This evaluation of experiences in Taiwan, Indonesia, Ghana, Colombia, and Brazil has focused on three questions:

1. How does science policy-making relate to development planning?

2. How do governmental and private organizations gain access to science and technology for developmental purposes?

3. How has American assistance (as exemplified by National Academy of Science activities in developing countries) improved national capabilities to use science and technology for development?
SCIENCE POLICY-MAKING FOR DEVELOPMENT

REFLECTIONS ON FIVE CASE STUDIES

Submitted to:
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by
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INTRODUCTION

Science policy-making is still more of an art than a science. Other forms of planning, especially economic, have been explored and debated both as an intellectual exercise and as a political process, with the result that even if there remains disagreement among experts, at least the boundaries of the discussions are generally recognized. Scientists, planners, politicians, and administrators, on the other hand, have participated widely in making policies governing the generation and use of scientific and technological knowledge for development purposes, but their efforts have been diffuse and dispersed. The experience has not been examined enough even to define the issues, let alone to resolve them.

This effort to identify some of these problems is itself a by-product. It arose from a desire on the part of the Agency for International Development to evaluate its support of a National Academy of Sciences program designed to assist underdeveloped countries to improve their national capabilities in science and technology. The program began in 1964. Today NAS is assisting more than a dozen countries in Asia, Latin America, and Africa through policy-oriented workshops, problem-solving panels, and a variety of activities of teaching and research.

How can such a diverse effort be evaluated? The approach taken here was to examine the development-related activities of science policy-making bodies in five selected countries (Taiwan, Indonesia, Ghana, Colombia, and Brazil). The studies also considered how various elements in the society became "clients" or "users" of
science and technology and how the NAS interventions affected these activities and relationships.

The project was undertaken under a contract between the Agency for International Development and the American Institutes for Research. The field studies were conducted in January 1974 by three mid-career participants in Harvard University's seminar in development administration, who visited countries that had received varying kinds and degrees of assistance from the National Academy of Sciences or the National Science Foundation.

In each country we examined the participation by science policy-making bodies in developmental decisions, as well as their relationships with various public and private elements in the community that are dependent on technological innovations. As a third component, we prepared several case studies of actual innovations that had been regarded by the scientists themselves as "success" stories. In each instance, the case studies described innovational decisions representing several distinct stages in the decision-making process: (1) the identification of the opportunity for devising or applying technologies to a developmental problem; (2) the scientific decisions regarding the research itself, including the allocation of resources and the selection of research organizations; (3) the decision to adopt the technology, once its feasibility was established and the alternatives, including postponement, had been considered; (4) decisions regarding the creation of incentives or the acceptance of other motivating factors leading to the adoption of the technology. These phases of the compound decision known as "technological innovation" represented the basis on which the reach of the scientific community was to be examined. Case
studies included innovations in agriculture, agro-industry, and industry.

The criteria on the basis which the case studies were selected included the following: each example represented a significant scientific or technological developmental effort, in terms of the resources and capabilities of the country or the institutions involved; each was the result of team research or organized efforts requiring the participation of several individuals or institutions; each required more than one agency or bureaucratic system for the performance of all phases of the innovation; they all possessed some international dimension, whether from NAS or NSF, the UN, AID, a multinational corporation, or a contract group, or at a minimum, related training in a foreign country; and they each involved the acceptance of some decision-making responsibility by the "users" for "client groups" who were the intended beneficiaries of the innovation. We did not examine projects that were considered complete as soon as the scientific or technological discovery had been made or the capital infrastructure constructed. These criteria, conjoined with the restriction that only "success stories" were used to analyze the functional participation by science policy bodies, permitted us to examine a fairly broad spectrum of fields in which some scientific or technological element contributed to a developmental goal.

The five countries studied showed a wide range of relationships between "users" of technologies, who are the "client groups" of development programming, and the scientific community. Participants in the relationships included various multinational corporations, university bodies, and government agencies, each acting separately with such potential users as cocoa farmers, fishermen, public
housing corporations, state farms, cooperatives, food processors, small farmers, and industries.

The country studies are on file in the Foreign Aid Seminar Reading Room, Littauer 119, Harvard University. David N. Merrill wrote the field reports on Indonesia (56 pp) and Taiwan (29 pp); Ronald Bobel on Brazil (58 pp) and Colombia (30 pp); and Michael Bloom on Ghana (75 pp plus appendices). John D. Montgomery visited Taiwan, Indonesia, and Ghana, and Milton Esman visited Brazil, while the field research was under way.

This inquiry was possible only because of the gracious cooperation of the directors and staff members of science policy bodies in these five countries: especially Y.S. Tsiang, Minister of Education, Professor Ta-Chou Huang, and Dr. Y.T. Wang, Secretary-General, JCRR, Taiwan; Dr. E. Otero Ruiz, Director, and Fernando Chaparro, staff member, COLCIENCIAS, Colombia; Dr. A.N. Tackie, Chairman, and Dr. Robert Dodoo, staff member, of CSIR, Ghana; Dr. Bachtiar Rifai, Chairman, and Rio Tachwartono, staff member, of LIPI, the Indonesian Institute of Sciences; and Dr. Manoel da Frota Moreira, Science Director, National Research Council (CNPq), Brazil.

Dr. Harrison Brown, Foreign Secretary of the National Academy of Sciences, and several staff members, especially Victor Rabinowitch, Julien Engel, and Michael Dow, generously briefed us in preparation for the field work and commented on the first draft of this report. Professors Harvey Sapolsky and Nazli Choucri of the Massachusetts Institute of Technology, joined Lester Gordon and Gustav Papanek of the Harvard Institute for International Development in an evening seminar devoted to a discussion of our findings. We were reassured by their recognition of the problems we identified
in this survey; they would not, however, wish to claim any responsibility for what we have written.

We hope that science policy-making can be examined in the future as economic planning has been in the past. For the "scientific method," with all its mysteries, is much better understood than are the processes by which it has been most successfully applied to developmental needs.

Newton, Massachusetts
Ithaca, New York
15 March 1974

John D. Montgomery
Milton J. Esman
This evaluation of experiences in Taiwan, Indonesia, Ghana, Colombia, and Brazil, has focused on three questions:

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In considering all three issues, our hidden agenda was to consider whether, and how, experience could point the way to improving performance in the future.


