DOCUMENT RESUME

ED 108 968 SE 019 473

TITLE Science Development, University Development, and the Federal Government.
INSTITUTION National Board on Graduate Education, Washington, D. C.
PUB DATE Jun 75
NOTE 61p.; Board report no. 4.
AVAILABLE FROM National Board on Graduate Education, 2101 Constitution Avenue, N. W., Washington, D. C. 20418 (free - limited quantities)

EDRS PRICE MF-$0.76 HC-$3.32 PLUS POSTAGE
DESCRIPTORS College Science; *Federal Aid; Federal Government; *Federal Programs; Graduate Study; Higher Education; Mathematics; *Program Evaluation; *Science Education; Sciences; Scientific Research; *Universities
IDENTIFIERS *National Science Foundation; NSF

ABSTRACT

In 1965, the National Science Foundation began an experiment in institutional funding, the Science Development (SD) program. Setting as dual goals an upgrading of the science capabilities of second-tier universities and a broader geographical distribution of scientific resources throughout the nation, this program awarded over $130 million to selected universities during the 1960's and early 1970's. In an effort to assess the impact of this funding mechanism, the National Board on Graduate Education undertook an evaluation of the SD program. The data gathered for this study covered the 15 years from 1958 through 1972. All nonfunded doctorate-producing American universities were used as controls. The three fields that received the largest share of the SD funds were chemistry, physics and mathematics. Among the major findings were that the funded institutions registered an increase in the rates of publication in key journals and were able to attract higher quality graduate students as measured by an improvement in the scores of first-year graduate students on the Graduate Record Examination. Of the 31 universities in 21 states that were funded, 25 fund recipients were distributed among 17 states that did not have a leading university in 1965. Therefore, the goal of geographic dispersion of funds was largely achieved. (Author/MLH)

Science Development, University Development, and the Federal Government

A Report of the

NATIONAL BOARD ON
GRADUATE EDUCATION

Washington, D.C.

Number Four • June 1975

Library of Congress Cataloging in Publication Data

National Board on Graduate Education.
Science develoment, university development, and the federal government

(A report of the National Board on Graduate Education; no 4)
Includes bibliographical references.
1 Federal aid to higher education—United States—Evaluation. 2. State encouragement of Science, literature, and art—United States. 3. U. S. National Science Foundation. 4 Science—Study and teaching (Higher)—United States. I Title. II. Series. National Board on Graduate Education A report of the National Board on Graduate Education; no. 4
Q183.3.A1N35 1975 379'.1214'0973 75-14490

Available from

National Board on Graduate Education
2101 Constitution Avenue, N.W.
Washington, D. C. 20418

Printed in the United States of America

Foreword

During 1971 the National Science Foundation (NSF) suggested to the National Academy of Sciences that an evaluative study be made of the Science Development (SD) program, just then drawing to a close. The program was a unique kind of venture not only for NSF, but also for all federal government agencies involved in assisting higher education. Comprising three subprograms—University Science Development, Department Science Development, and Special Science Development—the Science Development program was aimed not at support of project research, but at institutional building.

The National Academy of Sciences proposed that the National Board on Graduate Education (NBGE), an organization sponsored by the Conference Board of Associated Research Councils, undertake the desired study. Since NBGE had been established to consider the problems confronting graduate education in the 1970's, and especially the problems arising from the changing concern of the federal government with science research and graduate education, the Board members decided that the challenge of making such an analysis should be accepted. As a result, arrangements were made whereby an inquiry into the impact of the NSF Science Development program upon the science capabilities of the institutions involved could be undertaken.

In designing the study and in interpreting the results, NBGE and its staff were fortunate to have the assistance of an advisory panel of knowledgeable individuals who provided insight into the development of university science capabilities and made numerous suggestions regarding statistical and other aspects of evaluation technique. Members of the panel were as follows:

John Millett, Vice President and Director, Management Division, Academy for Educational Development

Donald Campbell, Professor, Department of Psychology, Northwestern University

Paul Chenea, Vice President, Research Laboratories, General Motors Technical Center

Robert Christy, Provost, California Institute of Technology

J. Patrick Crecine, Professor, Institute of Public Policy Studies, University of Michigan

Hans Laufer, Professor, Biological Sciences, University of Connecticut

J. Ross MacDonald, Professor, Department of Physics, University of North Carolina

Lincoln Moses, Dean of Graduate Studies, Stanford University

The study was directed by David E. Drew, Project Director, with the assistance of Joan Creager, Margo Jackson, Ronald Karpf, Marilyn Block, Edward Dolbow, James Bliffen, and Carol Cini. Financial support was provided by the National Science Foundation.

Evaluation of the performance of organizations or enterprises is scarcely an exact science. It is relatively easy to assert that evaluation begins with a carefully formulated set of objectives, examines the degree to which those objectives have been accomplished, reviews the complexities of the performance process, and assesses the costs and benefits of the organized endeavor. The difficulty with such an evaluation process is simply that no study yields sufficiently clear-cut, objective data from which readily acceptable conclusions regarding "quality" or "value" can be logically inferred. The success of an evaluation remains in large part a judgment to be made by each reader.

At the same time, in spite of its difficulty, the task of evaluating intangible outcomes cannot be set aside or avoided. Evaluation is an indispensable part of social behavior, and only as the process becomes more explicit, more exact, and more familiar can progress in responding to this vital concern with the performance of programs and organizations be realized.

It is in the spirit of acknowledging an urgent social concern, of seeking to advance the art and science of evaluation, and of accepting a challenging task that the National Board on Graduate Education presents this report.

David D. Henry, *Chairman*
National Board on Graduate Education

January 1975

In 1972, considering whether to undertake an evaluative study of the Science Development program, the National Board on Graduate Education (NBGE) discussed at length how such a study would fit into its total program of activities. At that time, the Board saw the potential benefits of the proposed study as including information and insight into a number of important issues, including:

1. the measurement of quality in graduate education and research in the sciences, and the factors that influence quality;
2. the strengths and weaknesses of the particular funding mechanism used in the Science Development program, and its relation to other federal funding mechanisms, such as project grants or training grants;
3. the issues involved in the explicit policy decision of the federal government to encourage geographical distribution of federal funds for research and graduate education, including the impact of this policy on the quality of graduate education, its impact on established universities, and the assessment of this policy in terms of regional benefits and costs;
4. the effects of large scale funding for science on the other disciplines within universities; and
5. questions of method in the evaluation of social programs, and academic programs in particular.

The completed study, reported in this document and in the companion technical report by David E. Drew,* the study's Project Director, has provided valuable information on a number of these and related issues. The effects of the Science Development program have been assessed in detail by a combination of statistical analyses, site visits, and applications of informed judgment. Much has been learned about the objective correlates of graduate program quality and the degree to which the Science Development program was successful in enhancing the quality of science graduate education in geographically dispersed universities. Perhaps most significantly, the study was able to detect and measure several effects specifically attributable to the Science Development program; this alone differentiates the study from many evaluations of heavily funded governmental programs where few, if any, significant effects were found and substantiated. This suggests that the study's major contribution may be to the growing literature on program evaluation.

In placing the study in the context of graduate education, it should be noted that it was not possible to investigate comprehensively a number of issues closely related to some of the objectives of the Science Development

* David E. Drew. *Science Development. An Evaluation Study*. (Washington, D.C.: National Academy of Sciences. 1975).

program. The study design ruled out analysis of an exhaustive list of attributes of graduate program quality; understanding of that subject has been advanced, but investigation of additional aspects of quality in graduate education is clearly warranted. Limitations of time and resources made it impossible to investigate in detail the impacts a major university has upon its state and region, nor was it possible to pursue the question of how many major research universities are needed in the United States. A rigorous comparison of the relative effectiveness of various mechanisms (institutional grants, project grants, training grants) for federal funding of scientific research and advanced education was not possible, nor did the study attempt a retrospective cost-benefit analysis of the economic value of the SD program to society. In short, the study does not lead directly to policy conclusions in some areas of concern, a limitation that explains the absence of NBGE recommendations for federal policy in those areas.

The study has established, however, that institutional development grants were effective in achieving a number of the goals set for them, indicating that this form of funding mechanism could reasonably be used as one model for future programs.

David W. Breneman, *Staff Director*
National Board on Graduate Education

January 1975

Preface

This summary of an evaluative study by the National Board on Graduate Education was first drafted by a panel appointed by the Board, and then revised in accordance with the suggestions of the Board members. The panel could not have accomplished its task without the professional assistance of David E. Drew, the project director, and the members of the project staff.

The role of the panel was actually twofold. First, the panel served as a mechanism for advising the staff in preparing the study outline and in developing the study data. Several members of the panel were specialists in the techniques employed in this evaluation, and their contributions were invaluable.

Second, the panel undertook to set forth its general interpretation of the data and to formulate the generalizations to be drawn from the study.

The panel is pleased that the National Board on Graduate Education has seen fit to associate its own views with those of the panel. In fact, throughout the study, a close relationship existed between the study director, the study panel, and NBGE itself. Board members made helpful suggestions about the prosecution of the study and about the conclusions to be drawn from it.

Well aware of the intricacies involved in evaluating higher education performance, and especially in assessing the quality of that performance, the panel has no illusions that this study has written the last word on evaluation. It is hoped, however, that the study has contributed to the development of evaluative technique.

At the same time, evaluation calls for the exercise of judgment. The panel, as well as NBGE, has endeavored to state conclusions that are based upon objective evidence and on reasonable and responsible judgment.

John D. Millett
Chairman of the Panel
Science Development Evaluation Study

January 1975

National Board on Graduate Education

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Highlights of the Study

In 1965, the National Science Foundation (NSF) began an experiment in institutional funding, the Science Development (SD) program. Setting as twin goals a dramatic upgrading of the science capabilities of second-tier universities and a broader geographical distribution of scientific resources throughout the nation, this program awarded over $230 million to selected universities during the 1960's and early 1970's. In an effort to assess the impact of this unusual funding mechanism, NSF asked the National Academy of Sciences to evaluate the Science Development program. The Academy, in turn, requested the National Board on Graduate Education to undertake the study. That work has now been completed. The methodology of the study and detailed findings from both a series of site visits and a large number of quantitative analyses are discussed in a companion document: *Science Development: An Evaluation Study*, by David E. Drew, the project director.

Several technical decisions were made at the outset to help isolate the unique effects of Science Development. First, wherever possible, the data gathered for this study covered the 15 years from 1958 through 1972. Second, all (nonfunded) doctorate-producing universities in the country included in the 1969 American Council on Education survey of graduate program quality[1] were used as controls. Third, the three fields

[1] Kenneth D. Roose and Charles J. Andersen, *A Rating of Graduate Programs* (Washington, D.C.: American Council on Education, 1970).

that received the largest share of Science Development funds—physics, chemistry, and mathematics—were analyzed in greatest detail, as was the nonfunded control field of history. Finally, to define "quality science education" in American graduate schools, multiple indicators (i.e., multiple criteria) were used.

The major findings are enumerated below.

1. *Faculty Size* NSF funds helped departments in all three science fields to enlarge their faculties. In physics and chemistry this increase in faculty size was limited to the public sector.

2. *Faculty Mobility* An analysis of senior faculty mobility in the field of physics showed that the funded institutions did not develop by recruiting extensively from the leading physics departments.

3. *Scholarly Productivity* Science Development funding had a positive effect on scholarly productivity as measured by rates of publication in key journals, i.e., the funded departments registered an increase in the number of articles published by their faculty members in journals that have high scholarly impact. This increase, however, was largely a function of the growth in faculty size; the effects on the publication rate of the individual faculty members were minimal.

4. *Graduate Student Enrollment and Quality* Receipt of a grant was not closely related to increases in graduate student enrollments. Funded departments, however, were able to attract higher quality graduate students (as measured by an improvement in the scores of first-year graduate students on the Graduate Record Examination), though there was no change in the quality of graduate students if one judges by the selectivity of their baccalaureate institutions.

5. *Ph.D. Production* Although Science Development funds increased the production of Ph D.'s in physics, in mathematics that effect was observed only in the public university sector. In chemistry, no impact at all was apparent.

6. *Postdoctorate Employment* Ph.D.'s from funded institutions differed very little from Ph.D.'s from nonfunded institutions with respect to attractiveness of jobs obtained upon graduation, whether in or outside of academe New Ph D.'s in mathematics from private Science Development institutions were somewhat more successful than those from (private) control institutions in obtaining positions at high-quality universities.

7. *Geographical Distribution* Under the major subprogram, University Science Development (USD), 31 universities in 21 states were funded. Six USD recipients were located in a state that already had at least one leading university according to a combined science measure based on the fields of mathematics chemistry, and physics. The other 25 USD recipients were distributed among 17 states that did not have a

leading university in 1965. Therefore, the goal of geographical dispersion of funds was largely achieved.

Genesis and Objectives of Science Development

The Science Development (SD) program came into existence as a result of several factors: (1) the realization on the part of the nation's leaders, including Presidents Eisenhower, Kennedy, and Johnson, that the number of high-quality graduate science education programs had to be increased; (2) growing criticism voiced by congressmen and educators concerning the traditional pattern of federal academic science assistance; and (3) the emergence of political pressure on the federal government and on the National Science Foundation to distribute federal science money along broader geographical lines.

