Session I
PRODUCTION OF SCIENTIFIC KNOWLEDGE

SETTING PRIORITIES FOR BASIC RESEARCH

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Introduction

Setting priorities for research can refer to any one of a number of dimensions of science policy, such as the choice of a performing organization, the balance between fundamental and applied research, or between investment in facilities and investment in scientists' salaries. However, the term as most commonly used refers to competition among fields or subfields of science, for example, physics versus chemistry.

Priorities placed among and within fields of science are usually based on a mix of two broad critiera: (1) promise for rapid conceptual advances in basic research and contributions to neighboring fields ("intrinsic criteria"), and (2) potential applicability to the most pressing social or economic problems ("extrinsic criteria"). The essence of the problem of setting priorities for research is to find the best way to satisfy both criteria.

Federal programs for the support of research have made little use of formal decisionmaking techniques for determining priorities across fields of research. Relative priorities among groups of related fields have depended largely on the budgetary fortunes of the mission-oriented agencies that sponsored them. Within each field, priorities have been set predominantly through a combination of intrinsic criteria advanced by scientists through internal or external agency advisory groups, professional societies, and the National Academy of Sciences, and extrinsic criteria put forth by Administration officials, agency administrators, Congressional members, and more recently a variety of organizations which now constitute the new "science lobby."

Scientists are *implicit* priority-setters, but historically have resisted involvement in explicit exercises. Decisions, such as when to enter and exit fields, and where to place valuable technical and human resources have been made routinely at an individual level since the dawn of scientific endeavor. This type of decisionmaking works best when resources are plentiful and individual priority-

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The authors would like to thank Carole Ganz Brown whose thoughts on research planning, management, and evaluation were fundamental to this paper's content and structure.

The views expressed in this paper are those of the authors and do not represent an official National Science Foundation position.

setting need not be closely scrutinized. By contrast, policymakers make policy by crafting budgets, and are *explicitly* involved in setting priorities for all dimensions of society under their control, including basic research.

Thus, there exists a natural tension between scientists and policymakers. And while each group is indispensable to the other, each is also fundamentally in conflict with the other. This basic conflict stems from the fact that although the Government's mandate is to support research in ways that are efficient and costeffective, scientists strive to conduct research in an atmosphere of impartiality and serendipity. To further complicate matters, the end-product of basic research – its output – can never be known *a priori*, or it wouldn't be called basic research. So its up-front value is difficult to ascertain. Nonetheless, until fairly recently, basic research has been a relatively unquestioned proportion of the Federal budget – one of the few remaining sacred cows.

The symbiotic relationship that exists today between the Federal Government and the research community has its roots in Presidential initiatives at the end of World War II that culminated in the creation of the Office of Naval Research (ONR) in 1946, and the National Science Foundation (NSF) in 1950. These actions were the beginning of large-scale Federal efforts to channel Government resources into private research institutions, thereby strengthening basic research through the use of public funds.

The 1950s and 1960s were generally viewed as the "golden age" of science. During that period, the Federal Government invested heavily in research and development. In the post-Sputnik decade, Federal support for basic research multiplied almost sevenfold. Most of this basic research was conducted in university laboratories, where scientists were relatively free to pursue projects and knowledge with few demands for social utility.

But the "golden age" ended in the late 1960s, and the effects of inflation, fueling the public's insistence on heavy cuts in the Federal budget and a purge of waste or abuse in the spending of public money during the latter part of the 1960s and the early half of the 1970s, brought the growth in Federal research support to a halt. Although the last two Administrations have made efforts to rescind the stagnation of academic research support, especially basic research support, such support has not been uniformly distributed among all fields of the scientific spectrum.

To the degree that basic research was in the past subjected to priority-setting exercises, these exercises were designed primarily to enhance particular areas without necessarily decreasing the coffers of other less fortunate ones. But increasing budget constraints have changed all that. The 1980s ushered in an era of zero sum or near-zero sum games. This new approach was applicable to all budget functions, including an essential cross-cutting one: R&D. Thus, within science, policymakers were no longer simply giving favored fields a bit extra, but rather *giving* particular fields increased resources of necessity meant *taking* from others.

Consistent with fiscal necessity and philosophical convictions, the President's

Science Advisor, Dr. George A. Keyworth II, captured the attention of the scientific community in 1981[1)] by strongly suggesting that scientists immediately put their own house in order by setting priorities themselves, both among and within fields, or face having it done for them. In testimony before the House Committee on Science and Technology in December 1981, Keyworth said:

> "To those who may still hope for constantly growing budgets across the board, let me say this – that time has passed and we need the scientific community's best and most thoughtful judgment and advice to maintain the health of our science and technology base. To those who object to such undertakings ... I must say that if scientists do not make such choices, others will, but with less acuity."

Keyworth further disquieted the scientific community by implying that budget cuts would in fact "be good for science," telling the Committee that his own experience had led him to believe that "the best overall quality of research may not occur in times of accelerating support, but in times of moderate restraint." Likening priority-setting and budget-cutting to the pruning of a tree, the President's Science Advisor stated his belief that applying cuts selectively in R&D would in fact promote, rather than retard, the health of science.

Although the message has been an implicit fact in the *quid pro quo* which underlies the Federal Government's support of science, it was the strength of Keyworth's convictions, the enormous and growing budget deficits, and the lack of lag time between statement and implementation that finally got the scientific community to sit up and pay attention. Federal dollars for basic research were no longer to be viewed as a right, but rather a privilege, to be subjected to the scrutiny of accountability and payoff just like everything else.

The purpose of this paper is to (1) place these recent events in historical perspective by assessing previous attempts to set priorities among and within fields of science, and (2) describe a new and promising approach developed by scientists to assist policymakers in setting priorities for basic research.

The Past as Prologue

Although "objective," or quantitative, methods of decisionmaking, such as benefit-cost analysis or input-output indicators may be seen by some as the ideal model, the process of scientific priority-setting in the "real world" has most often occurred on a more qualitative plane and at a far higher level of abstraction. The time-honored method used by policymakers and practitioners for broadly allocating resources in science has been of the task force/panel of experts/state-of-the-art review approach to the setting of scientific priorities.

One of the first and most notable examples of this approach is the so-called "Bush Report." In November 1944, near the end of World War II, President Franklin D. Roosevelt asked Dr. Vannevar Bush, Director of the Office of Scientific Research and Development, to draw lessons from his wartime experience that could be employed to organize peacetime scientific resources in the future. The President asked Bush to answer four key questions:

(1) What can be done, consistent with military security, and with the prior approval of the military authorities, to make known to the world as soon as possible the contributions which have been made during our war effort to scientific knowledge?
(2) With particular reference to the war of science against disease, what can be done now to organize a program for continuing in the future the work which has been done in medicine and related sciences?
(3) What can the Government do now and in the future to aid research activities by public and private organizations?
(4) Can an effective program be proposed for discovering and developing scientific talent in American youth so that the continuing future of scientific research in this country may be assured on a level comparable to what has been done during the war?

Bush interpreted the President's questions as pertaining only to the natural sciences, including biology and medicine, and moved quickly to answer them by appointing four panels of experts. In transmitting his report to President Truman in the summer of 1945, Bush said in part of this exercise:

> "In seeking answers to President Roosevelt's questions, I have had the assistance of distinguished committees specially qualified to advise in respect to these subjects. The committees have given these matters the serious attention they deserve; indeed, they have regarded this as an opportunity to participate in shaping the policy of the country with reference to scientific research."

Bush's report, *Science – The Endless Frontier*[2)], recommended the establishment of a National Research Foundation, whose purposes should be to "develop and promote a national policy for scientific research and scientific education, ... support basic research in nonprofit organizations, ... develop scientific talent in American youth by means of scholarships and fellowships, and ... support long-range research on military matters." While the report itself is not widely known today, its legacy, the establishment of the National Science Foundation five years later, most assuredly is. The Bush Report, though broad-brush in scope, was a significant attempt to set policy for science by setting priorities according to broad national goals and degree of potential payoff. And indeed, the 1950 enabling legislation for the National Science Foundation (NSF) closely resembled Bush's National Research Foundation in its choice of scientific fields slated for postwar Federal support. One consequence of this choice was the exclusion from NSF of all fields of social and behavioral science. It was not until 1967 that the social sciences were included in the newly revised NSF charter.

In a series of federally sponsored surveys assessing the state of the art, needs, and plans, the National Academy of Science's Committee on Science and Public Policy from 1962 to 1974 conducted reviews of ten major fields[3)]: ground-based astronomy; chemistry; physics; the plant sciences; the mathematical sciences; the behavioral and social sciences; the life sciences; astronomy and astrophysics; physics in perspective; and material and man's needs. These were relatively long-term, in-depth studies of major scientific fields which were prepared for use by scientists and policymakers alike. In addition, the NAS produced a variety of other surveys of the health and direction of particular fields, depending on need.

Perhaps the most extensive survey of a field ever conducted was an assessment of physics, by a committee chaired by D. Allen Bromley in 1972[4]. The Bromley survey described the people and institutions of physics in great detail. The report discussed the consequences of diminishing support, catalogued the various sources and mechanisms of support, summarized the work of physics in education and education in physics, analyzed the supply and use of manpower, traced the dissemination and use of information, and made some general recommendations on national policies concerning physics. But at the heart of its work was the task of determining how to decide program emphases and set priorities. Many have since conjectured that the exercise of struggling with the problem of priorities was one of the most valuable aspects of the entire enterprise. The Bromley Committee reviewed the possible approaches:

(1) setting priorities by the mechanisms of the "intellectual marketplace," which principally consider the capabilities of the people involved and their record of accomplishments;
(2) setting priorities by "marketplace evaluation," giving importance to proposal pressure and review by researchers' peers;
(3) basing priorities on criteria on "intrinsic and extrinsic merit";
(4) basing priorities on the identification of research "disaster areas" and determining what rearrangement of support at particular funding levels would suffice to optimize overall health of the fields involved; and
(5) setting priorities by judging the value of competing proposals in adversary hearings before a scientific tribunal.

The method the committee developed was a hybrid of the above approaches, involving a jury rating of committee members regarding the appropriate emphasis that should be applied to a given activity within the next five years, taking account of both the internal, intellectual needs of physics and their assessment of the impact of these scientific developments on other sciences, technology, and societal problems generally.

Viewing their work as an experiment, the survey committee cautioned that its ratings were primarily illustrations of the method, not incontrovertible evaluations. Nonetheless, in reviewing its exercise, the committee felt that the approach they had adopted and the criteria they had employed could be useful in providing a more quantitative evaluation of heretofore primarily subjective scientific judgments.

In a 1977 article for *Science*[5], William W. Lowrance reviewed the utility of surveys concerning the health and direction of major fields of science, including the Bromley Committee Report and the nine NAS major field studies, and enumerated some of their inherent limitations. First, it is important to recognize that although scientists can be drafted to work with others in conducting surveys, they are less likely to willingly participate in what they see as their own execution. Consequently, while in setting priorities for fundamental research there can be no substitute for the experience and guidance of active researchers. Scientists can be expected to be most forthcoming when they are addressing questions of identifying those areas which provide the greatest opportunities for growth and expansion, and less than candid when they are asked to determine areas in need of pruning.

A second limitation of surveys is that they must unavoidably sacrifice some precision of analysis and impact because of their breadth of coverage. Yet it is important to understand that these surveys are for the most part not meant to be scientifically rigorous studies and as the field of survey is broadened, comparison of its disparate elements becomes more difficult and the criteria for judgment become less a matter of science than opinion and experience. In the extreme, the task loses all validity: what does a comparison of astronomy and plant science, or cognitive science and materials research mean? The relevance of comparing vastly different fields directly is not clear. Thus, Lowrance concludes that the perennial plea from policymakers for the NAS or others to do global surveys and to appraise the value of all the disciplines relative to each other appears to be not only nearly impossible, but perhaps not even very useful.

In an assessment of five different scientific and technical fields – molecular biology, high-energy physics, nuclear energy, manned space exploration, and the behavioral sciences – Weinberg (1967)[6)] addressed the issue of incommensurable fields. The epitome of this problem is easily grasped in attempting to measure the merit of behavioral sciences and nuclear energy by the same scale of values. Neither in these surveys nor elsewhere has a perfect method been developed for deciding on the relative importance of different research problems. Although this is a "how to" problem that has not as yet been solved, the choices between scientific fields will eventually have to be made by scientists; they are being made currently by policymakers. Criteria for scientific choice will be most useful and valid only if they can be applied to seemingly incomparable situations.

A related limitation of the global survey method is that widely dispersed and/or "little science" fields are in many ways more difficult to survey than coherent, highly organized, facilities-dependent ones. This has some rather major implications for innovative or new areas of science and for the many disciplines that are not driven by large-scale instrumentation and hardware needs.

A third set of limitations is the lack of a "client-driven" orientation. Except in the most general sense, the surveys have not been oriented toward either social problems or agency missions. The surveys have principally examined what was needed to advance the sciences themselves and have looked for opportunities for exploitation of the field, rather than looking at external or societal requirements. As a tool devised by scientists and used by scientists, this egocentric orientation is appropriate, but as a mechanism to provide information to policymakers as part of their ongoing budget-making process to be used as an aid in setting scientific priorities, the orientation and content become more inadequate.

Nevertheless, the surveys in general were largely accepted by the scientific community and many have served that community well as guidance (if not examples of good report writing) in getting priorities which were eventually implemented.

Scientific Priorities in the Reagan Administration

Since there is no R&D budget per se, the budgetary process for science and technology has tended to be largely incremental and segmented. Allocations to research are based not so much on comparisons among the research sectors as on judgments of the contribution each kind of research promises to make to the societal sector to which it belongs. These judgments have been made most often on an agency level, with less coordination or centralized planning than one might infer from high-level policymaking bodies such as the Office of Management and Budget (OMB) or the Office of Science and Technology Policy (OSTP). A confluence of recent events, particularly increasing budgetary pressures, have changed all that. The Reagan Administration set out its new plans for science and technology not long after the President's Science Advisor was put in place as the Director of OSTP. The President's *Annual Science and Technology Report to the Congress:* 1981[7]), clearly stated that an effective science and technology policy must provide a consistent set of guidelines to be used in identifying the most effective investments that the Federal Government can make in science and technology, and in assessing the respective roles of the public and private sectors in those investments. Thus, the U.S. Science Policy under the Reagan Administration is designed:

- To enhance the contribution of science to needs of national defense and the industrial competitiveness of U.S. industry;
- To maximize the return on national R&D investments; and
- To ensure the long-term vitality of the U.S. science and technology base.

While the objective of the U.S. Technology Policy is:

- To ensure that U.S. scientific leadership results in economic and defense leadership.

From these broad objectives were crafted five major Administration guidelines for the formulation and implementation of science policy:

- Focus Federal R&D resources on basic research, particularly in those fields likely to undergird national security and economic growth;
- Couple basic research support with the improved education of scientists and engineers;
- Base priorities for research support on the informed consensus of practicing scientists;
- Use indirect incentives to encourage industrial R&D investments and industry – university cooperation;
- Leave the support of technological development for purposes of commercialization in the hands of private industry.

Within these general guidelines, the Administration adopted stringent criteria to discriminate between the scientific areas that are most promising and those thought to be less so. The key criteria used to determine the degree to which a scientific discipline or a project within a discipline qualifies for Federal research support are excellence in the investigators, excellence in the subject matter, and excellence in the expected results. Two additional, important criteria for the public support of applied research aimed at providing the foundation for future technological advance must be relevance and appropriateness to the nation's economic and social goals and needs.

The criteria of excellence, relevance, and appropriateness continue to be central to this Administration's science and technology policy, and they are being applied to all R&D funding agencies. The effects these broad objectives, policy guidelines, and funding criteria have had on R&D directions and budgetary thrusts are readily apparent in each of the Reagan budgets. Some of the major issues and developments of the FY 1984 R&D Budget are:

– Linked increased basic research budgets with contributions to high technology and economic revival

– Made explicit priority decisions among disciplines for basic research support

R&D obligations for the U.S. Government for the last five fiscal years are given in Table 1.

