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ABSTRACT

This work has been done as part of the effort to plan the National Institute of Education (NIE). The report, one of a series, describes the alternatives that must be considered in deciding the organization and management of a new Federal agency to conduct and support research and development. The alternatives examined are also germane to the design, or redesign, of an R&D agency anywhere in the government, since the alternatives presented are derived from the practices of nine existing Federal R&D agencies. The document considers seven critical organizational decisions that must be made in defining the organization of a Federal R&D institution. These deal with the major features of the organizational form; the organization of support, conduct, and administration services in R&D; the hiring of personnel; and the organization of advisory councils. The report concludes by examining six decisions that must be made in defining the management "style" of a Federal R&D institution. These decisions deal with the major features of managerial style; the methods of budget allocations; the manner of conducting program planning, development, and evaluation; and the management of institutional development. (Author/DN)

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NATIONAL INSTITUTE OF EDUCATION: ORGANIZATIONAL AND MANAGERIAL ALTERNATIVES

Roger Levien, John Wirt and Arnold Lieberman

A WORKING NOTE
prepared for the

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

This Note was prepared to facilitate communication of preliminary research results. Views or conclusions expressed herein may be tentative and do not represent the official opinion of the sponsoring agency.

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PREFACE

This Working Note describes the alternatives open to the planners of a federal R&D agency in specifying its organization and management processes. The alternatives were derived from the practices of existing federal R&D agencies -- National Institutes of Health, National Science Foundation, Office of Naval Research, Office of Economic Opportunity, Department of Agriculture, National Institute of Mental Health, U.S. Air Force, National Aeronautics and Space Administration, National Cancer Institute -- as they were described to us in interviews and official documents. However, not all of these descriptions have been checked by the agencies. This will be done in the near future.

This work was done as part of the effort to plan the National Institute of Education (NIE). If authorized by the Congress, the NIE would conduct research and development in the field of education. This report is one of a series on the Institute. The others are:

- National Institute of Education: Preliminary Plan for the Proposed Institute (R-657-HEW);
- National Institute of Education: Methods for Managing Fundamental Research (WN-7676-HEW);
- National Institute of Education: Methods for Managing Practice-oriented Research and Development (WN-7677-HEW);
- National Institute of Education: Methods for Managing Programmatic Research and Development (WN-7678-HEW); and
- National Institute of Education: Evaluation of Methods for Managing Research and Development (WN-7680-HEW).

Many of the R&D managers interviewed during this study expressed the need for additional study of the methods used in managing non-military R&D in the federal government. The literature on this subject is slight in comparison with the literature concerning the management of industrial and military R&D. This series of reports seeks to provide a basis for research into improved management practices for nonmilitary federal R&D. The principal purpose of these reports, however, is to enable the planners of the National Institute of Education to benefit from the experience of other federal R&D agencies in developing the NIE's R&D management procedures.

ACKNOWLEDGEMENTS

This Working Note has benefitted enormously from the thorough and thoughtful research assistance of Victoria Shoufani, who collected scattered statements and evidence from numerous sources and put them in a form that made subsequent analysis direct and convenient. We are also greatly indebted to the many individuals in the agencies we visited who were unfailingly generous with their time and open and frank in their discussions with us.

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I. INTRODUCTION

There are two principal categories of decision that must be made in designing a new institution. The first category of decision concerns the institution's static form -- the distribution of responsibilities and authority among its suborganizations and staff. These decisions define the institution's *organization*. The second category of decision concerns the institution's dynamic behavior -- the operations and processes through which it executes its responsibilities and exercises its authorities. These decisions determine the institution's *management*. In this report we describe the alternatives that must be considered in deciding upon the organization and management of a new federal agency to conduct and support research and development.

Our specific concern is with the proposed National Institute of Education (NIE), but the alternatives we examine would be germane to the design, or redesign, of an R&D agency anywhere in the government. Indeed, we have drawn upon the experience of a wide range of such agencies, already in existence, to define the spectrum of possible choices. The organizational and managerial alternatives adopted by the National Science Foundation (NSF), National Institutes of Health (NIH), Office of Naval Research (ONR), Department of Agriculture (USDA), National Institute of Mental Health (NIMH), Office of Economic Opportunity (OEO), National Aeronautics and Space Administration (NASA), U.S. Air Force (USAF), and industry have been described and evaluated in the four other reports* in this series. This report

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*J. Wirt, A. Lieberman, and R. Levien, *National Institute of Education: Methods for Managing Fundamental Research*, The Rand Corporation, WN-7676-HEW, November 1971. J. Wirt, A. Lieberman, and R. Levien, *National Institute of Education: Methods for Managing Practice-Oriented Research and Development*, The Rand Corporation, WN-7677-HEW, November 1971. J. Wirt, A. Lieberman, and R. Levien, *National Institute of Education: Methods for Managing Programmatic Research and Development*, The Rand Corporation, WN-7678-HEW, November 1971. J. Wirt, A. Lieberman, and R. Levien, *National Institute of Education: Evaluation of Methods for Managing Research and Development*, The Rand Corporation, WN-7680-HEW, November 1971.

takes the first step in translating that experience for use by the National Institute of Education; it collects and compares the different alternatives these several institutions have selected in making each of the critical organizational and managerial decisions.

ORGANIZATIONAL DECISIONS

Seven critical decisions must be made in defining the organization of a federal R&D institution. They are:

1. *What should be the major features of the organizational form?* The major features include linear or matrix *lines of authority*, horizontal or vertical *scopes of interest*, and centralized or decentralized *distribution of effort*.
2. *How should support of R&D be organized?* One major function of federal R&D agencies is the *support* of R&D to be conducted *extramurally* by nonprofit institutions, universities, or industry. This decision concerns the suborganization of the agency that provides such support.
3. *How should conduct of R&D be organized?* Some, but not all, federal R&D agencies also engage in a second major function -- the *conduct* of R&D *intramurally* by federal personnel located in the agency. This decision concerns the suborganization of the agency that conducts R&D.
4. *How should administrative services be organized?* All federal agencies must arrange for the basic fiscal, personnel, information, and budgeting functions; federal R&D agencies must also arrange for R&D grants and contracts management. These decisions concern the organization of such services.
5. *What personnel authorities are desirable?* The Civil Service personnel system was designed to meet the needs of the conventional government administrative agency. Many government R&D agencies have found that its provisions limit their ability to hire and effectively utilize scientific

personnel. Many agencies have been granted exemptions or modifications of the Civil Service procedures. This decision concerns the kinds of changes in the personnel authority that might be desirable for a new R&D agency.

6. *What personnel qualities are desirable?*
   This decision concerns the kinds of skills to be sought for each of the principal operational roles in a federal R&D agency: extramural program officer, intramural researcher, administrative officer.
7. *How should advisory councils be organized?*
   This decision concerns the mode of organization of the advisory councils, composed of nongovernment scientists and laymen, that most federal R&D agencies employ for guidance and communication.

Each of these decisions is discussed in Chapter II of this report.

MANAGERIAL DECISIONS

Six critical decisions must be made in defining the management "style" of a federal R&D institution. They are:

1. *What should be the major features of the managerial style?*
   This decision concerns the choice of the *allocation of effort* among planning, managing, and evaluating R&D programs; the *degree of control* exercised over extramural activities; the *amount of constituency participation* in decisionmaking; and the *variety of management styles* employed.
2. *How should budget allocations be made?*
   The central management decision is the allocation of the institution's budget among its various activities. This decision concerns the way that allocation will be determined.
3. *How should program planning be conducted?*
   The activities of an R&D institution are ordinarily grouped into *programs*. This decision concerns the methods by which new programs will be planned.

4. *How should program development be conducted?*
   Once a program is planned, the projects to implement it must be selected and monitored. This decision concerns the methods for such selection and monitoring.
5. *How should program evaluation be conducted?*
   Upon completion of a program, its results should be evaluated. This decision concerns the methods for such evaluation.
6. *How can institutional development be managed?*
   In addition to direct management of their own programs, many federal R&D agencies have found it desirable to decentralize program management to nongovernmental R&D centers, laboratories, and institutes through the provision of direct institutional support. This decision concerns the management of such support.

Each of these decisions is discussed in Chapter III of this report.

CHARACTERISTICS OF RESEARCH AND DEVELOPMENT

Three major characteristics of an R&D activity need to be distinguished during the examination of R&D organization and management alternatives.

- *Purpose:* is the R&D activity basic, practical, or programmatic?
- *Scope:* is the R&D activity a single project or the conjunction of projects into a program?
- *Phase:* is the R&D activity in the planning, developmental, or evaluation phase of operation?

Purpose

Many different categorizations of R&D activity according to purpose have been proposed. In this discussion of alternative managerial styles, we shall use the categories of basic, practical, and programmatic R&D.

The central purpose of *basic research* (or *fundamental research*) is the increase of disciplined knowledge concerning the fundamental phenomena and processes of the natural and man-made world. The choice of question to be studied and method of study is primarily determined by the current state of knowledge, the scientist's perception of important gaps in understanding, and by the available research tools. Consequently, the best qualified judges of basic research activities are ordinarily considered to be the scientists who are working close to and are familiar with the frontier of knowledge.

The central purpose of *practical R&D* is improvement in the performance of some practical activity, organization, or object. Practical R&D differs from basic R&D not so much in substance, as in motivation. The choice of question to be studied and method of study is determined by the current state of practice; by the practitioner's and scientist's perception of problems, needs, and opportunities; and by the available scientific knowledge and tools. Consequently, practitioners, as well as scientists, may participate in judgments and choices concerning practical R&D activities.

The central purpose of *programmatic R&D* is completion of some specific practical task within a finite span of time. Programmatic R&D differs from practical R&D not so much in its substance, as in its finite time horizon. Practical R&D activities seek the continuing improvement of practice; programmatic R&D activities are designed to achieve a definite goal. The choice of goal is ordinarily not a scientific question, while decisions concerning its feasibility and the means by which it shall be sought are. Consequently, both practitioners and scientists may be involved in making judgments and choices concerning programmatic R&D activities.

Scope

While there is no general definition of the scope of an R&D activity, common usage tends to distinguish between R&D projects and R&D programs.

The smallest unit of R&D activity is usually called a *project*. Projects range in size from the activities of a single investigator (perhaps only part-time) to the efforts of teams comprising a principal investigator and a staff of perhaps 10 or 20.

An R&D *program* is the conjunction of a number of related projects. The conjunction may be quite close, in that each project depends on or interacts with every other project, or it may be quite loose. Ordinarily, all the projects will fall within the same scientific research area or be addressed to the same practical objective.

Phase

The process of managing and conducting R&D falls rather naturally into three distinct and successive phases: planning, development, and evaluation. R&D management paradigms differ in the amount and type of effort they devote to each of these phases.

During the *planning phase*, the basic outlines of a program are defined: What are its objectives? How much should be expended on it? What projects should it contain? How should they be related to each other?

During the *development phase*, the outlines of the program are filled in. The performers of specific projects are selected; funds to support projects are disbursed; research or development is performed; and performance is monitored.

And during the *evaluation phase*, the results of program activities are examined to see how well they have achieved the program objectives.

In some R&D management processes, some of these activities or phases may be vestigial or absent entirely (this is especially true of the planning and evaluation phases), while in others those same phases may receive considerable emphasis. For example, most of the existing paradigms for the management of basic research devote very little effort to explicit program planning and evaluation, while most of the paradigms for the management of programmatic R&D lay particular stress on program planning.

LIMITATIONS OF THIS REPORT

In addressing each of the organizational and management decisions considered in this report, we have confined our discussion of alternatives almost exclusively to those that we identified in our examination of existing federal R&D agencies. In that way, we have been able to be explicit about each alternative and to draw upon the experience of employing it in some practical context to estimate its advantages and disadvantages. At the same time, we have been, as a consequence, limited in the range of possibilities we have discussed. We recognize that limitation as a deficiency of this report, but take some solace in the observation that the eight federal agencies we have studied employ a surprisingly broad range of structures and practices. While constrained, the alternatives we describe still span a wide range of potential choices.

II. ORGANIZATION DECISIONS

WHAT SHOULD BE THE MAJOR FEATURES OF THE ORGANIZATIONAL FORM?

There are *four major choices* that must be made in defining an R&D agency's organizational form. These are the choices between:

- *Linear* and *matrix* lines of authority,
- *Horizontal* and *vertical* scopes of interest,
- *Centralized* and *decentralized* distribution of effort,
- *Integrated* and *separated* location of intramural research.

Lines of Authority

R&D organizations may have either linear or matrix lines of authority.

Linear. Most conventional organizations have linear lines of authority. Each staff member has one and only one immediate supervisor. Each suborganization within the organization has one and only one immediate superorganization. But since each organization can have several suborganizations, the result is the conventional pyramidal organization chart, Fig. 1.

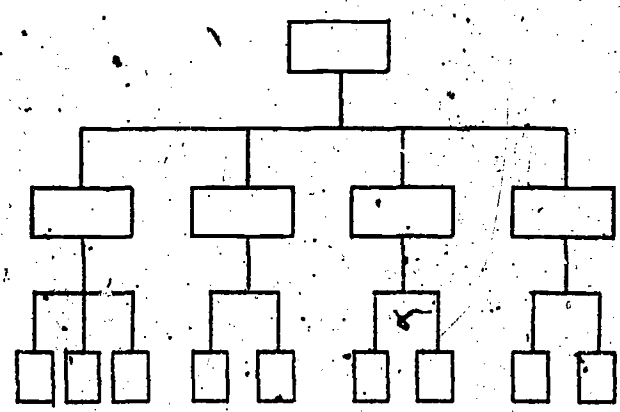

Fig. 1 Linear Lines of Authority

This is the basic structure of most R&D management agencies in the Federal government, including NSF, NIMH, and most of NIH.

The *advantages* of linear lines of authority are clear: each staff member knows precisely to whom he reports; responsibilities may be clearly defined and assigned. Linear lines of authority work well when an organization's responsibilities are reasonably stable and separable into fairly independent subtasks, each of which requires a predictable and reasonably constant mixture of skills. For example, support of basic research by NSF is a reasonably stable charter (despite rapid change within some fields), separable into fairly independent subtasks (support in each discipline), each of which requires a predictable and reasonably constant mixture of skills (program officers conversant with the relevant discipline).

The *disadvantages* of linear lines of authority are also clear: communication and coordination among separate suborganizations within an organization often pose difficulties (especially when they report to different superorganizations), suborganizations often tend to become identified with and overly protective of the external discipline, subject, or problem for which they have responsibility. In our interviews, comments such as the following testified to the existence of these problems:

- "When our organization has projects with one phase in one division and another phase in another division, we cannot get them coordinated easily."
- "Adjacent laboratories don't know each other's needs."
- "The training division is only interested in training more people; they do not care how that relates to the needs of research."
- "That division is the captive of its clientele; it concerns itself only with parochial solutions to the problems."

Linear lines of authority tend to work less well when an organization's responsibilities are changing, require the coordination of a number of different activities, or demand an uncertain and varying mix of skills. For example, development of spacecraft by the NASA-Goddard Spaceflight Center involves a sequence of changing tasks (each new class of spacecraft requires different technologies), requiring the coordination of a number of different activities (ranging from experimental physics through structural and electronic fabrication to launch operations, telemetry, and data reduction), and employing a wide and uncertain range of skills (from physics through various engineering skills to biology, meteorology, statistics, and computer science).

Matrix. To overcome some of the disadvantages of linear structures, a number of industrial R&D organizations and federal R&D agencies have adopted matrix lines of authority. These add a second line of authority, usually a flexible and changing one, that "cuts across" the first. Thus, some staff members will have more than one immediate supervisor. Each suborganization, however, still has one and only one immediate supergroup. The result is a matrix organization chart, Fig. 2. Matrix organizations, which in practice do not

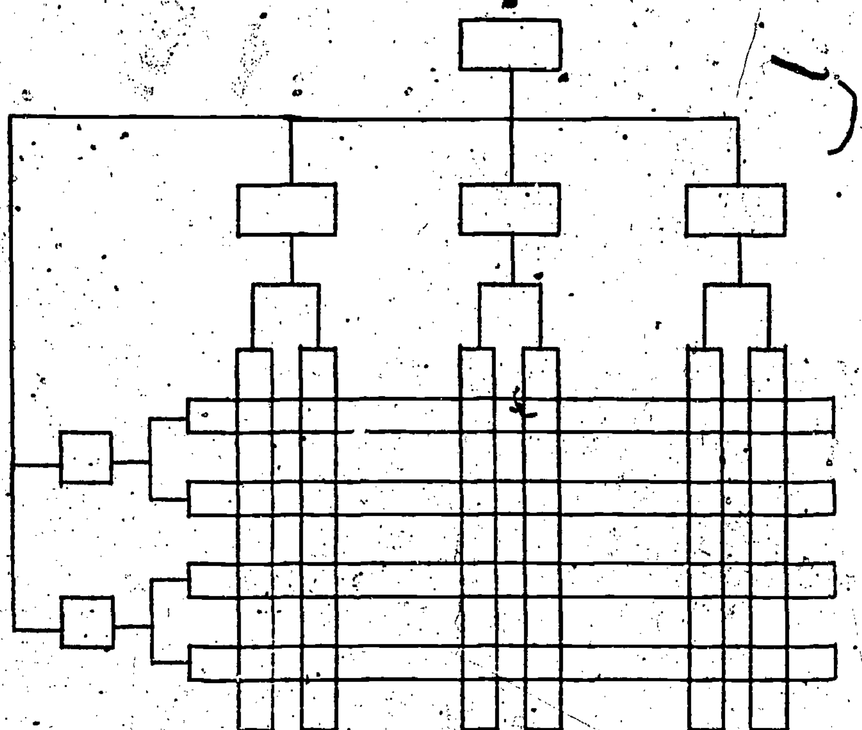

Fig. 2 Matrix Lines of Authority

have quite so regular a structure as suggested by the above diagram, have been adopted by NASA-Goddard Spaceflight Center and by the National Cancer Institute.