Economic development plans in all five countries have incorporated major assumptions and aspirations involving science and technology. Only rarely, however, were these elements of the plans generated by the science community itself; quite properly, they have reflected economic decisions and sectoral objectives developed by ministries and operating agencies of the government. For the most part, scientific participation in this level of planning has been minimal. Such haphazard attention to science and technology
may not be sufficient in the years ahead because of the potential contribution of technology to development and because of the obligation of scientists to reflect on the feasibility of proposed national goals. As yet, however, we have observed few instances in which scientific judgments played an important formal role in decision-making. In Indonesia, scientists have begun to participate in feasibility considerations, but largely because of friendly personal relations and shared professional experiences among leaders of the economic planning and science policy agencies. The national science agency, LIPI, contributed chapters to the current 5-year plan, and task forces made up of economists, scientists, and administrators have studied long-term problems in such fields as natural resources and environmental policy. Conscious efforts to expand this approach have recently taken the form of mixed panels of university, ministerial, and agency scientists and technologists organized to consider economic elements such as labor absorption, the use of local materials, and foreign-exchange effects, in assigning priority ratings to research projects. But these efforts have not yet been institutionalized.

Responsible scientists are understandably reluctant to make administrative and policy decisions that lie outside their professional spheres of competence; yet science agencies have to be concerned if discoveries or potential discoveries are ignored because no agency is organized so as to act on them, or if there is no incentive for their adoption, or if plans disregard technological feasibility. Scientists cannot ignore the social consequences of their efforts, even though they hesitate to depart from their professional roles.
Attention on the part of Taiwan's scientists and technologists to problems of organization and incentive has paid off in that country. Organizational styles of science policy-making are much more isolated from social and economic planning in Brazil, Ghana, and Colombia; and while many other factors contribute to Taiwan's successful uses of science and technology, it is clear that the extensive range of links available to its scientists has contributed to the rapid communication of scientific advances.

One of the most successful efforts in this direction is the extensive use of the task force technique in Taiwan. An example is the Technical Committee on Mushroom Improvements, which was organized after scientists had discovered how to use synthetic fertilizer for raising mushrooms. The efforts of this committee produced a new industry whose annual exports reached $53 million in 1972. The committee was chaired by a representative from the Ministry of Economic Affairs, and included representatives from twelve organizations, including public, mixed, and private agencies. Scientists participated in all of its decisions, including those of technological applications, administrative arrangements, and incentive structures. The Committee financed research only after identifying the most promising areas for support, and it established methods for rationing quotas to farmers' associations and packers, arranged prices, and resolved disputes, thus performing a series of actions that involved all major types of developmental decisions. The success of this enterprise led to the creation of a similar structure for the diffusion of innovations in the production of asparagus -- producing another new export industry amounting to $39.6 million in 1972. Taiwan has found that the most effective
way of planning innovations has been to invite representatives of other ministries to participate in the deliberations and decisions of national science policy agencies, rather than to attempt to impose "science policies" on operating agencies.

Science policy agencies have also found it necessary to maintain close liaison with planning offices and budget agencies which influence the setting of priorities and the allocation of resources. A sympathetic understanding on the part of these agencies of the role of science and technology in development, of the importance of investing in science infrastructure, and of the need to link R & D facilities with users, can be the margin of difference between success and failure in a nation's developmental performance. The closer the liaison between the science policy agency and the agencies responsible for planning and for finance, the more likely it is that adequate resources will be allocated for science activities, that they will be focussed on national priorities, and that operating agencies will be induced to emphasize the critical link between research facilities and potential users. The close link in Brazil between the National Research Council and the Ministry of Planning has contributed to the scale and the focus of Brazil's current investment in science and technology and their link to national development priorities.

Generally, the flow of information regarding the relevance of technology to developmental problems is strongest when the perceptions of need and utilization are strongest among potential clients, not when scientists attempt to increase their collective influence by "colonizing" other agencies.
Recommendation 1: Scientists should seek to introduce technological considerations into national economic planning decisions. One way they can approach this goal without exceeding their professional mandate is to invite planners and administrators from staff and operating departments to serve as advisors to science policy-making bodies, so that the developmental thrust of their own activities can be integrated into national plans. Gaining access to national planning processes for the purpose of analyzing feasibilities can be facilitated by such institutional linkages.

Plans for the development of a nation's scientific resources tend to be made by a process of internal bargaining and negotiations, without much attention to national developmental goals. Conversely, when science and technology policy issues reach major proportions, they are not made according to scientific criteria alone. In most cases, the process of reconciling proposed investments in science with other claims on the national budget, and integrating new technologies with existing practices, involves so many potential interest conflicts that planning becomes a political process. At times this process has produced from the science and technology community a mere shopping list of intentions, leaving choices to be made with little systematic basis for comparing alternatives and consequences.

A more rational approach has been to integrate these decisions with other national priorities. Thus, for example, a joint Brazilian-American study group organized by NAS strongly recommended
a series of policy interventions in industrial research that would involve significant changes in the nation's stewardship of its economy. These recommendations, most of which have been implemented, have been directly instrumental in defining Brazil's national goal of technological modernization, which was to enable its exports to compete in world markets in technology-intensive products. Colombia, on the other hand, has identified in its science and technology plan the need for developing labor-intensive processes and making more effective use of excess capital equipment in order to reduce growing unemployment. As should be expected, these national goals and priorities have implied different science policies. Both approaches called for an extensive financial commitment of non-market oriented investments, to be preceded by major scientific activities. Each, however, involved policy interventions at that no-man's-land where economics merges with technology. In both cases, moreover, the institutional capacities for integrating these elements of national policy determined the extent to which these plans became more than hopes.

Recommendation 2: Since economic plans and national science and technology policy statements usually call for major commitments that cannot be financed by commercial means, they necessarily imply substantial public investment. In such cases, the plans should set forth a clear set of priorities in terms of which budget allocations can be made and scientific personnel and other resources assigned. Such investments involve both economic and scientific consequences, and priorities should be established by consultation with both communities.
One of the major infrastructure problems in science policy is choosing between engaging a limited technological capacity in many areas, as against having a "critical mass" of scientists at work in a few problem areas. Our observations lead us to opt strongly for the latter choice. A proliferation of understaffed units does not produce the broad range of scientific capacity needed to solve developmental problems; it has been much more likely to generate a series of tiny but ambitious empires, each enclosed by feelings of isolation and neglect. A "critical mass" of scientists and technologists working on important national problems has not only permitted creative interaction and provided psychological reinforcement to the participants where it has developed, but it has also attracted clients and generated respect for R & D activities. Both Indonesia and Ghana displayed some examples of proliferation for the sake of a comprehensiveness that did not seem essential given the limited resources.