Table 1. Federal R&D Obligations

	(Billions of Dollars)					Percent Change	
	FY81	FY82	FY83	FY84	FY85	85/84	85/81
Total Federal R&D	$35.0	$37.6	$39.5	$46.7	$53.1	14%	52%
Total Defense R&D	$16.5	$20.9	$23.2	$28.1	$34.2	22%	107%
Total Basic Research	$5.1	$5.4	$6.4	$7.2	$7.9	10%	55%

(Source: Special Analysis K: Research and Development, The Budget of the United States Government)

New thrusts in R&D in FY 1984 include the following:

- Department of Defense
  - Advanced Systems
  - Manufacturing Methods
  - Laser Test Range
- National Aeronautics and Space Administration
  - Planetary Exploration
  - Space Telescope
  - Aeronautical R&D
- Department of Energy
  - Materials Sciences
  - Non-nuclear Energy R&D
  - No New Funds for Clinch River Breeder Reactor
- National Institutes of Health
  - Neurosciences
  - Digestive Disease Research Centers
  - Aging
- National Science Foundation
  - Science and Engineering Education
  - Mathematical and Physical Sciences
  - Engineering
- Agriculture
  - Animal Science
  - Plant Science
  - Human Nutrition Research

Creating a Structure for Setting Scientific Priorities

Thus, in contrast to previous Federal policies that viewed increasing funding across the board as the key to success, the Reagan Administration has insisted on greater selectivity to maximize the public return on Federal R&D investment. Of course, the question of how the Administration's science and technology policy goals and objectives were in actuality *translated* into scientific priorities has yet to be answered. The Administration said from the outset that "these decisions should be determined by the scientific and engineering communities themselves, working in cooperation with responsible Federal officials." Yet no *one* structure existed that could generate the advice the policymakers needed from the scientific and engineering communities. Indeed scientists participate through a variety of different mechanisms to assist in setting scientific priorities.

Some of these ways include:

- Agency Advisory Committee
- Study Groups
- Direct contacts with Federal officials
- Formal policymaking bodies (e.g., National Science Board, Defense Science Board)

All these existing mechanisms are rather ad hoc in nature, some having little direct ties to the policymaking or budget-making process at the highest levels of government where the advice is most critically needed. The OSTP set about to rectify this situation and gain access to the information it so vitally needed in order to make informed choices about scientific priorities. In 1982, on an experimental basis, the National Academies of Sciences and Engineering and the Institute of Medicine, through their joint Committee on Science, Engineering, and Public Policy (COSEPUP), developed research briefings on seven fields of science for the OSTP, NSF, and other interested Federal departments and agencies.[8)]

The seven fields were:

- Mathematics,
- Atmospheric Sciences,
- Astronomy and Astrophysics,
- Agricultural Research,
- Neuroscience,
- Human Health Effects of Hazardous Chemical Exposures, and
- Materials Science.

Each briefing, developed by a panel of experts, identified research areas within the field that were likely to return the highest scientific dividends as a result of incremental Federal investment in fiscal year 1984. Briefing papers were prepared by each panel and published by the National Academy Press in early 1983. Shortly thereafter, OSTP and NSF requested a second round of research briefings focused on Federal investment opportunities in the fiscal year 1985 budget. COSEPUP agreed to this request and with the assistance of units of the National

Research Council and through consultations with OSTP and NSF suggested five additional topics:[9)]

- Chemistry;
- Cognitive Science and Artificial Intelligence;
- Immunology;
- Solid Earth Sciences; and
- Computers in Design and Manufacturing.

The second round of briefings was patterned after the first. Each one-hour briefing was developed by a panel of about 12 experts who met once for several days to assess the field and identify areas of unusual scientific opportunity. At each panel meeting a rapporteur was present to summarize the discussions and prepare an initial draft of a briefing paper. After further review by the panels, the briefing papers served as the bases of one-hour oral briefings presented to COSEPUP for review in early August 1983. Based on this review, the briefing papers were revised and served as the basis for oral briefings presented to Federal officials in September and October 1983, including: the President's Science Advisor and selected OSTP staff, the Director of NSF and senior members of the NSF staff, and senior representatives of other interested Federal departments and agencies.

The intent of these briefings is to bring to the attention of Federal officials those fields that scientists believe would provide the greatest payoff in terms of advancing knowledge from the investment of Federal R&D support and where within those fields incremental funds would produce the greatest scientific gains. Although their intent is oriented towards "picking winners" *within* fields, once the fields of focus themselves are chosen, it should be apparent that the targeting of particular fields as topics for any given research briefing is, in and of itself, a choice *de facto* among fields as well.

Currently, COSEPUP is in the process of formalizing this mechanism and selecting its topics for next fall's set of research briefings. Since this is a relatively new process, it is still being tinkered with and some modifications have been made over the past two years. Nonetheless, this method of providing relevant, timely, policy-oriented scientific advice to Federal officials to assist in setting scientific priorities is one of the most exciting new ventures the scientific and engineering communities have devised.

Conclusions

The United States can now be considered to be at a turning point in the relationship between scientists and the Government. The arrangements of the last 25 years were liberal in the original eighteenth-century sense of the term. They were based on three key assumptions: (1) the individual scientist (seconded by his peers) was considered the best judge of what would produce the best science; (2) the best pure science would ultimately produce the greatest benefit for the nation; and (3) consequently, that science policy was best which governed least.

In recent years, policymakers have severely questioned, if not withdrawn, all three of these assumptions. By attempting to direct the nation's scientific work in the most socially useful directions, supporting agencies increasingly offered scientists a mix of incentives and restrictions which displaced the scientists' own professional judgments about what subjects to work on and how to proceed. Scientists confronted a rising tide of reporting requirements, restrictions, government audits and micromanagement in the national laboratories and research centers. Most importantly scientists increasingly encountered greater Government regulation of the choice of research topics. Whether this kind of oversight for setting scientific priorities is good or bad for science is not now known, and probably will not be known for some time to come. What is known, however, is that if scientists are to continue to receive Federal support for basic research they will need to learn to play by the new rules of the game – the most obvious one being: participation.

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FINANCIAL ASPECTS OF UNIVERSITY RESEARCH IN JAPAN

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I. Outline of an Academic Research System

Figure 1 shows the administrative structure supporting research activities in Japan. A general understanding of this structure is necessary if one is to understand the financial aspects of academic research in Japan. Monbusho (the Ministry of Education, Science and Culture) is responsible for policies related to education, science and culture in Japan, and promotes the study of humanities, social and natural sciences, and other disciplines, mainly through the universities.

Japan has 458 universities, all of which are involved in both research and education. There are 96 national universities, 34 local public universities, and 328 private universities. Monbusho funds all teaching and research activities at the national universities and gives subsidies to local public and private universities.

1. The Extent of Academic Research

As shown in Figure 2-1, university-affiliated researchers account for 32 percent of the national total of researchers in both the private and public sectors, while of those affiliated to national institutions, 86 percent are university researchers. Universities account for 24 percent of all research expenditures in Japan, while national universities are responsible for 76 percent of all research funds expended by national institutions. (See Figure 2-2).

The natural sciences account for over 60 percent of university research staff and expenditures (Figure 2-3), with basic research, the major area of research at universities, absorbing 57 percent of all research expenditures. However, sizable amounts are also expended on applied research and development (Figure 2-4).

2. Research Institutes within Universities

Research is carried out both in the universities under-graduate and post-graduate departments, as well as in university-run research institutes and facilities. There are at present 71 such research institutes and 310 research facilities affiliated with national universities, each of which is integrated into the university's research program. Many of these are open to researchers affiliated with other universities and institutions.

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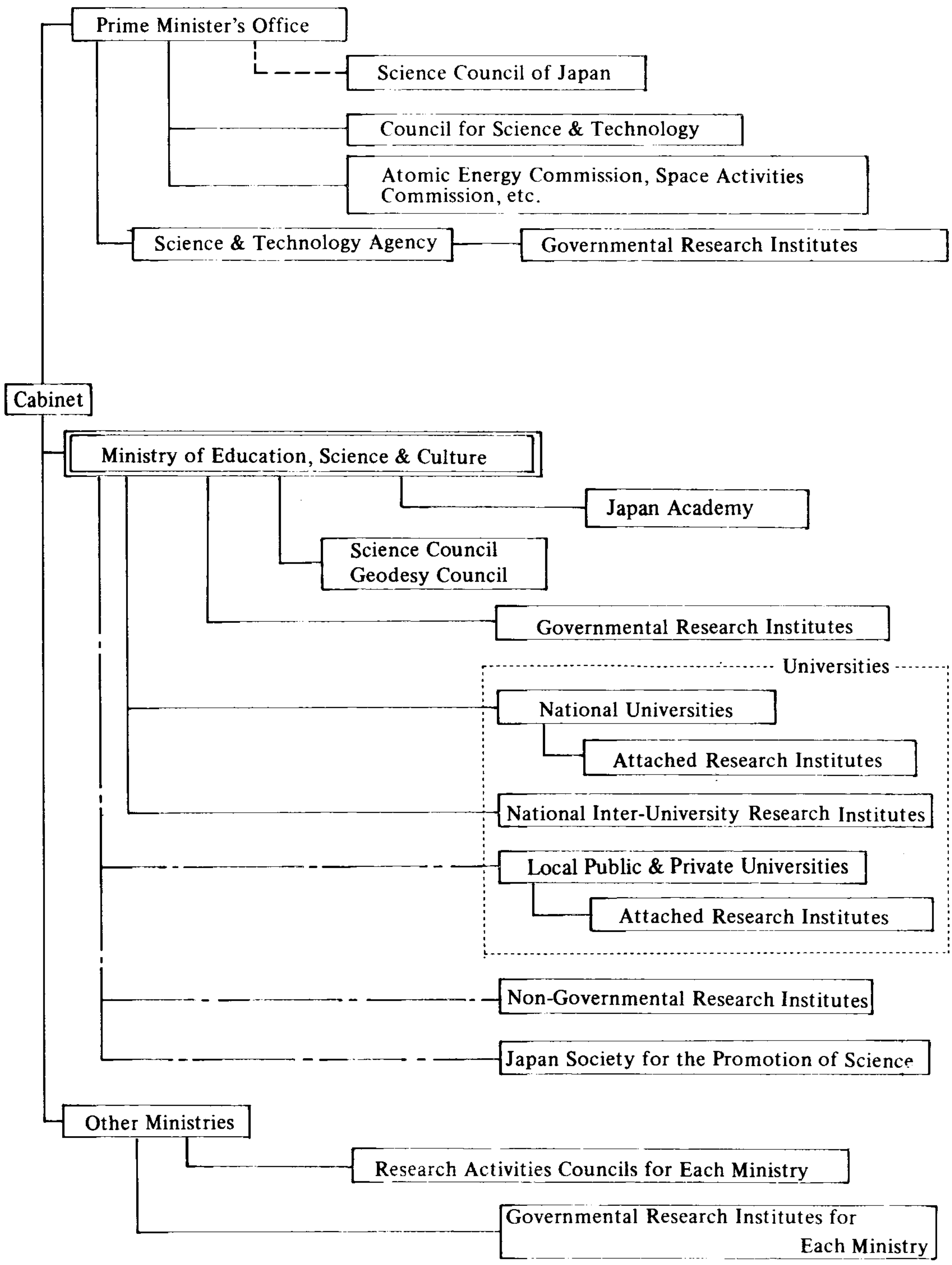

Fig. 1. Organization of National Science Administration

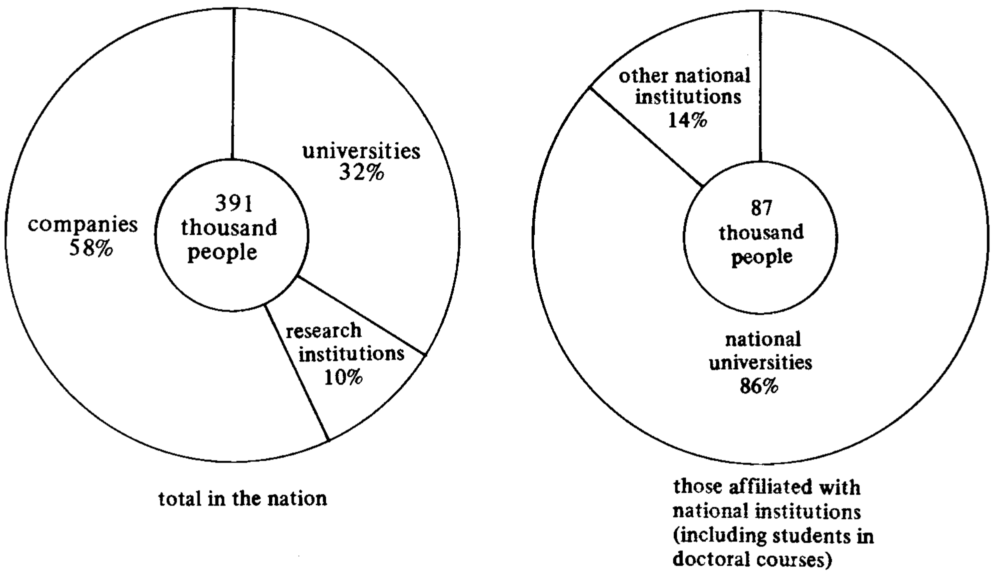

Fig. 2-1. Number of Researchers

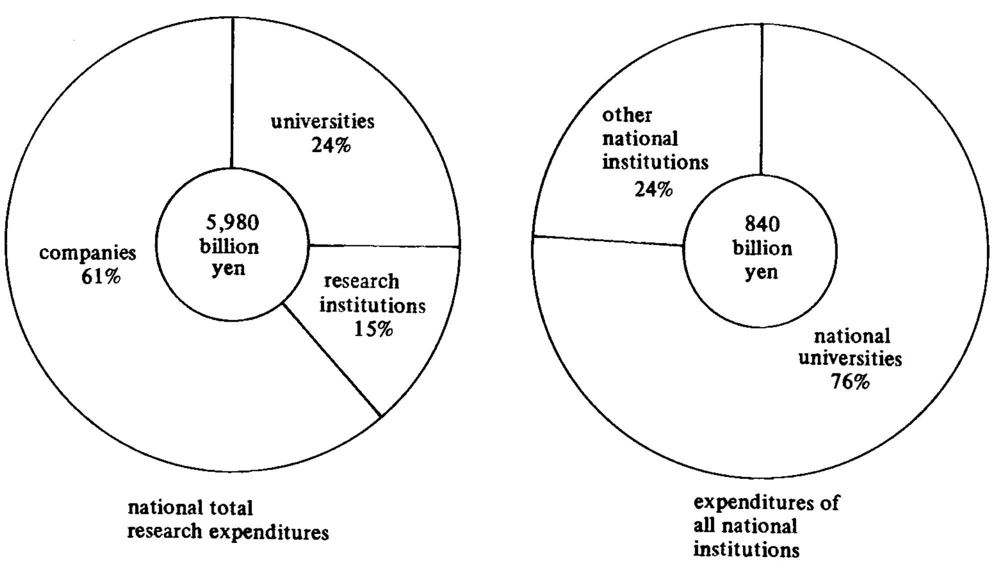

Fig. 2-2. Research Expenditures

Fig. 2-1 through 2-4 are based on "Report on the Survey of Research and Development 1982", Bureau, Prime Minister's Office except the left circle of Fig. 2-1 which is from the Report of the Science Council of Monbusho in 1984.

