam disaster of June 1976, the Secretary of the Interior requested the NRC to review the Dam Safety Program of the Bureau of Reclamation. An *ad hoc* committee of the Assembly of Engineering noted that, in contrast to what is needed, responsibility for dam safety was scattered through the agency and not coordinated in a single office. The report directed attention to the inadequate state of emergency preparedness at all existing dams and urged immediate correction. It indicated that risk analysis is not an element of the safety program, and suggested that major dams be ranked in the order of their hazard potential and the probability of failure. The Commissioner of Reclamation has taken steps to correct the first of two of these and consideration of the third is under way. It should be noted, however, that these were not novel suggestions, each having been made before, both within the agency and by external bodies.

In the report of the largest single study ever attempted within the National Research Council, the Committee on Health Care Resources in the Veterans Administration responded to the charge of the Veterans Health Care Expansion Act of 1973 (Public Law 93-82) to provide a basis for allocation of manpower and resources to maintain a high level of patient care in the VA hospital system. The resultant report provided thirty-seven explicit recommendations, of which twenty-three were adopted by the VA Administrator for immediate implementation. Two hearings were held by the House Committee on Veterans Affairs and six hearings by the Senate Committee on Veterans Affairs to explore the report and subsets of its recommendations. The most far-reaching recommendation was that ". . . VA policies and programs should be designed to permit the VA system ultimately to be phased into the general delivery of health services in communities across the country." An experimental approach to implementation of this recommendation was described. This recommendation derived from examination of the patient population of VA hospitals, eighty percent of whom are admitted for reasons unrelated to military service and to the fact that, in the offing, are thirteen and a half million veterans of World War II with a mean age of fifty-seven years, large numbers of whom may be expected to seek admission to VA hospitals in coming years. However, this recommendation was deemed unacceptable to the House Committee on Veterans Affairs and to the Administrator of the VA. Regardless of the outcome, public debate will have been well informed, paving the way for what must be, ultimately, a political decision in the best sense of that term. (Frank Putnam's article in this report provides further details on the genesis and some of the results of the VA study.)

A panel of the Committee on Research on Law Enforcement and Criminal Justice, concluding that the empirical evidence assembled to date does not warrant a clear conclusion regarding the magnitude of the deterrent effect of criminal sanctions, recommended to the Law Enforcement Assistance Administration an agenda for research on the subject of deterrence and incapacitation. This agenda has been used to guide the research program of the National Institute of Law Enforcement and Criminal Justice of the LEAA for the current year. The committee also reviewed the previous research program of that institute and concluded that it has been of inadequate quality. That program concentrated on improving the operation of the criminal justice system, giving little attention to approaches to reducing the crime rate. Believing that high-quality fundamental research is unlikely to be supported within the framework of the LEAA, which as a mission agency is under constant pressure to meet immediate goals, the report calls for reconstitution of the institute as an independent research agency within the Department of Justice, rather than within LEAA. The report formed the basis of extensive congressional hearings on the future of the Law Enforcement Assistance Administration and received widespread attention. Although no decision on the future of the institute has been made, there are indications that the committee's major recommendations will be adopted in some form.

After surveying the work of the National Institute for Education, the Committee on Fundamental Research Relevant to Education recommended a substantial increase in the proportion of NIE funds devoted to fundamental research on cognition and the learning process. On the basis of this recommendation, the NIE council resolved that the fraction of NIE resources devoted to fundamental research be increased from about four percent to twenty percent. This recommendation, explicitly attributed to the committee, has been incorporated in a draft proposal for national education policy by the Assistant Secretary for Education of HEW.

The Committee on Substance Abuse and Habitual Behavior concluded that " . . . study of commonalities in the use of foods and drugs is a powerful approach for developing further theoretical and applied knowledge of the processes of habitual substance abuse." The specific research agenda developed by the committee has been accepted by the National Institute on Drug Abuse and is to form the basis of a substantial portion of the agency's research funding effort for the next several years.

In a report concerning atmospheric and oceanic research and development in the National Oceanic and Atmospheric Administration, panels of the Committee on Atmospheric Sciences and of the Ocean Sciences Board assessed the quality, management, and content of the programs of seventeen atmospheric and thirty oceanic laboratories of NOAA. In general, the quality of these programs and the scientific productivity of the laboratories was found to be rather good. But the panels were concerned about lack of communication among the laboratories and between NOAA laboratories and the academic community. Recommendations to alleviate these problems were offered to the Administrator of NOAA, who took prompt action to correct them. The Administrator also indicated that the studies had been exceedingly helpful to the entire organization and that virtually all recommendations had been accepted and implemented.

A report from the Transportation Research Board on social, economic, and environmental consequences of *not* constructing a transportation facility provided guidelines for assisting transportation planners. These have been adopted by the state of Oregon and are currently under evaluation by the departments of transportation of eight other states and by the Urban Mass Transportation Administration of the U.S. Department of Transportation.

The report of a workshop on rail research needs sponsored by the Transportation Research Board, together with the American Association of Railroads and the Federal Railroad Administration, presented a set of priorities for research to upgrade the quality of the American railroad system. Although this has had little obvious impact in the Department of Transportation, both of the cooperating organizations have included various specific recommendations in their own R&D programs for the next two years.

The Transportation Research Board periodically revises its document entitled *Synthesis of Existing Information Related to Highway Problems*. The latest edition has contributed substantially to informing the decisions of state transportation authorities with respect to the use of studded tires, bituminous emulsions for highway construction, materials recycling, and equipment management. Earlier editions were translated into Portuguese and Spanish, and a Japanese translation of the current volume is in process.

A panel of the Transportation Research Board rendered a report to the Federal Highway Administration recommending five categories of needed research related to safety and operations on rural two-lane roads. The recommendations were well received and were used in structuring the future research program of that agency.

The Ship Research Committee of the Maritime Transportation Research Board developed a five-year plan for research on ship structures in addition to proposing a specific program for FY 1978. This program was adopted as a basis of the contract research project program administered by the U.S. Coast Guard.

A Committee on the Evaluation of Employment and Training Programs identified three major problems with respect to the operation of the Comprehensive Employment and Training Act (CETA): an upward shift in the socioeconomic status of persons entering the program; substituting federal funds for local funds in financing local positions; and an unsettled relationship between two manpower systems, CETA and the older U.S. Employment Service. Later that year, the act was amended to target the public service employment programs of CETA more specifically on the long-term low-income unemployed and to minimize substitution of federal for local funds by restricting use of those funds to projects outside of the regular public service activities. Moreover, a bill has been introduced that is intended to merge the two employment systems. The final report of the committee, due in early 1978, will include additional recommendations for legislative changes designed to improve and enhance the services rendered by implementation of CETA.

At the request of the U.S. Geological Survey, a committee of the Marine Board reviewed the procedures for "verification" of the structural adequacy of fixed offshore platforms for drilling for oil and natural gas. The committee recommended that USGS issue policy guidelines defining the elements of a standardized verification procedure, suggested some details for the procedure, and recommended that a third party verification system be utilized in each case. Procedures were proposed for the routine reporting of platform structural conditions and analysis. Such a program would require a major commitment on the part of the USGS, including recruiting and training a technically competent in-house staff. The USGS has begun to implement most of the specific recommendations and has issued a policy document as recommended in a prior Marine Board study. The Marine Board is currently reviewing the preliminary guidelines, which were prepared by the USGS.

SOME RECOMMENDATIONS THAT APPEAR NOT TO HAVE BEEN ACCEPTED

Whereas more than seventy percent of the Polar Research Board's recommendations, over the years, relative to the planning and conduct of research in the Antarctic have been implemented, recommendations from the board with respect to the research in the Arctic have, as yet, failed to gain acceptance. A proposal for a Nansen Drift Station (an icebreaker to be placed at the Sadko Trough of the Laptev Sea Continental Shelf, where it would drift along the axis of the Arctic Mid-Ocean Nansen Ridge) offers diverse opportunities for the study of marine geophysics, plate tectonics, marine geology and paleoclimatology, physical oceanography, marine acoustics, the heat and mass balance of the ice cover, and so forth. Although seemingly favorably received by the Navy, no funding arrangements have been developed or approved. Similarly, recommendations from this board concerning problems and priorities in offshore permafrost research, opportunities for permafrost-related research associated with the Trans-Alaska Pipeline, snow research and control, and glacier and ice sheet sliding have received attention but not implementation.

An *ad hoc* committee responded to the request by ERDA to develop a plan for the congressionally mandated Solar Energy Research Institute. The committee's report, which emphasized basic research relevant to diverse aspects of the utilization of solar energy, described a substantial institute to be managed by an external consortium. However, this plan was rejected by the management of ERDA, which preferred a smaller institute, administered by the agency, whose activities would be more immediately akin to current applied research and development under way in the agency.

A Committee on Societal Consequences of Transportation Noise

Abatement, supported by the Environmental Protection Agency, described the difficulty of measuring subjective benefits in order to trade them off against the real and quantifiable costs of abating noise pollution; great difficulty was encountered, for example, in deriving surrogate measures for the benefits of noise pollution abatement, which might permit quantification of those benefits. The report analyzed and recommended a variety of regulatory options for achieving subjectively desirable levels of transportation-related noise. Although the report was widely circulated within the EPA, it had no noticeable effect on policy; noise abatement does not currently loom large in the programs of that agency.

An *ad hoc* panel of the Commission on International Relations undertook an extensive evaluative review of the exchange program, begun in 1959, between the National Academy of Sciences and the Academy of Sciences of the USSR. The Soviet Academy was invited to cooperate in this review but declined. The extremely competent panel made an extraordinary effort and utilized a sophisticated methodology. In the light of the analysis, the panel recommended that the inter-academy exchange program be expanded in new directions befitting current conditions, that the NAS seek to promote joint or collaborative research efforts on the part of U.S. and Soviet scientists, and that the NAS continue to manage such an exchange program. This was, in effect, a self-analysis. Hence, the National Science Foundation, source of financial support for the exchange program, has made no formal response to the report. Implementation of its recommendations will, however, depend upon their acceptance by the foundation and by the Soviet Academy, and will be conditioned by the cordiality of US–USSR relations.

It seems appropriate to note how nongermane elements can account for what might be only the temporary failure of an NRC activity. The Committee on Scholarly Communication with the People's Republic of China proposed to its counterparts in that country an expanded program of exchange emphasizing individual research in laboratories and other institutions of the two countries, graduate education and postdoctoral fellowships, visiting lectureships, etc., intended gradually to replace the current program of formal touristic visits by organized delegations concerned with specific disciplines or research fields. These proposals were not accepted by the Chinese, who indicated that such arrangements could not be considered until the United States alters the state of its diplomatic relations with the Republic of China on Taiwan and with the government in Peking.

Three reports appear to have been misused in some manner. A Panel on the Evaluation of Crime Surveys, of the Committee on National Statistics, reported to the Law Enforcement Assistance Administration the results of an examination of the methodology and utility of the National Crime Surveys. While indicating that the design of that survey is generally consistent with its initial objective, i.e., producing data concerning trends and patterns of victimization in certain categories of crime, the panel noted that a continuing series of victimization surveys, carefully designed and validated, could help to fill in details of American life and illuminate society's concepts of crime and moral order. Regrettably, the extensive conceptual, procedural, and managerial criticisms of this program embodied in the report were used within the agency as justification for attempting the complete dismantling of the program, a conclusion entirely opposite to the views of the panel. When the panel's views were made clear to the agency, this eventuality was averted.

A report of the Institute of Medicine, entitled *Assessing Quality of Health Care: An Evaluation*, reviewed the progress of several current programs intended to maintain surveillance over the quality of health care, including Professional Standards Review Organizations (PSRO). Although the specific programs reviewed are widely regarded as among the best of such, the study team could not find objective data to substantiate this belief. The report carefully indicated that this may well be due entirely to the inadequacy of available information. Regrettably, it appears that, within the executive branch, this report was used to substantiate a preliminary recommendation that the PSRO program be eliminated, a conclusion that is not supported by the authoring committee.

In response to a request from the Navy, an *ad hoc* Committee on Biological Effects of Extremely Low Frequency Radiation examined in all respects the possibility of biological hazard from the extremely low frequency radio waves that would be emitted by an extensive horizontal antenna grid, planned for installation in upper Michigan as a mechanism for communication with distant submerged submarines. The committee reported that there is essentially no scientific evidence to suggest significant adverse biological effects, in contrast to the exhortations of various groups and individuals in a campaign that had been given some standing by press accounts and national television. The committee did note the possibility of conventional electric shock hazards of the installation as planned and described measures to avoid them. Nevertheless, the Governor of Michigan, apparently responding to aroused public alarm, vetoed the construction of the proposed antenna. The committee did not address the possible significance of such an action to the communication problems of the submarine fleet.

SOME RECOMMENDATIONS UNDER CONSIDERATION

Not unexpectedly, many recommendations to be found in recent NRC reports have as yet been neither accepted nor rejected, but there is reason to believe that they are currently under consideration. It is of some interest to note their varying character.

Whereas the Viking studies of the geophysics of Mars were extremely successful, review by the Space Science Board of the data from experiments intended to determine whether there is any evidence for life on Mars has made it clear that, if life does exist there, Viking did not find it. Previous planning for the successor to the Viking series of Martian landers had assumed that future missions would involve depositing on the Martian surface a self-propelled vehicle that could move over that surface, take soil samples, and perform various automated analyses. However, the board has indicated that the optimal places to seek evidence of life are at the edges of the polar ice cap, but that this effort would pose extraordinary difficulty for the program as envisioned and would probably not be successful. Instead, the board recommended that the next Viking lander include provision for return to Earth of an unsterilized sample of the Martian surface. It remains to be determined whether NASA will act upon this recommendation.

A panel of the Committee on Laboratory Biohazards has concluded that adverse effects to human health are extremely unlikely if research on recombinant DNA is conducted under the circumstances laid down by the NIH Guidelines. The committee recommended that any legislation in this regard be of the minimal character necessary to assure adherence to these Guidelines without undue restriction on the course of this highly promising research, and that criminal sanctions not be part of any legislated enforcement procedures. Since that time, the stringency of the NIH Guidelines has been relaxed somewhat and additional evidence has supported the conclusion of the committee. But the status of prospective legislation in this area remains uncertain.

An *ad hoc* committee of the Institute of Medicine, after reviewing the status of computed axial tomographic scanning, concluded that this technique shows great promise as an indicator of various forms of human pathology. However, this conclusion is based not on carefully designed large-scale clinical trials, but rather on the views of practitioners in the field, the classical mode of entry of new technology into medical practice. In view of the high costs associated with such procedures, because of the initial cost of the instrumentation, it appears desirable that a well-designed clinical trial be undertaken, the results of which may provide guidance both to hospitals and to health care insurers. Neither the government nor the insuring organizations have as yet taken action in this matter but both are certain to do so. Meanwhile, the report stands as a model of early assessment of an expensive technology freshly introduced into medical practice.

A panel of the Committee on Assessing Quality in Health Care has examined the reliability of the abstracts placed in the files of patients at the time of their hospital discharge. The purpose of the study was to assess the reliability of data compiled by abstracting services that are descriptive of the utilization of hospital facilities—data which, in turn, are based on the hospital discharge abstracts. A specially trained team reabstracted the original hospital records and compared their reabstracts with the abstracts that had been filed by the hospitals. For all principal diagnoses combined, their reabstracts agreed with only 65.2 percent of the original abstracts. As pressures are brought to bear on the medical care system to make more efficient use of its resources, analyses of hospital utilization based on the abstracts now on file will assume great importance for management planning, regulatory, and policy decisions. Patently, in view of the size of the errors in these abstracts, such data must be used with great caution. But it is not clear how the problem can be rectified.

A report from the Institute of Medicine indicated an excess of short-term general hospital beds in the United States, and recommended an overall reduction of at least ten percent in the ratio of short-term general hospital beds to the population, to be accomplished within the next five years, with additional reductions thereafter. This recommendation was cited by HEW in issuing proposed guidelines for health planning agencies.

However, perhaps because the latter proposal lacked the careful qualifications that accompanied the IOM recommendations, the HEW Guidelines were found unacceptable by the House of Representatives and hence have been withdrawn. Nevertheless, the report has successfully brought to public attention an issue that will necessarily receive serious attention as the nation attempts to constrain the continued increase in hospital costs.

A committee of the Assembly of Life Sciences formulated a set of recommendations to the Occupational Safety and Health Administration concerning the appropriate content of an Occupational Cancer Information and Alert Program. The report dealt with the circumstances in which a carcinogen should be made the subject of an information program, what the worker should be told about the substance, and how and when it is best to inform him. At this time, there has been no indication that the recommendations of the report will indeed be adopted by government agencies. The modest coverage given to the report in public health and trade periodicals has served to direct some attention to the problem and may continue to do so.

The Advisory Committee on Child Development transmitted to the Office of Child Development (now reorganized into the Administration on Children, Youth, and Families) a report entitled *Toward a National Policy for Children and Families,* which calls for a comprehensive national policy for children and families. The essential components of the policy include employment, tax, and cash benefit programs that would assure each child's family an adequate income; a carefully integrated system of support services for families and children; and coordination mechanisms to ensure adequate coverage and access of families to the full range of available services. Although many of the report's recommendations have been stated before by others, this report was the first in recent times to emphasize the criticality of economic and other support systems to enable families themselves to meet the needs of their children. This is a profound change in emphasis from the previous approach of piecemeal provision of services and advocacy of alternatives to family care. This change in emphasis has since been echoed by subsequent studies, notably that from Kenneth Keniston and the Carnegie Council on Children, and is reflected in some part in current administration proposals for welfare reform. A discussion guide combining this report with that by Keniston and the Carnegie Council was published by the Education Commission of the States for use at the local and state level. It is evident that although the NRC report has, as yet, had but modest impact on federal policy, it will have cast a long shadow into the future and will guide policy formation for years to come.

A committee of the Transportation Research Board made recommendations to the Federal Railroad Administration concerning "Post-1990 Planning Issues for the Northeast Corridor." These relate to better understanding of the factors that will affect demand for rail passenger travel and a computer model to permit forecasting of such demand. Information gained this way can permit rational cost/benefit analysis, which might enable planning of future improvements by relatively small incremental steps so that the effect of each improvement can be used in planning for subsequent actions. The response to this report remains to be ascertained.

The report, *Manpower for Environmental Pollution Control,* from the Commission on Human Resources offered eleven recommendations. Included were proposals that the Congress clarify its intent with respect to environmental manpower development and training as stated in existing legislation and provide EPA with a clear directive concerning its authority in this area. The EPA was adjured to focus its environmental manpower responsibilities by creation of an appropriate office in the upper echelon of the agency to manage a well-coordinated environmental manpower planning and training program. At the same time, the report noted that EPA could make better use of its technical personnel by assuring that its directives can be accomplished with existing or soon to be available technology. As yet, the agency has made no formal response.

The *Annual Report* of the Committee on National Needs for Biomedical and Behavioral Research Personnel submitted to the Secretary of HEW in 1977 contained some twenty-seven recommendations aimed, *inter alia,* at broadening the research training responsibilities of the Health Resources Administration, increasing the number of minority students in graduate education and the life sciences, lessening the inflexibility of the three-year limitation now imposed on National Research Service Awards, assuring that such awards will be made solely on the basis of quality and merit, and asking that more reliable information be obtained concerning the increasing population of postdoctoral and nontenured research staffs in academic institutions. This report is mandated by the Congress and the response of the Secretary of HEW is presently awaited. Meanwhile, the information and analysis in that report are of broad interest to all concerned with advanced education in the life sciences.

The Committee on Satellite Communications of the Space Applications Board reported its concurrence with the conclusion of NASA that, henceforth, research related to the use of satellites for commercial communications should be the responsibility of the common carriers themselves. In addition, the committee noted that a series of "public service satellites"—to be used, for example, for hazard alerts, some forms of navigation, general emergency warning systems, and emergency medical communications—would be widely welcomed. Recognizing the unlikelihood that the common carriers would undertake research relevant to such a communication system, the committee recommended that NASA begin conceptual definition of the needed technology and its experimental trial, but only if one or more potential user groups can be involved from the very start of the project and if estimates of cost appear to be reasonable. The Office of Science and Technology Policy in the White House expressed interest in this report and sought the views of departments of the executive branch and of various commercial organizations. It remains to be seen whether these proposals will be implemented.

The Committee on Telecommunications recommended to the United States Postal Service that inauguration of electronic message services would offer opportunity to reverse the present trend of rising costs, decreasing volume of first-class mail and increasing deficits. To achieve such a position will require a firm continuing commitment to this course, and an effective planning, research, and management staff, followed by field trials to test the new systems and to determine user acceptance. This report was warmly received by the Postmaster General and the House and Senate committees on the post office, as well as by the Commission on Postal Service. The 1977 report of the latter body echoed the report of our committee. Again, decision in this matter is still awaited.

In 1976, a joint committee of the Commission on International Relations and the Commission on Natural Resources reported on "Guayule: An Alternative Source of Natural Rubber," based on a plant that is indigenous to the American Southwest. This report attracted considerable attention and, in May 1977, S.1816 was introduced by the Senate Committee on Environment and Public Works "to authorize a program of research, development and then demonstration of guayule rubber and production and manufacture as an economic development opportunity for the southwestern states." It remains to be learned whether this bill will one day become a law.

A committee of the Institute of Medicine considered five alternative options for policy with respect to poliomyelitis vaccine in the United States. The committee recommended that oral (live virus) polio vaccine continue to be used as the principal vaccine, that inactivated poliomyelitis vaccine be available for certain categories of persons, and that a booster dose of oral vaccine be given to all entrants to the seventh grade of school. This report has been rather extensively discussed; it has been considered by the Public Health Service's Advisory Committee on Immunization Practices and its recommendations debated by the health ministries of several other nations. However, the recommendations have not been formally adopted by the U.S. Public Health Service or by state authorities.

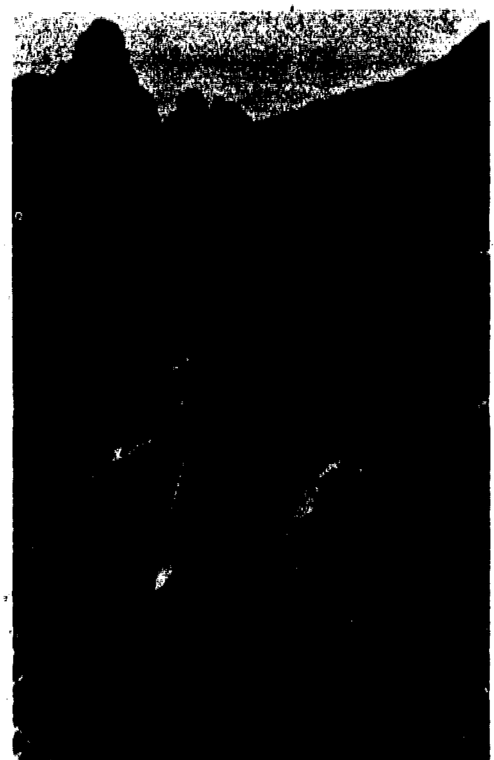
The Committee on Processing and Utilization of Fossil Fuels has engaged in a comprehensive evaluation of the status, technology, and research and development priorities for the major components of the coal processing and utilization system. A great variety of specific technical recommendations have been made with respect to advanced technologies for the direct combustion of coal, technologies for the liquefaction and gasification of coal, for advanced power cycles in power plants, and improved technology for coal mining. These reports were submitted to the Department of Energy (at that time the Energy Research and Development Administration) during 1977. At this writing their implications for the R&D program of the Department of Energy are under consideration, and the reports are currently being studied by the interested community.

This compendium, although quite incomplete, nevertheless reveals the extraordinary diversity of the problems addressed by the National Research Council. Since NRC committees are not infallible and since governmental decision makers may occasionally find other considerations more compelling than those discussed in an NRC report, it would be extraordinary, indeed, if recommendations by NRC committees were invariably adopted and implemented. If the reports and recommendations summarized above represent a reasonable sampling of the more important recommendations emanating from NRC committees during the period under consideration, the fraction of all recommendations that have already led to significant actions might well be regarded as remarkable. However, from the standpoint of those whose talents create our reports, the appropriate criterion for assessing the impact of a given report is not so much whether its specific recommendations have been adopted as whether the intended audience has given the report and its recommendations careful consideration and a fair hearing.

My wife has frequently asked me, "Who reads all those NRC reports?" The record above cannot supply a complete answer to that question, but it is clear that few, indeed, are the reports and recommendations that have gone ignored. In all but a handful of instances, those for whom a report was particularly intended have given evidence of careful study of the specific document and deliberate consideration of the merits of its case. The thousands of individuals who have so generously contributed to this huge effort have reason to find reward and satisfaction in that accomplishment. Actual implementation of their specific recommendations, when that happens, is doubly gratifying.

The hopes that we held as we entered upon this analysis have been largely borne out. Well-reasoned proposals for programs that would advance the frontiers of science do receive sympathetic attention and are generally accepted. Specific technical recommendations deriving from analyses of relatively narrow technical subjects and requested by a concerned mission agency almost invariably find acceptance. Recommendations of broader character, offered in a report that has been explicitly requested by the Congress or some agency of the executive branch, are frequently adopted. But formulations of major national policy must await prolonged discussion and, not infrequently, repeated reexaminations of the entire subject before they may hope to find acceptance. On balance, the nation has been well served.

Assembly of Behavioral and Social Sciences



Giving Advice on Social Dynamics

R. DUNCAN LUCE

Being involved with the Assembly of Behavioral and Social Sciences during the past five years has markedly increased my awareness of the difficulties faced by organizations that attempt to provide various governmental bodies with scientific advice on social problems. Much of that advice has to do with the interactions of social variables, what we call social dynamics. The first part of these remarks concerns some of the problems we encounter in attempting to answer apparently simple questions about social dynamics. Equally important is the invention of ways to deal with social problems when we perceive them. The second part of these remarks takes up some aspects of that problem, especially the fact that the social sciences are little called upon to provide advice in this area.

UNDERSTANDING THE NATURE OF CAUSES AND EFFECTS

The first category of advice typically arises when we are asked to answer seemingly simple questions about social processes. As usually posed, such

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questions involve at least two social variables, call them X and Y, one of which we care about, say Y. The question is: Does X affect Y and, if so, in what degree?

- Does an increase in the amount or degree of violence in the TV fare of children increase violent behavior, perhaps some years following the exposure?
- Does a particular innovation in the teaching of high school physics result in adults who, on the average, have a better understanding of the role of physical science and technology in society?
- Does compensatory education in the early grades overcome some of the educational deficiencies apparently due to severe cultural deprivation during the first five years of life?
- Does the imposition of more severe criminal sanctions deter criminal behavior in others?
- What is the impact of various dietary practices during adolescence on health later in life?

Society repeatedly asks such questions of the behavioral and social sciences, as well as of the life sciences and medicine. All too often, we fail to come forth with an answer or, if we do, our answer is murky and hedged. My impression is that on the whole we are becoming more sophisticated in our approach to such questions, that we know better how limited is our ability to answer them, and that we are sometimes able to devise ingenious ways to arrive at answers. But progress is painfully slow.

There are at least four sources of difficulty in achieving answers. They are:

1. *Statistical models in lieu of causal models.* For the most part, we lack much, if not most, of the dynamic theory for the social processes about which we are trying to answer questions. For example, although there is an extensive literature on how various organisms learn, only a tiny fraction of that relates to the various methods of educating children—open classrooms, the timing and rate at which materials are introduced into the curriculum, repetition of materials, and the like. And within that fraction, there is considerable dispute about the effectiveness of these various methods.

Because of the lack of substantive theory, we attempt to study what interests us by fitting models to the data by various statistical techniques. The mathematical form of these models can only be a crude approximation of the actual underlying relations; worse yet, we may well overlook variables of importance; and, at best, the statistical models provide uncertain extrapolations from past data. Even the most sophisticated of these, the econometric models of the economy, are limited in their ability to predict accurately the future course of the economy.*

2. *Observational rather than experimental data.* For the most part, we are unable to perform controlled experiments involving manipulation of important variables. Even when we can, the results may be suspect if the participants are aware that they are in an experiment and that special attention is being paid to them. Most often, we must settle for observing the naturally occurring variations in social relationships and attempt to explain resulting differences in behavior, somehow measured, by using statistical models. Between these two extremes—a perfectly controlled experiment, which hardly ever occurs outside of the laboratory (and often not there), and a natural occurrence—there is a region of partial experimental intervention that has come to be called quasi-experimentation. There is a small, but growing, literature on this.[1]

3. *Long delays between cause and effect.* In many cases, there is a long delay, years or even decades, between an event or an exposure and its possible effects. Of the examples given earlier, only two—the relationship between television violence and violent behavior and the deterrent effect of criminal sanctions—can be studied in the short term; and, of course, the question of longer-term effects is also meaningful for these examples. The others—compensatory education, curricular innovation, and health effects—are all inherently long-delay questions. However, when more than a few weeks elapse between intervention and purported consequence, numerous uncontrolled events and experiences occur; and one becomes increasingly skeptical of any correlations that are found.

4. *Poor data base.* The data on which we depend for answers are often very poor in one or another respect. In many cases, they were not collected

*Perhaps it is well to make absolutely clear that I do not mean to identify causal models with deterministic ones, nor statistical models with stochastic ones. Almost certainly, satisfactory dynamic theories of social processes will be stochastic and not deterministic, but they are not likely to assume the form of the statistical models we normally invoke.

by the scientists who wish to use them; often they are not comparable from place to place or time to time; and sometimes they are subject to major political or economic influences and are suspect for that reason (e.g., federal crime statistics). There are, of course, many data banks whose virtues and limitations are well understood and whose quality is gradually being improved. Often, however, good sources of data do not exist for problems to which society seeks answers.

THE EFFECT OF PUNISHMENT

Perhaps a concrete illustration will make some of these problems more vivid. Do sanctions for crimes committed deter others from committing crimes? We are unlikely to perform any controlled experiments to manipulate the risk of sanctions, so analyses must be based on variations in crime rates and the application and degree of sanctions that occur over time and over jurisdictions. Moreover, since we do not have any detailed causal model for the social factors that inhibit or encourage criminal behavior, there is no choice but to approach the problem using some sort of statistical model. The general approach is to calculate the crime rate at various times and locations, calculate some measure of the risk of sanctions being applied, usually at the same times and locations, and then test for a negative effect of risk of sanctions on the crime rate within the context of a fitted statistical model. For example, does a greater risk of sanctions result in less crime?

The first problem is exactly which crime rates should be associated with which sanction rates. The measured sanction rates (as defined below) are used as surrogates for the criminal's perception of the risk of criminal activity. But is a perception formed on the basis of this week's sanctions (e.g., arrest), or last month's sanctions, or last year's? Further, how is this perception of risk in one part of a city related to the number of arrests in another part? Usually, the assumption is made that the risk is perceived in the same time period and in the same geographic areas in which sanction rates are measured; hence, crime rates and sanction rates are correlated without any time or spatial adjustments.

Now, let us examine three problems that may arise in drawing inferences from any naive examination of the regression of crime rate with risk of sanctions; that is, in estimating the effect of the second variable on the first.

1. *Spurious correlation because of poor data.* Suppose one uses the following measures of the two variables:

$$\text{crime rate} = \frac{\text{number of crimes}}{\text{population}}$$

$$\text{risk of sanction} = \frac{\text{number of times sanctions are imposed}}{\text{number of crimes}}$$

Note that if there is any variation in the rate at which actual crimes are reported to the police over jurisdictions, which is almost certainly the case, or over time, which also is likely to be the case, then this alone induces a negative association between the crime rate and the risk of sanctions; because the number of crimes appears in the numerator of the former measure and in the denominator of the latter one. Thus, poor crime data produce a negative correlation even if there is no deterrent effect whatsoever. Of course, one can estimate the magnitude of this artifact as a function of the quality of the data.

2. *Confounding of deterrent and incapacitative effects.* If we assume that an apprehended criminal has a higher probability of committing another crime than does a random member of the population, then incapacitating him or her will, with some probability, reduce the crime rate whether or not it deters others or (in the long run) even the incapacitated criminal. Of course, if one can estimate the chance that an apprehended criminal again commits a crime, which is very difficult to do, then one can estimate the magnitude of this artifact.

3. *Simultaneous effects of other variables.* A third artifact is that both variables, the number of crimes committed and the risk of sanctions, are also affected by the behavior of people other than the criminal. The number of crimes reported is a function of the number of crimes actually committed, those reported to the police, and those recorded by the police. The imposition of sanctions is a variable affected by, at least, the prosecutor, who has some discretion as to what is brought to the court, the jury, and the judge. Thus, any social factors that affect the behavior of any of these groups can change the relation between measured rate and risk. For example, if at some time a jurisdiction imposes fewer or lesser sanctions just because its crime rate is high and its criminal justice system is therefore overloaded, we will observe a negative correlation between rate and risk,

which has nothing whatsoever to do with deterrence. Again, by making further careful measurements and modeling these factors, one can estimate the magnitude of the effect.

CAPITAL PUNISHMENT AS DETERRENCE

The above discussion is drawn from a recent ABASS report.[2] One part of this report is concerned with the evidence concerning the deterrent effects of capital punishment on murder. A major study,[3] analyzing data covering the years 1933–69, concluded that there is a deterrent effect of capital punishment. The Panel on Research on Deterrent and Incapacitative Effects of the Committee on Research on Law Enforcement and Criminal Justice conducted a careful reanalysis and raised many methodological questions that make one suspicious of the conclusions drawn from these data. Perhaps the most startling observation is this: During the period 1962–69, all crime rates (including murder, and also all sorts of noncapital crimes) rose; however, during that period capital punishment was not employed in the United States. Drop these seven years and reanalyze the remaining twenty-nine years, where the variation in crime rates and sanction applied is primarily over jurisdictions, and there is no discernible deterrent effect of capital punishment. The panel concluded from their analysis that existing data provide no useful evidence of the deterrent effect of capital punishment.

This example is reasonably typical of the difficulties encountered when we attempt to answer many seemingly simple social questions. Social scientists have no real alternative but to attempt to deal with such questions as best they can, and I am personally much encouraged by our growing body of well-trained, sophisticated researchers who are sensitive to the pitfalls. But, equally, by the nature of our limited understanding of social processes, it is not always possible to provide simple, clear-cut answers in our reports.

DESIGNING INSTITUTIONS TO ALTER SOCIAL PROCESSES

Why does society want answers to questions about social processes? It is rarely, if ever, out of intellectual curiosity alone that a question is posed; it is rather because we wish to solve or modify a perceived social problem. We want less violence in our society, better-informed citizens, equal educational opportunity despite early cultural deprivation, reduced national health problems such as heart disease, and so on. Put another way, society is interested in understanding social processes primarily because such understanding may suggest interventions to ameliorate a perceived problem.

Assuming that the evidence is adequate for thinking *X* affects *Y* in a particular direction, that we indeed know the effect, for example, of a higher risk of punishment on crime rates, then the next question is the nature of the interventions to be imposed on *X* itself or on relationships between *X* and *Y* so as to achieve a desired change in *Y*. At this point, a number of options are available and an elaborate political process selects or devises the particular intervention to be tried. The choice of the intervention and the crafting of the institutional structure for intervening is largely in the hands of those in high- and middle-level government positions. These groups often seem confident that they understand how to create institutions to do particular jobs. Some of us, however, are less confident, our doubts being based on the repeated failures of interventions to work as intended.

It has become increasingly clear that the success of new programs rests as much on the structure and functioning of the institutions charged with their implementation as it does on the soundness of the program concepts. In practice, there has been a very wide variation in the efficiency and effectiveness of interventions. Increasingly, since World War II, and perhaps a good deal earlier, it has become obvious that the task of designing institutions to implement programs or of modifying existing ones to accommodate new goals or strategies is exceedingly complex and subtle.

Although there is research scattered among the behavioral and social sciences on the issues involved in institutional design and change, it is fragmented and has had relatively little impact on those who design new institutions or on those in the field who implement the new programs. We find ourselves in an odd position: Government increasingly recognizes that understanding exactly how social processes work is usually quite difficult and that little of a common sense, *a priori* nature is valid; but it has less fully recognized that we also rarely understand how to intervene effectively. Thus, to change the relation between two social variables in some desired ways, we create an institution to affect a process we only dimly understand, using methods whose effectiveness is unclear. There is little reason to expect common sense to be much better here than it was in understanding the source of the original problem.

To be sure, what social scientists know about the design of interventions is limited, but I do not believe that this knowledge has been as successfully marshalled as have been our methods to develop knowledge about social processes. Of course, the latter techniques can and are being used to evaluate the effectiveness of different social "experiments." In addition, however, ABASS and other advisory organizations should devote considerably more of their effort to inventing intervention schemes, to predicting the consequences of proposed techniques of intervention, and to attempting to codify the known methods and their apparent successes.

Let me list some of the issues to which I hope we will turn our attention in the coming years:

1. *What are the goals of the intervention?* As we all know, the processes by which legislation is drafted, amended, and passed, and out of which agencies are created or given specific responsibilities, are complex and political. More often than not, several partially conflicting goals are embodied in the same legislation; and only rarely are these goals sufficiently specific to provide explicit guidance. The result is that the ultimate goals of the institution responsible for the intervention often evolve gradually over time, through political interactions between the institution and various elements of the society. We understand this process only dimly, but it is clearly a very important aspect of the evolution of a bureaucracy and very important in the success or failure of an attempted intervention. We need to study carefully the dynamics of evolving institutions, particularly their childhood and adolescence, the time when they develop their values and style.

2. *What are the possible strategies of intervention?* It is not difficult to catalogue some of the more commonly employed methods of intervention:

- Creating a regulatory agency, with various interventionist powers, including information transmission, setting of standards, enforcement of standards, effluent charges, sale of pollution rights, prohibition, and licensing and setting of fees.
- Creation of legal rights, including well-specified avenues of access to courts.

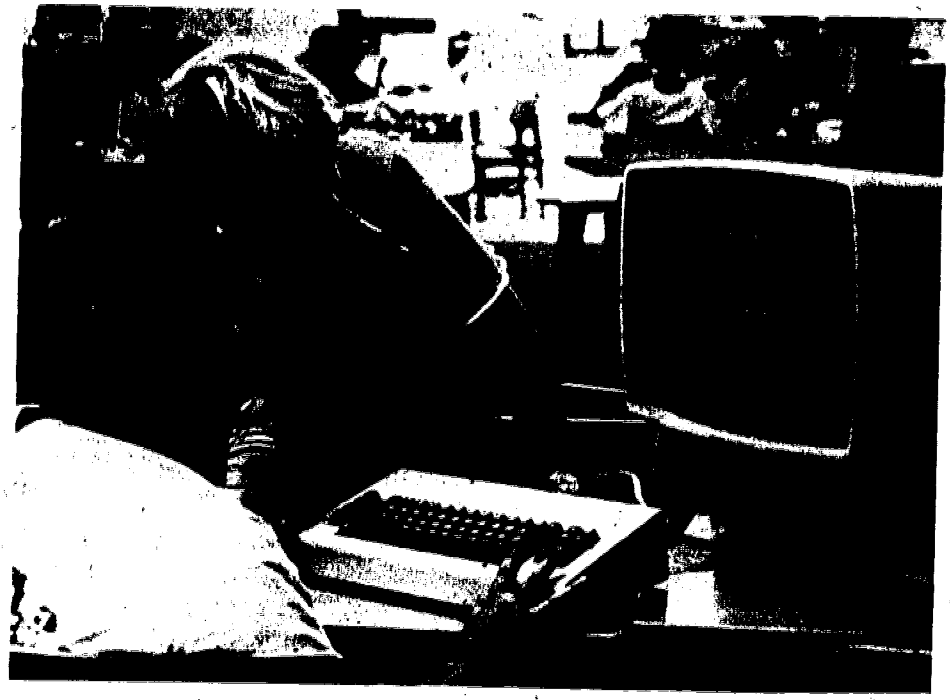
- Subsidization of specific groups, firms, or industries handled by specified agencies.
- Government-owned firms to produce specific products.
- Nationalization of particular industries.
- Government-financed services, such as the Veterans Administration, Medicare, Social Security.
- Tax policies.

Often there is little consensus about the type of intervention that should be adopted to achieve a particular set of goals. We are currently in the throes of just this problem vis-à-vis reduction of energy consumption. To take one explicit example: What techniques should be adopted in order to reduce the number of "gas guzzlers" on the road? Prohibit them, tax them, subsidize alternatives, try to create psychological pressure against them, or what? Aside from the political problem of attempting to select a balance between freedom of choice and long-range social goals, there is the fact that decision makers really do not have a very clear idea of what the consequences will be from the various strategies available to them.

I do not wish to suggest that social scientists know either—but I do think that it might prove useful to try to assemble what we know historically about various attempts to intervene and their results. The history of such attempts in our culture and in others is long and complex, and it is conceivable that some generalizations are either available or can be generated.

3. *Crash programs of research.* Our great engineering successes—the Manhattan project, Apollo, and many less spectacular ones, such as the design and construction of a modern weapons system or a large jet transport—are often held out as models of the type of organization needed to solve complex social problems. It is held that complex systems—be they the social network sustaining drug addiction, the failing structure of the inner city, the system of organized crime—are just that: complex systems. And as such, they should be susceptible to the finely developed systems techniques of the engineers and physical scientists.

Most social scientists fear that this approach, however good it may be for complex engineering problems, is doomed to failure when applied to social problems. The reason is not the great complexity of the social system, for by any reasonable count the inner city has no more components than a complex aircraft, but it is our very incomplete understanding of the



variables and the constraints on them—the dynamics of the process. Imagine the creation in 1700 of the equivalent of a $100-million, 10,000-person project to design a flying machine using the technology and physics of the day.

We suspect that it is more useful to be more modest. It is enough to try to systematize experience, to perform quasi-experiments, and to be happy when we induce a change of trajectory toward the desired direction.

4. *Pathologies of bureaucracies.* It is all too well known that the observed behaviors of institutions are often irrelevant to, if not in direct opposition to, their formal goals. One suspects that this tends to arise not out of perversity as much as from some sort of built-in or evolved structure of rewards for individuals within the bureaucracy. The phenomenon is so widespread that society cannot but ask itself in each case whether the pathologies that arise are such that it is better to live with the problem than it is to incur the long-range costs of the intervention; that the "solution" may be worse than the problem. At the very least, the information generated by such bureaucracies about the problems with which they are to deal, the impact they have had on them, and the nature of their own workings is most suspect.

I do not know how much knowledge there is about the misfunctioning of different types of institutions, but I am certain that it has not been properly marshalled for Congress and the executive branch.

Since I feel as I do about the importance of applying the knowledge of social science to the problems of social intervention, why has this not been a major fraction of ABASS activity? There are at least two reasons. First, there probably is not a large group of social scientists with the requisite interest and knowledge to bring adequate pressure on ABASS to go in this direction. Second, and I suspect somewhat more important, there does not seem to be a natural constituency willing to pay for such advice. Existing bureaucracies are not really very interested in being told they are not appropriate to their task or that they are carrying it out badly. We have tried, for example, to mount a committee to study the regulatory process in government, but we found no agency in the executive willing to fund it. The most natural constituency is Congress, but to date it has not provided itself with mechanisms for soliciting long-term advice of the sort I am suggesting it often needs. Although I think it would be foolhardy for the social sciences to offer any serious promises in this area might be possible to see whether there is enough knowledge and wisdom about the performance of institutions to improve somewhat on their design.

SUMMARY

There are two major types of advice an organization such as ABASS can try to give. The one that has preoccupied most of our effort over the past few years is on the nature of certain dynamic social processes. The major reason for gaining some understanding is to uncover potential sites for intervention in order to affect some social variable. I tried to outline in some detail the nature of the problems we have in studying such processes and why, so often, our answers are less than clear-cut. The other type of advice, for which we are little asked, concerns the design of institutions to effect the intervention. I tried to indicate both why this is at least as problematical as the questions we are asked, and why, as yet, we find it difficult to gain support for this work.

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Study Projects

ASSEMBLY OF BEHAVIORAL AND SOCIAL SCIENCES

POPULATION AND DEMOGRAPHY

One of the major changes in human behavior in some developing countries during the past twenty-five years has been a decline in the number of children born per woman. However, the decline in mortality has been even greater before and during these twenty-five years, so that total populations have grown in most countries. The population increase has raised emotional and rational concerns that have been looked at by many groups, including the National Academy of Sciences.[1] The NRC report, *World Food and Nutrition*, published in June 1977, commented:

> In the long run, no action is more important for improving the world food and nutrition situation than the reduction of birth rates. In view of this fact, we strongly recommend that the U.S. government sponsor a study to assess how U.S. research capabilities can best be applied to help countries desiring effective means of reducing birth rates.[2]

However, stating the problem is simpler than dealing with it. Many population policies and programs have been launched during the past twenty-five years, particularly since the mid-1960's, but the results and effectiveness of these programs intended to initiate or accelerate declines in fertility* are arguable. Moreover, there is a continuing debate, in the United States and the rest of the world, as to the best tactic. Three approaches are at issue:

- family planning† should be promoted as part of overall development, in an attempt to accelerate fertility decline;
- family planning is not enough: more basic social changes or more stringent measures, perhaps even coercion, are needed to reduce fertility rates in order to lower the rate of increase of population in low-income areas where population growth is rapid; or
- development is the only way to reduce fertility: fertility decline will automatically occur with development, and concern about population growth is a false issue or smokescreen to divert people's attention from real problems.

DATA DOUBTS

However, there are considerable uncertainties about the levels and trends of human fertility and mortality in developing nations now and in the recent past. For example, is the 1976 birth rate of Indonesia thirty-eight per thousand as reported by the Population Reference Bureau, forty-eight per thousand as reported by the Environmental Fund, or something else? How has the birth rate changed since 1970, when a major family planning program was initiated in that country? What proportion of the decline in fertility in Turkey since 1960 can be accounted for by changes in marital patterns, particularly rising age at first marriage? One recent (1976) review of available data on fertility trends in developing nations suggests that thirty-one countries, including some of the most populous, had estimated crude birth-rate declines of ten percent or more in the quarter century 1950–74.[3] However, the author, a member of the Committee on Population

*Fertility is used here in its demographic sense: the number of live births produced by a woman or by groups of women. This differs from the medical definition in which fertility refers to the ability to become pregnant; demographers refer to the latter as fecundity.

†Family planning means the provision of fertility regulation supplies and services, plus training, education, promotional and infrastructure-improvement efforts designed to increase the coverage and use of the offered supplies and services.

and Demography, points out some of the problems associated with the information on population size and on the numbers, rates, and trends of births and deaths. For example, "estimates of China's population vary by 100 million; those of Nigeria by more than 10 million. . . . A few countries have never taken a census and others have only recently begun to take censuses." In many developing nations "registration systems are inadequate and inaccurate, and systems for estimating such numbers and rates are only moderately good, and often their application is both variable and deficient."[4]

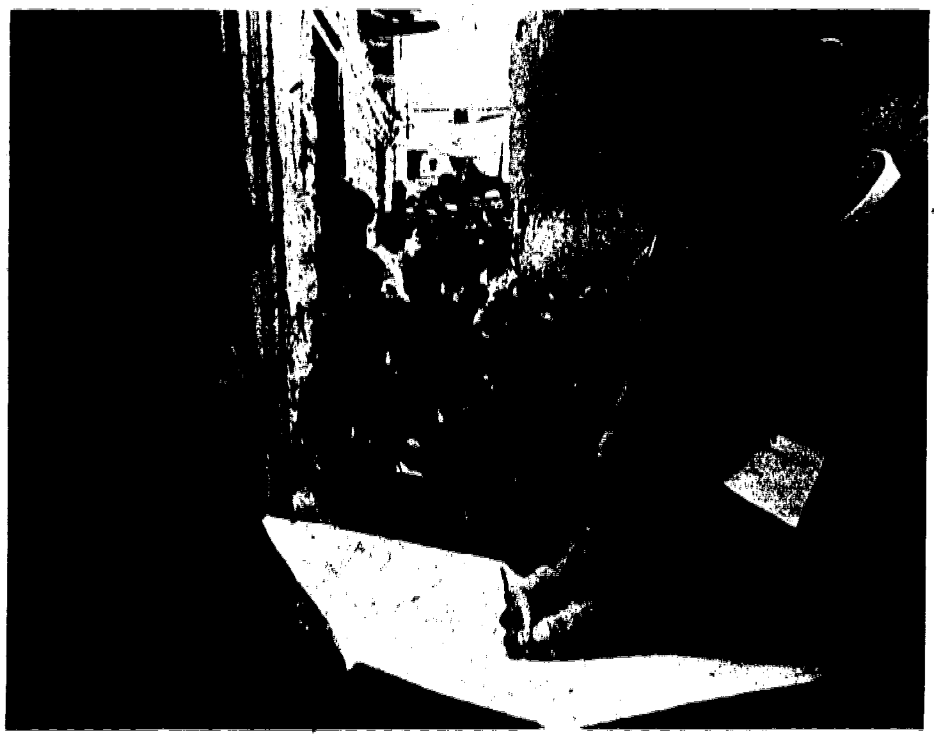
In short, a major set of social phenomena (changing fertility and mortality patterns) creates problems that many feel must be addressed by explicit programs (such as family planning, increased maternal and child health efforts, government policies to liberalize abortion laws); and yet our knowledge about the levels and trends of fertility and mortality in countries in the developing world is unsure. The very trends the programs are designed to affect are not measured by reliable statistics, and are differently estimated by different observers.

Against that background of a problem, possible remedies, and uncertain data, the Agency for International Development (AID) asked the National Research Council to create a committee to study fertility and mortality levels and trends in developing countries. The Committee on Population and Demography, of the Assembly of Behavioral and Social Sciences, was accordingly established in April 1977 for three years.

This move by AID coincided with a belief among professional demographers in the United States in the value of an expert assessment of the technical problems in estimating fertility and mortality, and an analysis of the validity of different estimates. As a result, the committee has taken on three primary tasks:

1. estimate levels and trends of fertility and mortality;
2. improve the technologies of estimating fertility and mortality when incomplete or inadequate data exist (including techniques of data collection); and
3. evaluate the factors determining changes in birth rates in less-developed countries.

The committee began with the first two tasks, and its first major



project was to undertake intensive studies of countries of particular interest to institutions and groups concerned with international development, particularly countries for which there is considerable uncertainty concerning levels and trends of fertility and mortality and where there is interest within the country in the objectives of the committee. These countries include: the Philippines, Indonesia, Thailand, Malaysia, Korea, India, Bangladesh, Pakistan, Iran, Turkey, Egypt, Tunisia, Algeria, Mexico, Colombia, Brazil, and, as groups, countries in tropical Africa, Latin America, and the Middle East.

JIGSAW PUZZLE

For these intensive country studies, the committee is assembling data that may reveal clues about levels and trends. These data include incomplete registration,* age distributions from censuses or large-scale surveys, data on all children born and children surviving, and any detailed fertility histories collected from a large sample. Tests of consistency among estimates based on different sources will be particularly important.

The intention is to view all such information as pieces of a jigsaw puzzle that, assembled, will give the best overall picture of demographic levels and trends for a particular country. One expected result is that in some countries the fertility levels will be estimated only within rather wide ranges, and the existence of trends may be uncertain because of insufficient or inadequate information.

However, as part of the committee's second task, an effort is being made to improve available techniques and devise new ones that will squeeze as much information as possible from existing data, however sparse or incomplete, permit collection of data at feasible cost, and provide estimates of the accuracy needed. There are only a very few senior scholars giving primary attention to the improvement of current techniques and development of new methods for estimating fertility and mortality from scanty data. They are members of the Committee on Population and Demography, notably Ansley Coale, Professor and former Director of the Office of Population Research, Princeton University, and William Brass, Director of the Centre for Population Studies, London School of Hygiene and Tropical Medicine. Younger scholars with similar intellectual interests are also represented on the committee and staff, and several others have been asked to serve on specific country panels or otherwise assist the committee.

SQUEEZING THE DATA

Efforts to estimate fertility and mortality in developing nations are often hampered by an inadequate grasp of how to apply demographic techniques designed for use with incomplete data. The usual result is that information from population surveys, registrations of births and deaths, and censuses is not fully used as a data source to estimate levels and trends of fertility and

*Incomplete registration refers to the situation in many developing nations where not all births and deaths are registered, i.e., a birth or death certificate obtained, or at least having the event recorded, and the resulting information summarized in a civil registration system.

mortality. The committee believes its program—particularly the work of panels created to carry out the intensive studies, and the publication of results and methods—will serve an incidental educational purpose, by training more demographers and statisticians around the world in methods of estimation and data collection.