**Recommendation 3:** The structure of the scientific and technological research effort should be "lumpy" rather than "thin-but-even," especially in situations where resources are scarce. Each new incremental addition to the national capacity should appear in concentrated form rather than by proliferation of individual isolated efforts.

Technological interventions from the public sector have been especially valuable in cases where small-scale producers were unorganized or could not finance or make use of advanced technologies. National plans are increasingly calling for modernization of the "informal" sector, which is primarily made up of numerous small-scale producers that are not effectively organized and cannot afford their own R & D facilities. The reason for this trend is
that the poorest sectors usually employ technologies that follow traditional patterns, are labor-intensive, and use little capital; often it is they that have the most to gain from research and development. In response to such a problem, the Animal Husbandry Institute in Ghana devoted considerable attention to developing cheap incremental improvements in the care and feeding of household livestock (families with a few chickens and goats), somewhat against preferences in Accra for the development of a modern livestock industry. Similarly, in Taiwan, new industries in the informal sector -- growing mushrooms, asparagus, and eels -- started from scratch a few years ago and now bring over $150 million annually in foreign exchange. All involved low technology, small-scale, mass-produced commodities. When the National Institute for Metallurgy in Indonesia did not see any way it could be of service to the multinational mining corporations at work in the country, it decided to concentrate on extracting metal from low-grade ore and on "people's mining" technologies. In Ghana, the trend is exemplified by a new Technical Consultancy Centre at the University of Science and Technology, Kumasi, to serve cottage industries. Usually the informal sector is not aware of the possibility of developing technological improvements that will permit it to advance from traditional processes. In such cases, it may not be possible for laboratories to confine their activities to responding to "felt needs" of organized clients; they may have to develop innovations and then disseminate them themselves simply because no other agencies are able to do so. They should develop as many links with these potential users as may be necessary. In short, government laboratories should be prepared to take over diffusion
and extension activities wherever necessary, and as long as necessary to accelerate the introduction of new technologies.

**Recommendation 4:** Government laboratories should explore ways of developing and supplying technologies that can benefit small-scale producers who have least access to modern processes and commercial sources of improvement. Successful involvement in such projects may require a departure from conventional scientific activities.

2. Organizing for Science Planning

Patterns of official science decision-making and the organizational linkages of science policy agencies tend to reinforce traditional approaches in most of the situations we observed. Central science policy-making bodies in Ghana and Indonesia have concentrated on what they regarded as purely scientific problems and on their relationships with international organizations and resource-supplying government ministries. They have not been much concerned with developing channels for conveying new research findings to clients, or with transmitting user needs to researchers, or even with developing incentive systems that rewarded innovation in their own laboratories. For this reason, such "secondary" decisions have had to be made at subordinate levels, peripheral to the centers of power, without guidance from above. Thus they have often lacked legitimacy; their importance was not confirmed in policies proclaimed from the top, and indeed some activities of scientists and technicians that seemed the most innovative of any we saw almost resembled bootleg operations.
Recommendation 5: Central science policy agencies should explore ways of involving government laboratories and research institutes in the problems of innovation, especially in field and service units of national ministries and operating agencies. Devices that have been used for this purpose are: conducting special training programs for agricultural extension personnel; supplying field stations with new products and demonstration equipment; and performing contractual R & D functions for local government units.

Recommendation 6: Central science policy agencies should devise internal incentive systems that will reward development-oriented research. They should encourage laboratories and technological institutes to provide appropriate services to sectors that represent important thrusts of the national development plan. Devices for opening up these possibilities have included the following: careful internal review and analysis of the national development plan to identify research opportunities and technological needs; staff conferences to review the internal organization and operating styles of science agencies that have succeeded in developing and disseminating applied research; comparative analysis of cases of successful technological innovation arising from the efforts of science and technology agencies; and ad hoc problem-solving conferences devoted to the problems of sectors and agencies in a relatively primitive state of technology, including participation from other sectors that have advanced to more productive stages.

Recommendation 6 will encounter skepticism and even resistance from
some centrally located science policy-makers. They may even be unaware that success has accompanied any of the efforts of their colleagues (all five countries had such experiences, however, even though they have often gone unrecognized). It will also risk arousing rivalries among researchers and agencies that have achieved different stages of development. But success, even on a small scale, seems to be one of the most important underutilized resources in science policy-making. Progress in one area is more likely to contribute to progress in others than to inhibit them. Scientists who have produced "success stories" have explained their achievements more by citing administrative ingenuity -- which is transferrable -- than scientific genius -- which is not.

Scientific purism (i.e., lack of concern for externalities) has sometimes inhibited innovative approaches to policy-making. We observed several instances in which central science agencies were urged to differentiate their structures along disciplinary lines or according to some imaginary spectrum of pure research, problem- or mission-oriented research, and applied research, and then to identify and assign functions in terms of these abstract categories. In Indonesia, for example, a recent UNESCO report criticized LIPI for operating research laboratories while offering overall science policy advice; this despite the fact that LIPI's institutes constituted only about 10% of the total number of such agencies, and that the potential grouping together of the laboratories offered some economies of scale and also enabled scientific and technical manpower to reinforce each other. Such niceties of organization are counterproductive: quite often our field studies concluded that the most effective institutions were those that did not follow
conventional distinctions like science and technology or pure and applied research. In the most successful applications of research to development, the science agencies concentrated on problem-solving and developing strong client support.