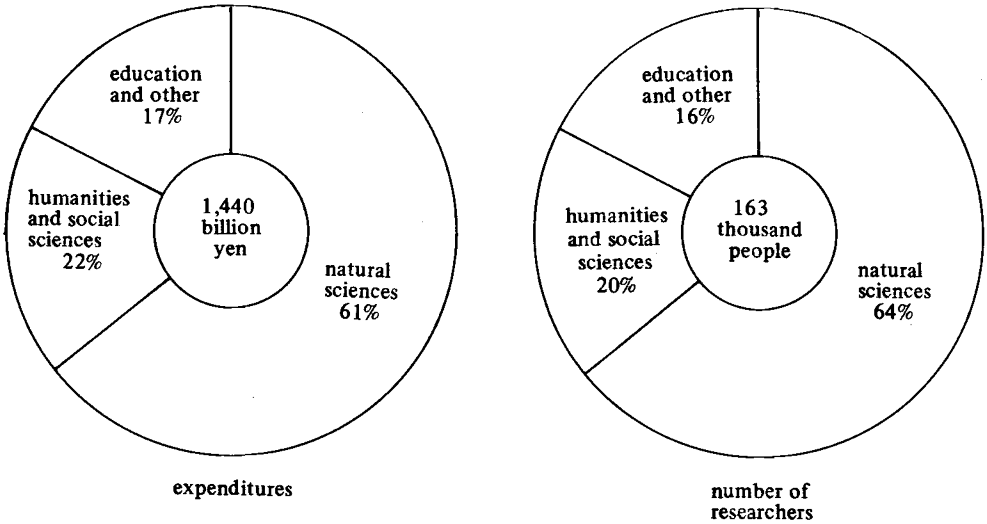

Fig. 2–3 University Research Expenditures and Number of Researchers by Type of Specialization

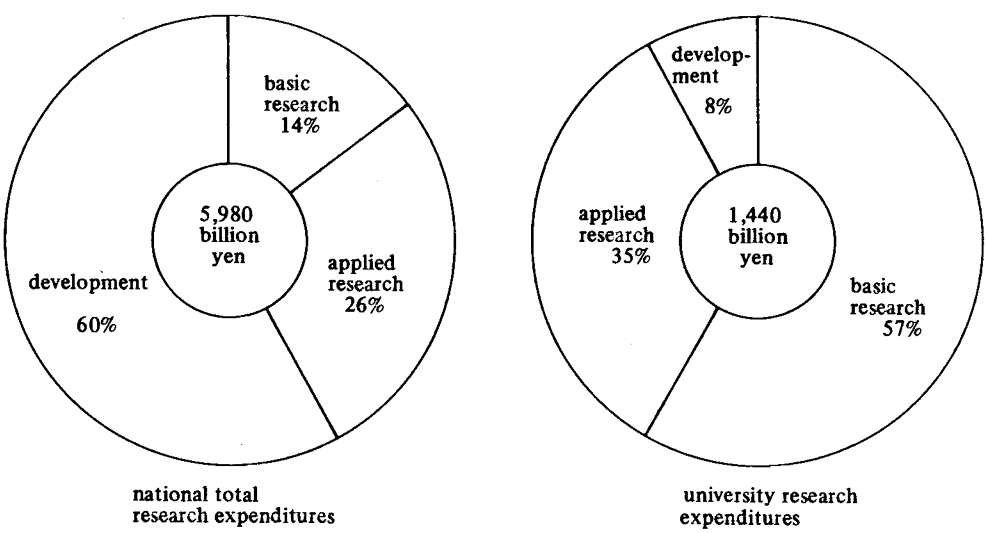

Fig. 2–4 Research Expenditures by Type of Research

3. National Inter-University Research Institutes*

A significant development in recent years has been the creation of inter-university research institutes, which are under the direct control of Monbusho rather than attached to any particular university, and are open to use by any university researcher. These institutes have been established in fields in which the nature of the research demands large-scale facilities and equipment, systematic data collection systems, and team research by a large community of researchers. (Table 1). The first institute of this type was the National Laboratory for High Energy Physics, established in 1971. Others have since been established in such fields as polar research, molecular science, basic biology, physiology, Japanese litterature, ethnology, history, space science and genetics.

II. Support for Academic Research

1. National Universities

In addition to providing the salaries of all researchers affiliated with national universities, Monbusho finances research activities at the national universities through a number of different types of research funding explained below. These funds are disbursed from the Special Account for National Schools allocated within the national budget, and are completely separate from grants disbursed under the grants-in-aid system.

(1) General Research Funds

Each year, general research funds for each faculty or department of every national university are allocated within the national budget. The total for FY 1983 was 96 billion yen ($403 million). These funds, which cover the basic costs of ordinary research activities, are allocated to each *koza* (chair) or the equivalent on a standard formula based essentially on the number of researchers at the university. Consideration is also given to the nature of the research – experimental, non-experimental or clinical – and to whether the *koza* or division in question offers post-graduate degrees (masters or doctorate). Research funds provided in this category are designed to guarantee free research activity to individual researchers and to enhance research standards.

(2) Special Research Funds

Special research funds are designed to finance research projects which meet the social and scientific needs of today and are in line with international research trends. Such research ranges from large projects such as accelerator science, nuclear fusion and space exploration to vital fields like earthquake and volcanic eruption prediction. Before Monbusho's budgetary allocation, top-level researchers in each respective field are asked to give their opinions on the future prospects of the research in question and the measures needed to implement such research projects.

Policies that promote research at the leading edges of known areas of study and encourage pioneering efforts have become even more important in recent years. Diversifying fields and the increasing need to use expensive research equipment seem to suggest a shift from the present researcher-based pattern of allocations to one that emphasizes the special needs of each research project.

Funds in this category finance the construction, operation and maintenance of installations, including those of large-scale installations required by specific projects. Applications for funds by national universities are rigorously screened to determine their level of necessity and timeliness before being included in Monbusho's budgetary request package. This screening is entirely separate from the university's general research funds allocation.

The 1983 budget for this category included 17.2 billion yen ($70 million) for energy (fusion and atomic energy, etc.), 19 billion yen ($77 million) for accelerator science, 15.2 billion yen ($62 million) for space science, and 2.1 billion yen ($8.5 million) for prediction of earthquakes and volcanic eruption.

2. Government Subsidies to Local Public Universities

Since FY 1966, the government has provided subsidies for local public universities' research facilities and equipment, and since FY 1968 has supported overseas exchange programs involving local public universities' staff. These funds amounted to 3.97 billion yen ($16 million) in 1983.

3. Government Subsidies to Private Universities

While private universities have received government funds for research facilities and equipment since 1953, the largest subsidies are for current expenditures, which commenced in FY 1970. In FY 1983, the former amounted to 4.485 billion yen and the latter to 277 billion yen ($1.12 billion), or 25 percent of total current expenditures by private universities.

III. Grants-in-Aid for Scientific Research

1. Outline

The system of grants-in-aid for scientific research is designed to enhance the nation's overall academic and scientific standards by supporting and fostering productive research which is planned independently by researchers. The allocation of funds to these research projects is competitive, and selection is based on submissions by the researchers concerned. The system thus differs fundamentally from the allocation of current research expenditures described above.

A total of 39.5 billion yen in grants-in-aid was budgeted for FY 1983, more than double the 16.8 billion yen allocated in FY 1975. Thus, over the past five years, the budget for grants-in-aid has grown at an annual average rate of about 8.5 percent (Table 2 and Figure 3). These grants are divided into 8 categories, 63 divisions, and 199 subdivisions, covering the humanities as well as the social and natural sciences. Any researcher in any of these fields is eligible to apply. The grants also include a special reserve fund to support research in areas of particular social or scientific need.

Applications in each category are divided according to the research objectives and contents (Table 3). The subject-designated categories range over a total of 20 research areas including cancer, natural disasters, environmental sciences, energy, microelectronics and recombinant DNA. The non-designated categories, defined by their mode of research, the size of the research budget, etc., are divided into "special distinguished research," "cooperative project research, A or B," "general scientific research, A, B or C," "encouragement of young scientist, A or B," "developmental scientific research," "overseas scientific surveys," "expenditures for publication of research," and others. The fiscal 1983 budget for each of these categories is shown in Table 1.

Thus, research classified by content ranges from a limited number of "special distinguished research" projects of international recognition to "encouragement of young scientists" to undertake research in promising areas.

There are about 130,000 researchers affiliated with national, local and private universities, Monbusho and The Agency for Cultural Affairs research institutes, and private research organizations eligible to apply for these grants. About 48,000 applications were filed in FY 1983, of which about 14,000, approximately 29 percent, were granted.

2. The Screening Process

Research proposals and applications submitted by prospective grantees are screened by the Committee on Grants-in-Aid for Scientific Research of the Science Council of Mombusho.

The committee is made up of 10 Reviewing Committees and 50 Specialist Subcommittees, with more than 1,000 members who are responsible for screening over 40,000 applications from all fields of science.

Committee members allocate "specific" and "special project" research grants and decide grant amounts by reviewing written applications submitted by researchers. Submissions for "general scientific research" grants go through a two-step process. Written research proposals are first reviewed by three independent judges. More extensive consultations and coordinations then lead to final selection and decisions regarding the grant size. Grants for "special distinguished research" of international recognition are made after a written review and oral hearing of the applicant's presentation.

3. Assessment

In addition to the rigorous screening process to ensure the genuine worth of research projects considered for funding, the assessment committees in each field conduct annual reviews of research projects in progress. Similar reviews are undertaken by the Science Council. This system of evaluation has contributed greatly to academic research in every discipline.

Most research findings are also published at academic conferences, where they are subject to exacting scrutiny by fellow researchers. Grantees are required to report their findings upon the expiration of the term of the grant. These reports are kept at the National Library where they are available to the research public.

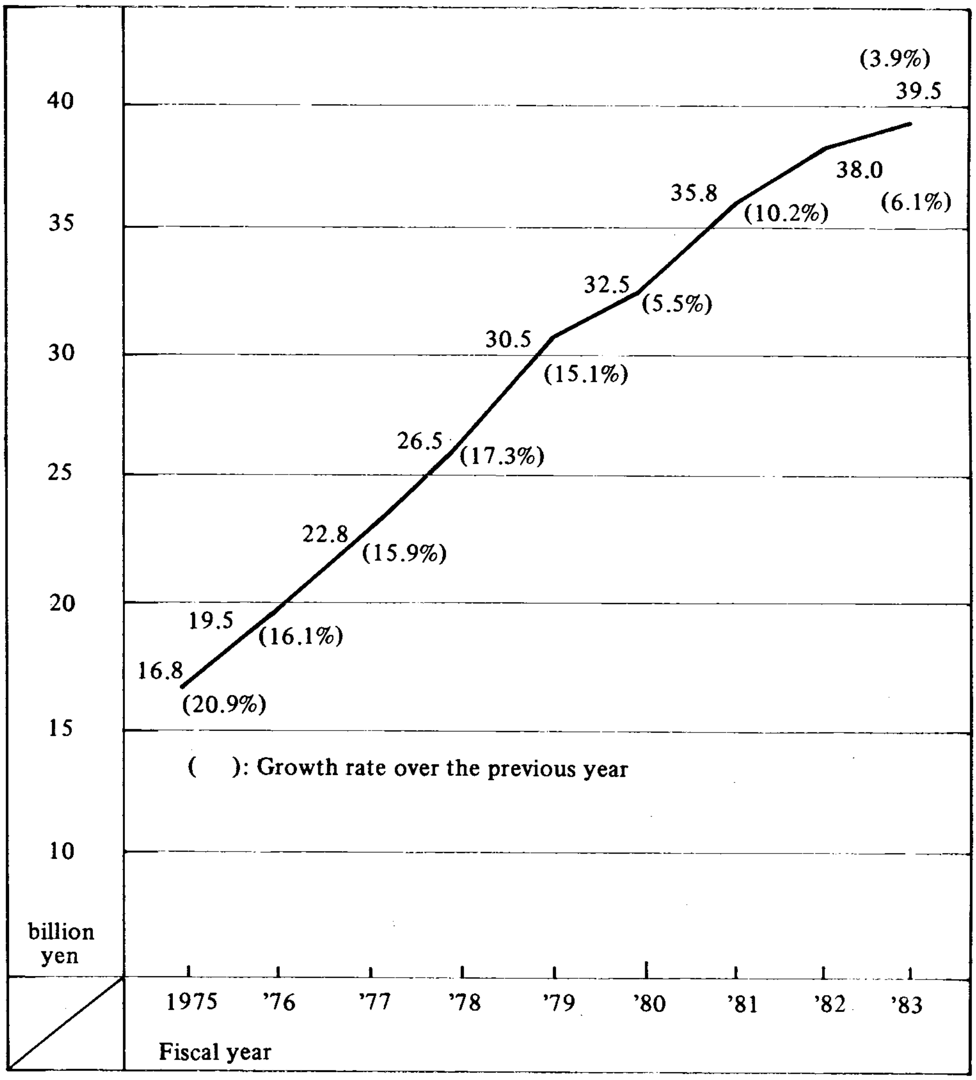

Fig. 3. Total amount of Grants-in-aid (in billions of yen)

Table 1. List of National Inter-University Research Institutes

Institute	Year of Establishment
National Laboratory for High Energy Physics	1971
National Institute of Japanese Literature	1972
National Institute of Polar Research	1973
Institute of Space and Astronautical Science	1981
National Museum of Ethnology	1974
National Museum of Japanese History	1981
Okazaki National Research Institutes	Combined in 1981
Institute for Molecular Science	1975
Institute for Basic Biology	1977
Institute for Physiological Science	1977
National Center for Development of Broadcast Education	1978
National Institute of Genetics	1984

Table 2.

(In thousands of yen)

Classification	Fiscal 1983 budget	Initial budget fiscal 1982	Up from the previous FY
Grants-in-Aid for Scientific Research	38,380,000	36,880,000	1,500,000
Special Distinguished Research	2,000,000	1,000,000	1,000,000
Cancer Research	2,070,000	2,070,000	0
Research in Natural Disasters	530,000	530,000	0
Environmental Science	950,000	950,000	0
Energy Research	2,100,000	2,100,000	0
Specific Research	4,770,000	4,770,000	0
Cooperative Research (A)	2,530,000	2,530,000	0
ditto (B)	180,000	180,000	0
General Scientific Research (A)	3,910,000	3,910,000	0
ditto (B)	5,460,000	5,460,000	0
ditto (C)	4,520,000	4,520,000	0
Encouragement of Young Scientists (A)	3,230,000	2,980,000	250,000
ditto (B)	90,000	90,000	0
Developmental Scientific Research	3,015,000	2,834,000	181,000
Overseas Scientific Surveys	1,125,000	1,056,000	69,000
Fund for Promoting Special Research	1,900,000	1,900,000	0
Expenditures for Research Publication	780,000	780,000	0
Special project research promotion	340,000	340,000	0
Total	39,500,000	38,000,000	1,500,000

Table 3.

Classification	Objectives and Contents
Grants-in-Aid for Scientific Research	Provision of research funds
Special Distinguished Research	Internationally acclaimed research likely to produce outstanding results and which requires large expenditures.
Special Research	Long-term research undertaken in the fields of academic importance as well as of social needs. Ongoing are cancer research, research in natural disasters, environmental science and energy science.
Specific Research	Special research projects in fields of special scientific and social needs, those terminating with a fixed term (3 years for example). Ongoing fields include life science and material science, etc.
Cooperative Research	(A) Cooperative research made by researchers of not a single institution but of widely selected and different research institutions. (B) Studies performed through research communications among researchers.
General Scientific Research	Original studies performed by one researcher or more researchers of the sam einstitution. This is a leading item among grants-in-aid for scientific research (classified A, B and depending on amounts of funds).
Developmental Scientific Research	Important applied studies which are in the basic phase but have high likelihood of practical use.
Encouragement of Young Scientists (A)	Research independently done by a young scientist or of young research history who attaches to research institution.
ditto (B)	Studies made by inexperienced researchers, by teachers of the upper secondary school level or below or by private researchers.
Overseas Scientific Surveys	Survey or research conducted abroad.
Fund for Promoting Special Research	To make necessary adjustment for the promotion of urgent & important research subjects, the experimental practice of research promotion and the distribution of research funds.
Expenditures for Research Publication	To assist publications of research results and scientific reports of higher scientific value.
Special Project Research Promotion	To support private sector research institutions and research projects with outstanding social relevance.

IV. Social Relevance of Academic Research

Society in general and the business world in particular have in recent years developed higher expectations for academic research. Indeed, the Scientific Council itself now recognizes that a university's response to societal needs, within the framework of its independent position and essential functions, can prove a great stimulus to the university's academic research programs.

Monbusho has been implementing new policy measures to encourage appropriate and productive responses to such needs. The national universities' 1983 budget for commissioned research by outside organizations, particularly corporations, was 2.67 billion yen ($10.8 million). In 1983, a system for joint research by university and private sector researchers was established, with the universities sharing some of the costs. The 1983 budget for joint research is 675 million yen ($2.7 million). The number of private sector researchers accepted at national universities and other institutions for higher-level training is expected to increase by about 100 to 814 people in FY 1983.

Corporate contributions to academic research at national universities and other institutions are expected to top 13 billion yen ($50 million) in fiscal 1983.

The screening procedures for "developmental scientific research" applications within the grants-in-aid system are being revised to facilitate joint research projects between university and private sector researchers, and these revisions include the selection of judges from the private sector.