At the end of World War II the federal government began to fund academic science for the purpose of advancing knowledge and conducting research related to specific national goals, such as nuclear energy development. The Soviet–American space race added impetus to funding programs and, in the process, focused attention on the nation's need for research. During this period, the larger research grants went to a small number of universities concentrated in a few states (particularly Massachusetts and California). Outstanding research scientists were in short supply and those available were employed by the few universities already noted for their research commitment, their excellent graduate programs, and a generous endowment or substantial state government support. For example, in 1963 the federal government distributed $1.3 billion for academic science. Over $500 million—or 40 percent—went to 17 schools, each receiving over $20 million. Not one of these well-funded institutions was located in the South, the Southwest, the Plains states, or the Rocky Mountain states. Since research grants were awarded on the basis of peer review of both the project and the research potential of the principal investigator, it is hardly surprising that grants were most frequently awarded to outstanding research scholars at the most prestigious universities.

At the same time, leaders in government and higher education were calling for an increase in the number of universities with strong graduate programs in the sciences. In their view, the small group of leading universities could not provide the scientific base required to rapidly advance the nation's technologically oriented economic system. According to the widely discussed *Seaborg Report* (1960). "The growth of science requires more places with superior faculties and outstanding groups of students. Existing strong institutions cannot fully meet the nation's future needs."[2] The President's Science Advisory Committee, authors of the report, recommended that the existing imbalance be rectified. "Over the next fifteen years the United States should seek to double the number of universities doing generally excellent work in basic research and graduate education."[3] Since the gross national product had grown by a disappointing 34 percent during the 1950's, various means were sought to encourage greater economic growth and to distribute its benefits more widely. Creating additional outstanding research universities was one such means.

In the early 1960's it was asserted as a matter of conventional wisdom that scientific research contributed to the economic growth of the community in which it was carried out. Advocates of this view pointed to the growth of the electronics industry and its close association with leading universities in the sciences (e.g., the development along Route 128 near Boston and Cambridge). Understandably, many officials wanted to improve the quality of science education in their states in order to facilitate economic growth and attract new industry. These state leaders saw the major portion of federal science funds going to a handful of institutions in a few states and protested that, since all parts of the country pay federal taxes, all parts of the country should reap the benefits of federal expenditures. Demands were made on the federal government and on NSF to broaden the geographical dispersion of academic science funds. In response, President Johnson issued a proclamation directing all federal agencies that awarded research grants to consider the geographical distribution of the grants carefully.

> At present, one-half of the Federal expenditures for research go to 20 major institutions, most of which were strong before the advent of Federal research funds. During the period of increasing Federal support since World War II, the number of institutions carrying out research and providing advanced education has grown impressively. Strong centers have developed in areas which were previously not well served. It is a particular purpose of this policy to accelerate this beneficial trend since the funds are still concentrated in too few institutions in too few areas of the country. We want to find excellence and build it up wherever it is found so that creative centers of excellence may grow in every part of the Nation.[4]

[2] President's Science Advisory Committee, *Scientific Progress, the Universities and the Federal Government* (Washington, D. C., The White House, November 1960), pp. 14–15.
[3] *Ibid.*, p. 28.
[4] "Strengthening Academic Capability for Science," Statement by the President to the Cabinet, September 13, 1965. *Weekly Compilation of Presidential Documents*, Monday, September 20, 1965, pp. 267–268.

NSF, which prior to 1960 had received scant attention from Congress, now had to come to grips with political realities in order to obtain its periodic authorizations and annual appropriations. In the name of scientific integrity, the agency could not be indifferent to political pressures; its response to these national needs was Science Development.

The (SD) program's first objective was to augment the number of American universities with the capacity to do outstanding scientific research and with strong graduate curricula in science and engineering. About 20 universities in the United States already fulfilled these criteria. Policymakers wanted to double the number by moving a group of "second-tier" science institutions into the "top" category.

To do so required simultaneous improvements in the components of graduate science education: graduate enrollments, the quality of first-year students, the caliber of graduating Ph.D.'s, faculty and research productivity, equipment, and facilities. Science Development's second major objective was to build up promising science institutions in regions and states that did not have an outstanding university, thus satisfying political demands for a broader dispersion of funds and, ideally, creating "centers of excellence" in communities that would benefit both economically and educationally.

Structure and Implementation of the Program

These goals were new to NSF and so required new approaches. Traditionally, support had gone to individual researchers to carry out specific studies, experiments, or general lines of inquiry that would promote scientific knowledge or improve the capability of a federal agency to carry out its mission: Any institutional change that might result from the funding was a by-product of the grant, albeit a desirable one. With Science Development, however, NSF undertook to improve institutions rather than just to explore new realms of scientific knowledge and procedure.

The Policy Model

To implement this intention, NSF developed a new policy model for federal funding of graduate science education. The model was initially designed for what became known as the University Science Development (USD) program, although its features were later adapted to two other subprograms, Special Science Development (SSD) and Departmental Science Development (DSD). Its parameters, which will be discussed in the following pages, are as follows:

I. Broad national objectives
II. Institutional planning required by proposal

III. Peer review of the proposal
IV. Large influx of funds
V. Flexible administration

The broad national objectives of moving "good" universities toward excellence in science and distributing funds on a geographical basis have already been discussed. The other parameters of the model and the subprograms under Science Development are discussed below.

Institutional Planning Any university that wanted to be considered for a grant had to submit a detailed plan for the development of the sciences. The applicant institution was expected to indicate its needs with respect to personnel, graduate students, equipment, and facilities in those departments (typically four or five per institution) designated to receive the awards. As it turned out, the major portion of the money went to physics, chemistry, and mathematics, but virtually all scientific and technical disciplines were funded. The program was unusual in that many activities could be carried out under one grant. In its development plan, the university also had to demonstrate financial, organizational, and academic commitment to graduate science. Unlike matching grant programs, the SD program did not require that the school match federal money, dollar for dollar, with funds from other sources, but the institution did have to show a willingness to provide additional revenues to the appropriate departments to preserve and extend the gains achieved under Science Development.

NSF discouraged certain institutions from applying for grants. The agency did not fund schools already outstanding in the sciences, a group that in the early 1960's was felt to comprise about 20 institutions (although NSF was careful never to identify the particular universities in the "top 20"). In addition, schools whose potential for science development was obviously too weak (for instance, those that lacked graduate programs in the sciences) were precluded from consideration. Eligible institutions that initially submitted an inadequate proposal were, in some cases, encouraged to revise and resubmit the plan. Eventually, NSF accepted over 100 formal applications for Science Development grants.

Peer Review The procedures adopted by NSF to determine the grant recipients were similar in some respects to those used prior to 1965 for awarding project grants. After the formal application had been reviewed, NSF selected a site visit team that included several staff members, two or three scientists from leading universities, and—an innovation in the procedure—one or more persons experienced in university management who were expected to evaluate the administrative and financial potential of the applicant institution. The site visit team reviewed the proposal, visited the institution, observed the science resources, and consulted with the faculty and staff members involved in the proposal. Reports from the site visits, along with quantitative data, were reviewed by the NSF staff, which then prepared recommendations for discussion by top NSF officials.

NSF introduced a second innovation in its peer review-evaluation procedures. After visiting all campuses from which a formal proposal had been accepted, NSF invited university representatives from both successful and unsuccessful applicant universities to its headquarters in Washington, D.C. Foundation officials felt that the preparation of a development scheme called for an intensive effort on the part of the universities and that the meeting itself could be beneficial to the unsuccessful applicants. Representatives from the schools that had been turned down were able to discuss various features of their graduate programs with the NSF staff who then made recommendations for possible improvements. This strategy enabled the unsuccessful institutions to learn where they stood in comparison with other universities and what had to be accomplished in order to maintain and improve their graduate science programs. (It must be remembered that, in addition to selecting recipients on the basis of potential quality, a second criterion was to ensure geographical distribution of the grants.)

Funding A total of $177 million was delivered to 31 institutions under the SD program over an 8-year period (1965–1972).[5] Compared with the typical federal science project award, the individual grants were very large, ranging in value from about $2.3 to $9.2 million. The program did not begin to raise the recipient institutions to the financial level of the nation's leading universities, however; nor was it intended to do so. Science Development funds served as seed money designed to have a catalytic effect; the dollars, wisely used, could lead to stronger departments and hence to expanded financial support in the future. It was hoped that the program would spur the recipient institution to develop further plans, continue its recruitment of outstanding faculty, and attract more and better graduate students.

Despite the large size of the grants, they represented only a small portion of the total flow of federal science dollars to the recipient institutions. In 1965, the first year of the program, 20 of the funded schools received over $10 million each in science funds from all federal sources, and only 2 recipients received less than $6 million. Although

[5] Another $54 million was awarded under the two other Science Development programs, Departmental Science Development and Special Science Development.

the Science Development grants averaged $1 million per year per institution, this amounted to less than 16 percent of the annual federal flow to academic science at all but 2 institutions, where it represented less than 25 percent of the annual flow. Science Development funds had to have a powerful impact in comparison with other federal science money for the program to produce positive and permanent change among the recipients.

The award periods were relatively short term. The initial grant period lasted 3 years, after which the recipients were eligible for a supplementary grant, again large in value, that ran for 2 years. Thus, a recipient institution could participate in the program for 5 years, after which it became ineligible for further consideration.

By the nature of the program, the potential recipients were limited in number, constituting only a small group in one part of the nation's social structure. Targeting funds in this way enabled NSF to carry out an intensive evaluation of each proposal. The agency attempted to move a small group of institutions a long way rather than a large group a little way.

Flexible Administration NSF adopted a flexible administrative posture in two respects. First, although the applicants' plans had to be limited to scientific and technical disciplines, each recipient institution had broad discretion in pursuing Science Development goals. For example, the University of Rochester used most of its award for the construction of a new chemistry and biology building. The University of Arizona used a sizable portion of its award for a new 90-in. reflector telescope. North Carolina State University distributed funds among engineering disciplines, while its neighbor, the University of North Carolina, upgraded its computer facility and devoted funds to several social science disciplines. In some cases, NSF exercised a veto power over an applicant's development scheme by refusing to fund a particular department the site visitors considered too weak or by turning down part of a proposal for certain personnel additions, equipment purchases, etc. For the most part, however, the applicant institution chose the disciplines to be funded and determined the best means for advancing its own academic science. The second aspect of NSF's administrative flexibility was that, once awards were made, bureaucratic red tape was minimized. During the course of the grant, recipients were able to make modifications and adjustments in their plan without interference from the Foundation.

The Subprograms

Early in the Science Development program NSF recognized that the initial program could not adequately meet all the particular circumstances surrounding graduate education and established two additional subprograms, which came to be designated Departmental Science Development (DSD) and Special Science Development (SSD). Beginning in 1966, NSF awarded $11.9 million to 11 institutions under the Special Science Development program. The grant period extended for 3 years with no provisions for supplementary funding, and with the awards based on the applicant institution's USD proposal. The National Science Foundation awarded SSD grants to institutions when it found that a portion of the applicant's plan deserved to be funded, but that the overall strength to warrant a full USD grant was insufficient.

Beginning in 1967, the agency awarded 73 grants under the DSD program totaling $41 million with an average grant of about $600,000. Under this program, individual departments were funded for a 3-year grant period. Unlike the USD subprogram, though, no department was eligible for supplementary funding. The DSD program was created as an alternative to the USD program for several reasons.

First, some institutions had certain strong departments but lacked the overall potential in science to move toward excellence. The single department judged to have strength was recognized while the institution as a whole was not. Second, DSD grants were awarded according to the principle that specific science fields within institutions located in urban areas should be improved. Third, DSD funds were used to encourage interdisciplinary studies. Fourth, after a year had passed since the previous award, an institution became eligible for another DSD grant, as long as its proposal covered a different department. As a result, several schools acquired DSD funds for two departments, and in one case three departments were funded in succession. (See the appendix for a list of grant recipients under each of the three subprograms.)

The Evaluative Study

This section, drawn largely from the technical report,[6] first describes the method of evaluation; second, it discusses the findings with respect to the Science Development program's impact—its direct effects on science quality and other more peripheral effects—on the recipient institution; and finally, it considers the program's success in achieving the goal of geographical dispersion of funds to build up regional centers of excellence.

[6] David E. Drew, *Science Development. An Evaluation Study* (Washington, D. C.: National Academy of Sciences, 1975). The summary presented here is based primarily on Chapter 9. key tables and figures from other chapters in the technical report are also included.

METHODOLOGY

The evaluation employed multiple indicators of quality—i.e., faculty size, doctorate production, etc.—to measure the recipient's achievements under the program. The investigators hoped that, through this process, the study might contribute to a more sophisticated definition of quality in graduate education. One basic methodological problem was to design techniques for determining the impact of Science Development funds upon universities of varying size, programs, and budgets. A second methodological problem was to differentiate Science Development effects from the general development taking place in most universities during the 1960's.

Essentially two techniques were employed: (1) a series of site visits to selected institutions to obtain information and impressions from university officials about the impact of the Science Development program, and (2) multivariate analyses of quantitative data for a large sample of universities with graduate science programs. From the two sets of data—one qualitative and subjective, the other more quantitative and objective—it was hoped that some definite conclusions about the impact of the NSF program upon the recipient institutions might be inferred.