The *advantages* of matrix lines of authority are the flexibility that they provide the organization to respond to changing requirements by establishing new suborganizations along the second line of authority while retaining stable relationships along the first line of authority; and the enhanced communication and coordination that they inspire by bringing together under the second line of authority people who occupy distinct suborganizations under the first line.

Matrix organizations have been employed successfully by advanced technology firms in industry, where one line of authority usually follows disciplinary or technical speciality lines (e.g., there may be structures, thermodynamics, electronics, and propulsion departments), while the second line of authority follows project lines (e.g., there may be an orbiting telescope project, a Mars spacecraft project, and a weather satellite project). Thus, a thermodynamicist might be a member of the thermodynamics department and report to its head and also a member of the Mars spacecraft project and report to its leader. In the thermodynamics department he would be associated primarily with other thermodynamicists, but in the Mars spacecraft project he would associate with the mix of specialists from other departments needed to carry on the project. And while the department association is stable and continuing (like the disciplines), the project association is usually transient and finite. Matrix organizations are able, therefore, to respond to the demands of a changing environment while also maintaining a stable basic structure for staffing and developing competence.

The *disadvantages* of matrix lines of authority arise from the possible conflicts of authority and responsibility between the two dimensions, the possible mismatch in skills required by the functions along the two dimensions, and the tendency for an organization to revert to a linear line of authority. The first difficulty takes its most poignant form for the staff member who finds his departmental supervisor in conflict with his project supervisor concerning the quality of his work, his appropriate rewards, or his tenure, but it may also affect staff assignment, budget allocation, and project evaluation decisions. The second difficulty can occur if the range of activities (e.g., projects) undertaken along the second dimension fluctuates so broadly that it imposes widely varying staff requirements on the units of the first dimension (e.g., departments). The third difficulty can occur if, for example, the second dimension becomes stable, with staff assignments and subunits unchanged over long periods. Then, the matrix structure becomes two fixed, competing bureaucracies, one of which will probably prevail.

Undoubtedly, matrix organizational forms require greater skill from their managers, because the coordinating and balancing of overlapping authorities and responsibilities must occur continuously. However, NASA's Goddard Spaceflight Center has developed several mechanisms to alleviate those difficulties, which make the management problems less severe. For example, at Goddard a staff member's administrative and physical locations change or not depending upon his role in a project. Administratively, he may be either "solid-line" or "dotted-line" to a project. If he is solid-line, then he is physically and administratively colocated with the project, and his career advancement depends on the project director; if he is dotted-line, then he will physically colocate with the project, but administratively remain with his department, and his career advancement depends on his department head. For all spacecraft projects, the system-level staff are solid-line to the project, as are some subsystem-level staff; most component-level staff are dotted-line to the project. For the smaller projects, even subsystem-level people are dotted-line.

Goddard also avoids the second difficulty of matrix management (mismatch of staff skills and needs) because its staff is large and quite diverse. Goddard's managers emphasize that "staff diversity is the key to matrix management; you must have the competencies when you need them." In addition, the choice among prospective new projects is affected by the availability of appropriate staff. The National Cancer Institute has adopted a somewhat different approach;

it avoids mismatches between staff availability and needs by drawing upon outside scientists to fill certain positions in the program organization.

The third difficulty in matrix organization (reversion to a linear line of authority) can be avoided by assuring that one line is constantly changing in its suborganizations (e.g., tasks or projects) so that it does not rigidify into simply another fixed way of organizing the same people; the flux and constant reorganization of one line is what gives a matrix organization its ability to coordinate effort on a changing series of projects or problems.

Scopes of Interest

The core of an R&D organization's scope of interest is its collection of R&D projects and programs. We shall consider an R&D organization to have an *horizontal* scope of interest if it builds on that core collection solely through the addition of R&D projects and programs on new topics (as has NSF). An R&D organization has a *vertical* scope of interest if it builds on that core through the addition of:

- o dissemination activities (as has the Department of Agriculture)
- o service and training activities (as has the NIMH)
- o policy planning activities (as has OEO)

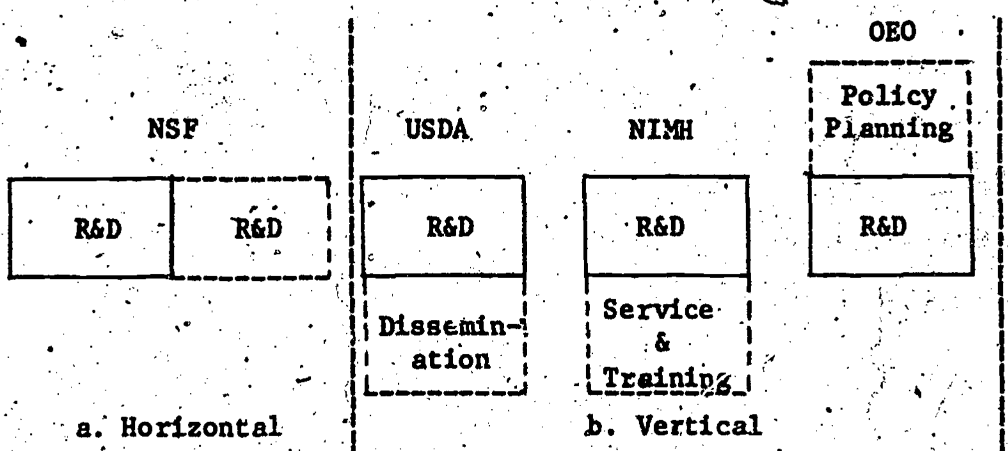

Fig. 3 Horizontal and Vertical Scopes of Interest

Horizontal. Those who argue for a horizontal scope of interest feel that:

- if *service* or *policymaking* functions are added, the organization finds operational priorities overbalancing research priorities, demands for immediate results driving out basic and long-term research, and demands to support decisions already taken supplanting the neutral study of future alternatives.
- if *training* or *dissemination* functions are added, the organization finds its energies diverted by the heavy efforts essential for effective training and dissemination.
- only if it restricts its concerns to R&D activities alone, can the organization satisfy the needs of science and ensure proper attention to basic, long-term, and controversial R&D.

Vertical. Those who argue in favor of some form of vertical scope of interest feel that:

- linking R&D with dissemination, service, or policy-making is "very effective in generating political (and financial) support" for the organization's programs (including R&D).
- such linkage "forces the nasty questions -- what do the research outcomes mean for service? -- to be asked by the organization's own staff" and, therefore, to be taken seriously. Without it, research tends to drift away from practical needs.
- linkage between R&D and dissemination is crucial to success of both activities because it provides research with constant awareness of problems needing solution and provides dissemination with a continually refreshed pool of research findings.

- linkage between R&D and policymaking (especially through participation of R&D managers in policy studies) brings R&D findings into policy influence and assures that R&D will address policy-relevant topics.

Three specific models of vertical R&D organizations are:

- *National Institute of Mental Health*
  NIMH combines responsibilities for research, training, and service (through support of Community Mental Health Centers). Its internal structure, however, is a combination of horizontal and vertical substructures, Fig. 4.

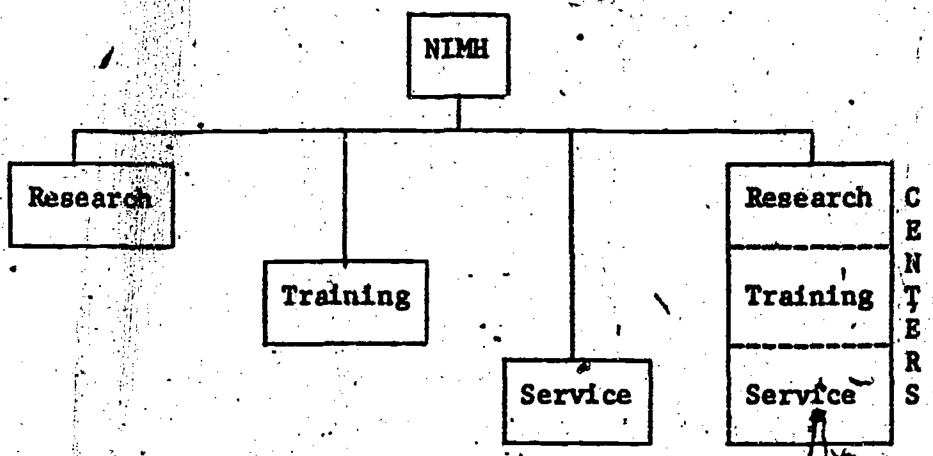

Fig. 4 National Institute of Mental Health

  There are separate internal divisions for research, service, and training, but there is also a division that contains centers concerned with specific problem areas (e.g., crime and delinquency, minority studies, metropolitan studies), some of which combine research, service, and training functions related to their problem areas.

- *Department of Agriculture*

  The success of the Agricultural R&D system has been critically dependent on the close linkage among three different types of specialist:

  - *county agents* (serving the farmer by helping him identify his problems and making available to him the findings of research),
  - *extension specialists* (serving the county agent as a source of specialized, up-to-date knowledge about research on a particular commodity or problem, and transmitting new problems to the researchers),
  - *researchers* (pursuing new knowledge and the solution of practical problems).

  The three types have been essential because: the county agents alone quickly use up their store of research knowledge and lose the farmer's confidence; the researcher alone cannot communicate directly with the farmer; but the county agent also has difficulty communicating directly with the researcher; thus, the extension specialist serves as a crucial middleman. These three functions are the direct responsibility of the Department of Agriculture in varying degrees. There is considerable overlap with both state and local agencies.

- *Office of Economic Opportunity*

  The Office of Planning, Research, and Evaluation (PR&E) of OEO has a dual role; it serves both as a planning staff to the OEO director and as the manager of a research and evaluation program that has a strong policy orientation and whose findings exert a direct influence on policy.

Both the *National Science Foundation* and the *National Institutes of Health* are, with slight exceptions, examples of R&D organizations with horizontal scopes of work.

Distribution of Effort

A *centralized* R&D organization is one whose R&D activities are carried out at a single locale under the direct authority of a single agency executive. An R&D organization may be *decentralized* in several senses:

- regional location -- portions of the organization are at different geographic locales, but they report to the same agency executive. (For example, regional offices of NIMH.)
- regional operation -- portions of the organization are at different geographic locales *and* each has independent operating authority through the provision, for example, of formula-grant funds (the fifty-three State Agricultural Experiment Stations are formula-funded and receive state matching grants).
- dual operation -- part of the organization is centralized, part decentralized.

The Agricultural R&D system is dual -- it comprises both centralized and decentralized R&D activities. This is frequently cited as a principal strength of the agricultural R&D system.

- The *Agricultural Research Service* (ARS) provides centralized management of USDA's intramural R&D, about 50% of the total R&D budget. This coordinated, concentrated R&D is conducted at facilities distributed around the country, many colocated with universities.

- The *Cooperative State Research Service* (CSRS) provides formula grant support (on a state matching fund basis) to State Agricultural Experiment Stations (SAES) in each state and territory.

The ARS laboratories are assigned problems of national scale. They can form a large team easier than CSRS can, can cover all phases of R&D, and can bring problems to the pilot plant stage. They can act to fill gaps in the programs carried out with little coordination by the stations. The CSRS state experiment stations are free to expend their formula grant money as they wish on problems of concern in their state. They act to keep the system fully aware of what the problems are. However, they have a tendency to dissipate their efforts by putting a little in each area and to duplicate the efforts of other stations. The result is often multiple problem solutions.

The decentralization of USDA's R&D program provides several distinct benefits:

- the states and counties pay part of the cost of support, and are generally strong advocates of agricultural R&D.
- Congressional support is strengthened because of the location of R&D facilities in many congressional districts and R&D's benefits to farmer constituents.
- the decentralized facilities are aware of and responsive to local needs.

The tension between national and local interest in USDA's R&D program also provides several benefits:

- it promotes and broadens competition in serving the farmer,
- it broadens the R&D perspective to include both local and national problems,
- it provides a mechanism for communication between national and local R&D efforts.

NIMH has a regional organization, but the regions primarily have a service orientation; their involvement in research is slight and decreasing.

Most federal R&D agencies are centralized. NSF, NIH and OEO's PR&E manage their research and conduct it (when they have intramural activities) in a central locale (with the slight exception of NIH's environmental institute in North Carolina). They benefit from the advantage in coordination and cooperation that geographic contiguity provides. In the case of NSF and NIH, constituency support is built through the highly distributed expenditure of extramural grant and contract funds.

Location of Intramural Research

Most Federal R&D organizations having both intramural R&D performance and extramural R&D management responsibilities, *separate* them at the highest level in the organization. Intramural research at most NIH Institutes and at NIMH is geographically and organizationally distinct from extramural research support. The opposite extreme, complete *integration* of intramural research and management of extramural R&D so that they are done either by the same individual or by individuals adjacent both geographically and organizationally, is relatively rare. However, NASA-Goddard, the National Cancer Institute (NCI) and OEO's PR&E have accomplished it in one form or another. Their organizational structures are shown in Fig. 5.

Separate. In the *NIH Institutes* there is a separation immediately below the Institute Director between intramural and extramural research, a different Assistant Director having responsibility for each. This separation mirrors a separation at the overall NIH level. The separation is sharpened by the fact that the intramural research facilities of all the Institutes are physically adjacent on the main campus, while the extramural offices are geographically separate. Moreover, the intramural research directors of all the institutes meet together regularly under the aegis of the NIH's overall intramural director. The communication between intramural and extramural personnel within an institute is less regular. The

NIMH has inherited a similar pattern from its mother organization, including the geographic separation of intramural and extramural facilities.

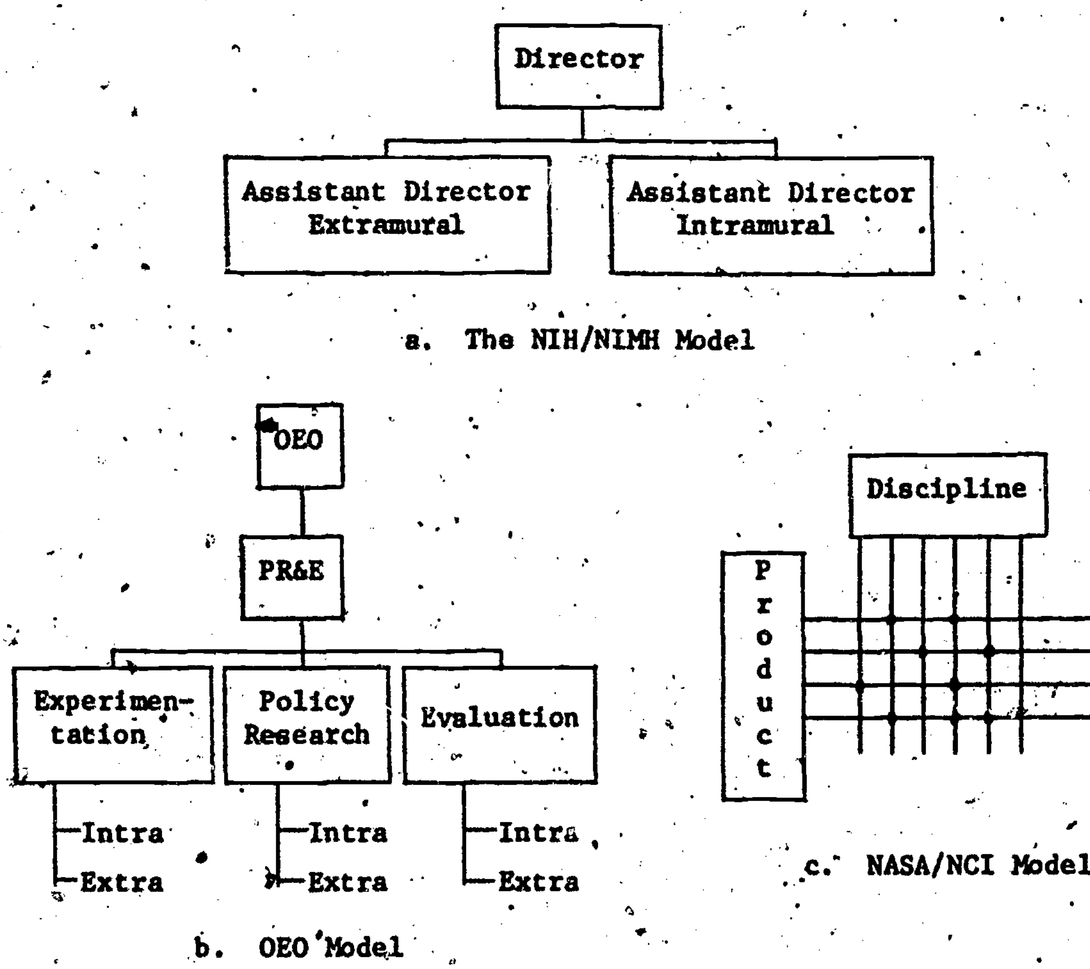

Fig. 5 Location of Intramural Research

The *advantages* of intramural separation are:

- o different personalities and styles of work are required for intramural research in the biomedical sciences and the management of extramural research; they cannot be done by the same person and different people among them do not work closely together, even if placed together.

- intramural biomedical researchers are scientific "competitors" of the extramural researchers seeking support and must, therefore, be kept from seeing proposals.

Integrated. In the *OEO's Office of Planning, Research and Evaluation (PR&E)*, a fair degree of integration between a modest intramural R&D activity and extramural R&D programs is achieved through the close interactions among a small staff divided along functional lines: one group concerned with experimentation, one with evaluation, and one with policy research. Each of the first two groups does considerable extramural funding of research, but project monitors often participate directly in the project or carry on their own research. Intramural researchers both have close contact with extramural project monitors and may contract for work that their research suggests is important, but that cannot be done intramurally.

The *advantages* of this form of intramural/extramural integration are:

- the PR&E staff may focus on specific policy questions and seek answers by whatever means -- intramural or extramural -- is appropriate to the question.
- the existence and availability of intramural R&D competence improves the quality of the planning, selection, and monitoring processes for extramural R&D.
- intramural researchers provide a direct channel for the findings of extramural R&D into policy decisions.