V. The Japan Society for the Promotion of Science

Although Monbusho is by far the most important government agency for promoting academic research in Japan, there are some areas, such as fellowships, travelling expenses, international exchange programs, publication, and so on, that need to be handled flexibly and thus do not lend themselves to processing through the national administrative channels. The Japan Society for the Promotion of Science is a special public corporation established by law in 1967 to meet these needs. It trains promising researchers (384 post-doctoral fellowships), subsidizes domestic joint research programs, promotes the academic community's responsiveness to social needs, manages government-owned patents, and offers academic information services. It also promotes international exchange by supporting, in fiscal 1983, 107 joint research programs, 48 international seminars, 17 international academic meetings, 509 visits by overseas researchers, and 539 overseas trips by Japanese researchers. It also supports a scientific exchange scheme with developing countries, particularly those in the ASEAN region, known as the "core university system." In 1983, this system was responsible for 10 joint research programs, 4 international seminars, 258 visits by researchers to Japan, and 264 visits by Japanese researchers abroad.

JSPS's operating expenditures in fiscal 1983 were 3.8 billion yen ($15 million), of which Monbusho provided 3.2 billion yen, or 85 percent.

INNOVATION AND THE UNIVERSITY: CAN WE MAKE BETTER USE OF FACULTY TALENT ?

Martin D. ROBBINS *1

Technological innovation is the driving force behind economic growth in the United States. In this context "innovation" means that process by which a new idea is successfully translated into economic impact within our society by providing better products and simultaneously creating new jobs in the manufacturing and application of those products. Thus, an idea or invention is a necessary but not sufficient prerequisite for innovation. Only after an invention is put into sufficient use to have an economic effect is it to be termed an innovation.

Robert A. CHARPIE *2

Technological change is a basic characteristic of the industrialized nations of the world. Many people have, therefore, struggled to assess the influence such change has on society, such as employment opportunities, the quality of life, and economic well-being, both individual and national. The dynamics of a modern economy depend to a considerable extent on the forces set in motion by effective uses of relevant technology.

Before World War II there was little need to be concerned with the issue of stimulating the technological innovation process: most basic research was performed in academic institutions; industry carried out developmental efforts, supported by private funds; and government policy and dollars devoted to research and development were minimal, reflecting the low relative position of R&D in national priorities. Due to the rapid growth of government-funded R&D activities during the past four decades, a number of important policy questions have arisen that call for a greater comprehension of the relationships between R&D, technological innovation, technological progress, and economic growth, on the one hand, and between universities, industry and government as the actors, on the other hand.

More particularly, there has been a continuing controversy over the sources and the motivations of technological advance, and the role universities and their faculties play in this advance. The quantitative relationships between technologi-

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*2 Robert A. Charpie, "Technological Innovation and Economic Growth," in *Applied Science and Technological Progress.* A report to the committee on Science and Astronautics, U.S. House of Representatives, Washington: Government Printing Office, June 1967.

cal change and the rate of economic and social development are still subject to debate. Even more so is the debate about the role of basic research in the innovation process. In spite of numerous studies by both technologists and economists, many aspects of the quantitative role of technology in advancing an economy remain elusive. Nevertheless, in the case of the industrialized nations, it is intuitively evident that the rapid past growth of the economy is intimately related to the country's historical ability to develop and exploit technology.

The United States predicament at the beginning of the 1980's with respect to world trade, low economic growth, a declining rate of productivity, and under-employment of scientists and engineers has fostered recent concern about the role of the university in the innovation process. Some observers feel that this nation is facing a technological crisis, attributing the apparently low level of innovation to policies which distorted priorities in our colleges and universities by emphasizing certain advanced, often exotic uses of science, while other industrialized nations focused on more "useful" technology. The result, according to these commentators, is that industry in the United States is now behind, no longer able to compete in manufacturing technology-based products such as scientific instruments and consumer electronics, and not able to meet the growing and complex needs of an increasingly urban, consuming society.

Given the theme of this seminar, "Transforming Scientific Ideas Into Innovations," and given my role to examine how the university can make a more effective contribution to this process, I would like to start by looking at the university itself, its values, norms and structure. Only then do I believe we can develop an understanding of why some things work and some don't, and why we must talk about new types of "incentives" to bring about a more effective use of faculty in the process of transforming scientific ideas into application.

Let us begin by recognizing that the university is a most remarkable modern institution. It functions as a teaching enterprise at the same time that it serves as an advanced research establishment; it provides service to the state at the same time that it remains aloof from political squabbles; and it has a major committment to advancing fundamental knowledge while many of its faculty members earn substantial consulting incomes by engaging in the most applied of scientific and engineering activities.

These statements are not contradictions of fact about universities but rather they are examples of the richness, diversity and uniqueness of the institution itself. The university is also what I like to call "refractory": it will seldom change even when subjected to the most intense heat. It is as stable an institution as we have in America, yet it is at the same time, highly fragile. Its structure in its various departments and schools is based upon disciplines (or, put another way, on ways of organizing knowledge) as well as upon professions (or ways of applying knowledge). Its governance is a manager's nightmare, one based upon the concept of shared roles and changing boundaries. Faculty, as a generalization, cannot be told what to do or how to do it; they are not employees in the traditional sense of the word. Faculty constitute a special body of research talent that is clearly different than that found in industrial or government laboratories.

Given this background, let me now turn to what is special about university research, if anything. Universities are obviously not the sole source of new knowledge. In point of fact they are not even the major source of new knowledge. But universities have one major difference when compared to other research performers: the mission of the university is education, and education is a continuing vital social concern in all of the industrialized nations. This distinction leads to a commitment to the institution but it also leads to the development of a special research culture within the university.

The strength and at the same time the weakness of the research culture lies in its discipline-orientation. Research in the university is usually pursued in rather narrow but well defined areas of specialization: compartments of knowledge which are constantly expanded. The reward structure for such activities resides within the discipline, with peers accepting or rejecting, bestowing recognition or withholding it, based upon the publication of research results in discipline-oriented journals. As the structure of knowledge becomes more complex, an increasing number of new journals appear, each directed towards its own specialized group of peer scientists. It is what Alan Weinberg called "the pursuit of purity" in which the ultimate recognition is awarded to a scientist whose results are so pure, pristine and narrow that only the smallest group of peers are capable of understanding, let alone using the results of the faculty member's intellectual efforts.

This leads to some conclusions about how university research works.

- One, since the reward structure of the university is based upon publication of new knowledge in discipline-based journals, research performed in the university usually has little to do with those activities which help to put knowledge into use, or help to shape knowledge so that it can more readily be put into use. In point of fact, faculty who forget this basic rule often find themselves in trouble when it comes to tenure, promotion and salaries. This means that faculty identification, affiliation and loyalty are rooted in the discipline.
- Two, because the structure of the university is based upon disciplines, we find that the institution tends to be problem-poor. What I mean by this is that the only problems the institution is capable of generating are those that derive from within the disciplines themselves, those that serve to advance the discipline. These types of problems are usually limited to the creation or organization of disciplinary knowledge. At the same time, the university tends to be a methodologically-rich environment. This is because much of the substance of developing basic knowledge is in fact taken up with creating new tools, new ways of looking at phenomena, and new techniques for analysis. In sum the faculty member lives in a problem-poor but methodology-rich environment.

Contrast this with an industrial environment concerned with innovation, in which we have a multitude of very focused and applied problems searching for new techniques and methods by which they might be solved. In other words, the industrial scientist usually lives in a problem-rich but methodologically-poor environment. The "marriage" opportunities for this mirror image of institutions and people are obvious, but to make the marriage work we have to recognize the special nature of the university reward structure, as contrasted with the profit based reward structure of industry.

Let me now shift to the issue of comparative advantage. The faculty/student environment of a university in terms of research gives it, perhaps, two advantages. First, faculty at a university have large amounts of discretionary time. By this I mean that while faculty are expected to engage in research, they have a tremendous amount of control over the research they choose to do (of course, within the constraints of the above mentioned reward structure). This amount of discretionary control over selection of research effort is rare in industry. Second, universities have a large body of very low-paid graduate students who serve as apprentices on the research projects most often chosen by the faculty. These apprentices have a great incentive to function at their highest possible level of intellectual capability. They are under constant evaluation and the award of a degree ("license to practice") is directly dependent upon their performance.

This is the university's real comparative advantage in research: discretionary faculty time and an abundance of low-priced manpower. There is no other institution that has these two characteristics, and it is part of what makes the university special in the research world.

Given these situations, the question we must face is how do we focus these "discretionary" efforts into a more directed enterprise, so that the scientific ideas which are created in the university are more readily transformed into innovations? Fortunately we are seeing the development of a whole new set of university/industry collaborations which attempt to overcome the problems and exploit the strengths.

The best of the collaborations recognize the special nature of the university reward structure, and try to provide incentives that will "capture" the faculty discretionary time. For example, any collaboration that forecloses the possibility of open publication is doomed to failure. Since commercial success is often based upon secrecy, contract negotiations in this area are often the most difficult.

The best of the collaborations are designed to 1) marry the methodology-rich environment of the university with the problem-rich environments of industry; 2) recognize the reward structure; and 3) exploit the low-priced labor of graduate students in the most effective manner. This often means greater flexibility on the part of the university and the industrial firm than either may have been accustomed to in the past. The best of the collaborations, for example, provide incentives for faculty so that they will do with their discretionary time what they might not have done otherwise. If not thought through and applied properly, misdirected incentives can be very upsetting in a collegial atmosphere.

We have run a number of experiments in Colorado which have tried to deal directly with some of these issues: reward, problem/methodology marriage and incentive. The most successful of these was a form of "seed" funding for energy-related research activities.

During the late 1970's we were faced with problems related to the possibility of massive energy development. Unfortunately, we were finding it difficult, with some exceptions, to get the faculties in the universities in the state to devote their research to solving the specific applied energy problems which we were facing.

At the same time, competition for limited R&D funds was forcing academic investigators to devote increasing time towards preparation of research proposals. Often these proposals were for research in areas which were relatively new to established investigators, many of whom were switching fields or broadening their research range. In addition, we found that new academic researchers who had not yet developed a performance or publications record found it extremely difficult to secure funding for initial projects.

In both cases, the probability of success for any single proposal was much lower than for the well-known researcher working in his or her area of demonstrated, disciplinary expertise. The result was a "flooding" of funding agencies with proposals, many of which were not well developed due to time limitations and pressure to secure funding in the increasingly competitive and tight marketplace. High costs were incurred by submitters in preparation as well as funders in review.

Our approach was to exploit this situation by providing an incentive for faculty to move into problem-oriented areas of energy research while at the same time reducing the number and increasing the quality of proposals. This was done by internal financing of the first stage in the life cycle of a research project. This financing was limited to areas of specified need. Such funding, leading to the preparation and submission of the research proposal, provided support for energy-related ideas when the risk was greatest and when the faculty member found support most difficult to obtain. We made the submission as easy as possible, required industry collaboration, allowed for full use of graduate students and encouraged early publication of initial results.

Experiments with "seed" financing of energy-related research by this group of Colorado-based investigators resulted in an appreciably greater funding percentage from outside sources for subsequently submitted proposals. The Colorado experiment was competitive and limited to initial stage support, not exceeding \$5,000 for any single project. Range of activities supported included: information gathering through travel and meeting attendance; trial experiments; initial computer runs; support of graduate students for first-phase data gathering and reduction; preparation and submission of initial publications; and literature searching using on-line data bases.

Evaluation of funding obtained from successful proposals which were prepared after initial seed support indicated a highly cost-effective return on investment of time and money. More importantly, they indicated that incentives properly designed could move discipline-oriented faculty into highly applied areas of need.

INTERRELATION BETWEEN FUNDAMENTAL RESEARCH AND TECHNOLOGICAL RESEARCH IN JAPANESE FERMENTATION INDUSTRIES

Hirotoshi SAMEJIMA *

Although the development of Japanese fermentation industries, or bio-industries in a broad sense, owes much to Western technology and basic research, Japanese fermentation industries have themselves made some technological break-throughs which helped to establish these industries as they are today.

In terms of the historical background of Japanese fermentation industries, technology-oriented research often led to new directions in fundamental research, while the results of such fundamental research in turn contributed to the further improvement of technology. It would appear that the accumulation of experiences of this sort has made it much easier for Japanese fermentation industries to absorb new biotechnologies, such as recombinant DNA technology and other recent innovations.

Despite these experiences, many Japanese people believe that it is essential that Japan increase its efforts in fundamental research if it is to maintain a rapid rate of technological advance. This paper addresses the question as to why until today relatively little progress in basic research has been made in Japan, and how Japan's capabilities in fundamental research might be strengthened.

It can be said that the production of scientific knowledge by Japanese industries varies considerably from one industry to another. In this respect, from the point of view of my own business perspective, I wish to discuss the past and present status of Japanese fermentation industries, or bio-industries in a broad sense.

Japanese fermentation industries in their current form originated from the domestic brewery industries which produced the alcoholic beverage, "Sake", and fermented foods such as soy sauce and "Miso" (fermented soy bean paste). Before World War II, these industries were classified as one of the relatively affluent and protected industries. Most of their products were sold for domestic use, thus it was rare that these industries were faced with international competition. This suggests that those industries were well protected socially at that time.

Nevertheless, the owners and managers of the relatively big companies in such brewery industries were enthusiastic about introducing modern technologies into this field. As a result, from the early days they provided financial support for research in universities and colleges of their concern, and were rather generous in

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employing the graduates from those institutions. Consequently, most of the pioneers who contributed to the development of Japanese fermentation industries as they exist today were graduates of the department of agricultural chemistry in the faculty of agriculture or the department of fermentation technology in the faculty of engineering of those institutions that were heavily supported by the big brewing companies.

Before World War II, the fermentation industries primarily produced alcoholic beverages such as "Sake" and beer, and fermented foods such as soy sauce and "Miso". Of course, some modern fermentation products such as industrial alcohol, acetone, butanol, citric acid and a limited number of enzymes were already produced at that time, but they were still minor products.

Within these general circumstances that prevailed at that time, one interesting example of a new trend in fermentation technologies was an invention to produce isooctane from sugar by a combined process using both fermentation and organic synthesis technologies. This invention was developed by a small research group of the Kyowa Chemical Research Laboratory headed by Dr. Benzaburo Kato who later became the founder of the Kyowa Hakko Kogyo Company. As you may know, isooctane was the most precious* airplane fuel at that time. The industrialization of this process was therefore promoted under the auspices of the Japanese Army during the last war, but was interrupted when the war ended. However, this technological experience helped to stimulate originality in Japanese fermentation technologies in later years.

After the war, procedures for the production of penicillin were provided to Japan by the United States Government. Since the patent right for this technology was free, more than 60 Japanese companies became involved in its production. Later, most of these companies dropped out of the market because of the excessive competition. On the other hand, the streptomycin manufacturing process, which was introduced in our country from the United States, was protected by patents and only a few Japanese companies were licensed to produce it. This resulted in steady progress in the streptomycin business in our country.

The successful introduction of the antibiotics industry led to active research on new antibiotics in Japan, and contributed to advances in Japanese antibiotics research, both scientifically and industrially. The submerged fermentation technology, which was introduced accompanying the introduction of the antibiotics industry, also made a significant contribution to the later progress of Japanese fermentation research in general, not only in the antibiotics filed but in many other areas of new fermentation products as well. In this regard, we owed much to the technology of the United States. Without the introductions of American technological aids, Japanese research, both industrial and academic, could not have caught up so fast in the fermentation technology field.

Another influx with considerable influence on Japanese fermentation technologies was the advanced knowledge of biochemistry and microbial genetics in

*Note to author: precious defined as most expensive or scarcest?

the United States and Europe at that time. This new knowledge was introduced mainly through the universities. Young researchers of those days were fascinated with new information on advanced bio-sciences, even though it was uncertain whether it would be useful for any practical application in the future. However, it did not take long for Japan to realize that knowledge of pure basic science would be an essential factor in any breakthrough in fermentation technology.

Dr. Shukuo Kinoshita of the Kyowa Hakko Kogyo Comany and his associates, who learned this new knowledge through the universities, began research under one hypothesis. The hypothesis was that a specific compound on the metabolic pathway would be accumulated in the fermentation broth when an enzyme located on a specific position of the metabolic pathway of a certain microorganism was injured or deleted by artificial mutation techniques.

As expected, the research was successful. In 1956, Dr. Kinoshita and his associates were the first in the world to succeed in the fermentation of glutamic acid. They made a further success in the fermentative production of L-lysine in 1958 by applying the same hypothesis. These findings had a tremendous impact on both universities and other industries in Japan. Thereafter, further studies along this line were made in many Japanese universities and other companies in addition to the Kyowa Hakko Kogyo Company. Fermentative production technologies for almost all of the amino acids and many nucleic acid-related substances were explored and made available by Japanese researchers. At the same time, such production technologies were industrialized within a relatively short period of time. These discoveries may be associated with the present situation in which the world is paying close attention to developments in the Japanese fermentation industries.