THE THAI EXAMPLE

An example may make this point a bit clearer and illustrate an intensive country study. One of the committee's panels will make estimates of fertility and mortality levels and trends in Thailand. The panel has six members, including the directors of three Thai population institutions. These directors will bring selected Thai colleagues, including junior scholars, to a workshop in June 1978. In preparation for the workshop, participants are applying demographic techniques for using incomplete or inadequate data to six sets of population data on Thailand:

1. Population Censuses of 1947, 1960, and 1970;
2. Vital registration—births by age of mother and by birth order, deaths by age, for as long a continuous sequence of years as possible, to the most recent year possible;
3. Surveys of Population Change, 1964–67 and 1974–76;
4. Longitudinal Survey of Social, Economic, and Demographic Change, 1969–73;

5. Field Worker Evaluation Survey, 1971; and
6. World Fertility Survey, Thailand, 1975.

Ten demographic methods are being applied to these data to extract the maximum information. Three completed examples may be useful:

• The completeness of birth registration was checked by comparison with information on children ever born available from the 1960 and 1970 censuses, a methodology developed by committee staff. The technique is also to be applied to the data from the second Survey of Population Change. A method developed earlier by William Brass, a committee member, for comparing the birth order composition* of registered births against a suitable reference standard can also be applied.

• Child mortality was estimated from the proportion dead† among children ever born by age group of mother, with data taken from the 1970 Census, the 1974–76 Survey of Population Change, and the 1975 World Fertility Survey.[5]

• Recent fertility was estimated using maternity histories‡ from the World Fertility Survey, the Longitudinal Survey, and the Field Worker Survey. Fertility was also estimated for earlier time periods for comparisons with other sources. The maternity histories were examined for errors in dating events when women answer questions about the history of all births they have experienced.[6]

DATA GATHERING

The committee is also preparing a simple "cook book" manual on the application of methods currently available for making estimates from data that are either incomplete or inadequate, or both. There are about

*Birth order composition is the distribution of births in a given time period (usually one year) by birth order—some are first births, some second births, some eighth births, and so on. Obviously, the distribution will vary considerably among age groups.

†Proportion dead refers to all children born alive but who subsequently died, expressed as a proportion of all live births. For example, if among 1,000 live births, 200 die within their first five years of life, the proportion dead at exact age five is 0.20.

‡A maternity history is a record of pregnancies that a woman has experienced, including information on date of birth or other outcome, sex, still living or not if a live birth, and so on.

seventeen methods, ranging from analysis of age distribution by stable population methods to use of the numbers of children ever born, classified by duration of marriage of the mothers, and to analyses of data on orphanhood and widowhood as reported in censuses or surveys.

How the data are gathered is itself an important aspect of making estimates of levels and trends of fertility and mortality in the countries studied by the committee. If, for example, the information gathered in a survey or census is based on an inadequate sample or includes poor data because of inadequate interviewer training or inaccurate translations among two or more languages in a country, then the estimates made from such information probably will have errors. Turning the process around, sometimes the addition or substitution of a small number of simple but specific questions can generate data from which a great deal can be learned about fertility and mortality patterns. In the 1960's, William Brass showed the power for estimation purposes of asking simple questions in surveys and censuses on the numbers of children born alive and the numbers surviving, by sex. These are now referred to as "Brass questions," and are used frequently but not universally in surveys and censuses in countries lacking complete registration of births and deaths.

Given the importance of data collection related to fertility and mortality estimation, the Committee on Population and Demography created the Panel on Data Collection, chaired by William Seltzer, Assistant Director-in-Charge, Demographic and Social Statistics Branch, United Nations Statistical Office, and a member of the committee. This panel includes three other committee members and four scholars with extensive experience in data collection in developing nations. For example, one member is Jacques Vallin, who brings to the panel his experience with the French demographic community's approaches to data collection for fertility and mortality estimation. The objective of the Panel on Data Collection is to assist the Committee on Population and Demography in its task of developing recommendations in the improvement and standardization of techniques for the estimation of fertility and mortality levels, trends, and patterns in developing countries. To this end the panel will focus on methods of improving the accuracy, coverage, timeliness, and reliability of such estimates through improvements in the collection of underlying data. The methods may range from improvements in data collection procedures that can be applied immediately to long-term processes that take many years to bring into fruitful operation.

As an initial step, the panel is preparing a document reviewing population census, civil registration, and sample survey experience. This will be a state-of-the-art report on available procedures and problems of special relevance to the estimation of fertility and mortality. The work will cover:

1. basic design of collection process;
2. organizational context;
3. questionnaire content and design;
4. staff selection, training, and supervision;
5. methods of processing, including editing and tabulation;
6. methods of storage and dissemination;
7. quality control and evaluation procedures; and
8. resource and cost considerations.

The Committee on Population and Demography is coordinating its work with other units in the National Reseach Council on topics and activities of mutual interest and concern; for example, a 1978 symposium by the Assembly of Life Sciences on contraceptive technology, a study by the Institute of Medicine on health needs in Egypt, and a study by the Commission on International Relations on population, health, and nutrition.

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ROBERT J. LAPHAM

Committee on Population and Demography, Assembly of Behavioral and Social Sciences. Committee Chairman, Ansley J. Coale of Princeton University; Study Director, Robert J. Lapham.

REHABILITATION IN CRIMINAL JUSTICE

Criminal justice policies have been the focus of considerable controversy in recent years. Often the policy choices turn on assumptions about human behavior as well as on questions of value. For example, the classic philosophical issue of the justice of punishment might be answered in Kantian terms: that retribution is an end in itself. But it can also be justified in utilitarian terms: that punishment has a deterrent or rehabilitative effect on future behavior, or both.

The utilitarian view presumably requires proof of instrumental effect. But the debate over such issues is often ideological, with the result that key assumptions about behavior tend to be obscured or treated as matters of conventional wisdom rather than as hypotheses that need to be tested.

Addressing these behavioral assumptions has been the task of two panels of the Committee on Research on Law Enforcement and Criminal Justice of the Assembly of Behavioral and Social Sciences. The Panel on Research on Deterrent and Incapacitative Effects has completed an analysis of methodological issues underlying the measurement of some effects of sanctions policies.[1] The Panel on Research on Rehabilitative Techniques is now reviewing the methodological problems involved in evaluating the effectiveness of correctional rehabilitation programs. The following is a discussion of some of the issues being considered by the latter panel.

THE PROBLEM

A brief overview of the debate is necessary to set the context of the problem. For many years, a philosophical commitment to rehabilitation has dominated correctional policy in American criminal justice. This commitment is seconded by the theory of rehabilitation that holds that an individual's propensity to repeat criminal behavior can be controlled by "treatment." However, crime rates have been increasing and recidivism rates—the traditional measurement of success or failure in corrections—remain high. The result is that the goal of rehabilitation is being seriously challenged.

The nature of the "treatment" involved in rehabilitation programs can vary considerably. Some people view criminal behavior as a disease or an illness, and have therefore defined rehabilitation as a way to "cure" the criminal offender of his potential for criminal behavior. Others see rehabilitation more as a form of specific deterrence in which the treatment program is designed to change, or correct, the behavior, whatever its cause. The former, often called the "medical model" of rehabilitation, relies primarily on a variety of individual and group therapy programs, ranging from traditional psychoanalytic therapy to encounter groups. The specific deterrence approach leans more toward behavior modification techniques. The point of behavior modification is to manipulate the motivations of a group of individuals by structuring incentives to encourage a stable community. Between these two approaches—that of the medical model and of specific deterrence—are programs designed to remedy defects in the individual's educational background. These range from remedial training in reading and other learning skills to job training.

The medical model and specific deterrence are both rejected in the current controversy over the effectiveness of rehabilitation. Behavior modification has been attacked as a punishment that disguises its coercive functions by cloaking them in the mantle of science; critics argue that this is an attempt to legitimize punitive techniques and is therefore a form of scientism. The medical model of rehabilitation is rejected on the grounds

that compulsory therapy violates individual rights and deprives both the offender and society of "just deserts." Thus, the two rehabilitative techniques are being challenged not in scientific terms, but because their aims are not consistent with what are argued to be the proper goals of the justice system.

ANALYSIS

But underlying this debate over values is the growing belief that "rehabilitation," however defined, is not working. And this statement—unlike arguments over the proper goals of the justice system—is, in principle, subject to scientific investigation. Unfortunately, even a cursory review of recent literature on corrections indicates that reliable knowledge about the effects of rehabilitative techniques is difficult to obtain. Almost all studies of the results of various treatments lack experimental validity, largely because these studies are done in "real" settings where scientific methods are easily, often necessarily, compromised. A recent review of these studies, which are mostly evaluations of rehabilitative programs, has concluded: "With few and isolated exceptions, the rehabilitative efforts that have been reported so far have had no appreciable effect on recidivism."[2] This review itself is now a center of controversy among policymakers and researchers interested in rehabilitation. Policymakers are considering whether rehabilitative programs should be continued, changed, or terminated; while researchers are debating the validity of conclusions drawn from admittedly inadequate studies.

The Panel on Research on Rehabilitative Techniques was established to clarify the difficulties of measuring the effectiveness of treatment programs, to review existing evaluations to determine if they can provide reliable knowledge about the effectiveness of rehabilitative techniques, and to recommend methodological strategies for evaluating treatment programs.

BARRIERS TO KNOWLEDGE

A variety of complex, possibly intractable, problems makes it difficult to obtain reliable knowledge about the effectiveness of rehabilitative techniques in corrections.

The first kind of problem arises because of the institutional setting in which most correctional programs are attempted. The institution is necessarily a coercive one—a prison. Voluntary participation in programs, usually important to the logic of the "treatment," is often illusory, since participation is understandably equated with cooperation and is therefore perceived by inmates as a stepping stone to early parole. In addition to ambiguities about motives, research in prisons can be contaminated simply because it is difficult to separate out the effects of rehabilitation from those of punishment. Aversive conditioning in behavior modification programs may be sound in theory and even acceptable in practice, and may also produce cooperative or otherwise "rehabilitated" behavior by inmates; but whether the induced behavior is the result of punishment or of rehabilitation is not clear. It is necessary to separate out these effects, because, for example, programs that have useful short-run results—e.g., the prisoners are more docile—may be adopted even though there are no lasting influences on postprison behavior.

Research that takes account of these kinds of problems has not been undertaken, in large part because it must be done with the cooperation (and often the funding) of prison administrators, who, as a group, have a narrower interest in the use of research and evaluation. In particular, there is the potential for conflict between the two goals of rehabilitation and prison stability. A department of correction or a particular prison administration may adhere to the overall goal of rehabilitation and may even be very supportive of developing treatment programs in the institution; but the uses of these programs may be different from or even be inconsistent with rehabilitation. The most pressing institutional goal is always stability, and treatment programs serve that goal very well: they keep inmates occupied, focused on personal problems rather than on the world outside, and generally pacified by the attention paid to them by virtue of the "treatment." In such a situation, treatment programs tend to adapt to the institutional goal rather than developing the inmate's capacity

to maintain a normal and lawful life outside the prison. Using recidivism rates to measure the effectiveness of such programs is not a valid test of the effectiveness of rehabilitation.

Another institutional constraint blocking sound evaluation is the lack of fit between treatment programs and the rehabilitative needs of inmates. Most prisons have neither the resources nor the incentive to mount a major diagnostic effort. Furthermore, institutions normally do not command the variety of skills necessary to offer different treatments. Once a particular treatment gains some currency, an institution is likely to commit all or most of its available resources to it rather than establishing a variety of programs. Consequently, there is little effort to determine whether a particular inmate is amenable to the treatment programs being offered, with the result often being a poor fit between a prisoner's needs and the treatment program. Evaluations of the relationship between participation in such programs and recidivism again cannot provide a valid test of the effectiveness of rehabilitation.

The problems discussed so far are rooted in institutional constraints. Some of the most interesting efforts at rehabilitation in recent years have been noninstitutional, including work release programs, various forms of small-group homes, and community support programs aimed at helping the former inmate adapt to the outside world. Evaluating the effectiveness of these programs outside the prison also has its own and distinct problems. The chief difficulty in separating out treatment effects is the difficulty of controlling for all the variables that affect individual behavior, including family and group interactions, availability of school or employment, and many other factors. Existing studies suffer from serious methodological defects that could be mitigated if programs were designed and implemented properly.

Finally, it is necessary to consider the broad question of what outcomes are appropriate as measures of success. The emphasis has always been on recidivism rates, for the obvious reason that rehabilitation means that the offender will not return to crime. There are many problems in measuring recidivism, however. For example, data that are available from normal reporting sources—police, prosecutors, court records—are not standardized across jurisdictions with respect to any definition of what counts as a repeat offense. This is a generic problem that is compounded by variations in recording and reporting procedures, law enforcement practices, and individual perceptions of the relative seriousness of deviant acts. Other factors, such as defining and standardizing the appropriate lengths of time to be used for follow-up observations, contribute to the problematic nature of recidivism rates in measuring the effects of treatment programs.

But if recidivism rates are not used, what outcomes do indicate success or failure? Some would argue that institutional goals of stability and humaneness should dictate the measures to be used, because these goals are important in themselves and programs that achieve them should not be discontinued on other grounds. It is also argued that a complete turnabout in behavior is too much to expect in most cases, and that less dramatic effects should be measured and considered in determining the success of a program.

In any case, selecting a particular outcome to measure the results of a rehabilitation program is as problematic as the question of rehabilitative effectiveness itself. Research on rehabilitative techniques is still in an early stage of development. The purpose of the Panel on Research on Rehabilitative Techniques is to clarify these complex methodological issues and to identify the most fruitful avenues to follow in order to advance our knowledge in this field.

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SUSAN O. WHITE

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Assembly of Engineering

Technological Innovation and National Priorities*

N. B. HANNAY

Innovation in new products and services is central to the process by which an economy grows and renews itself. Also, technological innovation is an important element in international trade and the balance of payments. Innovation and productivity are closely interlinked, as cost reduction and efficiency gains arise mainly through innovations in methods for production and distribution. Innovation is also required for progress with issues of great urgency for the United States—energy and materials resources, the environment, health and health care delivery, transportation, and many others. Opportunity for application of science and technology was never higher.

The national capability for innovation is a legitimate matter for public concern. The public is the ultimate beneficiary of technological innovation,

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and the public will be the loser if there is any decline in our capacity for innovation. Most of this innovation must come from industry.

THE PROBLEM

The headline over an article[1] in *Business Week* read: "The Breakdown of U.S. Innovation." Another[2] called attention to "The Silent Crisis in R&D." In a report[3] to the U.S. Senate, R. Gilpin opened with the statement that "technological innovation in the civilian industrial sector of our economy is at a critical point." Jean Gimpel[4] states, "The collapse of U.S. innovation will bring down U.S. society." These are ominous declarations.

Certainly, there are increasing uncertainties in industrial research. Many companies feel that there are decreasing incentives for innovation. The climate for innovation is less hospitable. This includes not only the economic climate, but also all the incentives and the barriers that are intentionally or unintentionally supplied by a range of government activities and interventions in the process of translating science into application. I believe that it is a matter of national necessity to strengthen the U.S. innovative capacity. Fortunately, national attention is finally being given to the problem.[5] Unfortunately, national actions and policies remain a major part of the problem.

What are the signs that indicate this decline in our innovative capacity? Some are to be found in the various measures of the U.S. economy, and the role technology is currently playing in supporting its growth.[6] The growth rate of the Gross National Product (GNP) has been lower than that of other industrialized countries. The rate of increase in productivity is the lowest for any of the major industrial countries, and is at its lowest level in one hundred years. Business investments and trade figures also reflect this lower growth rate.

U.S. total R&D (all funding sources) in current dollars totaled an impressive $41 billion in 1977, continuing its strong upward trend; this is more than double the 1965 figure. In constant dollars this represents little or no change over this period, however. As a percent of GNP, it shows a strong decline from its peak in 1964 and no longer leads other countries. Moreover, a substantial part of the U.S. R&D goes to defense and space, whereas relatively little does in such countries as Japan and West Germany.

In 1977, U.S. industry will have spent $17.5 billion of its own funds on research and development for commercial markets. However, in constant dollars there has been a small decline in the last few years.

This $17.5 billion is highly concentrated, with some eighty-five percent of the R&D expenditures in just six industries—electrical equipment and communications, chemicals and allied products (including pharmaceuticals), machinery (including computers), motor vehicles, aircraft and missiles, and instruments. Only thirty-five companies spent $100 million or more on R&D in 1976. The top fifty companies in R&D expenditures accounted for over three-quarters of the industrial total, and the top four companies for nearly one-quarter of the total. Company-funded R&D, as a percent of sales, shows substantial variation. Some five industries, often called "high technology," are in the three to four percent range or higher (aircraft and missiles, electrical equipment and communications, instruments, chemicals and allied products, and machinery). At the other extreme are companies showing only a few tenths of a percent, or less.

Thus the gross totals for industrial R&D are mainly the result of a few industries and companies with substantial commitments to R&D, while large segments of industry contribute little.

Basic research is even more concentrated, with two-thirds of the 1974 expenditures in just two industries (chemicals and allied products, electrical equipment and communications). The total basic research funded by industry is around $600 million, representing a twenty-three percent decline in real spending over the last twelve years. At the same time, national totals for basic research have held essentially constant, so our concern is directed to the industrial portion.

The U.S. balance of trade is favorable in industries that are R&D-intensive, and it is unfavorable in industries that are not. Products in the deficit area included motor vehicles, textiles, and metals, among others. Computers, machinery, aircraft, chemicals and drugs, and electrical equipment contributed on the positive side.

Numbers don't tell the whole story. We must look also at the quality of industrial R&D. Innovation is of several kinds. There is incremental, or "nuts and bolts," innovation, and while this can be worthwhile, it isn't very exciting. A substantial part of this is aimed at process improvements, and this is useful and understandable in these days of high costs.

However, much of the product work is basically little more than product differentiation. Many companies do nothing more and not only survive, but flourish. But innovation at this level will hardly move us forward to new levels of social well-being, nor will it add significantly to our economic strength. Its main purpose is to achieve a favorable shift in market share, or to counter a similar move by a competitor.

More fundamental innovation results from major technical advances. The transistor, synthetic fibers, antibiotics, Xerography, the digital computer, the Polaroid process, and the laser are examples. In such cases, there is a quantum jump to a new level of technological accomplishment, and major economic or social benefits flow from the innovation. It takes an inspired idea to start the process and, usually, a great deal of sustained, dedicated, organized effort to turn the creative idea into a practical reality. Yet this is where the rewards are greatest, for both society and the organization that makes the innovation. It is here that U.S. industrial research has accomplished so much, providing the impetus for our industrial progress.

The central issue is the decline of the U.S. industrial research capacity for this sort of fundamental innovation. Important innovations for the civilian sector often are the result of a commitment to R&D in which the reward comes in the long term. But, only a few companies in a few industries are willing to support basic research and take the long-term view that is needed for major new innovations. In much of industry the R&D is directed to short-term goals. Thus, even though industry funding of R&D is substantial and growing, the commitment to fundamental innovation is absent or has declined in broad segments of industry.

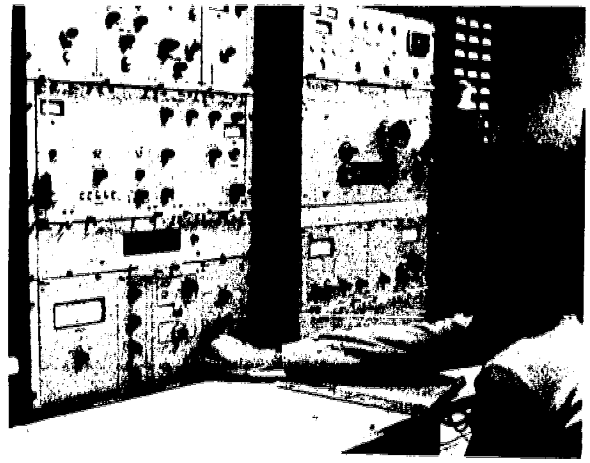
The innovation process is full of risks. It can be expensive. In the innovation of major new products, R&D may amount to less than ten percent of the costs. The expensive part of the innovation process is not invention, but engineering, tooling and start-up for manufacture, and market development. Should one then conclude that R&D for this kind of innovation is not worthwhile? I would draw the quite different conclusion that research and exploratory development, which provides important options for innovation even though not all of them are carried through to completion, is a bargain. However, the payoff is most often in the long term.

Many companies find major innovations to be less attractive today than they once did. Despite the fact that the R&D is not a major part of the cost of such innovation, it still costs something. When management has decided that, for any reason, it is less interested in major innovations, then forward-looking, risk-taking, long-term R&D suffers. There has been a significant and alarming decrease in the willingness of industry to undertake and support the kind of research that has the least certainty of success but the greatest potential payoff. Not many of our industrial contemporaries are talking about exciting new major discoveries that they think will change the world. The outlook has become more focused on defensive activities. Admittedly, there are strong forces working against innovation and the research that leads to it. But, in my view, industry should not succumb to these, and the government should give high priority to reducing these negative forces.

THE REASONS

There are several reasons for this change in the character of industrial research. First, and most important, are a number of related financial factors. Inflation and the cost of money has made it much more expensive to undertake R&D and to launch new ventures, and this had led companies to concentrate research efforts on cost-cutting activities—cheaper manufacturing processes, lower cost designs, labor-saving production methods, and so on. The high cost of capital for investment in new plant equipment means that a very high rate of return is required for an innovation to pay for itself. A substantial part of the capital that is available for investment in new plant is being committed to pollution control, and there is no financial return from this. Most important is financial uncertainty, stemming from high and rapidly changing inflation and interest rates, changing tax policies, and concerns about other elements of costs and markets.

Unless the innovation is expected to be profitable, it won't happen. A key characteristic of major innovations is uncertainty, both in the R&D stage and in creating a new market. If to these uncertainties is added an uncertain financial climate, the risk is correspondingly greater. The safe course, many think, is to adopt a defensive position, risk as little as possible, and seek to hold market share while keeping costs to a minimum. This leads to a strategy that concentrates on incremental innovations, where start-up costs are relatively minor. The financial advantage is much more certain, though smaller, and the return on investment comes sooner, though it is lower. Many companies have moved in this direction, including some with impressive past performances in innovation.



The unfavorable financial climate also discourages formation of new venture companies, most of which are based on an innovative idea. In 1972, there were more than one hundred such technical companies going into the market with new issue underwritings each year. In 1974, there were just four, and in the first six months of 1975, there were none.

Uncertainty over possible changes in tax law plays a part, also. Some proposals being advanced would make investment in innovation even less popular.

The Economist (of London) said,[7] "America is set for industrial senility unless its industrial investment rate goes up." That rate is now the lowest of any industrialized country, including Great Britain.

There are other government policies and activities relating to innovation. One is support of research. The federal government has, since World War II, funded most of the basic research in the country, largely in universities. This federal support has, of course, provided a firm foundation for all applied science programs, both federal and industrial. Industry strongly supports federal sponsorship of these programs.

The federal government has also successfully sponsored applied science in support of its own missions, notably defense and space. More recently it has sought to affect civilian technologies directly through support of applied science. But this is a different matter; here the government is less successful. The pluralistic nature of the federal government makes it difficult to agree on priorities and common purposes. Lacking the close coupling to the consumer that is provided by the marketplace, the government has no feedback mechanism to tell it what is succeeding and what is failing in choosing and managing R&D for commercial markets. A private enterprise has to be reasonably efficient at satisfying the market, or it soon goes out of business.

Another problem with government R&D and commercial technologies is that there is some tendency for private industry to reduce its expenditures in areas where government funding is increasing. To the extent that this occurs, it becomes merely the taxpayer paying for the R&D, instead of private industry. Government R&D spending obviously should complement private spending, not replace it.

Regulation clearly has an effect on innovation,[8] and the effect can be either positive or negative. An example of a positive effect on innovation is the new technology for pollution control that has resulted from environmental regulations. Regulation has a negative effect when it diverts R&D funds to work designed only to meet regulatory requirements and involving no significant new technology. In many industrial R&D programs, the portion of the budget allotted to meeting regulatory requirements is generally unproductive with respect to innovation.

The drug industry furnishes an example of regulatory impact. It is the industry which leads all others in terms of research as a percent of sales. Yet the number of new drugs marketed each year in the United States has decreased by a factor of four in the last twenty years. At the same time, there is no shortage of ideas for new pharmacologically active substances. The discovery of novel structure-activity relationships is no less frequent. The introduction of new drugs has not fallen off in Western Europe.

There has been an enormous increase in this twenty-year period in the effort to meet FDA requirements, which govern the methodologies for testing drug safety.[9] As an indication of the way these have changed, in 1938 an application for adrenaline in oil was presented in 27 pages. In 1948 an expectorant was described in 73 pages. In 1958, 439 pages, in 2 volumes, were required to describe a treatment for pinworms. In 1962 an oral contraceptive application ran to 12,370 pages, bound in 31 volumes. By 1972 a skeletal muscle relaxant involved 456 volumes, each two inches thick—seventy-six feet in total thickness and weighing one ton. The time to get a drug to market has greatly lengthened, and the cost has risen dramatically.

No one would argue against the need for drug safety and tight testing and reporting requirements. However, consumers are also vitally interested in the innovation of new drugs. At the least, it is time to reexamine the balance between the rate of innovation and safety standards. As stated in *Business Week,*[10] "regulation itself may become the nation's most serious health problem."

It is not regulation that is the issue. Rather, it is the imperfections of the regulatory process. Regulations are promulgated when the scientific facts are still unclear. When they do become clear, there is often no way to turn back from an ill-advised regulatory action. Regulations ignore economic logic when enormous additional costs are required for a minor additional benefit. Delays are introduced into the innovation process. The impact on innovation is generally not considered in setting regulations.

Antitrust threats inhibit certain activities that might promote innovation. Cooperative research between companies is effectively barred, as few company lawyers would let their firms assume the risk. Antitrust relief could encourage firms too small to sustain separate fundamental research efforts to undertake cooperative basic studies, or it could foster cooperation between companies with complementary talents. Also, we are now witnessing an assault on some of the most innovative private firms, with the goal of altering their essential structure, which, of course, has been central to their innovative success.

Patent policy is central to innovation. In one important respect, it is counterproductive with respect to innovation. Federal contracts for R&D generally require that any patents that flow from the work be available to all. The idea is that since publicly funded R&D led to the patent, everyone should be able to use it. The trouble is that what belongs to everybody is usually of interest to nobody, because the much larger investments necessary to manufacture and develop the market for a new product are unlikely to be rewarded by a satisfactory return on the investment, in the absence of an exclusive license. The result of patent clauses in federal contracts for R&D is that many patents that might otherwise be commercially exploited are unused.

Tax policy at present is mostly neutral with respect to innovation, providing some encouragement as well as some discouragement; but there are pressures to make it more negative. Some of the relevant tax issues are the treatment of capital gains, investment credits, depreciation, and the tax treatment of R&D expenses in multinational corporations. Our international competitors use tax incentives as a stimulant for innovation.

There are some other reasons for lack of faith on the part of industry in long-term research payoffs, unconnected to federal actions and policies. One is doubt about the appropriability of the research. The firm paying for it sees the possiblity that its competitors will be able to take advantage of the research almost as fully as the firm itself—without paying for it. But there is a strong counterargument. Basic research supplies background knowledge in the fields of interest to the firm. If it is published in the scientific literature, it does become available to the firm's competitors; however, only the people who actually do such research can have a full and early appreciation of its implications and potential value. Also, they are better coupled to academic research and in the best position to take advantage of its findings. When the long-term research suggests invention, there is lead time for its exploitation. The patent system provides ownership of the intellectual property created in the invention.

Many studies[11] have attempted to correlate growth with R&D. What seems to be rather generally true is that those industries which are R&D-intensive are the ones with the most rapid growth. Rates of return on investment from specific product innovations are estimated to average between ten and fifty percent per year, while returns on innovation leading to productivity growth are in the thirty to fifty percent per year range. This sounds ample, but with present money costs and inflation rates, it takes something like this to be attractive.

THE REMEDIES

There is a legitimate role for the federal government in stimulating innovation, but it is not the one most frequently proposed in Washington. The usual proposed cure for the inhibiting effects of government interventions in the market system is further interventions. The most useful thing the federal government could do is to stimulate the private sector to invest its own human and financial resources in innovation. While the risks, uncertainties, and costs of innovation have been increasing, there has been no compensating increase in incentives for undertaking innovative activities. The major thrust of policy intended to stimulate innovations should be on the production and marketing stages, where most of the costs and risks fall.

One of the most important elements in the relationship of government and industry is uncertainty. Changing government attitudes, policies, and regulations create a climate of uncertainty. The net effect is a shortening of the time scale on which a business makes its plans. But a long-term outlook is required for the process of transforming basic research and invention to a marketed product or service, and a heavy investment, both expense and capital, is involved before there is any return on the investment. If there is doubt as to whether federal actions will change the environment substantially before the process is completed, the innovation is not likely to occur.

One of the most important ways the government could foster innovation is to reduce this uncertainty. Although economic instabilities are probably most important and need primary attention, the provision of a greater degree of stability and wisdom in regulation and antitrust is also urgently needed. It would be possible to reduce the inhibiting effect on innovation without loss of any essential benefits provided by regulatory and antitrust laws.

The problems of capital formation and private investment in innovation are closely tied to such matters as tax policy, accounting rules, subsidies, and loans. This is a complex subject, but it offers significant possibilities for the stimulation of private investment in technological innovations.

A mechanism that has been proposed but seldom exercised is the use of government procurement to stimulate private investment. This is a potentially powerful lever, as the government is a very large buyer of consumer goods, health care, services, and so forth. This suggests that procurement could be used to provide a market for innovative products by reducing market entry risks for suppliers. Exploratory tests of this concept look very promising.[12] The government gets new or improved products, which also become available to the public. There may be a substantial savings in cost to the consumer. And the R&D is privately paid for, rather than by the taxpayer. Mechanisms like procurement are attractive because they focus on what the government can do with reasonable efficiency, that is, specify the result wanted. They do not depend upon what the government cannot do as well, which is to determine the method for getting the result.

Patents resulting from federal R&D contracts could be a source of innovation, through provisions for exclusive licensing.

Selective federal support for R&D for civilian technologies can be justified. Criteria for selection might include such characteristics as: a highly fragmented industry structure, the need for an R&D project on a scale beyond the capability of a single company, the need for R&D to develop a technology with little commercial potential but large social importance, and a national urgency that cannot be met by privately funded R&D.

There is a close linkage between innovation and productivity, and productivity gains are important to economic health. The U.S. has higher productivity than other countries, although the growth rate of its productivity is lower. Any policy that discriminates against investment also discriminates against productivity increases.

The advanced technology that increases productivity is concentrated

in a few high-technology and/or capital-intensive industries and firms, and in agriculture. Many smaller firms, and a number of basic industries, don't have the same access to the new technology that allows these productivity gains. We need to find mechanisms for extending to these industries the productivity gains that are clearly possible. It seems likely that specific directions of federal programs could aid in this. One way this might be done is through increased support of research and education in industrial engineering and manufacturing processes. A federal program of information transfer to smaller companies would be useful; there is evidence that many of them do not know what is possible in manufacturing technology. Some of the most significant gains in productivity will undoubtedly arise from innovations in the application of computers to the management and control of manufacturing processes and industrial operations.

CONCLUSION

Several points deserve reemphasis. First is the necessity for strengthening the U.S. innovative capacity in the civilian sector. The health of our economy, with all the attendant consequences of increased employment, improved standard of living, and progress in social areas, unquestionably depends upon this innovation. Innovation is not being given a high enough priority at the national level.

Second, innovation in the private sector will come only if there is greater effort on the part of both industry and the government. We cannot expect federally guided and funded research to provide the initiative—it lacks the focus and the connection to the ultimate user. What can be done federally is to create a better climate for privately funded innovation. At the same time industry has to show faith in its own future. Any industry that believes it has a future should be willing to invest something in that future and in longer-term objectives. We must ensure that the technological achievements of industry in the future are a match for those of the past. And, we must see to it that government constraints do not limit the application of science for the public benefit.

Third, we must develop a much higher degree of cooperation and understanding between government and industry. All too often this relationship has been marked by suspicion, or even hostility, on both sides. This is in stark contrast to the attitudes in almost all other countries. Government officials are frequently suspicious of the motives of large corporations and believe that industry is only interested in profits. Industry is concerned that government officials do not understand the role of profits in supporting the economy, and sometimes seem to act irrationally in the administration of regulation, antitrust, and other matters that affect industry. Industry believes that federal actions create uncertainty to an unnecessary degree, and uncertainties force business to shorten its time horizons and concentrate its R&D on cost reductions and short-term payoffs, rather than on major innovation.

Progress in these three respects is essential if we are to realize our full potential for the application of science and technology for the common good. We have the R&D resources for this, and the issue is: Will we use them effectively?

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Study Project

ASSEMBLY OF ENGINEERING

ICAM

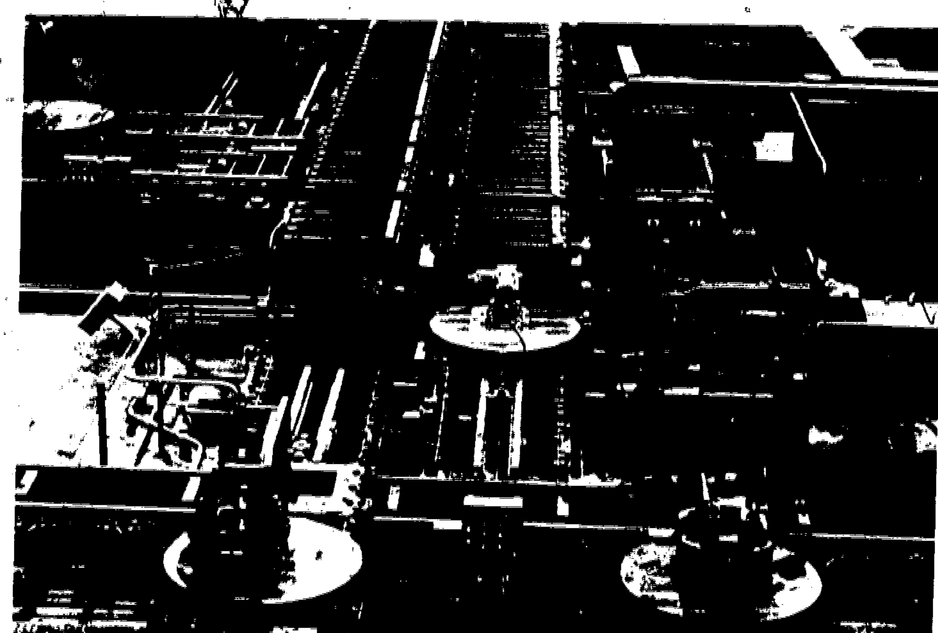
The development of Integrated Computer-Aided Manufacturing (ICAM) would permit the use of computers in all phases of manufacturing from design through actual automated manufacture of tools, parts, and finished products, including automated assembly and testing, as well as automated control of the flow of materials, parts, and products through the plant.

Over the next five years, the Air Force will spend $75 million on its ICAM program, whose goals are: (1) to demonstrate that computers can be integrated in all phases of manufacturing aircraft (beginning with airframes and engines), thereby improving the capability of aerospace and related industries to meet U.S. defense needs; (2) to use what is learned to suggest ways to transfer ICAM technology to other U.S. industries; and (3) to show that ICAM will enhance manufacturing flexibility and reduce costs.

BATCH WORK

The Air Force is particularly interested in computer-aided manufacture of aircraft because of the high costs of relatively small production runs typical of aircraft, as compared with the mass production techniques that produce hundreds of thousands of assembly line automobiles each year. Perhaps seventy-five percent of all U.S. manufacturing is done on production runs of fifty items or less and is typified by frequent product changes. Computers could introduce efficiencies into batch production that are now only attainable with mass production. In a computer-managed system, the changeover costs of switching from one product to another could be greatly reduced. For example, the computer can be armed with automated tool-changing devices having a bank of sixty or more tools. In "a computer-managed-parts manufacturing system, the usual concept of an economic batch size does not apply because the setup costs are exceedingly low. It can be efficient to run a 'batch' consisting of only a single part. Since the batches are small, the cost of holding in inventory parts that are either finished or in process becomes almost negligible."[1]

Other economies also result; for example, while a conventional machine may be cutting metal three to ten percent of the time, a computer-managed system may be cutting metal more than fifty percent of its time.



Built by the Sundstrand Corporation, this U.S. plant uses a computer to control the machining of parts for hoists and winches

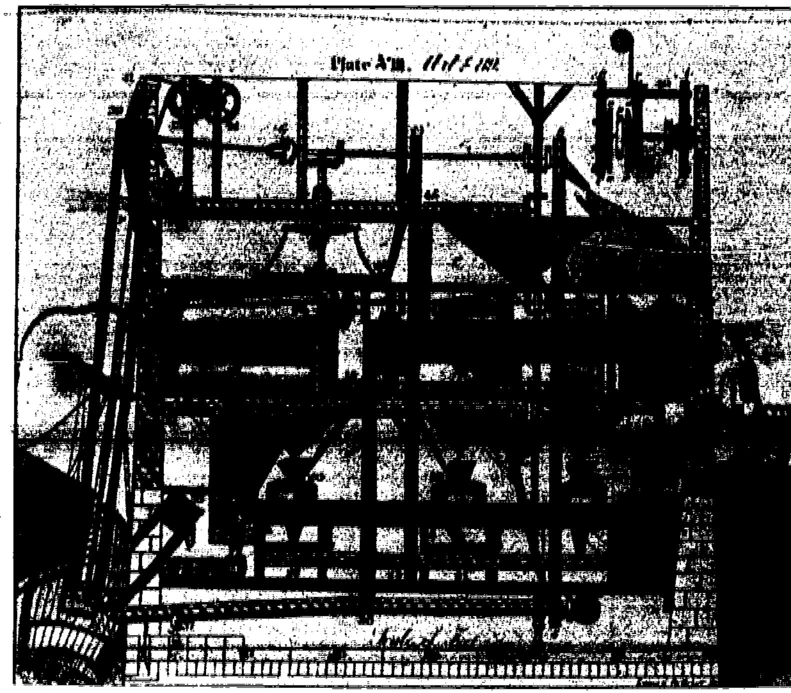
Also, with functions, tolerances, and testing for errors guided by a computer, it may be possible to speed the parts manufacture, shortening production runs.

It must be said, however, that computer-aided manufacture is still primitive compared to expectations. While computer-managed tools are common (for example, the computer-controlled boring of holes in an engine block), entire assembly lines managed by computers are not. Integrated systems of the sort envisaged by the Air Force do not yet exist, although there are plans to build such systems. Japan, for example, is planning a fully automated factory that is expected to cost $100 million. But, the fact is that the level of automation is still limited to control of single machines or of several machines doing similar work. In a sense, today's automation is not much more advanced than the entirely automated continuous flour mill built outside Philadelphia by Oliver Evans in 1784 or, more aptly, the automated loom controlled by punched paper cards that a Frenchman, Joseph Marie Jacquard, built in 1801 and then successfully commercialized in France.[2]

Mass manufacture, while highly automated, is relatively inflexible. Batch manufacture demands flexibility and rapid adjustments to cope with product changeovers and variations. The leitmotif of research on computer-aided manufacture has been—and still is—to supply flexibility and adaptability. Results already include improved control of machine movements, permitting control over complex operations that require both straight and angular movements, automatic tool changing, and simpler editing of the parts manufacture program. The latter improvement—a closing of the gap between production design and machine performance—is now at the center of considerable research on computer manufacture.

The transition from punched tape to computer instructions has made it simpler to define mathematically computer-controlled movements. Thus, rather than write out each joint angle for the movement of a particular machine, it becomes possible to say, in language suited to the computer, what you want the machine to do and then let the computer instruct the machine.

The linguistic effort, however, must be seconded by a kinetic one—a freeing of automated manufacture from its rigidity, whereby computer-controlled tools are limited to working on stationary, prepositioned objects always presented to the tool in exactly the same way. The technology



Automated continuous flour mill built by Oliver Evans outside Philadelphia in 1784

The Stanford Arm

remains one of limited programmable devices limited to specified movements infinitely repeated. What is now needed, and again the subject of research, is to give the computer-controlled machines the ability to sense and respond to the environment in which they're working—to feel the parts, eventually to see them, and then to apply their sensory talents to reject faulty parts, to turn and fix workpieces into proper position, and so on. The addition of sensors and the simplification of the steps by which the computer receives and applies instructions to machines under its control are now the major efforts in research on computer-aided manufacture.

It must be pointed out that the sophistication is already enormous, even if the actual level of complexity is limited largely to individual machines. Several factories have been built that intensively employ automated equipment in the production of machined parts. Possibly the most ambitious, according to a statement in 1975 by Professor Nathan Cook of the Massachusetts Institute of Technology, is the system operating at the Karl-Marx-Stadt in East Germany. "The system, enclosed in a special air-conditioned building as large as two football fields, employs linear induction motors to propel the work pallets, which are floated on air cushion supports. The system can handle workpieces as large as 1 × 1 × 1.6 meters [3.3 × 3.3 × 5.3 feet]."[3]

A plant built by the Sundstrand Corporation (now White-Sundstrand Machine Tool, Inc.), and first operated in 1972, is probably the first U.S. plant in which computers had a significant role in the manufacture of parts. Its major products are parts of hoists and winches. A twelve-hour shift for the plant requires only three operators and a supervisor, whereas a conventional shop would need thirty machines and thirty operators. And at any one time, the computer, a 360/130 IBM machine, can direct the machining of as many as twelve different parts.

Computers have been introduced into other batch manufacturing processes. For example, a computer in the Cincinnati Milacron plant is used to translate three-dimensional instructions into joint angles for the machining tools. However, in spite of these initial achievements, the ICAM objective of full integration of computers into all phases of parts manufacture is yet to be achieved. The reason that there are as yet no fully automated factories is not lack of technology, but the high capital investments needed for systems that are still only *potentially* rewarding. The Air Force ICAM program is thus an attempt both to explore and develop the potential of an unrealized technological possibility.

A committee of the NRC Assembly of Engineering is reviewing the ICAM program and will examine, among other issues, (1) existing and proposed policies, objectives, strategies, and technologies, as well as engineering and manufacturing approaches; (2) means for assessing the capabilities of the manufacturing industries—including the professional and technical work force as well as the management—to incorporate the program into their operations; and (3) methods of transferring the technology to the industrial user community.

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Committee on Computer-Aided Manufacture, Assembly of Engineering. Committee Chairman, Thomas H. Crowley of Bell Laboratories; Staff Officer, Joel Goldhar.

Assembly of Life Sciences

National Issues and NRC Perspectives: Two Case Studies*

FRANK W. PUTNAM

Many studies that come to the National Research Council are by definition complex. They may have political consequences, influence national policies, and have broad societal impacts. A committee, as the NRC unit actually responsible for producing a report, must in the final analysis decide which questions it will address, by what methods, and using what data. But how does the NRC first decide if the question as posed is answerable, what modifications in its scope and character may be needed, and whether the question should be addressed at all? How is a difficult, perhaps poorly framed question shaped into doable study, one that can effectively be addressed by a committee of volunteers having both limited time and funds? In short, how are studies designed within the NRC?

At first blush, these questions seem naive, almost disingenuous. The majority of issues that come to the NRC are those posed by federal agencies,

*It is a pleasure to acknowledge the help of Norman Metzger and Alvin G. Lazen in the preparation of this report.

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either by the legislative direction of the Congress or on their own initiative. Therefore, the answer as to what decides what an NRC committee will do seems to be deterministic, dependent, in the case of congressionally mandated studies, on what the act says or, sometimes, on the act's legislative history; or, in the case of questions initiated by federal agencies, on the priorities and programs of the agencies or on the particular imperatives of the requesting officials. The short answer might seem to be that committees do what they are asked to do.

However, like most simple answers to difficult questions, this one is not merely misleading, but invariably wrong. The truth of that assertion has now been confirmed for me several times, even in my still relatively brief tenure as Chairman of the Assembly of Life Sciences (ALS).

As evidence, I would like to offer brief excursions into how the workscope or study agendas for two studies involving the ALS were actually developed. These are the already completed study of the health care resources of the Veterans Administration (VA) and the proposed study on the biological effects of microwaves and other nonionizing radiation—the former an ALS study and the latter a joint effort of the ALS and the Assembly of Engineering. These studies are both large ones—in the breadth of their subject matters; in the numbers of committee members, consultants, and staff members involved; and in their budgets—some $6 million for the VA study and $1.5 million for the proposed microwave study, both sums for three-year projects. Both studies dip into controversial ground: the VA study necessarily dealing with issues having political ramifications, as we have already, at times painfully, learned, and the microwave study dealing with a subject matter that intertwines quite intense environmental concerns with ones affecting both the economy and national defense. The VA study meant dealing with issues affecting a politically important population—U.S. veterans, more especially those who have or expect to use VA facilities. The microwave study, for its part, required an enormous effort on the part of the NRC to weave together into a coherent proposal the different interests, needs, and constituencies of a very considerable number of federal agencies.

To repeat, both these studies, in terms of the typical NRC study, are very large. Therefore, this analysis is really somewhat skewed and is really the tale of how two very big babies were conceived, born, nourished, and put out into the world. Therefore, it is nonsense to pretend that the experience of the ALS with these studies is at all representative for all or even a significant fraction of NRC studies; nevertheless, I do think that they very well illustrate the complexities that can lie behind the seemingly simple question of how study agendas are set.

HEALTH CARE FOR AMERICAN VETERANS

In June 1977, the NRC issued *Health Care for American Veterans,* the product of a three-year study with a budget of $6 million. Given the budget, some 300 committee members and consultants, and a staff of about 100, the study was the largest ever undertaken by the NRC. The size of the study was apposite to its theme: the analysis of the largest single health care system in the United States, one of the largest such in the world—a system with 180,000 employees, a budget of over $4 billion (Fiscal Year 1976), and operating 171 hospitals with 95,000 beds.[1]

The reaction to the study was considerable and not unexpected, given its subject matter, the criticism and recommendations that the committee made, and the intense interest of the Congress in the study. Results included national publicity, at times acrimonious congressional hearings, and a 355-page response from the VA. But beyond the brouhaha, the report had several effects—for the future, possibly profound changes in the national health care system, and, more immediately, major and productive changes in the ways the VA cares for its clientele.

Why did Congress ask for this study? The legislative history is complex, but the essential reasons are summarized in the introduction to the NRC's report:

> In the last decade, an influx of patients resulting from the Vietnam War drew public attention to some of the VA's problems. The controversy over their treatment sharpened the debate between the Congress and the Executive Branch on the resource requirements of the VA hospital system. Congressional committees responsible for veterans affairs and for VA appropriations were repeatedly told by veterans' groups and medical schools that shortages of hospital staff and equipment were jeopardizing the quality of patient care in VA hospitals and forcing some hospitals to deny admission or outpatient services to veterans who needed care. Congressional hearings emphasized the disparity in staff-to-patient ratios between VA hospitals and community hospitals: VA hospitals were said to be greatly understaffed. These problems were said to persist despite the rapid growth of the VA's medical-care budget in recent years—growth that roughly paralleled the general increase in costs in the health industry.[2]

The result of this concern was the enactment on August 2, 1973, of Public Law 93-82, *The Veterans Health Care Expansion Act of 1973*. Section 201(c) of that law specified that:

the Administrator [of the VA], in consultation with the Chief Medical Director, is directed to conclude negotiations for an agreement with the National Academy of Sciences under which the Academy (utilizing its full resources and expertise) will conduct an extensive review and appraisal of personnel and other resource requirements in Veterans Administration hospitals, clinics, and other medical facilities to determine a basis for the optimum numbers of and categories of such personnel and other resources needed to insure the provision to eligible veterans of high quality care in all hospital, medical, domiciliary, and nursing home facilities.[3]

A very brief look at how the NRC and the VA came to an agreement on what the study was to be is instructive. The Governing Board of the National Research Council first considered a study of several aspects of the VA system in April 1973. The proposed budget was then $300,000 for a three-year study. The final budget agreed upon by the VA and the NRC was $6 million for the study of the VA's health care system. This rather dramatic increase was due to several events. For one, the scope of the study as originally contemplated was severely limited, compared to the final study, and confined by the NRC Governing Board to purely a planning phase for an eventual analysis of the impact of VA medical training and research programs on the quality of VA care. Moreover, Public Law 93-82 had not been enacted at the time the Governing Board first considered the matter, and the academy and the VA believed that the bill when passed into law would indeed ask the academy to design the study rather than doing it—a feasibility study rather than a full-scale one. Finally, once the scope of the study was actually put forth in the law, it took the NRC some time to appreciate its full import, particularly the enormous amount of data-gathering and analysis that would be needed to address the issues posed by the legislation. The latter realization implied that the burden of the task was far greater than could be done by volunteers serving on the committee, and therefore a sizeable staff, including consultants, would be needed.

NRC staff spent much of the 1974 summer designing the actual study and produced an anticipated budget of $6.5 million, eventually reduced to $6 million. The design was reviewed in a full-day meeting with staff by a subcommittee of the executive committee of the ALS, chaired by Paul Marks of Columbia University and including as members Robert Berliner of Yale

University, Nevin Scrimshaw of MIT, and James Wyngaarden of Duke University. The study plan was approved by the subcommittee and then in turn by the entire executive committee of the ALS and the Governing Board of the NRC. The refrain in all this was a concern if not outright anxiety over both the swelling of the budget and whether the study as designed was in fact doable.*

The concerns as to whether the methods to do the study were available or could be devised were certainly understandable. However, in retrospect, the methodology developed by the committee has turned out to be one of the pillars of the study. For example, Robert L. Van Citters, Chairman of the Special Medical Advisory Group of the VA and Dean of the University of Washington School of Medicine, in testimony on September 30, 1977, before the Senate Committee on Veterans Affairs stated that "the Special Medical Advisory Group did give some study and attention to the methodology employed by the NAS report, and it was the conclusion that it was in general very sophisticated and appropriate. We have no criticism of their methodology."[4]

In a synopsis sent to the Administrator of the Veterans Administration on December 20, 1974, the academy summarized the reasons for the increase in budget as being due largely to three factors:

1) The decision to conduct a series of major scale surveys and a cohort study of veteran applicants for medical care, with the associated data collection and analysis.

2) The scope of the quality-of-care assessment which involves the analysis of large numbers of patient records and the conduct of multiple site visits by professional experts.

3) The impracticability of utilizing the time of the Committee members beyond that necessary to provide guidance and direction to the professional staff in the design and conduct of the individual studies.[5]

The data to be gathered, in addition to what was available in the VA and other files, was to be obtained in four ways: by surveys—of veterans,

*As one example of this concern, an agenda item on the study prepared for the ALS Executive Committee noted that it "is uncertain whether suitable technology and techniques required for such study are available, and, if so, whether they would be applicable to the study. These questions will require assessment. Methodology may have to be modified or developed as an integral part of the project. . . . The likely degree of success is difficult to predict, and the project in the fullest sense, at some point during its conduct, may be determined to be unfeasible."

cohorts of applicants for VA care, VA staff, and health professional schools; by patient records; by site visits; and by examinations of patients.