Site Visits

Twenty-one institutions were selected for the site visits: 16 recipient universities and 5 nonfunded institutions, included for purposes of comparison. Of the recipient institutions, 9 had received University Science Development grants, 6 had received one or more Department Science Development grants, and 1 had received a Special Science Development grant. The institutions were chosen to represent diverse characteristics: large and small, public and private, funded and not funded, and reportedly successful and not-so-successful in achieving the program's goals. In addition, because NSF emphasized geographical dispersion of funds, site visit teams went to institutions in all parts of the country. In terms of control (public or private) the institutions were distributed as follows:

Type of Institution	USD and Special Grant Applicants		DSD Applicants		
	Recipients	Nonfunded	Recipients	Nonfunded	Total
Public	5	2	4	2	13
Private	5	0	2	1	8

The teams visiting the USD recipient institutions numbered four or five individuals: a senior member of the study staff, a member of the study panel, two or more scientists who were familiar with the funded disciplines, and others specializing in university assessment or in academic administration. In the case of DSD recipients, the team consisted of a senior member of the study staff and a scientist who had been involved in the original NSF site visits to institutions applying for grants.

During the visit, members of the team met with the institution's chief administrative officers, with those university officials who had been involved in the preparation and management of the grant proposals, and with academic deans. Faculty members and graduate students, from funded and nonfunded departments, were interviewed in depth to determine the impact of the grant on the recipient departments and on nonrecipient departments that may have been aided or hindered by the funding.

Quantitative Analysis

If the quantitative analyses were to be meaningful, it was necessary to identify trends already under way at the time the NSF grants were made (chiefly 1965–1967) and to look at the concluding years of the program (1971–1972).[7] For this reason, the study utilized data extending over the 15-year period, 1958–1972, whenever possible. In addition to longitudinal data, a variety of statistical techniques were employed to isolate the unique effects of Science Development grants.

As is customary in this kind of analysis, a group of control institutions were specified and trends were also examined within that group. To make the comparisons as complete and as illuminating as possible, every major doctorate-awarding institution in the United States was included in the control group. The selection was made by consulting *An Assessment of Quality in Graduate Education* by Allan M. Cartter[8] and *A Rating of Graduate Programs* by Kenneth D. Roose and Charles J. Andersen,[9] two assessments of graduate education that covered all major universities at the time they were conducted. The Cartter survey was made in 1964, one year before the program began to distribute funds, and served as the basis for defining the control groups. Data were collected on all universities included in the 1969 Roose–Andersen survey to ensure that information would be available for the largest sample of major universities.

[7] More recent data were not available

[8] Allan M. Cartter, *An Assessment of Quality in Graduate Education* (Washington, D.C.: American Council on Education, 1966)

[9] Kenneth D. Roose and Charles J. Andersen, *op. cit.*

The nonfunded institutions were subdivided into three categories: the "high controls." the "medium controls" and the "low controls." The second category. "medium controls," comes closest to fulfilling the classic definition of a control group. The control groups included institutions whose proposals were rejected and institutions who never applied for a grant. Each school was categorized according to the following procedure. The high-control group included the universities that received a rating in the Cartter survey above the score of the most highly rated USD recipient in that field. This group contains those institutions generally recognized as outstanding in science that were ineligible for USD grants. The medium control group included those schools rated in the same range as the recipients. or institutions roughly similar in quality to USD schools prior to funding. The low control group comprised the universities that were rated below the lowest recipient departments in the Cartter survey. or those institutions whose science capabilities were found by their peers to be weaker than the Science Development recipients. Suppose. for example. 25 USD recipients in physics were all rated between 2.00 and 3.00 on the Cartter scale. Then the high controls would be the universities with a rating of 3.01 or better. the medium controls would be all nonfunded schools with a rating between 2.00 and 3.00. and the low controls would be those universities with a rating below 2.00. This procedure allowed the control groups to be defined in a consistent and objective fashion for each field. At the same time, by collecting data for a 15-year period. it was possible to determine whether NSF funded only the universities that were already showing signs of rapid expansion. (The investigators found that this did not occur; in part, of course, because recipients were chosen according to their geographical location as well as the quality of their graduate science program.)

Comparisons were restricted to the scientific disciplines of mathematics, physics, and chemistry. the three fields that received the majority of Science Development funds. Twenty-eight USD institutions received grants in at least one of these three fields. As a further control. a field not included in the program, history. was also used in the analysis.

Partly because of limitations on the availability of data. the analyses were restricted to six criteria. The variables considered to be measures of quality were:

Faculty size
Faculty publication rates
Graduate student enrollments
Graduate student quality
Ph.D. production
Post-Ph.D. employment

EFFECTS OF SCIENCE DEVELOPMENT ON QUALITY

Science Development grants did produce positive changes in the quality of graduate education in the funded departments, as measured by the six criteria listed above. These changes were not uniform, however; some institutions advanced more than others. In addition, most recipients showed the greatest gai on those indices related to the research function of science departments, e.g., faculty size and publications. The recipients also realized some gains in the measures directly related to the educational function of graduate science, e.g., Ph.D. production, but these changes were not extensive.

Faculty Size and Mobility

Faculty sizes were compared at Science Development institutions and at control institutions between 1958 and 1970 (Tables 1-4), using data from the American Council on Education's quadrennially published *American Universities and Colleges*. All five groups of institutions registered increases in faculty size in all three fields, though not in the control field, history. (The reader is reminded that the most pertinent comparisons are those between USD recipients and medium controls.) Further inspection of the data revealed that this substantial growth at funded institutions was manifested chiefly in the public sector. For example, the faculty size in mathematics departments at the public recipient institutions increased from an average of 22.0 in 1958 to 50.6 in 1970, whereas at the private recipient institutions mathematics faculties increased from 18.0 to 29.7 in this same period.

A field-by-field comparison revealed some interesting patterns. In the mathematics departments at public and private institutions, the USD recipients had smaller faculties than the medium control institutions before funding and larger faculties after funding, although the change was greater at the public institutions. In the physics departments, however, the trends in faculty growth at public and private institutions diverged. The public USD recipients began with smaller faculties than the medium controls (18.1 vs. 25.3) and by 1970 the situation had been reversed; the USD faculties exceeded the medium controls in size (42.9 vs. 35.4). On the other hand, in the private institutions (where once again, the departments tended to be smaller) the USD recipients began with larger physics faculties than the medium controls and retained this advantage, but the gap grew smaller. Again, in chemistry the public USD recipients began with smaller faculties than the public medium controls (18.9 vs. 23.4) and ended with larger faculties (35.7 vs. 31.5), although the change was less pronounced than the one found in mathematics and

TABLE 1 Departmental Faculty Sizes in Science Development and Control Institutions: Mathematics

	No.	1958	1962	1966	1970
All Institutions					
USD recipients	15	20.4	24.3	37.8	42.2
DSD recipients	5	13.4	14.2	22.4	33.4
High controls	17	30.4	35.9	52.7	50.9
Medium controls	15	24.2	26.9	37.2	35.7
Low controls	16	14.0	17.9	23.2	28.8
Public Institutions					
USD recipients	9	22.0	27.9	44.3	50.6
DSD recipients	2	17.5	18.0	25.0	43.5
High controls	6	36.8	47.7	78.2	74.2
Medium controls	8	28.6	32.1	44.4	43.9
Low controls	10	19.0	22.7	29.7	37.9
Private Institutions					
USD recipients	6	18.0	18.8	28.0	29.7
DSD recipients	3	10.7	11.7	20.7	26.7
High controls	11	25.6	27.1	33.6	33.4
Medium controls	7	19.1	21.0	29.0	26.4
Low controls	6	5.7	10.0	12.3	13.7

TABLE 2 Departmental Faculty Sizes in Science Development and Control Institutions: Physics

	No.	1958	1962	1966	1970
All Institutions					
USD recipients	25	17.6	23.3	33.0	37.4
DSD recipients	9	9.3	12.7	17.7	24.1
High controls	14	33.8	39.4	45.3	48.9
Medium controls	18	19.4	21.9	28.3	29.7
Low controls	19	9.8	11.6	15.8	19.1
Public Institutions					
USD recipients	16	18.1	24.3	36.3	42.9
DSD recipients	6	9.2	12.2	17.5	27.0
High controls	4	31.3	37.5	46.0	53.3
Medium controls	8	25.3	27.6	34.4	35.4
Low controls	13	11.1	13.5	18.6	22.6
Private Institutions					
USD recipients	9	16.6	21.6	27.2	27.8
DSD recipients	3	9.7	13.7	18.0	18.3
High controls	10	35.3	40.4	45.0	46.8
Medium controls	10	14.7	17.3	23.5	25.1
Low controls	6	6.7	7.3	9.7	11.3

TABLE 3 Departmental Faculty Sizes in Science Development and Control Institutions: Chemistry

	No	1958	1962	1966	1970
All Institutions					
USD recipients	22	18.0	20.4	26.5	31.3
DSD recipients	12	16.2	16.3	18.8	24.7
High controls	15	27.4	28.9	32.6	35.3
Medium controls	17	21.7	23.7	26.9	29.4
Low controls	24	11.9	13.4	15.8	18.0
Public Institutions					
USD recipients	13	18.9	21.6	30.0	35.7
DSD recipients	8	18.9	18.3	21.1	29.0
High controls	5	35.0	35.8	40.4	46.6
Medium controls	13	23.4	25.2	28.8	31.5
Low controls	13	13.5	14.9	17.8	21.5
Private Institutions					
USD recipients	9	16.8	18.6	21.4	24.9
DSD recipients	4	10.8	12.3	14.0	16.0
High controls	10	22.0	24.5	27.8	27.1
Medium controls	4	16.0	18.5	20.8	22.8
Low controls	11	10.1	11.6	13.4	13.9

TABLE 4 Departmental Faculty Sizes in Science Development and Control Institutions: History

	No	1958	1962	1966	1970
All Institutions					
USD recipients	24	15.5	18.4	24.4	27.7
High controls	14	28.3	32.4	41.3	39.8
Medium controls	18	14.3	17.7	22.9	26.7
Low controls	18	9.8	12.2	16.8	20.3
Public Institutions					
USD recipients	14	16.2	19.5	27.4	32.2
High controls	4	27.5	30.8	49.8	54.3
Medium controls	10	17.8	21.5	29.1	33.8
Low controls	9	8.4	9.9	16.7	21.4
Private Institutions					
USD recipients	10	14.6	16.8	20.2	21.3
High controls	10	28.8	33.3	37.1	31.6
Medium controls	8	10.0	12.9	15.1	17.9
Low controls	9	11.2	14.6	17.0	19.2

physics; in the private sector the recipient chemistry departments and the medium controls began with very similar faculty sizes (16.8 vs. 16.0) and remained that way until 1970, when the USD faculties were slightly larger (24.9 vs. 22.8). A multivariate analysis based on a linear model confirmed that Science Development funds had a significant positive effect on faculty sizes in the science departments of recipient institutions.[10]

Obviously, no grants were given to departments of history, the control field, but for purposes of analysis, data on all USD recipients with doctoral-granting history departments are shown in Table 4, along with data on history departments at the control institutions. Note that, with respect to history faculties, the recipient schools and the control institutions retained their relative position throughout the time period, a finding confirmed by the multivariate analysis.

One debate surrounding the Science Development program concerns its effect on faculty mobility in higher education. If funds were used to "rob" the leading institutions of their top science talent, then it would not be clear that the nation as a whole had benefited. Instead, the program would simply have supported the movement of scholars from one section of the academic world to another, with no apparent national gain in science quality. A special analysis of faculty mobility in physics (the most heavily funded field) was conducted to test the program's impact on faculty recruitment at USD recipient and medium control institutions.

The basic research design was as follows: A study was made of the last institution of the senior faculty members who joined the faculties of USD institutions during the period 1965–1971. These patterns were compared with the patterns of senior faculty members who took positions at the medium control institutions during the same period. Finally, as a further control, the analysis was repeated for the period 1959–1965.

The findings for physics did not support the charge that the USD recipient institutions developed by extensive recruiting of talent from the

[10] The multivariate analysis incorporated the following procedures. A number of dimensions representing prefunding departmental factors likely to affect subsequent faculty size were used as the independent variables in a series of multiple regression equations. These variables were systematically regressed on faculty size for each year from 1965 through 1972. Residual scores (actual minus predicted size) were then calculated Finally, the mean residual scores were aggregated for each group of institutions and the group means compared for each year from 1965 through 1972.

Use of this linear model made it possible to predict faculty size in each school for each year on the basis of all key factors but Science Development funding. Differences in the predictive efficacy of the model between experimental and control groups (as measured by the gap between predicted rates and actual faculty size) were taken to indicate that the funding had an impact.

leading institutions, or from any other group of institutions. Prior to funding, the Science Development and medium control schools had been acquiring new senior faculty from leading universities at about the same rate. After funding, the recipient institutions continued at the same rate while the controls slowed down. It is clear that Science Development funds allowed the recipients to maintain the pace set between 1959 and 1965 without any substantial changes in the academic sources of the new senior faculty. Moreover, the postfunding advantage of the Science Development-funded schools (over the controls) was limited entirely to the publicly supported universities.

Given the large size of physics departments in leading institutions, the movement on the part of faculty members to Science Development schools in either time period was not great. During the prefunding period (1959–1965) the USD recipient institutions recruited a total of 40 senior faculty members from the 14 high control institutions, and in the period after funding (1965–1971) they acquired a total of 57 senior faculty members from the high control institutions; this represents an increased loss of about one faculty member per leading university over a 6-year period.

Faculty Publication Rates

One crucial measure of a university's science capabilities is the research productivity of its faculty, particularly their rate of publication in leading journals. Measuring that rate called for rather elaborate procedures.