The effectiveness of national science policy agencies is strongly correlated with the breadth and the intensity of their links with agencies that finance, sponsor, and control R & D activities. Central science policy agencies usually have direct control over only a few R & D units themselves, since most R & D has to be conducted by operating agencies as a function of their substantive responsibilities in such fields as agriculture and transportation. Science policy makers need to maintain constant communications with such units, not only to reinforce their access to funding, but also to encourage widespread technological diffusion and evaluative feedback. If central science policy makers are to influence manpower development, for example, they must maintain close liaison with the ministry of education and with the universities. If they are to sponsor interdisciplinary research or to promote the doctrine, policies, and practices of effective coupling between research agencies and research users, they must forge links with ministries and departments that operate R & D programs. Almost every example of successful innovation we observed involved direct client participation in the transition of technology from laboratory to field. In many, though not all, cases, this participation was structural, and it involved devising some formal means for ascertaining which client needs could be served by technological means. Even in sectors or industries where the
science community has been understaffed and ill organized, and where neither the government nor user groups had adequate links to research and development, the introduction of client participation in decision-making has accelerated the generation and introduction of technological innovations. The Animal Husbandry Institute in Ghana, for example, solved problems of livestock-feeding and developed new products to render poultry produce commercially attractive only because individual scientists happened to become aware of these needs. Farmers' Associations in Taiwan not only took prompt advantage of new research that had commercial possibilities, such as the mushroom discoveries and the technology of eel production, but also successfully urged government-sponsored laboratories to solve such problems as "downy mildew" in the newly developed hybrid corn industry. The polymer chemistry laboratory in Brazil, although clearly in an early stage of development, made use of contract funding for industrial clients not only as a means of increasing its staff resources, but also in order to identify priority research problems to guide its own activities.

Recommendation 7: Science policy agencies concerned with development cannot confine their activities to the scientific community. They must relate both to public agencies charged with operating responsibilities on development and to potential clients for technological innovations.

This recommendation runs counter to the preferences of some science policy-making officials we encountered during this study, who perceived problems of internal organization as matters of high priority but took it for granted that once these problems were solved valuable client relationships and socially useful discoveries
would follow automatically.

In one country where science and technology plans seemed to be exclusively concerned with the development of communications within the scientific community, science policy became a mere re-assignment of responsibilities among government agencies and neglected to arrange for client participation in the chain of development. But there is no reason why problems of central organization should have to be resolved before science bodies can approach client groups for support. Indeed, our field reports suggest that when centralized science agencies and research laboratories undertake a joint search for client relationships, this process itself helps to resolve problems of internal organization and management. Numerous examples illustrate this point: the skepticism with which contract relationships were greeted when first explored by geologists and seismologists in Taiwan, or by the chemists in Brazil, or by the Bandung institutes in Indonesia, or by the Buildings and Road Research Institute in Ghana, eventually gave way to central acceptance of the practice as a means of supplementing scarce budget resources, and later as a device for speeding technological innovation. In some cases governments were able to reduce their budgetary support to public research institutes as a result of successful entrepreneurial ventures with private sector sponsorship.

The contract route has its risks, however: it may reduce the capacity of research laboratories to deal with problem-solving tasks if they devote too much attention to the search for funding in order to supplement personnel resources, or if they continue to accept routine service and maintenance functions that would be
better performed in the commercial sector. Research laboratories need a constant (even if small) flow of funds to develop their own ideas. Thus we were concerned over the report that Indonesian facilities that had been created to render glass-blowing services to research laboratories had to supplement their resources by accepting contracts to make neon signs; and that facilities intended for research and development of military and civilian electronic equipment in Indonesia began to engage heavily in simple repairs of television sets and communications equipment. In Ghana, the Soils Research Institute is now routinely used in soils testing in connection with loan applications to the Agricultural Development Bank, a task which might eventually absorb its entire capacity. Like other administrative devices designed to encourage change, contract relationships need to be periodically reviewed.

Another device useful in cases where clients are not aware of the potential benefits of research for their own needs is that of issuing licenses for the use of ideas generated and patented by government laboratories. A case in point is an improvement in tire retreading processes discovered by the polymer program of the National Research Council in Brazil. The discovery came about as a result of a casual visit by scientists to a plant in Rio Grande do Sul, who returned to the laboratory, developed the process, secured a patent, and sold licenses for its operation.

Recommendation 8: Government laboratories should be encouraged to engage in contract tasks for the performance of routine service functions only until other instruments can be developed for that purpose. A few routine public service operations
like testing and standards setting should continue to be performed by governmental laboratories because they are necessary for regulatory and developmental purposes. In other cases, however, research directors should review the practice of performing routine functions that detract from R & D.

Mobilizing scientists and technologists from industry, government, and university communities to solve developmental needs is a difficult task. In most countries, scientific equipment and human resources are scarce, and yet it is not easy for scientists and laboratories to share equipment, exchange personnel, and collaborate on technological problems. These forms of cooperation do not take place automatically even in small scientific communities; in many cases we learned that an NAS workshop or panel had identified common concerns among scientists and technologists who were acquainted socially but had found no occasion to exchange their professional views and concerns. Science policy-makers should not have to wait for foreign intervention to create such opportunities; but sometimes only an external catalyst like AID and NAS can provide the occasion for such preliminary exchanges.

Historic relationships among these groups is no guarantee of future cooperation. In Ghana, the palm oil laboratory was originally part of the university research station, but when it became a separate entity, the tendency was to duplicate equipment and compete for personnel. University personnel were engaged by the Volta River Authority to study schistosomiasis vectors and by the Cocoa Producers Association to study entymological problems, but even in this small community the two groups were reluctant to share equipment purchased under different budgets. In several countries we
observed jealousy over the assignment of graduate students to
government laboratories for research, difficulty in establishing
educational opportunities for qualified personnel who lacked
credentials, and a surprisingly great amount of career uncertainty
even among young men and women who possessed skills that are in
short supply. Such uncertainty has clearly contributed to the
internal scientific "brain drain." In Colombia, COLCIENCIAS has
been exploring means for motivating scientists to return to their
homeland and for enlisting their professional interests in develop-
ment-related research. This effort should be extended and emulated.

Recommendation 9: The tensions between the "university," "government," and "industry," or between "science" and "technology," should not be resolved at the expense of either. Science policy agencies have the obli-
gation to create institutional opportunities for both "factions" of the community to interact so that they can find ways of differentiating their functions while reinforcing each other's efforts.