This considerable and necessarily expensive activity was needed so the committee could do what legislation had requested, i.e., "determine a basis for the optimum numbers and categories of such personnel and other resources needed to insure the provision to eligible veterans of high quality care in all hospital, medical, domiciliary, and nursing home facilities." Moreover, information gathered by the committee was to be used to support statements to be made in the final report about specific issues. These issues were described in the letter sent to the VA informing them of the need for increased funding. Since the changes in the committee's mandate have been the source of some dispute, particularly in House hearings, it may be useful to quote them in full. The issue to be addressed in the final report as given in the letter to the VA were:

1) The roles being filled by the VA system in the national system of health care;

2) The effectiveness and efficiency with which the VA medical system is carrying out its primary mission of providing high quality care to eligible veterans who require such care from the VA;

3) The quantitative and qualitative adequacy of the staff and other resources

available to the VA medical system to carry out its missions, and the appropriateness of the distribution of these resources;

4) The factors other than resource availability and distribution—e.g., education and training programs, research programs, sharing arrangements, regionalization—which affect the performance of the VA medical system in carrying out its patient care missions;

5) The possible effects of major external factors—National Health Insurance, health planning and regulatory legislation, continued inflation, increased unemployment—on the roles, programs and resources of the VA system; and

6) The effect of selected statutory and administrative policy changes, including staffing policies, that may be needed to improve the ability of the VA system to carry out its present and future roles.[6]

The VA in turn asked the views of the cognizant committees of the House and Senate. A meeting was held that included NAS, VA, and Senate and House staffs. The additional funding and the revised NAS study scope was subsequently approved by the chairmen of the Senate and House committees. This occurred in March 1975 (eighteen months after enactment of the law), and work on the study itself, rather than simply its planning, could now begin.

The final report, issued in June 1977, made thirty-seven specific recommendations and included detailed documentation on most of these, either within the report or in supplementary material. The VA has agreed, wholly or in part, with twenty-three of the recommendations. Eleven of the twenty-three recommendations of the committee were implemented prior to the formal issuance of the report, which is compelling evidence of the symbiotic relationship that often exists in the course of a study between the committee and the affected agency.

The recommendations can be divided into two categories: first, a series of detailed organizational recommendations that mainly pointed out inadequacies in management or opportunities for effective changes; and, second, a set of recommendations that have been construed by the VA and by parts of the Congress as affecting policy.

In brief, the VA largely concurred with the first category of recommendations. Some of these should immediately benefit the patients, such as the VA's agreement to all five recommendations of the report dealing with the delivery of mental health care, including suggestions for improvements. Other recommendations will also be helpful to the VA in improving its services, such as the recommendation that "Comprehensive services need to be developed for patients with primary and secondary diagnoses of alcoholism and alcohol addiction." This recommendation has already firmed the VA's resolve to take the initiative in research on the biomedical factors that make people prone to alcohol addiction.

The second, much more troublesome category of recommendations, which are perceived as recommending policies, is itself divisible into two subcategories: one relating to VA's administrative policies, including how it distributes its resources, and, cutting much more deeply, suggesting an evolving role in the future for the VA in a national system of health care.

The first set of recommendations, affecting the VA's administrative policies, relates to the allocation and redistribution of resources, the retention of undersubscribed facilities, the concentration of cardiac surgery and kidney transplantations into fewer centers, the elimination of inpatient surgery in psychiatric hospitals, the reassignment of staff to rehabilitation medicine services, a narrower delineation of the VA's responsibility for dental care, and the suggestion that VA payments for treatment of patients in nonfederal hospitals be funded through VA's Central Office rather than through the budgets of the individual VA hospitals. Reasons offered by the VA for disagreeing with these recommendations include budgetary and legislative constraints, traditional practices, and alternative views on health services policies.

It is the set of recommendations regarding the future role of the VA in a general and national system of health care delivery that has aroused concern by the VA, generated heat in congressional hearings, and provoked harsh indictments of the academy by VA client groups such as veterans' organizations. It is difficult to titrate how much of the antagonistic response is due to the actual recommendations, how much to emphasis in initial press reports on recommendations perceived as negative by the VA, and how much to various concerns that the VA be kept as a separate system outside any comprehensive plan for national health care.

I cannot really settle the question of whether the committee exceeded its mandate by making the latter recommendations. One can say that the committee certainly had to confront the issue and that the decision it had to make was whether to offer its views or to duck. This study by the NRC marked the first time that this huge medical system had to publicly confront the question of what its future was going to be. And it is difficult to consider the future structure and operations of a system such as the VA without considering its relationship to an overall system of health care.

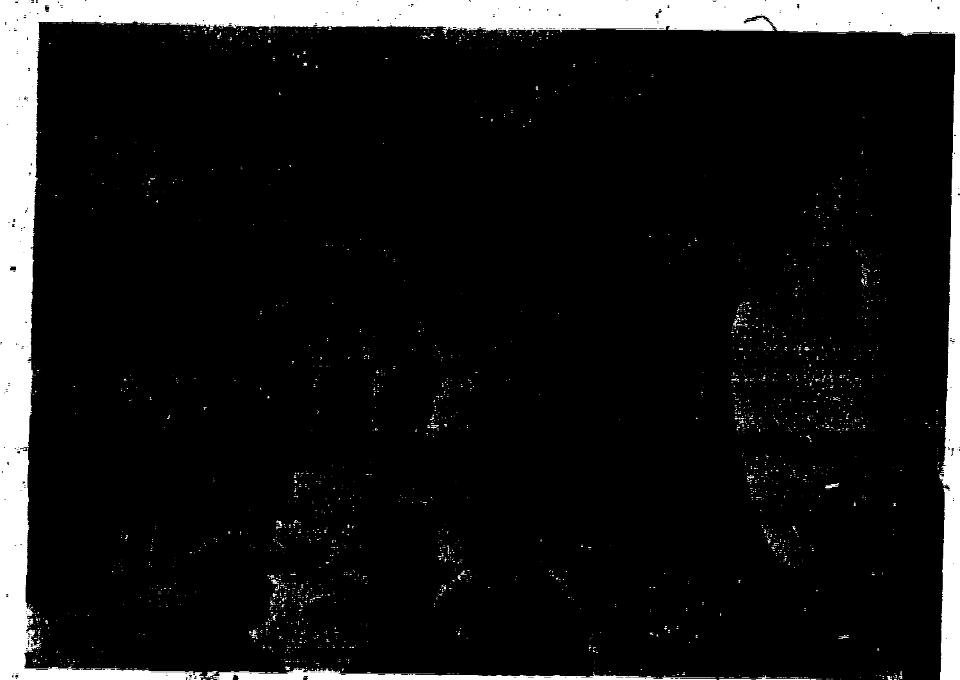
I might mention very briefly that while the report *Health Care for American Veterans* has received the most attention, and contention, another report issued at the same time has, in contrast, received little public attention and for the most part enthusiastic agreement by the VA. This report, *Biomedical Research in the Veterans Administration,** was the third of a series of similar reports prepared by the NRC (1960 and 1968) and was done in response to a request by the Administrator of the VA for "an assessment of the biomedical research efforts including relevant aspects of the training program with respect to quality and to the manner and extent of its contribution to patient care provided by the Veterans Administration." While the committee found that "a sizeable fraction of VA research is of less than satisfactory quality," it also found that most of VA's research is of "acceptable quality" and stated its belief "that the VA has made important contributions to medical science through its research programs, especially the career development and the cooperative studies program." The VA has already used this report to defend parts of its biomedical research program.

MICROWAVES

The second project I want to use as an example of how study designs are arrived at is one proposed on the biological effects of microwaves and other nonionizing radiation, given the infelicitous if useful acronym of MONIR.

This study, which if done will be a joint project of the Assembly of Life Sciences and the Assembly of Engineering, is in several ways comparable to the VA effort: It will be a large study, as measured by budget; and, like the VA study, its scope was considerably enlarged once the NRC began to examine the original question. The intended study also differs from that of the VA in several respects. For one, its support, rather than coming from one agency as in the case of the VA study, may come from among fifteen agencies, each representing different constituencies, needs, and levels of interest. Moreover, the very nature of the study means that expertise other than that contained within ALS must be involved, and therefore the problem of coordinating the requirements of many different federal

*The academy report was the first major public recognition of the stature of biomedical research in the VA; and only six months later two VA scientists, Rosalyn S. Yalow and Andrew W. Schally, were awarded, with Roger Guillemin of the Salk Institute, the Nobel Prize in physiology or medicine, thus becoming the first Nobel laureates in the VA.



agencies is complemented by the need to assure the effective collaboration of different units of the NRC. Considerable time, and diplomacy, is required to achieve this external and internal coördination.

The genesis of the microwave study, in terms of concentrating academy interest, was in an informal request made in late 1976 by the National Aeronautics and Space Administration. NASA wanted the National Research Council to assess a research plan, to be designed under NASA sponsorship, intended to determine the biological and ecological effects of energy transmission by microwave for solar satellites to six-square-mile receivers on earth.

The ALS Executive Committee was not happy with the idea of reviewing only a research plan; and it felt that the question as posed was simply too limited. The NRC Governing Board felt even more strongly that a comprehensive approach was called for, one that would include at the same time a response to NASA. A broadening of the scope was needed.

It is important to bear in mind that the academy addressed the NASA request in a context of widening concern about microwaves, spurred by a number of more-or-less coincident events: for example, news reports of the beaming of microwaves into the American embassy in Moscow that set off a series of speculations in the media, in the Congress, and in the federal government about the potential health hazards of microwaves; a two-part article on microwaves in *The New Yorker* magazine, since expanded into a book entitled *The Zapping of America*;[7] the planned construction of very high-voltage power transmission lines that because of their associated emission of high-frequency radiation has raised concern in several states; the expected widening of the MONIR environment due to new technologies, with the most recent examples being microwave ovens and citizen band radios; and the interest aroused generally in the effect of electromagnetic radiation by the planned construction in Michigan by the U.S. Navy of a system for transmitting an extremely low-frequency signal. (The last issue was considered in a 1977 NRC report, prepared by a committee of the Assembly of Life Sciences, entitled *Biological Effects of Electric and Magnetic Fields Associated with Proposed Project Seafarer.*)

Against this background of wide, if unfocussed, interest in the possible hazards of microwaves and similar radiation, the academy prepared a proposal for a study of the biological effects of microwaves and other nonionizing radiation. This proposal was circulated and discussed in detail with the many federal agencies having some programmatic or regulatory concern with microwaves. This base touching was necessary to assure the soundness of the study—as well as to gauge whether funds might be available to do the study—since, as already mentioned, unlike the situation with the VA report, involvement with MONIR extends horizontally across the federal structure; and as yet there is no congressional mandate that designates an agency to support the study. Thus, to give some examples, the Bureau of Radiological Health of the Food and Drug Administration includes in its responsibilities the setting of regulations, and the assurance of compliance, for the manufacture of equipment that emits microwaves and similar radiation. The Department of Energy is interested, not only because nonionizing radiation is emitted in high-voltage electrical transmission, but also because microwaves have been suggested as a conduit of energy from solar satellites to earth. The National Institute of Occupational Safety and Health is interested because of the widespread occupational exposures to microwave radiation, the U.S. Environmental Protection Agency because of the issue of "electromagnetic pollution," the Veterans Administration because of possible compensation claims based on exposures to nonionizing radiation, and the Department of Commerce because of its involvement in telecommunications policy.

While discussions with these and other agencies were in progress, the academy learned of strong congressional interest in the issue. The Senate Committee on Commerce, Science and Transportation, in reviewing *The Radiological Control for Safety and Health Act of 1968,* was considering mandating a study by the academy of the biological effects of nonionizing radiation, particularly the implications, if regulation results, for existing and emerging technologies. The academy, at the request of the Senate committee, testified on its plans for a study. The committee, for its part, asked very specific questions concerning what the academy wished to do. From still another direction, the Committee on Telecommunications of the NRC Assembly of Engineering was developing a study of the impact of regulating microwaves and other nonionizing radiation.

Out of this rather active chrysalis emerged the proposed academy study on microwave and other nonionizing radiation. It has four parts (with the latter two representing Assembly of Engineering initiatives included as part of the total study):

1) Review existing data on the biological effects of MONIR and, to the extent possible, provide estimates of safe levels of exposure that may be used in establishing guides for protection. Where data are not available, research programs will be suggested for obtaining them.

2) Perform an epidemiological study of Navy veterans exposed to radar during the Korean War.

3) Collect information regarding current and emerging technologies causing or using MONIR to determine present and projected exposure levels, and the potential biohazards of such increased exposure to the general population and for special occupational groups.

4) Assess the socioeconomic impacts of changing perceptions of safe levels of exposure of MONIR on over-the-air telecommunications.

SOME GENERAL COMMENTS

The two case studies selected for my very cursory examination of how a study is designed have both unique and typical aspects. They are unique, as are all studies, in the difficulties posed in organizing and in doing them; the tactics used had to be fitted to each study. They were typical in that the sorts of studies that finally emerged were the results of a coming together of interests, needs, and perspectives.

The difficulties inherent in these studies were, I hope, clearly illustrated in the case studies—whether in fact the VA study as envisaged was doable and the need to look at microwaves not only as to their biological effects but also as to the effects of possible regulation on various technologies that for their first-order effects seem desirable, even necessary.

What is typical is, I think, heuristically much more interesting. In both cases, as with many NRC studies, the need was apparent, but the scope of the study and the approaches to making supportable conclusions and recommendations somewhat amorphous. For both studies, the time seemed propitious, in spite of, or rather *because of* a lack of adequate information. The VA, for example, did not know what fraction of the eligible veteran population it actually serves or how this fraction differs from those who do not use the VA system; for the proposed microwave study very little is known, to take only one example, of the cumulative effects of low doses of nonionizing radiation.

Finally, let me try to extract from these two case studies some generalizations on how study designs are put together that I think are applicable to many studies undertaken by the NRC. Specifically, both studies confirmed the role of the NRC in providing the tensions necessary to structuring a sound study. The members of NRC committees and staff are by their roles disinterested parties, in the sense that they are uncoupled from the immediacies that drive agency officials and the Congress—they are not wedded to particular programs, not defending budgets for an agency, not caught in the intense pressures of constructing new legislation or revising existing laws. (This is not to say that committee members do not have their biases, sometimes bearing directly on the matter under study. However, the bias forms that most committee members are asked to fill out at the time they are asked to serve are designed to reveal these, so that even if biases are unavoidable they can at the very least be balanced out.)

This removal from the day-to-day pressures of running the government enables the NRC to look at proposed studies somewhat in the abstract—to look at whether the study itself, regardless of ancillary pressures, is doable; to determine whether the right questions are asked and to revise them if they are not; to determine what data are needed; and to determine what expertise is required by the committee as it begins the very difficult task at its first meeting of reforming a study agenda into specific issues that it can usefully address within its study period and budget.

The NRC by its position can look at a proposed study somewhat as a puzzle to be solved—as an intellectual exercise that, if carefully and analytically approached, will produce rewarding results. While all parties to a study are concerned that the job be done right, each one operates under a different set of constituencies, pressures, and perspectives. The constituency of the NRC is in the final analysis the scientific community, and its concern with rigorous analysis and supportable statements; the pressures are those that this community can bring to bear on faulty work; the perspective is an intellectual one, a method of framing questions and seeking answers combined with a professional aversion to accepting established truth without thorough verification. Hence, the tensions I referred to earlier.

I think, in the case of the VA study, that these qualities were amply demonstrated. An initial study design was judged inadequate and revised under intense pressures and with a great deal of labor to a level that satisfied the officers of the NRC that the final product would in fact be worthwhile. Similarly, the NRC's initial work on the microwave study will, if the study is done, yield a broad rather than piecemeal examination of an important issue—an examination that is sure to be of immensely greater value to the government and to the society generally than what was originally contemplated.

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Study Project

ASSEMBLY OF LIFE SCIENCES

LIFE IN THE AIR

Did the agent that caused Legionnaires' disease travel via the air conditioning ducts of the hotel where the original outbreak occurred? The evidence is more circumstantial than direct. As scientists from the Center for Disease Control of the U.S. Public Health Service put it, "No association was found between illness and contact with birds, mammals, or souvenirs. Patients did not complain of insect bites. A hypothesis of airborne spread is difficult to test directly, but it is consistent with the observed association of illness with time spent in the lobby and on the sidewalk in front of the hotel. Several patients with Legionnaires' disease and most with Broad Street pneumonia [i.e., had the disease, but neither attended the convention nor had recently entered the hotel] had only transient exposure in these areas and no identifiable exposure there other than to air."[1]

How far does pollen travel? The question is of some importance—to interpreting the geographic diversity of plant life, and to aiding the mapping of historical vegetation patterns through an analysis of fossil pollen.[2] Such knowledge is considered basic, but some of its uses are not; for example, pollen analysis may be used by oil companies to determine the histories of stratigraphic layers, helping the search for new petroleum deposits.

What are the effects of pollutant gases and particles on biological materials in the air, from pollen to microorganisms? Is there, for example, a synergistic relationship between some pollutants and the infectivity of microbes, the first perhaps a carrier for the second?

These questions all deal with biological materials in the air—how they travel, how far, and the relationship of their aerodynamic properties to their various effects, whether on legionnaires or on plants. Thus, the questions are properly within the province of aerobiology, the scientific discipline concerned with such matters. The formal name was coined in the 1930's, but the concerns of aerobiology are more ancient, focused originally on airborne pathogens and attracting the interests of Louis Pasteur and Joseph Lister, among others.

Aerobiology grew up with this emphasis on diseases, reinforced by the interest, during and after World War II, of several nations, including the United States, in developing germ warfare techniques (and therefore needing to know something of how microbes behave in air, particularly indoors). However, aerobiology, with its contemporary concern for materials in air, is today considered an umbrella science for a variety of more specialized disciplines. These include, for instance, palynology, or the study of pollen; allergology, or the study of allergies; phytogeography, concerned with the geographical distribution of plants; and entomology, the study of insects.

However, the historical antecedents of aerobiology—or, more exactly, its earlier, somewhat provincial emphasis on disease aspects—mean that problems, techniques, and data common to seemingly distinct sciences, such as palynology and entomology, have often escaped attention and have therefore neither been well investigated nor efficiently used. Sampling techniques, analysis of aerodynamic properties of different particles (such as their rate of settling), or attempts to relate aerial movements to biological effects (such as the relation of release times and dispersal of pollen to allergy patterns) have been developed or done for individual sciences, rather than shaped in a way to be broadly useful for many sciences. Research has tended to be compartmentalized. Broad principles generally applicable did not emerge. Rarely was a truly comprehensive approach used to design a research program, for example, in incorporating the aerobiological view in an analysis of the biological, physical, and chemical dynamics of an ecosystem.

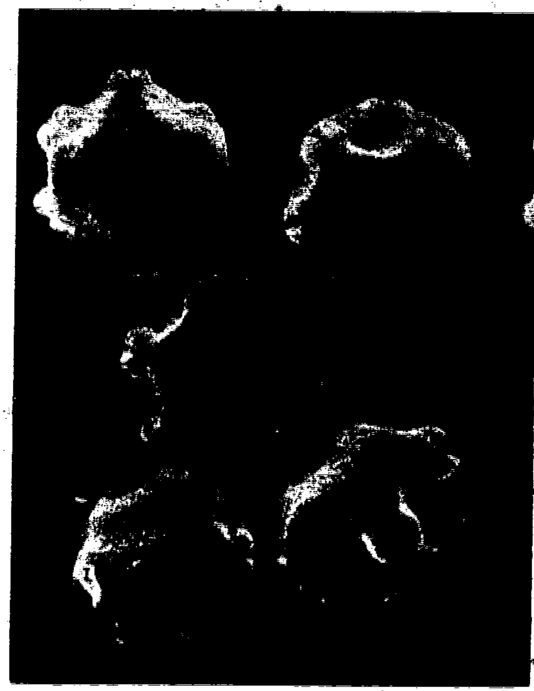
The unification effort really began with the International Biological Program (IBP), especially with the U.S. effort to develop an IBP Aerobiology Program. As remarked in an IBP volume, "Before the inception of the US/IBP Aerobiology Program, aerobiology tended to be fragmented and had little cohesiveness as a discipline. The US/IBP Aerobiology Program provided a cohesive framework by considering aerobiology in a systems analysis framework where each particle is considered with respect to its source, release into the atmosphere, dispersion, deposition, and impact."[3]

In part to continue the IBP momentum, a Committee on Aerobiology has been established within the Assembly of Life Sciences, with support from the U.S. Department of Agriculture, the National Aeronautics and Space Administration, and the National Science Foundation. The purposes of the committee include an effort to encourage the maturation of aerobiology as a discrete and coherent science, to consider whether it would assist in launching an American professional society for aerobiology, to define the boundaries of the discipline, to note the key issues that should be addressed from an aerobiological perspective, and to determine whether these issues are being addressed by federal agencies.

These issues take in many of the concerns to which an understanding of the aerial movements of biological materials in the atmosphere is pertinent. A brief description may be useful.[4]

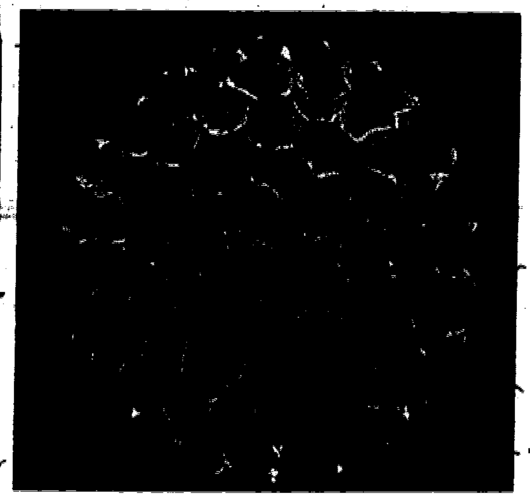
POLLEN AND SPORE DISTRIBUTION

Too little is known of the role of wind and insects in distributing pollen through different ecosystems; nor is there much information on rural and urban differences in how pollen is distributed. Factors determining the movements of pollen indoors is another research need. The importance of these questions is apparent; for instance, hay fever, asthma, and other allergies account for one-third of all chronic conditions of people under seventeen. The research difficulties are considerable. For instance, as remarked in *Nature,* "the study of pollen movement has been rendered difficult by the problem of relating pollen grains, once dispersed, to their sources."[5] Moreover, the distance traveled by pollen grains depends on



Left: Pollen grains of the alder tree (*Alnus crispa*)

Below: Pollen grains from smartweed (*Persicaria orientale*)



their densities and aerodynamics, which vary among species. Surrounding plants may filter pollen movements, shaping the pattern of plant growth; for example, the hazel flowers more abundantly on the forest periphery and in clearings than it does in the interior of the forest.

Aside from research, a better way of gathering and collating data is needed. While worldwide samplings of allergenic pollens are published yearly in the *Statistical Report of the Pollen and Mold Committee* of the American Academy of Pollen and Allergy, similar data on nonallergens are not as available.

PLANT PATHOGENS

There are sufficient examples of plant diseases caused by airborne organisms, primarily fungi, to alone justify a more active research program in aerobiology. For instance, the corn blight epidemic in the United States in 1970 was caused by airborne spores and resulted in a fifteen percent overall loss in harvest yields. Similarly, rice blast epidemics are attributed to airborne fungi, while an outbreak of coffee rust in Brazil may have been due to fungi windblown from Africa across the South Atlantic. If one had a clear idea of the rate and pattern of travel of plant pathogens, such as fungi and insects, more effective prophylaxis might be possible. Certainly, improved air sampling and better use of collected data may make it possible to contain an initial infection and prevent it from becoming an epidemic.

MICROFAUNA, INCLUDING INSECTS

Again, there are research difficulties; for example, it is at best hazardous to generalize on the patterns and rates of travel of insect species, since these may depend on the time of release, the wind conditions at the time, and other factors. Moreover, some insect species, such as aphids, are carried long distances, while others, such as leafhoppers, mosquitoes, houseflies, and moths, are restricted by natural barriers, weather conditions, and similar factors.

HEALTH OF HUMANS AND ANIMALS

This province of aerobiology, once its largest and still among its more important, has its interesting stories to tell. For instance, "cloud babies" in hospital wards, who show no symptoms of "staph" infections, but nevertheless disperse *Staphylococcus aureus* throughout a ward; or the fact that in some outbreaks in hospital wards—nosocomial infections—patients along walls are infected, but those in the middle of the ward are not. Nevertheless, aerobiology remains an esoteric aspect of medicine.[6] Obviously, some of the interest in learning how pollen and fungi are distributed through the air is applicable to medicine. Furthermore, one would like to know more of the relationship of the size and shape of pollen, and the topography of the lungs, to their rate of settling and deposition in different parts of the respiratory tract. There is considerable uncertainty about the movements of microorganisms in the air and their potential for producing infections by that route. While airborne infections are hardly a major category of contemporary disease, there are documented instances when diseases caused by bacteria (anthrax), rickettsia (fever), and viruses (hoof-and-mouth disease) have spread because of meteorological conditions or aerosolization. Also, given its intimate concern with the spread of infectious diseases, aerobiology can contribute to developing and improving technology for the high-level containment of experiments involving very infectious agents and recombinant DNA.

EFFECTS OF POLLUTANTS

Air pollutants fall partly into the ambit of aerobiology in that pollutants may influence the development of plant disease by modifying the progress of a disease, the host, or the virulence of a particular pathogen. Thus, pollutant gases, especially ozone and sulfur dioxide, can inhibit the germination of some pollens and fungal spores; and they may affect the

viability of airborne fungi and bacteria. Pollutants may also kill bacteria; perhaps carbon monoxide interrupts cytochrome enzymes, sulfur and nitrogen oxides cause lethal pH changes, and so on.

METEOROLOGY

Atmospheric transport can be microscale (travel times and space limited to less than an hour and a few hundred meters), mesoscale (time and space on a scale of days and a few hundred kilometers), and macroscale (a year or more and global transport). Each scale presents different conditions and is therefore a different arena for study; for instance, sinks for atmospheric materials, important on a meso- or macroscale, are nonexistent at a microscale level. The aerobiologist, beyond applying known meteorological methods to his science, must consider other factors, including the conditions under which pollen, fungi, and other biological materials are released, their aerial characteristics, and so on. Biological particles can also be nuclei for cloud condensation and ice formation and can serve as surfaces for chemical and physical interactions. These latter effects, while real and important, are poorly understood. In addition, the indoor, or intramural, movements of bacteria and allergens reflect certain meteorological characteristics of diffusion and turbulence, which must be considered.

These are some of the issues that now concern aerobiology. In all, they add up to a fairly large bank of unknown data and missing methods. Very broadly, we are largely ignorant of the biological content of the atmosphere and its interactions with life on the ground. We need to improve our ability to relate changes in disease patterns with physical and chemical changes, such as in the constituents of the atmosphere. We tend to believe that airborne diseases are largely, if not exclusively, transmitted indoors, because we have no information on outdoor transmission. Not that airborne infections indoors are not a very real problem; there is ample evidence, as indicated earlier, that staph infections are transmitted in various ways indoors, including through hospital laundry chutes, while home heating and air conditioning ducts can be serious sources of allergenic dusts and molds. (As an aside, the evidence is not persuasive that modern forced-air ventilating systems are more, or even as, sanitary as earlier practices that depended on very large room sizes and open windows to dilute and change indoor air.)

As to a lack of methods, there is no one instrument yet developed that can adequately sample all the sizes and types of materials in the atmosphere. Partly as a result, monitoring programs are inadequate.

Some of these sampling and monitoring problems are of a piece with inadequate research. As one illustration of the problem, it was recently pointed out that, "Apart from the serious problem of where to sample in relation to where people live, how frequently to sample, with what response times and averaging times, etc., we're not sure what to sample, and by what method. It is clear that the biologist would like to sample fine sulfuric acid mist, but no such method exists for community atmospheres. It would be desirable to measure acid sulfates, but acid sulfates are formed in part on the filter after samples are collected. We would like to identify specific sulfates, since the range of sulfate toxicity is wide, but present collectors yield too little material for analysis."[7]

The Committee on Aerobiology will take up some of these matters, as well as others, and plans to issue its final report in 1979.

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Committee on Aerobiology, Division of Biological Sciences, Assembly of Life Sciences. Committee Chairman, Robert L. Edmonds of the University of Washington; Staff Officer, Russell B. Stevens.

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Climate and Public Policy

ROBERT M. WHITE

THE GROWING VULNERABILITY

Few scientific issues have the potential public policy ramifications of climate and climate change. Few natural phenomena have the global impact of climate and occupy so central a role in determining the nature of society. Changes in climate and weather have historically resulted in jarring economic, social, and political consequences throughout the world. The past decade, however, has seen a new intensity of concern about the impacts of abnormal weather and climate change.* They have challenged the idea that technology has freed us from climate constraints. We had begun to believe that our technology could allow us to develop climatically stressed

*The definition of "climate" and "weather" is a topic of endless discussion among meteorologists. For purposes of this paper, I consider climate to pertain to the statistics of weather parameters over time periods that are greater than those for which deterministic predictions of day-to-day weather are theoretically possible. As a practical matter, this means that the statistics of weather parameters over periods of two weeks and greater would qualify as "climate."

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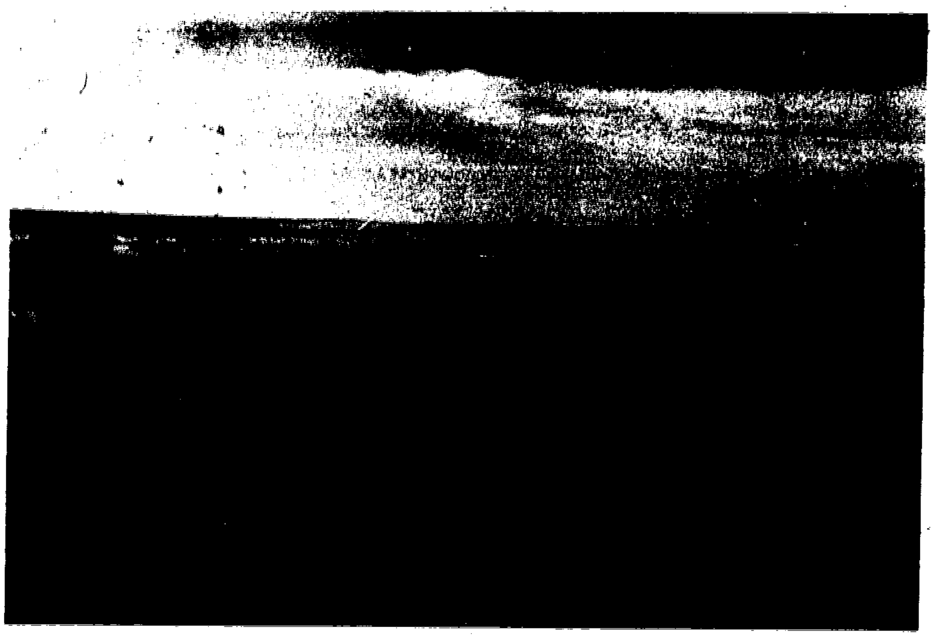
areas beyond their natural carrying capacity. Indeed, some societies in climatically stressed areas are already sustained by artificial technological respirators, and, in many cases, they can no longer sustain the patient. We irrigate, build dams, construct levees, mine fossil water, and build ourselves air-conditioned cocoons. We also overpopulate, overgraze, overindustrialize, and overcultivate. We should not be surprised when nature sometimes reasserts itself.

It is, however, not only our willful technological advance into hostile climates that has brought about our climatic vulnerability, but also more fundamental changes that have forced advances into climatically stressed areas. Increased population presses against world food supplies. Fluctuations in world food reserves are now of the same order as fluctuations in annual food production that result from normal variations in climate. There is only a thin margin between shortage and adequate supply. Population pressures are also extending human habitations into marginal agricultural and climatic areas. Sensitive ecological systems are being stressed, as in the Sahel, resulting in the destruction of their stability and resiliency. Our land-use patterns in many areas have succeeded in establishing conditions that are sensitive even to moderate shifts in normal



climatic patterns. The vulnerability of society to climate has now increased to a point where major economic, political, and social consequences flow from fluctuations of climate that occur repeatedly around the world as part of the normal shifts of the global circulation.

The increasing vulnerability of our social and economic life to natural changes in weather and climate is now paralleled by a new phenomenon: the susceptibility of climate to man's activities. We have come to realize that certain industrial, agricultural, and land-use practices can affect the earth's radiation balance, the photochemistry of the upper atmosphere, and the boundary interactions between earth and atmosphere. We have acquired observational evidence of changes in key physical processes, and have begun to understand their effect on the global atmospheric circulation, which determines our climate. Our knowledge is still imperfect, but our concerns are real. We are thus confronted with a complex situation: Not only is modern society vulnerable in myriad ways to the effects of weather and climate change, but the climate itself is vulnerable to the actions of man.

THE RESPONSE OF THE NATIONAL RESEARCH COUNCIL

The task for science is to address the question of how the growing vulnerability of our society can be reduced by improving our scientific understanding of the causes of climatic fluctuations and, through such understanding, developing methods of anticipating climate changes better than we can today. It must also attempt to define the social and economic impacts of climate change so that remedial actions can be taken by governments and industry. The Climate Research Board has been established by the National Research Council to act as the focus for addressing this broad set of questions and coordinating NRC's effort.

The National Research Council has had a long history of contribution to our present awareness and understanding of climate change. In 1973, the Committee on Atmospheric Sciences issued *Weather and Climate Modification: Problems and Progress*; in 1974, the Ocean Sciences Board published *The Ocean's Role in Climate Prediction*; in 1975, the U.S. Committee for the Global Atmospheric Research Program issued *Understanding Climatic Change: A Program for Action*; in 1976, the Board on Agriculture and Renewable Resources produced *Climate and Food*; and in 1977 the Geophysics Research

Board produced *Energy and Climate* and *Climate, Climatic Change, and Water Supply.* There were other reports dealing with aspects of climate in other contexts. For example, the Committee on Impacts of Stratospheric Change issued in 1975 *Environmental Impact of Stratospheric Flight* and in 1976 *Halocarbons: Effects on Stratospheric Ozone* and *Halocarbons: Environmental Effects of Chlorofluoromethane Release.*

This wide interest in climate within the National Research Council has stimulated and been stimulated by a similar growing interest in the U.S. government as well as among international organizations. As a result, a U.S. Climate Program Plan has been approved by the Chairman of the Federal Coordinating Council for Science, Engineering and Technology;* and the Congress is in the final stages of considering legislation establishing a National Climate Program (see below). On the international scene, the World Meteorological Organization of the United Nations has recently approved the planning for a World Climate Program and has decided to hold a World Climate Conference in 1979.

THE CONFLUENCE OF SCIENCE, TECHNOLOGY, ECONOMICS, AND POLITICS

How did we get to this point of broad action on climate issues? How do we account for the escalation of the interest of scientists and governments during the last decade? Until two decades ago, the study of climate was a scientific backwater. It was principally a descriptive activity. Theories of causes of climate change were speculative. Hypotheses could not be tested. However, in the past decade, scientific, technological, economic, and political events interacted in a way that rendered the problems of climate change not only politically and economically important, but also scientifically attractive.

Technologically, the space age matured, and earth-orbiting satellites could observe the global oceans and atmosphere in ways hitherto not possible. Global data required to define the state of the earth's fluid envelope came within our reach. With large-scale computers, mathematical models of the ocean/atmosphere system were developed, providing the

*The President's 1979 budget, submitted to the Congress on January 23, 1978, provides for a thirty-eight percent increase in funding for the Climate Program, from a 1978 level of $75 million to a 1979 level of $104 million.

means for conducting a new range of predictability studies. The models could also be used for studies of the sensitivity of the atmospheric general circulation to natural and man-made changes in important physical processes and hence provided a means for testing hypotheses.

Developments in oceanographic and geological science provided new capabilities for acquiring ocean cores at great depths, for sampling oceanic sediments, and for accurate paleoclimatic dating. The study of past climates took on a wholly new character and provided insights on the intensity and frequency of past climate changes that lent new perspectives on recent and possible future climate changes.

During this period it became possible within the limitations of the mathematical and physical frameworks available to examine the ocean/atmosphere system, and, using the new technology, to mount a new kind of field program that could define critical and unknown physical processes. Excellent bibliographies of the many scientific contributions can be found in the NRC reports referenced above.

The Global Atmospheric Research Program (GARP), jointly sponsored by the World Meteorological Organization and the International Council of Scientific Unions, became the framework within which large-scale international field programs and collaborative research were mounted to define some of the key physical processes associated with climate and its variations, such as those involved in air–sea interactions, and role of tropical convection in the energetics of the global circulation. This program will culminate in 1978 and 1979 in the Global Weather Experiment, one of the most comprehensive international scientific experiments ever conducted.

This resurgence of scientific interest in the climate coincided with and was stimulated in part by a series of disastrous climatic events in many parts of the world and by a growing concern for the impact of man's activities on climate. Beginning in the sixties and running through the seventies, climatic events generated startling economic and political consequences:

- About 1970, the southern border regions of the Sahara Desert, the Sahel, succumbed to a five-year drought. Famine and death on a continental scale resulted. Nomadic populations had to be herded into refugee camps to be fed and sustained by a vast and costly international food aid program.
- In 1972, a killing winter freeze, followed by a severe summer heat

wave and drought, reduced Russian grain production by twelve percent. As a result, the Soviet government entered the world food grain market and drew world reserves down to a marginal point with reverberations on the international price structure. In the same year, the anchovy harvest off Peru collapsed, with a serious impact on the world's supplies of animal protein and on world demand for soybeans. The United States was forced to embargo the export of soybeans, an action that generated severe political reactions. The collapse of the anchovy harvest was due partly to overfishing and partly to the occurrence of El Niño, a warming phenomenon that invaded coastal Peruvian waters as a result of changes in atmospheric circulation.

- In 1974, India and Southeast Asia suffered poor monsoon rains with consequent reduction of food supplies in that region.
- In 1975, a severe frost in Brazil destroyed half of the coffee trees in that country. Coffee prices on the world market skyrocketed, and a pound of coffee in the local supermarket exceeded $4.00.
- In 1976, drought in Western Europe destroyed the potato harvest. The potato growers of the United States found an unexpected market for their supplies.
- The winter of 1977 brought abnormally cold weather to the eastern and midwestern parts of the United States. A shortage of natural gas supplies forced the closing of schools and industries and caused widespread temporary unemployment.
- Starting in the autumn of 1976 and continuing through the summer of 1977, a prolonged drought plagued the Pacific Coast with forest fires and low water supplies.

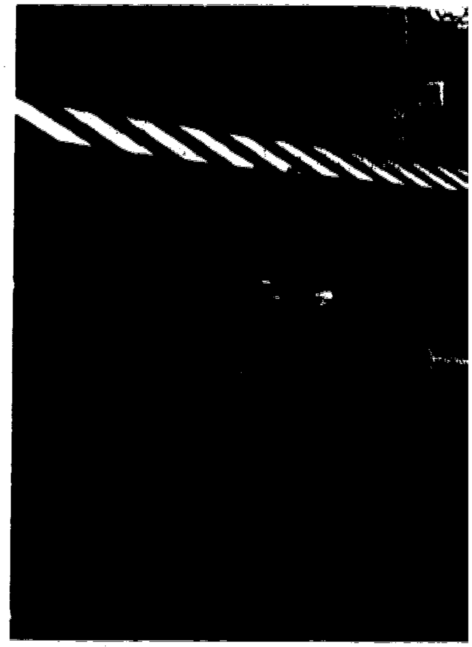
Why has the reaction to these climatic events been more acute than in the past? Similar climate changes have occurred previously in the instrumented record of the past century. The difference is that the vulnerability of the society, even to small fluctuations of climate, is now so severe and so persistent that governments must act in whatever ways they can.

The consequent politics of disaster and economic disruption generated deep concern among leaders of governments throughout the world. As never before, political leaders realized that we had moved into an era of marginal food supplies. We had reached the marginal condition where a failure of the monsoon in India or a drought in the midwestern United States could have worldwide consequences. We realized that the world could meet its food requirements, given present distribution systems, only when growing weather is favorable throughout most of the globe.

As never before, U.S. leaders realized that the increasing world requirements for oil and gas and the dependence of the United States on foreign sources had rendered our energy distribution and allocation vulnerable to the vagaries of climate. The marginality of our energy supplies in the face of climate changes was emphasized during the Arab oil embargo of 1973. Then, only by the grace of a warm winter, was the United States able to provide its heavily populated and industrialized eastern and midwestern areas with adequate energy supplies. The cold winter of 1977, and the natural gas shortages, finally brought home the full implications of climate fluctuations for our energy policies.

As if these natural climatic calamities were not enough to motivate governments and the scientific community to action, there now emerged, contemporaneously, a sequence of ominous findings on the potential for man-induced climatic catastrophes. Suggestions that agriculture and land-use practices might have an impact on climate or that changes in carbon dioxide or particulates might affect the radiation balance of the atmosphere and hence the climate were elements of various theories of climate change going back many years. However, only in the past several decades have we had available the observational data, the understanding of the physical processes, and the means for hypothesis testing to place these ideas on a reasonable scientific basis.

Such concern with man's impact on climate must be seen as part of the emergence of the national and world environmental movement whose interest was in all aspects of man's impact on the environment. New chemicals used as pesticides and insecticides and as household and industrial materials were found to affect the viability of ecosystems and the health of humans. The pollution of the oceans, the destruction of the wetlands, and the depletion of endangered wildlife led to a new environmental consciousness. The result on the national scene was the 1969 National Environmental Policy Act, and on the international scene the United Nations Conference on the Human Environment in Stockholm in 1972 followed by the establishment of the United Nations Environmental Program that same year.



As a result of the work in the early seventies of Harold S. Johnston and Paul J. Crutzen,[1] the controversy surrounding the decision to build a U.S. supersonic transport served as the first forum in which the issue of environmental and hence climatic impact of stratospheric contamination was raised. The effects of the oxides of nitrogen (NO_x) created by the high engine operating temperatures became the focus of concern, and the catalytic effects of NO_x by SST's on the photochemical equilibrium maintaining the ozone in the stratosphere were thoroughly investigated. Calculations showed that introduction of NO_x into the stratosphere by SST's could lead to a reduction of total ozone.

The principal concerns then gradually shifted to the effect of the reduction of ozone upon human health, the health of ecosystems and the noise problem. It was already well established that the reduction of total ozone would increase the amount of ultraviolet radiation reaching the earth's surface. Increased incidence of skin cancer could be predicted with more uncertain consequences for all living organisms.

It was further recognized that the reduction of the ozone would also affect the heating of the stratosphere, the ozone being a key absorber of solar ultraviolet radiation. Only vague speculations, however, were possible about the type of climate changes this would imply. But the issue had been joined. The concerns led to some of the most extensive examinations ever attempted of the possible impact of climate changes on world agriculture and other economic activities, as part of the Climate Impact Assessment Program of the Department of Transportation.

The stratosphere soon began to appear as an Achilles heel, sensitive to attack by other chemicals. As a result of work by F. W. Rowland and Mario J. Molina in 1974,[2] fluorocarbons used as refrigerants and as propellants in spray cans were also found to be effective photochemical catalysts in reducing the total amount of ozone. Calculations showed that at the going rate of production of chlorofluorocarbons and at the rate that they could be expected to diffuse into the atmosphere, significant decreases in the total amount of ozone could be predicted, with the maximum decreases occurring some years in the future.

These two events touched off a search for other substances or industrial processes that might contaminate the stratosphere. The increasing use of nitrogen fertilizers became a matter of concern. The process of nitrogen fixation and the subsequent processes of denitrification can add significant amounts of nitrous oxide to the atmosphere, which, transformed into various nitrogen oxide compounds, might reduce ozone. Recent research on photochemical reactions in the stratosphere indicates that the NO_x effect on ozone reduction may have been overestimated.

As a result of the drought in the Sahel and the failure of the monsoons in India, interest in the relationship between climate, land use, and food production intensified. It was clear that climate changes were triggers for the process of desertification, whose underlying causes were poor land-use practices. Increased population pressures, introduction of new technologies, and changes in land-use patterns produced a situation that was highly sensitive even to small changes in climate. It was suggested that the land-use practices themselves might be direct causes of changes in regional climatic conditions, thus intensifying the climatic conditions that triggered the disaster in the first place.

Climaxing this series of alarms were the conclusions of the Geophysics Study Committee of the Geophysics Research Board set forth in its recent report, *Energy and Climate* (1977). In a stark set of findings, couched in scientific caution and uncertainty, the board concluded that our present energy policies, which rely heavily and increasingly on the use of fossil fuels, especially coal, could result in a four- to eightfold increase in carbon dioxide. The consequences could be global temperature rises of as much as 6°C over the next century and a half. An increase in world temperature of this magnitude is of the same order as that which accompanies the change in world climate from a glacial to an interglacial period. While some scientists question the magnitude of the increase, few question the direction. The publication of the NRC report, *Energy and Climate,* further emphasized the need to address the scientific and public policy alternatives.

THE STATE OF OUR CLIMATE KNOWLEDGE

What is the state of our knowledge of climate and what needs to be done to improve that knowledge? A comprehensive assessment was published in 1975 in the National Research Council's *Understanding Climatic Change: A Program for Action,* prepared by the U.S. National Committee for the Global Atmospheric Research Program. An outstanding treatment of the problem by an international group can be found in *The Physical Basis of Climate and Climate Modelling,* a publication of the Global Atmospheric Research Program.[3]

Understanding Climatic Change contains a fine treatment of the physical basis of climate and climate change, of our knowledge of past variations of climate and what these imply for the future, and of the scope of present research now under way on problems of climate. That report concludes by examining the nature of the present deficiencies in our knowledge and outlines a national and international research program required to fill present gaps. A panel of the U.S. GARP Committee has recently completed preparation of a new report, "Elements of a Research Strategy for a United States Climate Program."

There appears to be general agreement on the major deficiencies.* For example, climatic research is hobbled by the lack of suitably organized climatic data. Data needs for climatic research span a broad spectrum. The vast amounts of instrumental data that now exist in the climatic archives need to be reordered so they can be used easily for climatic analyses. There is a need to assemble noninstrumental historical data from manuscripts, logs, and journals. Proxy data of all kinds need collection. Tree ring data, movement of glaciers, lake and deep-sea sediments, ocean and ice cores—all provide invaluable sources of paleoclimatic information. With such data it would be possible to extend the climatic record many tens of thousands of years into the past. And insight into the past is valuable for foreshadowing what may be in store for the future. There is, in all, a formidable task in climate data management.

There is also a need for well-designed global monitoring efforts based on new technology that can supply observations of the global fluid envelope and define critical physical processes and boundary conditions. High priority must now be given to the conduct in 1978 and 1979 of the Global Weather Experiment of the Global Atmospheric Research Program (also known as the First GARP Global Experiment or FGGE). The Global Weather Experiment will place the world's atmosphere and oceans under the most extensive observation in history. Five geostationary and two polar-orbiting satellites, networks of ocean data buoys, and fleets of aircraft will augment the global weather observing system. This effort should provide the first comprehensive set of global oceanic and atmospheric data suitable for the study of the dynamics of interannual climate variations.

Beyond this effort, there is a need to monitor oceanic, biospheric, and

*My summary draws heavily upon the NRC publication *Understanding Climate Change: A Program for Action.*

cryospheric conditions that determine essential boundary exchange processes. It will be important to monitor the radiation balance of the atmosphere by more precise measurement of the solar constant, the spectral distribution of solar radiation, and the outgoing shortwave and longwave radiation.

The oceans play a fundamental role in the processes of climatic change. Measurements of the thermal condition of the ocean and the interaction of the oceans with the atmosphere are essential. Some progress has been made in monitoring the worldwide distribution of sea surface temperatures from satellites, but much more needs to be done. It will require a combination of ships, buoys, and satellite observations. We have no economic way to monitor the state of the thermal reservoir of the mixed layer, which is critical to any long-term prediction of atmospheric conditions.

Changes in the cryosphere may be the most visible aspect of climate change. But more than that, snow and ice covers directly affect climatic conditions and in turn are affected by them. They are principal determinants of the surface energy balance. We need better measurements of the distribution of sea ice in the polar oceans and the extent of glaciers and ice cover over land.

A knowledge of the exchange between the biosphere, lithosphere, hydrosphere, and atmosphere is essential for many outstanding climate problems, such as those involved with carbon dioxide. Ultimately, we will need to understand the natural changes in the vegetative cover of the surface of the earth. Fortunately, such global monitoring is gradually coming into being through the Landsat satellites. We will need to know about soil moisture and groundwater, about the flow and discharge of major river systems, and about the total precipitation, including the rainfall over the oceans.

We will also need to acquire greater knowledge of a wide range of atmospheric chemical constituents. We need to know more about the global carbon and nitrogen cycles. And it will be important that we have a knowledge of ozone concentration, water vapor, and various other chemical constituents of the stratosphere, all of which can be responsible for changing the photochemical equilibrium of the stratosphere.

Without a theoretical base, however, there is no way to decide what to observe, how to organize our observations, or how to use them other than in subjective appraisals. Our theoretical understanding of stratospheric photochemical processes is reasonably well developed. But while our understanding of climate dynamics has progressed substantially, we are far from a theory of climate and much remains to be done. A fundamental problem centers on the predictability of climate. Excellent progress has been made in understanding the nature of the predictability of daily fluctuations of weather and the theoretical possibilities for extending the time range of daily forecasts. Similar studies are required with respect to the predictability of climate.

The key to developing a rational theory of climate change is the simulation of the atmospheric general circulation by global numerical models called general circulation models (GCM's). In recent years, these models have become sufficiently sophisticated to permit the initial examination of theories of atmospheric behavior and the reaction of the global atmosphere to changes in various physical processes and to external impulses. Important sensitivity studies have already been conducted and have given us new insights into the reaction of the atmospheric circulation to changes in sea-surface temperature, variation in carbon dioxide content, and introduction of volcanic aerosols, and climatic response to variations in orbital parameters. We have entered an era in which it is becoming possible to carry out studies of the sensitivity of global atmospheric circulation to changes in boundary conditions or other physical processes.

For all the progress made, however, general circulation models are still primitive in their treatment of many physical processes. They do not treat wet processes well. Cloud formation and dissipation are only crudely simulated. Convective processes and phenomena smaller than the mesh length of the numerical grid systems (about 100 km) are poorly parametered. The interactions between the atmosphere and the underlying surface, which are critical in determining heat, momentum, and moisture exchanges, are only crudely taken into account.

Ultimately, coupled global atmosphere/ocean models will be required to simulate the important processes in the fluid envelope of the earth. We have a long way to go. Our knowledge of the dynamics of the oceans and of the response of the seas to atmospheric motions is sketchy and inadequate for the development of models of the oceanic general circulation. This must be a key area of research. Projects of the National Science Foundation's International Decade of Ocean Exploration, such as the Mid-Ocean

Dynamics and North Pacific experiments, are opening new avenues for such study.

Our knowledge of past climates has improved immensely through the growing accumulation of paleoclimatic information. It is now possible to reconstruct major aspects of the boundary conditions and physical characteristics of the circulations that occurred in remote historical and geological time. An attractive opportunity now presents itself to reconstruct the atmospheric circulation consistent with these reconstructed boundary conditions. Such reconstructions can provide insight into the nature of the circulations that are associated with geological and historical fluctuations of climate.

In the rush to focus on those aspects of the climate problems that relate directly to our need for greater physical understanding, we must still insure that empirical and diagnostic studies of climate variations are encouraged. There is no substitute for the careful analysis of actual fluctuations in climate in providing insight into important processes in oceans and the atmosphere. These studies can contribute greatly to our understanding of climatic processes and provide empirical bases for attempts to improve climatic predictions. However, even the modern data base is inadequate to define, unambiguously, the global structure of climatic variability of the last forty years.

Also, our focus on longer-term research must not obscure the need for substantial effort to improve present predictions of climate changes or provide more precise estimates of the consequences of man's impact on climate by the systematic application and testing of present capabilities. Studies of the impact of climate changes upon existing social and economic conditions can provide inestimable help for those who must formulate public policy. These studies are essential.