The leading journals in physics, chemistry, mathematics, and the control field of history were rank-ordered on the basis of an *impact factor*:[11] the ratio of citations to a given journal (in other journals) divided by the number of source articles appearing in that journal. The journal at the top of the list, then, was the one whose articles were assumed to have had the greatest impact in that other scientists had cited them frequently in their work. In the ranking process, various technical adjustments were made for such factors as the representation of American authors in English-language journals published in other countries. The list for each field was limited to approximately 20 leading journals, but these journals accounted for a majority of the citations in each field. In physics, for example, the 20 journals represented over 75 percent of all citations.

Figures 1–4 show the rate of publication in these journals by faculty members in USD-funded and in medium control institutions over the 15-year period 1958–1972. In examining these graphs, the reader should

[11] Impact factor is taken from the *Journal Citation Reports*, published by the Institute for Scientific Information, Inc., Philadelphia, Pa

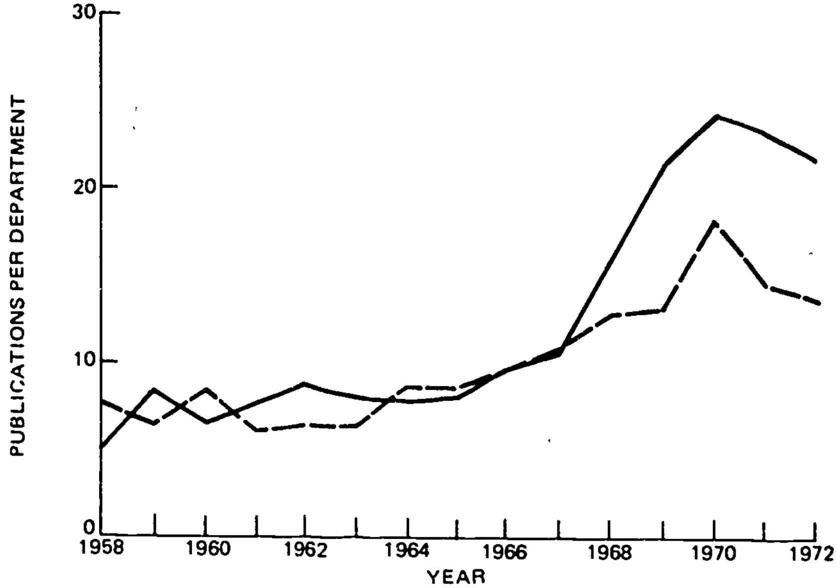

FIGURE 1 Departmental publication rates in science development and control institutions: mathematics.

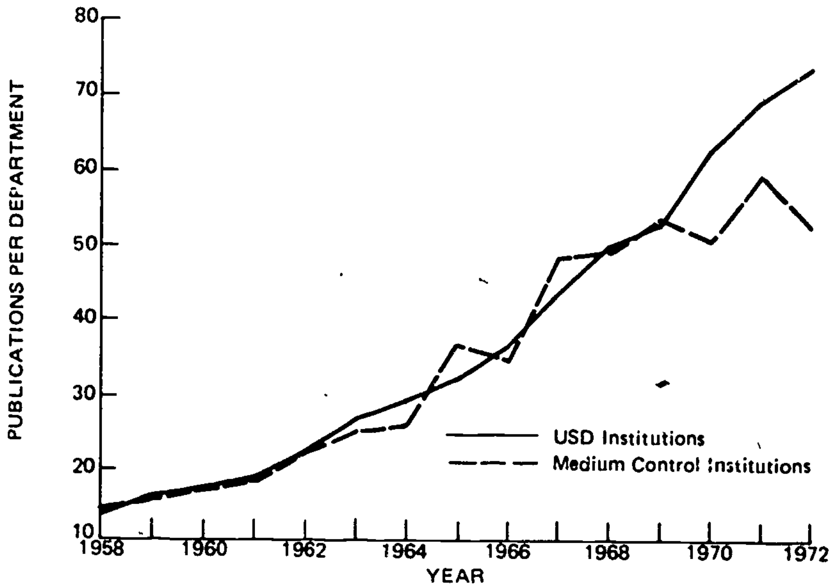

FIGURE 2 Departmental publication rates in science development and control institutions: physics.

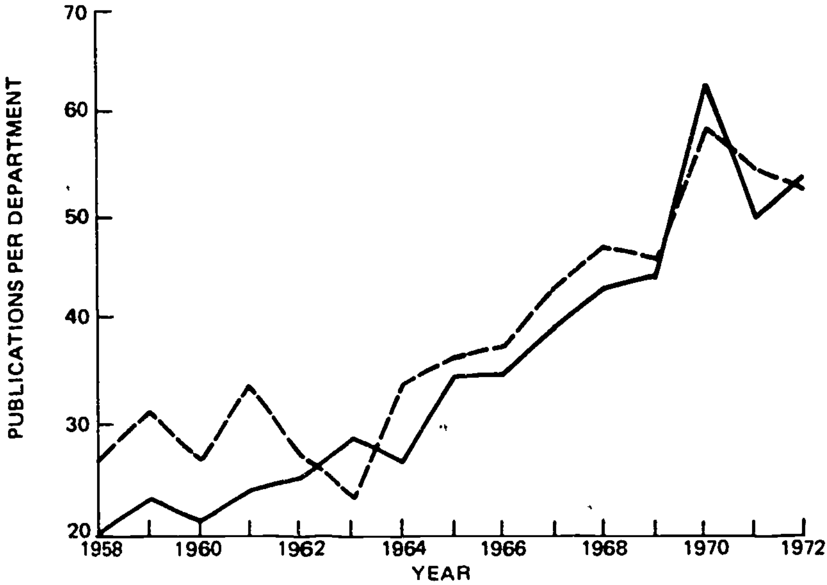

FIGURE 3 Departmental publication rates in science development and control institutions: chemistry.

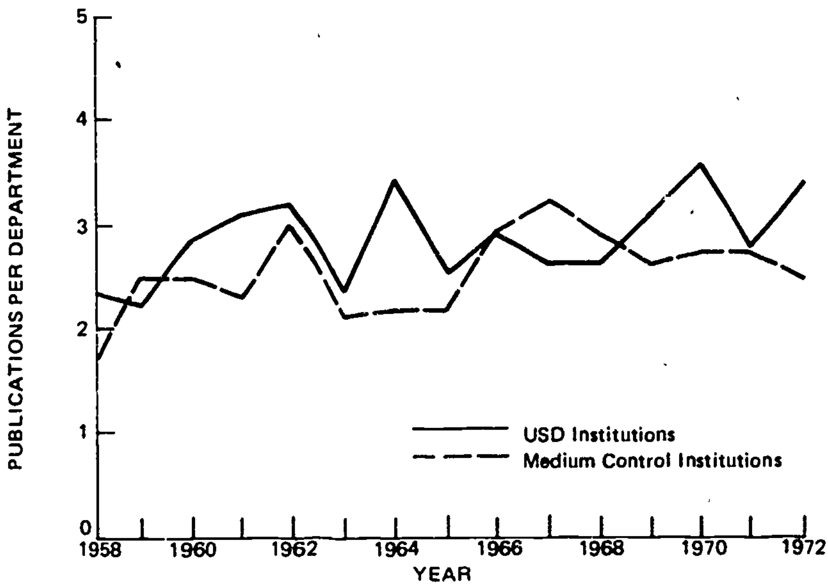

FIGURE 4 Departmental publication rates in science development and control institutions: history.

bear in mind the time lags involved. Although the Science Development program was launched in 1965, many institutions did not receive funds until 1967 or 1968. Time was needed for the department to hire new faculty, for the faculty to produce papers based on their research, and for the journals to review and publish those papers. Considering all these factors in combination, one would expect to see the initial effects of Science Development funding reflected in publication rates no earlier than 1968–1970.

Figures 1–3 are indicative of the rapid expansion in academic scientific research during the 1960's. Publication rates in all three science fields, particularly physics, sharply increased over the 15-year period, while the publication rates in history (Figure 4) remained about the same.

NSF funding had a positive impact on departmental productivity in mathematics, physics, and chemistry. In chemistry, this effect was revealed only through the multivariate analysis, but in mathematics and physics it was clear from the descriptive analysis. The most dramatic effect can be seen in the increase in 1968 of the publication rate of mathematics departments in USD schools over that of mathematics departments in medium control schools (Figure 1). In physics (Figure 2), where the publication rates in general were higher than in mathematics or chemistry, the USD recipients remained about equal to the medium control group until 1970 when they began to surpass them by widening margins. Comparing USD and medium control publication rates in chemistry (Figure 3), virtually no effects were obvious on inspection, but the more sophisticated statistical techniques revealed a positive, albeit small, impact. The multivariate analysis substantiated the changes in mathematics and physics described above.

During the period 1958–1972, research productivity as measured by the number of journal publications in the control field of history was far below that in the three science fields. Publication rates in the USD and medium control history departments did not exhibit a consistent trend. The improvements found in the three recipient science departments were not matched by increases in the USD university history departments.

The publication rate was also examined on a per-person basis to determine whether the changes resulted from larger faculties or greater individual productivity. Although the data for mathematics indicated an increase in the publication rates of individual faculty members, the multivariate analysis suggested this change was a result of other factors. Conversely, the multivariate analysis suggested a possible impact in chemistry, although the descriptive data revealed no effects of funding on per person productivity in either chemistry or physics.

Graduate Student Enrollments

One key question relating to the success of the program is whether it helped to attract more and better graduate students to the funded departments. Several analyses were conducted to determine the impact of the program on both the quantity and quality of graduate students; the results are reported in this section and the next.

Data on first-year, full-time enrollments and on total graduate enrollments (full-time and part-time) were assembled and compared for Science Development and control institutions. Figures 5–8 plot the trends in total graduate enrollments in the three science fields and in history at the USD and medium control institutions. Figures 9–12 plot the same trends for first-year graduate enrollments. In all four fields, total graduate enrollments grew more or less steadily from 1959 to 1967 or 1968, and then declined.

The receipt of a Science Development grant had very little effect either on total graduate enrollments or on first-year, full-time graduate enrollments. The USD schools had consistently higher total enrollments in physics and history and consistently lower enrollments in chemistry and mathematics (except 1970). One exception was found among public recipient institutions, where graduate enrollments in USD mathematics departments increased in comparison with the medium control schools.

Graduate Student Quality

Turning from quantitative to qualitative considerations, the next analysis examined changes in a measure of graduate student ability: the scores of entering students on the Graduate Record Examination. Through a special retrieval effort it was possible to obtain the mean scores per department of graduate students entering chemistry and history departments in a prefunding year (1964) and a postfunding year (1973). Examination of these data indicated that the relative standing of graduate students enrolled in Science Development departments improved significantly in comparison to the medium control institutions during the time period. Graduate students entering recipient chemistry departments scored below students entering medium control chemistry departments prior to funding and above them subsequent to funding; this reversal was true for both the verbal and the quantitative components of the GRE. However, findings from the control field, history, suggest that the changes in the quantitative component of the test might be the result of factors other than NSF funding.

As another measure of the quality of graduate students, the bac-

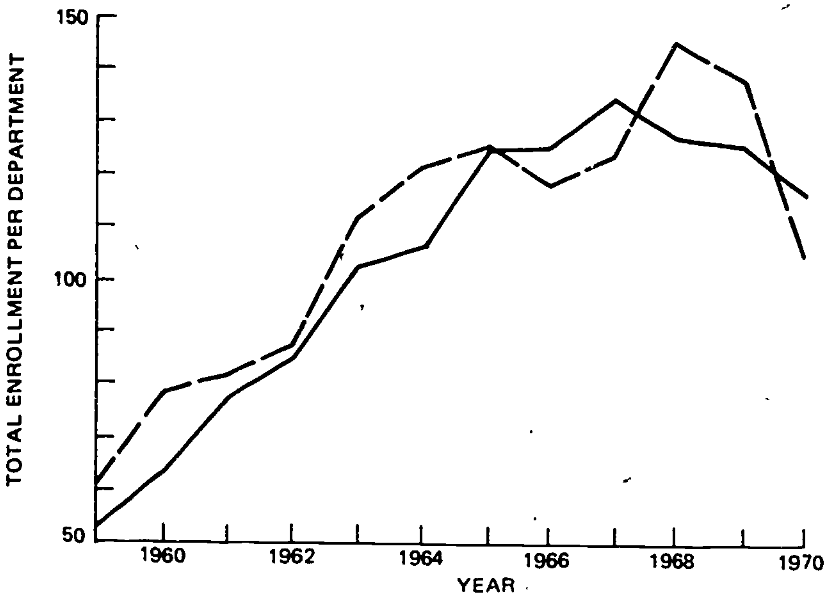

FIGURE 5 Departmental enrollments in science development and control institutions (all graduate students): mathematics.