During the course of artificial mutation of microorganisms, researchers obtained much new biochemical and genetic information useful for the subsequent improvement of the process. Thus, the success of Japanese fermentation technology has its origin in the technology-oriented type of study which stimulated basic research. This, in turn, helped to further the improvement of the technology. This repeated cycle of technology and basic-oriented research may be a special feature of fermentation research and development in Japan.

Industrial success encouraged the researchers to continue their explorations. They were futher encouraged by the fact that many of the companies permitted them to publish portions of their research results associated with the basic sciences in journals of the formal academic societies. Greater opportunities for conducting basic research were provided to those researchers who developed the more fruitful technology. This process of cyclic alternation of research between technology and basic science seems successful, at least in Japan.

Researchers from industry who experienced this style of scientific study realize the importance of basic research and share a common scientific interest with researchers from universities. Today, Japan has many scientific societies and meetings. Among those symposia related to the fermentation industry, the number of publications presented from industry seems relatively higher than in other scientific fields. And, I think that in international scientific meetings relating to fermentation, the contribution of Japanese scientists is considerable.

Among the reknowned new biotechnologies in recent years, the recombinant DNA technology was first developed by Drs. Cohen and Boyer at Stanford University in 1973. This is one of the most important breakthroughs in biotechnology in this century; however, all knowledge employed in this technology is totally dependent upon the knowledge of molecular biology and related biological sciences accumulated over many years. Until the breakthrough in recombinant DNA, molecular biology was classified as a part of the basic sciences. It turned out, however, to be a most powerful production technology. This provides a very good example of the relation between basic science and technology.

The initial response of Japanese fermentation technologists to news of the development of recombinant DNA technology was the feeling that this technology would prove to be one of the most powerful tools in producing artificial mutants of microorganisms. We believed that the survival of Japanese fermentation industries absolutely depended on technology for obtaining better artificial mutants of microorganisms. Therefore, we believed that the survival of the fermentation industry depended on the ability of Japan to acquire experience in the new technology. Japanese industries sent their scientists to the United States. Fortunately, this technology has already been disseminated to many universities in the United States, as well as parts of Europe. It was also soon discovered that many Japanese researchers working abroad had played important roles in both basic and applied research related to this technology.

Because of such favorable circumstances and because of the long history of expertise of Japanese fermentation technologists in microbial genetics, the transfer of this technology was accomplished surprisingly fast. This is reflected in the fact that Japanese scientific papers and patents relating to this technology have suddenly increased in number during the last several years.

The fermentation technologists were not the only people who contributed to the transfer of recombinant DNA technology to Japan. Researchers in the medical field contributed as well. The microbiology departments of medical schools in Japan made advances of their own independent of fermentation technology in the early days of the Meiji, etc. This line of development has its traditional base in the fact that soon after the Meiji Restoration, Dr. Shibasaburo Kitasato was educated by Dr. Robert Koch in Germany and contributed to the discovery of the cholera germ, and that Dr. Sahachi Hata was educated by and cooperated with Dr. Ehrlich to develop Salvarsan, the most promising potential antispirochete at that time.

On this occasion, researchers in Japan in the medical field, with the long history mentioned above, moved quickly to cooperate with fermentation technologists. This is one reason why Japan was able to catch up quickly with the West in both basic and applied aspects of recombinant DNA technology.

In fermentation technology, we believe that Japanese scientists contributed considerably to various aspects of the basic sciences. However, because of Japan's distinguished progress in its application and industrialization, we are generally misunderstood and thought to have relatively disregarded the basic sciences.

Of course, Japan has a rather short history of involvement in basic research in various fields, and we are certainly aware that Japan should make a larger contribution to the basic sciences. The Japanese Government and people are now emphasizing the importance of making a greater contribution to the world through the promotion of basic science and we are pleased to see that national policies along this line are now being put forward. There are also an increasing number of industries that realize that part of their research budgets should be used for basic research.

Until today, most research budgets of Japanese industries have consisted of their own funds. Financial support by the government was far smaller than that in the United States and European countries. In addition, we have to admit that cooperation between industries and universities has not been sufficient because of various forms of social opposition.

Apart from those reasons mentioned above, we must note other reasons for the relative lack of advances in basic research in Japan. The reasons seem to be associated with the atmosphere based in the Japanese society and tradition. For example, in Japanese society, there is a social tendency to respect harmony within a group and accordingly to suppress individualism. This runs counter to the conduct of basic research, which requires the individualism of each researcher. Researchers of strong character sometimes would leave Japan and often would conduct basic research of considerably high quality in foreign countries.

Secondly, there seems to be a difference in the way of thinking between the people of Europe and the United States and the people of Japan. This difference often appears in the manner in which scientific research is approached. In scientific research, many scientists of Europe and the U.S. begin by proposing some hypothesis based on their findings and then make an effort to prove it. This sometimes leads to a breakthrough in basic research, but, in the worst case, it produces nothing. By comparison, many Japanese researchers have a tendency to extend one initial finding in other directions by adding further findings one after another, and then expanding their theory. While the chance of a big breakthrough may be less, the results obtained may be more solid and reproducible. The kind of approach may be more suitable for the development of technology but less so for basic research.

Recently, the number of Japanese who have become conscious of this situation has been increasing. How to guarantee freedom and a suitable working environment for eager young researchers is now under active discussion. Policies along this line are gradually being implemented by both the government and private sectors. A rather extreme idea that has been suggested is that if it proves to be too difficult to develop the appropriate environment for basic research within Japan, an alternative is to establish research institutions somewhere outside Japan and to manage them entirely in the American style. In any case, there has been a slow but steady change in our attitude toward basic research.

Last but not least, I want to make one comment to the U.S. friends of Japan. Currently, many of the important scientific articles in most of the major journals of the academic societies of Japan have been published in English, and people living in countries where English is the predominant language can have ready access to the results of research done in Japan.

I also consider personal contact to be extremely important in fostering increased scientific communication and greater understanding between researchers in the two countries. To accomplish this, it will be necessary to make an effort to provide the researchers of both Japan and the United States with greater opportunities to visit one another.

THE FACULTY SALARY PROBLEM: PAYMENT OF FACULTY SALARIES UNDER NSF GRANTS

Robert B. HARDY*

Introduction

The U.S. National Science Foundation (NSF) currently provides approximately 17% of all Federal support for academic R&D in the United States. NSF policies and practices governing the administration of its research support funds play an important role in the overall framework for the conduct of U.S. academic research. One aspect of these policies of particular importance in this system is NSF payment of the salaries of college and university faculty through research project support funds. Payment of such project-based salary compensation by NSF differs from the practice followed in Japan and other countries with regard to government support of academic research, and has led to some particular problems and concerns. This paper describes NSF policy and operations concerning payment of faculty salaries, and discusses various facets of the faculty salary "problem."

In order to begin to appreciate the complexity of this issue, it is important to understand that in the United States, faculty members generally are paid by their colleges and universities both to teach and to do research during the academic year (eight or nine months). Should they desire to work during the summer months, faculty must find additional sources of income. With rare exceptions, NSF research awards (which typically take the form of grants) are made to the academic institutions, not directly to the faculty member. Where grants include funds for faculty members' academic year salary support, one (or both) of two things may happen: the NSF funds may be paid by the institution to the faculty member for some portion of his or her *research time* in lieu of using university funds for this purpose, or they may be used to enable the faculty member to be released from some part of his or her normal *teaching* obligation in order to do the research. In the latter case the university's own funds which otherwise would have been paid to the faculty member for teaching can be "released" to compensate someone else for this purpose. Note that in either case the NSF funds

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Any opinions, findings, conclusions or recommendations expressed in this paper are those of the author and do not necessarily reflect the views of the National Science Foundation.

substitute for university funds which otherwise would be used to pay the faculty member's salary. (Where NSF funds summer salary, typically an incremental research effort is involved for which the individual faculty member would not otherwise be compensated by the university. Hence the substituted salary effect does not exist).

While oversimplified for purposes of clarity, the above funding model provides a reasonably good brief description of the nature and effect of NSF faculty salary support. It might seem fairly straightforward. However, in actuality both NSF policy and its implementation have been anything but simple. The whole topic of payment of faculty salaries on research grants has proven remarkably contentious for NSF over the years. The current NSF policy statement on this is as follows:

> "As a general policy NSF recognizes that salaries of faculty members and other personnel associated directly with the research constitute appropriate direct costs in proportion to the effort devoted to the research ..."
>
> "NSF regards research as one of the normal functions of faculty members at institutions of higher education. Compensation for time normally spent on research within the term of appointment is deemed to be included within the faculty member's regular institutional salary. Grant funds may not be used to augment the total salary or rate of salary of faculty members during the period covered by the term of faculty appointment or to reimburse faculty members for consulting or other time in addition to a regular full-time institutional salary covering the same general period of employment."
>
> "Summer salary for faculty members on academic-year appointments will not be funded for more than two-ninths of their regular academic-year salary. This total includes summer salary received from all NSF-funded grants. Exceptions to this limitation are permitted only in unusual cases, which must be fully justified in the proposal."[1)]

This policy has been in effect essentially unchanged for 20 years. But to fully understand the present situation, it is necessary to go back in history to look at the genesis of the current NSF policy and its evolution over time.

Historical Background

The present practice of payment of academic salaries by U.S. government agencies to permit faculty to pursue government-supported research may be traced back to the immediate post-war period. It was at that time that the current pattern for Federal government support of university research was established, based on policies set by the National Defense Research Committee during the war. A principal feature of these policies was reliance on contracts with universities for (basic) research rather than undertaking all necessary research "in-house" with government facilities or personnel. A corollary principle was that the Government was to pay "full costs" of the research.[2)]

From the first, implementation of the latter concept in the context of faculty salary payment evidently proved troublesome. The U.S. Office of Naval Research (ONR) began to allow faculty salary support under basic research contracts in

1947 (including payment of extra compensation for research conducted during the summer months). ONR did not, however, encourage requests for such support, and would allow neither salary augmentation nor any compensation to faculty beyond "release" time for research performed during the academic year.[3) Other U.S. government research agencies also began allowing salary payments in awards to universities for research, with less concern than ONR for avoiding paying faculty for their "normal" research. Thus, the basic framework for U.S. government support of academic faculty salaries for research was in place before establishment of the U.S. National Science Foundation in 1950.

From its beginning, NSF shared ONR's concern about faculty salary payments. NSF's first Director and a number of its initial administrators came from ONR, and this undoubtedly had some influence. At its 11th meeting in February 1952, the National Science Board (NSF's governing body) declared:

> "... When an investigator is a permanent officer of an educational institution (i.e., having professorial rank) and therefore in a position to influence the research and educational policies of the institution, he should not receive a major part of his compensation as a result of work under a Foundation grant."[4)

During its early years NSF, like ONR, allowed faculty salary compensation on research project grants only for time explicitly released from teaching during the academic year, and for summer work. Furthermore, academic year compensation was limited to no more than 50 percent of the total academic salary. Release had to be from specific non-research duties; time normally available for research could not be charged. Compensation was paid at the investigator's normal monthly rate, grant funds could not be used to augment the monthly rate of compensation of faculty. Compensation for research performed during the summer months could be paid at a rate comparable to monthly salaries during the academic year up to a maximum of two-ninths the normal academic year salary. In 1958, both the fifty percent academic salary limitation and two-ninths summer salary limitation were removed.[5)

While the above was NSF's stated policy, NSF shared ONR's general antipathy to actually paying academic year faculty salaries. Academic year salary assistance was given only in rare instances (except for sabbatical leave half-salaries).[6) During this period, however, pressures were building on the Foundation from the universities to liberalize this policy. Part of the Foundation's concern about academic year salary payments can be traced to traditional concerns about their effect on relations between government and higher education in the U.S. These concerns will be discussed later. However, the Foundation's resistance was also partly due to the belief that universities should share the costs of NSF-supported research as a joint enterprise, since research was among a university's chief responsibilities.[7) Under this view, the cost of time normally spent on research by a faculty member was particularly appropriate for the institution to absorb. NSF would then support other costs of the research (graduate students, equipment, supplies, etc.).

Many university administrators did not share NSF's "joint enterprise" view. Instead, they advocated the principle of full reimbursement for the costs of all research supported by government awards, believing that the government was procuring services from them (and their faculty) for which it should be expected to pay in full. More practically, it should be noted that the "substitution" effect of NSF salary support represented a particularly attractive source of additional income to universities. Indeed, there were pleas that universities could not afford to allow their faculty adequate research time unless funds were made available by the government so that additional instructors could be hired to share the teaching load.[8] Accordingly, in 1960, the National Science Board authorized NSF to reimburse salaries according to effort, without regard to distinction between "teaching" time or "research" time.[9]

Predictably, this liberalization of Foundation policy led to a rapid spread in the practice of requesting faculty salary support in university grant proposals. However, institutions varied tremendously in their requests for such support, and Foundation program offices varied in their responses. NSF program staff and advisers continued in many cases to resist payment of academic year stipends for tenured faculty. This led to often conflicting pressures from university administrators, university faculty, NSF advisory groups, the Federal Council for Science and Technology, the President's Science Advisory Committee, and other Federal agencies and the U.S. Congress.[10]

While in principle the payment of summer salary compensation seemed much better accepted than academic year support, it also presented a number of troublesome issues: What is the proper rate for payment, given the different kinds of academic calendars in the U.S.? What kinds of limitation, if any, should be placed on the total summer work period for which reimbursement could be provided, given the need for vacation, etc? There was also some pressure for augmented salary compensation during the academic year for work performed on grants during university vacation periods.[11]

All of this led the National Science Board to consider the matter of faculty salaries eight times between June 1962 and May 1963 Aspects discussed included two-ninths vs. three-ninths summer salary, the possibility of inducing all institutions to adopt a twelve-month salary scheme to simplify government salary reimbursement, the vacation issue, and the so-called "Robertson Plan" (named for the Foundation's then Associate Director for Research). The gist of this plan was to stop making payments for faculty salaries under individual research grants. Instead, an annual faculty support grant would be substituted to provide equivalent assistance to the institution (thus eliminating the troublesome individual grant salary negotiations).[12]

The result of these repeated considerations was reflected in a June 1963 policy statement essentially identical to the current statement quoted above. As noted, this salary policy in principle has been followed by NSF for the past 20 years without substantial change. What then is the problem?

The Problem

The faculty salary "problem" has a number of dimensions. For one, deep policy concerns about government support of academic year salaries of university faculty persist. A related concern is the questionable, and highly variable, degree of NSF implementation of its own stated policy in this area. Another dimension has to do with equity; there are issues both as to whether NSF-supported faculty receive "excessive" compensation and whether the effect of NSF salary compensation is to distort the academic salary structure. Finally, there are familiar questions about monitoring and accountability – how to assure the government is getting what it pays for.

Taken together, these present an extremely complex picture. Some have concluded that the "problem" may be easier to live with than any of the "solutions" suggested.[13)] In this paper we shall be concerned mainly with policy and implementation issues. The equity and accountability concerns will be touched on only briefly.

It should be kept in mind that these issues transcend the operations of the National Science Foundation, and go to the heart of the complex interactions between government and institutions of higher education in the system for support of academic science in the United States. While this paper focuses on NSF policies, operations and procedures, it has clear implications for the larger discussion.

Policy Aspects

The brief historical review presented above implies that there must be deep concerns about NSF payment of academic salaries. It has been said that "Reimbursement of faculty salaries touches more intimately on the integrity of universities as institutions than practically any other form of Federal support."[14)] In the context of NSF, what are some of the concerns?

The biggest one is potential conflict of interest. Faculty members who submit research grant proposals to NSF that include requests for salary reimbursement essentially are put in the position of trying to raise part of their own salary from the government. Obviously this could lead to a situation of divided loyalties, and perhaps induce a faculty member to put his or her obligations to NSF ahead of that to the university. A closely related concern is the familiar principle of academic freedom. Again the dependence on Federal support for salaries could theoretically subject faculty members (and their universities) to pressures which might limit their academic freedom. Third, salary reimbursement can be viewed as a disguised grant for generalized assistance to the university, since broadly speaking NSF has no control over the university's use of its own released funds. Viewed this way, the effect is possibly to divert NSF support from the intended purposes. These concerns have persistently troubled many faculty (in contrast to their own university administrators).[15)]

A more practical kind of concern involves the potential financial risk to universities. Since universities tend to make other commitments for the use of their funds released through NSF payment of faculty salaries, sudden cuts in NSF support could leave universities in a vulnerable position. Other concerns that have been identified include that payment of faculty salaries increases the costs of research to NSF without necessarily resulting in the performance of more research, that it provides incentives for "stockpiling" the best scientists at a limited number of leading research universities, and tends to reduce the time senior faculty devote to teaching while reducing student-faculty contact generally.