CLIMATE AND PUBLIC POLICY

The directions for science seem clear, but what about the directions for public policy? The prime goal of our public policies must be to reduce the vulnerability of society to the adverse impacts of climate changes. Public policy must also seek to ameliorate the impacts of climate change when they occur. The range of possible public actions is broad. They include actions to improve our scientific knowledge, to provide economic incentives, to build protective works, to compensate for losses, and more. An interesting treatment of many options can be found in *An Assessment of Research on Natural Hazards.*[4]

Policy alternatives depend on the individual nature of climate threats. Their credibility, immediacy, and magnitude of projected impact determine the probability and character of public policy response. These characteristics vary greatly for specific climatic threats, and improvements in our knowledge of them can come only through improved scientific understanding of the nature, causes, and impacts of climatic fluctuations. As a result, emerging public policies are directed toward stimulating a vigorous research effort to increase our understanding of climate changes and their impacts. As a matter of public policy we are now moving, as mentioned earlier, toward the establishment of a National Climate Program. The executive branch and the Congress are joined in supporting this policy. For example, S.1980 states that the Congress finds and declares the following:

The present ability to anticipate and explain either natural fluctuations or man-induced changes of climate is insufficient to provide meaningful contributions to policy formulation concerning agriculture, energy, transportation and other critical sectors of the economy.[5(a)]

Similarly, the House bill, H.R. 6669, in its findings, states:

Congress finds that . . . the United States at the present lacks a sustained and coordinated program of climate monitoring, analysis, information dissemination, and research; [and that] the present ability to anticipate and explain either natural fluctuations or changes or human-induced changes of climate is insufficient adequately to guide policy formulation concerning agriculture, energy, transportation, and other critical sectors of the economy.[5(b)]

These congressional views are similar to those of the executive branch. In his foreword to *A United States Climate Program Plan,* Frank Press, Chairman of the Federal Coordinating Council for Science, Engineering and Technology, states:

There is today a growing consensus and a sense of urgency concerning the Nation's needs for anticipating climatic changes. While we have made tremendous strides in recent years in understanding the basis for long-term climate change—changes over the last 20,000 years—shorter variations, seasonal and year-to-year, have proved far more difficult to understand. We now must intensify our efforts to

anticipate climate variations on a useful time scale, to work toward the recognition of patterns of climate formation that will allow us to forecast regional and local change, and to plan for contingencies on the national scale.[6]

Typical of the views in the science community is the statement of Verner E. Suomi, Chairman of the U.S. Committee for the Global Atmospheric Research Program of the National Research Council. In *Understanding Climatic Change,* he states that " . . . neither the scientific community nor the nation can afford to be complacent with its present level of understanding on this important aspect of the earth's physical environment. The natural forces determining the world's weather and climate are beyond our control, but having better insight into what nature might do should help the nation to plan for what it must do."[7]

Finally, in the recent NRC report *Energy and Climate,* issued by the Geophysics Study Committee of the Geophysics Research Board, Philip Abelson and Thomas Malone, co-chairmen, stated that "to reduce uncertainties and to assess the seriousness of the matter, a well coordinated program of research which is profoundly interdisciplinary in character and strongly international in scope will be required."[8]

We have unanimity on what is perhaps the central aspect of public climate policy—the need for a broad research effort to reduce uncertainties in our climate projections and to enhance our ability to anticipate climate changes. This unanimity extends to international policy. The World Meteorological Organization, the United Nations Environment Program, and other U.N. agencies, as well as nongovernmental bodies, such as the International Council of Scientific Unions (ICSU), are taking action. At the United Nations Desertification Conference, held in Nairobi in September 1977, there was unanimous agreement on recommendations for a strengthened international climate research effort. At the September 1977 meeting of the Executive Committee of ICSU, there was a similar recognition of the need for an international research effort.

Public actions are closely tied to the perceived reality of climate threats such as those that occur on monthly, seasonal, or interannual time scales. Fluctuations of climate on these time scales are responsible for severe but familar economic and social impacts. The threat of drought, flood, or abnormally warm or cold spells are fully appreciated. They have occurred repeatedly, and public policies have evolved to address their consquences.

Most such public policies are based on the view that climate changes are unpredictable.

However, while there is only slight skill in monthly and seasonal forecasting, and none for interannual periods, our knowledge of climate variability is extensive. The historical instrumental record provides information on the frequency of past occurrences of climatic events. Such frequencies are reasonable measures of the probability of events and hence a basis for estimating risk of various courses of action. Further, many climatic events are the result of weather conditions extending over a period of time. Droughts are a good example. Because they are the cumulative result of dry weather over weeks, months, and sometimes years, useful projections are possible, even in the face of great uncertainty about the future course of climate. Incorporation of knowledge of climatic variability into public decision making can help in risk assessment and hence be an improved basis for policy decisions. It is encouraging that the Secretary of Agriculture, Bob Bergland, recognizing the failure to incorporate our knowledge of climate variability in agricultural decision making, has launched a new effort to acquire and use such data in risk assessment in the work of his department—and none too soon, as the recent presidential decisions on wheat acreage illustrate.

On August 31, 1977, the headlines of the *Washington Post* highlighted President Carter's decision to reduce U.S. wheat acreage. With the price of grain plummeting on the world market as a result of anticipated good foreign harvests, the President was confronted with a major decision on agricultural price supports. Good growing conditions in 1978 both in the United States and abroad could cost the U.S. taxpayer billions of dollars in price supports. A twenty percent reduction in acreage to enable farmers to qualify for price supports would reduce grain surpluses and could reduce the anticipated cost of price supports in 1978 by $6 billion. On the other hand, poor growing conditions in 1978 could result in marginal world grain supplies. The President bet on good 1978 growing conditions.

But, as if to point up the need for strengthening the climatic underpinnings of such agricultural policy decisions, the Soviets, on November 1, 1977, disclosed a serious shortfall of twenty million tons of wheat in their 1977 harvest. This came just two months after the presidential decision to reduce crop surpluses. This shortfall was a surprise to the U.S. government, which, even as late as a week before the Soviet disclosure, was projecting good 1977 grain harvests in the Soviet Union. The existence of the Soviet shortfall raised the question about the wisdom of the presidential decision. The surprise in this case may not have been necessary; the cumulative effects of the summer and fall weather on growing conditions in central Asia in 1977 were known to climatologists at the Center for Climate and Environmental Assessment of the National Oceanic and Atmospheric Administration. The experience pointed up the critical need for more systematic use of available climatic knowledge in public policy decisions in which climatic factors are important.

The public policy response to natural climate catastrophes on monthly, seasonal, and interannual time scales, because of their economic costs and the social disruptions, have been principally directed at postdisaster relief, insurance, or long-term protective measures. Over the past half century, Congress has revised and up-dated public disaster policies to reflect political and humanitarian concerns stemming from specific disasters. The Disaster Relief Act of 1974 and the Flood Insurance Act of 1973 are examples of responses to sequences of actual climatic events. These are public policy responses to soften the impact of climate-generated economic losses of staggering proportions. Annual agricultural losses alone average about $3 billion. Dams, irrigation systems, and reservoirs are the technological insurance that public policy has willed us against the ravages of climatic change.

What the government seeks to do in its emerging policies to support major new climate research efforts is to alter this situation. It seeks to lay the basis for rational predisaster public actions based on an improved knowledge of risks. There are some excellent examples of what can be done in special situations where it is possible to predict climate-related events for periods of months in the future. In 1970, it was possible to predict the high probability of spring snow-melt floods in the upper Midwest several months in advance. This prediction was made on the basis of the snow accumulations on the ground during the preceding winter and estimates based on various climate scenarios. The Corps of Engineers, with other federal agencies, launched "Operation Foresight"—a program to build protective works around endangered facilities and along river banks to contain the expected flood. The Corps of Engineers estimated that such predisaster protective actions prevented hundreds of millions of dollars of economic loss, which otherwise would have occurred.

However, there has been no extensive look at how all these public policies relate to one another and to our climatic expectations. Some very tough issues, such as those related to land use or the establishment of food reserves, need examination through the climatic prism. We have developed a major agricultural dependence on areas climatically deficient in water, and we transport water at great cost to these areas. The problem is how to bring water and the food production activities together. As a matter of public policy, we have traditionally sought to bring the water to the food producers. Is there merit in modifying this policy by encouraging producers to move to areas with adequate water? Stephen Schneider, in *The Genesis Strategy*,[9] pleads for a food reserve policy as insurance against the climate fluctuations. Action along these lines is slow in forthcoming, but some forward movement is now taking place to establish internationally designated national grain reserves as a result of action by the World Food Council. From an ecological view, the time may be at hand when we must think in terms of climatic "zoning." We need to be clearer about ideas, and this suggests the need for a range of research on public policy alternatives.

The public policy outlook changes radically when we consider climate changes of lesser credibility and immediacy. Several of the climate alarms of the past decade are instructive for what they indicate about the process of policy formulation in these cases. Of special interest are the alarms about impacts on the stratosphere resulting from the release of chemicals that affect the photochemical equilibrium maintaining the stratospheric ozone. Special interest also attaches to the alarm about the impact of increasing carbon dioxide on global temperatures. These climatic threats are significant, because they are man-made, and government regulation can be invoked to ameliorate the causes of postulated climate change. They are caused by, and their amelioration directly affects, specific industrial and commercial sectors. Regulation to lessen the threats requires international cooperation, as the sources that produce them are internationally distributed and, therefore, regulation within a single nation would be ineffective.

Unlike the shorter-term natural climatic fluctuations, which are uncertain only in that their timing is unpredictable, these longer-term, less immediately obvious threats are uncertain not only as to timing, but also as to their magnitude and their impacts. These threats, while buttressed by specific observational data on pertinent physical processes, are postulated as a result of a difficult chain of theoretical reasoning and calculation. Public policy formulation must take place within a broader envelope of uncertainty.

Harvey Brooks,[7] in September 1975, testified on some of the public policy aspects of environmental problems of this type before the Subcommittee on the Upper Atmosphere of the Committee on Aeronautical and Space Sciences in the U.S. Senate. In addition to some of the characteristics indicated above, Brooks pointed out that the environmental impacts that could result from such threatened events may be difficult or impossible to reverse in the future if public action is not taken at an early date; yet the extent of future damage from the economic activities that contribute to these climatic threats is quite weakly linked to the timing of any regulatory measures. They represent a class of problems in which it is necessary to weigh longer-term potential detrimental effects against the near-term effects of regulatory actions on particular industries.

Brooks' concern is illustrated by the recent experiences involving possibly harmful changes in the stratosphere due to supersonic transport emissions and the widespread industrial use of chlorofluorocarbons. A current example is the interest in the effects of an increase in the carbon dioxide content of the atmosphere due to the combustion of fossil fuels.

The threat represented by the contamination of the stratospheric ozone layer was perceived principally as a threat to health rather than climate. The consequences for climate were uncertain. The major focus of public attention was on the potential increase in the incidence of skin cancer. The issue was raised about the time the Congress was attempting to decide whether to authorize continued construction of the U.S. supersonic transport. It was the high-water period of the environmental movement in the United States. The SST study by the Department of Transportation and the NRC's Committee on Impacts of Stratospheric Change indicates that a limited number of supersonic transports would have environmentally minimal effects upon the stratosphere, but that a much larger fleet could result in unacceptable environmental consequences. While the question of the environmental impact of the SST was of deep concern to the Congress, and, indeed, influenced the congressional decision, there were other more fundamental economic concerns that determined the outcome.

In the case of fluorocarbons, the course of public action was different. A special governmental task force, established jointly by the Council on

Environmental Quality and the Federal Council for Science and Technology, to study the effects of fluorocarbons on the stratosphere concluded that the ozone reduction threatened by continued use of fluorocarbons was sufficiently serious as to require consideration of regulatory action to reduce the amount of fluorocarbons being emitted to the atmosphere. The NRC, in September 1976, issued its reports, prepared by the Committee on Impacts of Stratospheric Change, and its Panel on the Effects of Halocarbons on Stratosperic Ozone, which confirmed the essential framework and scientific conclusions of Rowland and Molina, and the conclusions of the governmental task force. The NRC committee recommended a delay of up to two years in the decision to regulate, to provide time to reduce the scientific uncertainties.

In spite of the suggestion that there was time to carry out further research on the problem, the Food and Drug Administration concluded that the risks were unreasonable as far as long-term biological and climatic impacts, that a delay to carry out further research to improve the estimates was not warranted in the light of the risks, and that regulatory action was needed. In October 1977, the Food and Drug Administration, the Environmental Protection Agency, and the Consumer Product Safety Commission joined to take action to initiate a phase-out of the use of nonessential fluorocarbons in products.

In its draft Environmental Impact Statement on environmental and health implications of fluorocarbons, the Food and Drug Administration in May 1977 proposed a prohibition of all nonessential uses of fluorocarbons as propellants in self-pressurized aerosol containers subject to the Food, Drug, and Cosmetics Act. The stated environmental impacts are interesting to note. They dealt with reduction of the damaging ultraviolet radiation; the reduction of the number of new cases of nonmelanoma skin cancer; the reduction of other health effects of increased exposure to ultraviolet radiation, such as premature skin aging; and the reduced potential for adverse nonhuman biological impacts, and possible climatic changes. Note the emphasis on health rather than climate.

The time between the findings of Rowland and Molina in 1974 and the regulatory action of the U.S. government in 1977 is remarkably short. This is especially true given the fact that actually observed reductions of ozone could not be detected in the face of its normal variability. The public policy decision was based largely on the theoretical calculations supported by observations of key physical processes. How was it possible to bring about such a public policy response in the face of a postulated atmospheric effect that would not materialize in a serious way for ten or fifteen years and in the absence of any actual observations of the postulated effect?

The most important factor was the near unanimous scientific opinion on the matter, lending a high measure of credibility to the predicted impact. The unanimity of scientific opinion largely stemmed from a well-developed body of theory coupled with observations of certain critical physical processes—a result of sustained basic research over the years on stratospheric photochemical processes. Also important was the availability of alternatives and an enlightened impacted industry. The economic consequences for the fluorocarbon industry were indeed substantial, as the record indicates. However, insofar as aerosol propellants were concerned, there were alternatives that could be adopted by industry. Propane or carbon dioxide propellants could be used in aerosol cans. The shift occurred rapidly as industry recognized that regulatory action was imminent. In short, there were reasonable alternatives, in spite of significant economic dislocations.

The public policy issues represented by the climatic threat of carbon dioxide are of a different nature. There is general agreement that the problem could be cosmic in its impact on national and international energy policy. If present projections of approximately a 3°C rise in average global temperature for each doubling of atmospheric CO_2 are reasonably accurate, the climatic effects of the increasing use of fossil fuel may indeed be a primary constraint on energy policy over the time period of the next century.

In this case, unlike that of stratospheric ozone, the CO_2 content of the atmosphere has long been observed to be increasing. Records over a period of several decades from the Mauna Loa Climate Observatory in Hawaii, of the National Oceanic and Atmospheric Administration, have shown a systematic increase in CO_2 content. Similar increases are reflected in other observations. Scientists have been alert to the situation for many years. Finally, through the work of Manabe and Wetherald (1975) at the Geophysical Fluid Dynamics Laboratory, National Oceanic and Atmospheric Administration, at Princeton University, sensitivity studies using a comprehensive but incomplete general circulation mathematical model provided the most recent and presumably the soundest answers to questions about the consequences for climate. The mathematical model calculations confirmed what had been suspected—that global sea-level temperatures could increase as a result of CO_2 increase.

The Geophysics Study Committee's report, *Energy and Climate*, suggests the possibility that by 2150 the consequences could include:

- A melting of glaciers and reduction in the amount of sea ice causing rises in sea level of the order of fifteen to twenty feet.
- Increased rates of photosynthesis that would beneficially increase plant growth.
- A northward shift of agricultural zones and a consequent shift in types of crops that would be adaptable to the new climatic zones. Much of this shift would be beneficial in parts of the world such as the Soviet Union and other areas where growing seasons are presently too short to support certain types of agriculture.
- Expansion of arid and semiarid regions. However, there is reason to suspect that some present arid areas might become wetter as was the situation in the "climatic optimum" several thousand years ago.

The uncertainty surrounding these projections is so great that a public policy dilemma of the first order is presented. Thomas Malone (1977) in a comment to the press likened the situation to the warning of a flashing yellow light rather than a red light. On hearing this analogy, Douglas Sargent, Director of the GARP office of NOAA, noted (personal communication, 1977) that rarely does anyone in Washington stop for yellow lights. The NRC report *Energy and Climate* raises many questions but avoids suggesting any public policy approaches other than a need for intensified research to reduce uncertainty and establish a level of credibility where specific public actions might be indicated.

One of the key questions goes to the ability of society to adjust to slow environmental changes. Man has experienced major shifts in climatic conditions over the centuries. He has adapted because the changes have been slow. Can we leave such adjustments to social and economic forces? If not, are we wise enough to take public action now to ease adjustments to slowly changing climatic conditions over a period such as two centuries?

The authors of the NRC report have taken the view that there is yet time, several decades, before there is a need for decisions about changes in our present energy policies. The public policy problem is complicated by the fact that a shift from dependence on one energy source to another is a process that extends over much of a century. If a shift is to be made, decisions to do so would have to be made at least half a century in advance to bring about a gradual and orderly changeover. But since no energy alternatives to fossil fuels are currently satisfactory for universal use, no immediate decision can be made. And so, for the moment, public policymakers can only explore the problem in as much depth as possible.

And that is exactly what is happening as a matter of public action. Stimulated by the findings of the NRC and other groups, the new Department of Energy plans to mount an extensive research program on the problems of carbon dioxide as a limiting factor in our energy policy development. The research and development necessary to explore this further are a major element of the newly emerging National Climate Program, and the legislation now before Congress is supportive.

If we examine the range of public policy actions that have been taken or are being considered, both domestically and internationally, in response to various climatic threats, one must have a sense of satisfaction. The interaction between scientists and public decision makers has been extensive and that has made for sound public policy. The impact of scientific findings upon the course of public policy is evident. If there appear to be any disagreements in our present public policy approaches, they are about institutions. The problems of climate are so pervasive, engage so many scientific and technical disciplines, and impact so many segments of the economy, that it becomes very difficult to get an overall institutional grasp on the problem and provide a comprehensive effort with some degree of overall guidance. This characteristic has been noted in *Energy and Climate*, and some suggestions have been made for innovative institutional arrangements for a collective governmental/nongovernmental approach, involving the full talents of both governmental and nongovernmental bodies. The institutional problem has been of great concern to the Congress, and pending legislation reflects its attention to this issue.

It appears that the climate effort lends itself very nicely to the creation of new types of networks of institutions in which existing groups, whose expertise is essential, can be motivated to participate in a broad and comprehensive program. An institutional nerve center is needed as a focus to take an overview of the problems, to stimulate comprehensive planning, and to monitor progress. In microcosm, we face the same kind of institutional problem within the NRC, where some thirteen boards and committees have been deeply interested in one aspect or another of climate. The Climate Research Board is, in a sense, an institutional response to this situation and, it is hoped, will be able to edge the NRC toward the kind of comprehensive approach that might serve as a model for a broader attack on a national and international scale.

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Study Projects

ASSEMBLY OF MATHEMATICAL AND PHYSICAL SCIENCES

COMPUTERS—SOME PROBLEMS

Although the idea of the automatic computer originated during the first half of the nineteenth century, it only has been during the last twenty years that electronic computers have become generally available. Now ubiquitous and indispensable features of our society, computers will surely influence societal evolution.

Computers are essential to scientific research, the modeling and solution of engineering problems, the simulation of complex systems, business administration, dealing effectively with large volumes of data, control of some types of manufacturing process (see, for example, the article on integrated computer-aided manufacturing in this report), and the enhancement of person-to-person and organization-to-organization communications. With such broad and diverse applicability in the use of computers, it is not surprising that there exist a multiplicity of important problems related to them—their science, their technology, and their impact on society. Several such computer-related problems are described below. This list is far from exhaustive; however, it indicates the variety of topics that need attention.

1. Spectacular developments in electronic technology during the past few years have resulted in a radical change, for many firms, in the ratio of costs of computer hardware to computer software. Processing power, which some years ago cost $1 million, can now be obtained for about one-hundredth of that cost. Concomitantly, production of software has proliferated to the point where its costs greatly exceed the cost of computer hardware.*

Unfortunately, there is very substantial redundancy in the software being developed, partly because software developed for one computer is not readily usable in another. Software problems are also due to the continual modification of programs as new applications are developed.

Several questions can be addressed. Should programming language standards, which would permit the portability of software (i.e., the easy use of software by different computer system), be developed and adopted? Would the existence of such standards inhibit innovation and the "natural" evolution of the computer industry? What shifts, if any, would take place in the structure of the industry? What effect would such standards have on the quality, reliability, and cost of software? How are any recommendations for the adoption of programming language standards to be implemented?

2. Another software problem is determining the correctness of programs. Many are so large and so complex that it is an almost impossible

*Hardware conventionally means the machines, and software their programs. The latter more specifically refers to the analysis and planning required to solve a particular problem, including the coding or writing down of specific instructions. These instructions can be given either in machine language directly usable by a particular type of computer or, much more convenient, in program language—ALGOL, COBOL, and the like—suited more to the needs of the programmer, rather than a particular machine. Program language is translated into the language of a particular machine by a special compiler program, or simply compiler.

As noted in the text, the rise of more powerful, very complex computers has driven the creation of better ways to use them. The result is very elaborate and very expensive programs, whose costs have risen faster than the costs of the machines, further testimony that the costs of people tend to rise and that of technology to fall.

In some ways the distinction between software and hardware is an artificial one. Computing plans are now made on the basis of computing *arrays*, which include the machines themselves, the programs with their codings, and large control programs called operating systems. In such a computing complex, with its intimate and symbiotic relations between instruction and design of the total system, it becomes increasingly difficult to tell, in terms of costs or any other category, what is machine and what is program.

task to determine whether they are free of pitfalls and will do, in diverse circumstances, what they are intended to do. What criteria can be used to verify the accuracy of a program?

Further problems arise from the recent development of multiprocessor computers. An ordinary computer does one operation at a time; a multiprocessor several operations at a time. Thus, an ordinary computer is similar to a manager without workers, who performs a sequence of tasks one at a time. One type of multiprocessor, on the other hand, is similar to a single manager who assigns a task to a worker, and while the worker is performing this task the manager is readying the assignment of a second task; a second type is similar to several managers all performing different tasks simultaneously. Whatever the type, programming a multiprocessor efficiently and accurately is not a small undertaking. The complex interactions between processes increase the chance of error; the nondeterministic sequencing of tasks makes it difficult to correct even observed errors in the program.

To determine if software is correct is an extremely difficult technical problem; a great deal of research is required to fully understand it. In the interim, should emphasis be placed on the testing and debugging, rather than on the certification, of software?

3. It was noted above that software costs are currently outstripping hardware costs. At the time when the reverse was true, it was economically desirable to have a main central processing center perform, on a time-shared basis, as many tasks as possible. Computer networking arose as a natural development from time sharing. In a computer network each one of a set of users has remote-controlled access to network machine time, algorithms or computing procedures, software, files, and so on. (These network resources may be located at different points within the network.)

Now, single-chip electronic microprocessors with a fair amount of processing power are generally available at a cost of less than one hundred dollars per chip. The economic constraints making it desirable to rely on a single central processing unit no longer obtain. It is now economically feasible to distribute "computers" (microprocessors or minicomputers—the latter having a capability between a microprocessor and an ordinary computer) at various points in a network; these computers may be designed for specific communication purposes or tasks. There are obvious advantages to such a "distributed architecture." For example, in the nondistributed case, if the central unit goes down, everything halts; in the distributed case, only tasks dependent on the failed processor halt. Failures in a distributed system are generally easier to locate and repair than in a central system; computers in a distributed system can serve local, as well as network purposes.

How should a distributed computer network, or, more generally, a communication network, be structured and controlled so that it is economic and performs reliably with minimal delays under both normal and severe conditions?

4. There are, at the present time, many computer-based communication systems. Advances in computer technology and the remarkable drop in the cost of hardware make it likely that, before long, many individuals will have access to display and communication terminals at work and at home. In conjunction with local and remote electronic storage facilities, these terminals may enable, for example, the replacement of the regular mail system for a substantial population by an electronic mail system (with fileable paper copy).

There are costs and benefits in an electronic mail system, including terminal and operator costs, communication facility and usage costs versus reduction in the time needed to transmit and receive messages, and displaced costs of regular postage. How the matter of privacy is to be rated in a cost–benefit analysis is uncertain. A study of the potential implementation of an electronic mail system would have to analyze these costs and benefits in detail.

Other questions would have to be addressed in such a study. Who and how large is the potential clientele? What range of services can be offered? How does the value of the system change with a change in the services available? How will the system be affected by changes in technology? What is a reasonable schedule for implementation?*

There are other problems of importance in computer science and technology, some intimately involved with questions of policy. For example:

*Similar questions were addressed in the 1976 NRC report, *Electronic Message Systems for the U.S. Postal Service;* a new study would focus on problems of implementation.

What should be the role of the federal government in maintaining a top quality computer science and technology base through agency grants and contracts? How can the scientific and academic freedom aspects of the publication of algorithmic results be reconciled with possible national security implications, such as application to encryption?

A group of highly qualified individuals is needed that can address and articulate the problems related to computer science and technology. To this end, the National Research Council established the Computer Science and Technology Board.

The responsibilities of the board include:

- Assaying and promoting the health of the discipline, which includes algorithms, architecture, artificial intelligence, design, information science, languages, numerical and nonnumerical methods, programming, systems, and technology as applied to computers.
- Fostering the interactions of computer science and technology with the other fields of pure and applied science and technology.
- Providing a base of expertise within NRC in computer science and technology.
- Responding to requests addressed to NRC from the government and nonprofit foundations for advice in the areas of computer science and technology.
- Initiating studies in computer science and technology that further the objectives of the first two items above.

JACOB K. GOLDHABER

Computer Science and Technology Board, Assembly of Mathematical and Physical Sciences. Board Chairman, Victor Vyssotsky of Bell Laboratories; Staff Officer, Jacob K. Goldhaber.

SUN, WEATHER, AND CLIMATE

Change is usually more intriguing than stasis, and in the matter of the possible effects of the sun on climate, the interesting question is not the effect of the sun on climate, but the relation of solar *changes* to climate *changes*. That the sun has an effect on the earth's climate is a trivial assertion, given the role of solar heat and its daily and seasonal variations in shaping and driving wind flow, clouds and rain, ocean currents, and other assorted factors that, put together, determine weather and the pattern of climate. But whether solar changes are followed by climatic changes is a much slipperier issue to which the immediate, scientifically conservative answer would seem to be no. There are two reasons for being negative. The first is that by direct measurement—whether on the ground or from space, for a day or for several years—the amount of sunlight, or radiant energy, streaming to the earth seems to stay virtually unchanged. If there are any changes in the total solar radiation, they are less than one percent of the total amount measured, although larger changes could occur over longer periods.

Given apparently invariant sunlight, the suspicion falls on more subtle changes in the sun's output, such as the influence of sunspots. But here the objection is that there is no obvious way by which sunspot patterns can affect the earth's climate. However, the lack of an explanation has not discouraged an intense interest in sunspot–climate relations. Sunspots are dark spots on the photosphere, or visible surface, of the sun. They are sometimes seen singly, and more often in groups or clusters; they are the marks of intense magnetic fields that come up to the surface from within the sun. Various solar events are linked to these strong magnetic fields, the most spectacular of which are solar flares and eruptive prominences—geysers of hot solar gas rising at times thousands of miles above the photosphere and penetrating through the solar corona, the normally invisible halo of the sun.

What makes sunspots so intriguing is their manner of occurrence. Best known is a well-established cycle of eleven years between maxima or minima in their numbers; there is also a twenty-two-year cycle, if one includes the fact that magnetic polarities of the sunspot clusters reverse every successive eleven years.

These cycles do occur. But do they affect the earth's climate, and if so how? There is circumstantial evidence of a correlation, such as an apparent correspondence between droughts in the high plains of the western United States and the twenty-two-year magnetic solar cycle. Recent evidence from an extensive study of tree rings has shown that this correspondence has persisted for several hundred years. But there are no detailed explanations of how the solar magnetic cycle and climate might be causally related. One may speculate that sunspot activity changes the chemical composition of the upper stratosphere, which could affect the heating of the lower troposphere, where climate is made. Or that charged particles carried away from the sun by the solar wind interact with the earth's magnetic field to in some way affect the climate. But these remain guesses. Moreover, any effort to establish a causal chain is confronted by a swarm of other possible influences on the climate. These include interactions between oceans and ice caps and between oceans and the atmosphere, as well as changes in the particulate, ozone, and carbon dioxide content of the atmosphere. Changes in the earth's orbit as it travels through space also may bring about climate changes.

There is, finally, the possibility that in looking at sunspots one is really looking only at Newton's pebble on the beach, failing to see the ocean of truth beyond; for sunspots are only the most visible indicators of solar activity, and hence may indicate more portentous changes occurring beneath the surface of the sun. It may be these latent events, signaled by changes in sunspots, that have a modulating effect on the earth's climate. These subtle and possibly slow solar changes, while perhaps trifling on a solar scale, may be momentous on an earthly one, and may constitute the trigger mechanism or the force itself that sets off climatic change. But, again, that is argument, not proof.

A student of the subject, John A. Eddy of the National Center for Atmospheric Research, has written that,

> The trouble is that weather and climate changes can happen in spite of the sun. Observable solar changes might have tropospheric effects, but not necessarily. The earth could enjoy dramatic weather and varied climate, with droughts and heat waves and ice ages, even if the sun were locked to a perfect thermostat and didn't change its output at all, in photons, particles, or whatever. There are lots of inputs to the weather machine, and many of them are intrinsically more variable, more immediate in their effects, and more poorly known than the rather stable sun. Moreover, if nature works in her usual way these causes are probably all at work

all the time, intertwined and inconsistent in dominance, so that the attempt to isolate one of them as a predictor is probably unrealistic.[1]

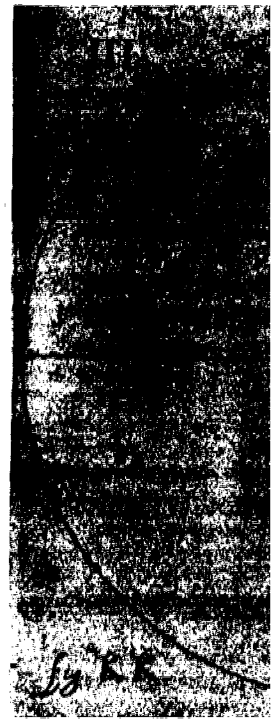
One way to piece out causal effects from a mass of confounding variables is to step back for a longer look—to extend the time scale to see if suspected causal chains become more visible in longer perspective. For example, one might argue that eleven-year cycles, even twenty-two-year ones, are simply brief bumps in a more important pattern whose existence only becomes apparent on a sufficiently long time scale.

Enter the Maunder Minimum. Between 1645 and 1715, the number of sunspots reported was unusually low, probably lower than the normal minima in the eleven-year cycle; and for some ten-year intervals no sunspots at all were reported. The episode is remarkable by itself, and made even more so by two coincidences: One, amusing but surely irrelevant, is that it blankets almost exactly the reign of the "Sun King," Louis XIV (1643–1715); and the other is its coincidence with one of the extreme excursions of the "Little Ice Age," a period of severe and very cold weather.

The time of the prolonged sunspot minimum was also marked by a burst of observations with optical telescopes; during that time, both the Greenwich and Paris observatories were founded, and Newton devised the reflecting telescope. The acute interest in observing the skies accounted for extensive records of what the sun, among other bodies, was doing. The curious absence of sunspots—remarked upon by the contemporary observers, but not thought unusual—was pointed out in the late nineteenth century by a German astronomer, Gustav Sporer, and soon taken up in much greater detail by E. W. Maunder, superintendent of the solar department at the Greenwich Observatory. Maunder's reports, between 1894 and 1922, neither gathered much support nor a great deal of attention; modern reappraisal, however, has verified the apparent reality of his claims.[2]

Moreover, the Maunder Minimum did suggest that the sun was capable of odd behavior, which surpassed, in its duration and in the virtual absence of sunspots, both the eleven- and twenty-two-year cycles. It therefore opened the possibility that there were other solar variations to consider in looking for a climate connection.

That the Maunder Minimum does indeed carry a story has been amply verified by tracing the history of the sun back several thousand years,



Seventeenth-century drawin
May 22-31, 1643

Seventeenth-century technique for observing sun using the related tools of radioactive carbon dating and tree-ring chronology. Radioactive carbon, ^{14}C, is formed in the upper atmosphere by cosmic rays. Incorporated into carbon dioxide, the radioactive carbon enters by photosynthesis into plants, including trees. The sun's extended magnetic field is one of the modulators of cosmic ray activity, and hence radiocarbon production. Therefore, in principle, one can trace the history of the sun back several thousand years by measuring the amount of radiocarbon, relative to nonradioactive ^{12}C, in the wood of datable tree rings. Tree rings that were formed when solar activity was high, i.e., when there were many sunspots, should contain reduced amounts of ^{14}C; those formed during periods of extended low solar activity, like the Maunder Minimum, should show increased radiocarbon.

When the tree-ring record of the sun's activity is plotted in this fashion, one finds evidence of a series extended of minima and maxima of solar activity like the Maunder Minimum—not a simple alternating series, but rather cyclic variations of clustered maxima and minima. If these are plotted, a 2,500-year cycle emerges; the Maunder Minimum is a point on the plot; the 11- and 22-year cycles are filtered out in the radiocarbon record and the 80-year cycle is scaled into insignificance.[3]

Moreover, there are intriguing correlations of this long-term record of solar activity with climate history (the latter, oddly, more poorly known). As John Eddy has pointed out,

> [t]he correspondence, feature for feature, is almost the fit of a key in a lock. Wherever a dip in solar activity occurs . . . the climate swings coldward, and mid-latitude glaciers advance. When a prolonged maximum of solar activity is indicated . . . glaciers retreat and the earth warms. . . . [4]

This is again suggestive, and what is now needed are improved radiocarbon data and detailed and quantitative physical explanations of how changes in the level of solar activity can affect the earth's climate. A possible explanation is that the solar constant, the radiant energy poured upon the earth, does change, but very slowly, perhaps no more than one percent in one hundred years. Such changes would be very hard to detect by direct measurement in real time. Other mechanisms of long-term connections between the sun and climate are also possible. These and other issues are being considered by the Panel on Sun, Weather, and Climate of the Geophysics Research Board.

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Panel on Sun, Weather, and Climate, Geophysics Study Committee, Geophysics Research Board, Assembly of Mathematical and Physical Sciences. Panel Chairman, John A. Eddy of the National Center for Atmospheric Research; Staff Officer, Donald C. Shapero.

Commission on Human Resources

The Ph.D. Employment Cycle—Damping the Swings

HARRISON SHULL

The new Citicorp building in New York City is by all accounts a remarkable building. Its architecture and the faith its builders demonstrated in the continuing vitality of New York City have been praised. But I'm especially intrigued by a 400-ton block of concrete that sits at the top of the building and moves counter to the building's movements in the winds, damping unpleasant and possibly destructive oscillations.

It isn't elegant but it seems to work. There are, of course, many other examples of sophisticated ways to damp small movements before they become large ones. For example, stabilizers damp the pitch of a ship in high seas. More esoterically, the product of a chain of reactions catalyzed by enzymes itself inactivates one of the enzymes. This biochemical feedback thereby slows or stops the reaction until the product is depleted and more is needed.

These are examples of the use of feedback in controlling destructive oscillations, reducing them to relatively minor fluctuations, or ideally producing a steady optimum supply. I would like to suggest that the same

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feedback principle, using fairly simple tools to control minor changes, can be applied to another type of oscillation: the supply and demand of highly educated researchers in science, medicine, and engineering.

OSCILLATIONS

Shortages and excesses in the supply and demand for scientists and engineers are not infrequent in the United States. The most recent mismatch, which still occupies much attention, is the sudden excess in supply of Ph.D.'s relative to demand that appeared in some fields in the late sixties. Up to that time there was an intense demand for Ph.D.'s because of federal investments in basic research, a boom economy, and large needs for teachers for the burgeoning student population. The curve dipped the other way just before the end of the decade, as the U.S. economy went into recession and as, for a variety of reasons, federal research investment, discounting inflation, declined. Suddenly, significant numbers of Ph.D.'s and similarly highly educated individuals, usually thirty years or older by the time they had finished their education, were either unemployed or underemployed. Now, less than a decade later, I see increasing signs that the supply of Ph.D.'s in the physical sciences may soon be dipping below demand.

Excess supply of Ph.D.'s was also a product of the depression years, and many scientists now reaching retirement remember ruefully their own difficult career beginnings. Many were sustained only by special WPA projects or by accepting one temporary post after another. The excess supply at that time suddenly changed to strong demand as the needs for scientists mounted feverishly during the war years. Many people do not remember that this period of high demand lasted only a few years after the end of the war, terminating in the very late forties when jobs were again scarce.

Quite apart from these very general oscillations in the availability of positions relative to the supply of Ph.D.'s, there are also corresponding examples in specific fields. The changes in federal research investments in the late sixties hit the market for high-energy physicists particularly hard. There currently seems to be developing a severe shortage of M.D. researchers. Oscillations are particularly apparent in the job market for engineers.

ENGINEERS

There are some important differences between training engineers and training research scientists and physicians. Potential Ph.D.'s in the sciences tend to make their go or no-go decisions concerning graduate school, subject to field switching, in their senior year in college. But the decision to become an engineer must be made four to five years earlier, usually no later than the senior year in high school. The engineering curriculum is tough and, frequently, all too narrow. There is usually little opportunity for much breadth of training and hence for field mobility. The program is long: frequently up to five years of a very rigid curriculum to get a bachelor's degree in engineering. The incentives are certainly there. Pay is good. The opportunities for advancement are excellent. Job satisfaction is usually high, and a student is easily convinced that he will contribute to society in very practical, highly visible ways.

But these attractions of engineering are also part of its problems. The demand by the market for newly minted engineers is strongly influenced by the state of the economy. A stagnating economy means fewer engineers are hired, not only because money is tight but because the psychology is not right. Industry becomes conservative and reduces not only its hiring levels, but also its plans for expansion and its future hiring goals.

A sharply rising economy generates a demand for new graduate engineers and expectations of more growth. The optimism becomes such that industry, fearing that it will not have enough engineers, tends to overhire and to stockpile them. That is what happened in the 1950's and early 1960's. The aerospace industry is the most trumpeted example.

The problem would be maddening enough if these demand fluctuations paralleling economic changes were the only element in the supply and demand cycle for engineers. But there is a link between supply and demand—a link that is five years long. If an oversupply of engineers occurs, it is made evident in newspaper stories about engineers looking for jobs, in advertisements (or their lack) by companies that hire engineers, and in the publicity generated by university placement offices. That news has a strong effect on the decisions of students who are in their junior and senior years in high schools—a highly impressionable time. But the bad, or good, news about engineering employment prospects has almost no effect upon those already in the educational pipeline. They've already invested too much individual effort and opportunity cost, let alone cash, to start again.

The overall effect of a recession then is a drop in freshman enrollments in engineering schools and a completely predictable drop in the size of the graduating class four or five years later. By then the economy has probably reversed itself. There is now an intense demand for engineers, at a time when the supply is unnaturally low. The cycle reverses: salaries skyrocket, companies advertise almost frantically for engineers. The good news gets back to the high schools. Freshmen enrollments zoom. Too many engineers graduate five years later. And suddenly engineers are again out of work.

MINOR MISMATCHES

These mismatches in supply and demand of doctoral scientists and also of engineers have never been of epic proportions. In fact they have in general been relatively minor. Those Ph.D.'s and M.D.'s who spent a year or more in postgraduate training, or those engineers who did graduate work and were caught in a downturn of demand, will hardly agree that their plight was a negligible one; and in terms of personal anguish and professional loss it was not. Indeed, many of my own students were affected, so I can cite some painful case histories. However, the overall unemployment rates of Ph.D.'s never went above three percent, which *is* minor compared with the double-digit unemployment rates among some other groups in our society, such as black teenagers. Nevertheless, this unemployment, however small, is in a group that has personally invested heavy opportunity costs with the expectation of being able to make valuable intellectual contributions to society. They are vocal individuals and are highly skilled in bringing their plight to national attention. And properly so, for they, along with their employed colleagues, form one of society's essential resources for the future, its educated manpower.

The very modest scale of the Ph.D. unemployment problem makes it solvable; and the rewards in solving it are great. The tools to smooth the relatively small discrepancies between Ph.D. supply and demand are partly in hand. Their proper use takes, as always, careful planning; mechanisms by which policy planners in government can obtain objective, dispassionate, and sound advice; and a willingness by our political leaders to support funding levels for research training that remain stable over times that are long compared with the usual political cycles. All this, I must emphasize, is not simply an academician's fancy, for the idea is already being tested in the effort to modulate, in response to probable demand, the future supply of researchers in the biomedical and behavioral sciences. More specifics later.

QUICK FIXES

What are not needed are quick fixes. We now have enough evidence that patchwork attempts to deal with Ph.D. unemployment will not work and indeed will usually make matters worse. For example, the natural reaction to the observation of a sudden glut of Ph.D.'s was to reduce the funds for graduate fellowships and traineeships (the first kind going directly to individuals and the other first to institutions and through them to individuals). That is just the action that was taken in the early 1970's when the federal government, and more particularly the Office of Management and Budget, systematically weeded out almost all federal fellowship and traineeship programs. From 1968 to 1975 there was a decrease from 3,846 to 1,367 in the number of students supported by such awards.[1] The response of the academic researchers and departments was to move support from postdoctorals to predoctorals. By their lights, the response was reasonable and humane, given the circumstances. The postdoctorals were finished with their formal education, but there was a moral obligation to continue support of the graduate students who already had made sizeable investments of time but were not yet at a marketable career stage. The result was counter-intuitive: Rather than experiencing a reduction in the number of Ph.D.'s looking for jobs, the market was suddenly swelled by an influx of Ph.D.'s caught in a difficult situation. Their postdoctoral support was gone, and they were asked to find jobs at a time when demand was already low—when the government was cutting research funding and a recession was coming on; when, in short, all the signs were pointing to not hiring. That was the first-order effect. The second-order effect was indeed the intended one of reducing the number of incoming graduate students. But the result is that some five or even more years later, or the time it takes to produce the finished Ph.D. product an undersupply of Ph.D.'s relative to demand is developing. The remedy [illegible] in 1970 not only did not solve the immediate problem, but quite possibly is creating another one years later; rather than damping the supply and demand swings, it exacerbated them.[2]

In all fairness, the government, once made aware of the plight of Ph.D.'s without postdoctoral support, did try to do something. But that also did not work as effectively as it might have. Special postdoctoral programs were proposed, but too late for that year's current budget and almost too late for the next one. When funds were finally included and appropriated, the responsible agencies had to assign staffs, write guidelines, issue notices that the fellowships were available, and make the selections. No funds went to postdoctorals until at least two years after the problem was recognized, too late to help many of the intended beneficiaries.

REMEDIES

These policy failures were avoidable. Two things were needed: (1) some stability in total support funds available to agencies supporting basic research, particularly the National Science Foundation and the National Institutes of Health; and (2) the ability of these agencies to shift funds quickly between pre- and postdoctoral support in response to a fluctuating job market. Specifically, the gaps between supply and demand could, I

think, have been closed or considerably narrowed if postdoctoral funds had been increased during the tight job market in the early 1970's (rather than, as they were, indirectly reduced). As supply came down towards demand, some of the postdoctoral funds could have been shifted the other way, into the support of predoctoral training. The postdoctoral term is a flexible one, and can be one, two, or even three profitable years. Thus the postdoctoral appointment can be a holding pattern for a one-, two-, or three-year supply of Ph.D.'s. (The study project article following this one gives more details on the history and nature of postdoctoral education in the United States.)

This rubber-band concept of the postdoctoral appointment can work only if the supply of new Ph.D.'s is itself controlled; otherwise graduate education becomes an open-ended process feeding into a limited supply of postdoctoral slots. Therefore, in addition to varying the number of postdoctorals, it's also essential to modulate by number and intended field of study each new class of incoming graduate students. With this scheme, the postdoctoral appointment can be used to respond to immediate problems related to relatively small changes in the job market, while changes in incentives for entering graduate study in different fields can affect the numbers of graduate students and thus deal with future and larger potential mismatches in supply and demand.

To put that into specifics, there are now fewer Ph.D.'s being produced in the physical sciences, and supply may soon be lagging demand. The response should be to reduce funds for postdoctoral support gradually, applying them instead to graduate student support. The expected results would be shorter postdoctoral terms and fewer postdoctorals, and therefore a gradual increase in the supply of Ph.D.'s entering a somewhat more receptive job market. There should also be a modest increase in the number of incoming graduate students, since more support money would be available. As projected supply begins to come up to demand, the process is reversed: Graduate support is lowered in various fields, depending on where the excess is likely to appear, and the money is shifted to postdoctoral training. The size of the incoming graduate class in those fields in danger of excess is reduced, but the postdoctoral pool is enlarged, enabling more Ph.D.'s to enter this holding pattern until the job market improves.

The guiding principle is gradual, fairly smooth, even predictable change. The changes in 1970 were none of these. The result was chaos, an irretrievable loss of years of productive science by talented individuals, and, for a time, a turning away by some of our best students from potentially productive research careers.

All this leaves a number of questions begging. Is there, for example, a structure in place within which to shift pre- and postdoctoral funds depending on supply and demand? The answer is yes and no: Such a structure does exist for the basic biomedical and behavioral research sciences, but does not for the physical and mathematical sciences, since the National Science Foundation has largely dismantled its special fellowship and postdoctoral programs. There are other questions. How does one decide what fields do or will have an excess supply of Ph.D.'s—that, for instance, there will be too many atomic physicists, but not enough solid-state ones? What are the clues to the current and future conditions of the job market, in academia and in industry? These latter questions hinge on the issue of whether it is actually possible to project, by number and by fields and subfields, the country's needs for researchers three to five years hence. I'll try to respond in two ways: by some general observations on the nature of pre- and postgraduate training and by a specific illustration already alluded to—the work of the commission's Committee on a Study of National Needs for Biomedical and Behavioral Research Personnel.

FLEXIBILITIES

There are some misconceptions about graduate and postgraduate education, perhaps left over from the 1950's when university education came to be regarded by many as job training rather than as a way of teaching young people how to think. Graduate education does not mean training a student to be an organic chemist or a viral geneticist. It isn't that narrow. For example, I had concentrated on organic chemistry as an undergraduate and originally had some expectation of continuing in that area. But I happened to pick one of the few graduate schools in the country that at that time did not have an extensive program in organic chemistry. Its strength was in physical chemistry. So, I switched goals, was educated as an experimental physical chemist, and eventually ended up as a theoretical quantum chemist. Graduate training is highly flexible (in spite of the contrary opinion of some employers and even of some Ph.D.'s). Its role is to teach those students who have the potential how to solve problems. The particular field is simply a useful case study for that process. Graduate education teaches students how to formulate a problem, how to attack it, how to get the right materials and equipment together, and how to ask reasonable questions that can be answered within a reasonable time.

Once a student has cultivated and demonstrated those skills, it's really a small matter to apply them to another related field; it doesn't take very long to learn the jargon and methods of a new field. Actually, one of the explicit purposes of the postdoctoral appointment, one of its historical reasons for being, is to enable students to shift fields if they wish or need to.

Indeed, field switching is almost a theme in higher education, occurring in undergraduate school, during the transition from undergraduate to graduate school, and, as noted, from graduate to postdoctoral training. *A Century of Doctorates*, a study just completed for the Commission on Human Resources, points out that "a student tends to specialize more as he advances, but, perhaps more often than we have supposed, he also switches from one major field to another. This may represent a growing awareness of one's deeper interests, a better knowledge of what is actually involved in the work of a given field, a testing of abilities, or the discovery that one does not have the talents for outstanding work in the field of first choice, but can compete very effectively in a different field."[3]

Peer influence is of enormous importance in cueing field switching. Graduate students are heavily influenced in their decisions by their own observations of what their peers just ahead of them in school do—whether they take postdoctoral appointments and in which fields, what kind of jobs they get, what they're being paid, and so forth. Thus, one of the factors influencing a graduate student doing a dissertation on viral genetics to spend a postdoctoral term learning immunology is the sense of excitement in the latter field derived from the graduate students he respects most. These peer observations are palpable surrogates of larger, less obvious elements in the world of a graduate student that are actually the key to the decisions that lead to productive employment and job security. I refer to elements such as the state of the academic and industrial job market, the overall slope and direction of federal research investments in different fields, and new advances that are ripe for exploitation.

The point is that decisions made at the graduate and even postgraduate level are not irreversible, that students are able to shift directions fairly quickly, and that there are a congeries of influences that decide career choices. Certainly, one of those influences is the amount of fellowship and training support available. Predoctorals can take the hint if postdoctoral support increases for physiological psychology but drops for developmental psychology; and the bright undergraduates will know what to do if fellowships are scarce for graduate work in cellular biology but are advertised as plentiful for immunology.

PREDICTING

This flexibility in career choice diminishes greatly the need for highly specific capability in predicting supply and demand field by field. This is fortunate, for that capability is exceedingly difficult. The problem of predicting *general* supply is a much easier one, since the demographics of the educational pipeline are well understood. Indeed, the surplus supply of Ph.D.'s in the late sixties was predicted well in advance, although the precise timing of the appearance of that surplus was heavily affected by the simultaneous occurrence of an economic recession and a significant cutback in federal funding. The problem was that few were listening—neither the academic community caught up in what was in retrospect a false euphoria at the munificence of federal research funding, nor the federal administration caught up in its Great Society programs and the beginnings of the Vietnam War. There was also no structure in place to receive, assess, and broadcast the warnings of Allan Cartter and a few others—no peer group of distinguished researchers to which the Congress and the administration would have to listen.

In addition to the capability of predicting future supply, one needs the ability to make some reasonable projections of demand. These are difficult, but not impossible. One can project, for example, trends in federal funding for research support by analyzing what the administration is asking for, what the congressional response is, the give and take going on between program agencies and the Office of Management and Budget, and so forth. Further, changes in the slope of research funding are not as sudden as usually pictured. The direction of these changes tends to continue across the terms of presidential administrations. The downward turn, in constant dollars, for basic research funding in the sciences, began in the Johnson administration and was continued by Nixon; the upward turn started during President Ford's tenure and has been affirmed in the 1979 Carter budget. One can also make use of econometric models to make some helpful forecasts of the economy, and therefore the state of the job market, some two to four years ahead; the tenets of econometric modeling may be a bit shaky, but the numbers are at least based more on careful thinking than on hopes.

PERSONNEL NEEDS

A cynic might justifiably label all this as a flimsy base for making judgments affecting the lives of some of our best students—melioristic fantasy. What really is needed is a test. Is it really possible deliberately to even out minor imbalances between supply and demand of research manpower? Fortunately, exactly such a test is now under way in the work of the Committee on a Study of National Needs for Biomedical and Behavioral Research Personnel.[4]

As its title suggests, the committee's job is to address exactly the difficulty I've described. Within the context of a generally slowing rate of increase of federal investments in research in the biomedical and behavioral sciences, the committee has the task of determining the amount and kind of research training needed to support future national needs. Moreover, that determination must include specific numbers, overall and for broad field categories, within the biomedical and behavioral sciences.* (This study was first mandated by the National Research Act of 1974 and extended by the Health Research and Health Services Amendments of 1976.)

The committee began work in 1975. Its first report, issued the same year, was understandably conservative, given both little time and inadequate data. The report simply recommended that predoctoral and postdoctoral support funds be maintained at existing levels. The 1976 report was more specific. For example, the committee recommended an inversion of the ratio of pre- to postdoctoral fellows and trainees in the behavioral sciences. From an existing ratio of ninety to ten percent predoctorals to postdoctorals, it urged a gradual shift to a ratio of thirty to seventy. This should have the effect of reducing the number of new graduate students in a field in which the academic job market is declining,

*One should note that in addition to these sciences, the committee's purview also includes the clinical sciences, health services research, and nursing research, the last added by the Health Research and Health Services Amendments of 1976.

while giving more specialized education and involvement in productive research to the best students. The 1977 report reaffirmed this opinion, stating that "the academic sector cannot continue to absorb new Ph.D.'s [in the behavioral sciences] at the same rate as in the past given current rates of production and employment conditions."[5] The 1977 report sharpened considerably some of the earlier recommendations as to the overall and relative levels of support for pre- and postdoctoral research training. Thus, in addition to recommending that the "number of NIH/ADAMHA/HRA* awards in the basic biomedical sciences should be reduced [from 5,400 in 1976] to 4,250 by FY 1979,"[6] the committee also recommended *more* predoctorals in several specific basic biomedical fields because of new demands. It suggested, for example, a future need for more biomathematicians and biostatisticians as well as epidemiologists. These numerical recommendations were accompanied by a description of the market outlook. The committee has not overlooked the significance of the information feedback loop. It has sought by its reports, by public hearings, and by talks at professional meetings to bring its findings to the attention of the relevant scientific public.