This recommendation is both less obvious and harder to achieve
than might appear. The need for development-oriented research
should not oblige university personnel to abandon "curiosity-led" research; indeed, policies that deny resources for academic re-
search projects are short-sighted, not only because they risk
alienating their own scientists, or because such research is some-
times the leading edge of change, but also because universities
cannot perform effectively in any society where their role is viewed
as "mere" training and the "dispensing" of knowledge. We identi-
ified several projects in Taiwan that derived from university
research which had no government support in its initial stages; in
one case in Ghana graduate students were able to participate in useful "applied" research only because a professor was interested in the theoretical implications of his findings; in Ghana, too, we found strong support among university personnel for a policy that permitted a faculty member to seek modest funding for research activities on the basis of demonstrated academic value, even when larger resources were available for applied research in that same faculty.

3. International Participation

The kinds of decisions in which science policy makers have participated are of three categories:

- first-order decisions, involving choices of technology, priorities in science programs, and major resource allocations;
- second-order decisions, regarding the assignment of responsibility among research and operating agencies for the development and application of new knowledge and the dissemination of approved technologies; and
- third-order decisions, exploring incentives that will encourage individuals to perform fruitful scientific research and to adopt promising new technologies.

Direct international participation has been most effective in analyzing first-order decisions. International workshops have also given scientists and other policy makers insights into second- and third-order decisions. But since these decisions are truly of a different order, in the sense that they involve a different range of experience, the structure of international collaboration needs to be broadened.
The form of international participation we observed most closely is the AID contract relationship between the US government and the National Academy of Sciences for holding workshops and study panels in underdeveloped countries. Other devices used for international technical assistance in scientific development include the assignment of individual specialists abroad, ad hoc host country contract relations with consulting agencies and the National Science Foundation, operations by multinational corporations, and internationally supported regional research agencies. All have served their respective purposes reasonably well. In the case of the NAS specifically, we see no reason to change the general approaches and formats that NAS has developed pragmatically.

The National Academy of Sciences represents both the eminent quality of America's science and the prestige enjoyed by its technology. While the NAS stands for the highest standards in science, it reflects also the American tradition of successful application of science to social needs. It maintains and nourishes a constantly expanding network of mutually reinforcing relationships with both government and industry and it draws upon a strong tradition of effective research administration.

The National Academy of Sciences is, therefore, an excellent vehicle for interpreting science and technology to countries interested in the possibility of applying American methods in the development of their own capabilities and policies. It has access to the most distinguished natural scientists in the United States and, through the National Academy of Engineering, leading engineers, and industrial researchers. Moreover, it can mobilize their participation in public service activities at an extraordinarily low cost.
and indeed, often enough, at no cost at all above operating expenses.

It appears that the workshop model has been most effective in three contexts: (1) for demonstrating to members of the participating political, administrative, and scientific elites that the role of science and technology in development is an instrumental one, i.e., that science policy has less to do with developing science than with applying scientific and technological capabilities to national goals; (2) for identifying specific problem areas for priority attention by the host-government, possibly giving a basis for future cooperation with American scientists; and (3) for periodic evaluations of the progress of the host-country's scientific and technological infrastructure, their application to the national goals, and the emergence of new problem areas.

The study groups and panels, on the other hand, have been useful for exploring lines of action associated with specific subjects identified in workshops or in other forums and for generating action by the host-governments to overcome these problems. They have also helped to highlight opportunities for assistance by AID or other international development agencies. Experience with bilateral cooperation seems to suggest a sequence from initial emphasis on comprehensive workshops to a subsequent focus on more specific activities, with workshops declining in importance, in favor of more intensive involvements in specifically defined activities, including the implementation of workshop recommendations and science policies.

NAS activities may also culminate in operational programs like the graduate chemistry project in Brazil, which proved to be a very
successful AID-financed but NAS-staffed technical assistance project.

Science policies are not made by scientists alone. As science and technology become more important ingredients of public policy, politicians, planners, and administrators begin to consider that science policy is too important to leave to the scientists. When substantial public funds are at stake and R & D comes to be recognized as important to the achievement of substantive development goals, science policy becomes involved in the politics of planning and budgeting. The government agency with formal responsibility for national science policy has to share this function with planning agencies, budget bureaus, and manpower offices. Unless it develops the interest and the capacity to expand its role beyond the training of scientists and the sponsorship of academic research, and into such substantive areas as manpower policy, choice of technology, research administration, interdisciplinary R & D, incentives and procedures for linking R & D agencies with users, and terms and conditions for the international transfer of technology, they are likely to find the science policy decisions are being effectively taken out of their hands. Science policy agencies, springing as they usually do from research councils with modest substantive range, must grow in scope and in sophistication with the expansion of science policy issues in their governments. Through linkage arrangements, they become participants in a complex of institutions which share responsibility for scientific and technological development. There may be built-in tensions within this complex between a science policy agency protecting the values of pure science, a manpower agency promoting the development of trained personnel, and a planning agency emphasizing applied technology and rapid economic payoffs.
The NAS usually finds itself cooperating directly with a National Research Council or similar "scientists'" agency formally responsible for science policy. But these agencies have to begin to expand their scope beyond academic research into more complex problems of development and the importance of forging links with planning agencies and with operating units that control funds and perform applied research. The NAS should staff workshop teams to include members who understand the frustrating complexity of national science policy structures and the tactics by which scientists' agencies can continue to exert influence within them.

Recommendation 10: The agenda of NAS workshops should not be limited to "research" topics, but should, as has been the case in the most productive examples of the past, include problems of implementation as well. Such workshops should include among their participants individuals who have experience in government and in industry and are familiar with the second- and third-order decisions that will have to be made to implement any practical recommendations that may be forthcoming.

Recommendation 11: In order to improve the prospects of implementing workshop recommendations, participants should take care that organizational and administrative considerations are included in the language of the final report. Disembodied recommendations that avoid second-order implications can lead only to disembodied policies.

Given the brevity and the discontinuous character of workshop and panels, NAS involvement of scientists and engineers has necessarily been episodic. Under these circumstances there are serious risks that persons with little overseas experience and
cross-cultural contact, and limited knowledge of the complexities of social and economic development or of an individual country situation, might commit unintended but embarrassing mistakes resembling the classical Ugly American syndrome. We found evidence of such behavior in Brazil and elsewhere, though this has not been characteristic of the NAS teams. On the contrary, the results have generally been increased understanding, opportunities for long-term influence, and in many cases a warm personal and institutional relationship.