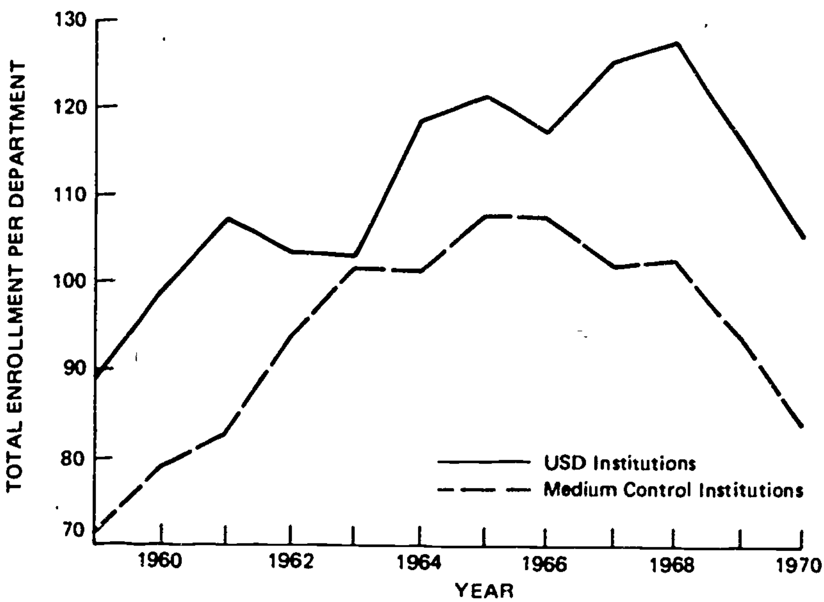

FIGURE 6 Departmental enrollments in science development and control institutions (all graduate students): physics.

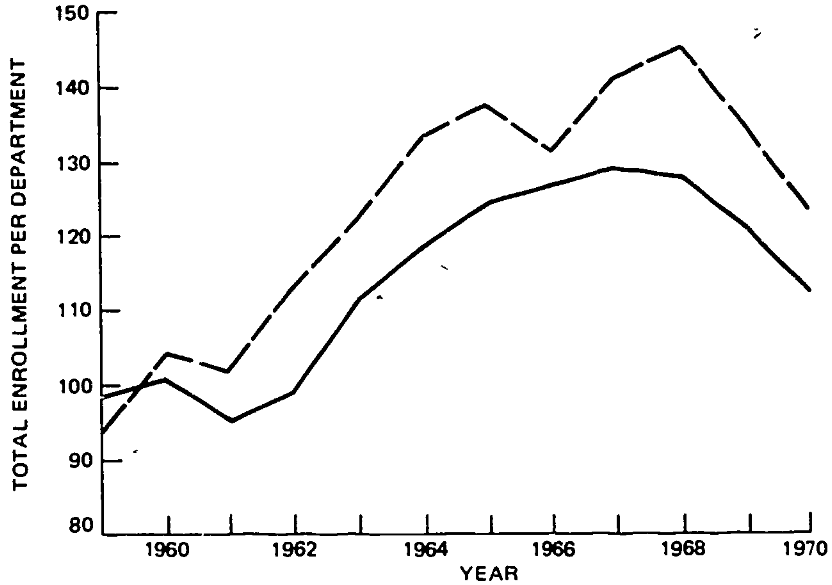

FIGURE 7 Departmental enrollments in science develoment and control institutions (all graduate students): chemistry.

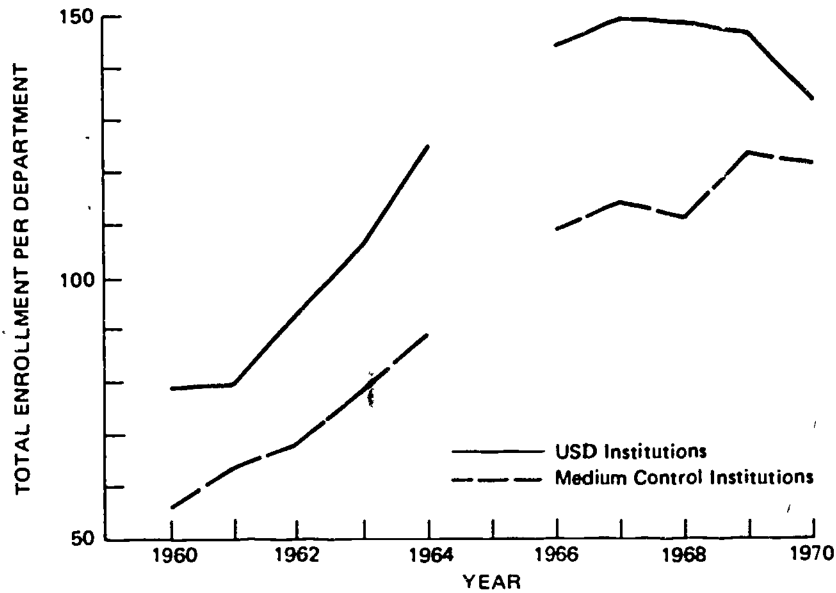

FIGURE 8 Departmental enrollments in science development and control institutions (all graduate students): history.

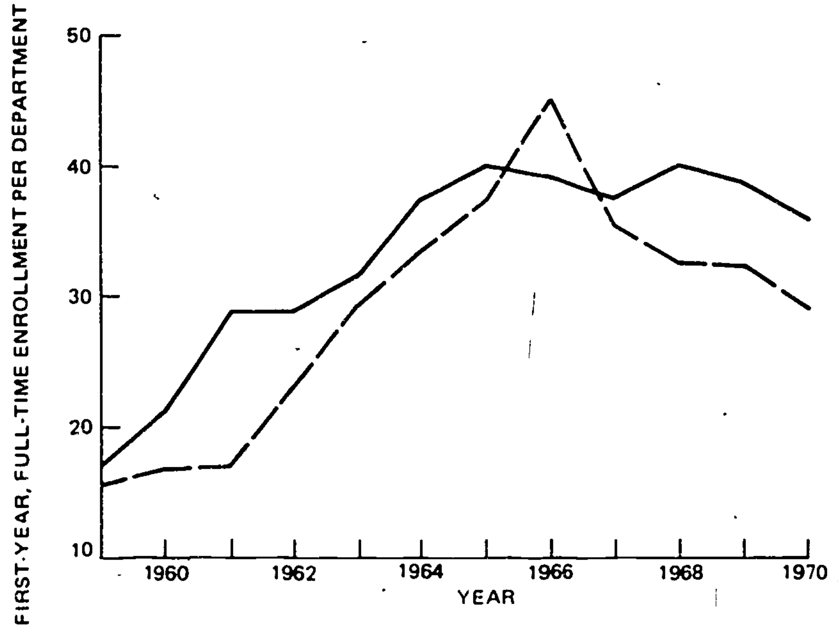

FIGURE 9 Departmental enrollments in science development and control institutions (first-year, full-time graduate students only): mathematics.

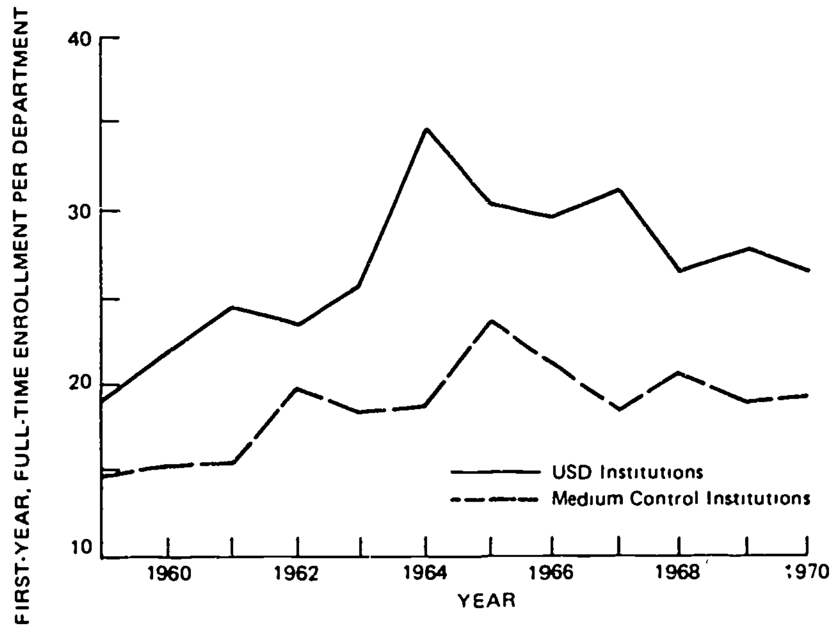

FIGURE 10 Departmental enrollments in science development and control institutions (first-year, full-time graduate students only): physics.

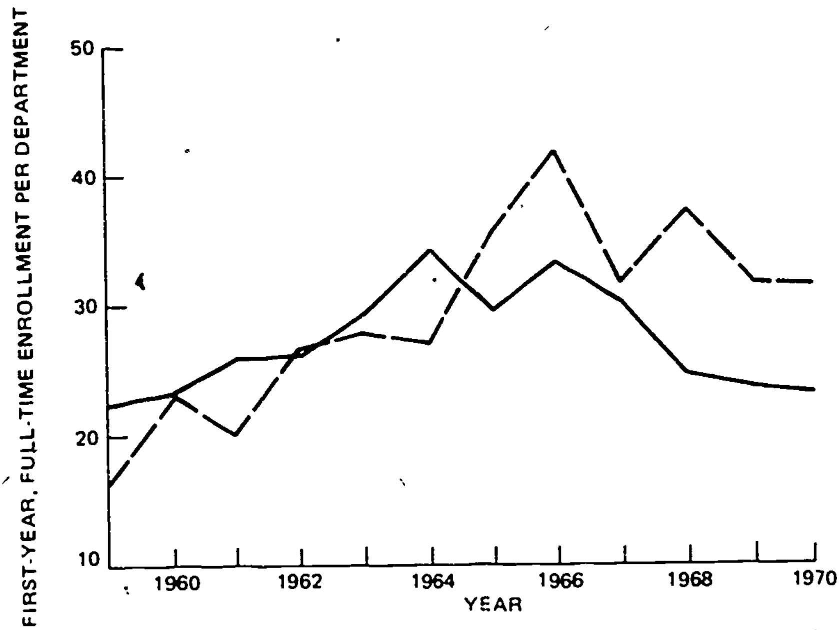

FIGURE 11 Departmental enrollments in science development and control institutions (first-year, full-time graduate students only): chemistry.

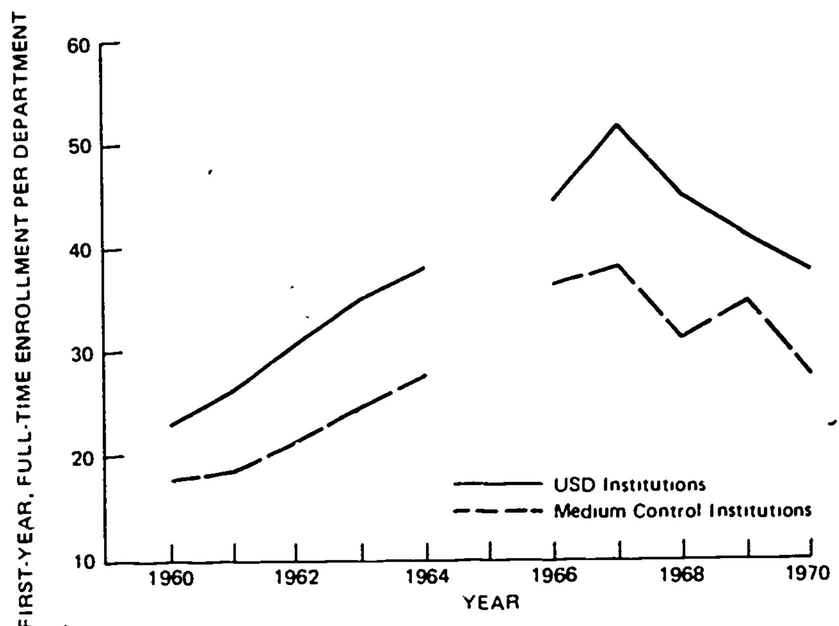

FIGURE 12 Departmental enrollments in science development and control institutions (first-year, full-time graduate students only): history.

calaureate origins of students entering funded and control graduate departments were examined. Specifically, the investigators wanted to see if the graduate students attracted to the recipient departments after funding tended to come from more highly selective undergraduate institutions. No such trend was found.

Doctorate Production

One problem facing graduate education today is the declining labor market for Ph.D.'s in several fields. A special set of analyses was devoted to examining the effects of Science Development funding on Ph.D. production and to tracing the subsequent employment of Ph.D.'s from recipient and control institutions.

Using data derived from the Doctorate Record File (DRF) of the National Research Council, the average departmental Ph.D. production of funded and control institutions was plotted from 1958 to 1972. Figures 13–16 show these trends for USD recipients and medium control schools. In chemistry (Figure 15), the USD recipients were consistently behind the medium control schools throughout the 15-year period. Although the funds had a positive impact on doctorate production in the recipient mathematics departments at public schools, the overall trend at USD and medium control institutions was mixed (Figure 13). In physics, the USD schools increased their Ph.D. production in comparison to the medium controls (Figure 14). The multivariate analysis substantiated these findings.

Post-Ph.D. Employment

The rate of Ph.D. production is a quantitative measure. In order to assess the changes in quality among new Ph.D.'s, data from the NSF National Register and the DRF were used to compare the first jobs taken by Ph.D.'s from recipient and control institutions, doing separate analyses for those entering academia and those taking nonacademic positions.