It is too early to tell if this process works and how well. We really won't know until the early 1980's, when the first class of graduate students affected by the committee's recommendations reaches the job market. The essential point is that one plausible mechanism is alive and well for equating supply with probable future demand. Under congressional mandate and with the support of the executive branch, distinguished scientists, under the aegis of the National Research Council, are passing judgments on the future directions and needs in their own fields. And, in these recommendations, the committee is not simply, as a cynic might suspect, asking for increases in support, but is, and often to the anguish of its members, recommending reductions in many areas of biomedical and behavioral sciences research training.

It is true that the biomedical and behavioral sciences are an ideal testing ground, in the sense that there is an extensive pattern of student support that can be modulated and also that the postdoctoral appointment is well used, particularly in the biomedical sciences. As I mentioned earlier,

*NIH = National Institutes of Health; ADAMHA = Alcohol, Drug Abuse, and Mental Health Administration; HRA = Health Resources Administration.

there is no current parallel support structure for the physical sciences, and for the moment the only way to modulate supply in that area is by applying pressure through research grants. But that is not a happy venue. It is indirect, unpredictable, and risky in its possible erosive effects on research.

REVOLUTION

Perspectives are needed. One is that the proposal to control the supply of research manpower, and indeed the work of the committee, is revolutionary, a sharp deviation from the usual way of doing things. Rather than confining funds solely to the nourishment of the research enterprise, the new tactic is also to use funding for controlling the rate and direction of growth, for cutting back overgrowth, and encouraging new shoots in fertile ground. The use of support funds as a lever to control supply means applying limited central controls to a normally decentralized, highly pluralistic, even messy process. The United States higher educational system is made up of thousands of individual institutions, private and public, led (usually) by very strong-willed people and staffed by individuals of high intellect. This system must not only respond to the individual decisions of millions of students, but also to the deeper, more hidden currents of demographic change, economic growth or its lack, and changing federal programs and emphases.

With this sort of institutional swamp, does my proposal have a chance? To repeat, the first indications will come through the work of the Committee on a Study of National Needs for Biomedical and Behavioral Research Personnel. However, the committee is advising on the use of only about fifteen percent of the total funds available in these fields for graduate and postgraduate training.[7] Will the fate of that fifteen percent affect what's done with the remainder? I think so. There will probably be a delayed effect: One to two years may pass before changes in federal support for students are paralleled by changes in the other eighty-five percent. The federal leverage is a powerful one. Research support usually goes not only to the very best students, but the decisions made on the distribution of funds for student support will inevitably infiltrate decisions made on research grants.

I should return to the special problems of engineering. There the decision to enter the field, as I remarked before, occurs earlier in a student's

career (usually in high school), and is influenced not so much by the immediate availability of scholarship funds as by the perception through the media that engineers are in demand and that the expected ultimate stipends are high. This makes it difficult to devise effective means of modulating the number of students entering engineering schools.

It is perhaps even more important in this case to use several possible mechanisms to modulate the output supply. For example, through fellowship funds, graduate schools can perhaps absorb excess supply in times of low demand, much like the recommended holding pattern concept for postdoctorals when the supply of Ph.D.'s is in excess. Innovative alternative holding patterns in industry would also seem to be a possibility. And of course at all levels (and for the Ph.D. programs equally importantly) there is a need for new mechanisms for counseling and information flow on career choices that do not have the all-or-none characteristics of our current mass media information flows.

CONCLUSION

The suggestions I have made for dealing with the oscillations in the supply and demand for research manpower are already being carried out, slowly and in part. The scheme, as I noted, is operating in the case of research training for the biomedical and behavioral sciences. It remains to be seen just how effective these techniques are. I am hopeful that only relatively minor modifications will be needed to ensure its continued effectiveness. The engineering problem is more difficult—its solution less obvious. But I think there too, given sufficient time and concern, eventually some of the losses and pain, both to society and to individuals, can be relieved.

Whether or not the ultimate solution lies in the thoughtful use and distribution of fellowship and traineeship support, we have an obligation to discover and to understand the factors that induce these supply and demand oscillations so that they can finally be brought under control in the interests of both the individual and of society as a whole.

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Study Project

COMMISSION ON
HUMAN RESOURCES

POSTDOCTORAL RESEARCH

In its purest form, the postdoctoral appointment offers an opportunity for one to two years of research unfettered by the usual academic duties of teaching, supervising students, obtaining research funds. A postdoctoral appointment is typically taken immediately upon receiving the doctorate or medical degree; however, established researchers may also take postdoctoral appointments, often as a step to moving into a new research area.

Postdoctoral tours have traditionally been regarded as the conduit to academic appointments, particularly to eventually obtaining tenured positions. But that purpose was formed at a time when the American universities and colleges were growing and when foundation support, and then federal investment in research, also grew appreciably. Conditions have now changed: The undergraduate population, in the wake of the "baby boom" population, has been declining; there is greater competition for a relatively smaller "pot" of research funds; and tenured positions, or any faculty positions for that matter, are increasingly difficult to obtain.

These changes underlie the suspicion that the postdoctoral appointment is no longer regarded, either by its occupants or by established researchers, as a necessary way station to academic jobs, but more as a temporary haven in an insecure job market and as a device for changing one's research orientation to more employable fields.

Some of the problems and suspicions were listed recently by a student of the postdoctoral institution, Professor Lee Grodzins of the Department of Physics at the Massachusetts Institute of Technology:

> The experience of the postdoctoral has been an unspoken requirement for those aspiring to a research position in academia; it has served vital functions for both giver and taker; it has been genuinely valuable to a scientist's career even when academia was not the end result. As academic opportunities diminish, however, the postdoctoral is seen by many to be unnecessary (even a liability) to available careers. There is anecdotal evidence that the postdoctoral is being increasingly used to switch to fields of greater employment potential or as a haven till an acceptable position becomes available. At the same time, the commitments to research productivity are forcing some mentors to use postdoctorals as regular (lower paid) research staff members. The pressures against the postdoctoral institution will almost surely increase as academia confronts the demographic problems of the 1980's. It appears inevitable that the postdoctoral institution must modify to accommodate new realities.[1]

These "new realities" and the accommodation of the postdoctoral institution to them form the substance of a study by a committee of the NRC Commission on Human Resources, chaired by Dr. Grodzins and supported by the National Science Foundation. The committee will explore a variety of issues linked to the central one of a change in the motivation for and premises of postdoctoral study. These include:

- The role of the postdoctoral in the nation's basic research efforts, particularly in university research;
- The career patterns of those who have held or are holding postdoctoral appointments;
- The extent to which the postdoctoral appointment remains an unwritten but universally accepted requirement for appointment to the faculties of research universities;
- The effects on research costs if able Ph.D.'s—those who normally would have sought and obtained postdoctoral appointments—bypass appointments and go directly to positions in industry and government offering greater security.

THE INVISIBLE UNIVERSITY

As perspective on the recent changes and consequent concerns, a brief review of the nature and history of the postdoctoral institution may be helpful. The institution is sometimes described as "The Invisible University," because there are typically no formal procedures, at the administrative level, for the hiring and maintenance of postdoctoral students. A freshly minted Ph.D. or M.D., wanting advanced research training, may seek a postdoctoral appointment with a particular senior scholar and be paid out of the latter's research grant. Or the appointee may be paid from a training grant awarded to a university department or division. The procedures for selecting postdoctoral students tend to be informal and *ad hoc,* with data correspondingly sparse and analysis difficult. Moreover, postdoctoral appointees are not always recognizable by their titles; they may be adjunct professors, visiting professors, research associates, and the like. A 1976 NAS report, *The Invisible University,* portrayed the status of postdoctoral students this way:

> Neither student nor faculty, the postdoctoral appointees have been virtually invisible to anyone outside their departments. Their major impact on the campus at large is the space they require. . . . For the most part, postdoctorals come to the university provided with their own support, seeking the use of certain facilities, or they come as employees under a faculty research grant. . . . Unlike undergraduate or graduate education, postdoctoral education is, with few exceptions, not consciously or intentionally undertaken by the university.[2]

If the postdoctoral is an anomalous figure within the usual university organization, his reasons for being there are (or were) usually quite clear. The heart of the postdoctoral was its promise of a research position with a distinguished faculty, its lure the opportunity to do unencumbered research with a senior scholar, and its sustenance flowing from the postdoctoral atmosphere—fundamental research challenges, often in an area removed from the student's doctoral research, new techniques to be mastered, and the discipline and exhilarating influence of highly productive research groups. An illuminating example is that of the late Jacques Monod, who, after earning his doctorate, was awarded a fellowship to work in the laboratory of geneticist Thomas Hunt Morgan at the California Institute of Technology. The experience, Monod wrote, "was [a] revelation to me—a revelation of what a group of scientists could be like when engaged in creative activity, and sharing in constant exchange of ideas, bold speculation, and strong criticism. . . . "[3] James Dewey Watson certainly benefitted by the freedom inherent in a postdoctoral fellowship, using it not only to work in England, but also to turn his interest from genetics to molecular structure and thus decipher, with Francis Crick, the structure of DNA. Another example is that of Linus Pauling in 1925 applying to the Guggenheim Foundation for a postdoctoral fellowship to study the possibilities of a new system of "mathematical chemistry," based on quantum mechanics, to explain how the position of electrons in an atom "qualifies the atom to form molecules and to enter into chemical compounds."[4]

Pauling's application to a private foundation for postdoctoral support was hardly unusual, since, until the late thirties, the federal government had virtually no role in fellowship programs, leaving the field by default to foundations such as Guggenheim and Rockefeller. The entry of the private foundations into fellowship programs seems to have been a matter of circumstances, needs, and the leadership of a small but forceful group foundation officials.

The need to provide further research training opportunities for graduates was articulated by the presidents of The Johns Hopkins University and the University of Chicago at the end of the nineteenth century.[5] This was a time of debate on whether universities should emphasize research or teaching loads in judging faculty; perhaps more significantly, it coincided with an enormous increase in the graduate student population, from 400 in 1877 to 4,392 in 1896–97. Formal examinations of the problems in preparing students for research careers soon appeared. In 1913, for example, the Committee of One Hundred of the American Association for the Advancement of Science asserted that " . . . in order to encourage the original minds in America, there should be more research professorships and research assistantships of high grade, which would raise their holders above the worry and inefficiency caused by financial need." Similarly, the epochal Flexner Report on the quality of medical education in the United States reported that there were few opportunities for advanced medical training in the United States, with the result that most M.D.'s wishing to do clinical research were forced to go to Europe for advanced research training.

Several of the private foundations were drawn in by these forces, with the Rockefeller Foundation playing a strong and pioneering role. Rockefeller's entry into the support of fellowship programs, including

postdoctorals, was led by Wickliffe Rose, a former professor of philosophy and history, who joined the Rockefeller Foundation early this century and rose rapidly as his skills as an administrator were recognized. Rose, according to the science historian Stanley Coben, "decided that the most rapid way to develop any field of knowledge was to strengthen and enlarge the foremost centres in the field, and then to arrange for trained persons and the most advanced ideas to radiate from these."[6]

The chief mechanism for providing the "trained persons" were the National Research Council fellowships established in 1919, going first to students in physics and chemistry and subsequently broadened to include the medical and biological sciences. The impact of the Rockefeller Foundation, as expressed through the NRC fellowships, was considerable, with, for example, almost a quarter of all new Ph.D's receiving fellowships in 1924. As noted in *The Invisible University*, "until the advent of large-scale federal programs for postdoctoral education in the 1950's, the Rockefeller Foundation, through the National Research Council, provided the single most effective means for the development of young American scientists as creative investigators."[7] Of the 1,359 fellows between 1919 and 1950, a majority became professors, 65 were elected to the National Academy of Sciences, and several won Nobel prizes.

The Laura Spelman Rockefeller Memorial Fund, before its merger with the Rockefeller Foundation in 1928, provided the gifts that enabled the Social Science Research Council and the American Council of Learned Societies to support scholars in the social sciences and humanities. The John Simon Guggenheim Foundation entered the field in 1925, and—although most noted for the support of study and research in the humanities, arts, and social sciences—a significant portion of the Guggenheim grants went for study in the physical and biological sciences.[7]

The involvement of the federal government in postdoctoral support began, somewhat in a camel's-nose-under-the-tent fashion, in 1937, with the passage of a bill establishing a National Cancer Institute within the U.S. Public Health Service. The legislation authorized the Surgeon General to provide facilities and funds for training promising researchers. (Trainees were to be paid up to $10 each day, and the new institute itself had a budget of $700,000; these sums have grown.)

During and immediately after World War II, the nation's medical research effort was enlarged and shaped, with the National Cancer Institute now joined by other institutes and all administratively linked as the National Institutes of Health (NIH). Throughout this evolution, the principle of support for promising researchers, including postdoctoral support, was both affirmed and strengthened. As noted in *The Invisible University*, "appropriations for fellowships of all kinds, predoctoral and postdoctoral, jumped from $45,000 in the fiscal year 1946 to $1.4 million in fiscal 1950. Appropriations for training programs during the same period increased from $25,000 to $6.4 million."[8] The National Science Foundation (NSF), a postwar creation, also entered the postdoctoral scene, but on a smaller level; for example, in 1960, NIH supported 822 postdoctoral fellows and NSF only 180.

With its growth, the postdoctoral appointment became not only a rich seed bed for new research advances, providing a fertile setting for investigators in the prime of creativity, but also the arena for judging the abilities of the next generation of university and college faculties, particularly their abilities to produce research of the highest quality. Now the belief is that for a variety of reasons those virtues of a postdoctoral appointment may be eroding. The study by the Commission on Human Resources is intended to assess changes in the historical premises of the postdoctoral and to evaluate the likely consequences.

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Committee for the Study of Post-Doctoral and Doctoral Research Staff, Commission on Human Resources. Committee Chairman, Lee Grodzins of the Massachusetts Institute of Technology; Staff Officer, Porter E. Coggeshall.

Commission on International Relations

Flying Beans, Botanical Whales, Jack's Beanstalk, and Other Marvels

ROGER REVELLE

Agriculture is mankind's basic industry. Where it has been successful over the past several millennia, civilizations flourished and populations grew, many other kinds of industries developed, and men freed from drudgery were able to practice such liberal and useful arts as scientific research and wide-ranging technical invention. These activities in turn were reflected in agriculture, which became an ever more scientific and productive enterprise. Where the natural environment made it difficult to practice productive agriculture, human populations were sparse, the arts of civilization lagged, and the people were backward and poor.

Agriculture is easiest in the temperate and subtropical semihumid climatic zones, where seasons of adequate rainfall alternate with dry seasons, and the soils are deep and rich. Starting with a few wild grasses, tubers, beans, and fruits, the farmers of these zones have produced, by an essentially evolutionary process of selection that fascinated Charles Darwin, a diversity of crop plants for many different human purposes and particularly suited to many microenvironments. Some of these crop species,

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such as maize, exhibit as much variety as the domestic dog, and like it are incapable of living without human beings.

Of the hundreds of thousands of plant species, only about a hundred have been domesticated, in the sense that they have undergone genetic changes to make them more useful for man. An even smaller number of species, some thirty in all, provide eighty-five percent of the weight of food eaten by human beings and ninety-five percent of calories and protein. Three-fourths of all human food energy and protein consumption comes from eight species of cereals—wheat, rice, maize, barley, oats, sorghum, millet, and rye. Three of these—wheat, rice, and maize—make up three-quarters of the total weight and calorie and protein content of cereals. All thirty species have been brought by scientific research and practical experimentation to an astonishingly high level of productivity, ten or twenty times the productivity of a few centuries ago.

The humid tropics, where rain falls throughout the year, and the arid and semiarid lands where rainfall is highly erratic, are both areas where man historically found it very difficult to develop a productive agriculture. Long and unpredictable droughts were the curse of the dry lands. Highly leached, acid soils, which could retain little water or nutrients, forced the peoples of the humid tropics to leave most of their land fallow for intervals of many years, until trees and other wild vegetation had captured a meager supply of plant nutrients that could be released by clearing the jungle and burning the debris. It is estimated that some 250 million people still practice this "slash and burn" agriculture.

NEGLECTED BUT USEFUL

The humid tropics contain about 500 million hectares of land that could be cultivated. Provided environmental difficulties can be overcome, three crops could be grown each year on this land, giving a gross cropped area of 1,500 million hectares—considerably more than the total area now cultivated on earth. Alternatively, and this is more likely, trees and treelike plants that can live on their own debris, even in a sterile soil, could be developed to produce useful crops. During the colonialist period, much scientific and technical effort was devoted to developing such tree crops as oil palm, cocoa, bananas, and rubber, whose products were desired by the people of the rich countries but yielded little that the local people could eat or use. The end of colonialism and the rise of many new nations in the tropical zone, with populations growing at an unprecedented rate, have brought a new need for agricultural plants that can provide food and other necessities for the people of these countries.

In recognition of this need, the National Academy of Sciences, under the inspiration of Noel Vietmeyer, a staff member of the Office of the Foreign Secretary, convened an *ad hoc* panel in 1974 to identify neglected but possibly useful tropical plants, both wild and domesticated, that might be widely introduced throughout the tropics. The panel was co-chaired by Edward S. Ayensu and Richard E. Schultes. Out of 400 promising plants nominated by scientists around the world, 36 were selected for more detailed examination. The properties of these plants are summarized in Table 1.

TROPICS

To meet basic human needs in the humid tropics, several kinds of agricultural development are essential. The supply of carbohydrates, protein, vitamins, and mineral nutrients must be increased, and a greater variety of foods should be produced to provide a more diversified diet. New export crops need to be developed to raise rural incomes. With growing populations it is essential to shorten the cycle of slash and burn agriculture, that is, to reduce and, if possible, to eliminate the need to leave most of the land fallow for long periods to replenish nitrogen and other nutrients. This can be partially accomplished by introducing leguminous plants that, because of their fruitful symbiosis with certain species of bacteria, are able to extract and chemically "fix" nitrogen from the air. Crops that yield an abundant harvest in as short a time as possible after they are planted are highly desirable. It should be possible to store or otherwise preserve the edible products for extended periods. Indigenous fibers are required as well as food, and the supply of nutritious feed for livestock and poultry should be greatly increased.

The plants listed in Part A of Table 1 have been selected with one or more of these qualities in mind. Cocoyam, peach palm, taro, and dasheen are known to yield large quantities of carbohydrates per hectare. The edible products from peach palm (*Guilielma gasipaes*) and cocoyam (*Xanthosoma* spp.) have an adequate quantity of protein relative to carbohydrate.

TABLE 1 Little Used but Potentially Useful Plants

Common Name	Scientific Name	Useful Portion	Potential Use	Present Growing Areas	State of Cultivation	Present Yield Per Hectare Per Year	Time to First Harvest
A. Humid Tropics							
Cocoyam	*Xanthosoma sagittifolium*	tuber	carbohydrate, protein	Tropical Americas, West Africa	domesticated	30–60 tons wet weight	3–10 months
Peach palm or pejibaye	*Guilielma gasipaes*	fruit and stem	carbohydrate, oil, protein, "heart of palm"	Central and Northern South America	domesticated	3 tons	6–8 years
Taro and dasheen	*Colocasia esculenta*	tuber	carbohydrate	Egypt, Philippines, Hawaii, Caribbean	domesticated	22–30 tons wet weight	6–18 months
Buriti palm	*Mauritia flexuosa*	fruit kernel, shoots, trunk and leaves	oil, starch, vitamins A and C, timber, cork, fiber, "heart of palm"	Amazon Basin, Venezuela, Guianas	mostly wild	?	?
Babassu palm	*Orbignya martiana*	fruit and kernel	oil, protein, fuel	Amazon Basin	mostly wild	1.5 tons	10–15 years
Pequi tree	*Caryocar brasiliensis*	fruit and kernel	oil, fuel	Amazon Basin, Central Brazil, Guianas	mostly wild	?	9 years
Seje palm	*Jessenia polycarpa*	fruit	oil resembling olive oil	Amazon Basin	wild	22 kg/tree per year	?
Winged bean	*Psophocarpus tetragonolobus*	pods, beans, tubers, foliage	protein, oil, carbohydrate, livestock feed	Papua New Guinea, Southeast Asia, Sri Lanka	domesticated	2.5 tons of dry beans	10 weeks
Durian tree	*Durio zibethinus*	fruit	carbohydrate, fat, vitamins, flavor	Southeast Asia	haphazardly cultivated	?	7 years
Mangosteen tree	*Garcinia mangostana*	fruit	highly prized flavor	Southeast Asia	domesticated	50 kg/tree per year	15 years
Pummelo tree	*Citrus grandis*	fruit	large citrus fruit	Southeast Asia	domesticated	?	several years

Soursop tree	*Annona muricata*	fruit	fruit and juice	Southern China, Australia, Africa, tropical Africa, West Indies	domesticated	6–10 tons	?
Uvilla tree	*Pourouma cecropiaefolia*	fruit	grapelike fruit	Western Amazon	wild	?	3 years
Chaya bush	*Cnidoscolus chayamansa*	leaves	vitamin-rich leafy vegetable	Mexico and Central America	domesticated	?	2–3 months
Ramie herb	*Boehmeria nivea*	stems and foliage	fiber and live-stock feed	East and Southeast Asia, Brazil	domesticated	1.4 tons fiber, 20 tons feed	2 months
Cauassu herb	*Calathea lutea*	leaves	commercial wax	Amazon Basin, Central America	wild	0.8 tons of wax	9 months
Leucaena	*Leucaena leucocephala*	leaves, wood, pods, seeds, bark	livestock feed, timber, fuel, paper, soil fertilizer, dye stuffs, human food, erosion and watershed control, nurse tree, fire and wind breaks	Central America, Mexico, Southeast Asia, Northern South America, Australia, Hawaii, East and West Africa, Papua New Guinea, Caribbean, India	domesticated and wild	12–20 tons of forage, 20–50 tons of wood	less than 1 year to more than 3 years, depends on variety planted

B. Semiarid and Arid Tropics and Subtropics

Channel millet	*Echinochloa tunerana*	seed, leaves, and stems	carbohydrate, protein, live-stock feed	Central Australia	wild	?	[illegible]months after heavy rain
Buffalo gourd	*Cucurbita foetidissima*	seed, root	oil, protein, starch	Mexico, Southwestern United States	mostly wild	2.5 tons of seed, 22 tons starch	2 years
Guar (cluster bean)	*Cyamopsis tetragonoloba*	seed, leaves, and stem	gum, protein, oil, livestock feed	United States, Pakistan, India, Australia, Brazil, South Africa	domesticated	18–24 tons green fodder, 0.9–2 tons seed	3–5 months

TABLE 1–Continued

Common Name	Scientific Name	Useful Portion	Potential Use	Present Growing Areas	State of Cultivation	Present Yield Per Hectare Per Year	Time to First Harvest
Apple-ring acacia tree	*Acacia albida*	leaves, shoots, pods, seeds	livestock feed, human protein	Tropical and Southern Africa	wild	200 kg protein	several years
Ramon tree	*Brosimum alicastrum*	leaves, twigs, nuts	livestock feed, carbohydrate, protein	Central America, Southern Mexico, Caribbean Islands	mostly wild	?	several years
Cassia shrub	*Cassia sturtii*	leaves	livestock feed	Australia, Israel	wild and cultivated	1/2 ton dry weight	1–1.5 years
Saltbush	*Atriplex* spp.	leaves and shoots	livestock feed	worldwide in warm arid zones	wild and cultivated	1–1.5 tons	2 or 3 years
Candelilla shrub	*Euphorbia antisyphilitica*	stems and leaves	hard wax	United States and Mexican deserts	wild	?	2–5 years
Tamarugo tree	*Prosopis tamarugo*	pods and leaves	high protein, livestock feed	Atacoma desert of Chile, Canary Islands	cultivated	10–20 sheep	5 years
Jojoba shrub	*Simmondsia chinensis*	seeds	liquid wax identical to sperm oil	United States and Mexican deserts, Israel	mostly wild	2 tons	3–5 years
Guayule shrub	*Parthenium argentatum*	whole plant	natural rubber	United States, Mexican deserts, Spain, Turkey	mostly wild	0.33 ton	1 year
C. Mountain Environments of Low Latitudes							
Grain amaranth	*Amaranthus caudatus*, etc.	seed, leaves	high lysine, high protein, starch, vitamins	Andean region of South America	domesticated	higher than maize	several months

Quinua (grain)	*Chenopodium quinoa*	seed	protein, carbohydrate	Andean region of South America	domesticated	?	5–6 months
Peruvian parsnip	*Arracacia xanthorrhiza*	tubers, stems, leaves	carbohydrate, livestock feed	Andean region of South America	domesticated	?	10–14 months
Naranjilla shrub	*Solanum quitoense*	fruit	fruit and juice	Central and Northern South America	domesticated	1–2 tons of fruit	6–12 months
Winged bean	*Psophocarpus tetragonolobus*	pods, beans, tubers, foliage	protein, oil, carbohydrate, livestock feed	Papua New Guinea, Southeast Asia, Sri Lanka	domesticated	2.5 tons of dry beans	10 weeks
D. Saline Environments							
Eel grass	*Zostera marina*	seed	carbohydrates, protein	tidal flats and estuaries in all latitudes	wild	?	?
Pummelo tree	*Citrus grandis*	fruit	citrus fruit	brackish marshy areas in Thailand	domesticated	?	several years
Saltbush	*Atriplex* spp.	leaves and shoots	high protein, livestock feed	worldwide, including salty soils and saline irrigation waters	mostly wild	1–1.5 tons	2 or 3 years
Tamarugo tree	*Prosopis tamarugo*	pods and leaves	high protein, livestock feed	Atacama desert of Chile, Canary Islands	cultivated	10–20 sheep	5 years
Silt grass	*Paspalum vaginata*	leaves and stems	livestock feed, sand stabilization	seacoasts from Australia to Spain, Argentina to Baja California	mostly wild	?	1 or 2 years
Spirulina, blue-green algae	*Spirulina platensis* *Spirulina maxima*	entire alga	poultry feed, very high protein human food	Lake Chad, Valley of Mexico	cultivated	3 tons protein	several days

Cocoyam tubers can be maintained in edible condition by leaving them in the ground (for as long as two years in fairly dry soil), or they can be stored in a cool, dry place for several months. Dasheen (*Colocasia esculenta*) can be stored at ten degrees centigrade for up to six months, and taro (*Colocasia esculenta*) fields can, in various stages of maturity, contain plants that can be harvested the year round. The fruits and kernels of the buriti (*Mauritia flexuosa*), babassu (*Orbignya martiana*), seje (*Jessenia polycarpa*) palms, and the pequi tree (*Caryocar* spp.) contain abundant oil, which could provide an export crop, as could the preserved fruits and juices of the durian (*Durio zibethinus*), mangosteen (*Garcinia mangostana*), pummelo (*Citrus grandis*), soursop (*Annona muricata*), and uvilla (*Pourouma cecropiaefolia*). These fruits, together with the leaves of the chaya bush (*Cnidoscolus chayamansa*), can give variety to the diet of local people. Ramie fibers (*Boehmeria nivea*) are several times as strong as cotton or silk, and much more durable than cotton. The cauassu herb (*Calathea lutea*) has very large quantities of a commercially valuable wax. Cocoyam, taro and dasheen, chaya, ramie, and cauassu have growing seasons measured in months, unlike the fruit and palm trees that require years before reaching maturity. The palm trees, however, have very modest soil requirements. They live largely on their own debris, as is generally true of the plants of the rain forest.

Much research is needed on most of these plants. For cocoyam, taro, and dasheen, the principal problem is infection of the tubers and roots by viruses, transmitted when the tubers are planted. Virus-free tubers could be produced if it were possible to reproduce the plants either by tissue culture or by seeds. Researchers at the University of Florida have recently grown cocoyam from seed, but there has never been a breeding program for taro and dasheen, either for removing pathogens or for genetic improvement. Taro grown in flooded paddies now requires long hours of hard work in muddy, flooded fields. Mechanical methods for planting, cultivating, and harvesting taro are badly needed and offer a great challenge to agricultural engineers.

In spite of its admirable qualities, ramie fiber is little used outside East Asia. In the harvested plant the fiber is covered with a tenacious, inert gum, which at present is best removed by tedious manual labor. This makes ramie fiber relatively expensive even in developing regions with an abundant supply of underemployed labor. More efficient and economical degumming methods must be developed. This will require research by organic chemists on the structure of the gum and ways to dissolve it, and by microbiologists to find microorganisms capable of consuming the gum without weakening the fiber.

A similar problem exists with cauassu. Chemical and engineering research are needed to develop more economical techniques for separating the valuable wax from the leaves.

For the palm and fruit and nut trees listed in the table, the principal problems of economic development are the long times required before a first harvest can be obtained, and the consequent tying up of land and capital for many years without a profitable return. Research and development to shorten the growing times of these species, or alternatively to find ways of interplanting them with other crops that do give an early return, could pay off handsomely.

THE FLYING BEAN

Perhaps the most remarkable and potentially useful food crop listed in the table is the winged bean (*Psophocarpus tetragonolobus*), which may have a greater capability for relieving the protein hunger of people throughout the humid tropics than any other known plant. It is a perennial legume, now grown by farmers only in Papua New Guinea and Southeast Asia as far west as Sri Lanka. The plant produces edible green pods within two and a half months after planting, and beans after four months. It continues to provide nutritious and tasteful food indefinitely, though the yields decline after several months, so that farmers usually treat it as an annual crop.

The winged bean resembles an ordinary runner bean, a bushy pillar of greenery with wirelike shoots that twist upward searching for support to hold the plant upright. The pods containing the beans vary from six to sixty-six centimeters in length, depending upon the variety, with four green flanges or "wings" running the length of the pod. The dried beans contain up to twenty percent oil and thirty-seven percent protein, with an amino acid balance and nutritive value equal to the protein of soybeans. Yields can be nearly as large as those of soybeans and much larger than other tropical legumes, over three and a half tons of dry beans per hectare in experiment station plots. The protein component of a mixed diet of winged beans and maize has as high a nutritive value as the protein in milk. Like soybean oil, winged bean oil is polyunsaturated and therefore presumably better for human health than saturated fats and oils. Some varieties produce protein-rich tubers that can be eaten like potatoes; the flowers and leaves are also nutritious and tasty.

Present varieties of the winged bean appear to be photosensitive, requiring a short day to flower, so that the plant produces seeds only at latitudes within twenty-five degrees of the equator. On the other hand, unlike most cultivated tropical plants it tolerates a wide range of altitudes. In Papua New Guinea it is grown from sea level to over 2,000 meters. For this reason, we have listed it both in Parts A and C of Table 1, as a potentially valuable source of protein and oil for human food and as a livestock feed.

In the future, the winged bean could become as important a crop plant as the soybean. Our knowledge of its genetics, physiology, agronomic requirements, and potential uses is about the same as knowledge of soybeans sixty years ago. Present varieties are grown mainly by home gardeners for family consumption or for sale in local markets. Larger-scale commercial production is less practicable, because the plants must be supported by stakes to produce high yields and the beans must be harvested over many months.

Research on the winged bean is needed to develop strong-stemmed dwarf varieties that will not require staking, and whose beans mature and can be harvested at about the same time. Fermentation and other food-processing technologies for preparation of curd, milk, gruel, and other foods similar to those obtained from soybeans should be investigated.

A report, *The Winged Bean, a High Protein Crop for the Tropics,* was published in 1975 by an international panel of the Advisory Committee on Technological Innovation of the Board on Science and Technology for International Development. Under the chairmanship of Richard E. Schultes, specialists from ten countries contributed to the preparation of this report, which describes the present state of knowledge concerning the winged bean, its promise as a crop plant, significant data gaps and research needs, and a proposed strategy for international cooperation in research and testing. The report contains a list of researchers known to be working with the winged bean and a bibliography of nearly fifty references. One of the panel's recommendations was that an informal international newsletter should be published, and such a newsletter, "The Winged Bean Flyer," published by the Department of Agronomy, University of Illinois, now appears semiannually.

Part C of Table 1 lists five little-known species that might be used to enrich the diets of the peoples of tropical highlands. One of these, the winged bean, has already been described. The remaining four are native to the highlands of tropical South America. One, quinua (*Chenopodium quinoa*), is a food grain that was a staple of the ancient Incas. Another, the Peruvian parsnip (*Arracacia xanthorrhiza*), is a starchy tuber that is less expensive to plant and harvest than the potato. A third, the naranjilla (*Solanum quitoense*), the "golden fruit of the Andes," has a sweet-sour flavor reminiscent of pineapples and strawberries. It is used in Ecuador and Colombia as a dessert fruit and to make a delicious juice. One hectare of naranjilla can produce one to two tons of fruit within a year of planting.

The grain amaranths (*Amaranthus caudatus, A. cruentus, A. hypochondriacus*) appear particularly promising as a source of carbohydrates and protein for highland peoples. They are reported to show a higher yield per hectare of seeds—containing about fifteen percent protein and sixty-three percent starch—than maize grown on adjacent plots. The lysine content—one of the essential amino acids usually deficient in cereals—of the protein is about the same as that of soybeans and milk. At the time of the Spanish conquest, amaranths were major grain crops in the tropical highlands of the Americas, where they played an important role in Indian religious ceremonies. In their efforts to eradicate the native religion, the Spaniards suppressed amaranth cultivation and introduced barley, a low-lysine cereal, in its stead, thereby improving the Indians' souls at the expense of their nutrition. During the last century grain amaranths were introduced in Asia, where they have become important to some hill tribes.

The lack of roads and vehicles restricts the cash crops that can be grown by the farmers of tropical highlands to high-value, small-volume materials that can be carried for long distances on human backs. A search needs to be made for essential oils and spices, medicinal plants, gums, and other natural products for industry that can be grown in the hills and mountains of the poor countries. Descriptions of some plants of this type, which might be suited to the highlands of Sri Lanka at heights up to 2,000 meters, are given in *Natural Products for Sri Lanka's Future,* the report of a workshop jointly sponsored by the National Science Council of Sri Lanka and the National Research Council in 1975. Some fifty scientists from Sri Lanka and nine from the United States participated in this workshop. Carl Djerassi chaired the American group.

Part D of Table 1 lists seven species that are now cultivated or might be used in beneficial exploitation of areas of saline water or soil. One of the most interesting of these is spirulina (*Spirulina platensis, S. maxima*), a blue-green algae that was grown by the Aztecs in the shallow lakes of the Valley of Mexico as one of their principal sources of protein. It is still cultivated near Mexico City as a high-protein, high-carotene additive to chicken feed. Spirulina also grows wild in Lake Chad, where it has been eaten by the local inhabitants for many generations. The microorganism is relatively large, and the Chad villagers recover quantities of spirulina by filtering the lake water through muslin. The material is then sun-dried in cakes, stored until needed, and cooked and eaten as a green vegetable. Seventy percent of the dry matter is protein with a relatively satisfactory balance of essential amino acids; the vitamin B_{12} content is also high.

The Seri Indians of Tiburon Island in the Gulf of California found that the common eelgrass (*Zostera marina*) produces seeds that can be used as a food grain. They threshed the sun-dried plants with wooden clubs, winnowed the grain, and ground it into flour. Recent tests have shown that this bland-tasting flour contains about thirteen percent protein and fifty-one percent starch, which compares favorably with wheat or rice. Applied marine biological research might develop eelgrass into an agricultural crop that could be grown in saline paddies.

DROUGHT AGRICULTURE

Many of the world's poorest people live a precarious existence in the semiarid and arid tropics and subtropics. They have the same needs as the populations of the humid tropics for increased supplies of carbohydrates, proteins, and other nutrients, and for agroindustrial products that could provide incomes. But there are two major differences: Crop plants for unirrigated arid or semiarid lands must be able to withstand long periods of drought and be able to grow vigorously during rainy seasons. Livestock husbandry is often the most economically efficient way to utilize the abundant land and scarce water resources of arid lands; consequently, plants that can provide a greater quantity and better quality of livestock feed are highly desirable.

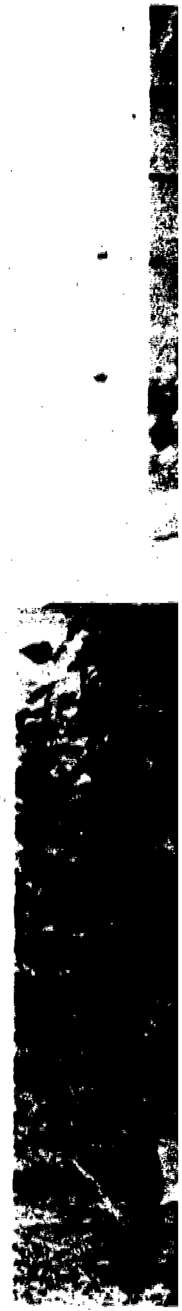
Part B of Table 1 lists seven plants, now grown only in a few regions, that might be used principally to provide livestock feed in other semiarid or arid regions. Four other plants have promising agroindustrial potentials, and several could provide carbohydrate and protein for human food.

One of the latter is the buffalo gourd (*Cucurbita foetidissima*), a vigorous long-lived perennial that grows wild on wastelands in the deserts of Mexico and the southwestern United States and is now being cultivated in Lebanon. Its abundant fruits enclose a prodigious quantity of seeds, which can be easily threshed out when the fruit dries. One hectare of plants can produce 2.5 tons of seeds, containing up to thirty-four percent of an edible polyunsaturated oil and thirty to thirty-five percent protein. The seeds have been eaten for centuries by North American Indians. The buffalo gourd's enormous root can weigh thirty kilograms after just two growing seasons; in three years it can be twice as large as a man. The roots are fifty percent starch. Very little is known about the plant's variability, its agronomic requirements, or even the length of time to maturity. The root starch contains bitter-tasting glycerides that must be washed out in a salt solution, and the protein meal left after oil extraction may contain toxic substances that must be removed before it can be used as a feed for livestock or as human food. Research is needed on all aspects of this promising plant.

The guar, or cluster bean (*Cyamopsis tetragonoloba*), is a leguminous herb resembling the soybean. It has been grown for food in India since ancient times, but its great potential lies in the gum in its seeds. Guar gum has five to eight times the thickening power of starch. It is useful as a filter aid in the mining industry; a thickener in cosmetics, hand lotions, and creams; a strengthening ingredient in paper; a stabilizer for salad dressings, bakery products, and ice cream; and in the drilling muds used by the oil industry. Some 25,000 tons of the gum, at a price of $1.50 to $2.50 per kilogram, are produced annually in the United States, and the demand exceeds the supply. Seed yields per hectare from irrigated guar are as high as 1.9 tons, with twenty-two percent being gum, which is worth $625 to $1,050 per hectare at present prices. Improvement through research could make guar a top-ranking agricultural crop in many semiarid tropical and subtropical regions.

THE BOTANICAL WHALE

Few plants can withstand the scorching temperatures, low humidity, and lack of rainfall in the desert. One of those that can is a slate green, twiggy,



To

stunted shrub called jojoba (*Simmondsia chinensis*). It grows wild, often in dense stands, scattered over 300,000 square kilometers in the Sonoran Desert of northwestern Mexico, Arizona, and California, where annual rainfall varies from ten to fifty centimeters. Each plant produces many soft-skinned nuts, long used by the Sonoran Desert Indians as food (roasted they smell and taste like roasted coffee beans) and as medicine. Half the weight of an average nut is a yellowish, odorless oil. The meal left after the extraction of the oil contains about thirty percent protein, as well as carbohydrates and fiber. Jojoba oil feels less oily than the usual edible oil. The reason is that it has a radically different chemical structure from any other known vegetable oil. Chemically, it is composed almost entirely of esters of high molecular weight, consisting of straight chain alcohols esterified with long-chain fatty acids. Jojoba oil is a polyunsaturated liquid wax: Both the acid and the alcohol portions have twenty to twenty-two carbon atoms, and each has one unsaturated bond. Waxes of this type are difficult to synthesize commercially, and for decades the only source has been the sperm whale. With growing industrial demands, sperm whales have been hunted ever more ruthlessly, until they have become an endangered species. In 1975 over 20,000 sperm whales were killed, and each whale provided several tons of sperm oil.

Importation of sperm whale oil is now prohibited in the United States, but the real hope for survival of these magnificent mammals is the possibility that jojoba's liquid wax, which is virtually identical with sperm oil, can be produced more economically and in larger quantities than the whalers can supply sperm oil.

The major application of sperm oil has been in lubricants used under extreme pressure in automobile transmissions and other high-speed machinery, and also in machinery operating at both high temperatures and pressures. Jojoba oil has been shown to duplicate sperm oil's lubricating properties; it serves well as a cutting or grinding oil when added to other lubricants; and it may be suitable as a transformer oil or an oil for delicate mechanisms. It has major potential in the cosmetic industry as a component of hair oil, shampoo, soap, face creams and sunscreen compounds, and in pharmaceuticals as a stabilizer of penicillin products and a coating for medicinal preparations. When combined with sulfur chloride it could be used in the manufacture of linoleum, printing ink, varnishes, chewing gum, and adhesives. Its alcohol and acid derivatives can be used in the preparation of disinfectants, surfactants, detergents, lubricants, driers, emulsifiers, resins, plasticizers, protective coatings, fibers, corrosion inhibitors, and bases for creams and ointments.

When hardened by hydrogenation (the process that produces margarine from vegetable oils), jojoba oil is transformed into a dense solid of sparkling white crystals, called jojoba wax, which resembles spermaceti (also from the sperm whale), carnauba wax, and beeswax. It has a high melting point of seventy degrees centigrade, and a hardness approaching that of carnauba, the "king" of waxes. Jojoba wax has potential uses in polishes for floors, furniture, and automobiles; as a protective coating on fruit, food preparations, and paper containers; in lipsticks and candles; as a sizing for textiles; and as a high-dielectric-constant material for electric insulators.

Yields of up to five kilograms of nuts from an individual jojoba shrub have been recorded; the wild stands of jojoba in Mexico and the United States are estimated to produce 10,000 to 15,000 metric tons of nuts each year. But the most that has ever been collected in the United States was in 1972, when about forty-five metric tons were harvested by the Apache Indians of the San Carlos Reservation in Arizona. The oil obtained from this harvest was distributed by the Universities of California and Arizona for testing by more than a hundred industrial firms across the nation. Only about thirty metric tons were harvested in Arizona and California in 1976, even though the established price of jojoba oil is $11 per kilogram in the United States and about the same in Mexico. The price is high because the nuts must be harvested by hand during July and August—the hottest period of the year—at picking rates of $2.20 to $3.10 per kilogram of nuts. The present world market demand of less than fifty metric tons of oil probably cannot be increased or even sustained unless the costs of the oil can be reduced. At a price for jojoba oil of $2 per kilogram, the estimated demand would be very large, about 127,000 metric tons. Such a price will be attainable only if the jojoba can be successfully domesticated and cultivated on commercial plantations in which the harvesting process is mechanized. This could presumably be accomplished by using machines similar to those employed in harvesting blueberries and grapes, which pick several thousand kilograms per hour. It is estimated that harvesting costs could then be reduced to ten to twenty cents per kilogram of nuts.

Jojoba plants are now being cultivated in Israel, where a plantation was started about ten years ago, and a small test plantation has been initiated by the University of California, Riverside. Several agencies of the federal government are helping Indians on reservations in Arizona and California to establish jojoba plantations. So far, about forty hectares have been successfully planted, and over a hundred hectares have been cleared for planting. The Indians have allocated more than a thousand hectares of their land for further plantations. To meet the projected world demand, about 100,000 hectares of plantations will be required, at a yield of 2,500 kilograms of nuts per hectare. This could result in a $250 million industry. Under the chairmanship of Parker F. Pratt, the National Research Council's Committee on Jojoba Production Systems Potential, made up of specialists familiar with jojoba in various disciplines from Israel, Mexico, and the United States, including Indian tribal representatives, has prepared a comprehensive report on the feasibility of cultivating jojoba in the Indian reservations of the Sonoran Desert region.

The principal economic difficulty impeding successful development of an Indian agroindustry based on jojoba is the long time required to produce a profitable crop, approximately five to ten years. Although comparable with the time required for profitable harvesting of other high-value crops such as almonds, macadamia nuts, and avocadoes, this long period of investment without return will be very difficult for the desert Indians of Mexico and the United States, with their limited capital resources and extreme poverty. Moreover, the Indian population currently lacks the training and experience necessary to successfully manage, operate, and develop enterprises of the required scale. The NRC committee has recommended establishment of a short- and long-range education and training program for Indian farmers, managers, and researchers, both those involved with jojoba production from the natural shrubs and those concerned with management of future jojoba plantations and processing plants.

Besides Israel and Mexico, research projects on jojoba have been initiated in several other countries, including Japan, Australia, Sudan, and Great Britain. Broadening of this international base of support for jojoba development as a commercial crop is highly desirable. It will encourage research workers in government and private agencies to create higher-yielding jojoba varieties. The international exchange of information on growing jojoba under different environmental and managerial conditions will be valuable. International cooperation can also be expected to promote production, marketing, and utilization of the nut and its by-products. An international newsletter, *Jojoba Happenings,* is now published by the Office of Arid Land Studies of the University of Arizona. The International Council for Jojoba Development was organized in 1972, and international conferences were held in 1972 and 1976.

GUAYULE—THE FORGOTTEN PLANT

Natural rubber occurs in some 2,000 species of plants. But only two species have ever been used as continuing sources of commercial rubber. One of these, the majestic rubber tree *Hevea brasiliensis,* first discovered in the rain forests of the Amazon and now grown principally in Malaysia and other humid, tropical parts of Southeast Asia, produces nearly a third of the 10 million tons of the total (natural and synthetic) rubber used in the world each year. The other is an inconspicuous shrub, *Parthenium argentatum.* It grows wild in the Chihuahuan desert of Mexico and the trans-Pecos region of Texas, where the rainfall is low and erratic. In pre-Columbian Mexico, the Aztecs made bouncing balls out of its rubber, which they obtained by chewing the stems and spitting out the rubber and vegetable matter separately. The conquering Spaniards corrupted its Indian name to guayule. It is said that half of the rubber used in the United States in 1910 came from guayule.

Both hevea and guayule yield an apparently identical polyisoprene rubber. During World War II, thousands of tons of guayule rubber were produced by the U.S. government in cultivated fields in California, and experimental plantations have been attempted in semiarid regions of many other countries. Yet, today there is no commercial guayule farming anywhere in the world, and the wild guayule plants are being experimentally harvested for their rubber only in Mexico.

Nevertheless, the dramatic rise in the price of petroleum (the raw material for synthetic rubber) during the last few years, and the increasing likelihood that the demand for natural rubber will exceed the capacity of Southeast Asia to produce it, have focused renewed attention on guayule as a potential biological resource for agriculture in semiarid regions. These regions contain some of the world's poorest peoples, not only in Africa, South America, and Asia, but also on the Indian reservations of the southwestern United States.

The history and prospects of guayule are described in *Guayule: An Alternative Source of Natural Rubber,* prepared by a panel chaired by Reed Rollins, sponsored by two boards of the National Research Council, and supported by the U.S. government's Bureau of Indian Affairs and four other federal agencies. The principal reason for the decline of guayule was the government's abrupt abandonment of its Emergency Rubber Project in 1946, when 10,000 tons of rubber in 12,000 hectares of guayule plantations were burned or disked into the ground. Most of the seeds from the genetic improvement program were destroyed, along with millions of seedlings, because it was thought that synthetic "rubber" elastomers would soon completely supercede natural rubber. But during the last three decades, natural rubber has proven superior to the artificial variety for many uses, and the relative costs of natural rubber have been kept low through intensive research. The Rubber Research Institute of Malaysia has achieved a sixfold improvement in the yield of hevea trees and has demonstrated the possibility of a further tripling of annual yields, up to seven and a half tons per hectare. This is in sharp contrast to the best yields for cultivated guayule in irrigated fields at the end of World War II, which were about 0.85 ton per hectare per year. Genetic research and the use of plant growth regulators (such as 2,4,5-trichlorophenoxy acetic acid and 2-chloroethyl phosphonic acid) have revolutionized hevea rubber production. There is good reason to believe that a similar revolution through research could occur in guayule.

The genetic diversity of the guayule plant is immense. Every bush growing in the desert appears to be almost a separate strain. There is a wide variation in the rubber content of the plants, from less than ten to about twenty-six percent, in the rate and size of growth, and in disease resistance, ease of defoliation, ability to compete with weeds, resin content, and cold and drought tolerance. Moreover, guayule can be hybridized with other larger species of *Parthenium,* and it has a unique "bimodal" reproduction system. In one mode, the female flowers do not have to be fertilized to set seeds, and this "apomictic" reproduction ensures that once a good variety is found, it can be multiplied indefinitely without genetic change. One of the greatest research needs is a simple, rapid method for screening plants for rubber content. If such an instrument were portable, the breeder could use it to comb wild stands for the best strains, instead of growing thousands of seeds in a blind groping for desirable types.

For every ton of rubber, the guayule plant contains about half a ton of resin, including various kinds of terpenes and low-molecular-weight hydrocarbons. In the past it was not easy to separate these liquid tars from the rubber, and almost all the guayule rubber sold was in a tarry form. This resinous rubber gave guayule a bad reputation that still persists in the rubber industry. It has since been found that the resin can easily be removed by use of appropriate solvents. But no deresinated rubber has ever been produced for commercial use. Two major research needs are the development of improved methods for resin separation and for extracting the latex from the shrub without coagulating it to rubber.

It could turn out that research on by-products from guayule will be the key to its successful use. The resin contains volatile and nonvolatile terpenoids, a shellaclike gum, drying oils, and cinnamic acid. In fact, the resin might prove more valuable than the rubber. A ton of guayule leaves also contains about twenty-five kilograms of a hard wax, with one of the highest melting points (seventy-six degrees centigrade) ever recorded. As with jojoba, there is an increasing demand for hard waxes; they also command high prices (about $4 per kilogram).

Guayule has two significant characteristics for potential dry-land agriculture. The plant easily survives long periods of drought by becoming dormant, and it is long-lived. So, while successful guayule production requires an *average* annual water supply of about forty centimeters, the plant can be grown in regions where rainfall is widely variable from year to year. During its long lifetime, the plant does not use or metabolize the rubber it produces, but simply accumulates it, up to periods of at least ten years. When guayule is actively growing, it produces little or no rubber. But when growth slows during periods of cold weather or reduced moisture, the products of photosynthesis are diverted to rubber production, and the rubber content increases. Consequently, the plants could be a living and growing stockpile of rubber and other potentially valuable products, which once established would require little or no maintenance, and could provide farmers with security in bad years. For this reason, guayule could be an excellent crop for stopping erosion, and possibly for grazing, in semiarid wastelands. It might also be a useful intercrop grown between rows of food crops.

Hevea rubber is one of the most labor-intensive crops in the world. If guayule is to compete with it successfully in the United States, not only would annual yields per hectare need to be raised, but production would need to be mechanized in order to increase yields per worker. In the semiarid lands of less-developed countries, however, guayule cultivation would be basically similar to that of other field crops, and mechanization would not be necessary in rural areas of high unemployment or underemployment. The possibilities in these regions for producing guayule rubber that would be competitive in costs and quality with hevea rubber depend on the development of high-yielding strains and the improvement of processing facilities.

The report *Guayule: An Alternative Source of Natural Rubber* recommends that the U.S. government should initiate a planned, coordinated program of research and development for commercialization of the guayule plant, with special emphasis on agricultural production. Such a program would require the combined skills of plant geneticists, physiologists, pulp and paper technologists, organic chemists, and chemical engineers. It should be undertaken in close collaboration with the government of Mexico, which already has a program for exploiting the estimated 2.6 million tons of wild guayule shrubs (containing over 250,000 tons of rubber) that can be harvested in northern Mexico. The annual budget for the United States' portion of this program could be in the range of $2 to $4 million, but the payoff could be a new agricultural enterprise worth several hundred million dollars.

FAST-GROWING TREES FOR FUEL AND FORAGE

Fuel for cooking and heating water is just as essential as food itself for the poor people of the developing countries. In mountainous and hilly areas, fires must be used if people are to keep warm. In some regions, cattle dung, wheat and rice straw, and corn husks are burned; but these materials have other necessary uses as fertilizer and feed for livestock. Wherever trees are available, firewood is used as fuel. On the average, nearly one ton of firewood per person is consumed each year in vast regions of Asia, Africa, and Latin America. Wood is the "poor man's oil."