**Recommendation 12:** Where possible NAS should attempt to structure and to encourage long-term, recurring commitments and associations by American participants to projects that involve host-country colleagues, both for the intrinsic values of these relationships and for the enhanced knowledge that inevitably contributes to better-informed advice.

Despite the conscientious efforts of the NAS staff to arrange for individual briefings of panel participants, the time devoted to them is far too short, and the atmosphere is often hurried and casual. The net benefit of the briefings is far less than the seriousness of the enterprise would seem to require. The NAS should find ways of providing more focussed documentary information before the briefings, and of extending the time and resources available for pre-departure study.

**Recommendation 13:** Because of the fact that NAS team members are recruited from a variety of backgrounds, they are usually handicapped by limited knowledge of the host country and of development processes. We believe that much more thorough attention should be given to pre-departure briefings.
One of the unique features of the NAS service has been its ability to involve distinguished scientists without paying them any honoraria above actual expenses. They have volunteered their participation in panels and workshops devoted to the problems of other countries as part of a professional obligation and as a valued learning experience for themselves. We confess our ambivalence about this practice. It seems to work; it is an eminent display of international good will; it probably encourages scientists and civil servants of the host country to participate on the same basis -- an essential condition in countries that do not permit compensation for such official assignments. On the other hand, it limits NAS access to scientists who value their time in terms of financial opportunity costs and to persons experienced in international development for whom such an assignment is not a novelty. It may also have contributed to an almost amateurish attitude about the seriousness of the workshop and study group efforts.

This issue cannot be resolved in the abstract. We are sure, however, that a general policy against compensating workshop participants would be unwise for the indefinite future. There have already been cases where NAS has paid hard-to-get workshop or panel members an honorarium in order to avoid actual opportunity-cost losses. Payment for the time they spend preparing for and participating in these overseas missions may not greatly increase the attractiveness of this form of public service to distinguished American scientists, but it might have the effect of creating a more serious and professional atmosphere during the briefing process. Payment does not guarantee performance, but it creates a basis for
enhanced expectations.

Recommendation 14: NAS should not hesitate to offer compensation to panelists whose services are deemed necessary and who are otherwise unavailable, especially those whose skills or expertise lie in international fields and in disciplines not represented by the NAS membership. Even where panelists offer their services overseas on a voluntary basis, there might be occasions where an honorarium is needed to compensate for time spent in briefing and preparation.

The field studies have underlined the importance of the NAS staff role in all phases of the workshop and study group cycle. From the original exploration of opportunities for cooperation to the establishment of terms of reference for workshops and study groups, and from the recruiting of team members and preparing them for their missions to managing the details of the workshops, maintaining continuous follow-up of individual workshops and panels, and monitoring the state of scientific and technological relationships between the NAS and the host country, the NAS staff members have a set of responsibilities which are intellectually taxing and which require extraordinary interpersonal and diplomatic skills. For the most part, the NAS staff members have performed well in these roles. Indeed, we perceive that if anything their efforts have been underestimated. They have been regarded as expediters and brokers in these relationships; their status and recognition have not been commensurate with their responsibilities. Indications are that the NAS staff will have a still larger role to play in future cooperative arrangements with developing countries. There is, however, some reason to predict that this role will change.
somewhat in the future.

The principal deficiencies of the natural scientists and engineers whom NAS recruits into its overseas activities are not in their scientific and technological knowledge, but rather in their understanding of public policy, especially of public policy in a developmental setting. These deficiencies are compounded by similar shortfalls of knowledge and experience on the part of host national participants. The NAS staff members may be the only component that can compensate adequately for such deficiencies.

**Recommendation 15:** NAS staff resources should include men and women who are professionally qualified in the processes of economic and social development, with special training in the emergent field of science policy. NAS staff should also be regarded as full participants in the workshops and other activities because of additional and indispensable expertise which they would bring to these forums.

Without sacrificing any of the necessary functions which they now perform conscientiously and effectively, the NAS staff can be upgraded to emphasize their special capabilities in economic and social development and in science policy matters; future NAS recruiting should be oriented in this direction. NAS should also give consideration to the fact that deficiencies in country information are inherent in the process of team recruitment. One means of compensating for such deficiencies is to assign NAS staff members over extended periods of time to specialize in the problems of a group of countries with which NAS maintains or expects to establish cooperative relationships.
TABLE I
CHARACTERISTICS OF NAS PARTICIPANTS

Number of scientists participating 305

Average Age, where available 55½ years

Professional disciplines represented

<table>
<thead>
<tr>
<th>Discipline</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physics and Chemistry</td>
<td>59</td>
<td>19%</td>
</tr>
<tr>
<td>Engineering</td>
<td>51</td>
<td>17%</td>
</tr>
<tr>
<td>Nutrition, Botany and Biology</td>
<td>40</td>
<td>13%</td>
</tr>
<tr>
<td>Social Sciences and History</td>
<td>39</td>
<td>13%</td>
</tr>
<tr>
<td>Geology and Oceanography</td>
<td>34</td>
<td>11%</td>
</tr>
<tr>
<td>Agricultural Sciences</td>
<td>30</td>
<td>10%</td>
</tr>
<tr>
<td>Science Policy and Technology</td>
<td>13</td>
<td>4%</td>
</tr>
<tr>
<td>Medicine and Public Health</td>
<td>10</td>
<td>3%</td>
</tr>
<tr>
<td>Mathematics</td>
<td>6</td>
<td>2%</td>
</tr>
<tr>
<td>Computer Science</td>
<td>3</td>
<td>1%</td>
</tr>
<tr>
<td>Education</td>
<td>3</td>
<td>1%</td>
</tr>
<tr>
<td>Law</td>
<td>3</td>
<td>1%</td>
</tr>
<tr>
<td>Information not available</td>
<td>14</td>
<td>5%</td>
</tr>
</tbody>
</table>

Institutions represented

<table>
<thead>
<tr>
<th>Institution</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Universities</td>
<td>184</td>
<td>60%</td>
</tr>
<tr>
<td>Government</td>
<td>59</td>
<td>19%</td>
</tr>
<tr>
<td>Industry</td>
<td>41</td>
<td>13%</td>
</tr>
<tr>
<td>Foundations</td>
<td>16</td>
<td>5%</td>
</tr>
<tr>
<td>No affiliation</td>
<td>5</td>
<td>2%</td>
</tr>
</tbody>
</table>

Members of NAS 27 9%
The range of disciplines and the high technological sophistication of the participants in the NAS workshops and panels are impressive (see Table I): in this sense they accurately represent the larger community from which they are drawn. The panel and workshop reports have also reflected the well-recognized American skill at "putting science at the service of man." Versatility, sophistication, and application are "all-American virtues" that have been successfully captured in the NAS ventures.