In *NASA's Goddard Spaceflight Center* and at the *National Cancer Institute*, the matrix organizational form is used to integrate intramural and extramural R&D. Intramural researchers report along one, stable line of authority according to their discipline. However, they may be assigned to a project team managing extramural R&D along a second, flexible line of authority. In the first role, they do intramural research; in the second role, they manage extramural

R&D contracts. At NCI 90% of the intramural staff is also managing extramural research as part of a project team. At NASA-Goddard there is a conscious management policy of moving people from intramural research to extramural management responsibilities.

The *advantages* of this form of integration are:

- o the existence of intramural expertise enhances the quality of extramural project management.
- o intramural research competence is extended by the ability to contract for extramural work and by contact with it.
- o attractive career paths are opened to staff who may grow through intramural research to a position of research management responsibility.

The *NIH Institutes* also support "collaborative" research projects, which are ordinarily carried out under contract; as opposed to the extramural research conducted under grants. Collaborative research originated as a way in which intramural researchers could contract for work that related to or extended their own work, but that could not be done intramurally. The testing of thousands of chemicals in the cancer chemotherapy program is an example. Thus, collaborative research is a way in which intramural and extramural activities are integrated at NIH. However, it is important to note that it involves the contract mechanism and the performance of tasks specified by the intramural researchers.

We conclude that the mores of the scientific community make it difficult to integrate intramural and extramural research of the kind usually funded by grants in response to unsolicited proposals. Attempts to achieve such integration must, at least, include mechanisms to insure the preservation of scientific priority and account for the different personalities and styles of work of active researchers and research managers.

However, there are several apparently successful models of the integration of intramural and extramural R&D of the kind usually carried out under contract in response to agency-defined statements of work. That is, developmental, project-oriented, or policy-relevant R&D are more likely to be hospitable areas for intramural-extramural integration.

HOW SHOULD SUPPORT OF R&D BE ORGANIZED?

We shall focus on structures for the management of extramural research (including integrated intramural research). Structures for the management of separate intramural research will be discussed in the next section. There are *two principal decisions* that must be made in specifying the organization's internal substructure. These are:

- What *taxonomy* will be employed in defining suborganization responsibilities?
- What *roles and functions* will each suborganization have?

Taxonomy

Most organizations are subdivided into suborganizations, each of which (in the ideal) has sole responsibility to carry out clear roles and functions in a sharply defined subarea. The assignment of responsibility is made according to a *taxonomy* that seeks to divide the organization's area of responsibility into a set of categories that are mutually exclusive and exhaustive. Some organizations, however, intentionally seek a degree of overlap of responsibility among their subdivisions. One recently formed Institute has consciously arranged a significant amount of overlap among its subdivisions in order to avoid the carving out of separate territories and to permit a responsibility to be easily shifted to another subdivision if the performance of the first is bad. The intent is to have 2-3 functional areas in which any given program could fit, and if it does not work in one, to try another. The price paid for such an arrangement is a great deal of internal conflict; a benefit appears to be that staff flexibility and initiative are promoted. The results of this recent experiment are still not determined. We shall continue our discussion as though the ideal of a mutually exhaustive and exclusive taxonomy were being sought.

Several different *subdivision taxonomies* have been employed by other federal R&D agencies, or are suggested by their experience. They are subdivision by:

- *Disciplines* (e.g., psychology, sociology, economics)
- *Problems* (e.g., reading disabilities, inadequate financial support
- *R&D Functions* (e.g., intramural research, extramural research, training, dissemination)
- *Subject Area Functions* (e.g., instruction, assessment, administration)
- *Client Organizations* (e.g., elementary/secondary, higher, preschool, adult)

Discipline. Subdivision by discipline occurs at the NSF. Its major *advantages* lie in the management and conduct of basic research, which is ordinarily carried out along disciplinary lines in universities and other extramural research organizations. Because of its isomorphism with the disciplinary subdivision of universities, this subdivision taxonomy also is advantageous in recruiting high-quality scientific staff.

The major *disadvantages* of discipline subdivision are the difficulty of forming the interdisciplinary teams needed for many applied and problem-oriented research topics, and the tendency of staff members to seek and be judged solely by the sanctions of the external discipline community to the detriment of other organizational goals.

Problem. Subdivision by problems occurs among the NIH institutes, at NASA-Goddard (if specific spacecraft projects are considered to be problem-solving activities), within the Agricultural Research Service, and within the Division of Special Mental Health Programs at NIMH.

The *advantages* of problem-orientation are that it facilitates the conduct of R&D requiring mixes of disciplines, encourages interaction among the disciplines, has strong "political" appeal to funding authorities and constituency groups, and smoothes the path of R&D products into practice.

The *disadvantages* of problem-orientation are its tendency to favor short-term over longer-term research, its sensitivity to political pressures both within and outside the organization, and the difficulty of staffing and managing problem-oriented R&D organizations (especially in the behavioral and social sciences).

Experience with attempts to introduce problem-oriented substructures at NIH Institutes suggest:

- o In some cases, the reorganization will be solely cosmetic: titles of programs will change, but program directors will still be chosen for their disciplinary competence.
- o Despite initial fears, recruiting will not be inhibited.
- o Extramural staff will like the problem-orientation.
- o The basic intramural/extramural division in the NIH Director's office will be inconsistent with problem-organized, joint intramural/extramural research programs in the separate institutes.

NIH actually has a dual structure in which both disciplines and problems (disease complexes) play a role. The subdivision into institutes is according to a problem or disease taxonomy (e.g., Cancer, Heart and Lung, Arthritis and Metabolic Diseases, etc.), while the major extramural grants management system, the study sections organized by the Division of Research Grants, are defined according to a disciplinary taxonomy. This duality has proven to be a highly effective political mechanism: the Institute's disease orientation generates considerable Congressional and public support, while the disciplinary study sections have built a strong constituency among the widely-distributed biomedical research community. The NIH institutes differ considerably in the extent to which the nominal disease-orientation is more than a *post hoc* classification of clusters of disciplinary research activities.

R&D Functions. Subdivision according to R&D functions occurs, at the NIMH and NIH, where intramural research, extramural research, service, and training are managed through separate divisions; at the Department of Agriculture, where research, extension services, and operating programs are the responsibility of separate divisions; at OEO's PR&E, where experimentation, evaluation, and policy research are separate groups; and at NSF, where applied research, education, and basic research are distinct divisions.

The *advantage* of such a subdivision is that it reflects the different management styles, personnel skills, and client groups, associated with each function and permits each subunit to organize so as best to carry out its job.

The *disadvantage* is that it can make very difficult the coordination of several instruments (research and training, basic and applied research, research and service) to solve particular problems. The specialists within each subdivision will tend to see only those aspects of a problem that concern them and to see them only within the context of their own plans.

Agriculture has overcome some of the problems of separation of functions at the federal level through the colocation of extension specialists and researchers at the state level. OEO's PR&E avoids most of the problems through its small size and careful overall management.

Subject Area Functions. Subdivision according to subject area functions occurs to some extent at the Agricultural Research Service, where there are divisions concerned with regulation and control; nutrition, consumer and industrial use; marketing research; and farm research.

The *advantage* of this subdivision is its correspondence to the major areas of continuing concern to user groups and the incentive, therefore, to develop continuing programs of R&D serving them.

The *disadvantage* is the prospect that problems that involve two or more functions will not be handled well and that basic research serving more than one function will be ignored.

Client Organizations. Subdivision according to client organizations does not occur in the organizations studied, although it is natural in both education (elementary/secondary, higher, preschool, adult and continuing, vocational) and criminal justice (police, courts, corrections).

The principal *advantages* would seem to be the close correlation that is thereby likely to obtain between the R&D program undertaken and the interest and problems of the eventual user organizations and the probable strong political support that that closeness will produce.

The major *disadvantages* are the possibility of co-optation of the R&D program by existing organizations, inhibiting the development of R&D activities that too severely challenge the *status quo*; the perpetuation of divisions and distinctions that are no longer valid or that are inappropriate for certain studies; and the probable undervaluation of basic research activities.

Multiple Taxonomies. Most organizations employ more than one taxonomy. Generally they are employed in constructing the successive subdivisions in a *hierarchy* of suborganizations: divisions, branches, groups, etc. Thus, within a Division of Higher Education (defined according to a client organization taxonomy) there might be an Administration Branch (defined according to a subject area functions taxonomy), and within it, an Applied Research Group (defined according to an R&D functions taxonomy). This is the structure associated with linear lines of authority. The result of such successive subdividing appears to be extensive specialization and strong communication up and down the structure, but poor communication and coordination across it.

The several taxonomies can also be employed in constructing the two overlapping subdivisions present in a *matrix* of suborganizations: departments and projects, branches and segments, or divisions and programs. Thus, staff may belong to a Biochemistry Department (defined according to a discipline taxonomy) and to a Cancer Chemotherapy

Project (defined according to a problem taxonomy). This is the structure associated with matrix lines of authority. The result of such overalpped subdividing appears to be improved communication and coordination across the organization.

Roles and Functions

Two contrasting approaches to the assignment of *subdivision roles and functions* exist: functional comprehensiveness and functional specialization.

Comprehensive. Subdivisions are functionally comprehensive if they may carry out all (or almost all) of the institute's functions, but only within a prescribed portion of the institute's area of responsibility. The NIH Institutes, some NIMH Centers, and NSF Divisions approach functional comprehensiveness in this sense.

Functional comprehensiveness has the *advantage* of enabling all the organization's tools to be focused on one important area of an organization's responsibilities. Its *disadvantage* is its tendency to "lock-in," by institutionalizing, concern for that area of the organization's responsibilities. Functionally comprehensive subdivisions of an institute acquire special emphasis when they are called "Center" or "Institute."

Specialized. Subdivisions are functionally specialized if they carry out only a specified part of the institute's functions, but do so for the institute's entire area of responsibility. The NIMH Divisions and USDA's Services approach functional specialization in this sense.

The choice between comprehensiveness and specialization is clearly determined by the subdivision taxonomy employed in defining subdivisions. For an R&D institution, the R&D Functions taxonomy leads to functional specialization; most of the other taxonomies suggest functional comprehensiveness.

Functional specialization has the *advantage* that it permits staffing, management procedures, and constituency contacts to be specialized to the function at hand. Its *disadvantage* is the difficulty in coordinating several functions (research, service, and training, for example) to solve specific problems and the tendency for functions (such as training) to be perpetuated with too little sensitivity to the changing importance of the task.

NIMH Experience. The NIMH has both functionally specialized Divisions (Service, Research, and Training) and functionally comprehensive Special Mental Health Programs Centers (Crime and Delinquency, Metropolitan Studies, Minority Studies).

There were a number of reasons for establishing Centers at NIMH. These include:

- They are a means of attacking contemporary problems that are not being addressed in the traditional functionally specialized structures.
- They provide visibility (to Congress and other constituents) for what is being done in a problem area.
- They provide leadership (to scientists and practitioners) for previously dispersed activities in a field.
- They stake out the organization's claim in a problem area of potential interest elsewhere.
- They provide an operational base for measuring the magnitude and importance of a problem (through Congressional, administrative and constituent response to the newly-visible center).
- They make it easier to get additional money because of their targeting on problems.

NIMH's experience is that it is impossible to start a Center full-blown: if the Center's interest is cross-cutting, there may be little or no initial expertise to plan the program; too rapid growth may lead it into conflict for resources with other Centers and Divisions. Consequently, Centers are started small and grow if interest and findings warrant. The big factor in growth is -- does a constituency form?

The growth of an NIMH Center goes through three distinct stages:

- *Coordinating Center.* This is a paper organization with no money or control over money. Its principal role is to stimulate research in priority areas. Its activities may include journal publication, conference sponsorship, visits, and so on.
- *Limited-funded Center.* This is an organization with funds for research on a narrowly-defined problem. It could be used to test the research community's interest in and acceptance of a particular problem focus. No centers in this category exist at present.
- *Fully-funded Center.* These centers have funds for research, training, and service and their own review committees. Since they have available to them all the mechanisms of support available to NIMH, they are really mini-institutes. By naming their own review committees, they can avoid the rigidities and discipline bias of conventional review committees; they can name non-professional, practice-oriented members.

Most centers have spun off from the services portion of NIMH; when created, they took over the related research projects in the research portion. One of the first centers established (in 1966) was that on alcohol abuse and alcoholism; it began as a research-only, limited-funded center. However, a strong constituency developed and it has since evolved to Institute status within NIMH.

The disadvantages of NIMH Centers, from the perspective of the functional divisions, are:

- They may lead to a segmentation of the research effort.

- o Their research may be less broadly conceived than that in a research division.
- o The applications of research findings to other programs may be lost.

HOW SHOULD CONDUCT OF R&D BE ORGANIZED?

Almost all Federal R&D agencies sponsor extramural research; some also conduct research intramurally. There are *three principal issues* concerning an agency's intramural R&D program:

- o What are the *advantages and disadvantages* of having an intramural program?
- o How should an intramural program be *organized?*
- o How can *intramural and extramural* research be interrelated?

There are intramural research programs at NIH, NIMH, National Cancer Institute (NCI), NASA-Goddard, USDA Agricultural Research Service, and OEO PR&E. The structural characteristics of these programs are summarized in Table 1.

Advantages and Disadvantages of Intramural Research

The prospective advantages and disadvantages of an intramural research program are as follows.

The potential *advantages* of an intramural program to an institute include:

- o Provision of an *initial showcase* through which a new agency can gain recognition.
- o Creation of a *model for research*, especially in new areas and the catalysis of research in new areas.
- o Conduct of *high risk research* that would not or could not be carried out in extramural institutions.
- o Conduct of *long-term studies* (e.g., longitudinal or epidemiological studies) for which continual funding is required.

Table 1

ORGANIZATION OF INTRAMURAL RESEARCH IN SEVERAL FEDERAL AGENCIES

	Research Emphasis	Internal Organization	Geographic Distribution	Relation to Extramural	Comments
NIH	Basic	By discipline	1 site	Separate	Physical and administrative separation sharp
NIMH	Basic	By discipline	1 site	Separate	Physical and administrative separation sharp
NCI	Basic and Applied	By discipline and by problem	1 site	Integrated	Some persons serve both intra- and extramural functions; project emphasis, matrix structure, and use of contracts (instead of grants) helps to link intra/extra.
NASA-Goddard	Applied and Development	By discipline and by project	1 site	Integrated	
ARS	Basic and Applied	By subject area function and by station	Over a hundred sites	Little extramural	Geographically distributed program
OEO	Applied and Policy	By R&D function	1 site	Integrated	Small group; physically colocated, serving both intra- and extramural roles

- *Replication of research* carried out at extramural institutions.
- Development of *new research techniques* too expensive or intricate to be developed by existing extramural agencies.
- *Faster conduct* of certain projects.
- Creation of a *critical mass of researchers* in areas not supported in extramural agencies.
- Attraction and *development of good research personnel* who can move on to extramural research management or institute administration.
- Conduct of *large-scale, complicated research programs.*
- Provision of the strong *in-house competency needed to manage contract research* effectively. Without such competence, it is impossible to keep on top of the program on a day-to-day basis, to evaluate progress, and to recognize and exploit advances.
- Ready source of *unbiased information on R&D* programs for institute management.
- Source of highly trained *R&D staff for extramural institutions.*
- Provide large, respected group to protect and *prevent application of political criteria* to scientific decisions.
- Source of knowledge to be used in satisfying needs for *short-term, policy relevant studies.*
- Creation of an *intellectually challenging environment* to help in attracting first-class administrative staff.

It should be evident that not all intramural R&D programs provide all these benefits to all agencies.

The *disadvantages* of an intramural program to an institute include:

- *Intramural programs tend to perpetuate themselves* because of the desire of intramural researchers to preserve their expertise, the formation of in-house lobbies, the need to maintain intramural program levels to preserve productive research, and the tenure of in-house staff in the civil service system.
- The possibility of *conflict with extramural researchers* who may resent the relative freedom and stability of intramural researchers and fear their competition for budget resources.
- The prospect that too much of an institute's *administrative resources will be diverted* in the early stages of an institute's growth.
- The possibility that too many *researchers will be attracted from extramural institutions* where their skills might be better employed to build research programs and train new researchers.

Organization of Intramural Research

The organization of intramural research must be determined by decisions similar to those discussed in conjunction with extramural research. This is obviously true when intramural and extramural are integrated. Separate intramural organizations are ordinarily subdivided by discipline, occasionally by problem, and in the case of the ARS, by subject area functions and commodities.

Relationship of Intramural and Extramural Research

As noted on pp. 19-23, the relationship of intramural and extramural research appears to depend critically upon the type of research, the funding mechanism used (grant or contract), the nature of the external research community, and the incentive system at the R&D agency. NIH (most institutes) and NIMH are institutions at which intramural and extramural research are quite *separate*; NCI and NASA-Goddard are institutions at which intramural and extramural research are highly *interrelated*.

NIH and NIMH intramural research is primarily basic biomedical research; their extramural research is primarily unsolicited project proposals funded by grants awarded on the advice of peer-review panels; the extramural community is primarily discipline-oriented and university-based; and the intramural reward system is based on recognition by the extramural community. As a result, there is an implicit scientific competition between the intramural staff and their extramural peers, which underlies the separation of the intramural research and extramural research management functions at the institutes. Other impediments to cooperation come from:

- the *geographical separation* of intramural and extramural activities
- the *separation at the NIH and NIMH Director's Office* levels of intramural and extramural research
- the *competition for funds* between intramural and extramural research
- the view that *extramural proposals are privileged communications* that should not be shown to intramural researchers because they are scientific competitors of the extramural researchers
- the tendency of *intramural researchers to become and remain highly specialized* in research interests
- the *dependence of intramural promotion on bench success*, not interchange with extramural research managers
- the fear that *intramural directors would divert too much time to extramural programs*, if given such authority
- the experience that the *personalities and tasks of intramural bench researchers and extramural research managers appear to be different*, so that the same person cannot function in both roles at the same time, nor can the two types fit comfortably in the same organization

- the distaste of intramural bench scientists for working for "paper pushers"

The one area in which intramural and extramural activities come together at NIH is *collaborative research.* These are ordinarily product-oriented, contract-funded activities that extend intramural interest in directions that cannot be pursued in-house. As such, there is considerably more interaction between intramural and collaborative contract research than between intramural and extramural grant research.