With the unprecedented growth of human populations in all the developing countries, more and more wood is being burned each year, and, in many areas, forests are being cut down for both fuel and livestock forage faster than they can be replenished. In the hilly or mountainous headwaters of great rivers, destructive erosion of steep slopes is rapidly increasing; the resulting sediments choke the rivers and cause more disastrous downstream floods each year. As the supply diminishes, the price of fuelwood continually rises. In Nepal the average family spends about one-fourth as much on fuelwood as it does on food. If the wood is not purchased, one member of the family is often fully occupied in collecting firewood from forest areas at ever-increasing distances from the village. One of the reasons the forests are being denuded is the slow rate of growth of most native trees. The widespread sal tree of India and Nepal, for example, requires eighty years to produce usable timber.

Small plantations of fast-growing trees for fuel and forage could bring great benefits to rural villages. Moreover, with the continuing rise in the cost of fossil fuels, many tropical countries may find it economically desirable to take advantage of their abundant sunshine and year-round growing conditions by establishing large "energy plantations" as a means of capturing solar energy for industry and transportation. Forest trees, with their low nitrogen requirement and their ability to grow on poor, rocky soils and steeply irregular topography, could make an important contribution to meeting future energy needs. The key is high productivity per unit area. For example, with an annual production of twenty-five tons of wood per hectare, which is attainable with several of the trees described below, an area 550 kilometers on a side could provide all of India's present energy requirements. This is about one-fifth of the existing cultivated area in India.

To help in the search for firewood trees suited to the diverse environments of the less-developed countries, Noel Vietmeyer and his colleagues sought the advice of over 300 foresters and botanists throughout the world. Each specialist was asked to nominate those tree species he considered most appropriate for firewood plantations. Out of more than 1,000 species nominated, nearly half were rated as having exceptional promise by one or more persons. For some species, there was general agreement among at least half the specialists that they deserved to be ranked as promising candidates.

Using the results of the questionnaire and other information, an international panel appointed by the Board on Science and Technology for International Development is preparing a manual of promising fuelwood species. This will contain references to institutions and individuals throughout the world who are conducting investigations on each species and a bibliography of published information and recommendations on desirable national and international action. The panel is chaired by Edward S. Ayensu of the Smithsonian Institution.

Table 2 shows the top species selected by these experts for the five principal environments of the developing countries: tropical highlands, savanna regions, semiarid regions, arid and Mediterranean areas, and wet-dry lowland tropics. About ten to thirty species are shown for each major environment. It will be noted that there is some overlap in the recommendations; eucalyptus and acacia species are highly rated for almost all of the regions, for example.

In considering this list, it must be remembered that in many poor countries trees are used both as a source of fuel and construction materials and as a feed for livestock. The branches are lopped off and carried to the animals, which eat the leaves and tender shoots. Leguminous trees such as acacia provide the most digestible and acceptable nutrients. Hence the trees chosen for village plantations may not be those that can produce the highest caloric value per unit area and time, but those that provide an optimum combination of fuel and forage.

JACK'S BEANSTALK

Heading the list of exceptionally promising trees for the low-lying humid tropics is an evergreen tropical legume, *Leucaena leucocephala*, which is one of the most versatile plants in the world. One of its varieties has traveled from its original home in Mexico and Central America throughout the tropics during the past two and a half centuries. The name Oaxaca (Mexico's fifth largest state and a prominent modern city) is derived from a pre-Columbian word meaning the "place where Leucaena grows." The plant was carried to the Philippines in the Manila galleons, which for 250 years sailed across the Pacific each spring from Acapulco. This "Acapulco" (usually called "Hawaiian") variety, is a short, rugged, bushy tree up to five meters high that makes good firewood and charcoal and is useful as a "nurse tree" to provide shade and nutrients for coffee, cocoa, pepper, vanilla, and other shade-loving crops. It was spread by colonial plantation owners in the nineteenth century to the Netherlands East Indies, Southeast Asia, India, East and West Africa, the islands of the South Seas, and the Caribbean. The Hawaiian variety flowers year round and produces seeds, even when only a few months old. Consequently, it easily becomes a

TABLE 2 Fast-Growing Tree Species for Fuelwood Plantations

A. TROPICAL HIGHLANDS

Casuarina spp.
Eucalyptus globulus
Eucalyptus grandis
Eucalyptus maidenii
Acacia mearnsii
Cupressus lusitanica
Inga spp.
Grevillea robusta
Pinus oocarpa
Pinus caribea
Prosopis chilensis
Quercus spp.
Alnus spp.

B. SAVANNA REGIONS

Gmelina arborea
Anogeissus spp.
Gliricidia sepium
Moringa oleifera
Cassia siamea
Terminalia spp.
Quercus oleoides
Trema spp.
Eucalyptus citriodora

C. SEMIARID REGIONS

Azadirachta indica
Prosopis juliflora
Acacia albida
Acacia decurrens

SEMIARID REGIONS (Cont.)

Acacia nilotica subsp. *indica*
Acacia senegal
Acacia tortilis
Albizzia lebbek
Tamarindus indica
Emblica officionalis
Tamarix spp.

D. ARID AND MEDITERRANEAN AREAS

Acacia albida
Acacia senegal
Acacia raddiana and *Acacia tortilis*
Acacia nilotica and *Acacia arabica*
Acacia seyal
Maerua crassifolia
Tamarix aphylla
Tamarix nilotica
Haloxylon persicum
Haloxylon salicornicum
Colophospermum mopane
Prosopis tamarugo
Retama raetam
Pinus halepensis
Ziziphus spina-christi
Balanites aegyptiaca
Acacia aneura
Acacia cambagei
Acacia brachystachya
Acacia saligna
Azadirachta indica
Cassia siamea

ARID AND MEDITERRANEAN AREAS (Cont.)

Casuarina equisetifolia
Eucalyptus camaldulensis
Eucalyptus microtheca
Eucalyptus gomphocephala
Eucalyptus occidentalis
Parkinsonia aculeata
Pithecellobium dulce
Prosopis africana
Prosopis alba
Prosopis chilensis
Prosopis cineraria

E. WET-DRY LOWLAND TROPICS

Leucaena leucocephala
Syzygium cumini
Acacia auriculiformis
Casuarina equisetifolia
Eucalyptus spp.
Muntingia calabura
Zizyphus mauritiana
Calliandra callothyrsus
Sesbania grandiflora
Guazuma ulmifolia
Terminalia catappa
Gliricidia sepium
Vitex spp. eg. *pubescens*
Prosopis pallida
Mimosa bracaatinga
Pongamia glabra
Trema spp.

196 noxious weed, forming dense, impenetrable tangles, when it is not regularly harvested for fuel or forage. In East Africa, its low, bushy growth is said to be an ideal breeding ground for the tsetse fly, even though the plant is considered useful for stabilizing eroded slopes. At the same time, the Hawaiian variety produces a highly palatable, digestible, and nutritious food for cattle, water buffalo, and goats. The dry leaves contain twenty-seven to thirty-four percent protein, with a balance of amino acids much

like that in alfalfa and one of the highest pro-vitamin A contents ever recorded in plants.

Within the last two decades two remarkable new varieties of *Leucaena* have been discovered in inland forests of Central and South America. One of these, the Salvador or Hawaiian giant variety, is a tall, virtually branchless tree that can grow to a height of nine meters in two years and twenty meters in six to eight years. In dense plantations, it appears to yield a larger quantity of wood than any known tree, at least in the Philippines. Annual growth increments have been measured from twelve to over fifty tons per hectare. This marvelous tree, with its giant pods packed with shiny dark red seeds, is about as close as a living plant can come to the beanstalk that Jack climbed in the famous fairy tale.

The Peru type, another recently discovered variety of *Leucaena*, produces little trunk but extremely high quantities of foliage—under favorable conditions up to twelve to twenty tons per hectare of edible dry matter containing over twenty percent protein, compared to eight to nine tons per hectare for alfalfa with about the same percentage of protein. The foliage can either be browsed in the field by free-ranging cattle, or harvested and hauled to the cowshed. Alternatively the leaves can be dried, separated by beating, and compressed into pellets for easy transportation to feedlots and dairies.

Unfortunately, *Leucaena* contains an uncommon amino acid, mimosine, which produces goiter in cattle when the diet contains more than thirty to fifty percent dry weight of *Leucaena*. In single-stomached animals—horses, pigs, rabbits, and human beings—mimosine causes hair to fall out. In cattle the bacteria in the rumen transform the mimosine to 3,4-dihydroxypyridine (DHP), which reduces the production of thyroxine by the animal's thyroid gland. This transformation to DHP in the rumen is so complete that the blood, meat, and milk of the animals are quite free of mimosine.

In practice, mimosine toxicity can be avoided by interplanting *Leucaena* with a tropical grass such as Guinea grass and allowing the animals to feed on this mixed pasture. Researchers in Hawaii and Australia have recently produced a low-mimosine *Leucaena* through hybridization with another species of the same genus. In cattle fed on a mixed *Leucaena*-grass pasture, annual weight gains of 900 kilograms per hectare have been obtained in northern Australia; in dairy cattle an annual production of 5,000 to 6,000 liters of milk per hectare was obtained. These yields are about twice those normally expected from tropical grass or legume pastures.

The newly discovered Salvador variety, with its virtual absence of branches, thin bark, and light color, is believed to have much commercial potential as a source of pulp and paper and round-wood poles and posts, and as a medium hardwood for lumber and plywood. As a fuel, used either directly or as charcoal, the wood has uncommonly high density and caloric value for a fast-growing tree. Energy plantations using *Leucaena* could be a continuously renewable source of fuel, because the stumps readily regrow or "coppice," and thus "defy the woodcutter."

Leucaena has a deep, aggressive root system that reaches far below the soil surface for water and nutrients. This enables the plant to withstand long dry seasons and to tolerate a wide array of soil conditions. The root hairs are usually infected with a beneficial mycorrhiza fungus, whose vast network of hyphae helps to obtain phosphorus and other nutrients from the soil. There are also many small lateral roots near the surface. These develop abundant small nodules, housing bright pink rhizobium bacteria that "fix" atmospheric nitrogen by combining it with hydrogen obtained from the carbohydrate produced by the plant. Nitrogen compounds and mineral nutrients are transferred to the leaves, which contain about four percent of nitrogen, 0.4 percent of phosphorus, and up to four percent of potassium under good soil and moisture conditions. Foliage with 500–600 kilograms of nitrogen per hectare, 44 kilograms of phosphorus, and over 200 kilograms of potassium, as well as calcium and micronutrients, can be obtained easily.

Six bags of dried *Leucaena* leaves contain the same nitrogen as one bag of ammonium sulfate. Thus small farmers, for whom commercial fertilizers may be too expensive or even unobtainable, can grow their own fertilizer. The foliage from a *Leucaena* grove can be cut and used to fertilize adjacent farm fields, or *Leucaena* can be interplanted in rows between other crops or under coconut trees. The continually dropping nutrient-rich leaves quickly decay and provide fertilizer for the main crop. In areas of shifting cultivation, where long fallow periods of ten years or more have been traditionally used, the fallow period can be reduced to about two years by reseeding with *Leucaena* after crop plants have depleted the soil.

Because the nutrients are only slowly released from the decaying *Leucaena* leaves, about sixty percent of the nitrogen is lost by the action of denitrifying bacteria, and only about forty percent is effective for enhancing crop growth. Hence *Leucaena* is economically useful as a fertilizer mainly in areas where land can be substituted for other resources. For every hectare of cultivated land provided with a hundred kilograms of nitrogen usable by crops, an additional half hectare must be allocated to *Leucaena*.

The many actual and potential uses of *Leucaena*, its limitations (it does not grow well in acid soils high in alumina or at elevations above 500 meters), research needed to expand its usefulness, and a scientific bibliography are given in a recently published report, sponsored by AID and prepared by a joint study committee of the Philippine Council for Agriculture and Resources Research and the Advisory Committee on Technology Innovation of the Board on Science and Technology for International Development. The study committee, co-chaired by James L. Brewbaker and Joseph C. Madamba, consisted of forty participants from seven countries: Australia, Malawi, Mexico, Singapore, Taiwan, the Philippines, and the United States.

FLORAL TRAVELS

Great migrations have occurred in the 400 years since the discovery of the New World. Not only human beings migrated: Many species of crop plants and useful trees, hitherto confined to one hemisphere or the other, spread across the world. Out of the sixty-four domesticated crop species whose geographic origin is known, some twenty-two originated in the New World and spread to the old one, and forty successfully made the western voyage across the Atlantic. The species native to the Americas that now provide a major part of the world's food supplies include maize, potato, sweet potato, cassava, tomato, yam, peanut, sunflower seed, and several species of beans. Wheat, rice, barley, grapes, soybeans, sorghum, sugarcane, sugar beets, bananas, oranges, and apples came from the Old World.

Plants often do better when moved to new habitats, because their diseases, parasites, and predators can be left behind. Monterey pines, almost extinguished by disease in their native California, have produced the largest cultivated forests in the world in New Zealand. Because of intractable diseases, the wild rubber trees of Brazil cannot be cultivated successfully in their own country, but their cultivated descendants in Southeast Asia form the basis of a billion dollar industry.

The pressing needs of the people of poor countries, and the great advances in agricultural and basic biological sciences of recent years, could easily result in another wave of plant migration and an extension of the areas of high-yielding agriculture to vast, previously neglected regions. The work of the National Research Council in identifying promising underexploited species and spreading information about them could make an important contribution to this new enterprise.

SUGGESTED READING*

Firewood Crops: Bush and Tree Species for Energy Production. (in preparation)

Guayule: An Alternative Source of Natural Rubber. 1977. 80 pp. Describes a little-known bush that grows wild in deserts of North America and produces a rubber virtually identical with that from the rubber tree. Recommends funding for guayule development.

Leucaena: Promising Forage and Tree Crop for the Tropics. 1977. 118 pp.

Natural Products for Sri Lanka's Future. 1975. 53 pp. Report of a workshop with the National Science Council of Sri Lanka. Identifies neglected and unconventional plant products that can significantly contribute to Sri Lanka's economic development. Published by National Science Council of Sri Lanka.

Products from Jojoba: A Promising New Crop for Arid Lands. 1975. 30 pp. Describes the chemistry of the oil obtained from the North American desert shrub *Simmondsia chinensis.*

Underexploited Tropical Plants with Promising Economic Value. 1975. 187 pp. Describes thirty-six little-known tropical plants that, with research, could become important cash and food crops in the future. Includes cereals, roots and tubers, vegetables, fruits, oilseeds, forage plants, and others.

The Winged Bean: A High Protein Crop for the Tropics. 1975. 43 pp. Describes a neglected tropical legume from Southeast Asia and Papua New Guinea that appears to have promise for combatting malnutrition worldwide.

*With the exception of the report entitled *Products from Jojoba: A Promising New Crop for Arid Lands,* these reports are available at no charge, subject to availability. Write to Noel D. Vietmeyer, Commission on International Relations, 2101 Constitution Avenue, N.W., Washington, D.C. 20418. The jojoba report is available from the National Technical Information Service, Springfield, Va. 22161.

Study Project

COMMISSION ON INTERNATIONAL RELATIONS

DEVELOPMENT IN EGYPT

President Anwar Sadat of the Arab Republic of Egypt once remarked that "more than any other state we have no hope but modern science." And Egypt is now embarked on an effort to couple science and technology to the needs of the state; to develop a vigorous program in applied research and development to deal with its major problems—in providing more food, in reducing the ominous increase in dependence on imports by agricultural villages, in combating disease, and in expanding Egypt's relatively meager resources. To assist Egypt, the U.S. Agency for International Development (AID) has embarked on a three-year program totaling about $9 million. A part of that program includes an effort by the NRC, acting through its Board on Science and Technology for International Development of the Commission on International Relations, to assist the Egyptian Academy of Scientific Research and Technology in its efforts to strengthen and reorient Egyptian R&D.

The immediate difficulty is that there is simply no tradition in Egypt of major involvement by its scientific and technological cadre in applied research. Nominally applied research institutions are used in good part for university-oriented thesis research, and there is a mismatch between the structure and organization of Egypt's scientific institutions and government's declared needs. In all, as one evaluation phrased it, while "Egypt as a society is committed to development, and Egypt has created over the past 25 years an impressive scientific and technological community," it remains a fact "that this community has been upon the periphery of the prevailing development process."[1]

That situation must be viewed against Egypt's current condition: a country with a foreign debt greater than its annual Gross National Product, a dense and growing population, extremely limited natural resources, and an inflation rate officially given as about thirty-three percent annually but probably closer to fifty percent. The Egyptian population is now about 37 million people, but with an average growth rate of 2.2 to 2.5 percent annually it is growing by 800,000 to 1 million people each year and will reach 70 to 80 million by the year 2000. The population is extremely concentrated, with no major cities in southern or upper Egypt and the narrow strip of land along the Nile and the Delta now the most densely populated region in the world. Among significant demographic shifts is the deterioration of the agricultural economy, marked by a transition from a labor-intensive agriculture able to provide relatively ample jobs to the considerably less-labor-intensive industrial and service sectors of an urban economy. Urbanization is rampant, the normal situation with developing countries, and an actual majority of the populations of Cairo and Alexandria are now first-generation fellahin who have immigrated from the countryside. These elements affirm the judgment that "[r]ural congestion, urban crowding, unemployment and underemployment, deteriorating infrastructure and insufficient social services of increasingly poorer quality are only a few of the problems of Egypt."[2]

Such conditions emphasize the urgent need for indigenous science and technology, relying largely on local *adaptation* of foreign technology, to participate in staunching Egypt's economic decline and in markedly improving conditions. The tools for the task are at hand. As already implied, Egypt has in being a considerable scientific apparatus whose ostensible if poorly realized role is to apply research to national needs. That point is indeed a constant refrain to three recent studies of Egypt's problems in applying science and technology for national purposes. The first study was in the form of a workshop held in 1975, jointly by the Egyptian Academy of Scientific Research and Technology, the U.S. National Science Foundation, and the National Research Council.[3] The second was by a team from the Research Triangle Institute that used a survey approach to analyze the current status and possible developmental role of Egyptian science and technology.[4] The third, somewhat more parochial, study was an analysis by a team from the National Science Foundation on Egypt's needs in scientific instrumentation.[5]

All three efforts looked generally at the Egyptians' scientific apparatus, including the universities, of which there are eight major ones; but with over ninety percent of the student population concentrated in three universities and forty-four percent in Cairo University alone. However, the emphasis in the analyses was on the national institutions for coordinating, funding, and supervising research efforts. These institutions are the already-mentioned Academy for Scientific Research and Technology (ASRT), the National Research Centre (NRC), and, in the case of the NSF instrumentation study, the Scientific Instruments Centre.

A word about these institutions. There is no counterpart to ASRT in the United States, since it combines the role of the National Science Foundation in funding basic research, the role of mission-oriented agencies such as the Department of Energy in the planning and support of supposedly "relevant" research, the policymaking role of the President's Office of Science and Technology Policy, and the advice-giving role of the National Research Council.

ASRT is the official coordinating unit for all governmental efforts in science and technology and is given grant-making authority to help finance R&D programs. The academy directly operates several institutes, such as the Institute of Astronomy and Geophysics and the Institute for Oceanography and Fisheries, as well as fourteen specialized research councils engaged in activities such as petroleum and mineral resources, transport, and the environment.

The National Research Centre's role is described by its title. It is housed in several buildings scattered about Cairo, employs about 1,400 professionals, and, while administratively it is reponsible to the president of the academy, in reality it receives funding and direction from several ministries. The NRC is akin to one of the national laboratories in the United States, but has research programs in widely divergent fields, including technology transfer, food and agriculture, health and environment, energy, and natural resources.

The assessments made of the ASRT and the NRC, by the workshop and by the Research Triangle Institute (RTI) study team, bespeak a common problem: Research that is supposedly applied is more often basic, and, however the research is categorized, is almost universally at a considerable remove from governmental priorities and goals. Thus, "Strategically important national needs of Egypt are not yet being met in any significant way by Academy-funded research."[6] Further, "significant improvement is needed in the national relevance of NRC research."

Of course, these problems are hardly unique to Egypt, nor news to its leaders. The issue is remedies, which is much more difficult. As a practical matter, for example, it is very costly to transform basic into applied research and follow-up development. Thus, the cost ratio in the United States is 1:5:19, or in percentage ratios of four, twenty, and seventy-six percent. The financial demands therefore increase fivefold once a decision is made to proceed beyond laboratory research. A less palpable, but possibly even more difficult, problem is that of scientific culture and tradition: the cues by which a scientist assesses his standing and attains promotions, tenure, higher pay, and prestige. Finally, the emphasis on applied research is difficult for many research scientists to fathom, because they have trained within a milieu of basic science, been inculcated with a strong belief in the worth of basic research per se, and, more practically, because their livelihoods are dependent upon papers published rather than projects completed.

It should again be remembered that the problem is hardly unique to Egypt. As two analysts of the role of scientists in development put it, the problem is that

> [t]here is no tradition of purposeful research, mainly because there are no external users around to convey their needs and wants to the scientists, and there is no established culture of such links between the academic and the practical. Thus the doctrine of academic freedom, according to which every professor should be quite at liberty to work at any scientific topic that pleases his fancy, is carried to an extreme.[7]

Aside from transforming the cultural cues that motivate scientists, the reorienting of Egyptian science and technology must also seek to avoid the easy solutions, such as the wholesale adoption of foreign technologies, which may on a first-order basis appear to be suitable but turn out to be intolerant or maladaptive to local conditons. Therefore,

> [p]articular stress must be laid on the adaption of science and technique to meet *local* needs [authors' emphasis]. New research, basic and applied, may have to be performed locally or regionally before the major problems faced by a given country on account of its particular geographical location or social history can be dealt with. Rice cultivation in Southeast Asia, soil desalination in Pakistan, ranching in East Africa, deep-sea fishing in Peru are examples of important human activities which cannot be understood and improved merely by the application of general biological and ecological principles taken from the international scientific literature.[8]

Implicit in the last statement is that applied research, purposeful and committed to certain goals, must be nurtured by first-class basic research. That principle is clearly recognized by the Egyptians, and the universities are intended to remain as centers of fundamental research, with the national institutions, such as the National Research Centre, increasingly turning their research toward the needs of the state.

Of course, good applied research does occur in Egypt, but overall it tends to be the exception. For example, the Egyptian Petroleum Research Institute, originally a part of the university-oriented National Research Centre, has been independent since 1971. Its research and development program, rather than being academically oriented, is now entirely applied, interacts strongly with industry, is adapting foreign technologies to Egyptian problems, and, as the surest signs of its success, has licensed *Egyptian* technology to foreign users. Other specific successes in applied research include the pilot plant production of pulp and paper from sugar plant bagasse and the introduction of highly innovative machinery into the textile industry.

The role of the overall program funded by AID in which the National Research Council is participating is to assist the Egyptian scientific and technological research community in reorienting its research toward institutional capability in the management of R&D. NRC, through its Board on Science and Technology for International Development, will assist in three ways:

- Policy planning and management functions of the Academy of

Scientific Research and Technology, including establishing a high-level U.S.–Egyptian Joint Consultative Committee. Technical assistance in the management of R&D projects by the ASRT, with the principal vehicle here being a resident U.S. advisor to the president of the academy. The advisor would assist in program conceptualization, assist U.S. consultants when they are in Egypt, help Egyptians evaluate R&D progress, and serve as the principal American link to the Joint Consultative Committee.

• Technical assistance for management of R&D projects with the National Research Centre, which involves the appointment of a second resident advisor to the Director of the National Research Center. A major pilot study would be started during the advisor's tenure on a multidisciplinary study of nutrition, food production, and food technology in a specific rural location.

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Commission on Natural Resources

Advising on the Environment

GILBERT F. WHITE

A major shift occurred after the mid-1960's in the role of the scientific community in providing advice on the management of the nation's natural resources. Discoveries of the growing environmental impact of industrial and agricultural technologies, particularly in the production and use of toxic compounds, coupled to public recognition of the likely impacts of impending resource shortages, led to significant new demands by public agencies upon scientists.

The consequences of man-made alterations in natural systems received more attention (see Robert M. White, "Climate and Public Policy," in this volume). Efforts were made to estimate the limits of physical and biological resources. Recognition of the magnitude of man's intervention in the environment in turn stimulated questions as to the character of the affected air, soil, and water systems. The value of various remedies was questioned. There was widespread disenchantment with the effectiveness of large projects to develop resources; for example, the massive water storage

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projects and nuclear power plants that had captured the public imagination in the preceding two decades. Concern led to regulation and caution, and, by the late 1970's, to a rethinking of what was known about environmental processes and about the actual results of efforts to protect them. For example, enthusiasm for regulation of toxic substances was tempered by questions as to the scientific grounds for setting standards and for judging the social feasibility of control options.

There was in tandem a new ordering of public values with respect to the protection of water and air quality in the past decade. This was accompanied by major revision both in the forms of federal organizations dealing with threats to the environment and in the management of natural resources. Whereas in the early 1960's the emphasis in research on natural resources was on ways to ease the development of resources of land, water, and minerals, the attention shifted increasingly to the impacts of human interventions, the problem of managing residual wastes from industry and agriculture, and to endangered sections of the continent and its oceanic shelves. The establishment in 1970 of the Environmental Protection Agency and the Council on Environmental Quality marked the outcome of congressional efforts to give coherence to a variety of resource regulations and to establish a national posture for managing the environment.

THREE TYPES OF ADVICE

The Commission on Natural Resources can provide three types of advice from the scientific community in these circumstances: (1) it can design and maintain baseline assessments of information on resource quality and use; (2) it can appraise the state of knowledge for both general and specific problems, including emergency requests for advice on controversial projects or policies; and (3) it can explore basic concepts or frameworks of study within which new research may be fostered. Circumstances sometimes force a blending of these types; and, whatever the nature of the advice, the appraisal of a current problem is inevitably and properly accompanied by an appeal for research to ease the next such exercise.

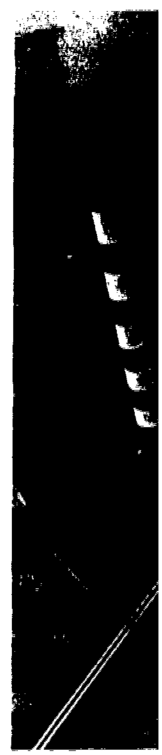
The more influential studies generally deal with issues that will be confronted within five to twenty-five years. Few major turnarounds occur in less time, and in the field of natural resources policies rarely survive a longer period in the face of expanding knowledge and changing social values.

BASELINE STUDIES

A special contribution of the scientific community to environmental policymaking is the maintenance of a baseline of information and methods on which to ground new studies and appraisals of special problems. An example is in the chemistry and technology of coal utilization and production. The chemistry of coal and its uses is fundamental to improvements in coal processing and in coping with the effects of various processes upon effluents. The earlier classic piece of information about the chemistry of coal, first produced in 1945, and revised in 1963,[1] currently is under revision by the Board on Mineral and Energy Resources of the Commission on Natural Resources and will provide a solid groundwork against which new policy decisions and research proposals may be examined.

Another example is provided by the methods for the scientific and technical assessment of environmental pollutants.[2] Appreciation of the extent and nature of the effects of pollutants upon human health and upon other elements in aquatic and terrestrial ecosystems has come piecemeal and involves findings from a wide variety of technical fields. As an example, understanding of the environmental influence of a substance, such as that of mercury as it is transformed to methyl mercury, requires a complex analysis, one that means giving precision and definition to the natural background levels, origins, routes, sinks, and final effects of the pollutant as it moves through the environmental media. A mass balance approach is usually employed in such an analysis, and there is explicit discussion of the feasibility of controlling the pollutant and of the costs and benefits from various degrees of regulation.

It is hardly the function of the National Research Council to undertake complete studies of each of the hundreds of significant pollutants; but it is appropriate for scientists who operate independent of regulatory agencies to indicate the ways in which scientific and technical assessments may be made and to illustrate this with specific substances. The current work of the commission's Committee on Scientific and Technical Assessment of Environmental Pollutants centers on four substances: mercury compounds, hexachlorocyclopentadiene (Kepone/Mirex), halogenated hydrocarbons, and nitrates. These are representative of the great spectrum of compounds being poured into the environment at an increasing rate and volume. The findings and methods suggested for these selected



studies may be expected to be revised as new advances take place, but in the meantime they can provide a base for studies of other substances.

Pesticide decision making is the topic of another methodological study by the commission upon which a broad array of scientific work may be based. The commission's Environmental Studies Board is now developing an explicit analysis of pesticides subject to reregistration, with the emphasis upon demonstrating methodology that would be broadly applicable. What is unique about this exercise is that it is being done in close collaboration with the scientists in the government agency who will probably be responsible for more extensive work of this kind in the future. Essentially, an explicit analysis means an effort to specify and illustrate means of estimating the relative strengths and weaknesses of available control options, the benefits and costs of each option, and the sensitivity of the choices to various assumptions as to results.

The question of what constitutes suitable nutrition for animals is a perennial problem calling upon all of the sciences that contribute to understanding animal health. To provide a continuing and periodically revised appraisal of what is known about the constituents of nutrients that affect animal health and the interrelationships of animal nutrition with the agricultural enterprise, the Board on Agriculture and Renewable Resources, through its Committee on Animal Nutrition, periodically publishes reviews of nutrition for particular animals; the latest such publications include reviews of the nutritional needs of rabbits, poultry, and dairy cattle.[3]

PROBLEM APPRAISALS

The second class of scientific advice lies in reviewing our knowledge concerning problems that command attention at the policy level, but where there is ambiguity or controversy as to the status of that knowledge and its policy implications. In these cases, the public agency that is faced with the need to make administrative or quasi-judicial decisions often finds it advantageous to rely on the carefully sifted and weighed opinion of an external group of scientists who are chosen for the balance of their experience and views and who can express their opinions without regard to political or administrative consequences.

An example of this function is the recent investigation of gas production opportunities in gas and petroleum fields under federal lease in the Gulf of Mexico outer continental shelf.[4] Those studies examined the technical, economic, and legal factors in increasing production over a one- to five-year period, and also sought to identify promising areas. Geological, geophysical, and engineering data were examined for selected fields, and individual field assessments were made. The studies were remarkable in that they used the full body of technical evidence available from the producing companies as well as from the U.S. Geological Survey and that they produced a substantial consensus as to how much gas might be extracted at what costs and ultimate recovery rates.

A different appraisal done by the Environmental Studies Board involved an evaluation of the extensive Environmental Studies Program, operating at a level of about $40 million a year, carried out by the Bureau of Land Management on the outer continental shelf.[5] In this case the question raised by the Department of the Interior related to the scientific character of a particular program, whose purpose was to provide a basis for determining likely impacts of offshore oil and gas exploration and production upon the environment of the outer continental shelf. The study committee concluded that the activities of the program were not likely to provide the kind of information that the Department of the Interior should have in making leasing decisions, and that a reorientation of the scientific approach and method would better serve the public interest.[6]

A current investigation of polychlorinated biphenyls (PCB's) in the environment illustrates how a review of a salient question may illuminate broader issues. Although much remains to be learned about some of the toxic effects of polychlorinated biphenyls on ecosystems and on human health, measures are being taken under the 1976 Toxic Substances Control Act to eventually prohibit further dissemination of PCB's. The urgent questions now are how long do they persist in the environment, given various media of water and soil and organisms, and what are practicable ways to cope with them over a long period? The underlying significance is the extent to which, taking into account the experience with PCB's during the past decade, it is now possible to suggest methods to identify and test for other such persistent and toxic chemicals *before* they reach serious proportions. Also significant is the evaluation of various ways to reduce the long-term impact of ubiquitous and persistent toxic chemicals in the environment by removal or accelerated degradation. (The article following this one further describes the study on PCB's.)

Sometimes the very way a study is done illuminates an existing problem. A request to the NRC to very quickly appraise the state of knowledge concerning a particular problem may simply reveal how little we actually know because the requisite research has not been done. An example is the request that came from the President's Office of Science and Technology Policy in August 1977 for an appraisal of the likely ecological effects of a sea-level canal in Panama. This problem had been reviewed in 1970;[7] seven years later the immediate issue was whether or not new scientific evidence changed in any way the findings from the earlier study. In approximately six weeks, a special committee of the Environmental Studies Board presented a letter report on the subject. One of the discouraging findings was recognition that since the 1970 examination remarkably little research had been started to help settle the questions raised in 1970 and asked again in 1977.[8]

When these hurried and rapid-fire appraisals are undertaken there always is anxiety about whether or not the allocated time is suited to the type of judgment that is required. Scientists who participate are obliged to put in large amounts of time over a few weeks or months and to lay aside other concerns during that period. This runs the risk of an incomplete canvass of the literature or of insufficient probing of troublesome aspects of the problem. It has the advantage, however, of forcing intense consideration of the topic; and, since the effort does not attempt to develop new research findings, it may yield relatively high-quality results.

CONCEPT EVALUATION

The third type of advice from the science community on resource management and environmental matters has to do with the exploration and elucidation of new conceptual schemes and definitions of problems that may then influence the approach by public agencies to policy matters or the deployment of their resources for research and investigation. The 1962 report of the Committee on Natural Resources of the National Research Council was prescient in this regard.[9] It took account of the wide concern at that time with the need for more effective management of water resources. Many of its suggestions are relevant to the current controversy on water policy, and the report also traced out new lines of inquiry, which became dominant in the mid-1970's. The 1962 report did not attempt to arrive at consensus on all aspects of the resource and environmental scene. Rather, it presented a few general findings and suggestions, and allowed individual members to state their views about issues that deserved more concerted attention from the research community and from government agencies providing financial support. For example, the report by M. King Hubbert on energy stated explicitly and forcefully the solid but then controversial body of evidence with respect to the prospect for exhaustion of North American resources of oil and petroleum,[10] estimating the late 1960's for the probable peaking of petroleum production. At the time, the argument was disputed in some quarters and ignored in most, but it pointed the way to what is now a widely accepted view of the prospects for domestic oil and gas production. Similarly, the report identified problems due to the influence of mounting pollution loads upon environmental quality and helped support further investigations of waste disposal technology and the concept of residual management. It also outlined the general characteristic of systems analysis as applied to natural resources management.

Investigations of this sort, which cultivate new perspectives and outline new routes for investigation of environmental issues, probably are the most significant in influencing the course of public action. However, they are difficult to organize, call for uncommon imagination, and often fail to attract funding.

Current examples of such investigations include the study to examine procedures and generate concepts for improving the estimation of uranium resources, and to identify ways to shorten the time span for uranium exploration, development, and production. These call for a combination of geological, geophysical, engineering, health, and economic considerations in defining what is a uranium resource and the conditions by which it may be identified.

Another inquiry deals with the redistribution of accessory elements and compounds in the physical environment, which might result from potential mining of coal, shale, iron, and other ores on a large scale. By shifting the focus away from the mining enterprise itself, a set of issues is raised that suggests reorganization of the more traditional approaches. The study will define areas of needed improvement in data, try to estimate what the long-term trends may be, and provide an alert as to possible problems due to environmental loading.

One of the more intractable aspects of resource management at present is land use planning and management. Hindered by public suspicion and opposition, and honored more in theory than in practice, it is still fundamental to maintenance of the national resource base. Without effective choices as to land use, many facets of environmental quality, such as air and water pollution, cannot be constructively managed in the long run. In the absence of effective means of making land use choices so as to assure consideration of the full range of alternatives for private and public use, regulatory action may seem the only corrective to continued degradation. So long as public policy and research shy away from tools for land management, heavy investment in corrective works, as in the case of flood control projects, may be expected to dominate the natural resources scene. These arguments are neither new nor unsupported, yet they fail to command support, and with the exception of a few inquiries, such as the review of opportunities for development of urban waterfronts, land management remains neglected in NRC activities.

The recent analysis by the Board on Agriculture and Renewable Resources of the opportunities and obstacles to achieving a national aquaculture asked what accounted for the very slow rate of development of aquaculture as a means of contributing to the nutrition, particularly of proteins, of the American people.[11] The study's realistic assessment of prospects for increased food supply from aquaculture showed severe limitations imposed by physical, genetic, technical, and economic conditions. It also suggested possible new approaches, including research and development initiatives, which, with the stimulation of a lead government agency, might bear larger fruit in the future.

SHORT-TERM AND LONG-TERM NEEDS

The tendency has been for public agencies dealing with natural resources to turn to the scientific community for support in the second type of advice—problem appraisals. The bulk of the funds and the administrative concerns are allocated to examinations of the state of knowledge for specified problems. It is here, of course, that controversy or dissatisfaction with the interpretation of scientific findings is most likely to arise among special interest groups and it is here that pressing issues of public action frequently seem to justify large outlays.

Usually the pressure of some kind of legislative or administrative deadline forces the hasty completion of the study. In accepting such assignments, be it for six weeks or six months or sixteen months, the NRC must decide whether or not it can provide sound evidence and judgment within the constraints of time and money. When the results provide relatively firm grounds for decision, all parties concerned may find little ground for regret. When the finding is that until more data are collected or more effective research is completed and the answer remains in doubt, there often is dissatisfaction. The prospect for the future is that the latter type of findings will dominate.

It is not easy to obtain funds for the baseline investigation; baseline work is less dramatic than the appraisal of current problems and is not likely to develop new concepts and points of view. Yet such investigations have significance for later definition of policy issues. In the long run, the most influential of the three types of studies involves exploration of new approaches and concepts; but it is this basic, deliberative, and risky exercise that often is *least* able to command public support. The risk in part is that such studies may lead only to a pedestrian recital of further research needs in the field, inviting the criticism that the results are self-serving lists of new directions for study that do not have direct application to policy decisions. To the extent that scientists emphasize those research opportunities that they judge to be immediately promising and practicable, these criticisms may appear to be warranted. But it is more likely that, for lack of such exploratory efforts by scientists who are one step removed from administration, the number and urgency of problems requiring emergency action will expand. The need for exploratory efforts is particularly critical as science generates new understandings of environmental systems. Timing is also crucial: Research may have little influence if it moves out too far in front of the administrative, regulatory, and supporting research efforts of the federal agencies; but, conversely, if such research is neglected, current environmental and resource difficulties may worsen.

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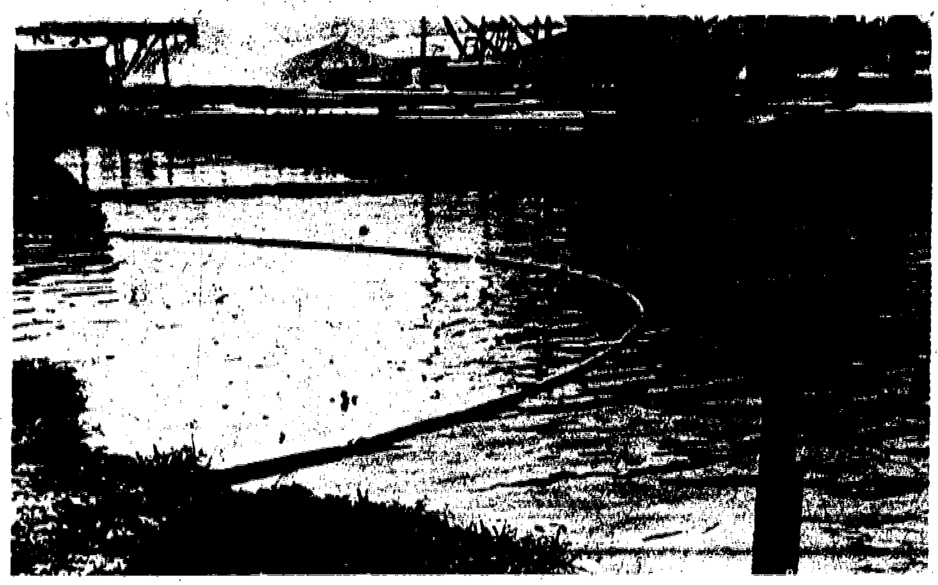

Study
Project

COMMISSION ON NATURAL RESOURCES

POLYCHLORINATED BIPHENYLS IN THE ENVIRONMENT

The Committee for an Assessment of Polychlorinated Biphenyls in the Environment of the Commission on Natural Resources will seek to identify the generic problems associated with persistent compounds, such as polychlorinated biphenyls (PCB's), that are widely used and dispersed in the environment. The study is funded by the U.S. Environmental Protection Agency's (EPA) Office of Research and Development.

PCB's were chosen for study because of the complex issues raised by their regulation and the range of alternatives for their control. These issues encompass many of the problems presented by other chemicals that are both persistent and widespread: the chlorinated pesticides Kepone, DDT, aldrin/dieldrin, Heptachlor/Chlordane, and others.

For example, the control options to be considered by the committee include the prevention of further release of PCB's to the environment, enhanced microbial or photochemical degradation, and removal by dredging, by harvesting of biota that concentrate PCB's, and by incineration of PCB-contaminated wastes. Many of these control measures may be applicable to other persistent pollutants; thus, the lesson learned from the options available for the cleanup of PCB's from the Hudson River, especially any analyses of the merits of dredging the river's sediments, should be useful for evaluating available options for cleaning up Kepone that has accumulated in the James River.

PCB's were first synthesized late in the nineteenth century, but they were not commercially produced until 1929. Commercial mixtures of PCB's, or formulations containing such mixtures, have been used industrially as cooling liquids, dielectric fluids, heat transfer agents, and for other electrical applications; they also have been used in paints, adhesives, rubber, certain synthetic resins, inks, cutting oils, and pattern waxes. Many of these uses now have been abandoned.

However, the dominant use of PCB's is in transformers and capacitors, and it is the ubiquity of these devices that accounts for the extensive presence of PCB's in both light and heavy industrial equipment and in many household appliances.

The properties of PCB's that most uses exploit are their stability to extremes of heat and light, their nonflammability, and their efficiency in transferring heat. The problem with PCB's is that they can also move throughout the environment and accumulate in fat tissue of humans and animals.

PCB's were first recognized as an environmental contaminant in 1966 during studies on the accumulation of DDT in food chains. Samples of fat tissue from both humans and wildlife contained not only DDT and its metabolite DDE, but also unidentified yet persistent materials. These turned out to be PCB's. In 1968, after additional evidence showed that PCB's were widely distributed in birds and fish, a poisoning incident in Japan raised the specter of a widespread human health hazard. Rice oil used in cooking was contaminated during manufacture by PCB's from a faulty heat-exchange unit. The victims suffered, in addition to headaches and nausea, from a variety of severe symptoms ranging from skin lesions to eye problems; the poisoning was serious enough to be a factor in the death of at least 29 of the 1,300 victims of the "Yusho" (rice–oil) disease. In addition to these acute health effects of PCB's, recent evidence indicates that carcinogenicity, teratogenicity, and suppression of the body's immmune system are also health effects of PCB's.

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The levels of PCB contamination in the Yusho incident are greater than the levels to which people are generally exposed; but the incident did demonstrate that PCB's pose a risk to human health. PCB's accumulate in the food chain, and many fish are particularly prone to concentrate them. People who consume contaminated fish regularly may accumulate PCB's. PCB's also are directly hazardous to fish, birds, and other wildlife, for these chemicals can interfere with reproduction. The hazards associated with PCB's are further compounded by the finding that they enhance the toxicity of certain other environmental pollutants, such as DDT and dieldrin.

The health and ecological effects of PCB's as a commercial mixture have been studied extensively, but the toxicity of individual isomers less so. Since chlorination of biphenyl to form PCB's can produce 210 different isomers, of which about 100 are found in commercial mixtures, determining the toxicity of individual components is extremely difficult. Further, polychlorinated dibenzofurans, which are contaminants of some PCB mixtures and also possible degradation products of light, bacteria, or extreme heat, may be responsible for some and perhaps most of the health effects associated with PCB exposure.

Much has already been done to control PCB's—by voluntary action on the part of the industrial manufacturer, Monsanto Industrial Chemicals Corporation, and by regulatory action in the United States at the federal and state levels. In addition, many other countries now regulate PCB's. In the United States, for example, Monsanto, as early as 1971, restricted sales of PCB's for use in closed electrical systems. In 1972 and 1973, the Food and Drug Administration reduced the levels of PCB's allowed in foods and eliminated the use of paper food wrappings impregnated with them. The Toxic Substances Control Act, which became law in 1976 and is one of the few examples of direct congressional regulation of an individual substance of a commercial mixture, requires the administrator of EPA to promulgate rules for the disposal and labeling of products containing PCB's. The act restricts PCB use to totally enclosed systems and bans the manufacture of PCB's two years after the act's passage and their processing or distribution after two and one-half years. However, exemptions are possible.

To date, regulations required under the Toxic Substances Control Act on disposal methods and marking of all items containing PCB's have been proposed; and regulations limiting the discharge by certain industries of effluents that contain PCB's have been issued in final form by EPA under the

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authority of the Federal Water Pollution Control Act. These regulations prohibit direct discharge of PCB's by the manufacturers of the chemicals and greatly limit discharges by manufacturers of electrical equipment containing them.

CONTINUING PROBLEMS

Other regulations by EPA for limiting air emissions of PCB's and specifying their recovery from solid wastes possibly will be developed by EPA. However, because of the persistence of PCB's in nature, problems will still exist even if all planned regulations are published and enforced. These problems are the focus of the NRC study.

Approximately 1.25 billion pounds of PCB's have been produced and used in the United States. Only a very small proportion, estimated to be 55 million pounds (4.4 percent), has been destroyed, either by high temperature incineration or by slow microbial or photochemical degradation in the environment. Some 750 million pounds (60 percent) of the PCB's manufactured are contained in various pieces of equipment still in use today. Possibly, this amount of PCB's can be effectively disposed of; but it is more likely that the PCB's contained in a large number of small pieces of equipment used in homes and in industry will eventually reach the environment, adding to the estimated 440 million pounds already there. Of that 440 million pounds, an estimated 290 million pounds are in landfills from where they may in time be dispersed throughout the environment. The remaining 150 million pounds are in the air, water, soil, and sediments.

With the Hudson River closed to fishing because of PCB's, and fishing in the Great Lakes and other bodies of water threatened by PCB contamination, the NRC committee will look carefully at the alternatives for controlling further release of PCB's, for accelerating their degradation, and for removing and destroying them. The three primary objectives of the study are:

1. To develop a model of the transport and fate of PCB's in the environment. This will permit a determination of the length of time and levels at which PCB's are expected to remain in the environment. The model will also be used to identify stages in the movement of PCB's where regulatory intervention would be appropriate.

2. To recommend means of quantifying the persistence of a substance in the environment, appropriate tests for persistence, and, if possible, tests that might have identified the hazards of PCB's at an early stage and therefore might identify other such substances before they are widely used.

3. To determine through cost–benefit analysis the environmental and health advantages and disadvantages of options for controlling further release of PCB's, for removing them from the environment, and for accelerating their degradation; and then to determine the costs and benefits of these options.

In the analysis of costs and benefits, an effort will be made to be as quantitative as practicable within the limitations of time, funds, and the uncertainties of the underlying data and assumptions. For cases in which costs and benefits are not quantifiable in a meaningful way, qualitative descriptions will be used.

This study should indicate whether further regulatory actions are necessary to alleviate the most hazardous exposures of PCB's and to suggest avenues of research likely to provide insight into the most vexing problems. These results, including an analysis of control methods now employed, should provide a framework for dealing with other persistent pollutants.

NATHAN KARCH

The Committee for an Assessment of Polychlorinated Biphenyls in the Environment, Commission on Natural Resources. Committee Chairman, Alfred Beeton of the University of Michigan; Staff Officer, Suellen Pirages.

Commission on Sociotechnical Systems

1 What Is the Public Interest?

HARVEY BROOKS

The purpose of the National Research Council is to carry out analyses and make recommendations that relate to the use of scientific and technical knowledge to further the public interest. The particular mission of the Commission on Sociotechnical Systems (CSS) is to deal with a certain subset of sociotechnical delivery systems. These are generally related to the basic "infrastructure" of an industrial society and involve interfaces with both a very broad public and a variety of social and economic institutions. The areas emphasized by CSS stem partly from the historical evolution of the NRC and its various subunits, and therefore it is not possible to explain or justify the CSS programs on the basis of an *a priori* deduction from a general mission statement.

The principal common threads are contained in the words "sociotechnical" and "public interest." Of these the second is the hardest to define. This is because the "public" is actually a congeries of often conflicting interests and highly pluralistic values. There is no simple prescription for aggregating the interests of individuals or small groups into a net sum

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defined as the "public interest." Even within a group, or within the mind of a single individual, goals are valued that may be partially or wholly incompatible with each other; one goal can only be maximized at some expense to another, equally valued goal. As society has become more interdependent, the conflict among simultaneously desired goals has tended to increase. Systemic effects of apparently isolated decisions extend more and more widely in both time and space. Decisions made today, which are universally regarded as "a step in the right direction," may have unintended and undesirable consequences twenty years hence. Society's expectations from its sociotechnical delivery systems have constantly escalated, and we have become more and more dissatisfied with their performance.

As pointed out in the accompanying essay by W. L. Garrison, public services that used to be regarded as options to be purchased by those that wanted to and could afford to pay for them are now claimed as a right available to every citizen on an equal basis. We expect our social delivery systems to satisfy the peak demands that are placed on them, almost irrespective of cost; yet we are coming to realize that meeting such demands means increasing the cost to everybody. For example, new households, which increase the total demand for electricity, now increase the price of electricity for everybody, since the capital cost of new power plants exceeds that of older ones, unlike the situation during the 1950's and 1960's. Yet a sense of justice forbids us to charge a new household more for electricity than one formed a decade ago; why should a family be penalized just because it is young? But, then, why should everybody be required to share the costs imposed by new entrants into the system?

In the past we relied on the market to iron out these problems, and it is still probably the best mechanism we have. But the market itself depends upon the particular ground rules that govern it; a truly free market without rules does not exist. Government, or some other collective form, must be the referee of the game, one in which the players seem increasingly disposed to call on the referee to change the rules.

But who is "government?" In answering this question we come immediately to the question of "participation." Who is it that should participate in the determination of the ground rules under which the market operates? What is the process by which governmental decisions can be seen to be "fair" and thus legitimized in the eyes of the public that has to live with them? This issue has been treated in one particular domain in a study by the commission's Maritime Transportation Research Board on the impact of maritime facilities on local populations.

We see all these themes emerging and intertwining in the various activities of the CSS. The subject of transportation for the handicapped, for example, has emerged as a major public policy issue, because access to public transit is now seen as a "right" that should be claimable by all citizens. Even if the claims of particular disadvantaged groups impose large new costs on the system, it is the responsibility of society as a whole to meet those costs.

Rapid technological change produces benefits to some groups and costs to others. The costs are often unforeseen, and society has developed few means of compensating for them. Many innovations are clearly in the interests of society as a whole, since they increase its aggregate productivity and thus increase the aggregate of goods and services available for distribution to all. Yet these innovations are often blocked or retarded because of their adverse impact on particular groups and the absence of any means for society to compensate those who are adversely affected. Thus, the costs of innovation are borne unequally within society, while the benefits are widely shared, but not tilted toward any one group. Those who are adversely affected can now register their distress to an increasing degree through the political process; in the past they have often simply been forgotten. The issue of widespread benefits and unequal costs seems to arise with particular force in the maritime industry, and it is a theme underlying several studies of the Maritime Transportation Research Board.

A much more subtle manifestation of the same effect relates to the development of contingency plans for mitigating the possible interruption of supplies of key raw materials. In the absence of government intervention, the costs of preparing for possibly remote political contingencies must be borne by private suppliers; yet, paradoxically, the likelihood of any one contingency is usually too small to warrant investment in an activity that is uneconomic *except* if supply is actually interrupted.

In what follows, I describe a selection of projects in the various units of CSS illustrating some of these themes.

BUILDING RESEARCH ADVISORY BOARD

The Federal Construction Council (FCC) has its twenty-fifth anniversary this year. It is a unique agency of the National Research Council in that it is composed primarily of individuals from federal agencies and was in fact created as a neutral mechanism to bring together the various federal agencies that are responsible for the construction of federal facilities in order to exchange information and work for the solution of common problems. Under policies established independently by the Building Research Advisory Board (BRAB), the council promotes the interchange of construction-related knowledge and experience and works to minimize duplication in technical studies. It also provides a forum for discussion of matters of mutual interest between technical specialists in federal agencies and other specialists with similar responsibilities in both the private sector and in state and local governments.