Figures 17–19 plot the average faculty quality rating (based on the 1964 Cartter survey) in departments at which graduates of USD and medium control institutions took their first jobs. The quality of the institution at which a Ph.D. took a first teaching job dropped over time for both groups. But this was less true for USD mathematics departments at private institutions. In physics and chemistry, Ph.D's from USD and medium control schools fared about the same in the postfunding years For those Ph.D.'s who took nonacademic positions, average starting salaries (the only available indicator) for graduates of funded and nonfunded institutions were compared. The starting salaries for graduating Ph.D.'s

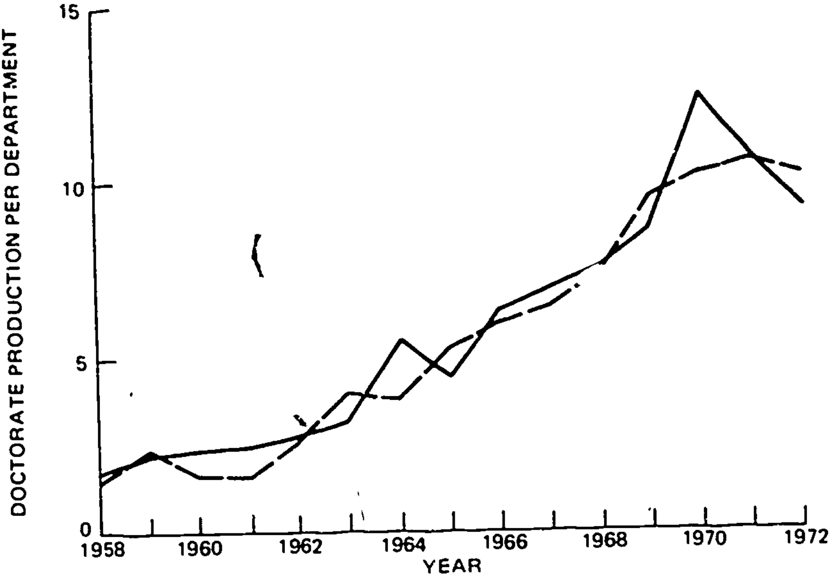

FIGURE 13 Doctorate production in science development and control institutions: mathematics.

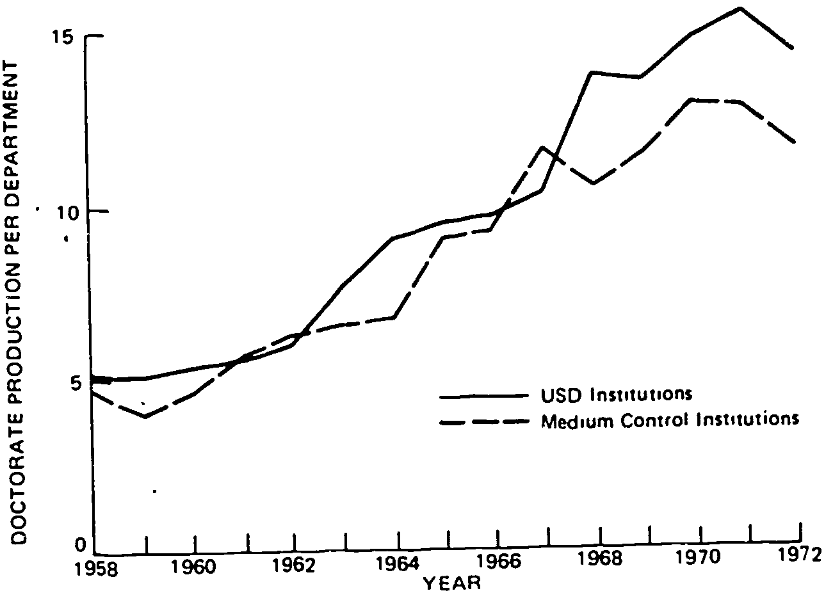

FIGURE 14 Doctorate production in science development and control institutions: physics.

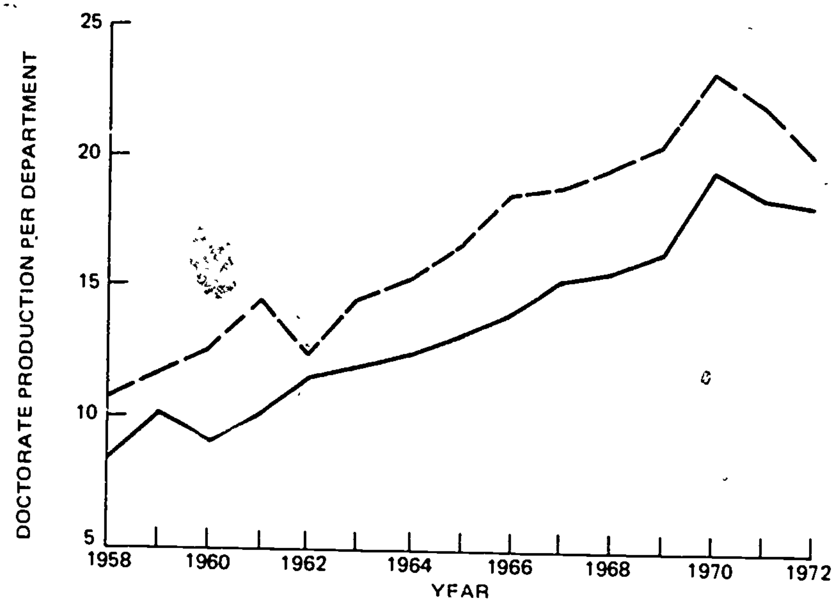

FIGURE 15 Doctorate production in science development and control institutions: chemistry.

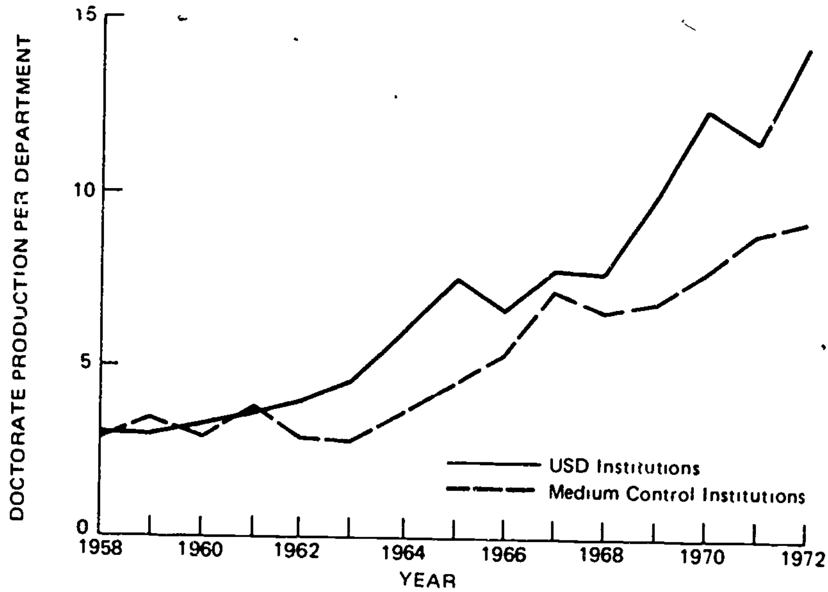

FIGURE 16 Doctorate production in science development and control institutions: history.

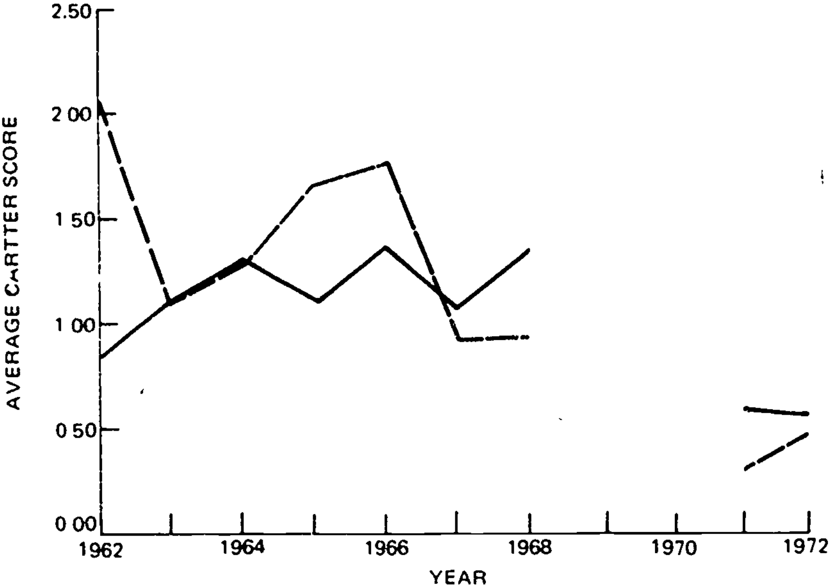

FIGURE 17 Average Cartter rating of academic departments at which graduates of science development and control institutions took their first job: mathematics.

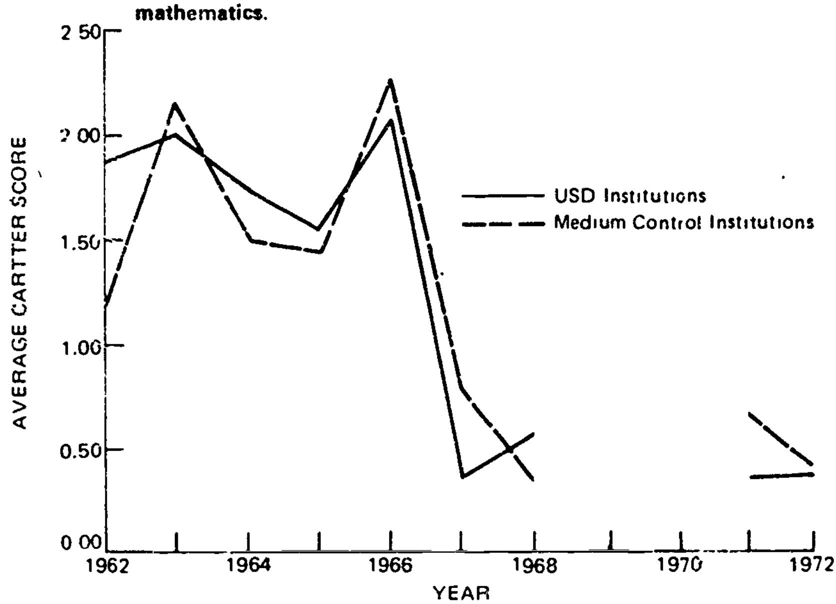

FIGURE 18 Average Cartter rating of academic departments at which graduates of science development and control institutions took their first job: physics.

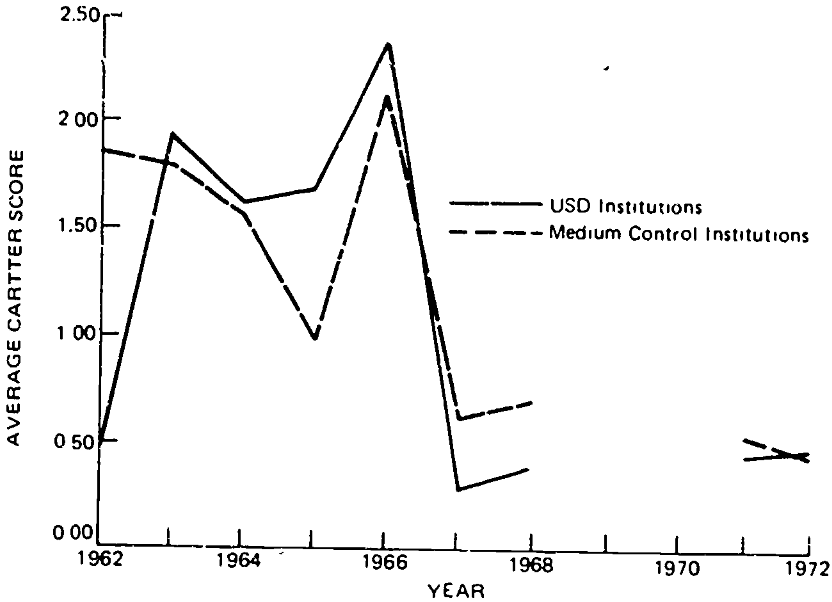

FIGURE 19 Average Cartter rating of academic departments at which graduates of science development and control institutions took their first job: chemistry.

from USD recipient departments and medium control schools rose at about the same rate.

OTHER EFFECTS OF SCIENCE DEVELOPMENT

In addition to the Science Development program's impact on the various measures of departmental quality, the more indirect effects of the program were also examined. These effects were not subject to quantitative analysis, but were instead based on information and observations from the site visits. One question investigated during the site visits was: Did the funded departments expand and improve at the expense of nonfunded departments? At a few institutions there was evidence of an uneven rate of development as a result of the funding, but this disparity reflected conscious and deliberate choices made by the central administrative officers at the institution. Generally, however, the site visitors found that funded institutions did not appear to have experienced major distortions in their programs, chiefly because the institutions took precautionary steps to prevent such imbalances.

A second issue investigated by the site visitors was: Were the recipient institutions able to absorb and continue the gains realized under the program? The data needed to examine the impact of Science Development on overall institutional budgets were not available. However, site visit reports indicated that some recipient institutions had given more careful consideration to the financial planning necessary for an effective program of institutional development than others. Despite the slowdown in the growth rate of federal research funding with its adverse financial impact on all research-oriented institutions, the recipients that planned more carefully maintained the improvements made under the program and continued to progress.