We are concerned that various international considerations have limited the flexibility NAS would otherwise enjoy in its cooperation with developing countries. For one thing, the list of countries that have access to NAS collaboration is narrowing. Countries that can benefit from such association range from AID "alumni nations" where the NAS association can be a continuing vehicle for bilateral intellectual cooperation, through the countries with active AID programs where the NAS activities might help to identify specific projects for more intensive AID or a third country financing, to the least developed countries with minimal scientific and technological infrastructures and almost infinite need for assistance of all kinds. Experience indicates that NAS relationships tend to be easier in countries which are relatively advanced in the development of their scientific and technological capabilities, because there is more for the NAS team members to work with. But this only means that workshops in the least developed countries will require more careful planning by the NAS staff, more intensive briefing of the workshop or panel participants, and in all likelihood much more imaginative programming than
has been necessary in Brazil, Taiwan, and Korea where conditions have been so favorable for rapid progress. Indeed, it may be at the polar extremes of the AID alumni countries and the least developed countries that most of the future opportunities for NAS participation will come. This concentration of effort will require a more conscious and systematic development of a body of knowledge and practice for planning and managing these relationships than has been needed in the past.

We are also concerned that NAS has had to take the lead in so many situations in announcing its own availability and gently promoting its own services. This function should, we believe, be more strongly supported by ambassadors, economic officers, science attaches, AID mission directors, and even the USIA.

Recommendation 16: AID and NAS should explore means of financing collaborative relationships in S and T with countries not officially receiving American bilateral assistance. Foundation support for such ventures and funding from information and cultural agencies of the US government should not be excluded from consideration. We recommend that the Office of the Foreign Secretary, NAS, undertake a major effort to develop means of financing ventures when American science and technology have special contributions to make even though the country involved may not be on the active AID list.

The principal problems facing developing countries in their science and technology policies are: (a) building their science and technology infrastructures in education, research, development, and engineering; and (b) directing them instrumentally toward
national development goals and priorities primarily through public policy measures.

The principal problem in international cooperation in science policy is to find the right "fit" between country needs and technological capacity. It is possible that further research will identify sequences or patterns of development in science and technology that will make it possible to identify institutional needs more quickly. For example, observations in Taiwan, Indonesia, and Ghana suggested that there are patterns of relationships between elements of the science and technology community and elements of the society that become the clients or users of technology. These sequences may not appear simultaneously in all sectors, and indeed it seems likely that in most countries science and technology are applied very unevenly across different sectors. The relationships among science and technology bodies, and between them and client groups, provide one way of identifying their respective needs and prospects in a given sector.

Situation "A" in Fig 1 is one in which the relevant science bodies are widely dispersed, relatively uncoordinated, and randomly related to users and potential clients. Many scientists in this situation perceive no user linkages; and many potential users are unaware that they had any access to technological advice. In Situation "B" it would appear that a process of regrouping is under way, with scientific bodies attempting to become more unified in their postures toward client groups, and more of them beginning to establish direct contact with real or potential clients. In sectors where this process is well advanced, we found increasing degrees of
"Stages" in the Development of Science Sectors

$s =$ scientist group
$c =$ client group

Characteristics
1. Acute shortage of personnel and institutional structure
2. Scientists define their own research problems
3. Scientists work in isolation, usually with insufficient numbers and limited equipment
4. There is no perceived priority agenda or user relationship; the international communications network dominates science and technology perspectives
5. Users are essentially dependent on foreign technology or traditional processes

Characteristics
1. Focus on domestic problems increases
2. Organizational strength increases
3. Personnel available to S & T increases
4. Ad hoc client relationships develop
5. Rudimentary beginnings of science policy
6. Some technological innovations

Characteristics
1. Increased capacity permits organized R & D efforts
2. Linkages, both scientists-clients and among science policy agencies, become structured
3. Increasingly centralized budgetary capacity and broadened base of funding, usually on sectoral basis

Fig. I
cooperation among scientific groups, some exchange or sharing of personnel among institutions and projects, the development or special task-force approaches to problem-solving, and a conscious effort to develop basic science policies with a mission orientation and an applied focus. Situation "C" is one in which research centers are linked together by means of a coherent science policy which provides a basis for various combinations of reinforcing and supplementary relationships, and converts the inadvertent duplications that appear in Situations "A" and "B" into purposive redundancies. These situation-types seem to be associated with an increasing use of science and technology, increasing consciousness of the potentials of scientists as contributors to the planning process, and increasing involvement by scientific councils and technological institutions in the processes by which goods are produced and services delivered.

The international role appropriate to each of these situations would presumably be different. The expectation is that in Situation "A," international assistance would ideally provide means for developing more coherent and cooperative ventures among individual scientists and between science policy and development agencies, while Situation "C" would provide an occasion for international scientific participation regarding certain client group needs involving interdisciplinary research and high technology inputs. Thus in Situation "A," international assistance would stress the training of basic scientists, and would explore the local institutional requirements for developing an adequate science policy to serve goals established in the development plans. In Situation "B," the problem is to provide opportunities for scientists from different
sectors to work on important development problems and to cooperate in developing a coherent science policy. Situation "C" would imply the possibility of supplying high technology or equipment where needed, and for reinforcing scarce specialties in order to solve developmental problems on behalf of user clients. Needless to say, there will be many exceptional opportunities for international cooperation that do not conform to these expectations: in Situation "A," for example, it might very well be suitable for an international agency to work on high technology problems where a given research group-client relationship permitted it, even though such a participation might run the risk of creating a "scientific enclave" in the society. Similarly, in countries in which large segments of the economy were in Situation "C," international efforts should still find ways of extending science policy and infrastructure to sectors that were lagging behind. But for the most part, the expectation would be that Situation "A" would call for manpower development and specific technical assistance based on known principles and applications; Situation "B" would call for institutional and infrastructure development; and Situation "C" would call for specialized services and integrated policy-making functions spreading out to technological fields.