NASA and NCI intramural R&D is disciplinary; their extramural R&D comprises programs with specified goals and finite time-span consisting primarily of solicited projects funded by contracts (in NCI's case, this is formally collaborative research) managed by staff who either formerly were in the intramural program or are simultaneously in it; the extramural community is problem- or project-oriented and industry-based; and the intramural reward system is tied to program and project success. As a result, there is an *intimate collaboration between intramural and extramural researchers in the achievement of a specific goal* which underlies the integration of intramural and extramural programs at the agencies. Other aids to cooperation come from:

- the use of a *matrix form of organization*, in which many staff members belong both to a discipline-structured intramural subgroup and to a problem-structured extramural subgroup
- the *geographic colocation* of intramural research and extramural research management activities
- the provision of *extramural funds to be used to support intramural research* (to help entice good researchers to extramural management)
- the use of a conscious *staff development policy* that moves staff from intramural research to extramural program management

- the focus on *R&D areas* (such as spaceflight and cancer research) *in which team effort is essential* and project management provides challenges and satisfactions sufficient to attract highly-competent personnel (project management is active rather than passive, as in grants management)
- the *need to rely on intramural staff for project definition and proposal selection* because of the infeasibility of peer-review of industrial R&D

HOW SHOULD ADMINISTRATIVE SERVICES BE ORGANIZED?

Administrative functions include:

- personnel services
- financial management and budgeting
- fiscal services (voucher auditing, payroll, record keeping)
- management information and analysis
- grants and contracts management
- conference management (a distinct function at NIH and NIMH)

These functions might occupy about twenty professionals early in an institute's lifetime, growing to perhaps fifty when the institute reaches 400 or so professionals (based on NSF experience).

Centralization Versus Decentralization

The major decision to be made with respect to administrative functions is: how much centralization or decentralization is appropriate?

Centralization. In a centralized arrangement, all administrative personnel are in a single administrative organization, generally reporting to the office of the director. This has the advantage of making it easier to apply the generally large number of policies and procedures consistently and, therefore, to avoid the situation in which grantees, contractors, and prospective employees receive different guidance from different parts of the organization. Another advantage is that such an arrangement enhances the prestige of administrative personnel, permits higher salaries to be paid because of broader responsibility, and opens career advancement paths within administration; consequently, the recruitment of good staff is easier. The disadvantage of this arrangement is the tendency for separate administrative staffs to become rigid in the application of administrative regulations and relatively unresponsive to the needs of the R&D program staff.

Decentralization. In a decentralized arrangement, administrative personnel are distributed among the organization's subdivisions, reporting to each subdivision director. The advantage of this arrangement is the greater responsiveness to the needs of the program staff that should result from closer association. Its disadvantages are the administrative inconsistencies among subdivisions that may occur to the confusion of those who deal with more than one; the greater difficulty in recruiting administrative officers because of the absence of a clear career path; and the inability to have much staff specialization.

Combination. NASA-Goddard has developed an effective compromise solution to the centralized/decentralized choice -- a combined arrangement, that fits well with the matrix management structure employed at Goddard. The administrative division is treated just like a disciplinary department when a new spacecraft project team is formed. Each project has an administrative officer assigned to the project manager on either a solid or dotted-line basis. Each project team has its own complement of administrative personnel for budget, contract services, and so on. These personnel are generally solid line to the project. The purpose of this assignment is to give the administrative staff an understanding of the project and a sense of participation in it. Their role is to facilitate the project's goals by helping the project manager do what he wants to do. Their rewards are linked to the project's success. At the same time, their association with the central administrative staff and their return there between projects provides them with an attractive career path, access to back-up specialists, and a source of consistent guidance. They also keep central administration informed of the project's progress.

WHAT PERSONNEL AUTHORITIES ARE DESIRABLE?

The basic personnel authority under which Federal R&D agencies operate is the *Civil Service System*. This provides for:

- o jobs to be filled through a competition among qualified applicants
- o approval of job offers by the Civil Service Commission
- o rank (GS-1 to GS-18) to be determined by job responsibilities, not qualifications of applicant
- o salary to be determined by rank and step within rank; new hires start at the first step
- o job tenure to be obtained after one year of probation
- o the total number of Federal supergrade (GS 16-18) positions to be fixed, and distribution to agencies determined by a bargaining process
- o professional and technical positions requiring skills in areas such as medicine, physical science, and engineering are not subject to the limitation on number of supergrades, but positions requiring skills in social or behavioral science are.

The Civil Service system was designed to satisfy the need for a stable, conventional bureaucracy, insulated from political influence and open to competitive advancement on the basis of competence. It was not designed with the needs of R&D management in mind and does not serve them so well. Its disadvantages in this regard are that:

- it emphasizes stability and tenure, when R&D management organizations need a high degree of staff turnover in order to bring in personnel who have fresh knowledge and ideas
- it emphasizes rank as a function of job description, when the competence and value of a scientist is determined by qualities not easily expressed in a concrete job description
- it emphasizes equality of treatment with regard to salaries and promotion, when most successful R&D organizations find that strong rewards for achievement are needed to attract and retain highly competent staff
- it makes the firing of unproductive staff exceptionally difficult and gives them little incentive continually to upgrade and refresh their skills, as they must if they are to serve rapidly advancing R&D areas
- it recognizes the need to provide competitive salaries for physical and medical scientists, but not for behavioral or social scientists or highly qualified practitioners
- it imposes delays that make it difficult to make timely job offers to professionals when they are available.

The Congress has recognized the inappropriateness of the conventional Civil Service personnel system for management of R&D and has given certain R&D agencies, NSF and NIH in particular, *special personnel authorities*. These are unique to each agency. On the basis of that experience, the provisions that a special R&D agency personnel authority might have are:

- *Hiring*

  The ability to hire qualified professional and technical personnel without a formal competition and without having to wait 3-4 months for Civil Service Commission approval

- *Tenure and Turnover*

  The ability to limit tenure to short periods, renewable only on demonstr ion of continued competence and productivity. A portion of the staff should be hired for fixed terms without tenure to encourage a constant rate of staff turnover. (It should be observed that NIH administration believes that the existence of long-term Civil Service tenure is essential to NIH recruiting in competition with tenure-offering universities.)

- *Grades and Supergrades*

  The ability to determine grade and step by the salary a professional staff member can obtain from industry or the university and not by some artificially-defined job statement. There should be no limitation on supergrades for scientific and professional employees except the requirement that each person's grade and step be justified by market factors and performance. The inequity in treatment of behavioral and social scientists should be removed.

- *Salaries and Promotion*

  The ability to tie salary increments and promotions to performance and not solely to seniority and job description. It should be possible to pay a within-grade salary to a newly-hired staff member if that corresponds to his market value.

- *Leaves*

  The ability to provide each scientific and technical professional employee with a sabbatical leave during which he must refresh his competence through active research, teaching, or studying. (NIH experience is that people who go off on leave bring back good ideas.)
- *Firing*

  The ability to remove scientific and technical professionals if their competence and performance fail to keep pace with the needs of the organization.

WHAT PERSONNEL QUALITIES ARE DESIRABLE?

The qualities required in successful staff members will differ among:

- *extramural* program managers
- *intramural* researchers
- *administrative* staff

Extramural Managers

The qualities required of extramural program managers differ according to the nature of their program management role, which can fall within a wide range, bounded at one extreme by the job of the NIH Executive Secretary and at the other by the NASA-Goddard Project Manager.

- An NIH Executive Secretary manages the process of review of unsolicited grant proposals by a study section comprising non-NIH scientists in a specified discipline. His principal role is to engineer the applications through the review process.
- An NSF Program Officer is typically more aggressive in the encouragement and discouragement of proposals;

in the selection of proposal reviewers, and in making the final decision.

- A NASA Project Director must determine what R&D is necessary, solicit its performance, award contracts, monitor their performance, and combine them to achieve his project objectives.

At NIH most executive secretaries and extramural program officers (within the Institutes) come from research backgrounds. About 90% have some research experience, 90% have a Ph.D. or M.D. Many pass through a training program for science managers run by NIH. Fewer than 10%, however, come from NIH's own intramural program, where the "publish or perish" syndrome discourages scientists from entering management. Attempts at NIH to train administrators to be good project officers have failed due to their lack of science background. Once a scientist takes on a management task he quickly loses his scientific competence and in NIH and NSF experience it has been impossible for him to get it back. Thus, the movement is one-way from research to management; the reverse is impossible. The turnover of executive secretaries is small.

The Institutes have found that 2-year Public Health Service Officers make good *collaborative* research managers. They know the science, but not project management, but are generally willing to dig in and learn; while their older, more established colleagues are not willing to do so.

At NSF almost every program officer has been a researcher, but he is made aware upon being hired that his job is management not science. Typically NSF program officers are young men on the way up or older men who have left research. Their administrative experience and skills make them prime targets for university recruitment. Many leave the Foundation for college and university administrative jobs -- department head, provost, college president. NSF has many 2-year rotating program officers (especially in the biosciences). Many program officers are hired on a leave-of-absence basis so that they can have a safe retreat.

At NASA-Goddard a project director may be:

- the study manager who developed the program plan
- the Goddard manager who has the best technical competence in the program's crucial area
- the manager of a successful terminating project

The first priority in choosing a project director is his technical competence; the second is his management experience. If the project director does not have high competence in a crucial area, his assistant must. NASA-Goddard develops most of its own project directors from within its intramural staff; a staff development program explicitly arranges for a number of years of intramural R&D followed by extramural project management. New project directors are trained in a project management simulation called GREMEX.*

Intramural Researchers

The qualities required of intramural researchers are those of competent scientists anywhere. It is useful to note that the quality of NIH's intramural program is ascribed by some to its considerable rate of turnover and high selectivity in making permanent appointments. The draft deferment afforded PHS Fellows has assured the NIH a flow of the best young bioscientists for two-year terms. The best among these are offered permanent positions. In general, NIH appears to have been better at growing its own researchers than at recruiting from outside at a high level. In addition to the PHS Fellows, NIH has a large number of other short-term appointment programs — Visiting Fellows, Guest Workers, Foreign Fellows, etc. All of these serve continually to refresh the scientific competence of the institutes.

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*McGregor, E. B. and R. F. Baker, "GREMEX-A Management Game for the New Public Administration," *Public Administration Review*, Vol. XXXII, No. 1, January-February 1972, pp. 24-32.

The ARS has an explicit policy of providing parallel career advancement paths in research and research administration. This has made it no longer necessary to go into research administration to obtain a high salary. The career guide given to each new employee, which explains this system, is considered by ARS to be its most important piece of paper.

Administrative Staff

The qualities required of administrative staff, especially grants and contracts officers, besides the natural administrative competencies, are two:

- the understanding that it is not their role to make scientific judgments
- the appreciation that it is their role to show the program officer how to do what he wants to do.

HOW CAN ADVISORY COUNCILS BE ADMINISTERED EFFECTIVELY?

There are *three basic issues* in the selection and effective use of an advisory council:

- What *purposes* should the council have?
- How should its *membership* be determined?
- How should it *operate*?

Purpose

The purpose of an advisory council can be to provide advice or assistance in one or more of four principal areas:

- program objectives and priorities
- program substance
- project selection
- political and constituency support

<u>Program Objectives and Priorities</u>. Advice on program objectives and priorities is probably the most common advisory council role. When the council is well-chosen for the prestige and representativeness of its members, the council's imprimatur on a program serves to validate and justify what must in the end be subjective, value-laden decisions, essentially political in nature. Some councils are chosen because their ideas and judgments concerning objectives and priorities are truly sought by the agency; in that case, extensive supporting staff work and frequent meetings are essential to provide the information they need if wise advice is to result from their deliberations. However, many councils are chosen only to provide the proper imprimatur to objectives and priorities determined by the agency itself; in that case, no staff support and short, busy meetings are the rule.

<u>Program Substance</u>. Advice on program substance is another common role for advisory councils, especially when they comprise prominent scientists. Some councils serve as useful channels for ideas from the agency's constituencies. (For example, NIH institute advisory councils channel ideas from organizations such as the American Cancer Society, hospitals, and medical schools.) Some councils provide continuing access for the agency to members with expertise that could not be afforded or obtained in the full-time staff. They provide fresh ideas and suggest new directions for the agency's programs.

<u>Project Selection</u>. Assistance in project selection is a less frequent role of advisory councils, although the NIH institute councils all have that responsibility formally. Their principal value in this role lies in their ability to give legitimacy to necessarily arbitrary decisions; they insulate the agency from certain kinds of political attack and indicate to the scientific community that the award process is not dominated by bureaucratic capriciousness.

<u>Political and Constituency Support</u>. Every advisory council plays an important, though often implicit, role in building political and constituency support for the agency. While few agencies go so far as to have their members formally lobby before Congress, advisory

council members frequently testify before Congressional committees, hold informal discussions with Congressmen, and engage in other restrained forms of advocacy at which they can often be more effective than agency staff. Their advocacy may also go on within the Executive branch, both within the departments and in the Executive Office of the President. They also play an extremely important role in building a professional constituency among their colleagues for the agency. It is generally intended that they will "tell their colleagues that the agency is on their side and doing a good job for the nation." Conversely, they can sensitize the agency to problems in the scientific and lay communities.

The National Institute of Dental Research formed an advisory council of prominent university scientists and engineers when it wanted to initiate a program of dental research in universities outside of dental schools. The council was able to advise the Institute on the capabilities of various universities, provide university contacts, and assure the university community of the seriousness and challenge of dental research and the quality of the Institute. The Council played an important role in building receptivity for the program in the universities and in identifying appropriate sites for research centers.

Problem. There are a number of problems and differences of opinion concerning the proper role of advisory councils.

A major problem concerns the appropriate degree of authority for councils; that is, the proper balance between *advice-giving* and *decision-making*. Those who believe that advisory councils should limit themselves to giving advice fear that if they are given decision-making power, control of the agency will be turned over to some faction from the outside research community. Further, some fear that the research community as represented on the usual advisory panels will be too tied to the *status quo* to change when the agency should. Those who argue in favor of decision-making power believe that such authority is necessary to attract and retain the active interest of first-class members for the council.

The difference of opinion is actually more complex because it concerns whether or not advisory councils should have decision power with regard to each of three areas:

- o program objectives and substance
- o program substance
- o project selection

One view is that councils should have decision power with regard to programs, but should not be submerged in the details of project selection. The opposite view holds that only by becoming familiar with the specifics of projects can council members gain a sufficient understanding of an agency's program to be able to provide useful advice. Part of the resolution of these differences lies with the amounts of staff support and pre-meeting council efforts undertaken; with proper support and effort a council can examine many projects without becoming overwhelmed by detail. Another part of the resolution depends on the seriousness of the council's independent review of the decisions it makes; if it is willing to examine in detail only staff-selected special cases, it can exercise decision authority without undue effort.

Another problem implicit in what has been said above is the balance between the *advisory council's power and the director's power*. Some advisory councils run their agency, others become the agents of the agency director. This is only partially determined by formal assignments of responsibility; much depends upon the character of the director, the membership of the council, and the way the council is supported and used.

Membership

The membership of an advisory council should be determined according to the purposes of the council, the degree of authority it is intended to have, and the ways in which it will be supported and used. Naturally, councils intended only to legitimize agency decisions, to build constituency and Congressional support, and to provide broad program guidance are comprised of scientists, practitioners, and representatives of the lay public chosen primarily for their eminence and influence. However, councils intended to participate effectively in making agency program and project decisions and to contribute useful substantive ideas comprise members chosen for their competence, willingness to devote considerable time to council activities, and ability to contribute effectively at meetings. The balance among scientific, practitioner, and public representatives favors the former where the agency's major concern is with basic research, and shifts toward the latter whether the agency's major concern is with applied and problem-oriented R&D. However, the effective use of public members on NIH institute advisory councils had required special efforts to draw them out because lay members do not feel competent to evaluate the scientific projects and hesitate to comment on the quality of science.

NIH institute directors emphasized the importance of the council members' personal qualities in making council meetings effective. They believe that the institute should:

- choose council members for style and interpersonal skill before professional competence;
- choose members who have a strong point-of-view.

Politics plays a role in council member selection, since nominees are ordinarily approved at departmental or higher levels, but some agencies feel that that has its benefits: political choices are believed to be better connected to funding sources and better able, therefore, to assure the agency a hearing for its programs and budget requests. An attempt is usually made to balance the representation on advisory councils so that they include: a range of scientific disciplines, institutional and geographic spread, representation of minority groups and women, and (sometimes) a range of ages.

A frequent recommendation was that advisory council membership have fixed time limits, otherwise there is a tendency for a small, fixed group to maintain dominance of the council for a long period.

Operation

The effective functioning of an advisory council is highly dependent on the way in which the meetings are organized, the staff work is done, and the director participates.

Experience with the NIH institute advisory councils suggests that effectiveness is enhanced by the following procedures:

- *The institute director serves as council chairman.* Since the general role of advisory councils is to establish two-way communication between the various constituencies and the institute, it is necessary to have someone in the chair who knows the institute well; that is not likely to be a council member. Moreover, unless the director is chairman, a tension will be established between the director and the council that is likely to result in his not bringing issues of consequence before the council.
- *Meetings are arranged to permit as much discussion of issues as possible.* One institute proceeds as follows: Before each meeting, the institute staff develops the key issues for discussion. The director asks one member of the council to think about each issue and present his thoughts at the meetings. This leads off the discussions; the institute director then attempts to focus the discussion during the meeting.

  Another institute relies slightly more on staff work before the meeting. Once the specific topics to be discussed have been identified, the staff prepares background papers on each one. The director selects one council member as "Agenda Chairman" and goes over the agenda with him before each meeting. During the meeting, the director:
  - does not ask council members to directly state their positions on a policy issue,

in the belief that most of them are reticent about taking unequivocal stands

- tries to keep debate from getting angry, in the belief that angry members will not spread a positive view of the institute
- tries to draw out the comments of lay members, who are reticent in the presence of scientists
- seeks to have everyone participate and have a feeling of participation

Still another institute insures effective discussions during the council meetings by dividing the council into subcommittees for discussion of the issues before the general council meetings; the subcommittees then make recommendations to the general council.