The FCC has eight continuing programs: (1) the development of Federal Construction Guide Specifications, (2) a construction cost forecasting and cost engineering study program, (3) maintenance of a computer program library of construction engineering techniques accessible by remote terminal, (4) running a series of seminars on design criteria for federal construction projects, (5) maintenance of an information exchange program for construction-related engineering investigations, (6) a program to promote the incorporation of fire safety criteria in construction designs, (7) a general program on safety criteria in design, and (8) a program for interchange of ideas and experience in procurement policy.

In addition, four short-term *ad hoc* studies were completed during the past year covering such subjects as steam boiler and hot-water generator construction criteria and techniques for the conduct of energy conservation surveys of buildings. Three new *ad hoc* studies are planned for the coming year.

Experience has indicated that apparently better cooperation and coordination between federal agencies can be achieved through such a nongovernmental mechanism that includes a few private sector people as well as agency specialists.

TRANSPORTATION RESEARCH BOARD

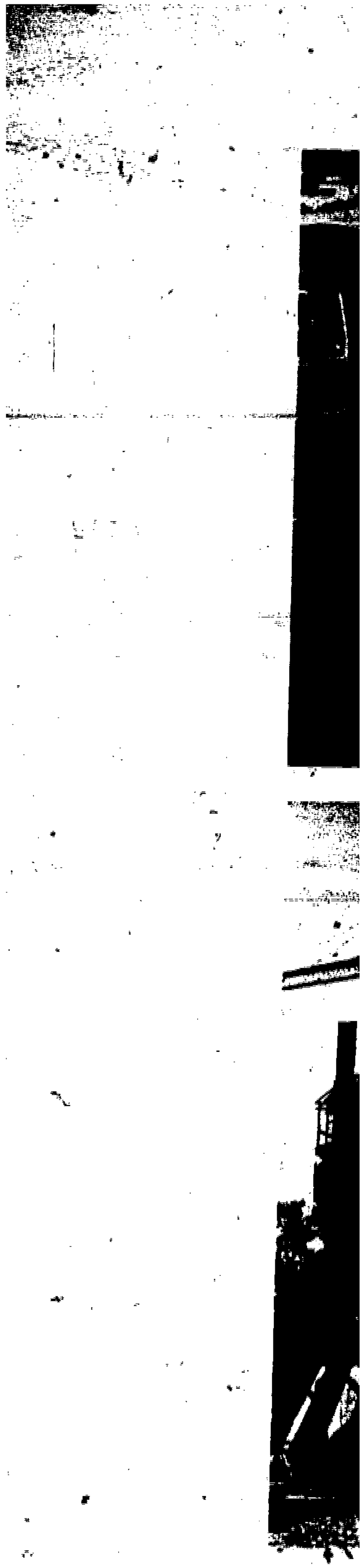
As the capital costs of new highway facilities have increased, and as public resistance to highway construction in urban areas has grown, attention has turned to institutional and administrative devices to reduce traffic congestion in metropolitan areas. A recently approved project under the

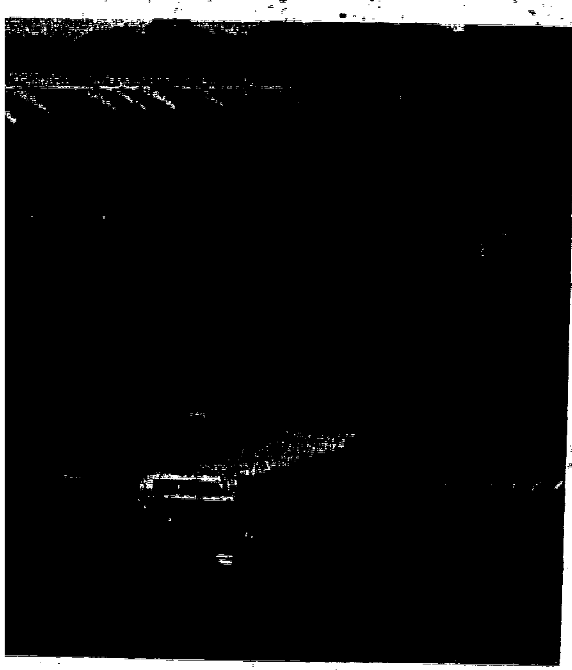
National Cooperative Highway Research Program of the Transportation Research Board (TRB) is undertaking to identify and analyze techniques for reducing congestion, and to study the institutional factors that stand in the way of their implementation. It has identified seventeen techniques, ranging from social techniques such as staggered work hours to technical techniques such as various applications of traffic engineering.

As a result of these studies, the project, being done by the consulting firm of Remak-Rosenbloom, has recommended eight "program-packages" of congestion-reducing techniques. It has then analyzed the institutional and administrative barriers to realizing these techniques. Many institutional barriers are common to several of the recommended packages, with major ones including: (1) dispersion of public authority in the regulation and planning of transportation, (2) separation of public responsibility for planning and implementation, (3) incompatible regulations, (4) unequal financial incentives for various participants in transportation planning and implementation, (5) conflicts between local autonomy and "collective rationality," (6) personality conflicts among public officials, (7) imbalanced representation of various interests in public participation (e.g., preferential representation of the "retired, well-educated, and economically secure"), and (8) inadequate cooperation and information exchange among agencies. The analysis has been aided by in-depth case studies of four communities: Jacksonville, Dallas, Houston, and Seattle.

The point made by W. L. Garrison in his article on public facilities systems—the tendency for access to public services to be claimed as a right equally available to all citizens irrespective of relative cost—is strikingly apparent in the case of public transportation for the elderly and the handicapped, and this issue is discussed in some detail in an accompanying study project article on "Transportation for Elderly and Handicapped Persons."

As noted in the article, the Transportation Research Board has established a committee to consider the implications of a national policy of providing equal access to public transportation for the handicapped and the elderly for the specifics of transportation planning. One issue is that, apart from costs, many groups feel that separate systems for the handicapped and elderly are psychologically demeaning, thus do not fulfill the spirit of the requirement for equal access, and are therefore not acceptable, regardless of cost. The committee is considering this issue, along with others discussed in the accompanying article.





MARITIME TRANSPORTATION RESEARCH BOARD

The Maritime Transportation Research Board (MTRB) has launched a new study, "Innovation and Technology Transfer in the Maritime Industry." The primary purpose is to understand the factors that influence the capacity of the industry to develop and adopt technological and institutional innovations that will ensure its future survival. Contrary to some conventional wisdom, the maritime industry has experienced remarkable technological changes within the last two decades, the most far-reaching having been the set of technologies associated with containerization, in which the United States led for many years. But, despite this, the economic health of all phases of the U.S. maritime industry is precarious to say the least, and even with federal subsidies it has been unable to hold its own in the percentage of U.S. foreign trade carried in American flagships.

The development of carriers of liquefied natural gas (LNG) is an example of an innovation that was pioneered in the United States, but in which other nations took the lead in adopting the technology. By contrast, the development of the bulbous bow, also an American idea, resulted in widespread and rapid adoption on U.S. slow-speed, deep-draft tankers; within one year after tests at the University of Michigan established that fuel could be potentially saved, nearly every tanker in the U.S. fleet had been scheduled for retrofitting with a bulbous bow. What is the explanation for this contrast? Answering this kind of question is one task of the MTRB committee.

There is, of course, a tremendous body of scholarly literature on the technological innovation process in general,[1] and part of the task of the MTRB committee is to relate this general literature to the specific situation of the U.S. maritime industry.

A second MTRB project is the study "Impact of Changing Maritime Services on Local Populations." This study may be thought of as presenting the converse side of technological change in the maritime industry: It deals with the secondary impacts of this technological change and the institutional mechanisms and processes available for mitigating them. 233

Cargo handling through trailer-on-flat-car (TOFC) and containerization-on-flat-car (COFC) railroad services, pipelines for bulk liquid transportation, and general containerization of cargo have had a profound influence on the character of port facilities and the location of ports.[2] For example, general cargo piers in downtown waterfront areas are obsolescent or obsolete, while the movement of industry to urban perimeters has created new demands for cargo handling in these areas. Environmental impacts and shifts of maritime employment have created serious political conflicts.

The MTRB committee is broadly concerned with the social and political process for adjusting to these changes, with special emphasis on the best modes of public participation. During the last seven years (since the passage of the National Environmental Policy Act) citizen groups have acquired considerably greater influence over developments through mandated hearing processes and through broadened access to judicial remedies against unwanted developments. Although there is a disparity in the resources available to citizen groups and proponents of development, this disparity tends to be partially offset by the large costs that delay can impose on the developer or the investor.

The question still arises, however, whether the costs of this adversary process are really necessary for effective citizen influence, or whether there are not better ways. A 1971 University of Michigan study[3] indicated that citizen advisory boards and informal contacts between local officials and citizens are much more effective than public hearings and other formal processes, since adjustments on both sides can be made before an issue becomes hopelessly polarized through overemphasis on adversary aspects. Costly delays and waste motions can be avoided if a best alternative can be selected by consensus before large intellectual or financial commitments have been made.

The committee has developed a set of eleven general principles for public participation, all aimed at ensuring the early consideration of alternatives by the broadest possible range of potentially affected interests. These principles include such ideas as agreement on decision criteria before specific alternatives are proposed, assignment of responsibility to a single lead agency for developing the hearing process, the development of understandable and enforceable time limits on agencies for commenting or acting on proposals, and efforts to identify all potentially affected interests or constituencies as early as possible, not relying exclusively on self-generated citizen initiative.

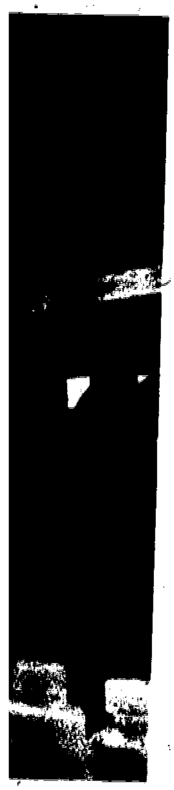
NATIONAL MATERIALS ADVISORY BOARD

The National Materials Advisory Board (NMAB) has been carrying on a number of studies related to possible future scarcities of critical materials and to possible contingency plans for substitution and conservation.[4] A good example is that of chromium, considered in a study completed in early 1978, *Contingency Plans for Chromium Utilization*. Chromium is an element that is relatively abundant and inexpensive and that has a wide variety of uses, ranging from steel alloying to drilling muds. However, despite large reserves, commercial ore deposits are concentrated in very few places (98 percent in Rhodesia and South Africa), and there is a danger that this supply may be cut off for political reasons. Recognizing this danger, the Energy Research and Development Administration (now absorbed into the Department of Energy), the U.S. Bureau of Mines, the National Aeronautics and Space Administration, and the Federal Preparedness Agency (of the General Services Administration) sponsored the study to identify alternative means of reducing U.S. chromium consumption so that plans might be formulated well in advance of any interruption of imports.

The committee looked at (1) possibilities for the substitution in present uses of materials containing little or no chromium, (2) possibilities of new or improved production processes that would reduce chromium requirements and facilitate chromium recovery by recycling, and (3) possibilities for component design changes that would minimize chromium requirements. The committee also considered the effectiveness of stockpiling and of research and development aimed at substitute materials and estimated how long it would take for these measures to affect chromium demand.

The committee concluded that there are no present or likely near-future substitutes for chromium in high-strength steels and high-temperature or corrosion-resistant alloys needed for jet engines, petrochemical and powerplant equipment, and several other critical products. On the other hand, chromium-free substitutes were possible for decorative stainless steels, automobile trim, flatware, refractories, and some chemicals. The overall conclusion was that by good planning and considerable effort chromium consumption in the United States can be reduced by one-third within five years without major economic dislocation, while with a strong R&D program an additional reduction by one-third could be achieved within fifteen years. Conventional stockpiling can provide short-term (five-year) protection against supply interruption.

In the longer term, continued use of chromium in easily collectible items such as hubcaps, flatware, and coins might actually be a cost-effective way of achieving a stockpile. In addition, exploration could possibly turn



up additional high-quality chromium ore deposits in less vulnerable parts of the world.

Because of the large reserves of chromium ores and the relatively low price, there are presently few economic incentives for private industry to develop long lead-time contingency technologies or substitutions, to search for new sources of ore, or even to update stockpiles. This is a common problem in the minerals field, one that becomes more serious as the claims of national sovereignties over mineral resources increasingly supersede classical relations of economic supply and demand.[5]

While industry and government in the Western industrialized countries tend to respond mainly to economics and to price signals, politics may prove to be the dominant controlling variable for future supplies. The problem is then how much and by what means governments can and should intervene in the free market to provide the necessary incentives for contingency actions, in order to reduce vulnerabilities to sudden shifts in the world political situation leading to discontinuities in the supply or price of essential raw materials.

During the past two years the level of political interest in this general problem has risen enormously, and much new legislation is under discussion.[6] Clearly, careful analysis and its wide dissemination will play an important part in stimulating the necessary investments and research; but it is doubtful whether better information and awareness by themselves, in combination with investor decisions, will be sufficient to ensure continuity of critical supplies.

The last several years have seen a rising legislative and judicial concern with industrial hazards and with health and safety in the workplace. Materials are implicated in most workplace hazards. One example is the toxicity of materials, such as beryllium oxide dust produced in grinding beryllium alloys, polychlorinated biphenyls (PCB's) in cutting oils and transformer dielectrics, and hydrogen cyanide produced in process heating of some nitrogen-containing polymers. Another instance is the injuries caused by the failure of materials in fracture. Hazards also arise as a result of interaction of materials with the environment as in corrosion or in the generation of explosions from dusts and gases. Still other hazards arise from improper disposal of industrial wastes.

Over the past fifteen years, the U.S. Coast Guard has supported studies by the NRC Committee on Hazardous Materials, which resulted in four volumes of reports covering explosive hazards of chemical vapors in relation to electrical equipment. These studies were suspended in 1975, and responsibility for the area has been assumed by the NMAB, which has set up a Committee on the Evaluation of Industrial Hazards, now supported by the Occupational Safety and Health Administration (OSHA).

Initially, this committee is expanding the earlier work on the classification of materials according to flammability and explosion hazard and is examining methods of classifying dusts as well as devising a new classification scheme for gases and vapors. The committee plans to expand its scope of interest, as support becomes available, to such areas as: (1) safety in extractive processes; (2) safety in conversion processes, including forming and shaping and the production of various intermediates; (3) safety in fabrication, including fire and explosion hazards and toxicity of ancillary agents such as cutting oils, grinding residues, and paint fumes; (4) safety in environmental protection, e.g., toxic wastes, scrap, and dusts; (5) safety in energy conversion, e.g., pipelines and distribution systems, power plants, and so on; and (6) safety in transportation systems where materials properties are primarily involved. The future of this activity will probably depend on the rate and manner in which the federal government organizes itself to implement the Occupational Health and Safety Act; at present the information gathering and research in this area are scheduled to be assumed in 1979 by the National Institute of Occupational Safety and Health (NIOSH). NIOSH will probably be more research oriented than OSHA, which is faced with urgent regulatory decisions based on whatever limited information now exists.

HAZARDS RESEARCH

The Committee on International Disaster Assistance completed its first year of work under contract to the U.S. Agency for International Development.[7] The resulting report primarily examined the U.S. government's foreign disaster assistance programs at the AID's Office of Foreign Disaster Assistance (AID/OFDA). Particular attention was given to problems of defining and measuring disaster-induced needs beyond the capabilities of developing societies and to which the United States and the broader international community can effectively respond. Contrary to popular stereotypes, these local unmet needs are not obvious; they vary by types of disaster, the vulnerabilities of populations and structures, and the local disaster preparedness and response capabilities. Drugs, blankets, food, protection against possible epidemics—in short, the kind of help usually associated with disasters—may not be germane to a particular situation. Even assuming that these needs can be accurately identified, the administration of international disaster assistance requires a clarification of the appropriate roles and relationships among the many public and private international donors who seek to provide such assistance.

While acknowledging considerable ignorance concerning the precise nature of the problems for which foreign disaster assistance should be provided, the committee was still able to recommend a series of policy and operational changes to the AID/OFDA. For example, the committee analyzed in detail the AID/OFDA disaster reporting and computerized data bank systems. It concluded that these systems cannot perform all of the multiple functions for which they were originally intended, but that, with some modifications, they will still be useful in improving the management of future U.S. disaster assistance programs. Specifically, these systems have limited potential for modeling the impacts of current or future disasters in various countries or for "automating" disaster responses; but they can still provide documentary information on the effects of past disasters and the U.S. responses to them. They also can be used to quickly provide foreign and international disaster officials and U.S. embassy and AID mission personnel with clear and current information on the kinds of goods and services that the United States is prepared to furnish (including a description of the design specifications and performance characteristics of materials).

On a broader level, the committee pointed out that although the largest number of U.S. disaster relief operations have been in response to disasters that occurred quickly—such as earthquakes, tropical cyclones, and river floods—the U.S. government has spent the largest amount of money on disasters due to civil conflict and "creeping" disasters, such as droughts and famines resulting from climatic fluctuations. For example, the Bangladesh civil war of 1972 and the 1972–75 drought in the Sahel alone accounted for thirty-four percent of all U.S. government expenditures for disaster relief from 1965 through 1976. Such disasters involve politically volatile situations; moreover, it is difficult to anticipate the kind and extent of help needed. Also, the usual administrative distinctions for sudden disasters made between relief, rehabilitation, and reconstruction break down for "conflict" and "creeping" disasters. The committee has recommended that the AID/OFDA planning be reexamined in the light of these problems. For example, organizational linkages should be strengthened or formed by AID with international "neutral" organizations that may be able to provide aid in a civil conflict in which direct U.S. aid is politically difficult. The committee also recommended stronger linkage between the AID/OFDA's disaster assistance program and the broader development program at AID. It pointed out that strengthening the organizational linkages between AID's disaster assistance and its general development programs, now administratively separate, would reflect the understanding needed of the relationships between disasters and development. Disasters may create conditions simplifying development efforts, perhaps by offering unique rebuilding or resettlement opportunities, as well as new sources of funds; while, on the other hand, hazard reduction efforts should be a normative part of development programs.

Finally, the committee noted the generally low level of disaster preparedness in potential recipient nations. In this connection, the committee recommended that the International Disaster Assistance Seminars held annually in Washington for a period of six weeks be continued with wider participation from developing countries and that expert consultations with disaster preparedness officials of potential recipient countries be offered on a much wider scale than at present.

Based on the first year's work, the committee recommended a concentrated study of the problem of damage and needs assessment. This recommendation has been incorporated in a second-year contract with AID, which will involve research on the techniques of hazard monitoring and postdisaster damage and needs assessment. The committee will review the uses, costs, benefits, and possible mixes of ground survey, aerial reconnaissance, and remote sensing assessment techniques in various natural disaster coordination requirements related to the integration and dissemination of assessment data generated by these technologies.

For many years, the NRC has created *ad hoc* teams of experts to visit the scenes of natural disasters immediately after they occurred to evaluate what lessons could be learned. This work is carried out under the general supervision of the Committee on Natural Disasters and is supported by the National Science Foundation. The most recent such report is being prepared in connection with the Big Thompson River flood of July 1976.

During the evening of July 31, 1976, an intense thunderstorm, due to an unusual concatenation of meteorological circumstances, stalled over a small area of Big Thompson Canyon in the Front Range of the Rockies in Colorado. More than ten inches of rainfall fell within less than three hours, and, because of the steep mountain topography, the runoff quickly concentrated and formed a virtual wall of water that displaced everything in its path—houses, trees, sediment, and large boulders. One hundred and forty-three people were dead or missing, and $41 million of property damage occurred within a small area.

Because no event of this character had been experienced in the one hundred plus years of records, it was erroneously supposed that such an event was impossible in the Front Range.* The valleys and mountain streams in the area had become prime residential and recreational areas, with little or no restriction on development.

Perhaps the most important lesson of this event is that conventional methods of floodplain analysis, used extensively for floodplain zoning in other areas in connection with flood insurance studies, are not applicable to mountain watersheds. A new model, which does simulate processes that can occur in regions like Big Thompson Canyon and which allows the prediction of the effects of various rainfall distributions, needs to be developed. Geological hazard analysis outside the immediate floodplain area is also necessary. For example, in the Big Thompson River flood, slope failures and earth movements outside the immediate flooded areas were still continuing more than a year after the flood.

Of course, the analysis of such events raises difficult philosophical issues regarding protection against very rare natural events. For instance, local residents resented restrictions on the use of their property due to efforts

*In retrospect, some attention might have been paid to the fact that a similar disaster did occur in 1972 at Rapid City, South Dakota. Like the Big Thompson River flood, the Rapid City flood occurred because a torrential downpour stalled over a small, canyon-filled mountain area. The two disasters differed in that in the Big Thompson case the damage was almost totally confined to the canyon area, whereas in the Rapid City case most of the damage occurred in the city, located on the floodplain at the mouth of the canyon. In addition, the failure of the Canyon Lake Dam in the Rapid City flood was certainly a contributing factor to the size of the flood crest: 50,600 cubic feet per second versus 31,200 cubic feet per second for the Big Thompson flood. The comparative magnitudes of the disasters are told in the amounts of damage and the number of lives lost: $100 million and 231 deaths for Rapid City versus $41 million and 143 fatalities for Big Thompson.

to mitigate the consequences of events having a predicted recurrence interval of 300 to 1,000 years.[8]

ADVISORY BOARD ON MILITARY PERSONNEL SUPPLIES

Expectations regarding the future of the enzymatic conversion of cellulose waste to useful products, including glucose and ethanol, were extensively reviewed at a Symposium on Enzymatic Conversion of Cellulosic Material sponsored by the Advisory Board on Military Personnel Supplies (ABMPS) and the U.S. Army Natick Research and Development Command (NARADCOM) in September 1975.[9] At that time the economic promise of the process did not seem very great. However, substantial progress has been made as a result of recommendations emerging from that symposium. Enzyme productivity has been increased fivefold. The milling time required to bring cellulosic materials to a given state of susceptibility to enzymatic hydrolysis has been reduced from twenty-four hours to six minutes.

For more than a year and a half, the Gulf Oil Chemicals Company has been operating a pilot plant for treating waste pulp from paper mills with enzymes produced by NARADCOM's *Trichoderma viride* bacteria to make glucose. Glucose is then acted upon by other enzymes, produced by a yeast, to convert it to ethanol from which can be made a variety of basic building blocks for a petrochemical industry. Gulf is now designing a commercial-scale plant capable of producing 2 million gallons of ethanol a year. Whether and when such a plant will be economically competitive with chemical plants using petroleum as a raw material base will depend, of course, on future trends in the price of petroleum and natural gas, as well as further development and practical experience with the process.

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Thinking About Public Facility Systems

W. L. GARRISON

Public facility systems—such as the postal service, public school systems, public transportation systems, and electric and gas utilities—are monopolies by virtue of their public franchises: Their markets are administered by the political system rather than by market forces. The goods and services they provide are highly valued; their disruption is not tolerated; and their clients claim equal rights to service. Such public facility systems form spatially linked networks, and network interdependencies are strong.

Each system has its own history, but all systems were brought into the political arena as interest groups claimed rights to services. Some mainly represent a claim by the public for benefits, previously obtained by privileged minorities—public schools, for example. In other instances, such as public mass transit, failure of private firms occasioned government intervention. Exercise of political power by special beneficiaries and the promotion of social needs by professional groups also affected the formation of systems. Politicians used claims to rights by interest groups as a basis for political power and action. While not all demands for services by interest

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groups resulted in the creation of public facility systems, all public facility systems were created in response to such demands.

Facility systems must respond to the manner in which those rights are viewed by the public, and debated and treated in the political process. The right of access to the transportation system was well established in medieval Europe; that right continues to be expressed in regard to the public road system and common carriers. The right to community health, first recognized in this country around 1900, accelerated the deployment of water and sewage facilities; the "right to health," expressed as the right to medical services, is currently a matter of widespread debate. The rights to services from electric and telephone utilities, in parallel with monopoly and efficiency issues, made strong imprints on those systems earlier in this century, and such rights continue to be debated.

A grasp of the scope and character of facility systems is often missing in current debates. Creative suggestions for system revisions or new systems seem to be no one's responsibility, and are too often missing in current debates. The objective of this essay is to broaden the debates. It explores how the common features of public facility systems affect their deployment and operations, and presents information in a form useful to those striving for system improvements. Although suggestions for systems change may be inferred from the discussion, the essay stops short of recommendations, for change is a matter of public debate and choice.

CHARACTERISTICS

Public facility sytems, like other systems, draw from supporting activities and serve markets. But, unlike other systems where the economic marketplace focuses control, control of facilities is dispersed. The control characteristics of the systems will be examined first. Facility systems are mandated to provide their goods and services at administered prices, and the manner in which markets are served under those requirements will be the second matter for discussion. An examination of some organizational features of the systems will close the discussion.

Control

The question of control of public facility systems is compounded by (1) the interfaces of the systems with governments and other organizations that exert control, (2) the disjointed internal structures of the systems, and (3) product standardization.

Taking the more straightforward matter of government interaction with systems first, there are three major decision nexuses operating within government layers. One provides day-to-day and month-to-month control by facility administrators. Secondly, the facility administrators, in turn, operate according to rules established by regulatory (e.g., Federal Power Commission and Interstate Commerce Commission), standard-setting, and sometimes funding agencies (e.g., Environmental Protection Agency, state and federal education agencies, Federal Highway Administration, Federal Railway Administration). The regulatory and standard-setting agencies, in their turn, respond to the third decision nexus, the legislative process.

Major changes in public facilities usually bring in the political process. Changes in circumstance or public expectations may spur debate about a public facility; boards or commissions are established, studies made, legislative revisions proposed, and action taken. Once action is taken, there is a tendency to shield the day-to-day operations of the facility from the political process. Institutions such as boards of education, highway commissions, or public utility commissions serve as a surrogate for the political process on dealing with small matters affecting the operations of facilities. But when major issues arise, they are again debated through the political process and resolved through institutional revision.

A debate about transportation may, for example, result in restructuring state highway commissions and giving them new authority and responsibility. The Railroad Revitalization and Regulatory Reform Act (the Quad-R Act) recently attempted to revise the authority and responsibility of the Interstate Commerce Commission with respect to the railroads. Or, to cite another instance, an activity reinvented every decade or so under one title or another is again at work under the name of National Transportation Policy Commission.

There is always a low level of pubic debate about facility control. In the main, it emerges as statements of frustration about fragmented responsibility, facility managers' lack of responsiveness and authority, and uneven performance. The cost of control, usually expressed as cost of regulation, and the uneven outcomes associated with regulations are not a matter of much public debate, although regulatory reform growing out of efficiency arguments is much pressed by economists.

The manager may have to deal with three layers of government—in the case of utilities, for example, city agencies, state utility commissions, and the Federal Power Commission. This further complicates and fragments control, since governments at different levels have differing interests and authority, and there is always a potential for mismatch between problems and effective remedial actions. A local problem may require federal action or a national problem may require local action. Such mismatches between the levels at which problems are sensed and appropriate levels for problem management create difficulties for system managers. Examples may be useful. There is a national need to reduce petroleum imports for reasons ranging from balance of trade to defense issues. The 55-mph speed limit has been imposed as a petroleum conservation measure. Yet the matter of appropriate speed limits for highways is highly dependent on geography, and highway facility managers, especially in the western states, often do not find this limit suited to their particular circumstances. The attempts to reduce noise near airports is an example of a local problem requiring national action, while school integration matters mix local and national goals and solutions. Invariably, the system manager is caught in the tension formed by the mismatch of the problems and available remedies, and often must administer federal solutions not necessarily suited to local needs. Such mismatches seem to increasingly fall on local system managers as solutions for many problems escalate to the federal level.

The internal structures of systems are affected by the multiplicity of controls on system components. While these components are all intended to contribute to a common goal, the reality is that they are subject to independent controls and hence may vary greatly in their performance within a system.

The highway system illustrates the problem. Guideways form one component of the system; vehicles, a second component. The guideways are provided by state, local, and federal agencies using civil engineering technologies. Guideway providers respond to rules ranging from those imposed on subdivision development to bridge clearance requirements on the Corps of Engineers, and they respond to interests ranging from the broad social requirement for road facilities to the desire of the construction industry for suitably timed and sized construction contracts. But vehicles are produced by private manufacturers, using mechanical engineering technologies and responding to market forces. Also, buyer preferences and government rules on vehicle safety, fuel efficiency, and emissions affect the type of vehicles and engines manufactured. But rules for vehicle operations stem mainly from traffic engineering. These rules involve traffic laws and licensing of vehicles and drivers, and are affected by safety organizations, other private groups, and government agencies.

The point is that there is no facility manager, that no one is in overall charge of society's goal of access to transportation. There are efforts to provide focused management, but the various components, such as vehicles and guideways, still operate by their own rules.

This property of disjointedness of components is readily generalized, although the pattern differs from facility to facility. Sanitary and water systems are provided locally and managed locally by fixed facility managers. System transactions are affected by users. Water purity and effluent standards are set nationally. Component independence is weaker in private facilities, but it remains. Equipment, right-of-way, and operations protocols of railroads, for example, follow different rules. Labor makes its claims component by component. Capital for equipment, obtained through equipment mortgages, is one thing; capital for improvements of right-of-way, if available at all, is another. And all railroads operate under common carrier rules enforced by the ICC.

Component disjointedness is a consequence of fragmented control and the tendencies for different interests—labor, managers, regulators—to make different and independent claims on system components. Managers generally have limited control over system transactions, that is, in rationing system access and use.

Because of component disjointedness, system change follows a pattern of component adjustments: component managers adjust their component to other components. Railroad guideway managers are searching for ways to adjust their facilities to heavier railroad cars and locomotives. Highway facility managers supply facilities to meet needs expressed by the number and kinds of vehicles and traffic rules.

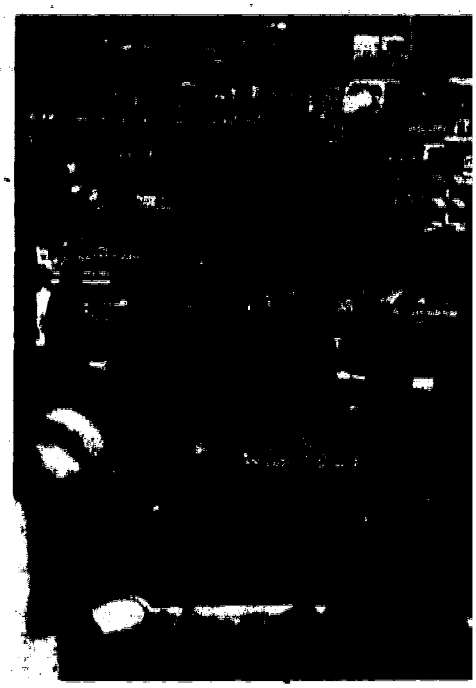
The division of facilities into disjointed components affects the flow of technology to the systems. System technologies are on no one's agenda; rather, component technologies are devised for and supplied to component markets, accompanied by a strong urge toward component standardization. But before discussing technologies and their standardization, the capital intensiveness of the systems should be noted.

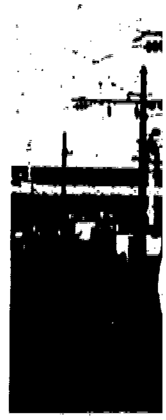
There are several reasons why public facility systems are biased toward capital intensiveness. Rate making for utilities based on return to capital is one. Another is the shelter of regulation or monopoly markets, or both, under which a number of the facilities operate. For instance, bankruptcy is not at issue (some railroads excepted), and the cost of capital does not entail bankruptcy risk or less traumatic market tests. Consequently, capital is relatively cheap. Finally, those facilities that are entirely within the public sector reflect legislative and voter biases toward expenditures of capital.

The type of technology that is available is a function of the bias toward capital intensiveness and the division of facility systems into components. Specifically, technology tends to be provided in a form suited to the nature of component supply streams, which may or may not fit the overall needs of the facility system. There are vigorous supply streams for larger pipes and pumps for sewage systems, deeper and stronger pavements for freeways, larger-capacity generating and transmission facilities for electrical facilities, and larger aircraft and electronic aids to learning suitable for use in large schools. Technology flows are not nearly so vigorous in the operating rules components of the system, which involve the soft technologies of management.

There is also great pressure for standardization of technology. It is in the interest of suppliers to produce many copies of a given product. Efforts by standard-setting and control agencies to assure that everyone has equal access to a facilities system are also a force for standardization. It is easy to see why not too many decades ago schoolbooks used in state-supported school systems were chosen by state legislatures. This both assured the legislatures that the quality of education was uniform and served the interests of the larger textbook companies. Today, this adoption process is mainly in the hands of state or local school boards, and therefore is shielded from day-to-day politics.

The need for articulation among systems is another force for technological standardization. A fifth-grade graduate in one school district is, in principle, expected to be ready for the sixth grade in *any* school district. Freight cars and, increasingly, locomotives must be able to operate anywhere, complicating changes in braking systems or track gauges. Terminal switching and transmission requirements impose similar constraints on communications and electrical facilities. This need for standardization and commonality is reinforced by the interests of





equipment suppliers, who, as mentioned, naturally desire aggregated, standard markets. Governments, bound by purchasing rules and seeking lower prices for their purchases, also contribute to standardization.

One result of standardization is that there is little market segmentation. The goods or services of particular public facility systems are the same everywhere, and may roughly fit every need but few perfectly. Standardization also is a brake on technological change. Any new technology has to meet systemwide standards (which means that the technology may not be so new after all) or obtain a revision in standards. Because so many actors are involved, obtaining a revision in standards is very demanding of resources, generally available only to large suppliers.

Serving Markets

As noted in the introduction, markets for public facility systems are formed broadly by claims of rights to goods and services. These claims are expressed as a right of access to goods and services at particular times and places with highly varied costs. How are these claims served?

The answer depends largely on population distribution and political geography. All parts of the country are represented politically, and therefore are able to claim access to goods and services. But while the claims are universal, the costs of supplying them tend to vary, resulting in many cases in cross-subsidies from one part of the facility system to another. For many facility systems, it is less costly to provide the goods or services in a dense market than in a sparse market. So the pattern of subsidy in these cases has been from cities to rural areas; and in transportation, water supply, telephone, postal service, and sewage systems, from heavily to lightly used routes.

These cross-subsidies have had enormous impacts on patterns of national development. Cross-subsidy has provided universal access to public facilities, regardless of the cost of providing the good or service. The ready availability of the telephone, sewage and water systems, and transportation has surely supported the explosion of the suburbs. It surely has supported the viability of small towns vis-à-vis major metropolitan areas.

These cross-subsidies are large. For example, approximately one-half of all telephone systems' income comes from charges for long distance calls. This income subsidizes other telephone operations, particularly those of companies serving relatively sparse markets. Gasoline taxes collected in the larger cities subsidize the provision of rural roads, and a water utility uses the same price schedule in the suburbs as in the inner city, which is less expensive to serve.

Service is not only a right with respect to space, but also with respect to time. The result is that facilities are geared to the highest level of demand, and costs to users, whether in taxes or in user charges, do not reflect the cost of service at a particular time. Electrical networks must continue to function in spite of the millions of turkeys being cooked in electric ovens on Christmas Eve; highway systems are not supposed to overload; Friday afternoon air travelers expect space to be available at the usual price; and there is an effort to make it possible for everyone to telephone home on New Year's Day. Every user has rights, and these rights are to be met regardless of when they are demanded.

Temporal service costs and prices are debated by economists, whose central concern is that the marginal user pay marginal costs. Economists suggest that capacity would be better allocated if the marginal cost of capacity was charged to the user during congested periods. But this is not, by and large, a matter of debate by the general public, and temporal pricing does not appear as an imperative on any politician's agenda. From the point of view of the system user, there is a very simple reason for this. Over and above the claim that the service is a right, the user is not just a person who makes a claim for service at a particular time; rather he makes continuous demands on public facility systems. He may heat his water night and day, or drive during congested and noncongested periods. There is in general no division of users into those who are responsible for unusual costs and those who are not. But if the division existed and had a base in political geography, it might provide a power base for political action.

Claims to rights are put forward by interest groups, by individuals, or by institutions acting for interest groups. One class of claims has deprivation as its base; for example, that the elderly are deprived of transportation and that the poor have the right to telephone service. Exceptional children are held to form a group with a claim to special rights to education.

Claims are formed in another way. The products of public facility systems are valued more highly by some groups than by others, and a group that values the product of a facility system is naturally quicker to claim that right than are groups that place less value on the product. So, industry and commerce have demanded that the public school system train students in business arithmetic, professional groups press the universities to provide professional training, and the (sometime) users of railroads are vocal on matter of railroad branch-line abandonment.

Rights are thus expressed at the extremes; deprived groups or their representatives are quick to argue for their rights, as are groups that are advantaged. Sophisticated groups argue for representation on control mechanisms. A government regulatory agency typically contains members representing both geographical regions and special interests.

Bargaining over rights has occasionally led to political action and major revisions of public facility systems. An examination of the preamble to the 1916 highway legislation, which brought the federal government into the highway business, reveals that the act was a response to the demands for mobility rights of rural dwellers. The Rural Electrification Administration was created to provide electric energy to spatially disadvantaged consumers, and public utility commissions are currently being pressed to provide low rates for the elderly and economically disadvantaged. This pattern of claims to rights and bargaining about rights is thus one force for change in public facilities systems. The pattern is also a strong brake on change, for it is difficult to deprive any group of an existing right.

With minor exceptions, goods and services have flat price levels regardless of space and time, although they may vary from one facility to another, as do state gas taxes and electric rates. For some facilities, the sum of charges is required to equal the sum of costs. For others, such as the public school system, no prices are charged. Public resource allocation would, in theory, judge the relative worth of each activity and the sources available; trade-off decisions would then be made about how much to spend for schools, postal service, water, and so on. But, in reality, the pattern is that of a hodgepodge of subsidy arrangements depending on utilitarian designs, political judgments of what is equitable, political strength of constituent groups, and historical circumstances.

The subsidy allocation process seems to have a strong streak of practicality. Boundaries are drawn around systems. If administered prices raise sufficient funds to cover cost, no direct subsidy is required. If the price charged does not raise enough money to cover cost, then the subsidy comes from somewhere else. At the federal level, constituent groups bargain and receive subsidies, almost as if the public purse were bottomless.

Decision making about subsidy at the local level seems to have more of a trade-off flavor, with citizens more directly involved by voting tax assessments for school and water districts, garbage pickup service, and the like. But, even here, fragmented control sharply limits local decision making. Federally mandated programs, such as sewage treatment, require that construction and operating funds be raised locally to match federal expenditures. Such local funds have differing purchasing powers, depending upon matching formulas.

There is an important direct subsidy to all public facilities in the fact that they are assured of continuity and longevity and that the system of administered prices provides some fiscal stability. Capital is therefore available to them at lower interest rates than is the case for riskier private activities. One result is a tendency for these activities to be capital intensive, a matter discussed previously.

It was also mentioned that the cost of serving a dense market tends to be less than that of serving sparse markets. System managers see little that they can do to reduce their losses in sparse markets. There are political restraints on price increases. Requirements for product and technology standardization are also restraining.

Exploitation of economies of density in dense markets is, however, a highly attractive option for management and technology. Telephone, electrical, and transportation routes can be used more intensively with reduced unit cost; sewer and water lines can be made larger; aircraft of increased size could be highly profitable when deployed on heavily traveled routes. There is a vigorous search for technologies that capture economies of density, reinforced by the relatively low cost of capital. The recent effort to create bulk mail processing centers is an effort to develop and deploy such technology. Economies of density, however, may be only partially achieved or entirely blocked by the tendency of systems to develop component independence and standardization.

For some services, such as public schools, welfare agencies, and health services, economies may be achieved by increased specialization, which improves the product rather than decreasing costs; for example, one could imagine a large school using different approaches to teaching science suited to different student abilities. However, this type of economy tends to be thwarted by product standardization; that is, only a few kinds of science classes are allowed. Private health service activities do achieve these economies of specialization. However, specification of standardized services by Medicare and other programs may limit such economies in the future.

Sometimes economies of density are partial to a component of a system. The cost of providing pavement and structures for a mile of travel on an urban freeway or arterial road is much less than it is on a lightly traveled route. But the total cost of highway transportation, including costs to users and nonusers, is not markedly different in dense or sparse situations. It may even be less on lightly traveled routes lacking pollution and congestion costs.

While railroads achieve some economies on their dense traffic routes, the standardization of operational protocols, guideways, and equipment limits these economies and blocks the deployment of technologies appropriate to dense traffic.

Some facility systems are fragmented by government boundaries. Other systems are divided because of entrepreneurial activities of many years ago; railroads and telephone companies are examples. These boundaries were not drawn to provide rational service, and the fiscal strengths of the parts of systems differ greatly. Some counties struggle mightily to meet their needs for roads from gasoline tax income; others have an easier time of it. Some railroads are healthy and others poor, largely because of route structure.

There have been varied efforts to circumvent facility systems boundaries or eliminate them. Boundaries have been jumped in highway financing, where the criteria for fund transfers reflect the cost of providing service. There is now an effort to develop mechanisms to increase district-to-district cross-subsidization in the funding of education. One dream of those who discuss railroad mergers is to link strong firms with weak ones. Not unexpectedly, however, the merger pattern has been that of strong railroads merging with strong, followed by weak railroads merging with weak in a futile effort to survive.

Individual and Facility Roles

The organizations that provide and operate public facilities and the roles of individuals within such organizations reflect the characteristics of the facility systems, the goods and services they provide, and the constraints within which they operate. They also reflect historical circumstances. Those created early, such as railroad, water supply, and sewage facilities, have a paramilitary character. The bureaucratic precedent for the railroads was the military establishment; the Public Health Service is also paramilitary in character. The division between line and staff roles within these and other facilities is sharp, as are the geographic divisions.

In light of the systems' role as a provider for the general welfare, the performance measures used by the facilities seem, at first glance, rather strange. There is a tendency to describe performance in terms of the size of the facility managed: The school superintendent discusses the number of teachers hired, the number of pupils in the district, and the value of the physical plant; the county highway engineer describes contracts let and the number of miles of road maintained; and the electric utility manager refers to kilowatt-hours produced and sold. Status among organizations is based on such measurements of size. Performance effectiveness is measured by comparing cost to the number of units managed or processed; for example, cost per kilowatt-hour, cost per student, or cost per mile of road. Other measures that are sometimes used include accident rate and the percentage of on-time arrivals (for air operations) or departures (for railroad freight trains).

Thus, performance is discussed in terms of outputs and inputs rather than in terms of benefits to the general welfare. The reasons are clear. For instance, the claims made on facilities take many forms. Managers are expected to provide jobs, support economic development, and provide markets for equipment manufacturers and construction contractors. So when managers describe their outputs, the important issue is apparently one of how the pie is sliced.

Advancing the general welfare is also not on a manager's agenda. Systems are rarely managed and thought of as systems; many are instead in the hands of component managers, and component (or quasi-systems) managers have little or nothing to do with the shaping of grand societal goals. The sewage system manager's aims are framed in terms of his physical facility; the health of the public is a much larger matter, and broad goals and programs are a matter for political processes. Often the manager is a professional who advanced through a particular facility, and the traditions of a facility profession may not be articulated in terms of social goals. Moreover, the entrepreneurial opportunities left to the manager are severely constrained by regulations, standards, and so on, thus leaving cost-cutting as the only outlet for his managerial skills. Preoccupation with cost-cutting in high-level management of public facility systems is unlike that of most large private enterprises where cost management is at profit center levels. Another management preoccupation is that of trying to increase or maintain the size of the organization. One can readily understand why highway organizations want to build more highways and electric utilities want to increase generating capacity, for, within their ground rules, increased size means increased importance.

Facility organizations are bimonopolies and, to some extent, trimonopolies. They are bimonopolies in the sense that there is a facility monopoly and a professional and labor monopoly that operates the facility. The strength of labor in these facilities is, of course, tied to the public view of the necessity for facility goods or services. The systems also have a "full employment" function, and the reduction of their labor forces raises political concerns. Highways, schools, sewage systems, and certain other systems or system components are associated with the professions. All are steered in part by professional practices, while the impact of business or industry practices is less strong. In those facilities where the professions are not strong, especially railroads and the postal service, management comes through the ranks and is professionalized in the trade. Because of their strong ties to professional groups, the work to be done within facility systems, often limited to one component of a system, affects the self-image, structure, and outlook of the professions.

Facilities are trimonopolies to the extent that suppliers of equipment and construction organizations (shippers, in the case of railroads) have varying degrees of monopoly power.

That organizations, individuals, and the professions associated with them have narrow views of their roles and behave accordingly is not a new issue. Disenchantment with highway department bureaucracies and telephone and electric utilities is much discussed, and other facilities organizations have been the targets of similar discussions in the past. The bimonopoly character of the systems, especially the tendency of management to accede to any labor or professional group demand and pass the cost on to the public, is currently a matter of some rather unfocused debate about transit systems.

PROGNOSIS

The discussion so far has treated some of the characteristics of public facility systems that may be useful in explaining how they work. To gain insight into the future of such systems, this section will interpret some of the forces working on the systems. The dynamic course of systems, the institutions and technologies upon which the systems are based, and the interplay of the systems with their markets will be discussed.

Growth Dynamics

The nation is served by networks of transportation routes, schools, electrical production and distribution systems, and so on. The systems are in place, and for this reason their users are in a rather different situation than those who witnessed their birth and growth.

At the time the systems were spreading to markets, the values of the systems to users increased from year to year. The issue of whether to participate in a system evolved as the system grew. The decisions were also private and individual or collective, depending upon the system. To purchase a telephone, to buy an automobile, or to have a house wired and connected for electricity were private decisions about access to systems. Decisions about water and sewage systems were collective decisions by relatively small groups of people. Participation in the education system was collective or individual, depending upon the level. To send children to schools was a collective decision mandated by society; while higher education was and still is a matter of individual choice. In pondering the private or collective decision, choice turned on the cost of participation versus the gains from participation, and the dynamics of systems were such that the more who joined, the less cost to the individual and the greater his gain. Systems improved by growing.

The automobile and the telephone were the rich man's toys in the early development of those systems; purchasers' costly private decisions gave access to services that were quite limited. One could buy an expensive automobile, but not have many paved roads to drive it on; one could pay the cost of a telephone, but not be able to call many persons. The built-in dynamic was the more that joined, the greater the advantage of joining. The dynamics of course differed from system to system. In the case of the telephone, as the system expanded and as more and more people were tied into its lines, the greater the advantage of making the private decision to have telephone service. The gasoline tax mechanism closed the dynamic loop for automobiles—the greater the number of automobiles and the more miles traveled, the more paved roads were built and the more desirable owning an automobile became. Expansion of electrical service increased the reliability of the service and provided for economies of scale both in distribution and production, which fed back to lower rates and increased the advantage of joining. Also, the more who were educated, the more important an education became to get a job and to other activities.

Now that the nation is served by transportation routes, telephone links, school systems, and similar facilities, the growth dynamics of the systems have largely run their course. Most of the nation's roads are already paved, so no dramatic increase in accessibility to new areas is likely. Not everyone is served by sewage and water systems, but further expansion of service from those systems will be achieved only at very high costs.

But to say that the dynamic era of growth is over is not to say that there is no growth potential left for the systems. Higher incomes and population increases continue to affect the systems, as do changes in social and economic oranization. Furthermore, if the systems increase productivity, this may lower their relative cost and influence private decisions about participation.

The systems perform functions. Might new systems with new growth dynamics be deployed to better serve those functions? Transportation offers a historical example of different mixes of systems at different times—once there were only sailing vessels and horse-drawn carriages; later came the railroads; and today a mix of transportation systems serve the public. Other systems have also changed.

The question of new systems or of major changes in the operation of existing systems is a large and difficult one. As far as public policy is concerned, it is not a matter that is ordinarily debated, perhaps due to the failure of the imagination of interested publics and the desire for the stability of mature systems. But there is some movement. Today there is a debate on alternative technology systems for the collection and transformation of energy and on new urban transportation systems, particularly urban people movers. Also, technological development is forcing system changes, with, for example, communications technology affecting the evolution of several systems.

Broadly speaking, facilities make resources available for society's use. Transportation changes the spatial restrictions on the distribution of resources; education is investment in human resources; the sewage system increases society's resources of clean water. Those who reflect or shape social ideas talk of resource limits. To what extent do these limits reflect what public facility systems can reasonably do for society? Might new public facility systems broaden the resource base for society? The question isn't asked often, for those involved with facility systems are mostly preoccupied with problems of existing system components.

The futures of existing systems will not be simply extensions of their past; the feedback loops that have improved performance year by year are no longer so strong. This suggests that system users accustomed to annual improvements may see their expectations unfulfilled. To the extent that those improvements have been a result of growth feedbacks, they are complete and expectations will not be met.

Technologies and Institutions

Turning now to questions of technological and institutional change, it is useful to adopt a perspective of duality between the organizations themselves and the technologies they use. In that light, the organizations that provide public facility goods and services are mechanisms to create and operate technologies of education, transportation, water supply, and so on. Therefore, the litany of problems identified for systems may be viewed as a list of technological problems or institutional problems, or, more usefully, of both.

The usefulness of this perspective can be illustrated with a problem mentioned earlier: the high cost of providing service in sparse or lightly populated markets. The technological view says that the problem is inherent in the technology that achieves lower cost where dense service is provided. Related problems such as the use of cross-subsidies and service and price regulation are often seen as institutional problems of one sort or another and correctable by institutional change. A fuller view might be that the problems derive from the failure to actively pursue technological and related institutional modes that lower cost in sparse markets. For example, service and price regulation of railroads, which, among other things, provides subsidy from dense to sparse markets, is seen as an institutional failure, and revisions in regulation are urged. The idea that, rather than seeking new regulations, the same set of problems might better be approached by seeking technologies and institutional change appropriate to sparse markets is simply overlooked.

The point is that we should approach facilities problems in terms of both technology and institutions. To lower costs on branch lines, the railroads need light-weight, low-horsepower locomotives *and* suitable labor agreements *and* appropriate management *and* appropriate guideway maintenance technology. The compartmentalization of professionals into groups that see either technological *or* institutional problems and solutions is most unfortunate.

The duality plagues another problem already referred to: that many public facilities operate within rather inflexible, historically determined geographic boundaries. County public works departments, school districts, and railroads face problems due to haphazardly drawn boundaries. Some school districts are wealthy; others are poor. Some county highway departments are required to build many expensive bridges; others are not.

A series of institutional arrangements has been developed to overcome boundary problems. As mentioned, in public sector institutions, this generally involves cross-subsidy from one jurisdiction to another using funding formulas. Facilities that are largely private have worked out a variety of arrangements for interrelations across boundaries.

Another view of the boundary matter is a technological one: There is a mismatch between technologies and the geographically bounded institutions created to operate the technologies. The large public university, for example, operates an educational technology drawing on a worldwide fund of knowledge and seeks students from around the globe who would best benefit from its resources. So there is a continuing tension between the best use of the university's technology and the state government's understanding of its mission. Railroads laid out to operate steam trains now use diesels that can operate long distances, but institutional boundaries block interchange. Arizona finds itself building an expensive bridge on an interstate highway to serve as a link through Nevada and Utah, one that only barely penetrates Arizona. The cure for such problems is to change the geographic span of institutions so that they better coordinate their technologies or to develop technologies matched to markets, or both. The importance of matching technology to markets goes beyond geography, of course, for markets are composed of organizations and individuals with differing needs.

Turning now to the question of both institutional and technological change, three scales of change may be identified.

1. Component change—a change in one of the components of a facility: the rules under which it operates, the fixed facilities it uses, or its equipment. In transportation, for instance, speed limits might be changed (operational component), or there might be a change in the vehicles using the facility and what they carry.

2. Articulation change—changes in the arrangements that tie facilities together across boundaries. Interties for water or electrical distribution systems and intermodality efforts in transportation are examples.

3. System change—the orchestrated change of all the components of a system or the putting together of components to form a new system. An example here is computer conferencing. Computers and programs, communications links, and management together permit a new form of information exchange and decision making.