There are also country situations which seem to be especially favorable for international cooperation. The most successful NAS activities have occurred with countries (1) which enjoy a friendly pattern of political relations with the United States, and (2) in which there is a pronounced feeling of dissatisfaction and need for new departures on the application of science that is shared by
members of the political and administrative elites, as well as by senior members of the science community.

The NAS should hesitate to venture into situations in which there is no interest on the part of the political and administrative leadership. Even in such cases there is risk of unintentional effrontery and superficiality in the advisory relationship. We believe that NAS can reduce such feelings by cultivating the feeling of reciprocity that emerges among those participating in its workshops and panels. It is important to avoid the traditional "technical assistance" syndrome, in which the American component represents elements that are associated with achievement and is in a position where it can only "give advice." In such cases host-country counterparts, though important and distinguished persons within their own societies, often find themselves in a subordinate learning situation. It obviously requires very considerable sensitivity and skill to manage a relationship of this kind.

Recommendation 17: Workshop topics should be structured so that they do not call for "instant solutions" or immediate applications of American experience. They should identify problems requiring international exchanges for their solutions, permitting a careful review of experience from different settings. One possible approach to this problem would be to make occasional use of third country scientists who have participated in previous workshops to augment American and host national participants.

There is another, somewhat less obvious, quality that is becoming increasingly important in the international applications
of science and technology to developmental and other social needs: the successful integration of knowledge and techniques from several disciplines in the approach to major problems. Part of the success Americans have had in developing cross-disciplinary skills lies in problem identification; another lies in the organization and mobilization of team efforts in problem-solving. We have already identified certain dimensions of the inter-disciplinary nature of developmental science policy in our discussion of the importance of second- and third-order decisions even in Situation "A" (scientist-led innovations are heavily dependent on successful diffusion and mass adoptions when user-groups are isolated and unorganized).

In Situation "C" (where well-organized clients are dependent on a centrally situated scientific establishment), problems of inter-disciplinary cooperation seem to be equally intractable. It is in these large-scale technological areas that the NAS access to the American experience in inter-disciplinary research and development may be especially valuable in the future. We heard expressions of interest in the processes of interdisciplinary cooperation both in Colombia and in Brazil. Ironically, the countries most likely to face Situation "C" problems are those least likely to be eligible for AID-sponsored NAS assistance (as advanced countries "graduate" from concessional foreign aid and are expected to finance their own development, they are compelled to use more primitive forms of technical assistance, the direct hiring of individual scientists).

Discipline-oriented technical assistance and conventional means of improving higher education may offer more immediate and more visible payoffs than participation in policy-making or developing
interdisciplinary approaches to problem-solving, but we are convinced that the NAS workshops and panels are better adapted to high-risk ventures than to more conventional traditional transfers of American science and technology. NAS can serve American interests better by using its resources to develop new approaches than by responding to requests for technical assistance of the "Point Four" vintage.

Our final recommendation is that NAS should avoid offering conventional forms of technical assistance, especially in countries where an AID mission is operating or where university groups are available. It should concentrate rather on activities such as science policy and interdisciplinary research where its unique resources constitute a powerful comparative advantage.
CONCLUSION: NEXT STEPS

Few of our findings can claim to be universally descriptive; they are, however, suggestive of areas in which relationships should be explored. They invite a closer inspection of the hypotheses on the basis of which we chose our case studies and developed our recommendations. Among these assumptions the first is that the "success stories" will be found to differ from the "failures" in the institutional dimensions we examined (i.e., if a potentially useful technological finding is produced or communicated to the science and technology community, but the society is unable to take advantage of it, the failure is likely to be associated with organizational and incentive deficiencies). The second assumption is that while the interests of economic planners and science and technology policy makers cannot be fully compatible, they will mutually benefit from cooperative interaction once the opportunities for joint planning appear. Such interaction will permit the economists to gain from an increasing awareness of technological potentialities and feasibilities while the scientists will benefit from improved perceptions of priorities and from better access to their nation's funding processes. A third assumption is that formal or informal linkages between scientists who produce technological innovation and the industrial, agricultural, or government users of these innovations are indispensable to the implementation of science policy, and that therefore the cultivation of such linkages is among the highest priorities for national science policy makers. A fourth assumption is that external assistance in science policy making is most effective
when it takes specific account of the institutional resources and stages of science and technology development of the host country, and particularly when it focusses on the diffusion and use of scientific and technological knowledge.

These assumptions can be affirmed or disconfirmed by research and given the necessary precision for policy and operational guidance. Carefully designed case studies can ascertain whether systematic attention to second and third decision orders is associated with the identification and definition of development-related R and D problems and with faster and more complete diffusion and use of technologies. Interviews and studies of actual field experiences can explore the effects of interaction between senior administrators, economic planners, and science policy makers in terms of their perceptions of national needs and priorities and technological possibilities, and in terms of the performance of the S and T community in relation to national economic and social goals. Patterns of relationships between R and D centers and users can be studied more carefully to determine their effects on technicians' attitudes, incentives, and performance and their impacts on users. Follow-up studies on NAS and similar international interventions can provide more information on the advantages of matching the personnel, substantive emphasis, and cooperative styles of each project with the "stage of development," institutional capacities, and problem priorities of science and technology in the host countries and the specific sectors involved.

Science policy seems to be as much an outcome of the processes by which scientists and technicians participate in national development as of the substance of the research they approve or the
manpower development plans they propose. There is evidence that as each successive country introduces science and technology in its production functions, a shorter "catch-up period" is required, less trial and error is necessary, and more conscious policy choices are made. No one should be deceived about the magnitude of the efforts that will be involved, even though each successive country has a larger "bankroll" of international experience on which to draw. Countries must plan to measure the time required in decades rather than years. But an even more dangerous and deceptive expectation is that because the experience is so extensive, institutional and process questions will be easily solved and experience from the developed world can be directly transferred to current problems of development elsewhere. There is more than enough relevant and on-going experience in international interactions in science policy to justify further research into these processes and their institutional prerequisites so that more precise understandings of these relationships can be achieved. In this way the lessons of these experiences can be captured and applied both for the benefit of science policy makers in developing countries and for international development agencies such as AID and NAS which are committed to participating in the advancement of science policy in developing countries.