- *Members are involved personally and informally in institute affairs.* The director of one institute makes a conscious effort to get to know every council member personally, especially through arranging social events. Between meetings, he engages in private, personal communications with council members; he goes to them *ad hoc* for advice, and involves them in institute activities (for example, having them head up task forces or serve on committees).
- *The council is listened to.* Fundamental to the effectiveness of an advisory council, of course, is that a feeling of mutual trust and respect develop between the council and the institute. Only if the staff of the institute asks for and listens to the council's advice will its members be willing to devote the effort needed to provide advice that will be listened to.

III. MANAGEMENT DECISIONS

WHAT SHOULD BE THE MAJOR FEATURES OF THE MANAGERIAL STYLE?

Four major features serve to define the basic management style of an R&D agency in the support of extramural research. These are:

- The *allocation of managerial effort* among the phases of R&D activity.
- The *degree of control* exercised by the agency over the R&D activities it supports.
- The *extent of external participation* in the management process.
- The *variety of management styles* employed by the agency.

Allocation of Managerial Effort

R&D agencies allocate their managerial efforts in different ways among the three principal phases of R&D activity -- planning, development, and evaluation. These different allocations derive from different philosophies of R&D management and from different R&D objectives.

Development Emphasis. One approach adopted by many R&D agencies has been to place primary management emphasis on the selection and funding of individual projects; that is, on the development phase of R&D activity. In this approach, little attention is explicitly paid to the prior planning of comprehensive programs or to the evaluation of program performance after completion. R&D management in these cases is almost entirely concerned with selection of the projects to be funded from among a large collection of prospective projects. The basic management styles of NIH and NSF share this development emphasis; they differ principally in the mechanism employed for project selection.

The *advantages* of this emphasis apply with greatest force when the R&D being funded is basic research in well-developed scientific disciplines. The development emphasis has its philosophical basis in the beliefs that:

- o scientists at the frontier are the best sources of ideas about what needs to be done;
- o ~~such~~ scientists will continually generate those ideas and present them to the funding agency;
- o selection among the proposals should be based primarily on the scientific quality of the proposal and the competence of the proposer;
- o the best scientists will not or cannot work on other people's ideas;
- o the best *ex post* evaluation of a scientist's performance is provided by his peers in the form of the decision to publish his papers in professional journals and the reputation that he obtains.

In sum, with this emphasis the R&D agency serves as a selective funding source for a more-or-less self-governing community of scientists; the agency has only indirect influence over the topics and evaluation of the research.

The *disadvantages* of this emphasis are:

- o it does not sufficiently serve the public interest in assuring that public funds are expended to meet public needs;
- o it does not permit sufficient coordination of activities conducted as separate projects;
- o it does not pay sufficient attention to assuring that the projects supported actually are well carried out;
- o it relies too much upon the self-direction and self-evaluation of the R&D community and there

are portions of the R&D community for which such reliance would be unwarranted;

- it is appropriate at best for the support of basic research; but is inappropriate for practical and programmatic R&D in which goals must be established, programs planned, and progress monitored.

Planning Emphasis. A second major approach places the primary management emphasis on the design of R&D programs comprising coordinated series of projects; that is, on the planning phase. The basic management styles of NASA-Goddard, Air Force weapons system development, the National Cancer Institute's collaborative research, and many industrial R&D agencies have this primary emphasis on planning.

The *advantages* of this emphasis are strongest when the R&D being funded is product or process development employing well-defined clinical or industrial skills. The planning emphasis has its philosophical basis in the beliefs that:

- the goals of an R&D program can be established "outside" the R&D community;
- the necessary R&D project can be specified by individuals other than those who will be performing the work;
- the best way to assure achievement of the specified goals is to design a coordinated series of projects;
- good scientists and developers will work on projects defined by others;
- close external monitoring of project progress is both feasible and desirable.

In sum, with this emphasis, the R&D agency serves as a purchaser of carefully-defined services from the R&D community; the agency has direct influence over the subject and evaluation of the research.

The *disadvantages* of this emphasis derive in large measure from fears that planning will extend to areas of research activity (especially basic research) in which it might be inappropriate; that the planning will be incompetent and the monitoring onerous; and that creativity and quality will be inhibited by too detailed a plan.

However, there is general agreement that for complex R&D activities in which there is a solid base of engineering knowledge and technique, a number of competent development organizations, and well-defined goals (such as in the design of spacecraft), a planning emphasis is appropriate. The primary disagreements concern the boundaries of propriety for such an approach: would it be suitable for managing the design of new forms of education, for example? In what areas is there a sufficient base of knowledge, technique, and institutions to enable adequate planning to be conducted?

Balanced Emphasis. A third approach places the management emphasis in fairly even balance between the planning and development phases. Planning, while present, is carried out on a continuing, incremental basis, rather than as a unique, comprehensive exercise. Consequently, the management effort being devoted to it at any instant is less than in the previous case. The development phase, while it includes project monitoring as well as selection, shares the managerial emphasis with the planning activities. This balanced emphasis is characteristic of some of the R&D management practices of NIMH, the Department of Agriculture, and the Office of Economic Opportunity.

The *advantages* of this balanced emphasis are strongest in the case of applied research on continuing problems of practical concern. The balanced emphasis has its philosophical basis in the beliefs that:

- the goals of an R&D program can be established "outside" the R&D community;
- the continuity of concern for most of the agency's issues means that planning may be accomplished in an evolutionary and incremental fashion;

- good scientists and developers can be attracted to projects defined by others;
- careful project selection procedures, relying upon practitioner as well as scientist judgment, are necessary and appropriate;
- careful external monitoring of on-going projects is both desirable and feasible.

In sum, with this emphasis the R&D agency is linked with its R&D community in a continuing association in which the agency provides monitored support in return for the R&D community's dedication to the goals established by the agency.

The *disadvantages* of the balanced emphasis derive from the belief that it does not go far enough toward either the planning or the development emphasis to satisfy the strong proponents of either.

Evaluation Emphasis. A forth approach is to place management emphasis on the evaluation phase of R&D management. To our knowledge, no agency has adopted it, although the Cooperative State Research Service of USDA has come close. Were it implemented, it would involve the devotion of considerable effort to reviewing the performance of projects and programs after their completion; the resultant information would then be employed in the planning and development of new programs and projects.

One *advantage* of such an emphasis would be that much program planning and almost all project selection is accomplished now on the basis of written proposals describing what will be done, yet in many cases this results in a premium on skillful writing and excessive optimism concerning what might be accomplished by the proposed project or program. Were major efforts to be undertaken to evaluate performance after the fact, it would probably have a positive effect on the realism of proposed projects and programs and on the ability to judge the competence of prospective performers.

The *disadvantages* of such an emphasis include the difficulty of actually making such evaluations (although they should not be any more difficult to make than project selection decisions on the basis of proposals) and of linking them effectively into planning and development decisions.

Degree of Control

R&D agencies have a choice of the degree of control they will exercise over the R&D activities they sponsor.

Passive. At one extreme, an agency may adopt a passive mode, leaving the planning, conduct, and monitoring of research up to the R&D community itself. This is the style generally adopted by agencies supporting basic research. Its justification lies in the same assumptions about the R&D process that were listed in justification of a developmental emphasis for R&D management. Its legal symbol is the *grant* as a form of support; grant-supported R&D is traditionally considered to be legally under the control and responsibility of the grant recipient.

Active. At the other extreme, it may adopt an *active mode*, closely specifying and monitoring what is to be done at each stage in the R&D activity. This is the style generally adopted by agencies supporting development. Its justification derives from experience with engineering and applied research. Its legal symbol is the *contract* as a form of support; contract-supported R&D is considered to be legally subject to the control and monitoring of the contracting agency.

Intermediate. In between, of course, there are a range of balances between passive and active control that have been found by a number of agencies. Some of these amount to changing the degree of control at different phases of R&D management. For example, the agency may exercise close control over program and project planning, but then spend less effort in monitoring the progress of the resultant R&D activities.

Degree of External Participation

Another characteristic that defines an R&D agency's management style is the degree of external participation in the performance of its responsibilities.

Considerable. NIH, for example, is characterized by extensive participation of the external research community in decisionmaking during all phases of management. Study sections, comprising prominent extramural biomedical researchers, assign the basic ranking of proposals for support of extramural research; institute advisory councils, comprising researchers and practitioners, ratify study section rankings and introduce program judgments. The NIH staff assigned to these groups -- the executive secretaries of study sections and institute program officers -- play a relatively small role in the decisionmaking; most of the substantive decisions are made by these external groups.

Minimal. ONR and NASA-Goddard, however, place almost exclusive reliance on internal staff for decisionmaking. ONR program officers rely on their own judgment to a greater extent than basic science program officers in most other agencies; NASA operates in an R&D context in which reliance upon outside judgments in making contract awards would be infeasible and in which a high level of staff competence and awareness of agency needs reinforces the inclination to reserve such judgments to insiders.

Determining factors. Several factors affect the degree of external involvement an agency finds desirable. All else remaining constant, the tendency to involve outsiders will be greater:

- as involvement with basic research increases (the outsiders will be basic scientists);
- as involvement with development increases (the outsiders will be practitioners and users);
- the higher the quality and prestige of a field of science being supported (the outsiders will be scientists in that field);
- the smaller and less qualified the internal staff;
- the greater the need to build an external constituency for the agency;

- the greater the chance of conflict-of-interest for agency staff;
- the lower the chance of conflict-of-interest for outside participants.

An agency supporting basic research in an area of high quality science and well-trained scientists, which feels the need to build an external constituency will find it desirable and feasible to engage many external scientists in its deliberations, as NIH has done.

An agency supporting hardware development in an area of high-quality science and engineering, but strong competitive industrial interest, is likely to find it necessary to rely almost solely on internal management competence, as NASA and the Air Force have done.

Variety of Management Styles

The final determinant of an agency's basic R&D management paradigm is the number of management styles it uses in dealing with different R&D communities and objectives.

NIH, for example, employs its basic *dual review* process almost exclusively (since it supports basic biomedical research almost exclusively), whereas NIMH has added to dual review a variety of other management processes:

- *coordinating centers* to encourage other components of NIMH to fund interrelated research, services, and training programs in specified subject areas;
- *funded centers* to suppo·* research, service, and training programs in specified subject areas;
- the *mental health services R&D program* to develop and implement improved modes of delivering health services.

Similarly, NASA-Goddard employs one basic paradigm (with a number of internal variations), while the Department of Agriculture has added processes for developing cooperative *region* *research projects*, to meet common needs of several states, and *special research projects*, to respond to high-priority national problems, to its basic process for funding state agricultural experiment stations.

A unitary management style, which uses essentially the same planning, development, and evaluation processes for every R&D activity supported by the agency, has the *advantage* of managerial simplicity and consistency; but it has the *disadvantage* of providing inadequate response to variations in the R&D communities and objectives that many agencies face. An agency, such as the NIE, that is likely to support a wide range of R&D communities (from the behavioral and social sciences to the physical sciences and education) and a variety of R&D objectives (from basic research to development and demonstration) will probably need to employ a number of different management processes matched to the needs of its several R&D communities and objectives.

HOW SHOULD BUDGET ALLOCATIONS BE MADE?

The primal management decision is budget allocation. The manner in which that allocation is made is a crucial determinant of an R&D agency's management performance. There are *three aspects* of budget allocation that must be considered in developing a management paradigm. They are:

- By what *process* shall the decision be made?
- What budget *structure* should be employed in decisionmaking?
- What factors limit or expand the *flexibility* with which budgets can be allocated?

Process

The process of budget allocation has three aspects: its *mode* -- comprehensive or incremental; its *direction* -- top-down or bottom-up; and its *procedure* -- collegial or adversarial.

Mode. Theoretically, at least, there are two opposing modes of budget decisionmaking: comprehensive and incremental.

In the *comprehensive* mode, the entire budget is assumed to be available for distribution in the way that maximizes the agency's objectives. For a substantial R&D agency, comprehensive budget allocation every year would mean a considerable task of comparing a large number of possible programs against each other to select the optimal combination. But comprehensive budget decisionmaking generally occurs, if at all, only once in the life of an R&D agency -- at its beginning. The programs chosen then tend to develop a certain persistence that reduces the flexibility of allocation possible in any subsequent budgeting period. Consequently, most actual budget allocation occurs in an *incremental* mode, in which only a portion of the agency's budget is really available for distribution to increase service to the agency's objectives. This incremental mode of decisionmaking substantially reduces the problems of making budget allocations (by reducing the number of degrees of freedom), while also reducing (somewhat) the degree to which the resultant allocation can optimize service to the agency's objectives in any one year.

Those who favor comprehensive modes of decisionmaking tend to do so on theoretical grounds -- after all, comprehensive comparisons are the only way to assure that maximum benefit will be received from a given budget; while those who favor incremental modes do so on both practical and theoretical grounds -- it is unlikely that any agency with continuing programs will have more than a small portion of its resources truly available for reallocation in any year and, moreover, it is not clear that any R&D agency's capacity to examine alternative allocations is good enough to obtain the theoretical benefits of comprehensive allocation. All R&D agencies that we examined make their major budget allocations incrementally.

Direction. Another distinction among budget decisionmaking processes concerns the direction in which the decision proceeds along lines of authority: bottom-up or top-down.

In *bottom-up* decisionmaking, each of the agency program officers prepares budget requests describing his best judgment of his needs for the next budget period. His immediate supervisor then combines and modifies the budgets from the several program officers reporting to him and forwards the merged budget to *his* immediate superior. The process continues up the line of authority until it reaches the agency director who combines and modifies the budgets to produce an agency budget that goes to the responsible executive agencies and the Congress. When the executive and legislative branches act on the proposed budget, their decision leads to a modification of the proposed budgets at each step down the line of authority. The modification may be a simple equal percentage reduction (or expansion) up and down the line, or it may be a different change at each step. In the latter case, the process comes to resemble top-down decisionmaking.

In *top-down* decisionmaking, the agency director decides upon an allocation of the agency's budget among each of his principal subordinates. Each of them, in turn, allocates his budget among *his* subordinates. The process continues until each program officer receives his allocation, which he then uses to support R&D activities.

The difference between bottom-up and top-down decisionmaking could be quite substantial, if budget decisionmaking were done in the comprehensive mode. However, when the decisionmaking is incremental, the two methods tend to merge into a mode in which signals about the desirable and possible budget increments at each level travel up and down the line of authority.

Procedure. A third distinction among budget decisionmaking processes concerns the procedure by which the decisions are made: adversarial or collegial.

In an *adversarial* procedure, the several subordinates compete for the budget allocated by their immediate superior; the amount each of the subordinate organizations receives depends on its ability to convince the superior of the value of its programs.

In a *collegial* procedure, the several subordinates decide among themselves how they will divide the budget made available to them by their immediate superior; the amount each subordinate organization receives depends on its competence in bargaining with its fellows.

Both collegial and adversarial procedures are employed in federal R&D agencies.

Structure

The taxonomy used to define budget categories establishes the framework within which the major resource allocation decisions at an R&D agency are made. There are two major classes of taxonomy, leading to two alternative kinds of budget structure -- input-structured and output-structured.

Input-structured. An input-structured budget is one in which the major subcategories correspond to factors that enter the R&D process. These may be the inputs recognized in conventional *accounting categories* -- salaries, facilities, equipment, travel, and so on; or the inputs defined in terms of *R&D funding mechanisms* -- basic research grants, development contracts, fellowships, and so on; or the inputs defined in terms of support for certain groups of *R&D performers* (disciplines) -- biochemistry, genetics, statistics, and so on. While these categories differ considerably among themselves, they represent simply different groupings of the resources entering R&D activities. They provide data that is most useful in making administrative decisions. Most R&D agency budgets are structured in one of these ways. For example, at NIH the budget is structured according to intramural, extramural, and special programs, and consequently, the competition for funds between institutes takes place in each of these categories.

Output-structured. An output-structured budget is one in which the major subcategories correspond to aspects of the results of the R&D process. These may be the resources associated with activities serving each of the major agency *objectives* -- develop leukemia vaccine, design and launch orbiting solar observatory, increase knowledge of DNA functioning, create new dental amalgams, and so on; or the resources devoted to programs serving particular *groups of users* -- dairy farmers, feedgrain farmers, high school science teachers, leukemia patients. The virtue of this form of budgeting is that it produces data directly useful in the process of planning. By displaying the resources currently devoted to specified agency objectives or user groups, it establishes the basis for rational consideration of the reallocation of existing resources and allocation of new resources among competing agency goals. As R&D agencies begin to devote greater emphasis to the planning and evaluation aspects of R&D management, output structured budgets should gain wider use.

Flexibility

The budget allocation decision is affected by a variety of factors that operate in one or another way to limit or expand the flexibility of budget choice.

Limit. Among the factors operating to limit budget flexibility are the following:

- *Program continuity*. Most R&D programs and many projects have great persistence. Some projects simply require several years for completion; most NSF and NIH grants are for 3 to 5 years for that reason. Others develop their own momentum through the growth of constituency groups; the NSF Summer Institutes for teachers have significant constituency and Congressional support. The consequence of these factors is that mature R&D agencies find very large portions of their budgets committed each year to continuation of existing activities, which considerably limits budget flexibility.
- *Ear-marking and line-items*. While many R&D agencies welcome positive Congressional concern for and support of their activities, it sometimes comes at the price of reduced budget flexibility, since Congress may earmark certain parts of the budget to specific activities that it favors. If done on a regular basis, this may take the form of Congressional budgeting not of a single total sum to the agency, but of a series of specific sums ("line items") to subcategories within the total budget. For example, Congress regularly earmarks significant

portions of USDA research funds for research on cotton, tobacco, soy beans, and so on.