With all these expressed concerns, on what policy grounds can payment of faculty salaries by NSF be justified? It appears there are several rationales which have been advanced in support of this policy. They vary in nature from philosophical to strategic to more pragmatic.

In fact, the basic philosophical issue of whether NSF, in supporting research at academic institutions, is assisting universities in a joint enterprise, or buying services from them, has never been resolved in any clear way. This dichotomy is surely oversimplified, yet the view that NSF grant support of university research is essentially indistinguishable from the purchase of research services from universities by government "mission" agencies or private industry retains influence with many university administrators. From their perspective, those faculty whose research is funded by NSF are performing a special service for the government, not undertaking a normal university duty. If this is the case, then NSF should be expected to pay the full costs of all research it funds, including salary expense for all personnel engaged in the research.

This view has never been clearly accepted by NSF, and was explicitly opposed by its first Director and the Board in the early years. They believed NSF was in a "support" mode, not a buyer-seller relationship, with the universities. Nevertheless, the history reviewed above seems to demonstrate a steady drift of the Board and the Foundation toward a "full reimbursement" policy.[16] As economic pressures on U.S. universities continue to grow, occasioned by changing demographic trends and increased costs, particularly for research facilities and equipment, we may expect that university administrators will continue to press for full faculty salary reimbursement from NSF.[17]

A more strategic basis for NSF salary policy was suggested by Task Group 17 of the NSF Advisory Council in a November 1981 Discussion Paper. Surveying past studies of the faculty salary issue, the Group concluded that more emphasis needed to be given by NSF to its responsibility for human capital generation and maintenance. "NSF support of faculty salaries represents an investment by NSF in human capital, especially given the close association of research with graduate training ... It represents a strategic investment by NSF in the best and brightest scientists ... to assure national long-term scientific health and vitality."[18] Encouraging faculty to forego other income opportunities to continue to spend their time at fundamental research maintains the scientific talent base and the transmission of scientific knowledge to future scientists and engineers through the recruitment of graduate students to assist in the research. It should be noted that there are also other ancillary "human capital" benefits, such as the employment of additional faculty both to teach and to assist in research made possible by the "substituted funds" nature of NSF salary support. But to the Task Group the intimate association between research and graduate and post-doctoral training in the American system of higher education seemed the most compelling aspect of the "human capital" approach.

A pragmatic basis for NSF salary reimbursement is suggested by the above: it tends to help keep faculty on campus doing fundamental research. Task Group 17 concluded that "Should salary payment from NSF no longer be available ... many researchers would turn to other agencies or private industry for (salary) support. But this is less likely to result in the performance of non-proprietary basic research at universities, so essential to the progress of science ..."[19] In essence, the Task Group is pointing to the fact that most faculty at major research universities in the U.S. are expected today to raise at least part of their salary for research from non-university sources. NSF thus is a "competitor" for the research time of this faculty, along with other government "mission" agencies and private industry. NSF needs to pay faculty salaries to assure the performance of the kind of research NSF wants done, i.e., non-proprietary basic research, which is much less likely to be supported from these other sources. Viewed this way, payment of faculty salaries might be seen as essential to the accomplishment of the NSF "mission."

To get around some of the objections to NSF payment of faculty salaries, while accomplishing NSF's purposes, it has been suggested from time to time that NSF move to a "block payment" mode of faculty compensation whereby salaries would be decoupled from individual grants. A periodic faculty support grant would then be made to provide equivalent assistance to the institution.[20] Claimed benefits of this approach are that it would lessen the potential conflict-of-interest problem and the possibility of undue government interference in university affairs. (It would also lower the visibility of faculty salaries by removing them from individual grant applications where they tend to be especially scrutinized and become the subject of negotiation.) The "Robertson Plan," which was seriously considered by the National Science Board about 20 years ago, is an illustration of this approach, and the Board has considered other variations of this plan several times.

In some respects this conforms to the funding model used in other countries for government support of academic research. For example, in both Britain and Canada a dual system is followed involving direct government subsidy of university operating expenses (including faculty salaries) with additional competitive research project grant programs (for support of costs particular to the research) administered on a national basis.[21] However, such direct assumption of Federal responsibility for university faculty salaries implies a radical change in the traditional relationship between higher education and the Federal government in the U.S. Other considerations aside, it is unlikely to be politically acceptable. This concern along with the difficulty of establishing an appropriate level of effort on an annual basis as well as concerns about increased costs, evidently led the NSB and NSF ultimately to decide against this approach in 1963.[22)]

What, then, is one to make of all the conflicting views and policy rationales raised by the present system? Before looking for some sort of "bottom line," it should be noted that this discussion has been almost exclusively in terms of academic year salary payments. NSF payment of salaries to faculty for research performed during the summer has never raised the deep policy concerns engendered by academic year salary payments. From the first, NSF appears to have regarded support of summer salary as involving an incremental addition to an investigator's total research effort. From this perspective, the conflict-of-interest and other concerns are less likely to arise. NSF support of faculty salaries for summer research increases the total stock of (basic) research performed (with attendant educational benefits), and helps encourage full utilization of facilities and equipment. The practice of providing summer salaries seems to have become well accepted before the pressures on NSF for academic year salaries began to develop.[23)]

However, the practice of providing faculty summer salary support originated when faculty salaries were relatively low. As these salaries have increased, the Foundation from time to time has been concerned about the increasing costs to it of summer salaries.[24)] In 1973, Task Group I of the former NSF Advisory Committee for Research was asked to review NSF summer salary policy and possible alternatives. The Group recommended that the two-ninths limitation be reaffirmed and strengthened, but that in addition a fixed ceiling amount per investigator per summer be established. In a strong dissent, some members of the Task Group pointed to the latter recommendation as unfairly discriminating against those faculty scientists who received high salary rates or whose principal research effort occurred during the summer and/or depended on NSF as their chief source of support. They thought it an unwarranted interference in university prerogatives to set salary rates for faculty.[25)] As a result, the full Advisory Committee could reach no consensus for change. Similar proposals previously had been made to the National Science Board. On at least two occasions the Board had apparently agreed in principle to the concept of placing an arbitrary upper limit on summer salaries but deferred taking any definitive action.[26)] Consequently, no such ceiling was ever enacted. While these nettlesome implementation questions about summer salaries thus have persisted, the basic practice does not appear to have been seriously challenged on policy grounds over the years of the Foundation's existence.

Is there any way out of the policy dilemmas posed by NSF payment of academic year faculty salaries? Perhaps not. In a memorandum prepared in 1977, Dr. Edward Todd, then Acting Associate Director for Astronomical, Atmospheric, Earth and Ocean Sciences, and previously NSF's Deputy Associate Director for Research, characterized the essence of the problem as follows:

> "The question of appropriate NSF response to requests for all or partial support of scientists' salaries or more particularly faculty members' salaries

has been a source of considerable friction and misunderstanding between the Foundation and its university constituency since the Foundation was established. In part this arises because of the inability or unwillingness of successive administrations to formulate a simple unitary statement of objective for the Foundation support of scientific research activities. Or to put it another way, the motivations which generate political support for a Federal investment in NSF programs vary widely. The simplest expression of the difference may be found in an illustrative oversimplification of the possible objectives for the Foundation's support of research projects. Two somewhat different objectives are thoroughly mixed in our annual budget rationale. The first of these might be oversimplified as follows:

"The Foundation's objective in its research program is to identify meritorious projects and by extending support make possible that basic research activity that will most effectively promote society's understanding of natural and social phenomena.

"The second statement, again similarly oversimplified for purposes of illustration, might be as follows:

"The objective of the research program is to provide the support needed to permit the nation's universities to have larger and more active programs of research and research training than would be possible for the universities to have relying solely on their own resources.

"If one were faced with the necessity of adopting a policy for salary support of faculty members based on one or the other of these objectives, one could arrive at distinctly different policies. If one examines the first set of objectives, then a reasonable statement could be that if the Foundation desires to accomplish the stated research project goals, it should then be willing to support the necessary research activities and to pay the total costs thereof. An examination of the policy statement in the brochure *Grants for Scientific Research* ... indicates that this expression of NSF policy is indeed essentially identical with that which is appropriate to the first of the two oversimplified statements of objective above.

"If one considers the second of the two objectives, one could say that it would be appropriate for the Foundation not to pay any academic year salaries at all since the faculty member is already on board at the university and the university is responsible for his total activities, including research, during the year and the Foundation could confine itself to support of summer salary, equipment, postdocs, etc. In the early years of the Foundation's history, it was the usual practice to avoid support of academic year salaries. Even though the statement in the grants brochure has been official Foundation policy for some years, we still (both NSB and staff) seem often not to be in very strong agreement with our own policy statement."[27]

Dr. Todd's last comment above is particularly noteworthy. Policy considerations aside, what does NSF in fact do with regard to reimbursement of faculty salaries in its grant operations? It is to actual NSF grant salary payment practice that we shall next turn.

Grant Practices

Over the years a number of efforts have been made to study the NSF grant data base to develop information about actual NSF faculty salary reimbursement practices in the grants which it awards. These efforts suffer from severe data limitations. The most serious of these is that actual budget expenditures by grantees can and do differ significantly from the approved proposal budget. There is no requirement that expenditures necessarily have to follow the budget. Recent years have seen a steady trend toward relaxation of NSF's ability to control budget expenditures by grantees, and NSF no longer routinely receives any kind of detailed accounting from its grantees as to actual expenditures. Monitoring and accountability issues will be discussed later in this paper. For now, the point is that NSF data reflect only the results of individual grant proposal negotiations and awards – not actual expenditures. Still, for present purposes these data do say someting about internal NSF implementation of faculty salary policy.

Studies have shown that typically about 20 percent of NSF grants for the performance of research do not include any funds for salaries of faculty. Table I shows the percentages of NSF grants supporting senior faculty, by NSF "directorate" for 1977–81. While there are year-to-year perturbations, the Biological, Behavorial and Social Sciences Directorate consistently shows a lower percentage of awards which include faculty salary support. For those grants where salary was included, the trend lines for percent of total grant budgets accounted by senior faculty salaries remained fairly stable over this period, except for Engineering (Table II). A comprehensive study done in 1978 found an average of about 2.5 months salary support per principal investigator per award (average grant duration was 15 months) in such grants. Roughly two-thirds of the grants where salary was paid were limited to summer research salary support.[28] Rarely if ever does NSF support 100 percent of a faculty member's time during the academic year. These data suggest that whatever its policy, NSF either discourages proposals or turns down requests for faculty salary support, particularly academic year salaries, in a fairly pervasive way.

In order to begin to understand how this situation could come about, it is necessary to understand the NSF proposal/grant system. NSF grant review, recommendation and negotiation processes are extensively decentralized. Proposals for scientific research project support are submitted by academic institutions (and others) to several dozen subdisciplinary research "programs," each administered by a "Program Director" (who is a scientist in that discipline, and in many cases drawn from a university on a "rotating" one- or two-year tour of duty with the Foundation). The programs are organized into discipline-oriented divisions, which in turn are organized into a number of large "research directorates." While Program Directors are accountable to both divisional and directorate management (as well as advisory groups and the peer community), considerable autonomy is afforded them in proposal decisions and grant negotiations.

From the Program Director's perspective, the central problem faced in proposal negotiation and grant decision-making is one of resource allocation. With regard to faculty salary reimbursement, several years ago Dr. Todd characterized the situation as follows:

"Present Foundation policies and practices with respect to the inclusion of academic year and summer salary recoveries in scientific research project grants are less than completely explicit and can place even the experienced Program Director in a bind in occasional cases where the proper exercise of sound program judgment may expose him to charges of undue interference in the internal affairs of the recipient university and/or failure to adhere to the NSF policies with respect to faculty salaries ...

". . . University administrations now seem to be under increasing pressure to recover an ever larger fraction of academic year faculty salary from research grants. This constitutes a fertile area for friction and misunderstandings. The Program Director is under considerable pressure to support first quality research by as large a number of investigators as possible. The renewal of support to a previously established investigator with the new award providing for several months of academic year faculty salary more than provided in the earlier award, requires the Program Director to provide such an increase at the expense of someone else's continued or new support. To the Program Director ... it also appears that he is being asked to pay considerably more for a continuation at about the same level of effort of ongoing research; i.e., he'll get the same amount of research for more money. Thus, the natural inclination of the Program Director is to resist this increase. However, he is on very uncertain grounds in doing so. I am sure that occasionally the Program Director in the stress of a full-fledged zero-sum game makes the mistake of suggesting to the Principal Investigator that he is not willing to pay the academic year salary. This, of course, is contrary to NSF policy . . .

"Nevertheless, the Program Director must find ways out of these dilemmas. The more experienced and usual way of handling this situation is for the Program Director to rely upon the solicitation of revised budget. First, he suggests that as a result of the reviewing process NSF thinks well of the proposed project or renewal, but that we cannot see our way clear to providing say $70,000 per year for the next two years for that project, but that we could perhaps consider it at a lower level of say $55,000 per year . . .

"The Program Director, however, while expected to convey significant elements of technical guidance extracted from the review and evaluation process, is expected to refrain from giving specific instructions to the Principal Investigator as to how to reshape the project to fit within the smaller budget. This then leaves the Principal Investigator to cope with local institutional pressures for higher academic year salary recovery. In the course of his negotiations with his administration, (he) is apt occasionally to cite pressure from the NSF Program Director as a reason for eliminating academic year faculty salary recovery. (This citation may or may not be correct.) The outcome of the negotiations depends on individual and local institutional attitudes towards NSF money as a source of academic year salary. In any event, it is obvious that at this point in the negotiation, the interests of the Program Director and the faculty member tend to coincide with respect to the inclusion of the academic year salary and it often is the first item to go . . ."[29]

The current situation, however, is nowhere near that clearcut on an NSF-wide basis. There is great variability in this respect among the scientific disciplines represented by NSF. And it is perhaps here that we come to the real reason for the friction and controversy that have plagued this subject for so long.