Quantitative data were available on trends in overall federal aid to academic science for the period 1963–1972. Table 5 and Figure 20 show the total federal science support per university for each of two groups: the 31 USD recipients and a control group of comparable institutions (based on the combined science rating in mathematics, physics, and chemistry). As the table shows, although the USD grants were very large in comparison with other federal science awards, they represented a small portion of the federal science flow to the recipients. The USD schools received slightly larger amounts of federal assistance from 1964

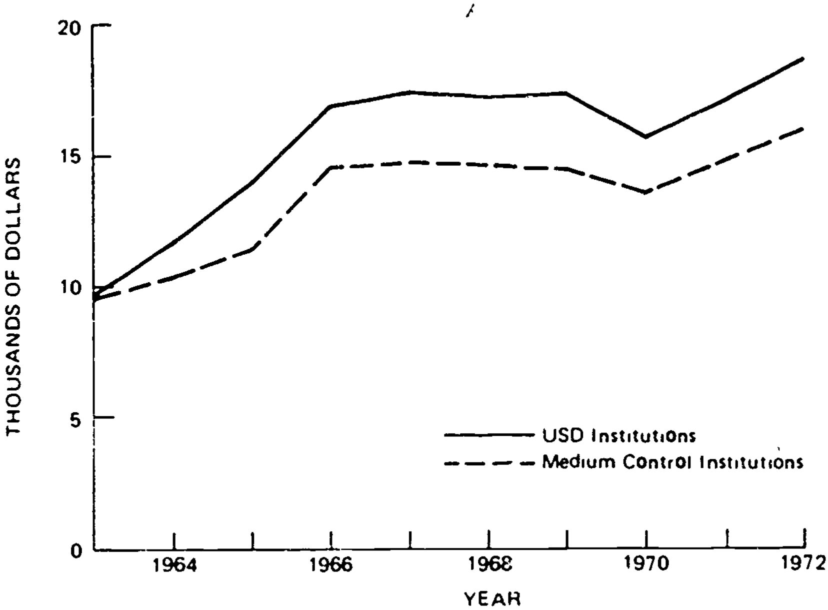

FIGURE 20 Total federal funds for science to science development and control institutions, 1963 –1972.

TABLE 5 Total Federal Funds for Science to Science Development and Control Institutions, 1963—1972 (in thousands of dollars)

	No	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
All Institutions											
Recipients	29	9,981	11,909	14,393	16,902	17,585	17,441	17,543	15,825	17,208	18,401
Controls	17	9,753	10,677	12,383	14,699	14,960	14,724	14,511	13,484	14,845	16,396
Public Institutions											
Recipients	17	9,836	11,642	14,571	17,218	17,216	18,088	16,974	16,183	17,925	18,737
Controls	9	8,715	9,409	11,465	13,657	14,662	14,655	13,936	12,873	14,554	16,082
Private Institutions											
Recipients	12	10,186	12,287	14,142	16,453	18,107	16,525	18,349	15,318	16,192	17,924
Controls	8	10,920	12,104	13,415	15,872	15,295	14,802	15,159	14,171	15,172	16,749

to 1972, but the grants themselves were partly responsible for the differences between 1965 and 1971.

Geographical Distribution of Funds

The Science Development program was created in part to disperse federal science funds among states and regions that lacked leading science research institutions. To determine its effectiveness in achieving this goal, the geographical location of the nation's outstanding universities in 1965 was compared to the location of the USD recipient institutions. The leading universities were identified on the basis of a combined science rating (for the departments of mathematics, physics, and chemistry) derived from Cartter's 1964 survey. Fifteen institutions, distributed among nine states, clearly stood out as "centers of excellence," according to the Cartter ratings. Under the USD subprogram, NSF funded 31 universities in 21 states. Six USD recipients were located in a state that already had at least one leading university. The other 25 USD recipients were distributed among 17 states that did not have a leading university in 1965.

A fundamental problem here is that the program's two major goals—dispersing funds on a geographical basis and developing promising institutions into outstanding ones—are not entirely compatible. The eligible institutions—i.e., the "second tier" of research universities—were not distributed uniformly throughout the country but tended to cluster in certain areas. Figure 21 is a map of the United States indicating the location of the 15 leading universities and 50 universities that would clearly be considered eligible for Science Development grants at the time of the program's inception;[12] Figure 22 shows the location of the recipient USD institutions. An examination of the location of the funded institutions indicates that the goal of geographical dispersion was achieved.

Finally, the grants satisfied geographical considerations in one other way. Table 6 lists the states, grouped according to the four principal Census Bureau regions, and indicates the numbers of leading institutions and USD recipients. Note that the leading universities are almost evenly divided among the northeast, central, and western sections of the country. The South, which in 1965 had no leading science institutions as defined here, was the chief beneficiary. Thirteen schools located in that region received USD funds. Looking at the figures in another way, the Northeast, with 24 percent of the nation's population in 1970, had 19

[12] *Eligible universities* were identified in terms of the combined science rating (physics, chemistry, and mathematics) derived from the Cartter study.

FIGURE 21 Geographical distribution of "leading" and "eligible" universities. (Selection based on the combined Cartter Ratings for mathematics, physics, and chemistry. Cartter, Allan, *An Assessment of Quality in Graduate Education.*).

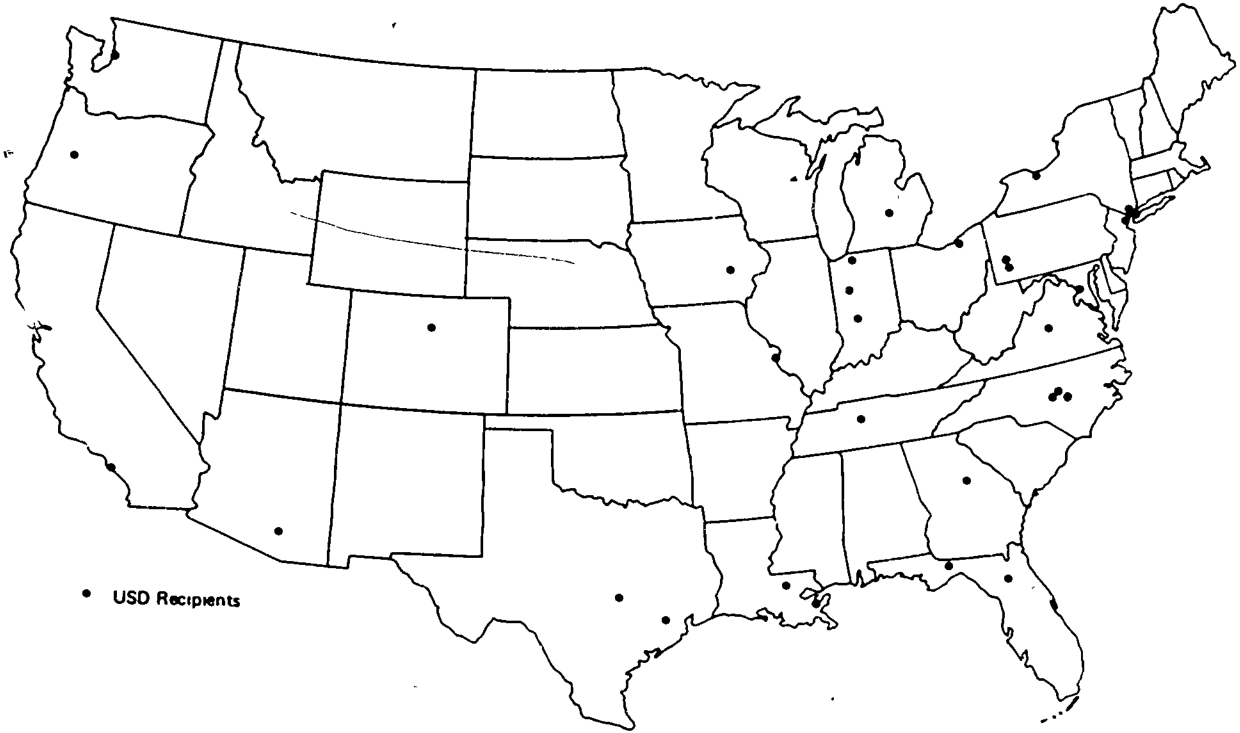

FIGURE 22 Geographical distribution of University Science Development recipients.

TABLE 6 Geographical Distribution of Leading Universities and of USD Recipients by Region and State

Region and State	No. of Leading Universities	No. of USD Recipients
Northeast		
Maine	0	0
New Hampshire	0	0
Vermont	0	0
Massachusetts	2	0
Rhode Island	0	0
Connecticut	1	0
New York	2	3
New Jersey	1	1
Pennsylvania	0	2
TOTAL	6	6
South		
Maryland	0	1
West Virginia	0	0
District of Columbia	0	0
Virginia	0	1
Kentucky	0	0
North Carolina	0	3
Tennessee	0	1
South Carolina	0	0
Georgia	0	1
Florida	0	2
Alabama	0	0
Mississippi	0	0
Arkansas	0	0
Louisiana	0	2
Oklahoma	0	0
Texas	0	2
TOTAL	0	13
Central		
Ohio	0	1
Michigan	1	1
Indiana	0	3
Illinois	2	0
Wisconsin	1	0
Minnesota	1	0
Iowa	0	1
Missouri	0	1
North Dakota	0	0
South Dakota	0	0
Nebraska	0	0
Kansas	0	0
TOTAL	5-	7

TABLE 6—(Continued)

Region and State	No. of Leading Universities	No. of USD Recipients
West		
Montana	0	0
Wyoming	0	0
Colorado	0	1
New Mexico	0	0
Idaho	0	0
Utah	0	0
Arizona	0	1
Nevada	0	0
Washington	0	1
Oregon	0	1
California	4	1
Alaska	0	0
Hawaii	0	0
TOTAL	4	5

Population. 1970 Census. in millions:

Northeast	48.9
South	62.1
Central	56.6
West	34.9

percent of the grant recipients; the South, with 30 percent of the population, had 42 percent of the grant recipients; the central states, with 28 percent of the population, had 23 percent of the recipients; and the West, with 17 percent of the population, had 16 percent of the recipient institutions. Given these population figures, the Northeast had fewer funded institutions, but it also had more leading universities to start with; the South had the largest proportion of funded institutions, but it had no leading science university as defined here in 1965; the central region also had relatively few funded institutions but it began with one-third of the leading universities; and the West had virtually the same proportion of the population and grant recipients. In short, the program reached a substantial number of universities located in states and regions that were not already occupied by a leading science institution.

Although several states received USD grants in more than one institution (three in Indiana, three in New York, and two in Pennsylvania), the Science Development program, to a considerable extent, achieved its explicit goal of dispersing federal science money to sections of the country that previously had been "disadvantaged" in this respect.

Concluding Observations

Several questions can be addressed in evaluating a new or "experimental" program. Did the funds delivered in this form produce positive changes of the type expected in the recipient institutions? Did the money distributed through the program have a greater impact than it would have had using traditional funding mechanisms? Did the program successfully pursue public policy goals that could not have been achieved through existing mechanisms? Were the gains worth the costs?

The quantitative analyses and site visit reports show that the Science Development program was responsible for many positive changes at the recipient institutions. The funds enabled the universities to support additional faculty members and had a definite positive effect on the research capacity of the funded institutions. Although graduate enrollments in the funded universities did not increase relative to the medium control institutions, the quality of first-year students as measured by GRE scores did improve in the funded departments relative to the controls. With Science Development money, recipient institutions were able to create new programs and to reorganize current endeavors. This report has not directly concerned itself with the changes in equipment and facilities brought about by the program, but the site visitors found numerous improvements in these areas. The positive effects of the program on research productivity, of course, are further testimony to the improvement in equipment and facilities, as well as in personnel.

The evaluation study did not have the resources to analyze traditional funding programs, and sufficient evidence from other sources does not exist to allow rigorous comparisons of the effects of Science Development funding with those of project awards or contract support. The data available on total federal science assistance show that, even during the period of SD awards, USD institutions received only slightly more total federal support annually than did the medium control schools. Yet, the evaluation study has shown that this small annual increment in total federal assistance was associated with some rather large changes in quality. That fact, in itself, speaks well for institutional support as a funding mechanism.

Furthermore, it must be remembered that the immediate goals of the Science Development program differed from that of research project grants and contracts. The goal of this program was to create outstanding science programs in universities throughout the United States, while the goal of research project grants is to increase knowledge through individual research efforts. As part of a research project, equipment purchases are often made, graduate students may obtain financial assistance, and faculty members may receive support, but these activities are not part of a systematic development plan for the institution. The Science Development funds, however, did serve a catalytic function for a sizable number of recipients and enabled them to accelerate the development of their science capabilities. The program did not create "centers of excellence" in the sense that every funded institution is now the academic peer of the nation's top universities, but notable improvements did occur in many of the USD schools.

Project support contributes little to the permanent strength of the university. A faculty member may receive several million dollars to conduct scholarly research at a university, but, should he or she depart during the work or after it is completed, the permanent contribution to the school will be limited. The goal of institutional support, on the other hand, is enduring improvement in quality. The evaluation indicates that this goal has been met with respect to some clear-cut measures of quality. A fear expressed in some quarters about institutional support was that this federal money would simply be absorbed into a school's budget without yielding discernible effects. The study has indicated that this fear was not justified.

The second major objective of the program, geographic dispersion of centers of science excellence, was largely achieved. Certainly the southern region of the United States benefited considerably from the program, and, in the West, centers of excellence outside of California began to appear. Moreover, it seems evident that greater equality in the distribution of top science research personnel throughout the various regions occurred as a result of the program. It must be concluded that one consequence of the Science Development program was a wider geographical dispersion of science research personnel and resources in the United States.

The site visit reports, as well as the statistical analyses, indicated that certain recipients made greater progress than others. One key factor that distinguished successful from less successful grants was the strength of an institution's central administration, particularly its president or chancellor. That person's continuity in office was particularly important. Grants tended to be most successful at universities that had a strong, dynamic leader who was in office before, during, and after the grant. An equally important factor—and one closely associated with a strong central administration—was the existence of a detailed development plan for the total institution. Such plans often served as the basis for a Science Development proposal, which then was likely to contribute to balanced overall growth within the university.