- *Formula-granting*. Some R&D agencies, most notably USDA and NIH, allocate a portion of their budgets according to a fixed formula. The USDA expends about a quarter of its total R&D budget on a formula basis in support of the state agricultural experiment stations; NIH provides certain institutional grants on a formula basis.
- *Intramural programs*. Organizations with intramural research programs find that the intramural budget is hard to adjust; this is especially true when the intramural researchers have Civil Service tenure. Budgets tend to be determined primarily on the basis of the number of intramural researchers and their interests, rather than on the basis of changing needs.
- *Budget shrinkage*. In times of budget stability or shrinkage, existing programs tend to take up most of the available budget, reducing the opportunities for new starts and redirection.

Expand. Conversely, the factors operating to expand budget flexibility include:

- *Finite programs*. The tendency for programs to develop excessive budgetary persistence can be counteracted, in part, by establishing a clear time limit on programs when they are initiated. To reinforce this approach, specific program goals and plans can be set and constantly reiterated.
- *Single line item budget*. R&D agencies have an obvious preference for receiving budgets as a single sum, without Congressional or other specification as to how it is to be allocated. NASA is one agency

that operates under this condition; consequently, the separate NASA Centers receive funds to the extent that their programs respond to the agency's needs.

- *Discretionary granting.* As opposed to formula granting, discretionary granting retains the agency's control over budget allocation among projects.
- *Budget growth.* Clearly, new directions and reallocations are easier to carry out in times of budget growth, when new funds may be allocated freely.

HOW SHOULD PROGRAM PLANNING BE CONDUCTED?

During the *planning phase* of R&D management, two principal functions must be accomplished:

- developing *new program ideas*
- *defining* the specific *objectives and major tasks* of each new program

The manner in which these functions are carried out differs considerably among the various R&D agencies. Those that emphasize the support of basic research tend to put little explicit and regular effort into planning; their efforts are usually *ad hoc* and responsive to the concerns of the external R&D community. However, those having an interest in practical and programmatic R&D generally employ more elaborate and routine planning procedures that respond to the interest of practitioners and other eventual users of R&D products.

New Program Ideas

Ideas for new programs come from a variety of sources, courted more or less assiduously by the several R&D agencies. In many cases, internal staff and managers generate most new program ideas themselves; in a number of cases, external practitioners and scientists play a large role in the establishment of new programs.

Internal Sources. Ideas for new program starts arise within R&D agencies from program managers, intramural scientific staff, and the agency's administration.

The *program managers* of existing extramural programs derive recommendations for new programs in several different ways, including:

- *Identification of promising redirections or spin-offs from existing programs.*
  Several agencies identified this as the most frequent source of new program ideas. The Forest Service, for example, redirected on-going work on disposal of pulp and paper waste in order to study the effects of distributing sludge from waste treatment plants on forest floors, when the latter idea was proposed. The National Institute of Child Health and Human Development separated a program on population from an existing program of reproductive studies when it became clear that the government was becoming interested in population problems.
- *Detection of changing directions in the R&D community.*
  In basic research agencies, such as NSF and NIH, new program areas frequently follow, rather than lead, the research interest of the basic research communities. When program managers detect changes in the activities of a field of science, they translate them into new agency program areas.
- *Perceptions of critical needs and opportunities.*
  In applied and programmatic research agencies, program managers should attempt to keep abreast of the needs of the practitioners and other users and the opportunities opened by new R&D developments. That information should suggest new programs.

This and the preceding method rely upon the individual perceptions and judgments of program officers. Some agencies attempt to proceed more formally, especially in the identification of need.

- *Analysis of data and formal studies.*
A variety of different kinds of studies can be undertaken to determine needs that R&D can meet.

  For example, NIMH is considering using *biometric data* to gauge critical needs for research. In one instance, observation of declining state mental hospital and increasing community mental health center case loads, plus data showing that blacks are not using community centers, has led to research focused on learning why blacks do not use the centers.

  NIMH also conducts small *surveys* of the views concerning critical R&D needs held by attendees at research conferences, panel meetings, advisory council sessions, and so on.

  NSF's Division of Research Applications (RANN) has a group that sponsors *problem assessments* and *exploratory research* intended to determine the need for and character of new R&D programs intended to respond to major national needs.

  NSF's Education Division has been concerned with developing new pre-college and undergraduate curricula in the sciences. The identification of new program areas is assisted by maintenance of a *matrix of subject matter versus level of schooling*. As curriculum materials, teacher training and retraining, and diffusion activities are completed in each entry of the matrix, it is checked off. Program funds can then be targeted to the blank entries. Before programs are undertaken, however, they are also expected to satisfy the requirements that there be a need for the curriculum that is perceived by Congress, the OMB, and the eventual user community; and that there be an available development team that is right for the job.

Yet another approach to identification of R&D program needs is *evaluation of existing operational programs*. Deficiencies identified during such evaluations suggest R&D goals.

In agencies that have *intramural staff researchers* who may become extramural program managers, new program ideas often come from the intramural staff.

- At NASA-Goddard new program ideas can and often do arise spontaneously from within the intramural staff. Since the staff is kept aware of NASA's long-range plans and priorities and since Goddard has both managed and conducted programmatic activities for over a decade, these ideas are usually close to the mark. The staff member can usually devote a few man-months of effort to development of the idea without need for high-level approval.
- At OEO's Planning, Research, and Evaluation Division, ideas for new extramural programs occasionally develop from the studies being conducted intramurally by in-house staff. For example, a program to experiment with various forms of health care delivery for the poor grew out of an in-house review of the OEO income maintenance experiment.
- At NIH, intramural researchers may suggest activities to be carried out by outsiders through NIH's

collaborative research mechanism (which is separate from extramural research). These are usually activities needed as a part of intramural research, or deriving from it, for which intramural skills are inadequate or inappropriate. At the National Cancer Institute these collaborative programs play a major role in carefully-designed R&D programs directed toward specific products.

Every agency, of course, finds itself subject to some extent to the R&D interests of its *administration*, most particularly its *director*. Some directors are content to exercise their interest through selection among the ideas brought forth by the staff, others often suggest new programs. In the case of OEO's PR&E, the director and deputy director's suggestions have a special relevance and value; since each of them serves on high-level policy task forces, each brings back to OEO's policy-oriented research program a strong feeling for policy needs and priorities.

External Sources. External sources of program ideas are more varied than internal ones. Some ideas come from operating agencies of the government, some from the broader practitioner and user communities, and some from the R&D community.

Three R&D agencies that receive program ideas from *operating agencies* are the U.S. Air Force, NASA, and NSF-RANN.

The Air Force has formal procedures for obtaining R&D program recommendations from the operating commands. Any general officer in any of the operating commands can begin the process by stating a perceived need to the Director of Requirements in his command. The Director prepares a document describing the Required Operational Capability (ROC) and sends it to his counterparts in the other commands for coordination, and then to his commanding officer for signature and transmittal to Air Force Headquarters. At Headquarters it is assigned to an action officer who sends it to the Deputy Chiefs of Staff and to subject area R&D panels (e.g., Strategic, Tactical, Airlift) for preliminary comments. He then prepares a position paper that is distributed with the ROC for concurrence (or disagreement). The position paper plus responses are then sent to an R&D panel for formal review. If the panel approves the ROC, a series of Required Action Directives (RADs) is issued calling for supplementary studies of various kinds. Management of the program is turned over to a Program Element Monitor who oversees execution of the RADs. Once the RADs are completed, the proposal receives two final reviews by the Air Staff Board and the Air Force Council. If both are favorable, a final RAD is issued to the Air Force System Command (the R&D agency) to develop the final program plan called the Concept Formulation Package/Technical Development Plan (CFP/TDP).

NASA's procedures are considerably less formal, at least insofar as they affect the Goddard Laboratory. Each year, all of the NASA Center directors meet to produce a long-range plan. They take into account both technical capabilities and political and budgetary realities. This serves as a framework against which the Center directors consider new program proposals. In some cases, it may lead to new program initiatives. In many cases, it serves to ratify new programs suggested by the Centers.

NSF's Directorate of Research Applications receives program ideas from federal, state, and local operating agencies. The process is only partly formal. Each Program Director has an advisory committee of federal agency representatives that reviews his program plans and suggests areas of R&D need. Most program directors also consult on an *ad hoc* basis with officials in other federal agencies. But the program directors also respond to the program ideas that arise within the R&D community, partly under the influence of operating agencies.

Practitioners are an especially important source of program ideas in agriculture. Their influence is strong in large measure because there are individuals -- the county agents -- who serve as links to the R&D community, who are in close and continuous contact with the farmers. The county agents take as their role not only the dissemination of new products and processes to the farmers, but also the transmission back into the R&D system of information about the farmer's problems and needs. They convey that information to extension specialists and research personnel at State Agricultural Experiment Stations, who in turn may suggest new or redirected research programs at their local stations, new regional programs conducted at all the stations in a region, or special programs attacking major national problems, such as corn blight.

Industrial growers, some of whom contribute to the support of R&D at the agricultural experiment stations, have been quite outspoken in demanding that the stations undertake programs that respond to their needs. For example, after the station in a western state developed a vegetable ideally suited to canning, a large packing firm in the midwest demanded that the local station develop a similar plant adapted to midwest conditions.

The *R&D community* makes its ideas for programs known in a variety of ways, both informal and formal. In most basic research agencies, for example, the scientific community is the primary source of program ideas, which it provides implicitly through the cumulation of its unsolicited project proposals. At NIH and NIMH, the advisory councils (comprising primarily research personnel) of the institutes make program recommendations. Frequently, they serve as conduits for program ideas suggested by scientific practitioner and public constituency groups, such as the American Cancer Society or medical school deans. (Advisory councils have been discussed in greater detail earlier.)

But many of the research agencies have found the need for a somewhat more orderly development of new program ideas, while still recognizing the preeminence of the scientist as formulator of program and project concepts. The almost universal response to this need has been the convening of some form of *ad hoc group activity* -- *committee, panel, workshop, or conference*, in which scientists are the principal participants.

The NIH employs these mechanisms quite frequently. NIH administration with whom we spoke felt that *small, informal panels* were "by far the best" of the possibilities for assessing past and present research in an area and suggesting future research. Conferences have been tried, but their group dynamics often turn out to be bad. Individual consultants, while helpful, cannot cover all the program areas at once or challenge each other's ideas face-to-face. Thus, it is better to bring them together in small panels, confronting each other informally.

NIH's experience provides some guidelines for organizing such panels:

- o form a small committee (3 or 4) of consultants to pick the panel;
- o select 10-12 men in the area to be assessed; they should be the "cream of the field";
- o tell them that their job is to assess research on the topic in the past and the present, but most importantly, to say where the next research should be;
- o have a top-flight external scientist chair the meeting, but be sure the program director prods the panel to keep it going in the right directions;
- o have a stenographic record kept, then have the program officer distill panel comments and send them to the panelists for review;
- o use the revised proceedings internally in program planning;
- o if stimulation of interest and proposals is desired, have a version of the panel's assessment published in a professional journal.

Definition of Program Objectives and Tasks

Once the idea for a new program has been accepted, its specific objectives and tasks must be laid out in sufficient detail to permit project activities to be undertaken and supported. R&D agencies use a variety of methods for elaborating program ideas, which we have categorized as ad hoc, semi-formal, and formal procedures.

Ad Hoc. In agencies supporting basic research, *ad hoc* program elaboration may comprise nothing more than an allocation of funds to the program area to await the unsolicited arrivals of project proposals from the research community. Some agencies take delicate steps toward soliciting such "unsolicited" proposals by:

- announcing their areas of interest with some specificity,
- holding conferences whose primary purpose is to generate proposals in an area,
- directly inviting particular researchers to submit proposals (this runs some risk of embarassment when project proposals are reviewed by an autonomous review panel and, as sometimes happens, they reject the invited project).

The more structured *ad hoc* procedures generally employ an external panel or an internal task force, whose members have been selected for the purpose, to suggest the program's necessary projects and objectives. The external panels are generally similar to, if not the same as, the informal panels described earlier as the source of program ideas.

The result of these *ad hoc* procedures is generally no more than a collection of desirable projects and, perhaps, an indication of potential performers. The plans rarely, if ever, interrelate the component projects in sequence, indicate critical subobjectives, or estimate costs or time.

Semi-formal. The semi-formal procedures used for program elaboration, as a rule, attempt to describe in greater detail what each project is to do, for how long, and at what cost. In contrast to the formal procedures to be described below, however, they rely on subjective and unstructured methods.

When OEO's PR&E division has decided to undertake a particular planned evaluation of a social program, for example, it initiates careful in-house preliminary planning to determine:

- o What to find out? (The emphasis is on separating the essential from the desirable.)
- o How to find it out?
- o How much it will cost? (Costs are estimated to within 50%.)
- o Who will use the results and how?

A two-person team, consisting of an analyst and a person knowledgeable about the program area to be evaluated, carries out this planning, employing consultants as needed. At the end of 2 to 4 months, a Request for Proposal (RFP) is written that will be used to solicit proposals from prospective contractors for the detailed design and implementation phases of the evaluation.

At NIMH when a new program area responding to a critical need has been identified, an effort is made to determine whether the information needed is already available through prior research. Systematic search efforts are undertaken. Each program chief is responsible for:

- o screening the relevant literature in his area,
- o preparing summaries of innovative information uncovered and projects visited,
- o screening all NIMH projects already funded.

If the needed information is not all available, then investigators will be "stimulated" to apply for a grant.

The most orderly of the semi-formal procedures is that employed by NASA-Goddard. There, any member of the staff can initiate a program idea, which then progresses through four distinct phases from conception to hardware. At the end of each of the first three phases, progress is reviewed and the decision to continue or terminate is made. The phases are:

- o A -- idea stage
- o B -- development of alternative approaches

- C -- detailed project design
- D -- hardware fabrication and operation

Phase A activity averages 3 to 6 months duration, is conducted internally, and produces a concise statement of mission objectives, identification of major research and technical requirements, assessments of feasibility and desirability, and sketches of alternative approaches to fulfilling mission requirements.

Only about 10 Phase B planning efforts are approved by the Goddard director each year. By this point, the required effort becomes "noticeable" to OMB, Congress, and the like, so NASA Headquarters receives copies of each Phase B plan and the project enters the "new start" category. From 6 to 12 months and from 10 to 50 persons are required to produce a report on alternative ways of achieving the mission, identification of state-of-the-art constraints, and estimates of development time and total cost. This is generally done internally, although in some cases up to half may be contracted out.

Formal. The formal procedures used for program elaboration generally attempt to impose a regular structure upon the process of deciding what projects must be carried out to achieve a program's objectives. This structure seeks to break large subjective judgments into smaller ones that can then be combined in some objective manner; the result is usually displayed in a highly specific format. The advantage of such procedures is the discipline that is imposed on the planning process; the result can be improved interproject comparisons. The disadvantage of these procedures is the procrustean nature of the bed into which program planning is forced; more may be lost in excluding implicit judgments than is gained in explicit evaluation.

The National Cancer Institute (NCI) has developed a formal planning procedure, the *Convergence Technique*, that provides the framework for planning collaborative R&D programs intended to achieve specified goals. Its product is a *convergence plan*, displayed in a *convergence chart*. The chart comprises three separate arrays:

- the *linear array* comprises the minimum sequence of research activities needed to achieve the program's objective
- the *concurrent array* comprises related, but not essential, research activities that may yield important insights
- the *supplementary array* includes "blue sky" projects that may have big impacts, but with low probability

The design of a convergence plan is a 4 to 6 week process. A planning group, containing 5 to 7 persons can carry it out.

The first task is to define an *operational* objective whose attainment would clearly end the program.

- "Cure leukemia" is not good.
- "Develop vaccine for acute leukemia in early childhood" is operational.

The second task is to define several *intermediate goals* between the objective and the current state. The intermediate goals define the program *phases*.

The third task is to determine what *criteria* would have to be satisfied to justify the decision that an intermediate goal had been reached.

The fourth task is to derive from the criteria the series of *projects* needed to provide the information to satisfy the criteria.

The resultant convergence plan (and chart) is used to manage the program as it proceeds. New projects related to a program can generally be entered in vacant sections in the chart under predefined headings.

A number of industrial firms have developed and employed formal R&D planning procedures that we shall refer to, generically, as *scoring models*.

These models vary in their complexity, although each aims to serve the same purpose: to select from among a set of proposed R&D activities those that maximize some measure of value (to the corporation in the industrial application).

The first step in each of them is to *list the possible projects* to be carried out as part of the program. The second step is to employ expert judgment (of staff, consultants, or outside panels) to estimate the *scores* of each project on a number of criteria, including time-phased project costs. Among the criteria might be:

- benefit in dollars of project completion
- relevance to program objectives
- probability of success

These scores are then combined into an overall score for each project. The third step is to select those projects that maximize some function of the scores subject to budgetary and time constraints. (Mathematical procedures would be used to do this.)

One complex variant of these methods seeks to link R&D projects with the attainment of a ranked list of operational objectives. Each project is described in terms of its criticality in serving each objective, and its costs. A computer program then determines how funds should be allocated among the various projects to achieve maximum attainment of the operational objectives.

HOW SHOULD PROGRAM DEVELOPMENT BE CONDUCTED?

During the program *development phase* of R&D management, two tasks must be accomplished:

- *selection* of projects to be supported
- *monitoring* the progress of projects that are underway

Project Selection

The task of selection among project proposals differs according to whether a *grant* or a *contract* is to be awarded, since the traditions and legal assumptions associated with these two forms of support are quite different.

The grant has ordinarily been the method used to fund basic research proposed by the researchers. Selection among project proposals has generally been on the basis of a judgment of the scientific quality of the proposed research and the researcher.

The contract has generally been the method used to fund programmatic R&D responsive to the needs of the agency or its constituency. Selection among proposals has had to consider both scientific quality and program relevance, as well as cost. Different selection procedures have evolved to handle these different situations.

Grants. There are four basic procedures for selecting projects to be funded by means of grants. These all rely upon a program officer (or executive secretary) plus:

- *no outside reviewers* (that is, the decision is the program officer's alone)
- *mail review* by outsiders
- a *single panel* of outside reviewers
- *dual panels* of outside reviewers (operating one after the other)

The *no outside reviewer* procedure is employed primarily at the Office of Naval Research (ONR). It depends upon having program officers who are in close and continuing contact with the research and researchers in their fields of interest, and who remain abreast of the program concerns of their agency. The program officer relies upon his own judgment and his general knowledge of the state-of-the-art and the reputation of individual researchers to decide whether or not to support a proposal. To be effective, consequently, program officers must spend considerable time keeping abreast, which means traveling and reading. This reduces the number of proposals each can handle.