The nature of systems facilities is such that component changes are relatively easy, articulation changes come hard but do occur, and system changes are few and far between. Changes in components are common because of the manner in which the facilities are organized, the character of their technology supply streams, and the array of supportive and controlling institutions that tend to ally themselves with components of the systems. Fixed physical facilities, for example, are mainly provided by persons using construction institutions and technologies; equipment is provided by another constellation of actors; and still another group is involved in management and protocol matters. As pointed out before, this organization around components is the source of the disjointed incrementalism that characterizes the systems.

Where articulation is required, change comes much more slowly, for consensus is required. Achieving an articulation change depends upon the distribution of the gains from that change and the way in which power is distributed among facility operators. Change can be slow and easily threatened by nonparticipatory veto, as indicated by the adoption of methods for the identification of rail cars.

The heavy demands for articulated change reinforce the disjointedness of components of systems as managers are drawn into negotiations with their component counterparts. State highway officials meet with each other and federal and local highway officials. They work with organizations such as the American Association of State Highway and Transportation

Officials. They attempt to gain information and solve problems at these various levels rather than by meeting with equipment manufacturers and persons in organizations that train and license motor vehicle operators.

Given system disjointedness and the preoccupation of management with articulation, it is not surprising that system change is rare and seldom imagined. Neither new systems nor revisions of old systems is on many people's agendas.

This is not to say that system change does not and cannot occur. System-changing technologies can find footholds in existing component markets and force major adaptive changes in other components. The use of the diesel engine by railroads is one example; computer-aided instruction in the schools may prove to be another. The development of the interstate highway was a sufficient technological (and institutional) change in one component of the highway–vehicle–protocol triad to induce systemwide change. Technological change in electrical distribution or creation of small-scale energy systems may change electrical systems. So system change is always a possibility, even if system managers do not seek it.

System changes, particularly those based on technological changes, are rarely considered in public debates. When considering change, policy and public works planners project demands and ask whether existing systems can produce the quantities that will be needed in the future. Can the capacity be provided to generate projected needs for electricity? Conflicting needs then confront each other in the political marketplace, as they are doing today. While the planner may deal with institutional change needed to answer needs, typically little or no attention is given to the necessary technological change. The alternative of meeting projected needs by doing something new with radically altered old systems or entirely new systems is rarely considered. Public planning that embraces technological change is much needed.

Markets 263

The market for public facilities is formalized in three ways: as a broad contract for rights of access to service, as contracts with special interest groups for outputs in the form of jobs and markets for equipment, and as contracts for service between a facility and individual customers at particular times and places. Nationally, market negotiations are fixed in part by the state-based senatorial system, but the congressional side is fluid among states and within states depending upon population distribution. Similar considerations hold within states and within smaller political jurisdictions. While one might think that continuing changes in population distribution would affect the geographical market bargains struck years ago, this hardly seems the case. Many features of the systems, such as cross-subsidy from dense to sparse markets, were built-in when the sparse markets (rural markets) were politically stronger than today; yet these features have been preserved.

Perhaps market change is not so much reflected in the statistics of population redistribution as by the geographical sorting of groups with differing social and income characteristics. For example, the concentration of the poor in the inner city gives them market strength through political representation. In this view, there is a continuing force for change as the systems respond to the requirements of particular interest groups. To the extent that today's movement to the so-called sunbelt and away from the major metropolitan areas continues the redistribution of interest groups, there is a future for public facilities that goes beyond simply their response to the size of their markets.

Another market issue is that of the public's confidence in its public facilities. The issue is complex, because contracts between the people and their public facilities are not simple ones. Any contract is partly written, and thus comparatively straightforward, and partly a matter of trust. And the contract between the public and its facilities does seem to involve a large element of trust—trust that the systems are deployed in the interest of beneficial outcomes and trust that the pricing and the quality of systems goods and services are somehow right. A puzzle for the future is that of the stability of the facilities' contracts with their publics. This is a future where contracts may be made in an increasingly litigious society, a future where development dynamics for systems have run their course, a future in which interest groups will continue to attempt to modify contracts as their basis of political power shifts and changes, and a future in which no one is charged with thinking about how systems are created for social purposes, are co-opted by interest groups within and without those systems, and perform and change.

The current debate about natural gas supplies and prices is illustrative. Many seem to feel that the public's contract for access to inexpensive natural gas has been violated. Trust in the facility system has been weakened. Solutions are demanded that solve the problem of increasing resource costs without violation of the contract. The rationality and logic of public facilities collide with that of resource depletion.

Finally, the gaps between prices charged and the costs of providing services in dense markets are widening as technologies are deployed to achieve economies of density. There is clamor for a reduction in prices (or deregulation) by interest groups served in dense markets; facility actors themselves may attempt to exploit those markets, especially in cases where there is some competition, such as airline service on dense routes. Sometimes new actors attempt to serve those more profitable segments of the market—independent parcel and letter services, long-line communications outside the Bell system, charter aircraft, and slurry pipelines in dense coal-hauling corridors. Such actors receive political support, for they appear to make some people better off without damaging others. Yet such developments threaten facility systems by threatening the complex web of subsidies from profitable to nonprofitable markets created in response to demands for access to goods and services in all markets.* So another puzzle for the future is the facilities' ability to achieve efficiencies and pass savings to users while providing more or less equal access to goods or services regardless of the place or time where goods or services are demanded.

Public facility systems are not simple. Yet the way in which they perform can be explained by reflecting on their structures and their market mandates. They are currently responding to forces for change, yet there is little effort to understand the consequences of those forces and for creative actors to seek socially desirable change, either through the deployment of new systems or the drastic modification of old ones.

*Deregulation of domestic air transportation is an informative exception. The cross-subsidy from profits on densely traveled routes to other routes appears to be small; moreover, price regulation has resulted in frequent flights with low average passenger loadings. So, the primary effect of deregulation may not be to set system access in sparse markets against dense ones, but rather to increase the variety of fare and service choices in dense markets.

Study Project

COMMISSION ON SOCIOTECHNICAL SYSTEMS

TRANSPORTATION FOR ELDERLY AND HANDICAPPED PERSONS

In 1970, the Urban Mass Transportation Act was amended to state that the mass transportation needs of elderly and handicapped persons are of national importance and to require that the U.S. Department of Transportation exercise a special leadership role to ensure that their rights were protected. This amendment added section 16 to the act, which reads, in part:

> Section 16.(a) It is hereby declared to be the national policy that elderly and handicapped persons have the same right as other persons to utilize mass transportation facilities and services; that special efforts shall be made in planning and design of mass transportation facilities and services so that the availability to elderly and handicapped persons of mass transportation which they can effectively utilize will be assured; and that all federal programs offering assistance in the field of mass transportation (including the programs under this Act) should contain provisions implementing this policy.[1]

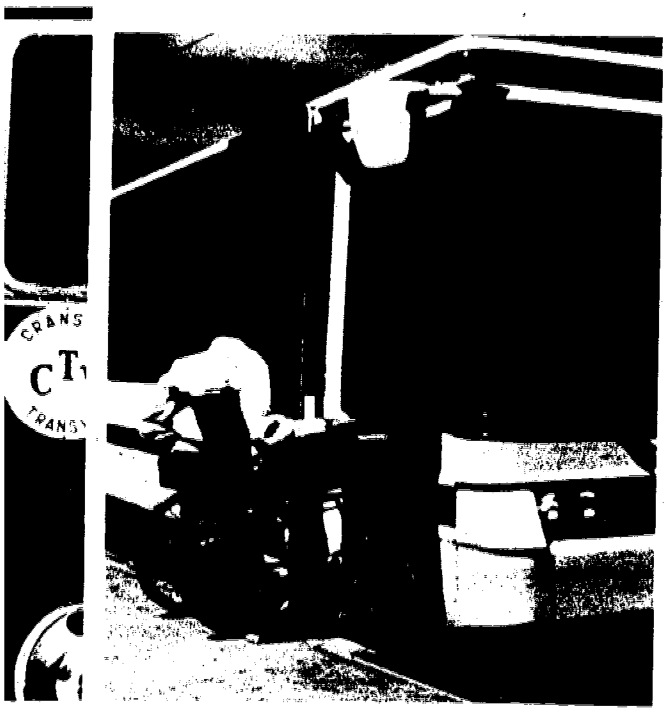
The Transportation Research Board, recognizing the need for further examination of the issues involved in this area, established the Committee on the Transportation Disadvantaged to study problems relating to the elderly, handicapped, and economically disadvantaged, including the services that various types of transportation should provide and the impact and value of transportation programs.

Historically, transportation planners have designed systems to accommodate work trips and the needs of those who have cars, can afford taxis, or are relatively mobile. Little attention was paid to the needs of the elderly and handicapped, because these were deemed outside of normal commuter needs.

However, statements of government policy dealing with the transportation problems of the disadvantaged have practically doubled over the last five years. Special programs have been implemented throughout the country, and considerable research has begun. The Urban Mass Transportation Administration (UMTA) began and continues to support a multimillion-dollar demonstration program for the handicapped, the elderly, and the poor, and has mandated requirements for public transit to ensure accessibility for the elderly and handicapped. A mandate by Secretary of Transportation Brock Adams takes effect in 1979, and requires that all standard-size buses acquired with UMTA assistance meet transbus design specifications. The specifications require a stationary floor height of not more than twenty-two inches, an effective floor height including a kneeling feature of not more than eighteen inches, and a ramp for boarding and exiting.

Lifts and ramps are two devices used for making transportation systems accessible. Lifts are mechanized platforms that are lowered to ground level to allow wheelchairs access to buses. Ramps extend over the steps and provide an incline for wheelchairs to enter a vehicle. UMTA's interim policy on accessibility for the elderly and handicapped calls for manufacturers to offer optional wheelchair lifts; and local transit authorities must either purchase buses with lifts or provide special services for elderly and handicapped passengers. The Southern California Rapid Transit District in Los Angeles has ordered 200 buses with lifts that will operate on regular fixed-route service; Seattle, Washington, has ordered approximately 80; and other transit agencies are taking bids on similar buses.

The states have also become more concerned and involved with the problems of the elderly and the handicapped. Florida State University, in



coordination with the Florida Department of Transportation, the U.S. Administration on Aging, the U.S. Department of Transportation, and the Transportation Research Board's Committee on the Transportation Disadvantaged, along with others, held a series of conferences to examine the methods of improving the quality and quantity of transportation for the elderly and handicapped. The State of Delaware has organized the Delaware Authority for Special Transit (DAST) to provide for the special transportation needs of its residents, and Michigan has instituted a dial-a-ride assistance program. The Bay Area Rapid Transit District, the Washington Metropolitan Area Transit Authority, and the Metropolitan Atlanta Regional Transit Authority all designed or redesigned their systems to be totally accessible to the elderly and handicapped. Those systems have installed elevators for moving nonambulatory and semiambulatory passengers vertically to and from streets, trains, and platforms. Elevators have been equipped with telephones within easy reach of a wheelchair for emergency use. Rest room facilities are designed for use by the handicapped. Stairs and cars have been modified to accommodate handicapped and wheelchair-bound passengers. Loudspeaker systems, information signs, special service gates, fare collection machinery, and elevator buttons have been designed to meet the needs of the handicapped.

Providing totally accessible systems for the handicapped places a great financial burden on public transportation systems that are already operating with tremendous deficits. But is society responsible for providing total accessibility for the handicapped in all transport systems? Or are these aims better served by separate systems designed specifically for the handicapped? These questions are not easily resolvable and the handicapped themselves are split on the issues.

These questions are also ones of social choice—political issues rather than technical ones—and hence beyond the competency of the Committee on the Transportation Disadvantaged. However, the committee can examine alternative policies and their probable effectiveness, including economic and psychological impacts on various groups. Thus, the committee will examine the various means by which accessibility is provided to the handicapped, how to pay for these services, and the various ways by which public mass transit can be integrated with social services and private paratransit.

Public transit has not adequately met the needs of the disadvantaged, and, therefore, along with its examination of public transit for the handicapped, the committee has also examined the potential role of special systems. Such systems developed largely as a result of categorical federal programs for special social and other services, and were designed to serve specific trips and needs. Many of these early transportation projects were funded and sponsored by the Office of Economic Opportunity. A great many are also financed under Title III of the Older Americans Act (which established the Administration on Aging), thus making the elderly important clients of special systems.

Title III, Section 308.(a) of the Act reads, in part:

> The Commissioner may, after consultation with the State agency, make grants to any public or nonprofit private agency or organization within such State for paying part or all the cost of developing or operating statewide, regional, metropolitan area, county, city, or community model projects which will expand or improve social services or otherwise promote the well-being of older persons. In making grants and contracts under this section the Commissioner shall give special consideration to projects designed to . . . (4) provide services to assist in meeting particular needs of the physically and mentally impaired older persons including special transportation and escort service.[2]

A few programs are financed under Titles VI and XIX of the Social Security Act of 1965 and involve services to the low-income elderly, including those eligible for Medicaid.

These special systems have addressed the wide range of trip needs (with the exception of work trips) of the transportation disadvantaged of all ages and types. Although some special systems do indeed provide transportation to work, their major purpose is access to social services, medical programs, and, frequently, recreation and shopping.

Because of the large population of elderly and handicapped among their clientele, special systems are typically characterized by highly personalized service, particularly from the drivers. Drivers may escort passengers from their homes when it is raining or slippery, help them carry bundles to and from vehicles, and help them board vehicles. They should also start slowly and stop carefully. The transportation disadvantaged need this personalized service, and they need it in a form and to an extent that goes well beyond the conventional door-to-door concept of taxi service. The key difference is the involvement of the driver and his concern for the passenger—the concept of "hands-on" transportation.

In contrast, in public transit systems (frequently including taxis), drivers must meet schedules, are not permitted to leave their seats, and must operate on fixed routes. Additionally, many transportation vehicles used by special systems can accommodate wheelchairs, but none of them meet the transbus design standards that will be required of all buses built after September 30, 1979.

Concern for the elderly and handicapped is now international. An international conference (co-sponsored by TRB) at Loughborough, England, was held in April 1978. The issues on the agenda included governmental policies for the elderly and handicapped, and vehicle and infrastructure adaptation and design. The TRB Committee on the Transportation Disadvantaged participated in the planning of this conference.

The potentials for improving transportation services for the elderly and handicapped involve four major efforts: (1) better use of the existing resources for these groups; (2) better planning process; (3) more testing of potential innovative techniques, both vehicles and equipment, as well as organizational and institutional arrangements; and (4) more research to determine how many of the elderly and handicapped actually need specialized services, the level of service to be provided (e.g., simply improving access to public vehicles or providing transit systems specifically serving the elderly and the handicapped), and so forth. In the long run, greater federal, state, and local participation in all phases of research, planning, innovation, and efficient resource use will be essential if the transportation needs of the elderly and handicapped are to be met effectively.

REFERENCES

1. Urban Mass Transportation Act of 1964, As Amended Public Law 88-365, 78 Stat. 302, 49 USC 1601 *et seq.*

2. Older Americans Comprehensive Services Amendments of 1973, Public Law 93-29, 87 Stat. 30.

STEPHEN E. BLAKE

Committee on the Transportation Disadvantaged, Transportation Research Board, Commission on Sociotechnical Systems. Chairman, Arthur Saltzman of North Carolina A and T State University; Staff Officer, Stephen E. Blake.

II

INSTITUTE OF MEDICINE

Institutional Management and Health Policy

DAVID A. HAMBURG

Little more than a year ago, the Institute of Medicine had passed the fifth anniversary of its founding and was engaged in a period of introspection, looking at where it had been and deciding how it could most effectively proceed.

A consensus emerged among the members that reaffirmed the broad scope of the institute's chartered role: to find ways to improve the health of the public, taking into account all the factors that influence health. There was also consensus on a specific pattern of operation that could help assure the best investment of our effort and guard against overlooking promising opportunities in the formulation of health policy.

We were encouraged to monitor the major areas of the health enterprise from multiple perspectives so that our agenda could be chosen wisely. It was thought important to maintain a continuing effort in each health area so as to gain substantive depth of experience. We were urged to maintain a high level of sympathetic understanding of government's problems in managing the complexities of health programs, but still to

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retain our independence and ability to take constructive initiatives on government policies and procedures. Our efforts should embrace the great variety of institutions across the nation that affect the health of the public and should not reflect an excessive preoccupation with the federal government. And, as a new function, it seemed desirable to the members that we conduct some studies and advisory functions on a very short time scale when important health policy matters require urgent attention—an "emergency room" function.

I am gratified to be able to report that clear, substantial, unmistakable progress has been made on each of these points during the past year. There is no way to measure with precision how far we have come, but there are many indications that the distance covered is not trivial.

I think we understand some of the factors that have enabled real progress. The most important, in my judgment, is the willingness of institute members and other people of similar ability, dedication, and integrity to work hard on institute activities. It is to me a remarkable fact of life that the academy in general, and the Institute of Medicine in particular, somehow brings out the best in us. We seem to be less parochial, less egocentric, less ethnocentric. I cannot explain the reaction, but I am grateful for it, and I believe the nation is well served.

This is certainly the institute's main strength: being able to mobilize talent in the health community—broadly defined—and to develop analyses of major health problems at a very high level of quality, unrestrained by the traditional boundaries of discipline, specialty, institution, region, and the like. The institute's usefulness to society depends on a novel chemistry among people with very diverse competences.

It is a source of never-ending fascination to me to observe the wide-ranging interplay of ideas, information, and values as one of our activities evolves. Information and judgment from different perspectives begin to fit together in a meaningful pattern. Pieces of the puzzle come to be assembled. The problem is seen collectively in a larger context than any of us individually had seen it before. More variables are taken into account. Mutual respect emerges among people of very different backgrounds. The assets and limitations of various data sets and of various policy options are better understood and fairly stated.

So it goes. Not always. Not easily. But usually—and with great stimulation—we learn from each other, broaden our horizons, and produce an analysis that clarifies "the facts about the facts," the problems that have to be faced, and reasonable ways of coping with them.

Aided by this extraordinary process and the people it engages, the institute in its seventh year has matured to a point at which one can reasonably expect it to become a social institution of lasting and exceptional value. Like the National Academy of Sciences and the National Research Council—and in some ways distinctive in its own right—the institute is a social invention that integrates special strengths of the private sector and the public sector of American society. In the decades to come, it should be one of the principal sources of dependable information, reasoned analysis, and broadly integrated perspectives on the complex and vital matters of human health and disease.

Such an enterprise would never be easy, even with the good fortune we have. Let me mention here a few of our problems. We still miss opportunities to involve members who could help greatly in identifying, clarifying, and even solving significant health problems. We have worked to remedy that situation and can see some gains. Interesting and useful ideas have emerged in response to my yearly letters to every member, inquiring about their current interests and preferences concerning institute activities. Our recent reorganization into six operational divisions, each with its own advisory committee, will engage more members than ever could be enlisted in project steering committees alone. But we must think of more ways of getting the right person into the right niche of our program at the right time.

The chronic scarcity of "hard" money is a basic flaw of our institution. Heavy dependence on federal government funding, project by project, is feasible but poses many problems. The availability of flexible funds offers several advantages: greater institutional independence, fostering of internal creativity, the ability to initiate our own studies, support for a "running start" on urgent issues, and the maintenance of a reasonably stable, highly competent staff, reliably available to help both government and private institutions.

So far we have been blessed with flexible support from a number of private foundations, which has been crucial to the building and shaping of the institution. More recently, the support of these foundations has made possible an increasing diversity of staff from the biological and behavioral sciences, clinical medicine, public health, and public policy—all key senior appointments that we could not otherwise have considered. It is deeply satisfying to be able to report that our present philanthropic bulwarks and also other foundations have recently reaffirmed or newly expressed their confidence in the institute. They have given us great encouragement, as have the principal federal health agencies and other units of the executive branch and the relevant committees of Congress.

These many recent manifestations of confidence in our future are enormously heartening for now, and perhaps also for the long term. But there is no doubt in my mind that the institute would be on a much sounder basis for making truly fundamental and lasting social contributions if it had a solid core of permanent funds. Think what an endowment of $10 million would do. This is surely a small endowment by the standard of social institutions of unusual value, but I regret to say it is nowhere in sight for the Institute of Medicine.

Beyond greater engagement of our membership and establishing the most suitable financial underpinning, there remains the problem of how effective we are. Policy research efforts are sometimes regarded as producing reports of doubtful value, of conducting redundant conferences, or of other such shortcomings.

Not so the institute's efforts, we like to think. But to reduce the nagging possibility that our program activities are less than fully effective, we are taking additional steps to increase the likelihood that our products will be socially useful.

The very careful consideration given to the substance, format, and timing of each project—by our divisional organization, program committee, and governing council—is calculated to assure that the project will help to answer significant questions using the institute's unique strength in membership and staff.

The range of our continuing contact with sectors of the federal government concerned with health is being widened and made more systematic, so as to produce reasonable confidence that our activities will be taken seriously in Washington. There is much evidence that this effort is going well.

To reach the big country beyond Washington, we have begun several activities that will help us learn from the many and varied nonfederal institutions with a health role. Several study groups across the country have been created by the institute in order to recruit regional competence on specific issues. We also are extending, with the enthusiastic support of a private foundation, a project that began as a modest speakers' bureau and now will become open forum programs on health policy problems. Guided to agendas of regional relevance by advisory committees that know the territory, the forums are expected to provide a more extensive and systematic exchange with institute members and with others throughout the country. The forums are intended to help us more readily understand the real nature of health problems across the nation, while at the same time making our reports more accessible and more useful to state and local policymakers.

For generations, improvements in nutrition, sanitation, biomedical sciences, and health professional skills have taken the lethal sting from many diseases in many parts of the world. But today's longer human life span, compounded by drastic changes in the conditions of life, highlights chronic and debilitative diseases, accidental injuries, and mental illness. Indeed, the pattern of our diseases and the various burdens of illness have changed remarkably in the twentieth century. The contrast in disease patterns between industrialized and developing countries is striking throughout the world. We have made much progress, but we still carry a heavy if different burden of illness.

The problems of health, and of health policy, have much to do with the immensity of the transition that our species has brought about in the period since the industrial revolution, and especially in the twentieth century. In a mere moment of evolutionary time, we have drastically transformed the world of our ancestors—from the intimate, slowly changing societies of hunters and gatherers, through small and simple communities of agrarian culture, to today's large, crowded, impersonal, heterogeneous, rapidly changing world in which we are barely beginning to learn how to live.

It is now our very difficult task to invent solutions to problems that are largely unprecedented in the history of the species. It is useful to see our health problems in this larger context. Issues of health and disease become commingled with such other concerns as resolution of conflicts, equitable distribution of limited resources, preservation of the environment, and the quality of human relationships.

Science can help a great deal to resolve these difficult matters. But for true effectiveness in meeting these human predicaments, science and the science-based professions must move beyond their traditional boundaries and establish a domain of mutual understanding, cooperation, and joint innovation rarely achieved in the past.

I firmly believe that the Institute of Medicine will, in the remainder of this century, make a significant contribution to the successful passage of this historic transition.

Study
Project

INSTITUTE OF MEDICINE

MEDICAL EDUCATION AND THE AGED

Americans over the age of sixty-five make up only eleven percent of the population, but account for nearly thirty percent of the nation's health spending. Their share can only go up; some fifty years from now, they will constitute seventeen percent of the U.S. population.

It's not that the elderly are necessarily afflicted with diseases unique to the condition of being over sixty-five. With some exceptions, the diseases found in the aged population also occur in the younger decades of life. Many diseases, however, appear with greater frequency in the elderly, particularly the chronic diseases. In addition, the course of many common diseases becomes longer and more severe with advancing age.

An increasing body of medical knowledge is bringing wider acknowledgment in the United States that the health problems of the elderly are different from those of other age groups, because the elderly have reached a point of human development at which their reactions to disease are different. The same concept at the other end of life's spectrum fostered the specialty of pediatrics.

With or without specialty designations, the attention of health care professionals to the needs of the aged has resulted in more educational programs for physicians and other practitioners in Europe than it has in the United States. A 1977 tabulation indicated ten endowed university chairs of geriatric medicine in Britain, for a population of 60 million. Only recently has the first endowed professorship of geriatric medicine been established in the United States (at Cornell University College of Medicine), for a population of more than 200 million. Robert N. Butler, director of the National Institute on Aging, estimated in 1976 testimony before a U.S. Senate special committee that fewer than 15 of the roughly 25,000 faculty members of American medical schools could be said to have a "genuine expertise" in geriatrics.

At the request of the National Institute on Aging, the Institute of Medicine undertook in the fall of 1977 to conduct a study whose findings could facilitate the incorporation of knowledge about human aging in medical education. The project is planned to extend over a one-year period.

At the outset, the study will define the areas of knowledge and research on aging and human development that are relevant to medical education, and then determine the extent to which that knowledge and research are currently incorporated in medical education programs.

The study also will include an examination and assessment of different ways in which knowledge in geriatrics is, or can be, conveyed to medical students, physicians in residency training, and experienced practitioners. Another task will be the review of potential methods for developing the faculty needed for education programs in aging. And extensive consideration will be given to the function of and requirements for research in the development of medical curricula, clinical training, and continuing education programs about aging.

The study's findings and recommendations are expected to assist in the shaping of policies for the support of training and research programs to enhance medical care directed specifically at the needs of the elderly.

Two earlier activities of the Institute of Medicine have contributed to the background of information that encouraged the undertaking of the present study. In 1976, the institute cosponsored—with the Royal Society of Medicine in London—an Anglo-American Conference on Care of the Elderly. The conference was directed to problems associated with decline of functional ability in the aging population, and, as a side-effect, pointed up the disparity between the United Kingdom and United States in medical education and health care programs for the elderly.

A follow-up study on the conference sifted the information provided by the entire program of speakers in order to find policy initiatives that would be relevant for U.S. application.

Among the recommendations of that study was the creation of a program of federal financial support to pay for long-term care for the functionally dependent elderly and to develop a program of long-term care services that could help the beneficiaries to remain in their homes or communities.

Study on the Incorporation of Knowledge About Human Aging in Medical Education. Study Chairman, Paul B. Beeson of the Veterans Administration Hospital, Seattle; Project Director, Peter E. Dans.

APPENDIXES

Appendix A Brief Description of the Academy Complex and NRC Structure

NATIONAL ACADEMY OF SCIENCES

Created by a congressional charter signed by President Lincoln in 1863, the National Academy of Sciences (NAS) is a private, honorary society of scientists and engineers, dedicated to the furtherance of science and its use for the general welfare. Although the academy is not a federal agency, it is called upon, by the terms of its charter, to examine and report on any subject of science or technology upon request of any department of the federal government. Whether contracted by the federal government or supported by private organizations, analytical studies are conducted by committees established in the Institute of Medicine (IOM) and the National Research Council (NRC). The latter is the "operating arm" of the Academy of Sciences and of the National Academy of Engineering (NAE).

In addition to its scientific advisory activities, the NAS awards medals and honoraria, publishes reports and the journal, *The Proceedings of the National Academy of Sciences*, organizes symposia, arranges U.S. participation in international organizations and programs, and—on occasion—issues public statements on matters of importance to the scientific community.

NATIONAL ACADEMY OF ENGINEERING

The National Academy of Engineering was established in 1964 under the charter of the National Academy of Sciences as an essentially autonomous organization of outstanding engineers. NAE elects its own members and shares responsibility with the National Academy of Sciences for serving the federal government through the medium of the National Research Council. The NAE also conducts symposia, publishes special reports, participates in international activities, and awards medals.

INSTITUTE OF MEDICINE

The Institute of Medicine was chartered by the National Academy of Sciences in 1970 to deal with problems associated with the adequacy of health services for all sectors of society. Through its own committee structure, the institute conducts studies of policy issues and problems related to health and medicine. It issues position papers for public consideration, cooperates with the major scientific and professional societies in the field, conducts symposia, and disseminates information to the public and the relevant professions.

THE NATIONAL RESEARCH COUNCIL

The National Research Council, which was established under the NAS charter in 1916, is now organized to include both multidisciplinary commissions and assemblies organized along disciplinary lines—thereby enabling it to respond more effectively to the increasingly complex problems facing American society today.

The major units of the Research Council are the Assemblies of Behavioral and Social Sciences, Engineering, Life Sciences, and Mathematical and Physical Sciences, and the Commissions on Human Resources, International Relations, Natural Resources, and Sociotechnical Systems. The assemblies are concerned with fundamental scientific and technical questions, the vitality of the national scientific endeavor, and those national problems that may usefully be addressed within the scientific or engineering disciplines represented in each assembly. The commissions are specifically called upon to deal with complex multidisciplinary problems.

The work of the Research Council is overseen by a Governing Board that is made up of seven members of the NAS Council, four members of the NAE Council, and two members of the IOM Council. The Chairman of the Governing Board, who is the principal administrative officer of the NRC, is the elected President of the National Academy of Sciences; the Vice Chairman of the Governing Board is the elected President of the National Academy of Engineering. Members of the assemblies and commissions are appointed by the Chairman of the NRC for five-year and four-year terms, respectively. Each year, the assemblies, the commissions, and the Institute of Medicine present their annual program plans and projected expenditures for the coming year to the Governing Board for approval.

Through the Research Council, the academies are able to enlist the talents of a very broad representation of the nation's leading scientists and engineers and other members of the scholarly and professional communities to supplement their own memberships. Although the academies rely primarily on the appointed committees to respond to requests for advice from the federal government, all committee reports are subject to independent review by a Report Review Committee made up of members of NAS, NAE, and IOM. Institutional responsibility is assured, also, in the procedures for selecting and appointing committee members, all of whom are subject to approval by the Chairman of the NRC, as well as by the respective assemblies or commissions. At the present time, about 7,500 individuals serve, without compensation, on some 800 committees, boards, panels, and subcommittees, the costs being met through contracts between the National Academy of Sciences and the government and private foundations.

Appendix B of this report lists recent reports by the National Research Council. The listing illustrates the nature and diversity of the problems and issues addressed by the Research Council in 1977.

Appendix B Reports of the NRC Published in 1977*

ASSEMBLY OF BEHAVIORAL AND SOCIAL SCIENCES

Common Processes in Habitual Substance Abuse: A Research Agenda. (Committee on Substance Abuse and Habitual Behavior; 39 pp.; available from the committee; supply limited.)

Community Reactions to the Concorde: An Assessment of the Trial Period at Dulles Airport. (Committee on Community Reactions to the Concorde; 17 pp.; available from the committee; supply limited.)

Energy Consumption Measurement: Data Needs for Public Policy. (Committee on Measurement of Energy Consumption; 122 pp.; available from Printing and Publishing Office, National Academy of Sciences; ISBN 0-309-02624-5; $6.50.)

Environmental Monitoring [Vol. IV of *Analytical Studies for the U.S. Environmental Protection Agency*]. (Joint project—Committee on National Statistics and Numerical Data Advisory Board, Assembly of Mathematical and Physical Sciences; and Environmental Studies Board, Commission on Natural Resources; 194 pp.; available from Printing and Publishing Office, National Academy of Sciences; ISBN 0-309-02639-3; $7.75.)

*Reports from the Printing and Publishing Office are available from the Printing and Publishing Office, National Academy of Sciences, 2101 Constitution Avenue, N.W., Washington, D.C. 20418. For National Technical Information Service (NTIS) reports, write to the National Technical Information Service, Springfield, Virginia 22161. For reports available from a committee, write to the committee, National Academy of Sciences. Other reports are available from the sources noted. Prices and availability subject to change.

Fundamental Research and the Process of Education. (Committee on Fundamental Research Relevant to Education; 126 pp.; available from the committee; supply limited.)

Guidelines for Preparing Environmental Impact Statements on Noise. (Working Group 69—Evaluation of Environmental Impact of Noise, Committee on Hearing, Bioacoustics, and Biomechanics; 145 pp.; available from Office on Noise Abatement and Control, U.S. Environmental Protection Agency, Washington, D.C. 20460.)

Noise Abatement: Policy Alternatives for Transportation [Vol. VIII of *Analytical Studies for the U.S. Environmental Protection Agency*]. (Committee on Appraisal of Societal Consequences of Transportation Noise Abatement; 206 pp.; available from Printing and Publishing Office, National Academy of Sciences; ISBN 0-309-02648-2; $8.00.)

Optical Properties and Visual Effects of Face Masks. (Committee on Vision; 8 pp.; available from the committee; supply limited.)

Planning and Coordination of the Federal Statistics System. (Committee on National Statistics; 35 pp.; available from the committee; supply limited.)

Speech Understanding and Aging. (Working Group 75—Speech Understanding and Aging, Committee on Hearing, Bioacoustics, and Biomechanics; 22 pp.; available from the committee; supply limited.)

Subnational Statistics and Federal–State Cooperative Systems. (Committee on National Statistics; 28 pp.; available from the committee.)

Understanding Crime: An Evaluation of the National Institute of Law Enforcement and Criminal Justice. (Committee on Research on Law Enforcement and Criminal Justice; 260 pp.; available from Printing and Publishing Office, National Academy of Sciences; ISBN 0-309-02635-0; $12.00.)

ASSEMBLY OF ENGINEERING

Advanced Gas Turbine Engine Development: The Potential Role of the NASA Lewis Research Center. (Aeronautics and Space Engineering Board; 37 pp.; available from the board.)

Development Schedules for Vehicle Energy Storage Systems. (Committee on Advanced Energy Storage Systems, Energy Engineering Board; 19 pp.; available from the committee; supply limited.)

Federal Research and Development for Satellite Communications (Committee on Satellite Communications, Space Applications Board; 33 pp.; available from the board.)

Modeling and Simulation for Engineering Manpower Studies. Proceedings of a conference. (Board on Engineering Manpower and Education Policy; 157 pp.; available from the assembly; supply limited.)

Operational Software Management and Development for U.S. Air Force Computer Systems. (Committee on Operational Software Management and Development, Air Force Studies Board; 80 pp.; available from the board; supply limited.)

Priorities for Research in Marine Mining Technology. (Panel on Marine Minerals Technology, Marine Board; 72 pp.; available from NTIS; ADA-042 359; $5.00 paper, $3.00 microfiche.)

Recommended Procedures for Settlement of Underground Construction Disputes. (U.S. National Committee on Tunneling Technology; 22 pp.; available from the committee; supply limited.)

Review of Activities of the Institute for Telecommunication Sciences, Office of Telecommunications, Department of Commerce. (Panel for the Office of Telecommunications Study, Committee on Telecommunications; 8 pp.; available from the committee.)

Review of the Plan for the Requirements Definition and System Architecture Phase of the Future Social Security Administration Process. An Interim Report. (Panel on SSA Data Management, Committee on Telecommunications; 11 pp.; available from the committee.)

Roles and Mission of the Transportation Systems Center of the Department of Transportation. (Committee on Transportation; 17 pp.; available from the committee; supply limited.)

Safety of Dams: A Review of the Program of the U.S. Bureau of Reclamation for the Safety of Existing Dams. (Committee on the Safety of Dams; 70 pp.; available from the committee.)

Selected Annotated Bibliography on Technology and Health Care. (Committee on Technology and Health Care; 213 pp.; out of print.)

Selected Issues of the Ocean Thermal Energy Conversion Program. (Panel on Ocean Thermal Energy Conversion, Marine Board; 53 pp.; available from the Department of Energy.)

Telecommunications for Metropolitan Areas: Near-Term Needs and Opportunities. (Steering Committee for the Metropolitan Communications Systems Study, Committee on Telecommunications; 78 pp.; available from NTIS; PB 265 960; $5.00 paper; $3.00 microfiche.)

Verification of Fixed Offshore Oil and Gas Platforms. (Panel on Certification of Offshore Structures, Marine Board; 84 pp.; available from the board; supply limited.)

ASSEMBLY OF LIFE SCIENCES

Army Rank and Subsequent Mortality by Cause: 23-Year Follow-up. (Medical Follow-up Agency; *American Journal of Epidemiology*, June 1977; reprints available from the agency.)

Arsenic [Medical and Biologic Effects of Environmental Pollutants]. (Subcommittee on Arsenic, Committee on Medical and Biologic Effects of Environmental Pollutants; 339 pp.; available from Printing and Publishing Office, National Academy of Sciences; ISBN 0-309-02604-0; $13.75.)

Biologic Effects of Electric and Magnetic Fields Associated with Proposed Project Seafarer. (Committee on Biosphere Effects of Extremely Low-Frequency Radiation, Division of Medical Sciences; 451 pp.; available from Naval Electronic Systems Command, Department of the Navy, Washington, D.C. 20360; PME 117-214; supply limited.)

Carbon Monoxide [Medical and Biologic Effects of Environmental Pollutants]. (Subcommittee on Carbon Monoxide, Committee on Medical and Biologic Effects of Environmental Pollutants; 246 pp.; available from Printing and Publishing Office, National Academy of Sciences; ISBN 0-309-02631-8; $9.75.)

Considerations of Health Benefit-Cost Analysis for Activities Involving Ionizing Radiation Exposure and Alternatives [EPA 520/4-77-003]. (Advisory Committee on the Biological Effects of Ionizing Radiations; 199 pp.; available from Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, D.C. 20460; AW-460.)

Copper [*Medical and Biologic Effects of Environmental Pollutants*]. (Subcommittee on Copper, Committee on Medical and Biologic Effects of Environmental Pollutants; 115 pp.; available from Printing and Publishing Office, National Academy of Sciences; ISBN 0-309-02536-2; $7.00.)

Drinking Water and Health. (Safe Drinking Water Committee, Advisory Center on Toxicology; 939 pp.; available from Printing and Publishing Office, National Academy of Sciences; ISBN 0-309-02619-9; $20.75.)

An Evaluation of the Carcinogenicity of Chlordane and Heptachlor. (Pesticide Information Review and Evaluation Committee; available from the U.S. Environmental Protection Agency, Office of Public Awareness, 401 M Street, S.W., Washington, D.C. 20460; supply limited.)

Factors Related to Survival Following Resection for Gastric Carcinoma. (Medical Follow-up Agency; *Cancer*, September 1977; reprints available from the agency.)

Fire Toxicology: Methods for Evaluation of Toxicity of Pyrolysis and Combustion Products. Report Number 2. (Committee on Fire Toxicology, Advisory Center on Toxicology; 39 pp.; available from NTIS: ADA-043 899; $4.50 paper, $3.00 microfiche.)

Folic Acid: Biochemistry and Physiology in Relation to the Human Nutrition Requirement. Proceedings of a Workshop on Human Folate Requirements, June 2–3, 1975. (Food and Nutrition Board; 305 pp.; available from Printing and Publishing Office, National Academy of Sciences; ISBN 0-309-02605-0; $13.50.)

The Future of Animals, Cells, Models, and Systems in Research, Development, Education, and Testing. Proceedings of a Symposium, October 22–23, 1975. (Institute of Laboratory Animal Resources, Division of Biological Sciences; 350 pp.; available from Printing and Publishing Office, National Academy of Sciences; ISBN 0-309-02603-2; $9.25.)

Informing Workers and Employers about Occupational Cancer. (Committee on Public Information in the Prevention of Occupational Cancer, Division of Medical Sciences; 42 pp.; available from NTIS; PB 269 599; $4.00 paper; $3.00 microfiche.)

Iron Nutriture in Adolescence. (Committee on Nutrition of the Mother and Preschool Child; Food and Nutrition Board; 10 pp.; available from Public Health Service, Public Health Administration, Bureau of Community Health Services, Rockville, Md. 20857; HSA Pub. 77-5100.)

Laboratory Animal Management: Rodents. (Committee on Rodents, Institute of Laboratory Animal Resources; *ILAR News*, Spring 1977; reprints available from the institute.)

Laboratory Animal Management: Wild Birds. (Committee on Birds, Institute of Laboratory Animal Resources; 121 pp.; available from Printing and Publishing Office, National Academy of Sciences; ISBN 0-309-02621-0; $7.75.)

Laboratory Indices of Nutritional Status in Pregnancy: Summary Report. (Committee on Nutrition of the Mother and Preschool Child, Food and Nutrition Board; 23 pp.; available from the board.)

Malnutrition and the Immune Response [Vol. 7 of *Kroc Foundation Series*]. (Subcommittee on Nutrition and Infection, Committee on International Nutrition Programs, Division of Biological Sciences, Food and Nutrition Board; 487 pp.; Raven Press, New York; ISBN 0-89004-066-5; out of print.)

Manpower in Basic Neurologic and Communicative Sciences: Present Status and Future Needs—Summary Report. (Committee on Teaching/Research Manpower Needs in Basic Neurologic and Communicative Sciences; *Experimental Neurology* 57:651–656; full report will be published as an NINCDS Monograph by the Government Printing Office in the spring of 1978.)

The National Center for Toxicological Research: The Evaluation of Its Program. (Advisory Center on Toxicology; 154 pp.; will be available from NTIS.)

Nitrogen Oxides [*Medical and Biologic Effects of Environmental Pollutants*]. (Subcommittee on Nitrogen Oxides, Committee on Medical and Biologic Effects of Environmental Pollutants; 340 pp.; available from Printing and Publishing Office, National Academy of Sciences; ISBN 0-309-02615-6; $13.25.)

Ozone and Other Photochemical Oxidants [*Medical and Biologic Effects of Environmental Pollutants*]. (Subcommittee on Ozone and Other Photochemical Oxidants, Committee on Medical and Biologic Effects of Environmental Pollutants; 726 pp.; available from Printing and Publishing Office, National Academy of Sciences; ISBN 0-309-02531-1; $18.00.)

Pilot Studies in the Clinical Evaluation of Narcotic Antagonists. (Committee on the Clinical Evaluation of Narcotic Antagonists, Division of Medical Sciences; 2 volumes; available from NTIS; Vol. I, 103 pp., PB 270 568, $5.50 paper, $3.00 microfiche; Vol. II, 295 pp., PB 270 569, $9.25 paper, $3.00 microfiche.)

Platinum-Group Metals [*Medical and Biologic Effects of Environmental Pollutants*]. (Subcommittee on Platinum-Group Metals, Committee on Medical and Biologic Effects of Environmental Pollutants; 231 pp.; available from Printing and Publishing Office, National Academy of Sciences; ISBN 0-309-02640-7; $9.75.)

Predicting Dependence Liability of Stimulant and Depressant Drugs. (Committee on Problems of Drug Dependence; 328 pp.; University Park Press, Chamber of Commerce Building, Baltimore, Md. 21202; ISBN 0-8391-1147-9; $19.50.)

Preliminary Statement of the Committee on Biosphere Effects of Extremely Low Frequency Radiation. (Committee on Biosphere Effects of Extremely Low Frequency Radiation; pp. IV-106–IV-109; available from Naval Electronic Systems Command, Department of the Navy, Washington, D.C. 20360; PME 117-214.)

Principles and Procedures for Evaluating the Toxicity of Household Substances. (Committee for the Revision of NAS Publication 1138, Committee on Toxicology; 130 pp.; available from Printing and Publishing Office, National Academy of Sciences; ISBN 0-309-02644-X; $7.00.)

Public Information in the Prevention of Occupational Cancer. (Committee on Public Information in the Prevention of Occupational Cancer; 219 pp.; available from NTIS; PB 265 650; $7.75 paper, $3.00 microfiche.)

A Review of the Use of Ionizing Radiation for the Treatment of Benign Diseases, Volume I. (Committee to Review the Use of Ionizing Radiation for the Treatment of Benign Diseases, Division of Medical Sciences; HEW publication (FDA) 78-8043, September 1977; 60 pp.; available from the U.S. Government Printing Office, Washington, D.C.; 017-015-00141-5; $2.10.)

Social and Behavioral Correlates of Successful Breeding in Nonhuman Primate Colonies. Seminar at the November 1976 meeting of the American Association for Laboratory Animal Science. (Institute of Laboratory Animal Resources; *Laboratory Animal Science,* August 1977, supplement; reprints available from the institute.)

Statement of the Committee on Military Environmental Research on the Status of Research into Biological Effects of Environmental Contaminants at Rocky Mountain Arsenal (January 1977; 10 pp.) and *Follow-up Statement of the Committee* (September 1977; 5 pp.) (available from NTIS; AD AO 45812 and AD AO 45813, respectively; $4.00 paper each, $3.00 microfiche each.)

Study of Health Care for American Veterans. Report to Committee on Veterans' Affairs, U.S. Senate. (Committee on Health-Care Resources in the Veterans Administration; Committee Print, 95th Cong., 1st Sess., June 7, 1977, 324 pp.; U.S. Government Printing Office, Washington, D.C.; Stock No. 052-070-04096-3; $3.50.)

Summary Report: Drinking Water and Health. (Safe Drinking Water Committee; 98 pp.; available from Office of Public Affairs, U.S. Environmental Protection Agency, Washington, D.C. 20460.)

Summary Report: Manpower in Basic Neurologic and Communicative Sciences: Present Status and Future Needs. (Committee on Teaching/Research Manpower Needs in Basic Neurologic and Communicative Sciences; published in *Experimental Neurology,* November 1977.)

Symposium on Impact of Infection on Nutritional Status of the Host. (Subcommittee on Interactions of Nutrition and Infections, Committee on International Nutrition Programs, Food and Nutrition Board; 363 pp.; reprint from *American Journal of Clinical Nutrition,* Vol. 30, August and September 1977; $12.00.)

Testing for Dependence Liability of Stimulants and Depressants in Animals and Man. (Committee on Problems of Drug Dependence; *Bulletin on Narcotics,* January–March 1977; reprints available from the assembly.)

ASSEMBLY OF MATHEMATICAL AND PHYSICAL SCIENCES

Assessment of the Current Status of the Nuclear Data Compilation Effort. (Letter report. Ad Hoc Panel on Basic Nuclear Data Compilations; Committee on Nuclear Science; available from the committee.)

Atmospheric Research and Development Program in the National Oceanic and Atmospheric Administration. (Steering Committee and Review Panels for the NOAA Atmospheric Research and Development Program, Committee on Atmospheric Sciences; available from the committee; limited supply.)

The Atmospheric Sciences: Problems and Applications. (Committee on Atmospheric Sciences; 124 pp.; available from Printing and Publishing Office, National Academy of Sciences; ISBN 0-309-02626-1; $7.75.)

Background Papers for a Workshop on the Tropospheric Transport of Pollutants to the Ocean, Miami, Fl., 8–12 December 1975. (Ocean Sciences Board; 351 pp.; available from the board; supply limited.)

Climate, Climatic Change, and Water Supply [*Studies in Geophysics*]. (Panel on Water and Climate, Geophysics Study Committee, Geophysics Research Board; 141 pp.; available from Printing and Publishing Office, National Academy of Sciences; ISBN 0-309-02625-3; $7.75.)

Comments of the NAS to the Third Notice of Inquiry, February 3, 1977. (Committee on Radio Frequencies; available from the committee.)

Computer Science and Crystallography. Proceedings of a Symposium on Application of Current Advances in Computer Science to Crystallography. (Committee on Chemical Crystallography; *Acta Crystallographica*, Section A, Part I, January 1, 1977.)

Earth Science Investigations in the United States Antarctic Research Program (USARP) for the Period July 1, 1976–June 30, 1977. (Polar Research Board; 56 pp.; available from the board.)

Energy and Climate [*Studies in Geophysics*]. (Panel on Energy and Climate; Geophysics Study Committee, Geophysics Research Board; 158 pp.; available from Printing and Publishing Office, National Academy of Sciences; ISBN 0-309-02636-9; $9.50.)

Environmental Monitoring [Vol. IV of *Analytical Studies for the U.S. Environmental Protection Agency*]. (Joint project—Committee on National Statistics and Numerical Data Advisory Board, Assembly of Mathematical and Physical Sciences; and Environmental Studies Board, Commission on Natural Resources; 194 pp.; available from Printing and Publishing Office, National Academy of Sciences; ISBN 0-309-02639-3; $7.75.)

Estuaries, Geophysics, and the Environment [*Studies in Geophysics*]. (Panel on Geophysics of Estuaries, Geophysics Study Committee, Geophysics Research Board; 137 pp.; available from Printing and Publishing Office, National Academy of Sciences; ISBN 0-309-02629-6; $8.50.)

An Evaluation of Arctic Programs Supported by the National Science Foundation. (Polar Research Board, Vol. 1; 141 pp.; available from the board; supply limited.)

An Evaluative Report on the Experimental Technology Incentives Program: National Bureau of Standards—Fiscal Year 1976. (Evaluation Panels for the National Bureau of Standards; available from the Evaluation Panels for the National Bureau of Standards.)

An Evaluative Report on the Institute for Applied Technology: National Bureau of Standards—Fiscal Year 1976. (Evaluation Panels for the National Bureau of Standards; 41 pp.; available from Evaluation Panels for the National Bureau of Standards.)

An Evaluative Report on the Institute for Basic Standards: National Bureau of Standards—Fiscal Year 1976. (Evaluation Panels for the National Bureau of Standards; 85 pp.; available from Evaluation Panels for the National Bureau of Standards.)

An Evaluative Report on the Institute for Materials Research: National Bureau of Standards—Fiscal Year 1976. (Evaluation Panels for the National Bureau of Standards; available from the Evaluation Panels for the National Bureau of Standards.)

An Evaluative Report on the National Bureau of Standards—Fiscal Year 1975. (Evaluation Panels for the National Bureau of Standards; 19 pp.; available from Evaluation Panels for the National Bureau of Standards.)

An Evaluative Report on the Office of Standard Reference Data: National Bureau of Standards—Fiscal Year 1976. (Evaluation Panels for the National Bureau of Standards; available from the Evaluation Panels for the National Bureau of Standards.)

An Evaluative Report on the Office of Standard Reference Data: National Bureau of Standards—Fiscal Year 1977. (Evaluation Panels for the National Bureau of Standards; 9 pp.; available from Evaluation Panels for the National Bureau of Standards.)

Evolution of Kinetics. Proceedings of a symposium organized by the American Chemical Society and the Committee on Kinetics of Chemical Reactions, April 6, 1976. (American Chemical Society, Department AP; four audio casettes, $35.00.)

Future of Nuclear Science. (Committee on Nuclear Science; 119 pp.; available from the committee.)

Geochemistry and the Environment. Volume II: *The Relation of Other Selected Trace Elements to Health and Disease.* (Subcommittee on the Geochemical Environment in Relation to Health and Disease, U.S. National Committee for Geochemistry; 174 pp.; available from Printing and Publishing Office, National Academy of Sciences; ISBN 0-309-02548-6; $18.00.)

Geodynamics Project: U.S. Progress Report 1977. U.S. Geodynamics Committee, Geophysics Research Board; 109 pp.; available from the board.)

Global Earthquake Monitoring: Its Uses, Potentials, and Support Requirements. (Panel on Seismograph Networks, Committee on Seismology; 86 pp.; available from Printing and Publishing Office, National Academy of Sciences; ISBN 0-309-02608-3; $6.25.)

Guidelines for Arctic Research Program Planning. (Polar Research Board; available from the board.)

Historical Bibliography of Sea Mine Warfare. (Mine Advisory Committee, now Naval Studies Board; 144 pp.; available from the board; supply limited.)

Karst Hydrology: Proceedings of the 12th IAH Congress. (U.S. Committee for the International Association of Hydrogeologists, U.S. National Committee on Geology; J. S. Tolson and F. L. Doyle, Editors; University of Alabama Press, Huntsville, Alabama.)

Limitations of Rock Mechanics in the Recovery and Development of Energy. (Panel on Rock Mechanics Problems that Limit Energy Resource Recovery and Development, U.S. National Committee for Rock Mechanics; available from the committee.)

Needs and Opportunities for the National Resource for Computation in Chemistry (NRCC). (Report of a Workshop, Woods Hole, Massachusetts, July 13-16, 1976; Planning Committee for a National Resource for Computation in Chemistry; available from the Office of Chemistry and Chemical Technology.)

Neutron Research on Condensed Matter: A Study of the Facilities and Scientific Opportunities in the United States. (Panel on Research Facilities and Scientific Opportunities in the Use of Low-Energy Neutrons, Solid State Sciences Committee; available from the committee.)

Permafrost Reviewed. (Committee on Permafrost, Polar Research Board; Troy L. Péwé, *Geotimes*, October 1977.)

Plan for U.S. Participation in the Monsoon Experiment (MONEX). (U.S. Committee for the Global Atmospheric Research Program; 132 pp.; available from the committee; supply limited.)

Planning and Management of Major Atmospheric Research Programs. (Committee on Atmospheric Sciences; 45 pp.; available from the committee; supply limited.)

Post-Viking Biological Investigations of Mars. (Committee on Planetary Biology and Chemical Evolution, Space Science Board; 26 pp.; available from the Space Science Board; supply limited.)

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