The capacity to obtain further funding from other sources was another characteristic common to the more successful recipients. Like most federal programs for higher education (other than those based upon the Morrill Act of 1862), Science Development made no distinctions between public and private institutions. Yet, the program was an exercise in institution building. Apart from federal government grants for project research and for other special purposes, state universities are dependent upon state legislatures and student fees for their primary sources of income, while private universities are dependent upon student fees and philanthropy for income. The state universities that made the most gains from Science Development grants were those that obtained continuing and enlarged state government support. The private universities that made the most gains were those that obtained substantial additional financial assistance from philanthropy. These circumstances, along with the slowdown in the rate of increase in federal government support of project research, contributed significantly to the success or nonsuccess of the Science Development program in institutional terms.

During the 1960's and early 1970's, there was some criticism that the Science Development program did not seek to maintain a reasonable balance between research and instruction. The site visitors did report some instances of imbalance between research and instruction, between the sciences and the arts, and between the sciences and professional fields of study, but this imbalance could not properly be laid at the door of either the federal government or the National Science Foundation. The maintenance of internal balance is a responsibility of university leadership. A major role of the federal government (and of the National Science Foundation) since the early 1950's has been to promote and support scientific research in American universities. This emphasis can easily lead to imbalanced development within universities, but it is the task of university leaders to allocate funds (derived from other sources) to maintain balanced institutions and to seek additional sources of support for nonscience activities.

At the same time that the Science Development program was getting under way, state governments were taking steps to improve and strengthen their own mechanisms for state planning in the field of higher education. The National Science Foundation received applications from state universities for Science Development grants directly and without the necessary endorsement of state governments. On the other hand, some state universities seeking Science Development grants did so with the encouragement and endorsement of their state governments. These state institutions tended to be those that were most successful in maintaining the gains made possible by Science Development. It is the state governments, rather than federal government agencies, that must enforce the integrity of state planning for higher education; but federal government agencies should be alert to the intricacies of such state planning.

The model employed by NSF to implement the program proved to be an effective mechanism for pursuing the objectives of the program without threatening the autonomy of the recipients. In the future a similar model might be applied to other endeavors, not necessarily restricted to the realm of science. For example, this approach could be used to encourage graduate schools to enroll more minority students and women. Professional schools might also benefit from this type of funding mechanism. In a limited sense the model is being applied currently in the new federal aid program for developing institutions.

Since the Science Development program was a unique effort for NSF, a procedure for evaluating its impacts should have been built into the program at the very beginning. NSF did ask for final reports at the end of the grant period from each recipient, but these reports for the most part did not provide the type of data required for a full evaluation.

One other conclusion must be mentioned. The Science Development program also served to strengthen the place of science research in the federal government scheme of national priorities and to enhance the status of the National Science Foundation as a federal government granting agency. The program demonstrated the responsibility of the agency to an official directive of the President, and it evidenced the desire of NSF to acknowledge the concerns of legislators and others with geographical distribution of research grants. There are some who see the Science Development program as a capitulation to political pressure. It is more realistic to observe the program as a necessary response to the political process of a liberal democracy and of a federal structure of government.

It is well to remind ourselves at this point of the two principal objectives of the Science Development program: to augment quality science research resources in the United States and to widen the geographical distribution of these resources. These objectives were reasonable in the circumstances of 1965 and were realized to a considerable extent. The program might have been judged as outstanding were it not for the fact that the duration of the program funding was not sufficient to have made a full impact upon the institutions involved. The institutions have had to carry on beyond the first stage of development made possible by NSF grants in an economic environment very different from that foreseen at the program's beginning. In some instances, the initial gains made possible by the development grants may be lost, victims of financial stringency. The ultimate judgment on whether the gains made possible by the Science Development program were worth their cost to society must await the outcome of the stresses that currently cloud the future of advanced education and research in the nation's universities.

* * *

An evaluative study on occasion becomes no more than a forum from which to plead for more federal funds. That is not the intention here. The conditions that gave rise to the Science Development program of the National Science Foundation have changed. The emphasis in the federal government research effort is concentrated upon project research, with a growing disposition to direct that research to particular national needs. The concern to build new centers of academic excellence, or of science research excellence, has subsided. A federal effort to develop institutional competence as research universities is not likely to be repeated in the near future; however, the concern with institutional development remains, in the federal government, in state governments, and elsewhere. Accordingly it is appropriate to set forth suggested guidelines that have been confirmed by the experience of the present study and may be useful in future programs.

1. Any endeavor at institutional development requires certain definite conditions for success. These include broad but fairly explicit national or other objectives, a sizable infusion of funds, careful institutional planning, adequate peer review of institutional potential for development, flexible management with a minimum of bureaucratic control, and assurance of continued institutional ability to sustain the improvements made possible by the development program.
2. If institutional excellence is an objective, then a positive plan for such achievement—a plan that has some reasonable prospect of realization—is essential.
3. The institutions to receive development grants should be selected on the basis of as objective and clearly specific criteria as possible.
4. It is essential that institutions (and state governments, where applicable) have a full understanding of the obligations they assume by participating in the development program and that they make adequate preparations to fulfill those obligations.
5. Some elasticity in the implementation of the development plan is as important as the element of accountability. Close and cooperative communication is desirable between the recipient institution and the granting agency. When there is reason to change or modify the development emphasis, the program management should be flexible enough to allow for such adjustment.
6. Any federal program that attempts to promote institutional de-

velopment is certain to encounter circumstances and conditions over which the federal government is not prepared to exercise control, since its commitment to higher education is a partial and limited one. The federal government has shown no disposition to take over the role of either state governments or of philanthropists, nor is any such assumption of responsibility desirable national policy. But the limited nature of the federal role needs to be recognized and acknowledged, and federal agencies must be circumspect in observing those limitations.

7. A development program need not be focused solely upon the advancement of particular disciplines. Other approaches appropriate to other circumstances may be in order. The disciplinary focus of the Science Development program is not the only possible model, although this emphasis was essential given the objectives of the Science Development effort.

8. A definite procedure for evaluation should be included in the design of an institutional development program. Assessment of performance is a continuing process and should be an ongoing part of the development program. Evaluation should be as precise as possible, concentrating upon a few limited measures clearly related to the objectives of the program itself.

9. A development program may be urgently needed at one particular time and be much less needed at another time. The ability to terminate a particular line of development is just as important as the ability to initiate one. The capacity to change remains an essential of government and of higher education activity and policy.

Appendix
Science Development Awards

University Science Development Recipients (funds in thousands of dollars)

Institution	Initial Award		Supplementary Award	
	Date	Amount	Date	Amount
Arizona	07-02-65	$4,045	06-10-69	$3,182
Carnegie-Mellon	05-10-67	4,399	05-26-72	450
Case Western Reserve	—	—	05-31-68	2,160
Case Institute	05-13-65	3,500	—	—
Western Reserve	05-13-65	3,500	—	—
Colorado	06-30-65	3,755	03-31-70	1,676
Duke	12-20-66	2,527	05-26-72	650
Florida	07-02-65	4,240	02-07-69	1,688
Florida State	03-21-68	4,820	05-26-72	1,200
Georgia	08-29-67	3,719	03-31-70	2,276
Indiana	12-20-66	7,886	05-26-72	1,470
Iowa (Iowa City)	08-29-67	5,101	05-20-71	612
Louisiana State	05-31-68	3,787	03-31-70	2,429
Maryland	05-10-67	3,703	05-20-71	652
Michigan State	05-31-68	4,307	05-26-72	1,180
New York University	06-10-69	4,560	05-26-72	1,600
North Carolina	05-10-67	4,995	05-20-71	1,071
North Carolina State	05-19-66	3,555	05-20-71	678
Notre Dame	05-10-67	4,766	05-20-71	451
Oregon	03-05-70	4,000	12-31-69	2,748
Pittsburgh	06-10-69	3,650	05-26-72	800
Polytechnic Institute, Brooklyn	11-03-65	3,332	02-06-69	1,210

University Science Development Recipients—Continued

Institution	Initial Award		Supplementary Award	
	Date	Amount	Date	Amount
Purdue	05-19-66	3,600	05-26-72	300
Rice	06-30-65	2,390	—	—
Rochester	06-30-65	4,500	12-31-69	1,205
Rutgers	05-19-66	3,708	05-20-71	334
Texas	05-20-71	5,000	05-20-71	959
Tulane	05-20-71	3,685	05-20-71	673
USC	11-03-65	4,473	02-07-69	3,000
Vanderbilt	05-10-67	4,053	05-26-72	1,350
Virginia	06-30-65	3,780	06-10-[illegible]	1,904
Washington (Seattle)	05-31-68	5,000	05-20-71	906
Washington (St. Louis)	05-13-65	3,919	02-07-69	3,090

Special Science Development Recipients (funds in thousands of dollars)

Institution	Date	Amount Awarded	Area
Brandeis	03-19-70	$1,900	chemistry, physics
Connecticut	03-31-70	145	environmental science
Kansas State	06-10-69	819	biology
Kentucky	03-20-68	974	mathematics
Nebraska	03-26-69	830	chemistry
New Mexico State	04-12-66	700	mathematics
Northwestern	05-19-70	1,500	urban systems engineering
SUNY Stony Brook	03-19-70	2,000	astronomy and astrophysics
Tennessee	03-20-68	1,450	chemical and metal engineering, physics
Wayne State	05-01-67	919	chemistry
West Virginia University	03-08-67	700	engineering

Departmental Science Development Recipients (funds in dollars)

Institution	Date	Amount Awarded	Area
Alaska	04-30-70	$ 720,000	geology
Arizona State	03-26-69	650,000	solid state science
Boston University	03-05-70	650,000	biological science
Bowling Green	03-26-69	531,900	psychology
Bryn Mawr	05-23-69	403,000	biochemistry
California, San Diego	09-15-70	571,000	economics
California, Santa Barbara	09-15-70	480,000	electrical engineering
California, Santa Cruz	03-26-69	600,000	astronomy
Claremont	05-31-68	491,500	mathematics
	04-09-71	466,000	psychology
Clark	06-12-67	545,070	psychology
	03-26-69	563,740	geography
Clarkson	03-26-69	800,000	chemical engineering
Clemson	03-05-70	650,000	engineering
Colorado School of Mines	04-30-70	700,000	geosci–mineral resources
Colorado State	03-05-70	600,000	civil engineering
CUNY, City College	05-31-68	765,000	physics
CUNY, Hunter College	05-31-68	617,800	biology
Delaware	02-16-68	556,000	physics
Denver	05-31-68	500,000	mathematics
Drexel Institute	06-12-67	527,700	chemical engineering
Emory	09-15-70	562,000	chemistry
Georgetown	04-30-70	460,000	language and linguistics
Hawaii	04-30-70	606,000	chemistry
Houston	09-28-67	420,000	chemical engineering
Illinois, Chicago Circle	05-31-68	545,000	chemistry
Illinois Institute of Technology	03-26-69	800,000	biology
Kent State	03-05-70	400,000	psychology
Lehigh	09-28-67	550,000	metallurgy and material sciences
	09-17-69	670,000	mechanical engineering and mechanics
Louisiana State, New Orleans	05-31-68	477,800	chemistry
Louisville	05-31-68	500,000	psychology
Marquette	09-28-67	540,000	biology
Massachusetts	04-09-71	582,000	psychology
Michigan Tech.	03-26-69	384,500	engineering
Mississippi	12-29-69	400,000	electrical engineering
Missouri	09-28-67	550,000	physics
Montana	04-09-71	500,000	geology
Nebraska	03-26-69	715,000	physics
New Hampshire	03-05-70	480,000	psychology
New Mexico	06-12-67	550,000	mathematics

Departmental Science Development Recipients—Continued

Institution	Date	Amount Awarded	Area
Oakland	05-31-68	570,000	engineering
Ohio	02-16-68	553,000	physics
Oklahoma State	03-26-69	665,200	systems science
Oregon State	03-05-70	600,000	chemistry
Rochester	04-09-71	848,000	fundamental studies (multidisciplinary)
RPI	02-16-68	569,000	mathematics
	06-30-69	490,000	chemistry
SMU	02-16-68	600,000	electrical engineering
	03-05-70	550,000	economics
	04-09-71	600,000	anthropology
South Carolina	05-23-69	500,000	chemistry
Stevens Institute	09-17-69	670,000	physics
SUNY, Albany	03-26-69	480,000	mathematics
	09-15-70	525,000	biological sciences
SUNY, Binghamton	05-31-68	500,000	geology
	03-05-70	390,000	economics
Tennessee Tech	06-12-67	300,000	mechanical engineering
Texas A&M	03-26-69	560,000	chemistry
	09-15-70	458,000	economics
Texas Tech	09-15-70	476,000	electrical engineering
Utah	06-09-69	720,000	physics
	09-15-70	695,000	chemistry
Utah State	05-31-68	550,000	ecology
VPI	09-17-69	500,000	geological sciences
Washington State	05-31-68	550,000	chemical physics
	09-15-70	530,000	sociology
Wesleyan	05-31-68	560,000	physics
William and Mary	03-05-70	610,000	physics
Wisconsin, Milwaukee	02-16-68	550,000	surface studies
Wyoming	02-16-68	477,000	geology
Yale	05-27-71	1,500,000	social sciences
Yeshiva	12-22-69	900,000	physics

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