Task Group 17 of the NSF Advisory Council studied data from all the NSF research divisions on their grant salary reimbursement practices in some detail. It came to the conclusion there were clear disciplinary differences. The Task Group found further variability in the basis for payment as between academic, summer and "calendar year" salary support. (Some U.S. institutions appoint their faculty on a 12-month contract basis, presumably for 11 months of service and 1 month of vacation. In the past, this has been largely confined to medical schools and certain other specialities such as agriculture.) For example, the Task Group noted that astronomy typically paid essentially nothing but two-months' summer salary support for faculty on its grants. Mathematics showed a similar tendency, with relatively little academic year salary provided. In the biological sciences (which fund many medical school researchers), a very high proportion of calendar year salary was provided. While data availability and quality varied among the disciplines (and as noted earlier the extent of the relationship between approved budget categories and actual expenditures by grantees is uncertain), the wide differences among NSF disciplinary areas in operating practices with regard to grant faculty salary reimbursement were striking.[30]

Other studies show similar variability. In a study done for the National Science Board, the percentages of total grant support that were budgeted for academic year salaries in 1972 ranged from highs of 14.7 percent in social sciences and 12.8 percent in engineering to 1.6 percent in chemistry and 2.5 percent in biology. Summer salary percentages were generally higher across the board, but extremely high in mathematics where they were 61.7 percent of total support. Furthermore, except for a steady increase in engineering (also shown for a later time period in Table II), similar disciplinary percentages generally prevailed over a seven-year time period from 1967–73.[31]

Task Group 17 did not rely on the data alone, but also amassed considerable anecdotal information in the course of its deliberations. The Group held interviews with NSF program officers from a number of divisions as well as various management officials, and received much input from the NSF divisions as to their perceptions of current salary practices. Some of this information also was quite striking. For example, the Group was informed by the Astronomy Division that upon the "strong advice" of its Advisory Committee, it had effectively been limiting support of faculty salaries to two summer months. The Division of Physiology, Cellular and Molecular Biology stated that its program directors tended to be lenient with young faculty members' request for academic year salary support, but that with tenured faculty, especially senior investigators, some – perhaps a majority – of the program directors attempted to negotiate out academic year salary. On the other hand, strong support for funding academic year salaries was expressed by the engineering divisions. Mathematics indicated by and large universities did not request (nor receive) academic year support for mathematics faculty from NSF, and that all of its faculty salary support was in the form of summer salary.[32] Explanations and justifications for present practices in the disciplines in most cases were based on claims for varying disciplinary needs and priorities. These are merely illustrative (but generally born out by the data). Some divisions did claim to follow the stated NSF policy and treat salary support like any other budget request, but indicated considerable differences among institutions (especially public vs. private) in patterns of salary requests.[33]

Faced with this situation, the Task Group concluded that NSF salary support performed different functions among the disciplines. The Group found that identifiable reasons and persuasive justifications could be put forward for particular disciplinary practices. The Group cited engineering and computer science as examples of where there might be a need to provide proportionately greater salary support for NSF to remain "competitive" (i.e., to keep the faculty on campus doing basic research) given the intense current demand for engineers and computer scientists. This is in line with one of the basic rationales suggested above for the payment of faculty salaries by NSF. The Group also pointed to some of the more newly emerging disciplines included in the NSF Directorate for Astronomical, Atmospheric, Earth, and Ocean Sciences (e.g., Ocean Sciences) where interviews with program officers indicated there was a relatively larger number of "soft money" positions in the field necessitating a relatively high degree of NSF salary support. Such disciplines tended to be in a rapidly expanding developmental phase and not yet fully assimilated into regular university structure.[34]

Others have also speculated as to the reasons for the great disciplinary discrepancies. An earlier study which also confirmed a comparatively low percentage of salary support in the biological and behavioral sciences advanced several possible explanations for this. One was a significantly lower "success ratio" of proposals submitted to NSF in these areas than most other research fields supported by NSF. The hypothesis suggested was that such heavy proposal pressure resulted in more severe funding constraints making elimination of faculty salary more likely in individual grant negotiations (as in the scenario outlined by Dr. Todd above). Another possible factor was that many of the NSF programs in these areas involved scientific subfields (e.g., biochemistry, genetic biology) where university research was also heavily supported by the U.S. Government's National Institutes of Health (NIH). Because substantial salary support was also available from NIH for faculty researchers in these fields, perhaps there was a corresponding lesser need for NSF to pay faculty salaries. However, the study recognized a need for more empirical evidence before placing too much faith in any of these explanations. Like the Task Group, the study concluded each NSF program was unique and seemed to have its own history and reasons for its particular salary funding pattern.[35]

One other interesting aspect of the data and information furnished Task Group 17 was the apparent trend toward conversion of faculty to calendar year appointments. This was mentioned by several NSF program staff and was also reflected in the data. The Task Group did not oppose the concept but felt it was a situation deserving of further analysis and close monitoring. While the Group felt there might be some advantages to greater calendar year-based salary reimbursement, it was concerned that NSF assure the proportion of such support generally conformed to that provided for academic/summer salaries.[36] Actually, there is some indication that NSF at one time made efforts to persuade institutions to convert faculty to a calendar-year salary basis.[37] Perhaps there was some feeling this made for a "cleaner" form of salary reimbursement. Whatever, it is evident that such appointments now extend well beyond the biomedical fields reflected in the BBS data. The implications for present NSF salary policy are unclear.

Having found valid reasons for the differences between the NSF disciplinary divisions in their patterns of salary support, the Task Group was faced with a nagging problem: how to reconcile the non-uniform practice with stated NSF salary policy. The Group's solution was to characterize NSF policy as essentially *permissive* in nature. Salaries were not required to be paid; they might be paid if appropriate. Appropriateness depended on whether, in the judgment of the NSF program officer, allocation of limited resources for salary expenses was necessary to assure overall viability of the research effort. There was no reason to assume *a priori* that viability was best accomplished in individual cases through support of faculty salaries rather than e.g., equipment or graduate students. Such a permissive policy wisely allowed for NSF responsiveness to the dynamic balance among disciplines, among institutions, and among geographic regions in grant salary reimbursement practices.[38]

Certainly no one had ever contended that NSF policy *required* payment of faculty salaries in every NSF research grant. On the other hand, some might (and did) view the Task Group's characterization as somewhat disingenuous, in that it left the operational consequences of the NSF policy entirely unclear. What did this do for universities and faculty investigators in their attempts to negotiate proposal budgets with NSF? If "local option" was to prevail entirely, of what significance was a general NSF "policy"? Did NSF management or the National Science Board, in the years of struggle over this issue, really contemplate that the effect would be to allow individual divisions or program officers to adopt *de facto* policies to disallow particular forms of faculty salary reimbursement across-the-board?

The Task Group was clearly uncomfortable with this aspect of its interpretation as well. While expressing strong support for the value of diversity and flexibility in salary practice, the Group made clear it did "not mean to imply that in some disciplines it might be appropriate for *no* faculty salaries to be paid at all. We emphasize our belief in the general appropriateness and desirability of such human capital investment in *all* disciplines." In its view, what was needed was clearer "standard-setting" by the NSF disciplinary divisions in this area, perhaps through the use of written guidelines on divisional operating practices that would be subject to review by management. In other words, the Group advocated "structured permissiveness." Better communication and understanding was necessary on all sides. "We believe NSF management and perhaps the National Science Board need to make clearer their understanding and support for varying divisional/programmatic operating practices in the salary area . . . At the same time, programs may need to make their standards clearer both to management and the community ... We believe that where disciplinary needs and priorities dictate particular program operating policies, these should be set and communicated in a clear fashion, and management should be informed and supportive of them."[39)]

The Task Group approach raises some obvious management questions, and has not been well received by university administrators, or, for that matter, NSF administrative officials (although NSF subsequently did issue a staff memorandum recognizing the legitimacy of variances among its research divisions in patterns of faculty salary support). Indeed, a paper by one of the NSF administrative officers previously had characterized the consequences of NSF grant salary practices as appearing to be "(i) an apparent conflict with NSF's policy statement of accepting academic year salaries; (ii) to force involuntary cost sharing of the salary ... which conflicts with NSF's cost-sharing policy; (iii) inconsistent with applicable (government) cost principles allowing reimbursement for reasonable, allowable, and allocable costs; (iv) unnecessary inconsistencies within NSF, confusion and consternation on the part of grantees, if not (Principal Investigators); (v) establishment of a *de facto* policy change through practice."[40)] While the Task Group took direct issue with these assertions, its "answer" is not likely to change such views. Nevertheless, the Task Group report represents a serious recent attempt to survey the situation on an NSF-wide basis and to suggest ways that some degree of order and structure might be provided in this area.

Our perspective so far has been primarily confined to NSF programs and staff. But there is a whole other dimension to NSF faculty salary policy and practice, and that is the effect on the faculty recipients. It is to this aspect that we shall briefly turn.

Effects of NSF Salary Support on Faculty Income

The literature abounds with studies of faculty compensation. Issues such as how faculty salaries are set, what they are paid for, how such salaries compare to those paid members of other professions, and their relationship to factors such as scholarly "productivity" (i.e., publications in the open literature), etc. have been studied and written about at great length.[41]

But what about the narrower question of the effects of NSF salary support on the compensation of faculty recipients? Here there is much less data and information available, but in fact NSF itself did a study of this issue several years ago.

In connection with the NSF study, several points need to be kept in mind. As reviewed earlier, NSF will not augment a faculty member's salary in providing salary support under a research grant but in effect reimburses the institution for some portion of the salary. NSF, like other U.S. government agencies and most private "donors," relies on the university to determine the rate of salary of faculty who work on funded projects. This may not relate the pay very well to the ultimate "value" of the work, but it offers great convenience to the sponsor and avoids interference with university autonomy and prerogatives. The sponsor does not have to administer a complex extramural salary policy, and the university does not face an exterior agency superimposing its judgment on the university's own attempts to provide internal equity.[42]

The equity concern, however, may be a deeper one. Several years ago, the U.S. Senate Appropriations Committee expressed concern about the appropriate rate of faculty salary reimbursement under NSF grants and whether the present rate, especially in the case of senior faculty, might be "excessive." The basis for this concern was a belief that the availability of government grant funds might enable or even encourage institutions to be incautious or irresponsible in establishing salaries for their faculty. In the Committee's view, NSF salary policies might inflate salaries paid to science faculty and distort the academic salary structure. The Committee directed NSF to re-examine its salary policies to assure "that the government is not creating inequities between the earned income of academic scientists and its own senior scientists."[43]

NSF responded with a study designed to elucidate not only whether NSF funding created inequities between academic scientists and government scientists, but also the influence of NSF funding on the income of academic scientists. The study found that the monthly salary rates paid faculty on NSF research grants for the most part were comparable to those paid to middle to senior level Federal government employees. The annual *incomes* of academic research scientists were about the same as the annual *salaries* of Federal government scientists.[44]

These findings are based on data now several years old, and so may not represent the current situation. However, there is no reason to believe that in relative terms the situation has changed all that drastically in the intervening years, especially since the trends in NSF salary support have remained fairly stable over this time (and government salaries at the middle and upper levels have risen). Certainly there was (and is) no evidence that NSF is paying "excessive" salary rates to faculty on research grants to any considerable extent, at least as measured by what NSF, or the U.S. government as a whole, pays its own scientist employees.[45]

Nevertheless, Congressional concerns about "excessive" pay to faculty researchers by NSF have persisted. In the Congressional Conference Report accompanying NSF's FY 1979 budget appropriation, there was a restriction against NSF paying more than the top salary rate of a career Federal government employee to investigators in any of its grants. This restriction was not renewed the following year, but in March 1980, NSF established an informal procedure requiring that all grants where the annualized salary rate for investigators was in excess of $50,000 per year be specially recorded. Where salaries exceeded $65,000 per annum the grants had to be personally reviewed by the Deputy Director. After about a year of this procedure, it was allowed to lapse. It was found that "high" faculty salaries were relatively uncommon and generally tended to occur in those disciplines where there was a vigorous private sector demand for top research talent. Absent further manifestation of Congressional concern, there was no good reason to single out salaries above a specified annual rate for special treatment.

Moving on to the question of the actual influence of NSF support on the income of faculty recipients, the 1978 NSF Report found little evidence of any direct effect of NSF funding on the incomes of individual academic scientists, using a number of statistical techniques. However, findings based on such techniques should be viewed with great caution, because to estimate the exact marginal effect on a faculty member's income from NSF support really requires a model that correctly incorporates the relationships between relevant variables. But, there is no causal model that specifies the behavioral relationships between NSF funding and other determinants of income. For example, funding of research by NSF provides faculty with opportunities to publish. This contributes to an individual's prestige. In turn, this may positively impact income. But to specify a complete model incorporating both individual and institutional behavior would go beyond both theory and data.

Nevertheless, one probably is safe in concluding there may be positive indirect effects from NSF grant funding on the income of faculty recipients. Whether or not the grant provides salary support, the enhanced opportunity to publish findings probably results in a potentially higher "market value."

Empirical studies show that faculty salary levels are positively related to the number of articles published (all else remaining equal).[46)] Also, faculty with high rates of publication have increased opportunity to earn outside income through consulting since they become better "known" in the community. NSF grant support may also have a positive effect on "nonmonetary" compensation as through tenure and promotion decisions. Given that NSF's peer review system is designed to select the best research proposals and researchers for support, there would be nothing suprising to find such excellence rewarded in other ways. So while these indirect effects undoubtedly exist, they are impossible to quantify and are intuitive rather than empirical in nature. They also do not derive from the level of NSF salary support.

Given the lack of a clear causal model, and the presumed association of NSF grant support with the most excellent scientists in any event, this exercise really does not warrant further discussion. Nonetheless, while hardly definitive, the results of the NSF study do suggest that NSF support of academic faculty salaries at least does not appear to raise fundamental equity problems, nor have any clear "distorting" effect on faculty salary rates or income.[47)]

Except for commissioned surveys of the type done above, NSF's ability to get "real" data on the effects of its faculty salary policies on institutions and their faculties is constrained by the fact that NSF has little direct knowledge of how universities and faculty investigators actually spend grant funds. Systematic data on the amount of faculty salaries actually "paid" (as opposed to budgeted) by NSF on its grants do not exist. But NSF expects the university will be able to demonstrate that the faculty member spends time on the research project at least in proportion to the amount of his or her salary derived from the grant.

How does NSF assure its expectations are realized? This brings us to the controversial area of monitoring and accountability.

Monitoring and Accountability

The control, expenditure and accounting for U.S. government grant funds used for research by colleges and universities is governed by government-wide standards and principles. Office of Management and Budget (OMB) Circular A-21, "Cost Principles for Educational Institutions," first issued in 1957, sets forth the basic guidance. Administration of NSF research grant funds by colleges and universities must follow these Federal cost principles, which among other things prescribe standards for apportionment of salaries to different activities and documentation of salary charges.

Certain other government-wide regulations also govern NSF grant salary practice. Some of these restrict NSF in ways that it might not always prefer. For example, from 1960 to 1976 NSF had a policy of limiting the amounts charged to NSF grants for faculty salaries to the amount shown in the grant budget approved by NSF. This amount could not be exceeded without specific NSF approval. However, in 1976 OMB Circular A-110 was issued. The purpose of A-110 was to reduce and make more uniform Federal administrative requirements on grantees. As a result, government agencies were no longer permitted to control or require approval of most changes in grant budget line items, including salaries. A-110 also did away with line item fiscal reports. Thus NSF no longer either had direct control over the amount charged to grants for salaries nor received any report of actual salary charges. Once a grant award is made, the grantee institution is more or less free to move funding in and out of budgeted categories at will.[48)]

It is not clear that NSF program officers or advisory groups have fully appreciated that the extensive budget negotiation and grooming typically engaged in during NSF processing of grant proposals may have little real effect. On the other hand, some knowledgeable observers believe that most faculty investigators tend to stick fairly close to the approved budget categories. In their view, principal investigators typically have a close relationship with their NSF program officers. The latter tend to be well informed of a particular investigator's grant activities through site visits, information from the peer community, etc. This leads to great concern on the part of the investigator about any actions which might jeopardize chances of further NSF research support, such as significant departures from the approved grant budget. Presumably this includes payment of salary not originally approved. Whether and to what extent this perception is true or not, the fact remains that in a formal sense all that a grant budget represents is a setting of a total maximum support ceiling for a particular research project.[49)]

How, then, is any real monitoring or control over faculty salary reimbursement in NSF research grants enforced? The answer is each grant is subject to Federal audit. Most major U.S. research universities have full-time Federal audit staff assigned to them who audit university expenditures under all Federal awards. Of course, not all expenditure actions are audited, but the potential for such audit constitutes the real "enforcement." But in the salary area what do they audit? This returns us to A-21.

The real problem, and the nub of the controversy in this area, has been the A-21 "effort reporting" requirement. Briefly, this requires that faculty members who receive Federal research money file "effort reports" showing the percentage of time spent on research, teaching, and other academic functions. These reports, then, are reviewed by Federal auditors in order to determine the propriety of claimed salary reimbursement.

This rule has a long and convoluted history. It was first adopted in 1965, as a by-product of the more formal, bureaucratized approach that began to characterize government-university relations with the great expansion of public funds for university research.[50)] It was dropped two years later after protests from academic groups and a Presidential commission recommended its abandonment. However, in the mid-1970's as Congressional pressure grew for greater scrutiny of Federal research grants to universities, one response was reinstitution of the requirement at many campuses.[51)]

The 1968 Presidential commission report found that time or effort reports "have engendered an emotional reaction in the academic community that will endanger university-Federal relations." This reaction has been characteristic over the course of the rule's history. What is it about the requirement that provokes such a reaction?

On an emotional level, many faculty feel that "cost-accounting" practices such as time and effort reports are inappropriately applied in a university context. They claim their work cannot so easily be divided by task and tallied by percentage, and to attempt to do so is both misguided and an unnecessary drain on time that could be spent in more creative pursuits.[52)] They find a requirement for detailed time or effort accounting by faculty deeply offensive.

In fact, there are serious definitional problems with such requirements occasioned by the familiar academic "joint project" doctrine.[53)] Tasks performed by faculty members may simultaneously benefit more than one research project or university function. For example, a faculty member who conducts a scientific experiment in collaboration with a graduate student may at the same time be engaged in both research and teaching. If the experiment is related to NSF-supported research, how should that portion of the faculty member's time be reported? Other examples abound. How should review of an article in a technical journal or consultation with colleagues be reported? Or, "joint project" aside, what about time spent by a mathematician at home in creative thought? This suggests a further complication of the "effort reporting" concept; just what activities are considered to fall within "normal" responsibilities of a faculty member for purposes of reporting "100% effort?"