The *advantages* of this procedure are:

- the program officer is free to develop a program that responds to his perceptions of agency needs;
- the program officer can bet on newcomers, mavericks, and outsiders who might be excluded by reviewers drawn from the most prominent in an existing discipline;
- the program can change quickly in response to new needs or opportunities;
- the program officer's judgment of quality can be more rigorous than that of reviewers drawn from a weak research area. (This can be of considerable importance in some areas of educational R&D and the applied behavioral and social sciences in general.)
- the program officer can combine an awareness of specific practical problems requiring R&D with his jugement of R&D quality in a way that few researchers can.

The *disadvantages* of this procedure are:

- its complete reliance upon the judgments of a single person, whose personal strengths, weaknesses, and prejudices affect an entire area of R&D;
- its vulnerability to favoritism and improper judgments and, therefore, to criticism from scientists and from Congress;
- its low profile in the R&D community does not generate the natural constituency support provided by scientists who participate in the panels employed by other procedures.

The *mail review* procedure is employed in the physical, mathematical and engineering sciences branches of the National Science Foundation, with the exception of the biological sciences. The cognizant program officer sends each proposal he receives to at least 3 or 4 reviewers, chosen *ad hoc* to be appropriate to the topic of the proposal. A complex proposal may be sent to several different groups of reviewers for comments on its several aspects. Reviewers do not generally see more than one proposal at a time; thus, the reviewers do not provide a comparative ranking, according to the same criteria, of all proposals arriving at a certain time. The program officer makes the comparison among projects as he draws upon the reviews in deciding which projects to fund. Summaries of the reviews, together with his decisions, are then forwarded by the program officer to his administrative superiors for approval.

Two variants of mail review have been employed at NSF.

- *Delphi variant.* One variant is an adapation of the "Delphi Technique," which employs an iterative series of questionnaires and feedback about prior questionnaire results to produce a better informed group judgment from a group of experts. The mail review adaptation is, when first round reviews disagree, to send to each reviewer anonymous summaries of all the reviews and then hold a second round in which each reviewer may revise his review in light of his colleague's comments.
- *Post award audit.* Another variant is to have a program advisory panel meet every six months or so to go over and comment upon the actions taken by the program officer, who can be given a little more flexibility to act quickly and make decisions on his own, since he knows his actions will be reviewed subsequently.

The *advantages* of mail review are:

- the agency can obtain the advice of scientists who could not be attracted to permanent government service;
- the choice of outside reviewers (including practitioners) can be tailored to the topic of each proposal;
- every reviewer has his say, without the chance of being dominated by colleagues with strong

personalities or large reputations as sometimes occurs in panel meetings;

- the work load of review can be spread over a great many individuals, instead of being concentrated on a few panel members;
- decisions are not subject to the prejudices and narrow viewpoints of a fixed panel;
- decisions are not as vulnerable to a program officer's weaknesses as they are in the "no outside review" case.

The *disadvantages* of mail review are:

- the difficulty in obtaining and maintaining lists of appropriate mail reviewers;
- the lack of interaction among reviewers (except in the Delphi variant) through which they can work out disagreements about a project's quality;
- the ease with which reviews can be orchestrated by a program officer through judicious selection of reviewers (some would count this as an advantage);
- the lack of opportunity for the reviewers to compare and rank groups of proposals, which mean that different proposals will be evaluated according to different criteria and standards of judgment;
- the lack of direct contact between program officer and reviewer means that the reviewer may not appreciate the program's objectives and priorities or know about its other activities; moreover, the mail reviewer is less likely to become a strong program advocate than is a panel member;
- many mail reviewers tend to see a proposal only in terms of their own field; some are mostly negative, because they downgrade everyone else's work; some are mostly positive, because they feel their field is important and should be expanded.

The *single panel* procedure is employed in the biological science and social sciences sections of NSF, and in other agencies on an *ad hoc* basis. The cognizant program officer presents a group of proposals to a panel compirising 10-15 scientists. The proposals may be only a selection of those received, generally the most difficult to decide. In the NSF system the panels are primarily advisory; they do not formally rank or approve projects. The program officer, however, is guided by the judgments of the panel. It would be possible, of course, to have the panels score the proposals and then make awards in order of scire, but that is not commonly done. The program officer decides what projects will be funded and then forwards his decision to his superiors.

There are two forms of single panel review.

- *Fixed panels.* In this form the panel is regularly constituted in a subject area (one panel per program officer) and meets a few times a year to review proposals. Panel members may serve 2 or 3 year terms.
- *Ad hoc panels.* In this form, the panel is specially set up to deal with a group of related proposals on a one-time basis. This may be done when a new area is being started, when enthusiasm for a particular topic peaks rapidly, or when a subject requires a special mix of specialists to give it proper review.

The *advantages* of single panel review are;

- the panel comprises many scientists who could not be attracted to full-time government service and program management;
- the panel has access to the full range of proposals and judges them comparatively according to the same criteria and standards;
- the panel can ask for and obtain additional information about the program or proposals from the program officer and each other (some may have

personal knowledge of the proposer);

- the program officer will benefit directly from his contacts with the participants and the meeting;
- the panelists are more likely than mail reviewers to become advocates and expositors of the program among their colleagues;
- the panelists have an opportunity to draw upon and dispute each other's judgments;
- the panel (if it comprises prominent scientists) provides assurance to the scientific community and Congress that decisions are being made fairly and objectively;
- decisions are not so vulnerable to program officer's weaknesses as in the "no outside review" procedure.

The *disadvantages* of single panel review are:

- the panel may be dominated by scientists with strong personalities or large reputations;
- panelists, since they are generally those who have succeeded under the existing research approach, may downgrade research that explores new approaches, combines several disciplines, or in other ways is outside the norm;
- if the research community in a subject area is weak, it may not be possible to obtain high enough standards of judgment from a peer panel;
- if the panel's area of responsibility is broad, it may not have enough members who can comment on a specific proposal to give a group evaluation; the results is that one or two panel members speak for the panel in that area, yet express only their own preferences and priorities.

The *dual panel* procedure is employed throughout the National Institutes of Health and (with slight variation) in many parts of the National Institute of Mental Health.

Proposals arriving at NIH are sorted by discipline to one of 48 *study sections*, which comprise groups of prominent scientists in each discipline. Each study section has a *chairman*, who is an outside scientist, and an *executive secretary*, who is the NIH program officer for the study section. The study sections review and assign a numerical score ("rank") to each proposal. The ranked proposals from the study sections are regrouped, and the scores rescaled so as to achieve comparability, according to the program interests of the 10 NIH Institutes and forwarded to the appropriate *institute advisory council*, which comprises scientists and practitioners. Each institute has several *program directors*, each of whom is responsible for the proposals in one subarea of the institute's concern. The program officers present the ranked proposals from the study section to the councils for approval. The study sections are supposed to judge proposals solely on the basis of their scientific quality, while the advisory councils are supposed to review their relevance to the institute's program. In practice, most proposals are paid in an order determined by their study section ranking. The exceptions are projects judged to have high program relevance (HPR) despite a relatively low ranking by the study section. They may be paid out of order by the council.

NIH staff (the executive secretaries and program directors) play a much smaller role in this selection process than of their opposite numbers at NSF or ONR. Most of the decision-making power is in the hands of the study sections, and theoretically at least, in the institute councils. Executive secretaries organize and manage the review process, write up summaries, and recommend new study section members; program directors "solicit" new work and handle the technical aspects of the institute's contacts with existing projects to be funded.

The *advantages* of dual panel review are those of *single panel* review plus:

- o an even greater reduction in the chances for improper program officer influence since the stimulation of new proposals (by the institute program directors) is completely insulated from proposal review (by the study sections);

- o a prospect of greater efficiency because of the greater specialization of function among study sections, institute councils, executive secretaries, and program directors;
- o an enhanced prospect of objectivity in each panel's decisions because the other panel is always looking over its shoulder;
- o a potential advantage over single panel review (which generally emphasizes scientific quality) in the provision for explicit judgments concerning program relevance by a group specially constituted for that purpose;
- o an enhanced assurance to the applicants that their proposals will be judged by competent scientists on scientific grounds;
- o an enhanced feeling of participation by the scientists that increases their sense of responsibility for the agency's programs and their activity in building the agency's scientific constituency;
- o an enhanced ability to support politically sensitive projects by reference to approval by a prestigious advisory council.

The *disadvantages* of dual panel review include those of single panel review with the addition that:

- study sections tend to undervalue activities in which problem relevance is high but prior research activity is small or nonexistent, yet councils are cautious about supporting proposals that have been ranked low by study sections (this leads to difficulties in the social and behavioral sciences, and indicates that dual review may be more satisfactory in the biological and physical sciences);
- o dual panel review leaves little control over program to the agency's internal staff, they become captive of their study sections and councils and frequently

cannot move the program in directions they feel are important.

In some single or dual panel review procedures, additional sources of information, beyond written proposals are used in making project selections. The most important of these sources is *site visiting*.

Site visits usually require 2-6 persons (10 or 12 in complex cases) to spend 2-3 days traveling and visiting the principal investigator and his project team at their institution. Since this is expensive and time-consuming, it is only done when certain conditions are satisfied, although most program officers feel that site visits save more money than they cost. For example, one agency site visits only for proposals that are over $200 thousand, have significant ambiguities, or whose deficiencies seem to be due to poor writing. Another visits all "complex" proposals. Size, complexity, and the importance of staff interrelationships and institutional support would seem to be factors that should justify site visits.

Site visits are different from panel reviews because:

- o the permit the project to be examined in far greater depth;
- o they reduce the importance of disciplinary biases, because the project team presents all its research (in every area) to the full review team and there is, therefore, less opportunity for biased attention;
- o they provide an opportunity for two-way communication between the project team and the review team.

The advantages are counterbalanced to some extent by the site visit's greater cost in dollars and time (it may add several months to the time required for review).

Some agencies award some of their R&D grants on a *formula-basis*, rather than on a discretionary basis.

The most striking example of this practice is the USDA's support of 53 State Agricultural Experiment Stations (SAES) through Congressionally-mandated formula grants (determined by rural population), which must be matched by the states and counties. This money is available to the

SAES to spend as they wish, subject to monitoring to see that the money is expended according to legislative intent.

The NIH also awards General Research Support Grants (GRSGs) on a formula basis to stable institutions that receive more than $40 thousand in discretionary support from NIH. The formula provides for a GRSG to be a percentage of NIH research grants at the institution; the percentage decreases as the total increases. The philosophy behind these formula grants is that no institution has a perfectly balanced mix of research grants and that flexible support is needed to permit the dean to:

- compensate for imbalances caused by the presence of eminent professors who get more than their share of research support or whose projects dominate a department;
- support young investigators until they build the credentials needed to obtain project support;
- support senior investigators who wish to follow a new path;
- fill gap areas in the institution's research;
- purchase new equipment;
- support research training programs.

The effect of this program is to increase the power of the dean's office in institutions where the project grant system has otherwise tended to increase the autonomy of individual professors. The grants are given to the highest administrative officer of the research institution, schools that have several equal ranking officers, receive the money in multiple grants, one for each officer. Most institutions receiving such grants make active use of them; in some instances the funds turn over 4 or 5 times during the year as they are loaned to cover project costs until other sources become available.

The *difficulties* with these grants are that the dean can use them for empire-building rather than research; they can be used to sustain mediocre faculty who are unable to obtain project support (although many institutions impose time limits on support from these funds); they tend to be used for lower quality and more risky projects than project grants; and they are more easily cut and more vulnerable to critical

OMB or Congressional scrutiny than project funds.

Some agencies have found it advisable to establish separate grant review mechanisms for *small projects* (say, less than $5,000), for *large projects* (say, more than $500,000), and for *interdisciplinary* projects. The separate mechanisms have seemed desirable because of the different selection criteria applicable to projects in these areas as opposed to the usual $50,000 grants in a single discipline.

NIMH's small grants program makes awards of less than $5000 for a year. The grants are used to support pilot studies, the development and field testing of instrumentation, and young investigators (who think they will not get an equal hearing in regular study sections). One panel and a staff of 2 handle 500-600 proposals a year. They respond in 2-4 months, as opposed to 6-8 months for dual review.

NIMH also has separate reviews for large, program projects because it found regular panels getting too bogged down in details of large projects. It seems that reviewers who are familiar with regular projects are unwilling to modify their criteria for the larger, more generalized projects.

The review of interdisciplinary projects causes special difficulties. NIH establishes separate study sections to make such reviews. The difficulty is finding proper reviewers, who will not be focused solely on their disciplinary interests. NSF's RANN has found it useful to employ representatives of the user and practitioner communities (federal, state, and local officials) in reviewing interdisciplinary problem-oriented research.

<u>Contracts</u>. There are a number of different methods of selecting applied and programmatic projects to be funded by means of *contracts*. Three models that span the range of variation are the ones used for:

- o NIH *collaborative research*,
- o NCI *programmatic research*,
- o OEO *evaluations*.

NIH *collaborative research* was created, as its name suggests, to permit intramural researchers to collaborate with extramural researchers on basic research projects. Grants could have been used to support the extramural researcher, but experience showed that under the freedom provided by the grant form of support, the extramural researcher tended to drift off onto interests of his own. The contract form of support was, therefore, adopted to permit closer control of the research performed. Its use has extended to cover purchase of research or research support activities that cannot be done so well within the institute, such as larger testing, survey, or data gathering activities.

NIH has the authority to bypass the normal competitive bidding procedure for awarding contracts, consequently it has developed its own procedures.

One institute employs a dual panel procedure that resembles dual panel grant review, except that both panels are creatures of the institute.

- *First level review* is provided by an *ad hoc* committee of 20, chosen to cover all scientific dimensions in the institute's program. Subgroups of the 20 are selected to perform certain review tasks. Three members perform an in-depth review of each proposal. The committee is instructed to judge contract proposals on both scientific merit *and* program relevance. To assure that the committee is productive, the institute director chairs it. If the committee suggests a site visit, that is arranged to take place before the second level review committee meeting.
- *Second level review* is provided by a committee of the 6 members of the institute directorate and 5 senior outside consultants (these are often individuals whose work on first level review committees was well regarded). The institute director is chairman. They examine summaries of the first level reviews, but generally only make marginal adjustments. Contracts are awarded according to their decisions. The principal advantage of this dual panel review over the simpler methods is the arrangement of checks and balances that it provides.

The National Cancer Institute has developed an elaborate procedure for planning, selecting, and monitoring collaborative research — the *convergence technique*, whose planning procedures have already been discussed. As part of that process, requests for proposals (RFPs) may be issued to obtain contractor assistance in specified areas. The responses to the RFP are evaluated by a dual panel system within the appropriate program area. For example, within the Carcinogenesis program, the proposal goes:

- o first, to the Carcinogenesis Contract Review Committee, which is made up of senior program managers, for a review of relevance, need, and logical priority (the order in which projects must be performed);
- o then, to the Technical and Science Excellence Review Committee, which is made up of outside consultants, (and perhaps chiefs of intramural research branches), for a review of technical competence.

If the second review group cannot narrow the choice to a single proposal, they select an *ad hoc* team to make site visits and choose among proposals.

The Office of Economic Opportunity's Office of Planning, Research and Evaluation is developing a carefully-structured competitive review procedure for the awarding of contracts to evaluate social programs.

One unusual feature it has recently employed is the division of evaluation into two phases. During phase I, the preliminary evaluation design that had been prepared in-house is completed by outside contractors. Phase II is the actual execution of the evaluation. The RFP covers phases I and II together, although applicants submit a proposal only for phase I. Three organizations are awarded phase I contracts; the one that produces the best plan at the end of phase I is awarded the phase II contract. Phase I, therefore, becomes an extension of the competition that permits better comparison of the prospective performers than a proposal alone does, yet compensates the contractors for the added effort required of them.

Among the *problems* arising from the use of strict competitive procurement systems are:

- contracting personnel apply strong pressure to select the lowest cost bidder, even though experience indicates that low price and poor performance often go together;
- RFPs must be widely distributed, which leads to a large number of responses, even for small contracts. The result is a waste of contractor resources (in sum, sometimes greater than the contract's value) and agency staff time.

Among the ways that the number of low quality bidders can be reduced is to employ a point-system in proposal evaluation that puts a heavy weighting on relevant experience and on staff quality.

Project Monitoring

The task of *monitoring project progress* also differs according to whether the project is being supported by a grant or a contract. Grants are assumed to impose fewer obligations on the recipient and, therefore, to require less oversight than a contract.

Grants. The usual pattern of monitoring grants awarded in support of basic research activities (many of which are awarded for 3 to 5 year periods) is for each to be assigned to a program officer (who may have responsibility for 15 grants) who reviews the grant annually on the basis of a written progress report. He checks the reports for substantive progress and for unscheduled expenditures and for changes in the distribution of expenditures from budgeted line items. (Expenditures are presented in terms of accounting categories -- salaries, equipment, travel; not in terms of project activities -- data gathering, experimental design, data analysis.) He may approve small (10%) supplemental grants, but larger ones will be sent back to the review panel. No explicit effort will be made to keep track of publications arising from the grant, although inventions must be reported separately. Each grantee is expected to provide a final report at the end of his grant and to submit a renewal application if he wishes to receive further funding; many grantees do not submit final reports, however,

The NIMH Mental Health Services R&D Branch has strengthened its grant monitoring procedures significantly with the intent of increasing the number of grants that produce results that are disseminated and introduced into practice.

- Program officers *site visit* grantees every 8 or 9 months.
- Each branch chief maintains a *monitoring board* in his office on which each project is listed. The data includes: project, state, investigator, program number, date, research progress. The panel review summary ("pink sheet") is also attached.
- Progress reports are required and monitored.

But the most important and striking innovation is the fact that planning for and encouraging dissemination and utilization activities are emphasized from the very beginning of each project.

- With his application form, each grant applicant receives a questionnaire containing the questions that will be expected to be answered in the final report of his grant (if he receives one). These questions put special emphasis on information dissemination, use of project results, and potential users. At this point, the questionnaire is solely for the applicant's information and use in planning grant activities.
- Six months after the grant is awarded, the grantee receives the same questionnaire with the reminder that the final report should cover the questions it contains.
- At the end of the project, the same questionnaire is sent; this time the final report must be completed and submitted.

- o When the report is submitted, it is evaluated by the executive secretary and project officer for:
  - (1) clarity of results
  - (2) cogency
  - (3) worldwide significance
  - (4) amount of dissemination and utilization.

The result of this closer monitoring is that the percent of projects submitting final reports containing usable information increased from 40% several years ago to 95% now. The same percentage of final reports now give indications of research utilization. The questionnaire is felt to be a definite success in encouraging more dissemination activities in projects.

Contracts. There is a greater diversity of practice employed in monitoring contract progress than in monitoring grant progress. Some procedures are quite extensive and detailed; for example, those used by the Air Force Systems Command in monitoring weapons systems development. Others approach the informality of most grants monitoring.

The NIH collaborative research projects may be monitored through biannual site visits by the project officer, an interim progress report, and a final report at the end of twelve months. If a contract is not proving to be productive, it may be cut off. (In contrast to a grant, for which termination would be very difficult.)

In the case of the National Cancer Institute's programs being managed according to a convergence plan, contract monitoring is even closer. Each "segment" of the plan is managed by a segment chairman; he may be running several different related contracts. These are monitored by a project officer; one officer per contract for large contracts (say $2 million), one officer per 4 or 5 contracts for smaller contracts (say $100,000 or $200,000). All contracts are visited at least once per year, some receive as many as 12 visits. More control is exerted in the early stages of a contract. Three times a year the contractor submits a progress report. The project officer summarizes these reports and circulates them to other project officers in the segment and the segment chairman. The segment chairmen report progress to the NCI Associate Director in charge of the program.

Each contractor submits a new proposal each year, which is subject to the same review process as the first year contract faced. The contract funding level may be adjusted according to previous results. Moreover, the contractor's performance is recorded for reference in ranking proposals. It has been found to be essential to evaluate both the individual investigator and the firm; the former seeming to be the most important.

In addition to individual contract monitoring, the convergence process is distinguished by the attention it devotes to monitoring the progress of the entire program via the convergence chart.

The chairmen of all the segments in a convergence plan, the working group (the core of the program management group), meet once per month to discuss progress reports, decide if the plan should be reviewed, discuss personnel problems, program funds, and related subjects. Progress is indicated on the convergence chart.

Once a year the working groups assess overall progress and reassign priorities among flows. These priorities are announced and new proposals flow back. The program management group evaluates the proposals, as noted earlier.

The OEO Office of Planning, Research and Evaluation's evaluation contracts are also closely monitored. Two or three OEO staff members may be required for a million dollar, two or three year evaluation.

OEO's basic mode of operation is to have the project officers participate in and oversee all substantive work done on the project. The Evaluation Division will not let the contractor alone decide what will be done on an evaluation; contractor staff and OEO project officers collaborate on developing questionnaires and analysis plans in the design phase. Subsequently, OEO monitors both the contractor and the sites of the activity being evaluated. As the contract progresses, contract rules may be modified.

General Questions

Certain questions of management arise in almost all of the different selection and monitoring procedures that have been described thus far and, therefore, can be discussed in separation from them.

One is the question of *how selection panels should be constituted.* The other is *what criteria should they employ* in making selection decisions.

Panel Composition. The exact composition of a review panel will, of course, depend on the subject area of its concern and on whether it is an *ad hoc* or continuing panel. Certain characteristics of such panels have general relevance, however.

The first panel chosen in a new program area has a disproportionate effect on the eventual quality of the program. (This is obviously even more true of the cumulative influence of all the first panels chosen on the eventual quality of a new agency.) The reason is that the panel members constitute a network within the "invisible college" within each discipline. They are the contact points for many who have heard of the program (or agency); if they are not good, they will not be able to attract the best of their colleagues to the program. As panel members rotate, the network grows and expands knowledge of the program. Five years may be required for a new basic research program to "take off" in this way.

NIH study section workloads are continually monitored. If its grant applications dwindle, a study section may be merged with another one; if they grow, it may be split into two. In any event, each study section's authority expires after 10 years; it must be reviewed to decide upon continuation.

At both NIH and NSF it is felt to be essential for the staff to pick new panel members. At NIH, the executive secretary and study section chairman recommend replacements, who must be approved by the NIH Director's office and the Secretary of HEW. At NSF, the program officers and section heads recommend panel members, who must be approved up through the Assistant Director's Office.

Experience with various discipline mixtures points to a number of potential problems:

- *Panels tend to reproduce the kind of research their members do.* One panel at an agency comprises biologists and biochemists who have proven hospitable to biological and biochemical research while rejecting, for example, most community research.

- *Placing nonscientists on panels has both benefits and costs.* If they participate actively, they provide strong pressure for relevant work. However, many are dominated by the scientists on the panel and some scientists are resentful that the non-scientists cannot share in the extra work of primary reviews (careful reading of proposals before the panel meeting).
- *Interdisciplinary panels are heir to a series of ills resulting from problems of prestige and communication among disciplines.* For example, on NIMH panels social psychologists and anthropologists find communication difficult with clinical psychologists and biologists, not to say physicists and educators. Only if the social scientists are very strong (especially with regard to methodology) can they avoid being dominated by the biological scientists. While interdisciplinary panels might be thought to be more open to unusual proposals in a single discipline, this is not likely to be the case if the disciplinary representative on the panel is strong, for his judgment will dominate and tend to be accepted by his colleagues. In a panel of his peers, however, his judgment might be challenged. Thus, for single discipline proposals interdisciplinary panels may be less open than disciplinary ones.

Project Selection Criteria. The principal criteria employed by panels in making grant awards are:

- *Training and competence of principal investigator.* "Without doubt the strongest influence on the panel decision is the reputation of the principal investigator."

- *Previous experience in area of proposal.*
  If the investigator has no prior publications in the area, the proposal is likely to receive a bad rating.
- *Adequacy of facilities and other resources.*
- *Strength of approach and research design.*
- *Value of project.*
  Is it repetitive? Does it add to scientific knowledge?
- *Relevance to problem area.*
- *Potential for use.*
  These last two criteria are emphasized in applied research, but not elsewhere.
- *Is budget reasonable?*
  This is generally only an antecedent to negotiating the budget downward if necessary.

These criteria are reasonable ones, yet they are strange from the economist's point-of-view, for they are concerned almost exclusively with the likely benefits of the research and not with the relative cost of achieving those benefits. (Only when some of the industrial scoring models are employed in project choice is some balance of cost against benefit made.) In the era when resources were growing more rapidly than quality research, such selection procedures may have been adequate. But when resources are scarce compared with what might be done, both costs and benefits should affect the decision process.

HOW CAN PROGRAM EVALUATION BE CONDUCTED?

During the *evaluation phase* of R&D management, the achievements of the R&D program should be ascertained and compared with its initial goals. The results of the evaluation should then affect the revision of the program or the design of new programs.

Program evaluation in this sense is difficult to identify as a separate phase of R&D management; it shades imperceptibly into project monitoring and evaluation as they occur during the program development phase and into program planning. Our intent, however, is to distinguish those activities that examine the achievements of the program *as a whole*, and not simply those of its constituent projects, one at a time. Moreover, we seek to separate those activities that undertake summary judgments of program achievement *at a point in time* from those that attempt continuous monitoring of progress. With these stringent distinctions, we find that R&D management agencies currently devote very little explicit activity to the program evaluation phase of management. The extent and nature of such activity differs according to the type of R&D being supported.

Basic R&D

In the case of the agencies supporting basic research, the generally held view is that the best judgments of progress in a program area come from the scientific community itself and, moreover, that these evaluations should be made with regard to a research subject area as a whole, not just those projects within it that happen to be supported by the agency. Thus, when explicit program evaluation occurs, it is generally in the form of a state-of-the-art evaluation that seeks to review past accomplishments and present knowledge and to identify promising future directions. Consequently, evaluation of prior programs and planning of future programs often occur together.

o. At NIH these state-of-the-art assessments are often carried out by workshops sponsored either by the study sections or the institutes.

The National Institute of Dental Research (NIDR), for example, organizes assessment workshops on fairly specific research topics; for example, the genetics of cleft palate or dental amalgam. Ordinarily, each program director at NIDR holds one or two such workshops each year, returning to each topic every five or so years. Attendance comprises 15 panelists selected by the program director to cover:

- all significant research approaches,
- practitioners associated with practical aspects of the area,
- foreign and industrial researchers who have contributed,
- new lines of research, and
- elder statesmen.

Formal state-of-the-art papers are presented at the workshop, followed by discussions, and an attempt to summarize promising directions of future research.

Judgments concerning the success of an agency's own programs (not just the success of the research area they are supporting) seem to be primarily implicit and associated with personnel and budget decisions.

Each branch chief, section chief, division director, and institute head should make such judgments in evaluating the quality of the efforts of his subordinates. His principal means of influence and correction then is through his selection and rewarding of his staff members. But at NIH, for example, the shape of the extramural research program is really in the hands of the study sections and to a lesser degree, the advisory councils; staff members have relatively little influence. At ONR, however, program responsibility does reside clearly with the program officer and evaluation of the program generally occurs implicitly as part of evaluating the program officer's performance. Thus, while program evaluation is implicit in personnel evaluation, its relevance varies considerably among agencies.

Program evaluation also must enter implicitly into budget decisions, not only within the agency but in its dealings with its superior agencies (HEW or DoD), with the Office of Management and Budget (OMB), and with the Congress. With respect to basic research, these judgments are ordinarily very subjective and crude. At best, the number of scientific papers published as a result of a program or some listing of major findings will be displayed as a measure of program success.

The difficulty of evaluating basic research programs is considerable and underlies the absence of formal methods or procedures. This is especially true of evaluation with respect to the criterion that OMB or the Congress might consider appropriate: *contribution to the public welfare*. The time lags and unpredictable relationships between new basic knowledge and improved technologies or public services make such evaluation virtually impossible. One step removed is a criterion that would be somewhat easier to employ and that scientists and R&D managers might consider appropriate: *contribution to knowledge in the field.* Nevertheless, it sometimes takes a considerable period before even the scientific value of new discoveries becomes plain. A third criterion for program evaluation may sometimes have to substitute for the preceding two. It concerns not the consequences of a program, but the process by which it was constructed: *adequacy of R&D management procedure*. The argument of this case would be that if first class scientists are consulted, if proper selection procedures are used, if adequate information is available, and good staff members are employed, the resultant program is likely to be good. While each of these criteria enters implicitly into the personnel and budget decisions made concerning basic research, to our knowledge none is employed in explicit, regular evaluations conducted as part of R&D management.

Practical R&D

In the case of agencies supporting practical R&D, it is appropriate to evaluate programs through their contribution to improvements in practice. Nevertheless, we have found only a few instances in which R&D agencies identify the evaluation of their programs as an explicit part of the R&D management process. However, since these programs tend to be continuous and linked to the practice community, some evaluation probably occurs on a continuing basis through feedback from practitioners and consequent adjustments in program plans. In the agriculture case, for example, there are numerous links between farmers and other users and the R&D system that serve to let the R&D program managers know how well they are doing. In addition, the same kind of implicit program evaluation during personnel and budget decisionmaking that occurs with respect to basic research doubtless occurs in these areas.

Perhaps the most explicit and regular procedure for program evaluation that we discovered is the one employed by the Mental Health Services R&D Branch of NIMH. It is *self evaluation* in terms of self-specified goals. It employs a formal "Goal Attainment Scale," which is a grid in which a program's goals for the year (usually five or so) are the columns and five possible levels of goal attainment are the rows. The rows are assigned integer scores from -2 to +2, and the columns a weighting of 0 to 10 according to importance. Within the grid cells are statements of what would have to be achieved for that level of attainment of that goal to be reached.

Each year each program director (there are 16), in consultation with the branch chief and the branch staff, decides on his program's goals for the year. The program directors and branch leadership revise the grid quarterly, although progress is evaluated by the branch chief only once a year. Moreover, progress is discussed in joint sessions of all the program directors twice weekly. Joint sessions reduce the likelihood of self delusion. Attempts to record progress narratively failed; the grid method is preferred.

The character of Agriculture's extramural research, which is almost exclusively carried out by the 53 State Agricultural Extension Stations under formula grants from the Cooperative State Research Service (CSRS) and other sources, makes formal program evaluation difficult. Instead, what has developed is a system of *institutional program evaluations*, in which CSRS reviews the activities and plans of each experiment station at least once every four years. Reviews are conducted as two or three day site visits by a CSRS program director, a CSRS visiting scientist, and possibly scientists from other stations. The nature of the evaluation has evolved over the years, but it now tends to be concerned with all the stations's programs and to focus on future direction for the programs, although past activities are necessarily reviewed.

Evaluations may also be conducted by independent *outside evaluators*. One such activity is a current review of 8-10 areas of agricultural research being carried out by the Natinal Academy of Sciences. The emphasis in the reviews will be on the quality of science in those areas; some attention will also be paid to the quality of the research environment and research personnel. The reviews will be conducted by separate panels of about 10 members each. The panels will examine each project in its field and evaluate the adequacy of funding in the area, the appropriateness and quality of current research, and future directions.

Programmatic R&D

In the case of agencies supporting programmatic R&D, a program evaluation is generally an obvious and essential part of R&D management; for, by definition, programmatic R&D is concerned with the achievement of a concrete objective in a finite time period. Rough evaluation of a program is immediate: does the spacecraft work as intended? is the weapon system operational? has a vaccine for leukemia been produced? did the new product reach the market as planned? More refined evaluation is generally more difficult, for it should consider whether the product performs in all respects as desired and whether the R&D program took longer or cost more than it might have. These latter questions rarely seem to be examined explicitly by R&D agencies themselves. If raised, it seems to be most often as part of an investigation by the OMB, Congress, or the General Accounting Office triggered by the poor performance or cost overruns of the R&D product.

HOW CAN INSTITUTIONAL DEVELOPMENT BE MANAGED?

In addition to the basic mode of research project support that has been discussed thus far, a number of R&D agencies have found it desirable to create and provide broad, institutional support to new extramural R&D institutions, generally called *R&D centers*. We shall examine four major issues associated with the establishment and management of such centers:

- How are they *organized*?
- What *purposes* do they serve?
- What *factors contribute to their success*?
- How can their *progress be monitored*?

Organization

Most R&D centers are organized at universities; many in order to foster interdisciplinary research on a topic of concern to the sponsoring agency. For example, the National Institute of Dental Research (NIDR) has supported the establishment of a number of Dental Research Institutes and Centers at universities, but outside of dental schools, in order to broaden the range of disciplines engaged in the study of dental problems. Similarly, the NIMH Institute of Alcoholism and Alcohol Abuse created a number of university research centers on alcoholism as part of its effort to build the community of researchers concerned with alcoholism.

These centers frequently are built around a central figure, usually the director, who is given multiyear institutional support and the charter of developing a viable research program and staff in the research area.

The NIDR Dental Research Centers are expected to have both an *institute policy committee*, to facilitate and guide the activities of the center in accordance with NIH and university policies, and a *scientific review committee*, to oversee the quality and cohesion of the scientific program.

Purposes

Extramural R&D centers are created to serve a number of specific purposes including:

- to help in recruiting highly competent staff to a problem area by providing stable support and giving it visibility,
- to demonstrate the urgency and priority of a problem,

- to focus a variety of talents (and disciplines), who would ordinarily work separately, on a specific problem.

Success Factors

Among the factors that are felt to contribute to the success of an R&D center are:

- *The quality of the director.* The NIDR insists on knowing who the director will be before approving a new center, although the real problem is to be able to anticipate the director's performance before he is installed. The NIDR, consequently, would like to establish training programs in each center to find potential directors and test them in subordinate positions. The problem in dental research, as it is in many other fields, is that there are few scientists qualified to be directors of interdisciplinary research centers.
- *The quality of the scientific review committee.* At the Dental Research Centers, these committees are concerned with on-going program review, new proposals, and the hiring of new researchers.
- *The university's commitment to the success of the center.* This commitment should be not only for resources and administrative attention, but for joint appointments in university departments for the center's staff. Joint appointments have proven to be necessary to recruit good research staff; they have the additional benefit of interesting other departmental scientists in the center's problem area.

Progress Monitoring

Perhaps the most crucial factor in the success of extramural centers is the means by which their progress is monitored and reviewed.

The NIDR has developed apparently successful procedures for monitoring and reviewing its centers.

The centers are given assurance of support for an *initial development period* of five years. The amount of support is negotiated each year in accordance with progress achieved and funds available. Since the centers are a separate line item in NIDR's budget, they do not compete with other dental research for support; they do compete with each other, however.

Every center is *examined annually* by a NIDR-appointed panel of prominent scientists in dental-related disciplines and scientist-administrators. The panel, consisting of 14 or 15 members, spends 2 days at the center with the principal objective of reviewing the scientific merit and the direction of development of the center's program. They will also seek to find out how well known and regarded the center's activities are on campus and how well it is administered. After an evening executive session, the panel will spend a day and a half conducting the review, first in a large meeting and then in smaller group and individual discussions. Several times the panel will regroup to be sure that all topics are being covered. During the final half day, an outline of the review report is composed; the panel members submit reports on their specialities subsequently. At the end of the visit, the university is asked if it is satisfied with the review (and, privately, with the reviewers).

The NIDR's Dental Research Institutes and Special Programs Advisory Committee *meets annually to review all the centers*. They are presented with the panel reports, previous reports, and the centers' annual reports, often in summary form. They spend several days reviewing all the centers and meeting with all the center directors. Their judgment weighs heavily in the annual budget negotiation with the centers and, especially, in the decision as to whether to provide support beyond the initial five-year period.