A number of different effort report methods have been sanctioned by OMB in recent years to try to meet these concerns and difficulties. None worked notably well, which led to continued discussions between universities and OMB over the effort reporting requirements. In 1981, OMB led an Interagency Task Group review which considered proposals made by various university groups and individual faculty members. In early 1982 a number of changes were proposed which were, in part, incorporated in a revision of A-21 in August 1982. The key to the revision was deletion of prescribed methods for salary distribution by universities on Federal grants. Instead, general principles and standards for documenting salary costs were set forth. The revision recognized that in an academic setting, teaching, research, service and administration often are inextricably intertwined. Precise assessments among them were not feasible or expected. The main effect of the changes was threefold: 1) they explicitly recognized that estimates of the distribution of faculty activities were expected and that individual faculty themselves need not bear the burden of filling in time sheets; 2) they provided for use of general principles and criteria to determine the acceptability of methods and acknowledged there was no single best method, and that differences among institutions required flexibility in documentation procedures; and 3) they limited reporting details and accepted alternative methods such as statistical procedures, surveys and negotiated fixed rates where appropriate.[54)]

The above is a necessarily brief and highly simplified excursion through a very complex subject. The basic premise is that universities must document the effort of their faculty if they expect reimbursement from the Federal government for that effort. This leads to natural tensions between the desires of government agencies like NSF for "accountability" and university insistence on responsibility for their own management and resistance to attempts to measure academic activity that lead to increased regulations and paperwork. The key is to find ways to permit universities to account for their use of public funds that remain compatible with the academic environment. The new A-21 seems the most reasonable attempt yet to achieve this.

One final point on "accountability" that should be made is the relative lack of "abuses" by faculty researchers of government grant funds. Despite some well-publicized abuses by occasional faculty researchers, NSF's experience (and that of other Federal agencies) has been largely quite positive. In NSF's experience both faculty and university management have been conscientious in discharging their responsibilities for commitments made on research grants. The past "effort reporting" system unfortunately tended not to provide positive incentives for close cooperation between universities and Federal research-sponsoring agencies in matters pertaining to Federal fund accountability. The hope is the new regulations will provide flexibility enabling differing academic institutions to account for Federal funds with systems consistent with their own unique circumstances and lead to a more cooperative relationship.[55]

Table 1. Percentage of NSF Grant Awards Supporting Senior Faculty, by Directorate: FY 1977–81

	Fiscal Years				
NSF Directorate	1977	1978	1979	1980	1981
Mathematical and Physical Sciences	79.7	80.8	81.5	81.0	81.0
Astronomical, Atmospheric, Earth, and Ocean Sciences*	80.2	81.6	56.5	79.5	80.0
Engineering	84.4	75.1	77.5	80.6	87.9
Biological, Behavioral, and Social Sciences	55.6	58.1	57.9	60.2	62.3

* Underreporting in AAEO, particularly in FY 1979 and 1980, may cause these data to be biased.
Source: Special tabulation from files maintained by NSF's Division of Information Systems

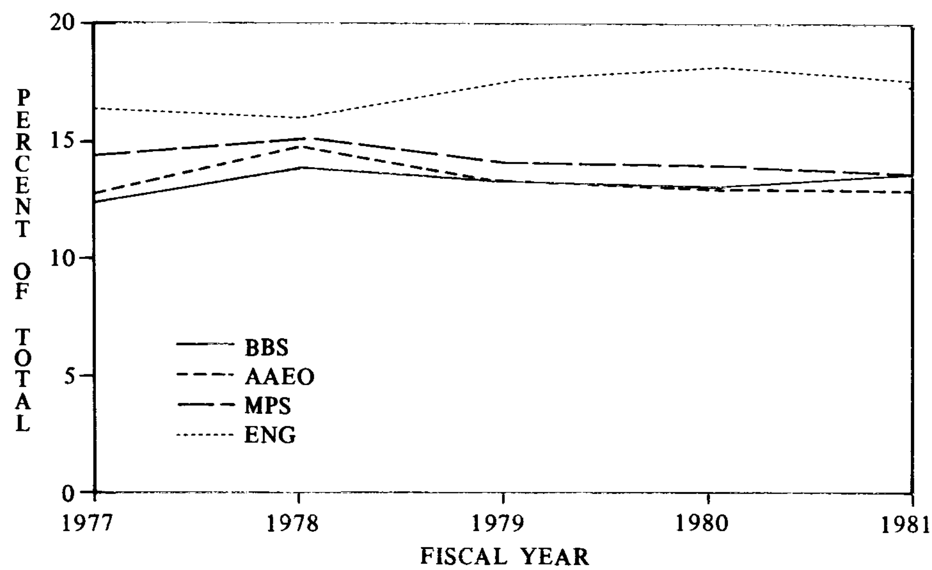

Fig. 1. Percent of Total Budgets Accounted for by Senior Faculty Salaries FY 1977–81

Source: Special tabulation from files maintained by NSF's Division of Information Systems

Conclusion

The faculty salary "problem" seems to be fairly intractable. Is this in fact the case? Is the "problem" indeed easier to live with than any "solution?"

One answer to this might be that some of the issues that have been raised about NSF faculty salary policies in fact do not appear to be "problems." Thus the equity concern has turned out not to be justifiable, at least based upon the (admittedly meager) evidence available. There appears to be no reason to believe NSF support of faculty salaries has a substantial distorting effect on individual faculty income. This concern hopefully has been allayed.

What about the other matters? As noted before, the policy issues raised by NSF support of faculty salaries really go to the heart of the relationship between government and institutions of higher education in the U.S. There has been increasing concern about that relationship. Considerable tension and mistrust have developed in recent years between government and research universities in the U.S. The long debate and acrimony over the "accountability" requirements reviewed above is one indication of this, but inherent institutional differences, fiscal contraints, and government regulations are all contributing factors. This has led to calls for a new "compact" between government and higher education.

In response to these concerns, the U.S. National Academy of Sciences several times over the past few years has suggested establishment of an independent mechanism to analyze issues and explore alternatives. In January of 1984, the Academy announced the formation of a Government-University-Industry Research Roundtable. The purpose is to provide a forum for consideration of issues and opportunities affecting partnerships between research sponsors and the universities. The hope is the Roundtable will provide a mechanism to find ways to resolve issues and problems and develop new approaches to these relationships that may be more appropriate for present conditions and those likely to exist over the coming decades. The Roundtable is to consist of distinguished leaders from all sectors. Its chairman will be Dr. Dale Corson, former President of Cornell University and a person who has long been active in U.S. science policy matters.

The real "solution" would appear to be an ongoing dialogue and improved understanding of this type on both sides. There are other encouraging signs. For one thing the recent OMB Circular A-21 changes seem to reflect a greater spirit of cooperation in the "accountability" area than has been characteristic in the past. This can go a long way to mitigating some of the more troublesome aspects involved in faculty having to "account" for their activities carried on with government salary support.

In the NSF context, there also may be ways to improve the situation without drastic changes in policy or practice that might prove exceedingly difficult to implement. In this connection, the Task Group 17 report may have had some positive effect. Partly in response to the Task Group's recommendations, NSF put out a directive (O/D 82-25) reminding program staff to emphasize only the "bottom line" amounts in recommended awards, and not to get involved in negotiation of individual cost items. Obviously this approach, if consistently followed, would help. But so long as line item proposal budgets continue to exist, it is unlikely this approach ever will be fully implemented.

However, the Task Group really had something else in mind. In essence it pointed to the need for a more open and clearer resource allocation process by NSF in its grant-making procedures. NSF should determine the needs of specific fields (in cooperation with the community through advisory groups, etc.) and decide how best to allocate its limited resources in each field in order to meet these needs. This would include consideration of the need for and nature of faculty salary support to be provided in individual grants. Of course this was done anyway but in an *ad hoc* fashion. The Task Group felt it should be done explicitly and then clearly communicated both to the relevant community and NSF management.

In fact, the above NSF directive did require the NSF research divisions to develop and disseminate statements of guidance and rationale on faculty salaries. One might expect resistance from program officers to formalizing their standards in such fashion, and the actual effect of (or degree of compliance with) this provision is uncertain. Clearly no guidelines could cover all cases. Such an approach is also unlikely to satisfy those who advocate "full reimbursement" from NSF of all university research costs. (If anything it could increase the current tension.) But it would alleviate some of the present misunderstandings in this area, and help rationalize policy and practice.

The long history and many facets of the faculty salary problem do not inspire confidence that a single NSF salary policy could ever be formulated that fully resolves all the competing considerations. But improvements such as the above can be made. This paper hopefully may stimulate greater awareness and suggestions for further improvements.

Notes and References

1) *Grants for Scientific and Engineering Research*, NSF 81–79.
2) See Betz, Kruytbosch, and Stimson, "Funds, Fragmentation, and the Separation of Functions in the State University," *Social Science Information* 8(1), pp. 131–148, 1969. This paper contains an interesting historical account of the development of government – university relationships in federal support of university research.
3) February 14, 1964, memorandum to National Science Board (NSB) from NSF Director, subject: *Faculty Salaries* (enclosing paper on *Background of Faculty Salary Problem* prepared by Randall Robertson, then NSF's Associate Director for Research, p. 1).
4) *Ibid.* (*Chronology of Academic Year Salaries*)
5) *Ibid.*
6) *Faculty Salaries,* paper prepared by Dr. David D. Keck (then Deputy Director of NSF's Biological and Medical Sciences Division), January 17, 1964, p. 4.
7) Robertson, *op. cit.*, p. 1.
8) *Ibid.*
9) *Ibid.* (*Chronology*)
10) Keck, *op. cit.*, p. 5.
11) February 14,1964,NSB memo, *op. cit.*

12) Keck, *op. cit.*, pp. 3–4.
13) Memorandum to NSF Assistant Director for Research from Dr. Edward P. Todd, Deputy Assistant Director for Research, March 9, 1972, *Support of Faculty Salaries*, p. 5.
14) Harvey Brooks, *Salary Policy for Government Contracts and Grants at Universities*, Revised Draft prepared for National Science Board, April 10, 1963, Tab B, NSB 63–82 (85th meeting, 4/18–19/63), p. 1. The concerns outlined by Dr. Brooks remain generally valid today.
15) Robertson, *op. cit.*, pp. 1–2.
16) *Ibid.*, p. 2
17) See Discussion Paper prepared by Policy Office, NSF Division of Grants and Contracts (DGC) April 7, 1981, *Background and Summary Discussion Information of the Current NSF Academic Year Salary Issue*, p. 3. This paper contains a useful summary of the historical NSF and NSB references noted above.
18) NSF Advisory Council Task Group 17, *Faculty Salaries*, Discussion Paper, November, 1981, p. 3.
19) *Ibid.*
20) Keck, *op. cit.*, p. 4; Brooks, *op, cit.*, p. 4.
21) *Report on Faculty Salaries to The Subcommittee on HUD-Independent Agencies of the Committee on Appropriations of the United States Senate from the National Science Foundation*, February, 1978, p. 32.
22) Keck, *op. cit.*, p. 4.
23) Draft Memorandum to Foundation Staff from Director prepared by Dr. Edward P. Todd (then Acting Assistant Director for Astronomical, Atmospheric, Earth and Ocean Sciences), August 1, 1977, *Foundation Policy and Practice for Support of Faculty Salary on Research Grants*, p. 9.
24) NSF Advisory Committee for Research, Task Group 1, *Majority Report on Faculty Summer Salaries*, August 31, 1973, pp. 1–2.
25) NSF Advisory Committee for Research, Task Group 1, *Minority Report on Faculty Summer Salaries*, September 28, 1973, pp. 1–2.
26) Memorandum to Dr. Edward C. Creutz, NSF Assistant Director for Research, from Harold S. Zapolsky, Associate Program Director for Theoretical Physics, August 25, 1970, *NSF Policy on Summer Salaries Under Research Grants.*
27) Memorandum to NSF Executive Council from Dr. Edward P. Todd, Acting Assistant Director for Astronomical, Atmospheric, Earth and Ocean Sciences, August 2, 1977, *Faculty Salaries*, pp. 2–3.
28) February 1978, NSF Report to Congress, *op. cit.*, p. 5.
29) Todd Draft August 1,1977, memo, *op. cit.*, pp. 9–11.
30) Task Group 17 Discussion Paper, *op. cit.*, p. 4.
31) NSB-72-66, *Support of Faculty Salaries*, Table C.
32) The source of this information is background memoranda furnished Task Group 17 (included in the NSF Task Group 17 files).
33) Task Group 17 Discussion Paper, *op. cit.*, p. 4. The variation in institutional practices is an important aspect of the situation, but one that cannot be explored further in the context of this paper.
34) *Ibid.*
35) February 1978, NSF Report to Congress, *op. cit.*, p. 35.
36) Task Group 17 Discussion Paper, *op. cit.*, p. 8.
37) Memorandum to NSB Committee from Dr. Edward P. Todd, Deputy Associate Director (Research), NSB/C-1-68-2, *NSF Support of Summer Salaries*, January 15, 1968, p. 4.
38) Task Group 17 Discussion Paper, *op. cit.*, p. 5.
39) *Ibid.* "Structured permissiveness" is not a term that was used by the Group, but coined in discussion by the full Advisory Council of the Group's recommendations.

40) DGC Discussion Paper, *op. cit.*, p. 3.

41) A comprehensive study which traced faculty pay over time and presented much comparative data on faculty compensation was done in 1978 by Professor Howard Bowen of the Claremont Graduate School (*Academic Compensation; Are Faculty and Staff in American Higher Education Adequately Paid?* TIAA-CREF, New York, 1978). It is interesting to relate the various episodes in faculty pay development traced by Professor Bowen to the evolution of NSF salary policy during these same periods. Also see the 1977 Report on *Faculty Salaries* by Task Group 16 of the NSF Advisory Committee for Research.

42) *Academic Compensation: Professorate, Pooh-Bahs, Parents and Proles,* W. Todd Furniss, American Council on Education, presented at Second Annual Academic Planning Conference, June 19–21, 1977, University of Southern California, Office of Institutional Studies, p. 8.

43) For more discussion of the Committee's concerns see *Government Funding: Legislative Concerns with Inflation of Academic Income*, Richard G. Woods, Legislative Assistant to U.S. Senator Henry Bellmon, presented at Third Annual Academic Planning Conference, January 25–27, 1978, University of Southern California, Office of Institutional Studies.

44) NSF February 1978 Report to Congress, *op. cit.*, Chapter II.

45) Other measures of "excessiveness" conceivably could be used. However, the NSF Report confined itself to the standard used by the Senate Committee.

46) Katz, *Faculty Salaries, Promotions, and Productivity at a Large University*, American Economic Review, June 1973, p. 471. Also see Task Group 16 Report, *op. cit.*, p. 22.

47) The study done the year before by Task Group 16 of the NSF Advisory Committee for Research, *op. cit.*, also tried to treat briefly the relative importance of NSF grant salary support to academic compensation. This used severely limited and older data, and relied primarily on a theoretical analysis of labor market behavior. However, the results were generally consistent with the later study in finding that NSF support had little direct effect on the level of academic salaries.

48) See DGC Discussion Paper, *op. cit.*, p.3. Recently NSF has adopted an "Organizational Prior Approval System" (OPAS), now in effect at most major universities. Essentially this approach delegates almost all administrative grant management authority to the university, provided it establishes an institutional review system meeting certain criteria. This includes authority not only to approve non-budgeted expenditures but also to co-mingle funds from different NSF grant projects, provided they are "scientifically related." NSF Important Notice No. 90 (April 15, 1983) provides further details.

49) With the implementation of the "OPAS" concept, this may no longer necessarily even be the case.

50) Betz, et. al., *op. cit.*, p. 139.

51) See New York Times, March 23, 1982, "Yale Bars U.S. Study Grant, Refusing to Account for Time" by Samuel G. Freedman. Part of the impetus for reimposing the rule was Congressional concern over a few cases where faculty members had been found to be charging the same time to more than one Federal project (and receiving "double reimbursement").

52) *Ibid.*

53) See *Higher Education: Who Pays? Who Benefits? Who Should Pay? A Report and Recommendation by the Carnegie Commission on Higher Education,* McGraw-Hill Book Company, New York, June, 1973.

54) Shapiro and Heller, *Science,* Vol. 216, April 9, 1982, p. 126.

55) *Ibid.*